DRAFT

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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March 2019

COUNTY OF SAN DIEGO

BORREGO WATER DISTRICT
EST. 1962

BACK COVER PHOTOGRAPHS

Bottom left: **Borrego Springs Subbasin nursery plants**, courtesy of Hugh McManus

Bottom middle: **Coyote Canyon spring 2019 flower bloom**, courtesy of Sicco Rood, Steele/ Burnand Anza-Borrego Desert Research Center

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TABLE OF CONTENTS

Section **Page No.**

APPENDICES

TABLES

FIGURES

EXHIBIT

EXECUTIVE SUMMARY

The Borrego Valley Groundwater Sustainability Agency (GSA, Agency), which comprises the Borrego Water District (BWD) and the County of San Diego (County), developed this Borrego Valley Groundwater Sustainability Plan (GSP, Plan) to provide a structure to enable local government, groundwater users and the local community to work together to achieve sustainable use of groundwater resources in the Borrego Springs Groundwater Subbasin (Subbasin) (California Department of Water Resources (DWR) Basin No. 7.024.01) of the Borrego Valley Groundwater Basin.

ES 1.0 INTRODUCTION

The multi-agency Borrego Valley GSA consists of BWD, which has water supply and water management responsibilities within its Borrego Springs service area; and the County, which has land use responsibilities and water management responsibilities (via the County's Groundwater Ordinance) throughout the Subbasin.

Current groundwater use in the Subbasin, which is located in northeastern unincorporated San Diego County, greatly exceeds groundwater recharge (i.e., the basin is being overdrafted). The Subbasin has been designated as being in critical overdraft by the DWR. According to Sustainable Groundwater Management Act (SGMA), "A basin is subject to critical overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts." The intent of this GSP is to achieve long-term groundwater sustainability by restoring balance to (i.e., reaching "sustainability" in) the Subbasin no later than 2040, as required by SGMA.

The overarching aim of SGMA is to establish and achieve the "sustainability goal" for the Subbasin through the development and implementation of a GSP. In enacting SGMA, the Legislature also set forward more specific purposes underlying the legislation, which include providing for sustainable management of groundwater, avoiding six designated "undesirable results" to groundwater resources that could occur without proper management, enhancing the ability of local agencies to take action to protect groundwater resources, and preserving the security of water rights to the greatest extent possible consistent with sustainable management of groundwater.

The intent of this GSP is to meet the requirements of SGMA. To this end, this Plan includes the scientific and other background information about the Subbasin required by SGMA and its implementing regulations. The Plan is also intended to provide a roadmap for how sustainability is to be reached in the Subbasin, including through projects and management actions (PMAs) to be taken, as well as the financial and other implications of implementing the Plan. At the same time, the GSP also recognizes that while some management actions can be taken early on in the

GSP implementation process, other actions, including those requiring environmental evaluation, are to be implemented over time.

SGMA also mandates that steps be taken to ensure the broadest possible public participation in the GSP development process. From its inception, the GSA has been focused on soliciting and receiving input from a wide variety of stakeholders regarding Subbasin issues. As part of the GSA's effort to consider the interests of all beneficial uses and users of groundwater, the GSA formed the Borrego Basin GSP Advisory Committee made up of key stakeholders from the Borrego Springs community. Beginning in March 2017, the Advisory Committee provided regular input to aid the GSA in the development of the planning and policy recommendations contained in this GSP.

ES 2.0 SUMMARY OF BASIN SETTING AND CONDITIONS

DWR has designated the 98-square-mile Subbasin as high priority and critically overdrafted. The majority of recharge that replenishes the Subbasin comes from streamflow exiting the mountains onto the desert alluvial fans that abut the mountain front. Land uses consist primarily of private land under County jurisdiction, and both the private land and the Subbasin itself are surrounded on nearly all sides by the Anza-Borrego Desert State Park. The developed land uses in the Subbasin include residential, agricultural, recreational, and commercial.

As represented in the "Hydrogeologic Conceptual Model" developed for this GSP, which is based in large part on work conducted by the U.S. Geological Survey, the unconsolidated sediments that fill the Subbasin are divided into three principal aquifers referred to as the upper, middle and lower aquifers, with the highest yielding wells located in the upper aquifer.

Prior to development in the Subbasin, the natural direction of groundwater flow was predominantly from the northwest near Coyote Creek to the southeast toward the Borrego Sink. The shallowest groundwater-level elevations occurred east of the Borrego Sink, an area of natural drainage in the middle of the valley that is dry most of the time. Groundwater levels and water quality in the Subbasin have been tracked by county, state, and federal agencies for over 50 years. The GSA monitors groundwater levels from a network consisting of 46 wells.

Over the past 65 years, groundwater levels have declined as much as 126 feet (average of nearly 2 feet per year) in the northern part of the Subbasin and about 87 feet (average of 1.3 feet per year) in the west–central part. In the southeastern part of the Subbasin where less groundwater has been pumped, groundwater levels have remained relatively constant during the same time period. Given the physical characteristics of the groundwater within the Subbasin, water quality, and other factors, this GSP establishes three management areas for the Subbasin: the North Management Area, the Central Management Area, and the South Management Area. These management areas will be utilized to monitor the status of groundwater quality and other SGMA parameters, and measure the progress towards achieving sustainability goals.

Defining the Subbasin setting also requires an examination of groundwater quality issues. In the Subbasin, the most critical aspect of water quality is ensuring that available supplies at municipal well sites are and remain in compliance with drinking water standards. Groundwater quality provided by BWD water supply wells is currently good and meets California drinking water maximum contaminant levels without treatment. Arsenic concentrations were increasing in multiple BWD water supply wells until 2014, but have since decreased. Historically, there have been nitrate-related water quality problems encountered in District wells that led to well reconstruction, abandonment, and replacement.

Total dissolved solids and sulfate are presently the only water quality constituents that show increasing concentrations with simultaneous declines in groundwater levels. Overall, the long standing overdraft has resulted in changes of water quality in the Subbasin over time. High salinity, poor quality connate water is thought to occur in deeper formational materials in select areas of the aquifer as well as shallow groundwater in the vicinity of the Borrego Sink in the southern portion of the Subbasin. The GSA monitors water quality from a groundwater quality network consisting of 30 wells.

The water budget for the Subbasin provides an accounting and assessment of the average annual volume of groundwater and surface water entering (i.e., inflow) and leaving (i.e., outflow) the basin and enables an accounting of the cumulative change in groundwater in storage over time. From 1945 to 2016, about 520,000 acre-feet of water was estimated to have been removed from storage. At present, the total baseline pumping allocation (BPA)[1] of 21,963 acre-feet per year (AFY) greatly exceeds the Subbasin's estimated long-term sustainable yield of 5,700 AFY determined by the U.S. Geological Survey and confirmed in this GSP. The BPA is defined as the amount of groundwater each pumper in the Subbasin is allocated prior to SGMA-mandated reductions, and serves as a cap from which annual pumping reductions to reach the sustainable yield by no later than 2040 will proceed.

ES 3.0 OVERVIEW OF SUSTAINABILITY INDICATORS, MINIMUM THRESHOLDS, AND MEASURABLE OBJECTIVES

To maintain a viable water supply for current and future beneficial uses and users of groundwater in the Subbasin, the GSA's sustainability goal is to ensure that by 2040, and thereafter within the planning and implementation horizon of this GSP (50 years), the Subbasin is operated within its

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[1] This rate is determined by adding up the maximum amount of water used by each pumper of groundwater in the Subbasin over the 5-year baseline period from January 1, 2010, to January 1, 2015. Because various users' pumping maximum could have occurred at any time during this period, it is higher than the total pumping in any one year.

sustainable yield and does not exhibit undesirable results. The GSA has established minimum thresholds and measurable objectives for the following sustainability indicators determined to be a current and/or potential future undesirable result.

Groundwater in Storage

The sustainability goal is to halt the overdraft condition in the Subbasin by bringing the groundwater demand in line with sustainable yield by 2040. This will be monitored by estimating the change of groundwater volume in storage every year, based on the observed changes in groundwater levels.

Chronic Lowering of Groundwater Levels

The sustainability goal is for groundwater levels to stabilize or improve and to ensure groundwater is maintained at adequate levels for key municipal wells. Observed groundwater levels will be compared to the Borrego Valley Hydrologic Model projected levels for the GSP implementation period.

Water Quality

The sustainability goal is for California Title 22 drinking water standards to continue to be met for potable water sources, and that water quality in irrigation wells be suitable for agricultural and recreational irrigation use. Water quality monitoring will occur throughout GSP implementation.

ES 4.0 OVERVIEW OF PROJECTS AND MANAGEMENT ACTIONS

The primary management tool to eliminate the overdraft is to require aggressive pumping cut-backs to a level at or below the Subbasin's estimated sustainable yield of 5,700 AFY before 2040. Reaching this goal requires an approximately 74% reduction in pumping compared to the BPA. The purpose of the GSA's proposed PMAs are primarily (1) to reduce water demand within the Subbasin by reducing the amount of water allocated to non-*de minimis* users and (2) to maintain water quality suitable for current and future beneficial uses. The selected PMAs are described, as follows:

PMA No. 1 – Water Trading Program

The Water Trading Program is intended to enable groundwater users to purchase needed groundwater resources to maintain economic activities in the Subbasin, encourage and incentivize water conservation, and facilitate adjustment of pumping allocations as water demands and Subbasin conditions fluctuate during the 20-year GSP implementation period.

PMA No. 2 – Water Conservation Program

The Water Conservation Program would consist of separate components for the three primary water use sectors: agricultural, municipal, and recreation. A water conservation program will be highly dependent upon securing funding such as through existing and future grants and low interest loan programs.

PMA No. 3 – Pumping Reduction Program

Each non-*de minimis* groundwater user within the Subbasin will be assigned an allocation based on its historical groundwater use. That allocation will be reduced incrementally as necessary over the GSP implementation period such that the total extraction from the Subbasin will be equal to the estimated sustainable yield (5,700 AFY) by 2040. Mandatory water metering for all non-*de minimis* groundwater users is proposed to take place following adoption of this GSP.

PMA No. 4 – Voluntary Fallowing of Agricultural Land

The voluntary Fallowing Program will create a process to convert high water use irrigated agriculture land to low water use open space, public land, or other development on a voluntary basis. Once implemented, the Fallowing Program would provide property owners with transferable BPAs in exchange for land fallowing.

PMA No. 5 – Water Quality Optimization

The Water Quality Optimization program is intended to identify as-needed direct and indirect treatment options for BWD to optimize groundwater quality and its use and minimize the need for expensive BWD water treatment to meet drinking water standards.

PMA No. 6 – Intra-Subbasin Water Transfers

The purpose of Intra-Subbasin Transfer Program is to mitigate existing and future reductions in groundwater storage and groundwater quality impairment by establishing conveyance of water from higher to lower production alternative areas in the Subbasin. This PMA will evaluate the feasibility and effectiveness of utilizing new or existing well sites in the Subbasin where groundwater conditions are more favorable for continued groundwater extraction. Construction of both potable and non-potable distribution pipelines will be evaluated.

ES 5.0 PLAN IMPLEMENTATION

The deadline for the Borrego Valley GSA to adopt this GSP is January 31, 2020. California Environmental Quality Act review would commence upon GSP adoption and be completed prior to implementation of many of the PMAs. California Environmental Quality Act review affords the

GSA an opportunity to refine specifics of the PMAs and develop implementing regulations. The Borrego Valley GSA is responsible for implementing the GSP over SGMA's planning and implementation horizon, with Subbasin sustainability required to be achieved by 2040. The GSA will submit annual and more detailed 5-year reports to DWR by April 1 of each year. The annual reports will document new data being collected to track groundwater conditions within the Subbasin, monitor progress on implementation of PMAs, and present an evaluation of measured data in comparison to interim milestones for each sustainability indicator. The 5-year reports provide the GSA an opportunity to evaluate the success and/or challenges in Plan implementation, including reporting on the effectiveness of PMAs. If knowledge of Subbasin conditions have changed based on updated data, if management criteria (e.g., sustainable yield, minimum thresholds, or interim milestones) need to be modified, or if PMAs need to be modified or added, revisions to the GSP may be proposed and the necessary steps taken by the GSA.

The GSA has performed substantial work toward estimating the cost of GSP implementation. Chapter 5, Plan Implementation, contains a breakdown of tasks and associated cost estimates for data collection, management, and evaluation; annual and periodic (i.e., 5-year) reporting; data gap analysis and additional evaluation; PMA development costs, including Environmental Impact Report; management, administration and other costs; and a 10% contingency. The estimated GSP implementation cost for the anticipated 20-year implementation period is $20,352,000. This estimate does not include the implementation of all PMAs or final costs incurred by BWD for internal management and administration. Additional budget will be required to implement PMAs once they have been developed. In general, the GSA plans to fund GSP implementation using a combination of administrative pumping fees, assessments/parcel taxes, and/or grants.

CHAPTER 1
INTRODUCTION

1.1 PURPOSE OF THE GROUNDWATER SUSTAINABILITY PLAN

The County of San Diego (County) and the Borrego Water District (BWD), acting together as the groundwater sustainability agency (GSA) for the Borrego Valley Groundwater Basin (BVGB), have developed this Groundwater Sustainability Plan (GSP, Plan) in compliance with the 2014 Sustainable Groundwater Management Act (SGMA) (California Water Code Section 10720–10737.8, et al.) and the Department of Water Resources (DWR) GSP Regulations (California Code of Regulations, Title 23, Section 350 et seq.). Among the legislative purposes of SGMA are for California's groundwater basins to be managed sustainably, "to manage groundwater basins through the actions of local government agencies to the maximum extent feasible," and to provide local public agencies acting as GSAs with the authority and technical and financial assistance necessary to achieve basin sustainability (California Water Code Section 10720.1). Appendix A includes the *Preparation Checklist for GSP Submittal*, which identifies where in this GSP each of the statutory requirements under SGMA are addressed.

In October 2016, the California DWR released final 2016 modifications to California's groundwater basin boundaries (Bulletin 118 Basins (2016 Edits)), which included the subdivision of the BVGB into two separate subbasins: the Borrego Springs Groundwater Subbasin (7-024.01) and the Ocotillo Wells Groundwater Subbasin (7-024.02) (Figure 1-1).[1] The GSA jurisdictional boundary consists of the entire Borrego Springs Subbasin (Plan Area) and the portion of the Ocotillo Wells Subbasin within San Diego County. The Borrego Springs Subbasin is designated by DWR as high priority and critically overdrafted; whereas, the Ocotillo Wells Subbasin is designated as very low priority and not critically overdrafted (DWR 2019).[2] The presence and potential interconnectedness of groundwater basins and subbasins adjacent to the Borrego Springs Subbasin, including the Ocotillo Wells Subbasin, are described and considered in this GSP, though the focus and requirement of the GSP is on achieving sustainable groundwater management in the Borrego Springs Subbasin by 2040. The 21 basins in California designated as critically overdrafted must be managed by a GSP by January 31, 2020, to avoid potential State Water Resources Control Board intervention.

SGMA defines sustainable groundwater management as the "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without

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[1] The Borrego Springs Groundwater Subbasin (7-024.01) and the Ocotillo Wells Groundwater Subbasin (7-024.02) are abbreviated as the "Borrego Springs Subbasin" and "Ocotillo Wells Subbasin" in this document.

[2] The basin prioritization process automatically assigns basins considered to be in critical overdraft a high priority, and automatically assigns basins whose pumpers are using less than 2,000 acre-feet per year of groundwater a very low priority, regardless of the prioritization score received from other metrics (DWR 2019).

causing undesirable results." "Undesirable results" are defined in SGMA and are summarized here as any of the following effects caused by groundwater conditions occurring throughout the basin:[3]

- Chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply
- Significant and unreasonable reduction of groundwater storage
- Significant and unreasonable degraded water quality
- Significant and unreasonable seawater intrusion
- Significant and unreasonable land subsidence
- Depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water

As described in Chapter 2, Plan Area and Basin Setting, undesirable results within the Borrego Springs Subbasin are occurring with respect to chronic lowering of groundwater levels and significant and unreasonable reduction of groundwater storage. Portions of the subbasin are also experiencing, or are under threat of experiencing, degraded water quality. Seawater intrusion is not possible for this inland basin. Land subsidence has been minimal to date and is unlikely to produce undesirable results in the foreseeable future. The depletions of interconnected surface water and resulting deleterious effects on groundwater dependent ecosystems have occurred pre-January 1, 2015, within the Borrego Springs Subbasin, as documented in Chapter 2.

The publication of this GSP represents a key milestone in achieving groundwater sustainability within the Plan Area by 2040 as required by SGMA. This GSP characterizes groundwater conditions, trends, and the cumulative impacts of groundwater pumping for each of the SGMA-defined sustainability indicators (Chapter 2); establishes minimum thresholds, measurable objectives, and interim milestones by which sustainability can be measured and tracked (Chapter 3, Sustainable Management Criteria); identifies projects and management actions to be implemented by the GSA and/or stakeholders to minimize undesirable results (Chapter 4, Projects and Management Actions); and outlines a plan for annual reporting and periodic (i.e., 5-year) evaluations (Chapter 5, Plan Implementation). The GSP documents a viable path, determined by the GSA in collaboration with stakeholders, and informed by the best available information, to achieving the sustainability goal within the Borrego Springs Subbasin.

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[3] "Basin" as defined in SGMA, means a groundwater basin or subbasin identified and defined in Bulletin 118 or as modified pursuant to California Water Code Section 10722, et seq. (Basin Boundaries).

1.2 SUSTAINABILITY GOAL

This GSP is intended to meet the overarching sustainability goal of SGMA to operate the Borrego Springs Subbasin within sustainable yield without causing an undesirable result. The subbasin must meet its sustainability goal no later than 2040.

1.3 AGENCY INFORMATION

The Borrego Valley GSA comprises the BWD, which has water supply and water management responsibilities within its Borrego Springs service area; and the County, which has land use responsibilities and water management responsibilities (via the County's Groundwater Ordinance) throughout the limits of the BVGB within the boundary of the County of San Diego.

The contact name and mailing address of the GSP Manager for the Borrego Valley GSA is as follows:

Jim Bennett, Water Resources Manager
Borrego Valley Groundwater Sustainability Agency
5510 Overland Avenue, Suite 310 | San Diego, California 92123 | 858.694.3820

1.3.1 Organization and Management Structure of the Groundwater Sustainability Agency

In October 2016, the District and the County entered into a Memorandum of Understanding (MOU) establishing the process/structure in which the GSP will be developed and establishes the organization and management structure of the GSA (Appendix B). The MOU designated a Borrego Basin Plan Core Team (Core Team) and an Advisory Committee (AC) made up of stakeholders. The Core Team consists of representatives from the County and the District, working cooperatively together to achieve the objectives of SGMA. Core Team members serve at the request of the GSA and may be removed/changed by the appointing party at any time. Members of the GSA must notify all other parties to the MOU in writing if the first party removes or replaces any Core Team members. “Each Core Team member’s compensation for their service on the Core Team is the responsibility of the appointing Party” (Appendix B). During the development of the GSP, at least two members from each party participated in the Core Team from project conception through completion of the GSP.

The Core Team has worked cooperatively with the AC to develop bylaws for the governance of the AC. These bylaws were subject to approval by the Core Team prior to adoption by the AC. The AC has provided input to the Core Team on GSP development on basin sustainability measures, as well as the planning, financing, and implementation of the GSP. Members of the GSA have agreed on the composition of the AC and acknowledge that the AC must meet the requirements established in SGMA (Appendix B). Members of the AC are not compensated for activities associated with the AC, GSP development, or any activity conducted under the MOU. Since early 2017, the AC has regularly held public meetings and received detailed reports on a wide array of GSP related issues. In addition, the AC has provided input to the Core Team on GSP development topics, including sustainability measures, projects and management actions and the planning, financing, and implementation of the GSP.

AC bylaws were adopted and approved at the June 29, 2017, Borrego Valley GSP AC Meeting. The AC is currently limited to nine members (Appendix B). AC representatives are nominated by the following six stakeholder organizations apportioned as follows:

1. Four members were nominated by the Borrego Water Coalition and fill the following representative roles (i.e., one agricultural member, one recreation member, one independent pumper, and one at-large member). The Borrego Water Coalition represents a cross-section of groundwater pumpers in Borrego Springs.
2. One member was nominated by the Borrego Springs Community Sponsor Group, which is an advisory board that provides local review and input for land use issues to the County.
3. One member was nominated by the Borrego Valley Stewardship Council, which represents community groups associated with the Anza-Borrego Desert State Park and geotourism initiative.
4. One member was nominated by the BWD Board of Directors to represent ratepayers/property owners, and is not an employee or elected official. The BWD represents over 2,000 ratepayers/property owners in Borrego Springs.
5. One member was nominated by the County to represent the Farm Bureau, and is not an employee or elected official. The San Diego County Farm Bureau represents farming interests in Borrego Springs.
6. One member was nominated by the California State Parks, Colorado Desert Region to represent the Anza-Borrego Desert State Park. The California State Parks represent the approximately 600,000-acre Anza-Borrego Desert State Park that surrounds Borrego Springs.

Each AC member serves a term, which runs concurrently with the development and completion of the GSP. A vacancy is recognized for any AC member who: (1) dies, (2) resigns, (3) has unexcused absences from more than three of the scheduled AC meetings within a single calendar year, (4) misses three meetings in a row, (5) regularly fails to abide by the discussion covenants of the AC, (6) violates the Ralph M. Brown Act, or (7) fails to properly exercise the purpose and authority of the AC. The current composition of the AC is described in Section 2.1.5, Notice and Communication (Appendix B).

Appendix B contains documentation, in reverse chronological order, of the formation of the GSA and initiation of the GSP in compliance with SGMA. Appendix B also includes the GSP AC bylaws followed by the GSA's notices to DWR regarding its intent to cooperatively develop a GSP. Appendix B includes the MOU between BWD and the County that describes the purpose, management, and structure of the GSA; and their mutual agreement to serve cooperatively as the basin's GSA. Previous notices to DWR from the County and BWD to individually serve as the GSAs, prior to their agreement to serve jointly as the GSA (thus eliminating geographic overlap) are included at the end of Appendix B as well, for reference. Information regarding the Borrego Valley GSA, including the MOU, Stakeholder Engagement Plan, Notice of Intent to Develop a GSP, and AC Bylaws can also be found at the County's SGMA Borrego website, http://www.sandiegocounty.gov/content/sdc/pds/SGMA/borrego-valley.html.

1.3.2 Legal Authority of the Groundwater Sustainability Agency

On September 16, 2014, Governor Jerry Brown signed into law Senate Bills 1168 and 1319 and Assembly Bill 1739 as part of the SGMA legislation, which provides among other powers local groundwater agencies the authority and the technical and financial assistance necessary to sustainably manage groundwater. SGMA legislation paved the way for the formation of the GSA between BWD and the County to manage the BVGB. The GSA has statutory authorities that are essential to groundwater management as well as SGMA compliance.

Section 10720.7 of SGMA requires that all basins designated in Bulletin 118 as high or medium priority be managed under a GSP and all critically overdrafted basins, such as Borrego Springs Subbasin, be managed under a GSP by 2020. Pursuant to Section 10727 of SGMA, the parties are required to develop, adopt, and implement this GSP to manage the basin and intend on using the authorities granted to them to memorialize the roles and responsibilities for developing and implementing the GSP.

1.3.3 Estimated Cost of Implementing the Groundwater Sustainability Plan and the Groundwater Sustainability Agency's Approach to Meet Costs

Annual implementation costs may vary from year to year as a result of the status of project and management actions (PMAs), significance of new data, and increased milestone reporting requirements every fifth year of implementation. However, the estimated GSP implementation cost for the anticipated 20-year implementation period for operations and monitoring, management, administration and other costs, 5-year annual reviews and 10% contingency is approximately $19,200,000. Estimated total GSP implementation costs assumes the following general components:

- Data collection, management and evaluation

- Annual reporting
- 5-Year review assessment and reporting
- Data gap analysis and additional evaluation (e.g., Coyote creek boundary condition analysis, etc.)
- PMAs development and implementation of components as funding allows
- Management, administration and other costs
- 10% contingency assumed over 20-year plan implementation period

In addition to the $19,200,000 required for 20-Year GSP implementation costs, an additional $652,000 is estimated to be required for PMA development costs. In addition, $500,000 has been budgeted for preparation of the Environmental Impact Report (EIR) for GSP Plan Implementation. Budget for the EIR has been secured though funding provided by Proposition 1 Severely Disadvantaged Community grant. Thus, the current total estimated GSP implementation cost is $20,352,000 including a contingency of $1,745,000. It is emphasized that this estimate does not include the implementation of all PMAs or final costs incurred by BWD for internal management and administration. Additional budget will be required to implement PMAs once they have been developed. Implementation of PMAs such as the water conservation program will be highly dependent upon securing funding such as through state or federal grants.

Additional information on GSP implementation costs, and how the GSA plans to fund these costs, is provided in Chapter 5. In general, the GSA plans to fund GSP implementation using a combination of groundwater extraction charges, including monthly fixed charges and variable pumping fees, assessments/parcel taxes, and/or grants. Potential funding sources specific to PMAs are presented in Chapter 4.

1.4 GROUNDWATER SUSTAINABILITY PLAN ORGANIZATION

This GSP is organized as follows:

- The **Executive Summary** is a plain language summary that provides an overview of the GSP and a description of groundwater conditions in the basin.
- **Chapter 1, Introduction**, includes the purpose of the GSP, sustainability goals, and agency information and outlines document organization.
- **Chapter 2, Plan Area and Basin Setting,** consists of two main parts. This first part provides a general overview of the Plan Area, including agency jurisdiction, relevant water resources monitoring and management plans, a description of land uses and land use policies, and an overview of GSP notice and communication activities. The second part describes, in depth, the hydrogeologic setting of the plan area, including a description of current and historical conditions related to each undesirable result defined under SGMA.

The second part also provides a summary of the groundwater modeling and water budget components established for the Plan Area.

- **Chapter 3, Sustainable Management Criteria**, describes criteria by which the GSA has defined conditions that constitute sustainable groundwater management for the basin, including the process by which the GSA has characterized undesirable results, and established minimum thresholds and measurable objectives for each applicable sustainability indicator.
- **Chapter 4, Projects and Management Actions**, consists of a description of the projects and management actions the GSA has determined will achieve the sustainability goal for the basin, including projects and management actions to respond to changing conditions in the basin.
- **Chapter 5, Plan Implementation**, provides an estimate of GSP implementation costs, a schedule for implementation, and a plan for annual reporting and periodic (5-year) evaluations.

1.5 REFERENCES CITED

Department of Water Resources (DWR). 2019. *Sustainable Groundwater Management Act 2018 Basin Prioritization Process and Results*. January 2019.

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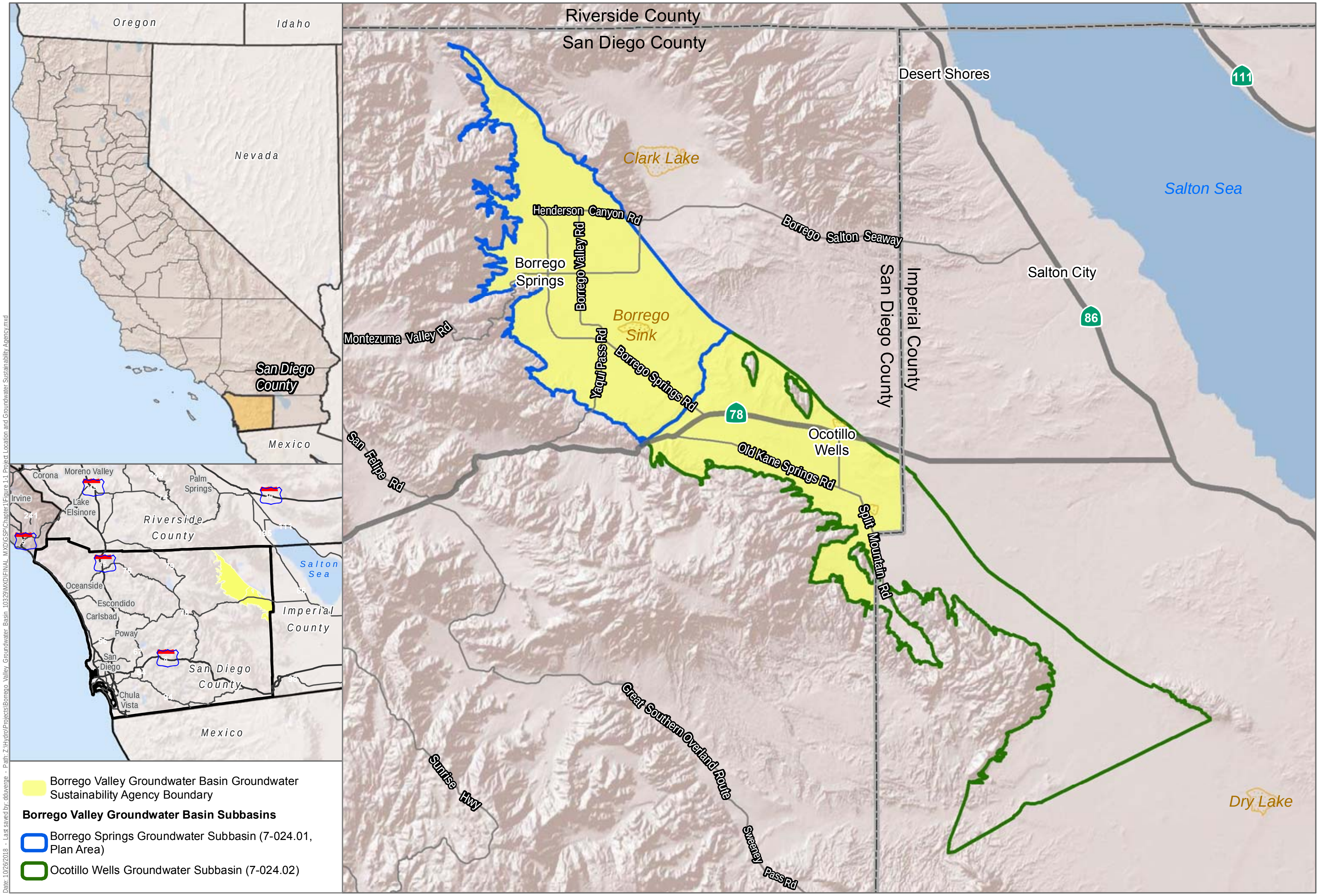
Date: 10/26/2018 - Last saved by: dduverge - Path: Z:\Hydro\Projects\Borrego_Valley_Groundwater_Basin_10329\MXD\FINAL_MXD\GSP\Chapter1\Figure 1-1 Project Location and Groundwater Sustainability Agency.mxd



DRAFT March 2018

DATUM: NAD 1983. DATA SOURCE: DWR 2016

DUDEK

0 3 6 Miles

FIGURE 1-1

Project Location and Groundwater Sustainability Agency

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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CHAPTER 2
PLAN AREA AND BASIN SETTING

2.1 DESCRIPTION OF THE PLAN AREA

As described in Chapter 1, Introduction, the Groundwater Sustainability Agency (GSA) boundary encompasses the entire Borrego Springs Groundwater Subbasin and the portion of the Ocotillo Wells Groundwater Subbasin within San Diego County.[1] The GSA comprises the County of San Diego (County) and the Borrego Water District (BWD). The California Department of Water Resources (DWR) has designated the Borrego Springs Subbasin (Subbasin) of the Borrego Valley Groundwater Basin (BVGB) to be high priority[2] and critically overdrafted (DWR 2016, 2018). The 2018 Sustainable Groundwater Management Act (SGMA) basin prioritization process automatically assigns basins considered to be in critical overdraft a high priority (DWR 2019). Under the DWR Groundwater Sustainability Plan (GSP) regulations, GSA's "have the responsibility for adopting a Plan that defines the basin setting and establishes criteria that will maintain or achieve sustainable groundwater management" (Title 23 California Code of Regulations (CCR) Section 350.4(e)).

For the purpose of this GSP, the "Plan Area" is defined as the Borrego Springs Subbasin, which has a surface area of approximately 98 square miles or 62,776 acres (Figure 2.1-1). The western and southwestern boundary of the Borrego Springs Subbasin is defined by the contact of poorly to moderately consolidated sediments with the plutonic and metamorphic basement of Pinyon Ridge and the San Ysidro Mountains. The northern and eastern boundaries are defined by the mapped trace of the Coyote Creek fault that trends northwest–southeast. East of the Coyote Creek fault lies Coyote Mountain, the Borrego Badlands, and the Ocotillo-Clark Valley Groundwater Basin. The southeastern boundary of the Plan Area is defined by the location of San Felipe Wash, as mapped by the U.S. Geological Survey (USGS) National Hydrography Dataset, which also marks the northern boundary of the Ocotillo Wells Subbasin.

Although the Plan Area is limited to the Borrego Springs Subbasin, information applicable to the Ocotillo Wells Subbasin, as well as the hydrologic characteristics of the watersheds contributing to the Borrego Springs Subbasin, is also provided in this chapter. DWR has characterized the Ocotillo Wells Subbasin as having a "very low" priority, because it meets the uniformly applied standard that any basin whose pumpers are using less than 2,000 acre-feet[3] per year (AFY) of

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[1] The Borrego Springs Groundwater Subbasin and Ocotillo Wells Groundwater Subbasin are referred to as the Borrego Springs Subbasin and the Ocotillo Wells Subbasin in this document.

[2] Basin prioritization classifies the California's 517 basins and subbasins into priorities based on components identified in the California Water Code. The priority process consists of applying datasets and information in a consistent, statewide manner in accordance to the provisions in California Water Code, Section 10933(b). Further information on DWR's basin prioritization process can be found on the following website: https://water.ca.gov/Programs/Groundwater-Management/Basin-Prioritization.

[3] The volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot. Equal to 325,851 gallons or 1,233 cubic meters.

groundwater be automatically assigned a very low priority, regardless of the prioritization score received from other metrics (DWR 2019). For reference, however, the Ocotillo Wells Subbasin received low priority rankings for most components of the 2018 SGMA basin reprioritization process because it has very low pumping demand, population density, and groundwater well density, as well as a lack of irrigated agriculture (DWR 2019). The Ocotillo Wells Subbasin is approximately 141 square miles or 90,075 acres. GSAs are not required to prepare a GSP for basins categorized as low or very low priority (California Water Code Section 10727).

The watersheds draining to Borrego Springs Subbasin contribute the majority of recharge to the Plan Area (focused infiltration of runoff) in the form of streamflow exiting the mountains onto the desert alluvial fans that abut the mountain front. The major contributing watersheds to the Subbasin include the Coyote Creek Watershed, which is approximately 179 square miles (114,615 acres); the Upper San Felipe Creek Watershed, which is approximately 194 square miles (124,124 acres); and the Borrego Valley-Borrego Sink Wash Watershed, which is approximately 158 square miles (101,371 acres). A summary of the groundwater subbasins, contributing watersheds and DWR designations is provided in Table 2.1-1.

Table 2.1-1
Summary of the Borrego Valley Groundwater Basin and Watershed Areas

Basin Name	Area			DWR Designations			Previous Groundwater Management Plan	2015 USGS Groundwater Basin Model	GSP Required per SGMA
	Acres	*Square Miles*	*Portion in San Diego County*	*Basin Number*	*Critically Overdrafted*	*Basin Priority*[1]			
Borrego Springs Groundwater Subbasin	62,776	98	100%	7-024.01	Yes	High	Yes[2]	Covered	Yes
Ocotillo Wells Groundwater Subbasin	90,075	141	44%[3]	7-024.02	No	Very Low	No	Partially covered	No
Watersheds Contributing to the Borrego Springs Groundwater Subbasin	277,334	433	80%[4]	*Not applicable, but relevant for recharge to the Borrego Springs Subbasin and the water budget. Consists of the Coyote Creek Watershed, Upper San Felipe Creek Watershed, and Borrego Valley-Borrego Sink Wash Watershed. This area excludes watershed areas overlapped by the Borrego Springs Subbasin*					

Notes: DWR = Department of Water Resources; USGS = U.S. Geological Survey; GSP = Groundwater Sustainability Plan; SGMA = Sustainable Groundwater Management Act.

[1] Based on the 2018 SGMA Basin Prioritization (DWR 2019).

[2] The previous Groundwater Management Plan was Adopted by the Borrego Water District in 2002 per Assembly Bill 3030 (BWD 2002).

[3] The remainder of the Ocotillo Wells Subbasin is within Imperial County.

[4] The remainder of the contributing watershed (Coyote Creek Watershed) is within Riverside County.

2.1.1 Summary of Jurisdictional Areas and Other Features

The Plan Area consists primarily of private land under County jurisdiction, which is surrounded on nearly all sides by land owned by the State of California. The developed land uses in the Plan Area include residential, agricultural, recreational, and commercial (County of San Diego 2011). The public water district serving the Plan Area is the BWD, which provides water and sewer service to the developed portions of Borrego Valley within its service area (Figure 2.1-2). BWD's service area is approximately 31,846 acres in size. Approximately 29,938 acres of BWD's service area is within the Plan Area, and the remainder, or about 1,908 acres, is outside of the Plan Area. BWD's service area covers approximately 48% of the Plan Area. With the exception of Air Ranch, a farm to the north of the BWD boundary, certain visitor facilities on Anza-Borrego Desert State Park land, and a few other minor developed uses, the developed portions of the Plan Area are entirely within BWD's service area boundary. As shown on Figure 2.1-2, there are several small water systems apart from BWD that also provide water service within the Plan Area, including Anza-Borrego Desert State Park at Palm Canyon and Horse Camp, Borrego Air Ranch Water Company, and Smoke Tree Ranch. Figure 2.1-2 also shows public water districts and small water systems within Ocotillo Wells Subbasin for reference.

Approximately 67% of the Plan Area consists of private land under County jurisdiction, and 27% of the Plan Area consists of a portion of the Anza-Borrego Desert State Park (ABDSP), based on mapping by the California Protected Areas Database (CPAD 2017).[4] ABDSP, which is owned and managed by the California Department of Parks and Recreation, intersects the edges of the Plan Area on all sides except a small part of the northeastern border, and occupies the mountain regions above Borrego Valley (Figure 2.1-3). Approximately 5% of the land within the Plan Area is owned by the Anza-Borrego Foundation, which acquires land for conservation in and around the park, supports research in the region, and is a reserve partner in public service programs. Approximately 1% of the Plan Area is owned by the County for parks and preserves, and the BWD for operations in conjunction with BWD's pre-existing water demand reduction program. Table 2.1-2 summarizes the land ownership and jurisdiction in the Plan Area.

To evaluate current and historical land uses within the Plan Area and the Ocotillo Wells Subbasin in San Diego County, each subbasin was intersected with land use layers from the San Diego Geographic Information Source[5], which has land use mapping specific to years 1990, 1995, 2000, 2004, 2008, and 2015. The percentage of various land use categories are presented in Table 2.1-3

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[4] The California Protected Areas Database contains GIS data about lands that are owned in fee and protected for open space purposes by over 1,000 public agencies or non-profit organizations, and is produced and managed by GreenInfo Network (http://www.calands.org/data).

[5] The San Diego Geographic Information Source is a Joint Powers Authority of the City of San Diego and the County of San Diego responsible for maintaining a regional GIS landbase and data warehouse.

for the Plan Area. The land uses in the Plan Area are shown on Figure 2.1-4. The ABDSP is included as “Open Space/Undeveloped Land” in the land use mapping presented in Table 2.1-3.

Table 2.1-2
Summary of Land Ownership in the Plan Area

Ownership Type	Agency	Description	Acres / % of Total
Private	Private	Urban/developed land, rural residential, agriculture, and open space under San Diego County jurisdiction	42,022 / 67%
State	California Department of Parks and Recreation	Anza-Borrego Desert State Park	17,072 / 27%
Non-Profit	Anza-Borrego Foundation	The foundation purchases land from willing sellers for addition to Anza-Borrego Desert State Park	3,190 / 5%
County	San Diego, County of	Old Springs Road Open Space Preserve, Borrego Springs Park Site Dedication	335 / <1%
Special District	Borrego Water District	District operations and historical water demand reduction program	158 / <1%
		Grand Total	**62,776**

Source: CPAD 2017.

Within the Plan Area, the majority of the land is undeveloped open space (Table 2.1-3). The primary developed land uses in the Plan Area are agriculture, residential, transportation infrastructure, and recreational (including golf course). Less than 1% of the Plan Area consists of institutional and commercial/industrial uses. Since 1990, the coverage of agricultural, residential, and recreational uses has increased. Agriculture is the most water-intensive land use in the Plan Area. Since 1995, between 3,400 and 4,000 acres within the Plan Area have been used for irrigated agriculture (SANGIS 2017; County of San Diego 2011; BWD 2009a) (Table 2.1-3). Gradual implementation of the BWD Water Credits Program has resulted in some reductions in the extent of lands used for agriculture in recent years. As further discussed under Section 2.1.2, property owners have fallowed approximately 600 acres of agriculture in exchange for water credits that can be sold to offset future increases in municipal water demand (BWD 2015). Note that the “agriculture” category in San Diego Geographic Information Source and shown in Table 2.1-3 does not distinguish between active, irrigated, and/or fallowed agricultural land and therefore does not assign these 600 acres to a different land use category. Currently, the total area of irrigated agriculture is approximately 2,624 acres based on updated mapping done by the GSA in 2018.

Table 2.1-3
Plan Area Land Uses by Year in Acres and Percent

Land Use Category	1990		1995		2000		2004		2008		2015		1990–2015 Change	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
Plan Area														
Open Space/Undeveloped Land	57,133	91.0%	55,649	88.7%	55,685	88.7%	55,054	87.7%	54,632	87.0%	54,500	86.8%	-2,632	-4.6%
Agriculture	2,343	3.7%	3,651	5.8%	3,582	5.7%	3,599	5.7%	3,472	5.5%	3,474	5.5%	1,131	48.3%
Residential	1,149	1.8%	1,288	2.1%	1,376	2.2%	1,809	2.9%	2,318	3.7%	2,369	3.8%	1,220	106.1%
Roadway/Parking Lot/Airstrip	1,048	1.7%	1,048	1.7%	1,064	1.7%	1,057	1.7%	1,064	1.7%	1,047	1.7%	-1	-0.1%
Park/Recreation/Golf Course	568	0.9%	573	0.9%	604	1.0%	723	1.2%	745	1.2%	838	1.3%	270	47.6%
Government/Other Public Institutions	300	0.5%	332	0.5%	192	0.3%	334	0.5%	335	0.5%	340	0.5%	40	13.2%
Commercial/Industrial	229	0.4%	229	0.4%	268	0.4%	195	0.3%	204	0.3%	202	0.3%	-27	1.1%

Source: SANGIS 2017.

Each jurisdictional area is described in greater detail below.

State of California

The total size of the ABDSP is about 615,000 acres. About 17,072 acres, or 27% of the Plan Area, is occupied by the ABDSP. Outside the Plan Area, the Anza-Borrego Desert State Park occupies 23,383 acres within the portion of the Ocotillo Wells Subbasin within San Diego County. ABDSP draws hundreds of thousands of visitors per year, the vast majority of whom arrive between November and April, with up to 35% visiting in March with significant increases in visitors occurring during the wildflower season. Most visitors are day-users, with about one in four camping overnight. Most (75%) visit the Park's northern sections. Half of visitor traffic is concentrated in the ABDSP Visitor Center/Borrego Palm Canyon area (CDPR 2015). The ABDSP Visitor Center and Palm Canyon Campground, group sites, and trailheads are located in the western part of the Plan Area, and the Vern Whitaker Horse Camp, Desert Garden, and portions of the Wildflower fields are located in the northern end of the Plan Area. The desert springs, palm groves, and the routes/trails within the hilly and mountainous areas of the park are outside the Plan Area. A 2012 economic study developed for the Anza-Borrego Foundation estimates the revenue to the region generated by visitation to the park during an average year is approximately $40 million annually (BBC 2012).

ABDSP partners with the Steele/Burnand and Anza-Borrego Desert Research Center and the Anza Borrego Foundation to advance research opportunities, and provide educational and interpretive programs. The Anza Borrego Foundation currently holds 3,190 acres (or 5% of the Plan Area) in fee for the purpose of adding to ABDSP lands for conservation in and around the Park, educating the public about the Park's resources, and supporting research relevant to the region (ABF 2017). The Steele/Burnand Anza-Borrego Desert Research Center, housed in the former Desert Club building at the western end of Palm Canyon Drive, hosts field research by biologists, astronomers, anthropologists and others, and is operated through the University of California, Irvine (UCI 2018). The center encourages research within ABDSP and its environs to foster management of the park's natural and cultural resources informed by high-quality science.

County of San Diego

Approximately 42,022 acres, or 67% of the Plan Area, consists of private land under County jurisdiction. Outside the Plan Area, there are approximately 15,408 acres of private land within the portion of the Ocotillo Wells Subbasin within San Diego County. The developed portions of the Plan Area consist of residential, agricultural, recreational, and commercial uses, with the majority of agricultural lands located in the northern portion of the Plan Area, where citrus crops and nursery stock, such as date palms, are grown for export out of the Subbasin (County of San Diego 2011).

The permanent population of the Plan Area is concentrated in the County-designated Borrego Springs Community Plan Area (CPA; Figure 2.1-4). About 13,283 acres of the Borrego Springs CPA extends outside the Plan Area; however, all of the currently developed portions of the CPA are within the Plan

Area. The CPA within the Plan Area covers about 49,972 acres of the Plan Area, or about 79%. Aside from California State Park wells within ABDSP, the water wells serving the Plan Area are under County and BWD jurisdiction. Based on County well permits and DWR well logs (including identification of database overlaps), BWD well data, field reconnaissance, and aerial imagery, it is estimated that there are approximately 121 active wells within the Plan Area, including municipal wells, irrigation wells, and private/domestic wells (Figure 2.1-5). Of these 121 wells, 53 are considered to be de minimis[6] users, the majority of which (49) are domestic wells. Of the non-de minimis users, 42 are in agricultural use, 8 are in municipal use by BWD, 13 are in recreational use, and the remainder are small water systems, non-recreational irrigation, and California State Park uses. The average well density within the Plan Area for all active and inactive wells is 2.6 wells per square mile (250 wells per 98 square miles). Figure 2.1-5 shows an estimate of the well density for each square mile township and range section in the Plan Area. The estimated average well density shown on Figure 2.1-5 is based on available well log records and may include wells that are inactive or abandoned.

Population within the Plan Area is reported by several sources. A substantial number of residents choose to reside in the Plan Area during the winter, spring, and fall only, when temperatures are more temperate. The seasonal change in population complicates the population counts. According to the Borrego Springs Community Plan prepared in 2011, the full-time population within the CPA was approximately 2,700, with another 2,000 or more seasonal or “snow bird” residents (County of San Diego 2011). According to the BWD Integrated Regional Water Management (IRWM) Plan prepared in 2009, the population is reported to range from less than 3,000 in summer months to over 8,000 in the height of the winter season (BWD 2009b). The 2010 Decennial Census reported a population of 3,429 and an average household size of 2.18 persons/household (U.S Census Bureau 2018; Table 2.1-4). The 2010 census counted 2,611 housing units, of which only 1,571 were found to be occupied for year-round residence, with the remainder occupied for seasonal use, not rented, or otherwise vacant (U.S. Census Bureau 2018).

It should be noted that the census count for 2010 appears to be high when compared to the population reported by the Borrego Springs Community Plan and the IRWM Plan. In addition, the 2011–2015 American Community Survey 5-Year Estimate for population within the Borrego Springs Census Designated Place (CDP) is 2,518 in 2015 (U.S Census Bureau 2018). For the purpose of projecting future growth, the 2015 estimate by the American Community Survey was used as the current population of the CDP.

Table 2.1-4 projects future population growth using a linear extrapolation of decennial census data from 1990 and the 2015 American Community Survey 5-Year Estimate. Because the 2010 census count appears to have captured at least some portion of non-permanent population, future growth population projections would be too high if based on the 2010 census count. Furthermore, the

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[6] SGMA defines a de minimis extractor as “a person who extracts, for domestic purposes, two acre-feet or less (of groundwater) per year.”

apparent growth in population in 2010 is not borne out by recently observed trends (for example, the American Community Survey estimate for 2015), and the same rate of population increase is unlikely to occur when considering current and future constraints on growth. These constraints include physical constraints such as the high Plan Area coverage within the FEMA 100-year floodplain, and economic and public service constraints, which besides groundwater availability limitations, also include the lack of economic sectors that provide year-round employment and limited medical services (particularly important for the older demographic of the Plan Area).

Table 2.1-4
Historical and Projected Permanent Population

Year	Population[a]
1990	2,244
2000	2,541
2010	3,429 [b]
2015	2,518
2020[c]	2,582
2030[c]	2,714
2040[c]	2,852
2050[c]	2,998
Estimated Annual Growth Rate[d]	**0.5%**

Source: U.S. Census 2010, 2018.
Notes:

[a] Borrego Springs is a Census Designated Place. The population estimates in this table are the permanent population. Seasonal population is a large factor in Borrego Springs since the winter population may exceed 8,000 according to Borrego Water District (BWD's) Integrated Regional Water Management Plan.

[b] The 2010 census count is considered an anomalous count and is not used in the annual growth rate estimate for the reasons discussed in the preceding paragraph.

[c] Population Future = Population Current x $(1 + 0.005)^n$. Where Population Current = 2015 Population (2,518), annual growth rate = 0.005 and n = 25 years between periods.

[d] Annual growth rate = ((Present Value – Past Value)/Past Value)) x100 = Growth Rate/Years (N) = Annual Growth Rate, N = 25; The population in 1990 was used for the past value and the population in 2015 was used for the present value.

The Borrego Springs CDP is considered a severely disadvantaged community, which means that households average less than 60% of the state's median household income; the median household income for the Borrego Springs CDP is $36,583 per year (U.S Census Bureau 2018). Other than agriculture and tourism, there is no major industry or source of high-quality employment within the Plan Area likely due to its remote location.

2.1.2 Water Resources Monitoring and Management Programs

Already existing water resources monitoring and management programs within the Plan Area are described as follows, beginning with statewide programs and ending with local programs. Since there are no surface water resources or imported water sources within the Plan Area, the programs described are exclusively related to groundwater monitoring and management. Furthermore, there are no urban water management plans or agricultural water management plans applicable to the Plan Area, because the thresholds required for the preparation of such plans under the Water Conservation Act of 2009, also known as Senate Bill (SB) X7-7 (California Water Code, Section 10610 et seq.), are not exceeded. BWD does not qualify as an urban water supplier, as defined in California Water Code, Section 10617, because it does not serve more than 3,000 customers or supply more than 3,000 AFY. BWD serves potable water through 2,059 water meters and provided approximately 1,645 AFY of water in 2016, with a 10-year average (between 2005 and 2015) of 2,502 AFY. Furthermore, BWD is not an agricultural water supplier[7] and thus is not required to prepare an agricultural water management plan.

California Statewide Groundwater Elevation Monitoring Program

In response to SB x7-6, passed by the legislature in 2009, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) Program to encourage collaboration between local monitoring parties and DWR and to collect statewide groundwater elevations for the purpose of tracking seasonal and long-term groundwater elevation trends in groundwater basins statewide. DWR works cooperatively with local agencies, referred to as CASGEM "Monitoring Entities," to collect and maintain groundwater elevation data in a manner that is readily and widely available to the public through the CASGEM online reporting system.

The BWD and the County are the Monitoring Entities for the purpose of tracking groundwater elevation trends within the BVGB. Both parties have been reporting groundwater levels to the CASGEM online reporting system at least semi-annually since 2011. Within the Borrego Springs Subbasin, the County has been submitting groundwater elevation data for two wells (Dr. Nel and MW-5B), and the BWD has been submitting groundwater elevation for eight wells (ID1-1, ID4-1, ID4-2, ID4-6, MW-1, MW-3, MW-4, and Paddock).

Data collected as part of the CASGEM program have been integrated into the BVGB data management system, the Borrego Valley Hydrologic Model (BVHM), and the monitoring and reporting program developed as part of this GSP. The groundwater elevation data collected through the CASGEM program are also made available to the public through DWR's "Groundwater Information Center (GIC) Interactive Map" application.[8]

Assembly Bill 3030: Borrego Water District Groundwater Management Plan

BWD adopted a Groundwater Management Plan (GMP) in 2001. However, the GMP will no longer be in effect once the GSP is adopted (California Water Code, Section 10750.1(a)).

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[7] An "Agricultural water supplier" is defined as a water supplier, either publicly or privately owned, providing water to 10,000 or more irrigated acres, excluding the acreage that receives recycled water (California Water Code, Section 10608.12(a)).

[8] http://www.water.ca.gov/groundwater/MAP_APP/index.cfm.

Under the existing GMP, BWD is the designated Assembly Bill (AB) 3030 groundwater management agency and, per California Water Code, Section 10754, has had the authority of a groundwater replenishment district for the BVGB (BWD 2002). Under the groundwater replenishment district law (California Water Code, Section 60220 et seq.), BWD has the authority, among other powers, to buy and sell water, exchange water, distribute water in exchange for ceasing or reducing groundwater extraction, recharge the basin, and build necessary works to achieve groundwater replenishment. Additionally, BWD has the authority to levy a replenishment assessment, but only if replenishment water is available. The intent of AB 3030 was for water districts to obtain the voluntary agreement of large water users regarding how much groundwater they would extract and how much they would rely upon purchasing imported water. BWD has used AB 3030 to do groundwater planning even though it is an isolated basin that has no access or right to any imported surface water from either the Colorado River or state water derived from the Sacramento-San Joaquin Delta.

Prior to implementation of this GSP, the BVGB remains an unmanaged basin, as the statutory provisions of the AB 3030 did not provide adequate authority for establishing a managed basin in the absence of imported water. Additionally, AB 3030 did not provide a cost-effective means to collect water extraction fees. For these reasons, BWD has previously attempted to address groundwater overdraft in the Plan Area through voluntary measures (BWD 2002, 2010). These measures have been paid for primarily by BWD’s ratepayers through new development, although the water used by BWD ratepayers between 2010 and 2015 accounted for only approximately 10%–12% of annual withdrawals from the Borrego Springs Subbasin. Since 2002, despite the efforts of the Borrego Valley stakeholders to address and manage the area’s groundwater resources, the BWD has lacked the authority and funding mechanisms to eliminate the overdraft within the Plan Area.

Integrated Regional Water Resources Management Plan

The Anza-Borrego Desert IRWM Region (Region), was formally approved through the California DWR’s Region Acceptance Process in 2009. In 2006, the BWD began working to secure a position within an IRWM Region in the San Diego or Colorado River Funding Areas. However, these attempts were unsuccessful due to jurisdictional boundary considerations. In 2009, BWD partnered with the County and Resource Conservation District of Greater San Diego County to form the Anza-Borrego Desert IRWM Region, to better reflect the geologic and hydrologic conditions of the Borrego Valley area. The original Region Acceptance Process submittal for the Borrego Valley area was limited to the Borrego Valley Watershed within San Diego County but was later expanded to include the portion of San Diego County that lies in the Colorado River Hydrologic Basin, the entire Borrego Valley Watershed that extends into Riverside County, and the area of San Diego County east of the Tecate Divide. The expanded Region includes the entire Anza-Borrego Desert State Park, four public water purveyors, and six separate tribal lands. The IRWM Plan prepared in 2009 presented an update on the water management and conservation measures being implemented or contemplated by stakeholders in the BVGB, including an evaluation of alternatives and costs for augmenting water resources by importing non-local supplies from sources outside the BVGB (BWD 2009b). The report accompanied applications to receive state grant funding through Proposition 50 (and subsequently Proposition 84) for a proposed water importation pipeline. Ultimately, BWD did not receive funding for the projects contemplated in the IRWM Plan.

The BWD is engaged in a Conservation Management Program as part of its continued efforts to preserve groundwater resources (BWD 2009b). The program is designed to reduce water use and mitigate impacts of new water uses in the community. The program includes a tiered rate schedule for residential, commercial, and irrigation water usage. Conservation incentive policies include an education program, promotion of low flush toilets, low water use washing machines, turf removal, and irrigation efficiency auditing (BWD 2009b).

Porter–Cologne Water Quality Control Act and Clean Water Act Permitting

The Porter–Cologne Water Quality Control Act (codified in California Water Code, Section 13000 et seq.) is the primary state water quality control law for California; whereas, the federal Clean Water Act applies to all waters of the United States, the Porter–Cologne Act applies to waters of the state[9], which includes isolated wetlands and groundwater in addition to federal waters. It is implemented by the State Water Resources Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCBs). In addition to other regulatory responsibilities, the RWQCBs have the authority to conduct, order, and oversee investigation and cleanup where discharges or threatened discharges of waste to waters of the state could cause pollution or nuisance, including impacts to public health and the environment. The BVGB is within the Colorado River Basin (RWQCB Region 7) and within the Anza Borrego Hydrologic Unit per the RWQCB Basin Plan. These statutes are relevant to the GSP in that they regulate the quality of point-source discharges (e.g., wastewater treatment plant effluent, industrial discharges, and on-site wastewater treatment systems (OWTSs) and non-point source discharges (e.g., stormwater runoff) to the underlying aquifer.

The *Water Quality Control Plan for the Colorado River Basin* (Basin Plan) designates beneficial uses, establishes water quality objectives, and contains implementation programs and policies to achieve those objectives for all waters addressed through the Basin Plan (California Water Code, Sections 13240–13247). The Porter–Cologne Act provides the RWQCBs with authority to include within their basin plan water discharge prohibitions applicable to particular conditions, areas, or types of waste. The Basin Plan is continually being updated to include amendments related to implementation of total maximum daily loads, revisions of programs and policies within the Colorado River Basin RWQCB region, and changes to beneficial use designations and associated water quality objectives. The beneficial uses for groundwater for the Anza Borrego Hydrologic

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[9] "Waters of the state" are defined in the Porter–Cologne Act as "any surface water or groundwater, including saline waters, within the boundaries of the state" (California Water Code, Section 13050(e)).

Unit are MUN,[10] IND,[11] and AGR[12]. According to the SWRCB "Sources of Drinking Water" policy, as adopted by the SWRCB on May 19, 1988 (Resolution No. 88-63), groundwater is considered to be suitable, or potentially suitable, for municipal or domestic water, except where:

- Total dissolved solids (TDS) exceed 3,000 milligrams per liter (mg/L) (5,000 microSiemens, electrical conductivity), and it is not reasonably expected by the RWQCB to supply a public water system;
- There is contamination, either by natural processes or by human activity (unrelated to a specific pollution incident), that cannot reasonably be treated for domestic use using either BMPs or best economically achievable treatment practices; or
- The water source does not provide sufficient water to supply a single well capable of producing an average, sustained yield of 200 gallons per day (gpd).

The Basin Plan recognizes that some hydrologic units contain multiple aquifers that may each support different beneficial uses.

The Basin Plan also designates beneficial uses for surface waters. The designated beneficial uses for San Felipe Creek are agriculture; fresh water replenishment; groundwater recharge; water contact and non-water contact recreation; warm freshwater habitat; wildlife habitat; and preservation of rare, threatened, or endangered species. The Borrego Sink Wash, receiving flows from ephemeral streams, is listed in the Basin Plan as having intermittent beneficial uses of fresh water replenishment, groundwater recharge, non-water contact recreation, and wildlife habitat. The Porter–Cologne Act requires a "Report of Waste Discharge" for any discharge of waste (liquid, solid, or otherwise) to land or surface waters that may impair a beneficial use of surface or groundwater of the state. California Water Code Section 13260 subdivision (a) requires that any person discharging waste or proposing to discharge waste—other than to a community sewer system—that could affect the quality of the waters of the state, file a Report of Waste Discharge with the applicable RWQCB. For discharges directly to surface water (waters of the United States), a National Pollutant Discharge Elimination System permit is required, which is issued under both state and federal law; for other types of discharges, such as waste discharges to land (e.g., spoils disposal and storage), erosion from soil disturbance, or discharges to waters of the state (such as groundwater and isolated wetlands), Waste Discharge Requirements (WDRs) are required and are issued exclusively under state law. WDRs typically require many of the

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[10] Municipal and Domestic Supply: Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

[11] Industrial Service Supply: Uses of water for industrial activities that do not depend primarily on water quality, including, but not limited to, mining, cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.

[12] Agriculture Supply: Uses of water for farming, horticulture, or ranching, including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

same best management practices (BMPs) and pollution control technologies as required by National Pollutant Discharge Elimination System-derived permits.

The National Pollutant Discharge Elimination System and WDR programs regulate construction, municipal, and industrial stormwater and non-stormwater discharges under the requirements of the Clean Water Act and the Porter–Cologne Act, respectively. The construction and industrial stormwater programs are administered by the SWRCB; whereas, individual WDRs, low-threat waivers, and other basin-specific programs are administered by the Colorado River Basin RWQCB. Programs and policies that have particular relevance to the BVGB include the following:

- **Stormwater General Permits (construction and industrial general permits)**: The SWRCB and Colorado River Basin RWQCB administer a number of general permits that are intended to regulate activities that collectively represent similar threats to water quality across the state and thus can appropriately be held to similar water quality standards and pollution prevention BMPs. Construction projects over 1 acre in size are regulated under the Statewide Construction General Permit and are required to develop and implement a Stormwater Pollution Prevention Plan. Similarly, industrial sites are also required to develop a Stormwater Pollution Prevention Plan that identifies and implements BMPs necessary to address all actual and potential pollutants of concern. The entities within the BVGB currently subject to an industrial Stormwater Pollution Prevention Plan include Borrego Landfill Inc., the Borrego Valley Airport, and the Borrego Springs Unified School District (for its bus maintenance yard) (SWRCB 2018).
- **Irrigated Lands Regulatory Program**: Water discharges from agricultural operations include irrigation runoff, flows from tile drains, irrigation return flows, and stormwater runoff. These discharges can affect water quality by transporting pollutants, including pesticides, sediment, nutrients, salts (including selenium and boron), pathogens, and heavy metals, from cultivated fields into surface waters and/or groundwater. To prevent agricultural discharges from impairing the waters that receive these discharges, the Irrigated Lands Regulatory Program (ILRP) regulates discharges from irrigated agricultural lands. This is done by issuing WDRs or conditional waivers of WDRs to growers. These orders contain conditions requiring water quality monitoring of receiving waters and corrective actions when impairments are found. Through a series of events related to the passage of SB 390 (Alpert), the ILRP originated in 2003. Initially, the ILRP was developed for the Central Valley RWQCB. As the Central Valley RWQCB ILRP progressed, a groundwater quality element was added to the filing requirement for agricultural lands that had previously been subjected to only surface water discharge concerns. To date, the different RWQCBs are in different stages of implementing the ILRP. The Colorado River RWQCB has a conditional waiver program for farms in the Imperial Valley but does not have a similar program for the Borrego Valley.

- **OWTS Requirements**: Requirements for the siting, design, operation, maintenance, and management of OWTSs are specified in the SWRCB's "Water Quality Control Policy for Siting, Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems (OTWS Policy)." The OWTS policy sets forth a tiered implementation program with requirements based upon levels (tiers) of potential threat to water quality. The OWTS policy includes a conditional waiver for on-site systems that comply with the policy. The County Department of Environmental Health (DEH) enforces these statewide requirements through Chapter 3, Division 8, of Title 6 of the San Diego County Code and the Local Agency Management for OWTS. The DEH Local Agency Management Program for OWTS prepared by the County in February 2015 applies to both the San Diego and Colorado River Basin RWQCBs. Provided that no public sanitary sewer system is available, the ordinance allows for installation of OWTS if the requirements and standards of the ordinance are complied with, and a permit issued by the DEH is obtained. Standards and requirements include, but are not limited to, soil percolation tests to determine soil suitability; the selection of a treatment system appropriate for the site conditions; groundwater separation requirements; contractor licensing requirements; and specific layout/setback requirements from lakes, streams, ponds, slopes, and other utilities and structures. The County DEH also provides permitting services for graywater systems.
- **Individual WDRs**: Individual WDRs are required for point source discharges to land not otherwise covered under a general permit program or conditional waiver. The purpose of individual WDRs are to define discharge prohibitions, effluent limitations, and other water quality criteria necessary to ensure discharges do not result in exceedances of Basin Plan objectives for receiving waters, including groundwater. Examples of individual WDRs in the Plan Area include those for the Rams Hill Wastewater Treatment Facility (WWTP) owned and operated by BWD (Colorado River Basin RWQCB Order No. R7-2007-0053) and the Borrego Springs Landfill (Order No. R7-2014-0051).

Demand Offset Mitigation Water Credits Policy

The current Demand Offset Mitigation Water Credits Policy (WCP) was initiated in 2004 as a means for the BWD and later the County to encourage the voluntary immediate cessation and/or reduction of measurable water use in the Subbasin. The objectives of the WCP include: (a) to reduce the demand on the upper groundwater aquifer that underlies the Borrego Valley; (b) to provide a mechanism by which new water demands are mitigated in compliance with the California Environmental Quality Act (CEQA); and (c) to create economic incentives for property owners engaged in high water demand activities to cease or reduce their groundwater demands consistent with the objectives of the BWD GMP as adopted by the BWD in 2001, and as subsequently amended and updated (BWD 2015). The WCP is designed to encourage the conversion of local farmland and high water use areas (i.e., golf courses) to land uses with less water demand. A Memorandum of Agreement between the County and the BWD identifies criteria that must be met to receive water credit for fallowed lands (BWD and County of San Diego 2013).

The BWD began issuing credits in 2008 that did not necessarily meet County approval standards but abided by the BWD's WCP and aimed to further encourage reduced groundwater demand within the Subbasin. A water credit is an entitlement created under the WCP that recognizes the fallowing of actively irrigated land in the Plan Area. Water credits can be used to offset the future groundwater use of proposed development. One water credit is defined as 1 AFY of groundwater use. The number of water credits issued is calculated by multiplying the total area of irrigated land by a groundwater consumptive use factor based on crop type. Water credits for future groundwater use are made available by the BWD and can be obtained from private landowners with existing water credits issued by the BWD. Although the County can decide if water credit applications meet County requirements, BWD has authority and has issued credits without County input.

To date, fallowed sites placed in one of two categories: (1) groundwater restrictive easements on lands that were fallowed as direct mitigation measures for development in which no water credits were assigned and (2) fallowing and/or groundwater reduction measure sites that were allotted water credits by the BWD without being related to any particular development. Four groundwater restrictive easements have thus far been issued for direct mitigation, and 12 groundwater restrictive easements for water credits. To date, these fallowed lands consist of approximately 600 acres of irrigated land and 1,886.5 originally issued credits[13]. Of this total, the County has approved approximately 178 acres and 727 credits. The County is also currently conducting compliance and enforcement evaluations related to the credits issued by the BWD program. At a later date, existing water credits associated with the WCP may be converted to a Baseline Pumping Allocation using the groundwater consumptive use factors developed by the GSA, as further discussed in Section 4.4, Pumping Reduction Program.

Groundwater Mitigation Program

By resolution, the BWD implemented a groundwater mitigation program that works in conjunction with the County's *Department of Planning & Land Use Policy Regarding Cumulative Impact Analyses for Borrego Valley Groundwater Use* (adopted in 2004) in the Borrego Valley (County of San Diego 2007). The County policy, originally adopted in 2004, and most recently revised in 2007, requires all proposed development projects subject to discretionary land use review by the County[14] to also be reviewed for potential adverse impacts on the Borrego Springs Subbasin. The County requires these projects to demonstrate that the proposed water demands are offset by an equal water demand reduction

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[13] These credits are representative of approximately 1,600 acre feet per year (rounded).

[14] This means discretionary land development applications for a project which proposes to use groundwater, including but not limited to, (a) general plan and specific plan adoptions and amendments, (b) tentative and revised tentative maps and parcel maps, (c) zoning and use regulation amendments, (d) major use permits or modifications, (e) certificates of compliance, and (f) lot line adjustments.

or additional water supply (County of San Diego 2007). In 2016, the BWD implemented a more stringent policy in anticipation of SGMA, in which all new development in Borrego Springs supplied by the BWD must retire existing water demands on a 4:1 basis (BWD Resolution No. 2016-01-01).

County of San Diego Groundwater Ordinance

The County adopted the San Diego County Groundwater Ordinance in 1991; it was last amended in 2013 (San Diego County Code Title 6, Division 7, Chapter 7, Secs. 67.701 through 67.750). The ordinance establishes legal standards for the protection, preservation, and maintenance of groundwater resources. One of the purposes of the ordinance is to ensure that development is not approved in groundwater-dependent areas of the County unless a project applicant can demonstrate that there are adequate supplies available to serve both existing and proposed uses (County of San Diego 2013). The ordinance includes provisions specific to the Borrego Valley Exemption Area, in which a project[15] that will extract or use at least 1 AFY is required to include one or more groundwater use reduction measures listed in in the ordinance to meet the performance standard of "no net increase" in the amount of water extracted from the basin. The ordinance incorporates the aforementioned groundwater mitigation and water credits program so that land use approvals do not occur within the BVGB without complying with the performance standard of "no net increase" in water demand. Updates to the Groundwater Ordinance are anticipated to ensure consistency with GSP sustainability goals.

Permitting of New Well, Replacement Well, and/or Well Destruction/Abandonment

The San Diego County DEH, Land and Water Quality Division, regulates the design, construction, modification, and destruction of water wells throughout San Diego County to protect San Diego County's groundwater resources (County of San Diego 2016). San Diego County Code, Sections 67.401 through 67.424, provide the regulatory authority to DEH to require and issue water well permits. In addition, Section 67.421 adopts standards from DWR Bulletin 74-81 and 74-90 (i.e., California Well Standards) for the construction, repair, reconstruction or destruction of wells (DWR 1981, 1991). California's Water Well Standards include requirements to avoid sources of contamination or cross-contamination, proper sealing of the upper annular space (i.e., first 50 feet), disinfection of the well following construction work, use of appropriate casing material, and other requirements. The County requires wells to meet certain setback criteria (e.g., septic system setback) and specific construction and sealing requirements. In addition, well drilling activities are required to reduce pollution to the maximum extent practicable using BMPs such as installing a sediment basin to contain run-off, using geotextile fabric to contain sediments and drilling mud, or eliminating the use of drilling foam (County of San Diego 2016).

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[15] A project is defined in the ordinance as any of the following: General Plan and Specific Plan Adoptions and Amendments, new or revised Tentative Parcel Maps and Tentative Maps, Zoning Reclassifications, new or modified Major Use Permits, Certificates of Compliance filed pursuant to San Diego County Code, Section 81.616.1 or 81.616.2, or in some cases Lot Line Adjustments filed pursuant to San Diego County Code, Section 81.901 et seq.

The DEH monitors and enforces these standards by requiring drilling contractors with a valid C-57 license to submit permit applications for the construction, modification, reconstruction (i.e., deepening), or destruction of any well within its jurisdiction. The processing and issuance of a water well permit is currently considered a ministerial action, meaning permits are issued to drillers meeting California Water Well Standards and County sealing requirements, and notwithstanding errors in the application. Certain circumstances, however, such as when installing a well could cause the spread of contaminants to uncontaminated water zones, may prevent DEH from issuing a well permit.

The passage of SB 252 added Article 5, Wells in Critically Overdrafted Groundwater Basins, to chapter 10 of the California Water Code requiring collection of specific information for water wells proposed in critically overdrafted groundwater basins. To facilitate the collection of the required information, DEH has revised the Well Permit Application and created a Supplemental Well Application. The Supplemental Well Application is included in the Well Permit Application and must be submitted for wells proposed in the Borrego Springs Subbasin. Wells drilled by the BWD to provide water solely for the residents are exempt from this requirement. The provisions of SB 252 are effective until January 30, 2020.

2.1.3 Land Use Considerations

County of San Diego General Plan

The County's General Plan outlines the County's vision for growth, community services, infrastructure, quality of life, and environmental resources. The Land Use Element is a framework that provides maps, goals, and policies that guide planners, the general public, property owners, developers, and decision makers as to how lands are to be conserved and developed in unincorporated San Diego County.

A major component to guiding the physical planning of San Diego County is the "Community Development Model." The Community Development Model is implemented by three regional categories—Village, Semi-Rural, and Rural Lands—that broadly reflect the different character and land use development goals of San Diego County's developed areas, its lower-density residential and agricultural areas, and its very low–density or undeveloped rural lands. The Community Development Model directs the highest intensities and greatest mix of uses to Village areas, while directing lower-intensity uses, such as estate-style residential lots and agricultural operations, to Semi-Rural areas. The Semi-Rural category may effectively serve as an edge to the Village, as well as a transition to the lowest-density category, Rural Lands, which represent large, remote areas where only limited development may occur. The General Plan Land Use Element includes a Community Services and Infrastructure section, which addresses the availability of public infrastructure such as roads, drainage facilities, sewer and water lines, and treatment plants, as appreciable growth cannot occur without such services being available or in place.

The General Plan land use categories within the Plan Area are shown on Figure 2.1-6. It should be noted that General Plan land use categories mapped within the Plan Area may not necessarily mirror the actual land uses on the ground, which are described in Section 2.1.1 and Table 2.1-4. For example, a large portion of the Plan Area mapped as rural or semi-rural residential (RL or SR) currently has an open space/undeveloped land use. In addition, there is no General Plan land use distinction between rural residential and agricultural uses, as the agricultural areas in the northern part of the basin have the RL and SR general plan land use designations. Overall, the most intensive General Plan land use categories are village residential, commercial, and industrial, and these are concentrated in a small portion of the Plan Area generally along the east-west Palm Canyon Drive and the north-south portion of Borrego Springs Road. Rural land designations dominate the Plan Area, with the portion of the Plan Area belonging to ABDSP shown as "public agency lands."

The development and implementation of the GSP is relevant to several General Plan elements, including the Land Use Element, Conservation and Open Space Element, and the Housing Element. The Land Use Element includes a requirement to document and annually review floodways and floodplains (LU-6.12) and to encourage sustainable use of groundwater and properly manage groundwater recharge areas (LU-8). The Conservation Element identifies and describes the natural resources of the County and includes policies and action programs to conserve those resources. The Conservation and Open Space Element identifies policies necessary to achieve (a) long-term viability of the County's water quality and supply through a balanced and regionally integrated water management approach (Goal COS-4), and (b) protection and maintenance of local reservoirs, watersheds, aquifer-recharge areas, and natural drainage systems to maintain high-quality water resources (Goal COS-5). The Housing Element describes the County's plan to provide decent and affordable housing, including appropriately designated land, opportunities for developing a variety of housing types, and policies and programs designed to assist in the development of housing for all income levels and special needs.

The Regional Housing Needs Assessment for San Diego County for 2013–2020 period projects an additional 22,412 residential units, 80% of which are to be accommodated within the San Diego County Water Authority boundary, where water and other public services are more readily available (County of San Diego 2011).[16] The eastern extent of the San Diego County Water Authority in North County is the Ramona Municipal Water District located about 30 miles west of the Plan Area. Recognizing the constraints on growth presented by the lack of readily available water sources and other public services, the last General Plan Update (adopted in 2011) substantially reduced the degree to which backcountry communities such as Borrego Springs were expected to meet the future housing

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[16] The Regional Housing Needs Assessment is a state-supervised process by which the San Diego Association of Governments allocates to its local jurisdictions their share of an eleven-year projected housing need at various affordability levels

demand. The General Plan Update reduced the maximum allowable additional residential units in Borrego Valley from 19,466 units to about 8,689 units (County of San Diego 2011).

Under the County's current zoning, there are 3,454 vacant and undeveloped parcels that could be converted to residential development and 526 vacant and undeveloped lots that potentially could be converted to commercial, industrial, office space, rural commercial, open space, public agency, or public/semi-public facilities (SANGIS 2017; County of San Diego 2011). This GSP uses the legal lot status estimate of 85% from the *Evaluation of Groundwater Conditions in Borrego Valley* to develop a more realistic number of buildable lots (County of San Diego 2010). The County developed this estimate considering that:

> "Having a legally created lot which meets Zoning requirements still may not be buildable due to a number of factors such as floodplain issues, having legal access to roadways, having access to sewer or water, etc. Building permits are granted on a case-by-case basis by the County, and it is not possible to accurately estimate the number of legally buildable parcels in Borrego Valley. However, the significant inventory of existing unbuilt lots could possibly provide up to an additional 3,000+ future residential units without any additional subdivision (County of San Diego 2010)."

Zoning ordinance designations for the Plan Area are shown on Figure 2.1-7. It should be noted that only 19 building permits for residential units have been issued in Borrego Springs since 2011 (County of San Diego 2018). As of 2018, there are approximately 2,615 existing residential units within Borrego Springs (County of San Diego 2018).

The 2011 County of San Diego General Plan Update Programmatic Environmental Impact Report (EIR) included a groundwater study that evaluated the impacts that maximum buildout under the 2011 General Plan would have on groundwater. The Programmatic EIR concluded that the buildout of the General Plan Update would have a potentially significant impact to the Borrego Valley aquifer in Borrego Springs. The General Plan Update groundwater study indicated that the General Plan Update allows for an additional 8,689 residential units, plus an additional 3,000+ residential units without subdivision, for a total of 11,689 additional units. Assuming 0.5 acre-feet/year water demand per residential unit, this would equate to 5,844.5 acre-feet/year for the 11,689 units. Future general plan and community plan updates should consider the sustainability goals of this GSP. Updated buildout estimates should be considered in conjunction with the sustainability goals, projects, and management actions outlined in this GSP.

Table 2.1-5 provides the residential buildout potential of the existing General Plan.

Table 2.1-5
General Plan Residential Buildout in Borrego Springs Subbasin

General Plan Residential Capacity	Number of Units
Existing Residential Units	2,615
Vacant Buildable Lots (Without Further Subdivision)	3,000+
Additional General Plan Capacity (Requires Future Subdivision)	8,689
Total	**14,304**

The County uses General Plan elements, goals, and policies to guide its discretionary permit decision making, and the policies relevant to the Borrego Springs Subbasin are included in Table 2.1-6.

Borrego Springs Community Plan

The CPA applicable to the Borrego Springs Subbasin is the Borrego Springs Community Plan (County of San Diego 2011). Community plans are part of the General Plan. These plans focus on a particular region or community within the overall General Plan area. They are meant to refine the policies of the General Plan as they apply to a smaller geographic region and provide a forum for addressing unique local issues. As required by state law, community plans must be internally consistent with General Plan goals and policies of which they are a part. They cannot undermine the policies of the General Plan. Community plans are subject to adoption, review, and amendment by the County Board of Supervisors in the same manner as the General Plan. Table 2.1-5 presents a summary of general plan and community plan elements, goals, and policies in the Plan Area.

When the County prepares its next General Plan (including community plan) update for Borrego Springs, this GSP will be a key consideration with respect to related goals and policies. The implementation of this GSP and the County’s General Plan update process are separate but related processes. Review of the policies in Table 2.1-6 indicate that the current policies are generally consistent with the sustainability goals of this GSP. The existing General Plan designations and policies allow for growth (e.g., community plan goal LU-2.4) and promote agricultural conservation (e.g., General Plan goals LU-7 and COS-6) in a manner that may be inconsistent with the sustainability criteria, pumping reduction program, and the agricultural land fallowing program described in Chapters 3 and 4 of this GSP. However, there are no urban water management plans or agricultural water management plans applicable to the Plan Area that contain assumptions or projections of water supply/demand that would be in conflict with implementation of this GSP (e.g., too generous given the GSP’s sustainability goals). Existing County land use regulations, including the Demand Offset Mitigation WCP, the Groundwater Mitigation Program, the Groundwater Ordinance, and the CEQA process, significantly constrain growth by requiring that new land uses result in no net increase in water demand. This, along with economic factors and other public service constraints, is the reason such limited growth has occurred in the Subbasin (e.g., issuance of only 19 building permits for residential units since 2011).

The County, in conjunction with adoption and implementation of the GSP, will ensure land use policies are brought in line with the sustainability goals of this GSP. This will be done by considering the sustainability goals and the projects and management actions of the GSP in the updated General Plan and community plan, and through revisions to the County's groundwater ordinance. The implementation of existing land use plans would not affect the ability of the GSA to achieve sustainable groundwater management over the planning and implementation horizon.

The Borrego Springs Community Sponsor Group is a seven-member group of representatives that assists the County Planning Director, the Zoning Administrator, the Planning Commission, and the Board of Supervisors in the preparation, amendment, and implementation of community and subregional plans. The principal function of a sponsor group is to be an information link between the community and the County on matters dealing with planning and the use of land in its community. The group provides a public forum for the discussion of planning issues that are important to the community. All meetings are open to the public, held in a publicly accessible place, and the agenda is published in advance according to Brown Act provisions.

Table 2.1-6
Summary of General Plan and Community Plan Land Use Policies Relevant to Groundwater Sustainability in the Plan Area

Element	Policy	Description	GSP Consistency
County of San Diego General Plan			
Land Use Element	Goal LU-5: Climate Change and Land Use		
	LU-5.2	Incorporate into new development sustainable planning and design.	Yes
	LU-5.3	Ensure the preservation of existing open space and rural areas (e.g., forested areas, agricultural lands, wildlife habitat and corridors, wetlands, watersheds, and groundwater recharge areas) when permitting development under the Rural and Semi Rural Land Use Designations.	Yes
	Goal LU-6: Development—Environmental Balance		
	LU-6.1	Require the protection of intact or sensitive natural resources in support of the long-term sustainability of the natural environment.	Yes
	LU-6.3	Support conservation-oriented project design.	Yes
	Goal LU-7: Agricultural Conservation		

Table 2.1-6
Summary of General Plan and Community Plan Land Use Policies Relevant to Groundwater Sustainability in the Plan Area

Element	Policy	Description	GSP Consistency
	LU-7.1	Protect agricultural lands with lower-density land use designations that support continued agricultural operations.	Supporting continued agricultural operations in Borrego Valley may be inconsistent with the goal of reducing groundwater demand.
	LU-7.2	Allow for reductions in lot size for compatible development when tracts of existing historically agricultural land are preserved in conservation easements for continued agricultural use.	Yes, although pumping limits in GSP will restrict continued expansion of agricultural lands.
	Goal LU-8: Aquifers and Groundwater Conservation		
	LU-8.2	Require development to identify adequate groundwater resources in groundwater dependent areas. In areas dependent on currently identified groundwater overdrafted basins, prohibit new development from exacerbating overdraft conditions. Encourage programs to alleviate overdraft conditions in Borrego Valley.	Yes
	LU-8.3	Discourage development that would significantly draw down the groundwater table to the detriment of groundwater-dependent habitat.	Yes
	LU-8.4	Support the Borrego Valley Water District with their program to slow the overdrafting and extend the life of the aquifer supporting the residents of the Borrego Valley.	Yes
	Goal LU-13: Adequate Water Quality, Supply, and Protection		
	LU-13.1	Coordinate water infrastructure planning with land use planning to maintain an acceptable availability of a high quality sustainable water supply. Ensure that new development includes both indoor and outdoor water conservation measures to reduce demand.	Yes
	LU-13.2	Require new development to identify adequate water resources, in accordance with state law, to support the development prior to approval.	Yes
Conservation and Open Space Element	Goal COS-4: Water Management		
	COS-4.1	Require development to reduce the waste of potable water through use of efficient technologies and conservation efforts that minimize the County's dependence on imported water and conserve groundwater resources.	Yes
	COS-4.2	Require efficient irrigation systems and in new development encourage the use of native plant species and non-invasive drought tolerant/low water use plants in landscaping.	Yes

Table 2.1-6
Summary of General Plan and Community Plan Land Use Policies Relevant to Groundwater Sustainability in the Plan Area

Element	Policy	Description	GSP Consistency
	COS-4.3	Maximize stormwater filtration and/or infiltration in areas that are not subject to high groundwater by maximizing the natural drainage patterns and the retention of natural vegetation and other pervious surfaces.	Yes
	COS-4.4	Require land uses with a high potential to contaminate groundwater to take appropriate measures to protect water supply sources.	Yes
	COS-4.5	Promote the use of recycled water and gray water systems where feasible.	Yes
	Goal COS-5: Protection and Maintenance of Water Resources		
	COS-5.2	Require development to minimize the use of directly connected impervious surfaces and to retain stormwater run-off caused from the development footprint at or near the site of generation.	Yes
	COS-5.5	Require development projects to avoid impacts to the water quality in local reservoirs, groundwater resources, and recharge areas, watersheds, and other local water sources.	Yes
	Goal COS-6: Sustainable Agricultural Industry		
	COS-6.1	Support the economic competitiveness of agriculture and encourage the diversification of potential sources of farm income, including value added products, agricultural tourism, roadside stands, organic farming, and farmers markets.	Yes, although pumping limits in GSP will restrict continued expansion of agricultural lands.
	COS-6.2	Protect existing agricultural operations from encroachment of incompatible land uses.	Land use designations may need to change to meet groundwater sustainability goals
	COS-6.4	Support the acquisition or voluntary dedication of agriculture conservation easements and programs that preserve agricultural lands.	Yes. Note: The GSP is not inconsistent with this policy although the preservation of agricultural lands in Borrego Valley would not help to fulfill the long-term goals of the GSP. It should also be noted that the land fallowing program of the GSP may result in open space conservation easements or other uses to replace the fallowed agricultural lands

Table 2.1-6
Summary of General Plan and Community Plan Land Use Policies Relevant to Groundwater Sustainability in the Plan Area

Element	Policy	Description	GSP Consistency
	COS-6.5	Encourage best management practices in agriculture and animal operations to protect watersheds, reduce GHG emissions, conserve energy and water, and utilize alternative energy sources, including wind and solar power.	Yes
	Goal COS-14: Sustainable Land Development		
	COS-14.3	Require design of residential subdivisions and nonresidential development through "green" and sustainable land development practices to conserve energy, water, open space, and natural resources.	Yes
	COS-14.4	Require technologies and projects that contribute to the conservation of resources in a sustainable manner, that are compatible with community character, and that increase the self-sufficiency of individual communities, residents, and businesses.	Yes
	Goal COS-19: Sustainable Water Supply		
	COS-19.1	Require land development, building design, landscaping, and operational practices that minimize water consumption.	Yes
	COS-19.2	Require the use of recycled water in development wherever feasible. Restrict the use of recycled water when it increases salt loading in reservoirs.	Yes
Borrego Springs Community Plan			
Community Growth Policy	Goal LU-2.4: The conversion of existing agricultural uses to other, less consumptive uses by 2020 consistent with a Plan population of 8,000.		
	LU-2.4.1	Establish a special study area to work with the BSCSG and Borrego Water District to devise a plan to: a.) convert a majority of agricultural uses existing at the time of the adoption of this Plan (generally, those lands north of Henderson Canyon Road) to other less water consumptive uses and/or b.) secure a permanent alternative supply of water, together sufficient to meet forecast requirements.	Though water credit program and fallowing are being pursued, imports from adjacent basins have been determined to be economically infeasible. See Section 2.1.6 for details.
	Goal LU-2.5: Restoration and revegetation of existing fallowed (abandoned) farmlands and their conversion to open space uses to enhance community character, health and safety, and tourism appeal.		
	LU-2.5.1	Prioritize the preservation and restoration of existing fallowed and abandoned farmlands with their conversion to open space lands held in trust by the County or other suitable governmental or non-governmental organization.	Yes
	LU-2.5.2	Encourage the use of existing fallowed farmlands for the installation of solar farms for energy production.	Yes
Infrastructure and Utilities	Goal CM-10.1: A capacity in the Borrego aquifer that supports continued domestic and recreational demand in Borrego Springs and development of options to augment the water supply to create a sustainable/renewable supply for the community.		
	CM 10.1.1	Analyze the capacity of the existing groundwater aquifer and develop programs to create sustainable supplies of water for the projected build-out of the community.	Yes

Table 2.1-6
Summary of General Plan and Community Plan Land Use Policies Relevant to Groundwater Sustainability in the Plan Area

Element	Policy	Description	GSP Consistency
	CM 10.1.2	Create incentives for golf courses to decrease turf areas and convert those areas to desert landscape with less water use.	Yes
	CM 10.1.3	Prohibit the approval of any new agricultural, golf or other water intensive activities in any area overlying or tributary to the Borrego aquifer.	Yes. Water Credits may provide mechanism to allow approval.
	CM 10.1.4	Request, upon achieving a sustainable supply of water for the domestic water use in the community planning area, the adjudication of the aquifer to insure that future use does not continue to overdraft the aquifer except in times of drought, thus protecting the elements of the local environment dependent on the aquifer in its diminished capacity.	GSP projects and management actions, including baseline allocation, are being pursued as means to regulate the aquifer through court validation process rather than adjudication.
Conservation and Open Space	Goal COS 1.1: Incremental reductions of agricultural production in the Borrego Valley over the next 20 years while protecting the rights of farmers and the continued environmental health of the Borrego community.		
	COS 1.1.1	Encourage a reduction in the production of citrus crops and palm trees to manageable levels or their replacement with low to very low water consumptive crops	Yes
	Goal COS 1.4: A sustainable supply of water, ending the current overdrawing of the Borrego Springs sole-source aquifer.		
	COS 1.4.1	Encourage and develop methods for Community Plan Area groundwater system human withdrawals to be less than or equal to replenishment amounts on an average ongoing basis.	Yes
	COS 1.4.2	Prohibit the construction of any new golf courses in the Community Plan Area, unless an alternate water source, such as recycled water is made available.	Yes. Water Credits and GSP baseline pumping allocation will need to be adhered to.
	COS 1.4.3	Encourage xeriscape landscaping in residential and business developments.	Yes. A County of San Diego landscape restrictive ordinance applies to Borrego Springs.

Source: County of San Diego 2011.
Notes: GHG = greenhouse gas; BSCSG = Borrego Springs Community Sponsor Group; GSP = Groundwater Sustainability Plan; County = County of San Diego.

2.1.4 Beneficial Uses and Users

As discussed in Section 2.1.2, designated beneficial uses for groundwater in the Plan Area include municipal and domestic supply (MUN), industrial service supply (IND) and agriculture supply (AGR) based on the Basin Plan. The Basin Plan definition of recreational beneficial uses applies only to surface waters where ingestion of the water is reasonably possible (e.g., contact and non-contact water recreation), and thus is not applicable to groundwater as an underground resource. However, as an important recreational use in the Plan Area, groundwater used to irrigate golf courses and/or to supply ornamental ponds is considered in this GSP separately from the municipal and domestic supply designations. Thus, the "beneficial uses" evaluated in this GSP are not strictly synonymous with those analyzed in the Basin Plan. Three primary sectors extract the majority of groundwater in the Subbasin: (1) agriculture use; (2) municipal use, consisting of BWD; and (3) recreational use, which consists of six golf courses—Borrego Springs Resort, Club Circle, De Anza Country Club, Rams Hill Country Club, Road Runner Golf and Country Club, and The Springs at Borrego RV Resort and Golf Course.

Additional groundwater users include two active small water systems and two non-potable irrigators. The two small water systems are the ABDSP and the Borrego Air Ranch Water Co. The two non-potable irrigators are the Borrego Springs Unified School District (Elementary School) and La Casa Del Zorro Resort and Spa. Industrial service supply includes use for two utility scale solar facilities, a redi-mix plant, a County service yard and the Republic Services Borrego Landfill. Private groundwater users who extract less than 2 AFY are considered de minimis users under SGMA.

There are an estimated 52 active de minimis users within the Subbasin. Domestic well users are generally considered to be de minimis users, provided however, that a few properties that would otherwise qualify as de minimis contain irrigated area in excess of about 0.5 acres, thus taking them out of the definition of de minimis pumper in SGMA. Table 2.1-7 lists beneficial uses and users of groundwater in the Subbasin, including general location and estimated water use.

Table 2.1-7
Beneficial Uses and Users of Groundwater in the Plan Area

Beneficial Users	RWQCB Basin Plan Beneficial Use	Areas of the Subbasin	Estimated Water Use	
			Baseline Pumping Allocation (AFY)	*2018 Estimate (AFY)*
Pumpers				
Agriculture	AGR	NMA, CMA	15,729	14,767[a]
Municipal	MUN	NMA, CMA, SMA	2,122	1,600
Recreation	N/A[c]	NMA, CMA, SMA	4,050	3,245[d]
Water Credits	AGR	NMA, CMA	1,840[e]	0
Domestic Users (Non-de minimis)	MUN	NMA, CMA, SMA	62	58

Table 2.1-7
Beneficial Uses and Users of Groundwater in the Plan Area

Beneficial Users	RWQCB Basin Plan Beneficial Use	Areas of the Subbasin	Estimated Water Use	
			Baseline Pumping Allocation (AFY)	*2018 Estimate (AFY)*
De minimis users	MUN and IND[b]	NMA, CMA, SMA	N/A	34
		TOTAL	**21,963[f]**	**19,704**

Notes: RWQCB = Regional Water Quality Control Board; AFY = acre-feet per year; AGR = Agriculture Supply; NMA = North Management Area; CMA = Central Management Area; MUN = Municipal and Domestic Supply; SMA = South Management Area; N/A = not applicable; IND = Industrial Service Supply.

a. The 2018 estimate includes fallowing of 153 acres of citrus on the Burnand parcels at an estimated water use factor of 6.29 feet per year (153 acres X 6.29 feet/year = 961 AFY, so 2018 Estimate is 15,728 AFY – 961 AFY = 14,767 AFY). The water use factor is determined from local station specific evapotranspiration, documented plant factors, and irrigation efficiency.

b. Industrial water use is based on the two utility scale solar facilities, the redi-mix plant, and the County service yard. These users were not given a baseline pumping allocation because they are anticipated to extract less than 2 acre-feet per year.

c. The recreational beneficial uses under the Basin Plan definition applies only to surface waters where ingestion of the water is reasonably possible (e.g., contact and non-contact water recreation), and thus is not applied to groundwater as an underground resource. In addition, there is no RWQCB Basin Plan beneficial use specific to groundwater dependent ecosystems.

d. The 2018 estimate was determined by removing the irrigation formerly applied at the Borrego Springs Resort, using a factor of 6.45 feet/acre.

e. Water credits issued for fallowed agriculture are based on the original face value. Water credits do not represent a current water use until they have been purchased by entities seeking in-lieu mitigation for the water use of their development projects. The total water credits issued by the BWD is 1,886.5 AFY. To date 45.5 AFY have been retired and there are 1,840 AFY remaining water credits.

f. The total Baseline Pumping Allocation currently excludes water credits which may be converted to Baseline Pumping Allocation during GSP implementation.

2.1.5 Notice and Communication

In 2017, the GSA prepared a Stakeholder Engagement Plan to provide individual stakeholders, stakeholder organizations, and other interested parties an opportunity to be involved in the development and evaluation of this GSP. To this end, the Stakeholder Engagement Plan, included as Appendix C of this GSP, describes the steps the GSA has taken, and will continue to take, to achieve broad, enduring and productive public involvement during the development and implementation phases of this GSP. The Stakeholder Engagement Plan includes a list of identified stakeholders as of 2017 and describes the methods and avenues in which the GSA has continued to identify additional stakeholders, continued to solicit public involvement and feedback, and considered and/or incorporated stakeholder comments and concerns into the development and future implementation of this GSP. In addition to the Stakeholder Engagement Plan, Appendix C also includes a list of public meetings that have been held to date as a means to document the level of public outreach that has occurred thus far.

One of the primary ways the GSA considers the beneficial uses and users of groundwater, pursuant to California Water Code, Sections 10723.2 and 10723.4, is through the establishment and regular meetings of an Advisory Committee (AC) to aid in developing and implementing this GSP. The AC is composed of nine members:

- Four members nominated by the Borrego Water Coalition and filling the following representative roles: one agricultural member, one recreation member, one independent pumper, one at large member
- One member nominated by the Borrego Springs Community Sponsor Group
- One member nominated by the Borrego Valley Stewardship Council
- One member, who is not an employee or elected official, nominated by the BWD Board of Directors to represent ratepayers/property owners
- One member, who is not an employee or elected official, nominated by the County to represent the Farm Bureau
- One member nominated by the California State Parks, Colorado Desert Region to represent the Anza-Borrego Desert State Park

The Borrego Water Coalition represents a broad cross-section of groundwater pumpers and users of the Subbasin who together represent approximately 80% of annual withdrawals from the Subbasin. The Borrego Springs Community Sponsor Group is the officially appointed representative body charged with addressing land use issues to the County. The Borrego Valley Stewardship Council represents community groups associated with the Anza-Borrego Desert State Park and geotourism economic development initiative. The BWD represents over 2,000 ratepayers/property owners in Borrego Springs. Through the Agricultural Alliance for Water and Resource Education, the San Diego County Farm Bureau represents farming interests in Borrego Springs who, at present, collectively use approximately 70% of annual withdrawals from the Borrego Basin. The California State Parks represent the approximately 600,000-acre Anza-Borrego Desert State Park that surrounds Borrego Springs. Table 2.1-8 describes and lists the various stakeholders with interest in the development and implementation of the GSP.

Throughout Plan development, the AC provided input to the Core Team[17] in the formation of the planning and policy recommendations included in the GSP. The AC was tasked with reviewing technical materials and providing comment, data, and relevant local information related to GSP development; assisting in communicating concepts and requirements to the stakeholder constituents that they represent; providing comments on materials and reports prepared; and assisting the Core Team to anticipate short- and long-term future events that may impact groundwater sustainability, and

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[17] The Core Team is comprised of County and District staff tasked with coordinating the activities of the GSP AC.

trends and conditions that will impact groundwater management. The Core Team regularly met between AC meetings to consider input from the AC and other stakeholders.

The first meeting of the SGMA AC occurred March 6, 2017. Meetings have occurred on a nearly monthly basis through the entirety of GSP development (see list of meetings in Appendix C). AC meetings were facilitated by the Sacramento State Consensus and Collaboration Program funded primarily through a DWR grant. In accordance with California Water Code, Section 10727.8(a), interested parties were encouraged to participate in the AC meetings by attending meetings in Borrego Valley and/or signing up to receive information about AC meetings and GSP development at the County's webpage. AC meeting notices were posted at the Borrego Post Office as well as outside of the meeting venue a minimum 72 hours in advance of the meeting, provided to the Borrego Sun, and posted to the BWD website at http://www.bvgsp.org. The County website publishes all AC meeting agendas, materials, and minutes. All AC meetings were webcast and/or accessible via teleconference line; public comment periods were held during each AC meeting; and correspondence sent to the Core Team and/or AC was published in each AC meeting agenda packet.

In addition to facilitating regular AC meetings, the GSA disseminates information and resources about SGMA and GSP development, as well as opportunities for public participation through email, newsletters/columns, water bill inserts, and the County's SGMA website designed to update the public. Recurring updates in the Borrego Sun newspaper and County Planning & Development Services newsletter, eBlast, are provided to advise, educate, and inform the public on SGMA implementation in Borrego Valley. A variety of information about SGMA and groundwater conditions in BVGB—including maps, timelines, frequently asked questions, groundwater information, and schedules/agenda of upcoming meetings and milestones—have been produced by the County and the BWD. This information is accessible on the County's SGMA Borrego webpage located at: http://www.sandiegocounty.gov/pds/SGMA.html. County staff update the website regularly and invite users to request information or be added to the interested persons list. Additionally, the BWD maintains a repository of groundwater, economic, and GSP-related technical studies on its website at: http://www.bvgsp.org/sustainability-plan.html.

Table 2.1-8
Stakeholder Categories in the Plan Area

Category of Interest	Examples of Stakeholder Groups	Engagement Purpose
General Public	General Public Borrego Springs Community Sponsor Group	Inform to improve public awareness of sustainable groundwater management
Land Use	County of San Diego (Land Use and Environment Group) Community of Borrego Springs Borrego Springs Community Sponsor Group	Consult and involve to ensure land use policies are supporting GSP and vice-versa
Private users	Domestic users	Inform and involve to avoid negative impact to these users
Urban/ Agriculture users/ Golf Courses	Borrego Water District Borrego Water Coalition Agricultural Alliance for Water and Resource Education Small Water Systems Golf Courses and Recreational Facilities	Collaborate to ensure sustainable management of groundwater
Environmental and Ecosystem	California Department of Fish and Wildlife California Department of Parks and Recreation (Anza-Borrego Desert State Park) Anza-Borrego Foundation	Inform and involve to sustain a vital ecosystem
Economic Development	The Borrego Springs Chamber of Commerce and Visitors' Bureau State Assembly Member Randy Voepel State Senator Joel Anderson County District 5 Supervisor Jim Desmond	Inform and involve to support a stable economy
Human right to water	Domestic water users Disadvantaged and Severely Disadvantaged Communities	Inform and involve to provide a safe and secure groundwater supplies to DACs
Integrated Water Management	Regional water management groups (IRWM regions)	Inform, involve, and collaborate to improve regional sustainability

Notes: DAC = disadvantaged community; IRWM = Integrated Regional Water Management.

In addition to the regular AC meeting process, an Ad Hoc Committee of the AC was formed to work with BWD and Le Sar Development Consultants on outreach and engagement activities focused on educating the Borrego community about the GSP, and for soliciting feedback related to water quality and availability, environmental and economic impacts, and GSP implementation and adaptive management strategies. With an emphasis of outreach to the severely disadvantaged portion of the community, the engagement team developed culturally appropriate educational materials (English and Spanish) and a variety of strategies for information dissemination, education, needs assessment, and ongoing feedback. Activities included a series of community meetings, surveys (residential and business), and distribution of educational materials and meeting announcements through door-to-door outreach and digital platforms. Stakeholders were also encouraged to attend SGMA AC and BWD ratepayer meetings. Through these efforts, the GSA gathered valuable information about community concerns, which primarily related to rising water rates, economic impacts (e.g., job loss), land use changes, water use allocations, water quality, and long-term environmental impacts. These issues were then incorporated into the development of this GSP, and lead to increased consideration in the evaluation of groundwater dependent ecosystem (GDE), development of projects and management actions, seeking additional funding opportunities to minimize impacts on ratepayers, and land use implications. For example, the GSA has sent letters to pumpers informing them of their specific baseline pumping allocation, along with information about opportunities to engage in the process. The outreach effort was guided by the GSP Stakeholder Communication and Guidance Document, the Borrego Valley Groundwater Basin Stakeholder Engagement Plan (Appendix C), and the AC. Many of the activities discussed above were funded through a Proposition One Grant from DWR.

2.1.6 Additional GSP Components

The elements included as “additional GSP components” in DWR’s annotated outline released in December 2016 (Title 23 CCR Section 354.8(g)) are presented in Appendix A.

- Control of sea water intrusion. Sea water intrusion is not applicable to the Plan Area because it is not a coastal groundwater basin.
- Wellhead protection. A summary of well development and destruction policies, including wellhead protection is provided in Section 2.1.2, New and/or Replacement Well Permitting. This topic also implicates the potential issue of inducing the migration of groundwater with undesirable quality within the hydraulic capture zone of groundwater wells. Groundwater quality issues within the subbasin are addressed in Section 2.2.2.4, as well as the water quality specific portions of Chapters 3 and 4.
- Migration of contaminated groundwater. Migration of contaminated groundwater from point sources (e.g., industrial and service commercial uses such as gas stations) has limited applicability to the Plan Area, because there are few release of contamination cases in the basin (as reported by regulatory agencies), and the depth of the static groundwater table is well below the areas of concern. The status and severity of open and historic cleanup cases managed by either Department of Toxics Substances Control, RWQCB, or the County are briefly discussed in Section 2.2.2.4. Contaminants of concerns from non-point sources, such as agricultural uses, consist of elevated nitrate concentrations in the upper aquifer of the North Management Area (NMA), discussed in Section 2.2.4.1.

- Well abandonment and well destruction program. San Diego County Code Section 67.421 adopts standards from DWR Bulletin 74-90 for destruction of wells. Section 67.430 through 67.431 provide for investigation and abatement if an abandoned or other well is causing a nuisance by polluting or contaminating groundwater, or constitutes a safety hazard. Well owners and/or well drilling contractors are required to follow DWR well standards, as described in Section 2.1.2, New and/or Replacement Well Permitting, when abandoning or destroying a well, and update the County to list the permit status as inactive or abandoned.
- Replenishment of groundwater extractions. There is currently no program to actively replenish the aquifer. Projects and management actions are described in Chapter 4, though aquifer storage and recovery are not being considered as an option at this time. As discussed in Section 2.2.3.7, a study by the U.S. Bureau of Reclamation (USBR 2015) determined that using imported water to recharge the basin was economically infeasible.
- Conjunctive use and underground storage. There is currently no conjunctive use and/or underground storage program within the Plan Area. Projects and management actions are described in Chapter 4.
- Well construction policies. Well construction policies are described in Section 2.1.2.
- Groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects. Section 2.2.2.4 provides background regarding contamination release cases listed in the SWRCB’s “Geotracker” database. There are no active groundwater cleanup sites in the Plan Area. Recharge is discussed in Section 2.2.3. Recharge includes stream recharge, irrigation return flows, septic recharge and subsurface inflow. There are no major diversions to storage in the Plan Area other than for irrigation ponds such as those located at the golf courses. Conservation has historically been used by all sectors to reduce water demand and is discussed in Section 4.3, including proposed water conservation projects and management actions. Water recycling has been evaluated by the BWD and determined to be economically infeasible at this time (Dudek 2018). Use of greywater systems may be evaluated as part of the Water Conservation Project and Management Action. Conveyance is discussed in Section 4.7.5 and limited to intra-basin transfers to mitigate existing and future reductions in groundwater storage and groundwater quality impairment by establishing conveyance of water between different management areas in the Subbasin. Extraction projects include drilling of replacement municipal wells to mitigate for loss of production.
- Efficient water management practices. Project and management action no. 2 (Water Conservation), addresses efficient water management and is described in Section 4.3.
- Relationships with state and federal regulatory agencies. This is addressed in Sections 2.1.2 of this chapter.

- Land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity. This is addressed in Sections 2.1.2 and 2.1.3. Notably, the County is both the local land use agency and a member of the GSA; thus, coordination has been inherent in the GSP development process.
- Impacts on GDEs: *See Sections 2.2.2.6 and 2.2.2.7*.

2.2 BASIN SETTING

Hydrogeologic studies of the Borrego Valley date back to the early 1900s, though the importance of the Plan Area's groundwater resources increased starting in the mid-1940s when more wells were drilled to support the growing agricultural and municipal water demand. Since the mid-1950s, various studies have been completed to assess the Subbasin's groundwater supply and quality and to evaluate the adequacy of water supplies. These studies included summaries of drillers' logs, compilations of geologic data, and hydrogeologic investigations to support planned development. In the early 1980s, the USGS and DWR completed a multiphase study to evaluate hydrogeologic characteristics, recharge rates, future water demand, and possible alternate water supplies in the Borrego Valley, including the application of a numerical model to simulate basin-wide changes in aquifer groundwater levels and storage (USGS 1982, 1988; DWR 1983a, 1983b, 1984). The U.S Bureau of Reclamation studied the adequacy of water supply and later evaluated the options for importing water into the basin when it became clear that there was an overdraft problem in the Subbasin (USBR 1972, 2003, 2015). Since then, the Plan Area has been the subject of two Masters' theses by Netto (2001) and Henderson (2001); and a comprehensive update to the earlier 1980's work that incorporates updated numerical modeling methods, geophysical and remote-sensing techniques, and groundwater quantity and quality observations for the years between 1945 and 2010 (USGS 2015).

This section describes the basin setting of the Plan Area based on the existing studies as well as an update of the existing USGS numerical model to incorporate the 2010–2011 to 2015–2016 water years.[18] The General Plan Update Groundwater Study, prepared by the County of San Diego (2010), states:

> Borrego Springs Subbasin is completely groundwater dependent, has a well-documented groundwater overdraft condition where year after year groundwater extraction exceeds the amount of groundwater that is recharged back into the aquifer. Groundwater extraction exceeds 20,000 AFY whereas average groundwater recharge is estimated at approximately 5,000 AFY. The aquifer holds a large amount of groundwater in storage, estimated to be approximately 1.6-million acre-feet of usable

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[18] A water year is a continuous 12-month period selected to present data relative to hydrologic or meteorological phenomena during which a complete annual hydrologic cycle normally occurs. The water year used by the U.S. Geological Survey runs from October 1 through September 30, and is designated by the year in which it ends.

> groundwater. Groundwater levels have been declining for decades as a result of the overdraft condition and groundwater production at current rates is not sustainable.

Under existing conditions, the overall magnitude of the overdraft problem within the Plan Area remains similar to that described in 2010, although updated estimates of extraction and recharge are provided in Section 2.2.3.

This section is organized as follows: Section 2.2.1 describes the hydrogeologic conceptual model (HCM) of the Plan Area; Section 2.2.2 summarizes the current and historical groundwater conditions in terms of groundwater elevations, storage, water quality, and the other issues identified in SGMA; Section 2.2.3 establishes the water budget of the Plan Area based on the updated groundwater model; and Section 2.2.4 describes the boundaries, basis and purpose of the three groundwater management areas established for the Plan Area.

2.2.1 Hydrogeologic Conceptual Model

The HCM provides the framework for the development of water budgets, analytical and numerical models, and monitoring networks. Additionally, the HCM serves as a tool for stakeholder outreach and communication, and assists with the identification of data gaps. A HCM differs from a mathematical (analytical or numerical) model in that it does not compute specific quantities of water flowing through or moving into or out of a basin, but rather provides a general understanding of the physical setting, characteristics, and processes that govern groundwater occurrence and movement within the basin. Figure 2.2-1 presents the parameters of the HCM developed for the Plan Area, which conceptually depicts basin boundaries, stratigraphy, water table, land use, and the components of inflow and outflow from the Borrego Springs Subbasin. The thickness of arrows depict schematically the magnitude of the inflows and outflows averaged over a 10-year period between 2005 and 2015 for various components of the water budget. Groundwater pumping for agricultural and recreational uses (i.e., golf courses) together and individually exceed the magnitude of pumping for municipal/domestic uses. Inflows/outflows for the period 2005–2015 are quantified based on the results of the BVHM that indicates outflows are about 20,000 AFY; whereas, inflows are about 5,000 AFY.

The following subsections detail the physical setting of the basin.

2.2.1.1 Climate

The primary sources of current and historical climate data come from the National Oceanic and Atmospheric Administration, the Western Regional Climate Center, the California Irrigation Management Information System (CIMIS), and the San Diego County Flood Control District. The primary web access portal for historical climate information is the National Oceanic and Atmospheric Administration National Centers for Environmental Information (formerly known as the National Climatic Data Center). In addition, weather stations were installed in 2015 by the University of California, Irvine as part of its Anza-Borrego Desert Research Center. Table 2.2-1 lists the weather stations available in the vicinity of the Plan Area.

Table 2.2-1
Weather Stations in the Vicinity of the Plan Area

Station Name (Agency No./ID)	Latitude	Longitude	Status	Period of Record
National Oceanic and Atmospheric Administration National Centers for Environmental Information and Western Regional Climate Center				
Borrego Desert Park, CA US (40983)	33.2559	-116.4036	Active	1942–present
Borrego Springs 2.4 WSW, CA US (CASD0014)	33.2225	-116.3904	Inactive	2009–2016
Borrego Springs 3 NN, CA US (46386)	33.28333	-116.35	Inactive	1944–1967
Borrego Springs 7.1 SE, CA US (CASD0130)	33.1934	-116.2786	Active	2016–present
Ocotillo Wells 2 W, CA US (40986)	33.1552	-116.1688	Active	2003–present
Ocotillo Wells, CA US (46383)	33.15	-116.13333	Inactive	1932–1975
California Irrigation Management Information System				
Borrego Springs/Station 207	33.26844722	-116.36505	Active	2008–2015
University of California, Irvine, Steele/Burnand Anza-Borrego Desert Research Center				
Viking Ranch 6 (VR)	33.328633	-116.356917	Active	2016–present
Clark Dry Lake 7 (CL)	33.296579	-116.280926	Active	2016–present
Elementary 2 (ELEM)	33.254722	-116.346389	Active	2016–present
Dry Canyon Weather Station 5 (MONT)	33.2194	-116.419583	Active	2016–present
Wilcox Well 3 (BWD-W)	33.211001	-116.365133	Active	2016–present
University of California, Irvine, Steele/Burnand Anza-Borrego Desert Research Center	33.240123	-116.388973	Active	2016–present
Culp Valley 4 (BAKER)	33.203721	-116.4772	Active	2016–present
San Diego County Flood Control District				
Borrego Palm (BRPC1 / 62)	33.2686111	-116.4113889	Active	1983–present
Coyote Creek (CCYC1 / 61)	33.3655556	-116.4161111	Active	1984–present
Borrego CRS (BGOC1 / 63)	33.2211111	-116.3369444	Active	1983–present
Ocotillo Wells RS (OCWC1 / 3886)	33.1536111	-116.1769444	Active	1988–present

Precipitation

Within the Plan Area, the County's 30-year isopluvial[19] map (1971–2001) shows that the average annual precipitation ranges from up to 8 inches/year along the northwest edge of the valley, to less than 4 inches per year to the southeast (Figure 2.2-2; SDCFCD 2004). Average yearly precipitation is greater outside the plan area in the mountains to the west, north, and northeast of the Borrego Valley (Figure 2.2-2).

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[19] A line on a map connecting places registering the same amount of precipitation or rainfall

Precipitation patterns in the Plan Area are influenced by two distinct sources. The first source is Pacific frontal systems that bring regional rain bands to Southern California, typically between October and April. The second source is isolated and scattered thunderstorms that occur when moisture from the Gulf of California advects from south to north through the Plan Area. This phenomenon, commonly referred to as the "monsoon" season, is strongest in the summer months, but is not a regular or consistent occurrence. Occasionally, the decaying remnants of former tropical storms or hurricanes can pass through the area and in some years these further enhance the precipitation totals during the monsoon season. As a consequence of these disparate influences, the precipitation record is highly variable both seasonally and annually (Figure 2.2-3 and Figure 2.2-4). This makes defining the parameters of "wet" or "dry" years difficult (e.g., one thunderstorm may drop half of the yearly total in an otherwise dry season). For the purpose of the precipitation record, years with above average precipitation are considered "wet," and years with below average precipitation are considered "dry."

The weather station in the Plan Area with the longest and most complete precipitation record is the Borrego Desert Park Station, which spans the period from water year 1942 to 2017 (Figure 2.2-3). Based on this record, the mean annual precipitation at Borrego Desert Park Station is 5.55 inches (shown as dashed line on Figure 2.2-3). The cumulative departure from mean precipitation shows a wet period for the basin between 1972 and 1986, with 1983 being the wettest year on record (Figure 2.2-3). The total precipitation in the 1983 water year was 21.82 inches. In contrast, the period from 1946 to 1972 was dominated by years of below average rainfall. In addition to year on year precipitation being highly variable, precipitation by month also has a wide spread. Figure 2.2-4 shows average monthly precipitation at the Borrego Park Station (1947–2017) along with a measure of one standard deviation which provides a statistical estimate of precipitation variability. The record of precipitation by month also shows the influence of the monsoon season, with an uptick in the average precipitation for June, July, and August.

Temperature

The climate of the Borrego Valley is arid with hot summers and cool winters. Based on the Borrego Desert Park Station, the average annual high (daytime) temperature is 87.6°F, ranging from a low of 68.9°F in December to a high of 107.4°F in July. The average annual low (nighttime) temperature is 58.3°F, ranging from a low of 43.3°F in December, to a high of 75.8°F in July. The historical minimum and maximum monthly mean temperature, and average temperature record for the Plan Area is shown on Figure 2.2-5.

Evapotranspiration

Reference evapotranspiration (ETo) in the Plan Area has been calculated from the data collected at CIMIS Station 207 on a daily basis between 2008 and 2017 (Figure 2.2-6; Table 2.2-2). The average ETo measured at CIMIS Station 207 between 2008 and 2017 is 72.21 inches per year or

6.02 feet per year (Table 2.2-2). In contrast, the average annual precipitation in the Plan Area is 5.6 inches per year. The ETo values calculated from the CIMIS data reflect the amount of water that could be transpired by grass or alfalfa if supplied by irrigation, but do not represent the actual transpiration from any specific crop or native vegetation. To calculate the ET rate for a specific crop or native vegetation, the ETo is multiplied by a crop coefficient that adjusts the water consumption for each crop relative to the water consumption for alfalfa.

Table 2.2-2
Monthly and Yearly Reference Evapotranspiration (ETo) Totals for California Irrigation Management Information System Station No. 207 from 2008 to 2017 (Inches)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total
2008[a]	0.46	3.43	6.16	7.60	9.30	10.02	9.07	6.76	6.77	5.13	3.36	2.27	70.33
2009	2.68	5.16	5.69	7.07	8.76	8.28	8.87	8.71	7.21	5.00	3.08	1.96	72.47
2010	2.41	3.21	8.81	9.84	8.58	9.22	9.51	9.11	7.44	4.36	2.88	1.98	77.35
2011	2.68	3.35	5.55	7.12	8.77	8.23	7.98	8.47	6.43	4.92	2.72	2.11	68.33
2012	2.85	3.56	5.33	6.77	7.66	9.47	8.77	8.04	7.09	5.04	3.20	2.23	70.01
2013	2.54	3.57	5.75	7.56	8.64	9.02	8.01	7.57	6.46	5.05	3.00	2.27	69.44
2014	2.67	3.66	5.94	7.23	8.66	9.13	8.83	8.00	6.97	4.55	3.14	1.58	70.36
2015	2.17	3.54	5.82	7.22	7.96	8.51	8.76	8.74	6.54	5.15	3.37	2.40	70.18
2016	2.42	4.15	6.35	7.44	8.97	9.79	10.17	8.91	6.51	5.17	3.37	1.99	75.24
2017	2.33	3.28	6.27	8.18	9.14	10.20	9.70	9.43	6.99	5.38	3.16	2.47	76.53
9-Year Average	**2.53**	**3.72**	**6.17**	**7.60**	**8.57**	**9.09**	**8.96**	**8.55**	**6.85**	**4.96**	**3.10**	**2.11**	**72.21**

Source: CIMIS 2018.
Notes:

[a] 2008 is excluded from the average as the record for that year is not complete.

According to the State of California Reference Evapotranspiration Map developed by CIMIS, the Plan Area is located within Evapotranspiration Zone 18, with an annual average ETo of 71.6 inches or 5.97 feet (CIMIS 1999). This regional average annual ETo estimate is comparable to the ETo measured at CIMIS Station 207 (Table 2.2-2).

2.2.1.2 Geology and Geologic Structure

The Borrego Springs Subbasin lies along the boundary of two major geomorphic provinces. To the west of the Subbasin is the Peninsular Ranges Geomorphic Province, which extends from the Pacific Ocean in the west, to the Colorado Desert in the east (CGS 2002). The Peninsular Ranges are dominated by granitic rock intruding older metamorphic rocks that makeup the San Ysidro Mountains, Pinyon Ridge, Yaqui Ridge and other local mountaintops that surround the Subbasin. The Peninsular Ranges trend northwest-southeast, subparallel to major branches of the San Andreas fault, including the San Jacinto fault and Elsinore fault.

The San Andreas fault is located approximately 30 miles east and the Elsinore fault is located approximately 22 miles west of the Subbasin. Individual segments of the San Jacinto fault zone are located in the vicinity of the Subbasin, including the Coyote Creek fault that forms the eastern boundary of the Subbasin. The Borrego Valley is often described as an embayment of the Salton Trough because the physiographic features of the Colorado Desert Geomorphic Province are also expressed in the Subbasin. This is indicated by the presence of the West Salton detachment fault that is part of a large block of basement rock that broke away from the mountains as a result of crustal stretching between active branches of the San Andreas fault.

The juxtaposition of these two Geomorphic Provinces result in dramatic vistas within the Plan Area. The elevation of the Borrego Springs Subbasin ranges between approximately 450 feet above mean sea level (amsl) east of the Borrego Sink to over 2,000 feet amsl at the northern tip of the subbasin (Figure 2.2-7). As shown on Figure 2.2-8, the Borrego Springs Subbasin, which underlies the Borrego Valley, is bounded to the north and west by the contact between Quaternary-age[20] sedimentary deposits (i.e., alluvium) and Cretaceous- to Mesozoic-age[21] plutonic and metamorphic basement rocks. The eastern boundary of the Borrego Springs Subbasin is defined by the trace of the Coyote Creek fault. The Borrego Badlands and the Ocotillo-Clark Valley Groundwater Basin lie to the east of the Coyote Creek fault (Figure 2.1-1; DWR Basin No. 7-025). The southern boundary of the Subbasin is marked by the course of San Felipe Creek. It should be noted that this section focuses on geologic structures, geologic history, and traditional geologic nomenclatures (i.e., formations); whereas Section 2.2.1.3 generalizes the geology of the water bearing formations, described as follows, into three aquifers based on a textural model developed by the USGS (2015). Therefore, the stratigraphic boundaries of geologic units below do not necessarily co-occur with the three aquifer boundaries described in Section 2.2.1.3.

Geologic History

The geologic history of the Subbasin is complex but can be generally divided into three primary phases of activity. The first begins 450 million years ago when the region’s oldest rocks were deposited in a near-shore marine environment along a passive continental plate margin. As stated on the Anza-Borrego Desert Natural History Association website,

> With deep burial and cementation, these ancient sediment layers hardened into marine sedimentary rocks, including sandstone, mudstone, and limestone. Later, these marine sedimentary rocks would be squeezed and baked by intruding magma (molten rock in Earth’s interior) and transformed by pressure and heat into metamorphic rock. Limestone transformed into marble, sandstone into quartzite, and mudstone into

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[20] The most recent Period of the Cenozoic Era. Encompasses the time interval of 1.6 million years ago through today.

[21] The Cretaceous period spans from 65 to 144 million years ago, the Mesozoic era spans from 65 to 245 million years ago.

> layered schist and banded gneiss--all metamorphic rocks exposed in Anza-Borrego's prominent mountain ranges, including Coyote Mountain as well as the Santa Rosa, Vallecito, and San Ysidro Mountains (Barrie 2018).

The intruding magma marks the second major phase of geologic activity, when the Eastern Peninsular Ranges Batholith[22] formed in place along a continental volcanic arc about 100 million years ago as a result of subduction. The batholith includes varieties of plutonic rocks, including granite, that comprise the basement rocks of the Subbasin and those mapped in the San Ysidro Mountains (Figure 2.2-8). Finally, about 30 million years ago, a complex plate boundary formed as a result of both transform and divergent plate tectonic motions that are responsible for development of the Salton Trough as well as the Elsinore, San Jacinto, and San Andreas fault zones. An overview of the Plate Tectonic History of the Anza-Borrego region by Don Barrie is available on the Anza-Borrego Desert Natural History Association's website: http://www.abdnha.org/anza-borrego-desert-geology.htm

Geologic Units

The granitic and metasedimentary basement complex is the oldest geologic unit underlying the Borrego Valley, and the contact between the low permeability basement complex and the overlying basin fill defines the bottom boundary of the Subbasin (Dibblee 2008, USGS 2015). The rocks of the basement complex crop out in the San Ysidro Mountains, Coyote Mountain, and Borrego Mountain, but are over 3,000 feet below land surface in the center of the Borrego Valley (Dibblee 2008, USGS 2015). Overlying the basement complex is a sequence of older marine and younger continental basin fill deposits. The marine deposits, which range in age from possibly Miocene to possibly Pleistocene, make up the Imperial Formation; whereas, the Pliocene and Pleistocene-age continental deposits make up the Palm Spring and Borrego Formations, as well as the Ocotillo Conglomerate (Dibblee 2008, USGS 1982). The youngest deposit in the Subbasin is the Quaternary alluvium (Figure 2.2-8). The Quaternary alluvium covers the majority of the Borrego Valley floor (Figure 2.2-8). Outcrops of unnamed terrestrial sediments are found in the northern portion of the Borrego Valley, within the boundaries of the Subbasin. Outcrops of the Palm Spring Formation are found in the southern area of the Subbasin, associated with the Desert Lodge anticline and a series of synclines and anticlines to the north of San Felipe Creek (Figure 2.2-8).

Imperial Formation

The deepest water bearing rocks in the Subbasin are the marine deposits of the Imperial Formation (USGS 2015). These deposits are composed of late Miocene to early Pliocene gray to yellow gray claystone. The claystone is weakly to moderately consolidated, and has been tilted and folded by

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[22] Very large mass of intrusive (plutonic) igneous rock that forms when magma solidifies at depth. A batholith must have greater than 100 square kilometers (40 square miles) of exposed area.

motion along the San Andreas and San Jacinto faults (USGS 2015). Age dating of the Imperial Formation is based on fossil oyster shells, other mollusks, and corals. Overall, the fossil record is insufficient to define specific time-stratigraphic units within the Imperial Formation (USGS 2015). The Imperial Formation grades upward into the overlying Palm Spring Formation (Netto 2001). The Imperial Formation is likely not widespread in the Borrego Springs Subbasin, as it has only been identified in two well borings.

Palm Spring Formation

Deposited by the ancestral Colorado River, the Palm Spring Formation consists of thousands of feet of Pliocene- to Pleistocene-age fluvial and deltaic sand, silt, and clay deposits (USGS 2015). Similar to the underlying Imperial Formation, the Palm Spring Formation is weakly to moderately consolidated, and has been tilted and folded by motion along the San Andreas and San Jacinto faults (USGS 2015). In the vicinity of Borrego Valley, the deposits of the Palm Spring Formation are typically interbedded light gray arkosic sandstone and red claystone (Netto 2001). In areas of the Borrego Valley where the Imperial Formation is absent, the Palm Spring Formation directly overlies the basement complex (Netto 2001).

Borrego Formation

The Pliocene- to Pleistocene-age Borrego Formation, which is primarily composed of light-gray lacustrine claystone and siltstone, was deposited in a perennial lake that became tectonically isolated from the Gulf of California (Dorsey 2005; USGS 1982). The Borrego Formation, based on its origin, may locally contain evaporites (e.g., gypsum). Sandstone beds are rare in the Borrego Formation but, where present, are composed of both Colorado River and locally derived material (Dorsey 2005).

Ocotillo Conglomerate

Locally overlying the Borrego Formation in the Borrego and Ocotillo Badlands is the Ocotillo conglomerate (Dorsey 2005). The Pliocene- to Pleistocene-age Ocotillo conglomerate comprises gray alluvial fan and ephemeral stream deposits (Dorsey 2005; USGS 1982). This formation outcrops on the surface at the southwestern margin of the basin.

Quaternary Alluvium

Quaternary alluvium deposits are exposed over most of the Borrego Valley floor (USGS 2015; Figure 2.2-8). These deposits include lacustrine silts and clays that are present at or near the surface of the Borrego Sink, as well as coarse to fine sands derived primarily from Coyote Creek but also the numerous ephemeral stream channels that enter the Subbasin. The Quaternary Alluvium is further described in Section 2.2.1.3.

Soil Units

Overlying the geologic units described above are surface soils mapped by the U.S. Department of Agriculture. Soil types present within the Plan Area are mapped and described in U.S. Department of Agriculture Web Soil Survey of the Anza-Borrego Area, California (CA804), and San Diego County Area, California (CA638) (USDA 2018). The predominant soil units in the Plan Area (i.e., greater than 10% coverage) include the following, from greatest to least coverage:

- Carrizo very gravelly sand, 0%–9% slopes (CeC)
- Rositas fine sand, 0%–2% slopes (RoA)
- Sloping gullied land
- Indio silt loam, saline, 0%–2% slopes (IoA)
- Mecca fine sandy loam, 0%–2% slopes, eroded (MpA2)
- Rositas loamy coarse sand, 0%–2% slopes (RsA)

Figure 2.2-9 presents the soil units mapped within the Plan Area in terms of their predominant texture. Coarser soils occur around the valley edges and along the major stream corridors, whereas the finest soils occur in the valley center and within the Borrego Sink. According to the U.S. Department of Agriculture (USDA 2018), the Carrizo very gravelly sand has a “very high” saturated hydraulic conductivity[23] (Ksat) in the Plan Area (the weighted average of representative values for all soil horizons is 141 micrometers per second (µm/sec)). This soil unit develops over coarse alluvial fan units close to the mountain front, and along Coyote Creek and San Felipe Creek. The Rositas soil units, which underlie the developed community and the agricultural areas of the valley, have a high Ksat (the weighted average of representative values for all soil horizons is 92 µm/sec). The Mecca soil units also have a high Ksat, but are less permeable than the Rositas soils (the weighted average of representative values for all soil horizons is 28 µm/sec). The Indio soil units, which underlie undeveloped open space areas north of the Borrego Sink, have a “moderately high” Ksat (the weighted average of representative values for all soil horizons is 9 µm/sec). The only soil in the Plan Area with a moderately low Ksat is the playa unit, which underlies the Borrego sink (the weighted average of representative values for all soil horizons is 0.215 µm/sec). Areas mapped as sloping gullied land do not have a Ksat value assigned (USDA 2018).

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[23] Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. It is based on soil characteristics observed in the field, particularly structure, porosity, and texture. Ksat are grouped according to standard Ksat class limits. The classes are: Very low (0.00 to 0.01 µm/sec), Low (0.01 to 0.1 µm/sec), moderately low (0.1 to 1.0 µm/sec), Moderately high (1 to 10 µm/sec), High (10 to 100 µm/sec), and Very high (100 to 705 µm/sec).

Geologic Structures

Coyote Creek Fault

The right-lateral Coyote Creek fault, which is one of seven segments of the larger San Jacinto fault zone, defines the eastern boundary of the Subbasin (USGS 2015; Figure 2.2-8). The Coyote Creek segment is approximately 80 kilometers long and has an approximate slip rate of 2–6 millimeters per year (SCEDC 2018). The Coyote Creek fault is mapped by the USGS (2006) as having a well constrained location, and as being "latest Quaternary" in age, meaning its last rupture occurred less than 15,000 years ago. Historical (less than 150 years ago) motion along the San Jacinto fault zone has opened cracks as large as 2 feet wide along the Coyote Creek fault (USGS 2015). These cracks were later observed to infill with low permeability surface sediments (USGS 2015). Groundwater level contours are generally perpendicular to the fault, suggesting that groundwater flow parallels the fault in most places (USGS 2015). It should be noted that because groundwater level data coverage on either side of the fault is poor, groundwater contours are subject to a high degree of interpretation.

Changes in groundwater elevations of 40–50 feet across the fault indicate that the Coyote Creek fault acts as a partial barrier to groundwater flow between the Borrego Springs Subbasin to the west and the Clark Lake Valley to the east (USGS 1982). An electrical resistivity study conducted by San Diego State University students in March 1983 under the direction of Professor David Huntley, along with groundwater level measurements reported by the USGS (1982), were reviewed to evaluate groundwater conditions in the early 1980s on either side of the fault, and to provide a screening assessment of potential flux across the fault using a groundwater flow equation. Given the hydraulic conductivity of the fault zone is not known precisely, a range of flux into the Borrego Springs Subbasin from the Ocotillo-Clark Valley Basin was estimated to be anywhere between 32 and 3,200 AFY (Wiedlin, pers. comm. 2018). Thus, there is a potential that the groundwater flux across the Coyote Creek fault and into the Borrego Springs Subbasin could be significant (Wiedlin, pers. comm. 2018).

Given this assessment is based on limited data, and is inconsistent with the assumption in the BVHM of a no flow boundary across the site, it represents a data gap. The flux into the Borrego Springs Subbasin from the Ocotillo-Clark Valley Basin could be verified by incorporating existing water wells on either side of the fault into the groundwater monitoring networks, evaluating the salinity of groundwater on the northeast side of the fault, and conducting a groundwater model sensitivity analysis (Wiedlin, pers. comm. 2018). The GSA does not consider this a critical data gap because historical groundwater levels and trends suggest the flux would be into the Subbasin rather than out of the Subbasin (i.e., a potential missing input to the water budget), and because the Coyote Creek Fault is distant from the active pumping centers within the Subbasin. This data gap does not affect the GSP's establishment of sustainable management criteria in Chapter 3, or the effectiveness of projects and management actions described in Chapter 4. If inflow from the Ocotillo-Clark Valley Basin is indeed significant, it would contribute to progress towards the GSP's interim milestones and measurable objectives, and/or contribute operational flexibility within the Subbasin.

Borrego Syncline

The Borrego syncline, which developed during the early stages of faulting in the San Jacinto fault zone, forms the deep portion of the Subbasin (Lutz et al. 2006; Kirby et al. 2007; Steely et al. 2009; Janecke et al. 2010; USGS 1982; cross section A-A' on Figure 2.2-10). The deepest part of the Subbasin, where bedrock is buried beneath sediments, is in the vicinity of the Borrego Valley Airport (cross section A-A' on Figure 2.2-10; USGS 1993). The basement rock underlying this area is estimated to be at a depth of 3,800 feet (USGS 2015).

Yaqui Ridge/ San Felipe Anticline

The Yaqui Ridge/San Felipe anticline and San Felipe fault create a basement high in the vicinity south and east of the San Felipe Creek (cross section A-A' on Figure 2.2-10**)**. These structures are also related to deformation in the San Jacinto fault zone (Steely et al. 2009). The basement bedrock underlying the basin sediments drops away southeast of Ocotillo Wells following the southern limb of the San Felipe anticline into the Lower Borrego Valley. These structures effectively offset sediments north of San Felipe Creek from those to the south, forming the boundary between the Borrego Springs Subbasin and the Ocotillo Wells Subbasin (cross section A-A' on Figure 2.2-10**)**. The upper and middle aquifers, described as follows in Section 2.2.1.3, essentially pinch out in the vicinity of the San Felipe anticline, where the lower aquifer drapes down over the basement high. This structure creates a barrier to groundwater flow, which is evidenced by groundwater levels in the Borrego Springs Subbasin that are several hundred feet higher than those in the Ocotillo Wells Subbasin (which are at or near sea level).

2.2.1.3 Principal Aquifers and Aquitards

The USGS (2015) has subdivided the groundwater system within the Borrego Springs Subbasin into upper, middle, and lower aquifers. The differentiation between the three aquifers is based on a textural analysis of driller's lithologic logs and geophysical logs. Differences in overall texture were determined by analyzing the fraction of coarse material like sand and gravel with depth for available logs. Historically, different nomenclatures have been applied to the Quaternary and late Tertiary geologic units (USGS 1982; Henderson 2001). Despite the differences in nomenclature, however, all the lithologic descriptions indicate that the basin fill sediments of the Borrego Valley consist of unconsolidated to poorly consolidated mixtures of gravel, sand, silt, and clay. As a result, the establishment of a purely textural definition for the three aquifers relies on a basin wide analysis of subsurface data rather than previously assigned geologic unit names.

As there are no regionally extensive aquitards (e.g., a thick clay layer), the upper aquifer behaves in a predominantly unconfined manner, and the lower and middle aquifer exhibit leaky confined or semi-confined characteristics based on limited aquifer testing (Netto 2001; Dudek 2014, 2015a, 2015b). The lower aquifer is the most fine-grained unit, containing higher amounts of silt and clay. The Imperial Formation was identified in two borings located in the southern part of the Subbasin, though it is not likely a wide-spread formation within the Subbasin. USGS (2015) notes that,

> hydraulic conductivities generally decrease with depth and with increasing distances from the original source of the sediments in adjacent mountain ranges and stream channels, which is consistent with the fining-down and fining-toward-the-basin-center sequences observed in the aquifer sediments and texture model.

The USGS prepared a cross-section running from Borrego Springs in the northwest to the southeast that illustrates the basement low in the Borrego syncline and the basement high of the San Felipe anticline (cross section A-A' on Figure 2.2-10) (USGS 1982). This cross-section also illustrates that neither saturated portions of the high permeability sediments of the upper aquifer nor saturated sediments of the middle aquifer extend to the area south of the San Felipe anticline. Only the lower permeability sediments of the lower aquifer drape over the San Felipe anticline, and these older sediments are higly folded. This explains why the overdraft resulting from pumping of the upper and middle aquifers has been confined to the Borrego Springs area and has not propagated southeast of the San Felipe Creek area.

The three aquifers are shown on Figure 2.2-10 and are summarized from USGS (2015) as follows:

- **The upper aquifer** consists of coarse sediments (i.e., unconsolidated gravel, sand silt and clay of Holocene to Pleistocene age), primarily sourced from the Coyote Creek Watershed. It represents the unconfined aquifer, which historically has been the main source of water in the valley with well yields as high as 2,000 gallons per minute. The upper aquifer has been extensively dewatered by municipal, agricultural, and recreational pumping. The maximum thickness of the upper aquifer is estimated to be 643 feet where Coyote Creek enters the Subbasin, thinning to less than 50 feet near the Borrego Sink. The upper aquifer becomes mostly unsaturated south of the Desert Lodge anticline near Rams Hill.
- **The middle aquifer** consists of Pleistocene-age continental deposits of gravel to silt with moderate amounts of consolidation and cementation, and is thought to originate from lower energy sediment sources prior to the initiation of slip along the Coyote Creek fault. The maximum thickness of the middle aquifer is estimated to be 908 feet in the northwestern part of the Subbasin, and like the upper aquifer, thins to less than 50 feet toward the southeastern part of the Subbasin. USGS (1988) indicates that the middle aquifer yields moderate quantities of water to wells, but is considered a nonviable source of water south of San Felipe Creek in the Ocotillo Wells Subbasin because of its diminished thickness.

- **The lower aquifer** consists of partly consolidated continental and lacustrine sediments of the lower Palm Spring and Imperial Formations. The maximum thickness of the lower aquifer is estimated to be 3,831 feet in the eastern part of the basin near the Borrego Airport. The lower aquifer yields smaller quantities of water to wells than the upper and middle aquifers.

USGS (2015) summarized information on the hydrogeologic properties of each aquifer, and aquifer tests have been conducted on multiple wells in the basin (ID1-1, ID1-2, ID1-8., RH-3, RH-4, RH-5, RH-6, Bauer 1, and Borrego Springs Water Co. Well 5); the range of aquifer values are shown in Table 2.2-3. The highest hydraulic conductivities were defined in the central portion of the valley where sand deposits of Quaternary age were characterized and older fan deposits at the base of the San Ysidro and Vallecito Mountains. Lower hydraulic conductivities were identified in areas characterized with younger fan deposits and consolidated continental deposits (Appendix D). The Borrego Sink was characterized with a uniform hydraulic conductivity of 6 feet per day in all three aquifer units (USGS 2015). The lower hydraulic conductivity in the middle and lower aquifers relative to the upper aquifer are based on a lower energy depositional environment to the Borrego Valley prior to activity along the Coyote Creek fault that opened the northern portion of the valley to sediment deposition from Coyote Creek (Appendix D). USGS (2015) reported that the specific storage defined for each aquifer unit under confined conditions ranged from $5.1\text{x}10^{-7}$ in the upper aquifer to $1.6\text{x}10^{-6}$ in the middle aquifer.

Table 2.2-3
Aquifer Hydraulic Conductivity and Storage Properties

Aquifer	Mean / Maximum Thickness (feet)[1]	Horizontal Hydraulic Conductivity (feet/day)[2]	Average Specific Yield (percent)
Upper	258 / 643	0.3–184	15 (Range: 2–28)
Middle	267 / 908	0.02–10	17.5 (Range: 15–21)
Lower	1,015 / 3,831		3 (Range: 0.7–5.6)

Source: USGS 2015; Dudek 2014, 2015a, 2015b, 2017.
Notes:

[1] Based on the sediment texture analysis developed for use in the Borrego Valley Hydrologic Model (BVHM) (USGS 2015).

[2] The range of hydraulic conductivities for the middle and lower aquifers are based on aquifer testing in wells screened across both zones, primarily in the South Management Area. The range for the upper aquifer is based on based on the distribution of coarse-grain sediments defined by the textural map created from lithologic and geophysical logs in the BVHM. The Borrego Sink was characterized by U.S. Geological Survey (USGS 2015) with a uniform hydraulic conductivity of 6 feet/day in all three aquifer units.

2.2.1.4 Recharge and Water Deliveries

There are no water deliveries to the Plan Area from external sources, and surface water imports are not available for managed recharge. In addition, there are currently no managed stormwater recharge facilities in the Plan Area. Thus, recharge is limited to natural infiltration of stormwater, and to a lesser degree, return flows of applied irrigation water and septic recharge.

The Coyote Creek Watershed, which drains the Santa Rosa Mountains to the north of the Borrego Springs Subbasin, provides most of the recharge to the Subbasin through infiltration of streamflow into the shallow alluvial sediments. Mountain front recharge that occurs at the interface between surrounding bedrock and unconsolidated sediments is the primary source of recharge along the smaller tributaries that enter the Subbasin, largely comprising the Borrego Valley-Borrego Sink Wash Watershed. These include Borrego Palm Creek, and washes exiting the San Ysidro Mountains, Pinyon Ridge, Yaqui Ridge, Coyote Mountains, and the Borrego Badlands. These areas of recharge are shown on Figure 2.2-11. USGS (2015) reported that "over the 66-year study period, on average, the natural recharge that reaches to the saturated groundwater system is approximately 5,700 acre-ft/yr. Natural recharge fluctuates in the arid climate from less than 1,000 to more than 25,000 acre-ft/yr."

The other, though less voluminous, source of recharge are return flows from agricultural irrigation. USGS (2015) estimated recharge from irrigation return flows to be between 10%–30% agricultural and recreational pumping based on the results of the BVHM. This is consistent with the estimate of irrigation return flow by Netto (2001), who used a chloride mass balance technique at a citrus grove located northwest of the intersection of Di Giorgio Road and Henderson Canyon Road to estimate a return flow of 22%. Netto (2001) used a similar approach to estimate a return flow for golf course irrigation of 14%. As agricultural efficiency increases, this fraction decreases. It can take years to decades for irrigation return flows to pass through the unsaturated zone to the underlying water table, and much of the water that initially infiltrates into the soil is likely lost to evapotranspiration within the root zone, or (past the root zone) remains in storage within the unsaturated zone. However, elevated nitrate concentrations in the northern part of the Plan Area does provide evidence that agricultural return flows from years' past may be reaching the underlying aquifer (see Section 2.2.2.4).

Septic tank treatment and disposal systems also constitute a source of recharge to the basin, but is considered negligible when compared to natural recharge (USGS 2015). Most of the homes in the area utilize septic-tank treatment and disposal systems. The BWD estimates that about 80% of the domestic water deliveries are to homes with septic-tank systems (Dudek 2018). Potential recharge from this water use is difficult to quantify, but is believed to be small. The infiltration from septic tanks was simulated by the USGS (2015) at an application rate of 0.056 AFY per home at land surface into the unsaturated zone. This estimate was based on estimates per home water use of 100 gpd, and a 50% loss rate owing to evaporation and transpiration that was cited in the BWD IRWM Plan (USGS 2015). Septic tank treatment and disposal systems are known to be potential contributors to groundwater quality degradation, particularly when used in high concentrations and built to poor or outdated standards.

Recharge sources are quantified as follows in Section 2.2.3.

2.2.2 Current and Historical Groundwater Conditions

The primary sources of existing data for wells and groundwater include the various entities that have been collecting groundwater level and water quality data within the Plan Area since the early 1950s, primarily the BWD, County, DWR, SWRCB, and the USGS. As part of development of this GSP, the GSA is implementing a data management system (DMS) used to display and track groundwater well locations and monitoring data for groundwater levels, water quality, and production. The groundwater monitoring network established for the Plan Area by the GSA is intended to support tracking progress toward sustainability goals established in this GSP and to continue to report the data to the CASGEM Program and DWR's Water Data Library.

The location and type of monitoring for wells in the Plan Area are shown on Figure 2.2-12 and listed in Table 2.2-4. Water wells included in the groundwater monitoring network were incorporated from previous monitoring networks established by the BWD and consultants, County, DWR, and USGS. In addition to monitored wells in the Plan Area, there are four wells monitored within the Ocotillo Wells Subbasin, which are: "Dr. Nell" Well, "State" Well, SVRA Well, and Split Mountain Road Well. The Borrego Springs Subbasin monitoring network currently consists of 50 groundwater wells owned by BWD, the County, ABDSP, and private parties; some are strictly observation wells (no pumping), while others are used for municipal, recreation (e.g., golf courses and ABDSP), and rural residential purposes. The groundwater level-monitoring network currently consists of 50 wells, including 23 dedicated monitoring wells and 27 extraction wells. Of the 50 wells in the network, 46 are monitored for groundwater levels, 30 are monitored for water quality, and 19 are monitored for production. Groundwater levels are measured manually in the majority of the wells in the monitoring network, although the BWD and the Rams Hill Golf Course collectively have 17 wells equipped with pressure transducers that collect groundwater level data at frequencies as high as every 15 minutes. These wells are listed in Table 2.2-5.

The groundwater monitoring network is expected to evolve over time. The GSA expects to add additional wells as suitability issues are resolved, and as access permissions are granted from private well owners. The monitoring network currently lacks representation from certain recreational pumpers and agricultural pumpers in the NMA (see Section 2.2.4 for a description of management area). The GSA has prepared a Groundwater Extraction Facility Registration Form for each private well owner to complete in order to expand the inventory of private wells in the Borrego Springs Subbasin. Table 2.2-4 includes the wells' State Well ID, which is a unique well identifier designated by the DWR.[24]

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[24] Wells monitored by the DWR and cooperating agencies are identified according to the State Well Numbering system. The numbering system is based on the public land grid, and includes the township, range, and section in which the well is located. Each section is further subdivided into sixteen 40-acre tracts, which are assigned a letter designation of A, B, C, D, E, F, G, H, J, K, L, M, N, P, Q, or R. Within each 40-acre tract, wells are numbered sequentially. The final letter of the State Well Number refers to the base line and meridian of the public land grid in which the well lies. "M" refers to the Mount Diablo base line and meridian; "S" refers to the San Bernardino base line and meridian; "H" refers to the Humboldt base line and meridian (DWR 2017).

Table 2.2-4
Groundwater Monitoring Network

Common Well Name[a]	State Well Identification (SWID)	Latitude	Longitude	Use	Groundwater Monitoring Networks		
					Elevation	*Quality*	*Production*
North Management Area							
Horse Camp	009S006E31E003S	33.349264	-116.400345	Other	X	X	—
Private Well	010S006E09N001S	33.314535	-116.366688	Residential	X	X	—
ID4-4	010S006E29K002S	33.277136	-116.374327	Public Supply	X	X	X
ID4-18	010S006E18J001S	33.306751	-116.384715	Public Supply	X	X	X
ID4-3	010S006E18R001S	33.298040	-116.384339	Public Supply	X	—	—
MW-1	010S006E21A002S	33.300634	-116.349471	Observation	X	X	—
Evans	010S006E21E01S	33.29429300	-116.36194000	Observation	X	—	—
Central Management Area							
County Yard (SD DOT)	011S006E15G001S	33.220966	-116.337613	Industrial	X	X	X
BSR Well 6	011S006E09B002S	33.23906	-116.35567	Irrigation - Recreation	—	X	X
BSR Well 3	011S006E04P001S	33.24559	-116.35875	Irrigation - Recreation	—	—	X
Hanna (Flowers)	010S006E14G001S	33.306115	-116.323982	Observation	X	—	—
Gabrych No. 2	011S006E01C001S	33.257255	-116.304700	Observation	X	—	—
ID4-1	010S006E32R001S	33.257486	-116.371035	Observation	X	—	—
ID4-5	010S006E33Q001S	33.257428	-116.355899	Observation	X	—	—
Airport 2	010S006E35N001S	33.257385	-116.326102	Observation	X	—	—
MW-4	010S006E35Q001S	33.257561	-116.313108	Observation	X	X	—
ID4-2	011S006E07K003S	33.231602	-116.388737	Observation	X	—	—
Palleson	010S006E33J001S	33.26156287	-116.34875075	Observation	X	—	—
Abandon Motel-1	011S006E10N001S	33.23.359532	-116.34704679	Observation	X	—	—
Abandon Motel-2	011S006E10N004S	33.23048074	-116.34689137	Observation	X	—	—
State Park No. 3	010S005E25R002S	33.27038000	-116.40354600	Other	X	X	X
Anzio/Yaqui Pass	011S006E22E001S	33.206040	-116.347150	Observation	X	—	—
Paddock	011S006E22B001S	33.211593	-116.334036	Observation	X	—	—
Cameron 2	011S006E04F001S	33.249652	-116.357102	Observation	X	—	—
ID5-5	011S006E09E001S	33.237067	-116.364304	Public Supply	—	X	X

Table 2.2-4
Groundwater Monitoring Network

Common Well Name [a]	State Well Identification (SWID)	Latitude	Longitude	Use	Groundwater Monitoring Networks		
					Elevation	*Quality*	*Production*
ID1-10	011S006E22D001S	33.211790	-116.346813	Public Supply	X	X	X
ID1-16	011S006E16N001S	33.216557	-116.362440	Public Supply	X	X	X
Wilcox	011S006E20A001S	33.210910	-116.364826	Public Supply	X	X	X
ID1-12	011S006E16A002S	33.226030	-116.348317	Public Supply	X	X	X
ID4-10	011S006E18L001S	33.218319	-116.392226	Public Supply	X	—	—
ID4-11	010S006E32D001S	33.267499	-116.383357	Public Supply	—	X	X
White Well	010S006E29A001S	33.280900	-116.367011	Residential	X	—	—
South Management Area							
RH-5	011S006E26B001S	33.195428	-116.319088	Irrigation - Recreation	X	X	X
RH-6	011S006E26H001S	33.194778	-116.314273	Irrigation - Recreation	X	X	X
ID1-2	011S006E25C001S	33.195655	-116.304156	Irrigation - Recreation	X	X	X
RH-4	011S006E24Q002S	33.199973	-116.303654	Irrigation - Recreation	X	X	X
ID1-1	011S006E25A001S	33.198121	-116.295854	Irrigation - Recreation	X	X	X
RH-3	011006E25C002S	33.197950	-116.307563	Irrigation - Recreation	X	X	X
WWTP	011S006E23H001S	33.207400	-116.315199	Observation	X	X	—
MW-5A	011S007E07R001S	33.226557	-116.279352	Observation	X	X	—
MW-5B	011S007E07R002S	33.226557	-116.279352	Observation	X	X	—
Bakko	011S006E22A001S	33.210901	-116.330845	Observation	X	—	—
Army Well	011S006E34A001S	33.184156	-116.332830	Observation	X	X	—
Hayden (32Q1)	011S007E32Q001S	33.173998	-116.264318	Observation	X	—	—
Bing Crosby Well	011S007E20P001S	33.199489	-116.267939	Observation	X	—	—
MW-3	011S006E23J002S	33.203481	-116.314252	Observation	X	X	—
ID1-8	011S006E23J001S	33.203160	-116.314343	Public Supply	X	X	X
Air Ranch Well 4	011S007E30L001S	33.190830	-116.286730	Public Supply	X	X	—
JC Well	011S006E24Q001S	33.201936	-116.303268	Residential	X	X	—

Table 2.2-4
Groundwater Monitoring Network

Common Well Name [a]	State Well Identification (SWID)	Latitude	Longitude	Use	Groundwater Monitoring Networks		
					Elevation	*Quality*	*Production*
La Casa	011S006E23E001S	33.208044	-116.328359	Unknown	X	X	—

Notes: X = Monitored; — = Not Monitored; SD DOT = San Diego County Department of Transportation; BSR = Borrego Springs Resort.

[a] Common names beginning in "ID" are Borrego Water District (BWD) wells, common names beginning in "RH" area Ram's Hill Country Club Wells, and common names consisting of pronouns refer to the well owner or small water system.

Table 2.2-5
Wells Equipped with Pressure Transducers

Well ID	Period of Record	Frequency of Data Collection (minutes)	Well Owner
Currently Monitored Wells			
ID1-1	April 2014 to Present	15	Rams Hill Golf Course
ID1-2	April 2014 to Present	15	Rams Hill Golf Course
ID1-8	March 2014 to Present	15	Borrego Water District
RH-3	August 2014 to Present	15	Rams Hill Golf Course
ID1-12	March 2018 to Present	30	Borrego Water District
ID1-16	March 2018 to Present	30	Borrego Water District
ID4-4	March 2018 to Present	30	Borrego Water District
ID4-18	March 2018 to Present	30	Borrego Water District
RH-4	January 2015 to Present	15	Rams Hill Golf Course
RH-5	June 2015 to Present	15	Rams Hill Golf Course
RH-6	November 2015 to Present	15	Rams Hill Golf Course
Jack Crosby (JC Well)	September 2014 to Present	15	Rams Hill Golf Course
MW-1	April 2016 to Present	120	Borrego Water District
MW-3	April 2014 to Present	15	Borrego Water District
MW-5A (Lower)	May 2016 to Present	15	Borrego Water District
MW-5B (Upper)	June 2016 to Present	15	Borrego Water District
WWTP	March 2014 to Present	15	Borrego Water District
Previously Monitored Wells			
Air Ranch Well No 4	May 2016 to February 2017	15	Borrego Air Ranch

The following subsections address current and historical conditions related to each of the undesirable results identified under SGMA, including groundwater elevations (Section 2.2.2.1), changes in groundwater storage (Section 2.2.2.2), groundwater quality (Section 2.2.2.4), subsidence (Section 2.2.2.5), and groundwater-surface water interactions and groundwater-dependent ecosystems (Sections 2.2.2.6 and 2.2.2.7) in the Borrego Springs Subbasin.

2.2.2.1 Groundwater Elevation Data

Current Groundwater Levels

Current groundwater levels in the Borrego Springs Subbasin were measured in Spring and Fall 2018, and are shown on Figure 2.2-13A and Figure 2.2-13B, respectively. Measured groundwater elevations in Spring 2018 ranged from a high of 644.76 feet amsl in the northern part of the subbasin (DWR Well No. 009S006E31E003S (Horse Camp Well)) to a low of 377.58 feet amsl north of the intersection of Henderson Canyon Road on Di Giorgio Rd (DWR Well No. 010S006E09N001S), which marks central area of the primary agriculture area in the valley. Measured groundwater elevations in Fall 2018 were similar to those measured in the spring, showing a similar spatial pattern of static groundwater level elevations. On average, groundwater elevation measurements in Spring 2018 were 12.59 feet lower than Fall 2018, with a maximum rise of 2.48 feet amsl (DWR Well No. 011S006E22E001S (Anzio/Yaqui Pass)), and a maximum fall of 10.51 feet amsl (DWR Well No. 011S006E23J002S (MW-3)). In certain wells and at certain times of the year, particularly the irrigation season, near-by pumping can influence groundwater level elevation in monitored wells.

The predominant direction of groundwater flow within the Subbasin is away from mountain front regions, and away from San Felipe Creek, toward the center of the valley near Palm Canyon Drive about 2 miles north of Borrego Sink. The steepest groundwater gradient measured in Spring 2018 occurred across the cultivated areas of the northern part of the basin. In this area (between the ABDSP Horse Camp Well and DWR Well No. 010S006E09N001S), the groundwater gradient in Spring 2018 was 0.016. The groundwater gradients in the central and eastern parts of the Plan Area were relatively flat.

Two pumping-related depressions were exhibited in the data collected, one centered on the agricultural areas north of Henderson Canyon Road, and possibly another centered around a cluster of wells north of the Ram’s Hill Country Club. Groundwater levels in terms of depth from the surface tend to shallow towards the Borrego Sink and tend to deepen around the northern, western and southern margins of the Subbasin, as shown on Figure 2.2-10.

Historical Groundwater Levels

Historical groundwater levels in the Borrego Springs Subbasin are shown on Figure 2.2-13C for 2010 and Figure 2.2-13D for 1945. In 2010, groundwater contours indicate that groundwater elevations ranged from a high of over 500 feet amsl in the southern part of the Subbasin near San Felipe Creek to a low of about 340 feet amsl about 3 miles east of the Borrego Sink (Figure 2.2-13C). The 2010 contours show two pumping depressions. One appears as an elongated zone centered north of Henderson Canyon Road extending south toward Christmas Circle within the 400-foot groundwater contour. The other is centered just north of the intersection of Borrego

Springs Road and Anzio Drive, extending further west towards the mouths of Culp Canyon and Dry Canyon, also within the 400-foot groundwater contour.

In 1945, prior to development in the Plan Area, the direction of groundwater flow was predominantly from the northwest to the southeast (Figure 2.2-13D). Groundwater elevations ranged from more than 600 feet amsl near Coyote Creek in the northwestern part of Borrego Valley to about 460 feet amsl in the southeastern part. The lowest groundwater-level elevations occurred east of the Borrego Sink, an area of natural drainage in the middle of the valley that is currently dry most of the time. According to the USGS (2015), the Borrego Sink was historically the site of about 450 acres of honey mesquite (*Prosopis glandulosa*) and other native phreatophytes, indicating that shallow groundwater and occasional accumulations of surface water was sufficient to support a GDE. Borrego Springs, located about 2 miles west of the Borrego Sink, was flowing in 1945, but ran dry as agricultural uses began in the following decade. In 1945, the groundwater flowed parallel to Coyote Creek in an easterly to southeasterly direction.

Groundwater Level Trends

Since the early 1950s, groundwater extraction has exceeded recharge, and the direction of flow has been altered in all areas of the valley to the current period. The human influence on groundwater levels within the Plan Area is most pronounced in the northern part of the basin, generally decreasing in intensity towards the southeast. One exception to this general trend is that municipal and recreational well clusters, generally located east and south of the Borrego Sink do show more intense pumping than the areas north of the Borrego Sink within the central part of the Subbasin.

As shown on Figure 2.2-13E, groundwater levels between 1953 and 2018 declined by as much as 133 feet in the northern part of the Plan Area (Northern Management Area (NMA)), equivalent to an average rate of 2.05 feet per year. The rate of groundwater level decline in the northern area was greatest prior to 1965, which is around the time that irrigation of grape crops in the Plan Area ceased. During grape cultivation, groundwater levels were dropping by as much as 3.4 feet per year (USGS 2015). Groundwater levels briefly stabilized and slightly rebounded from the mid-1960s until the early 1970s, at which point groundwater levels began dropping again, albeit at a lower rate than in the 1950s and early 1960s. Starting in the late 1970s, cultivation of citrus crops began in earnest, and groundwater levels in the northern part of the Plan Area have been dropping at a relatively constant rate since that time. Figure 2.2-13E includes key wells with a long-running record, however, hydrographs for every well in the GSA's current monitoring network is included in Appendix D.

Also shown on Figure 2.2-13E is a second, smaller area of groundwater-level depression in the west-central part of the basin (Central Management Area (CMA)), which is associated with pumping for municipal and recreational purposes. The magnitude of the groundwater level decline is smaller, dropping by about 88 feet between 1953 and 2018, or an average rate of 1.35 feet per year. In the southeastern part of the valley (South Management Area (SMA)), where less groundwater has been pumped, the groundwater-level has remained about the same in the historical record, remaining at an elevation of about 500 amsl (approximately 10 feet) at DWR well Nos. 011S007E20P001S and 011S007E32Q001S. An exception to this observed trend in the SMA is the resumption of pumping for the Rams Hill golf course starting in 2014, and shown in the groundwater level record for DWR well No. 011S006E23J002S on Figure 2.2-13E.

To visualize the recent rate of groundwater decline across the Subbasin, Figure 2.2-13F shows the difference between the 2010 and Fall 2018 groundwater elevation contours. Furthermore, Chapter 3 Figures 3.2-1, 3.2-2, and 3.2-3 depict the remaining saturated thickness of each aquifer in the upper, middle and lower aquifers, respectively. The upper aquifer currently hosts the most accessible (i.e., shallowest) and highest-yielding wells within the Subbasin as a whole. As shown on Figure 3.2-1, the water table has dropped below the base of the upper aquifer in some parts of the Subbasin, particularly within the southwestern half of the CMA, which overlies the more developed portion of Borrego Springs that is served by the BWD with wells located in the CMA (Figure 3.2-1). Up to 175 feet of the upper aquifer remains saturated in the east central part of the CMA, and roughly 50 feet, on average, of the upper aquifer remains saturated within portions of the SMA and CMA. The middle aquifer maintains much of its saturated thickness over much of the Subbasin, except where the aquifer unit pinches out in the southwest part of the Subbasin (Figure 3.2-2). The lower aquifer is the thickest aquifer underlying the Plan Area (Figure 3.2-3).

Data Gaps

Review of existing groundwater elevation data within the Plan Area suggests that although three distinct aquifers are delineated in varying thickness across the Subbasin, the effect of well screen lengths and intervals is potentially negligible with respect to measured depths to groundwater (i.e., potentiometric surface). An example includes MW-5A/5B with dual nested wells screened across the upper/middle aquifers and middle/lower aquifers. Variation of groundwater depths between these wells averages less than 0.01 foot. Therefore, although the Subbasin may not include data for groundwater monitoring wells screened solely in each of the three aquifer units for each of the three management areas, these data gaps are not considered significant with regard to groundwater levels. As such, for the purposes of the GSP, the need for wells screened solely in each vertical aquifer unit independently does not appear to be necessary to achieve adequate spatial representation of groundwater elevations in the Subbasin. Spatial (vertical) distribution suggests that the existing well infrastructure may be adequate to determine the minimum threshold for chronic groundwater lowering.

Lateral distribution suggests that existing wells are adequate to meet SGMA requirements; however, elevation data from some critical monitoring points have yet to be received from sources such as the DWR. The adequacy of the lateral distribution of monitoring wells in the NMA, CMA, and SMA is described as follows.

- *North Management Area*: The well distribution in the NMA appears adequate to meet SGMA requirements; however, groundwater elevation data from agricultural pumpers are limited. The compiled data currently includes existing well data from four wells in the NMA, but historical data from additional wells would be beneficial to establish the minimum threshold. Developing a better understanding of groundwater elevations and quality in the future is a goal for this portion of the Borrego Springs Subbasin.
- *Central Management Area*: The well distribution in the CMA appears adequate to meet SGMA requirements, and because this area has been well studied historically, sufficient groundwater elevation data has been obtained to establish the minimum threshold.
- *South Management Area*: The well distribution in the SMA appears adequate to meet SGMA requirements. This area includes wells that are routinely monitored by the BWD, in addition to several wells that are routinely monitored under the CASGEM program.

Significant data gaps have been identified associated with access to the DWR and private well information in the Plan Area, which are primarily agricultural wells. In addition, additional groundwater level data on either side of the Coyote Creek fault would aid in verifying the degree to which the fault acts as a partial barrier to groundwater flow (Wiedlin, pers. comm. 2018). As previously discussed, the GSA has been working to close these data gaps by identifying additional monitoring locations. The GSA has developed the Borrego Springs Subbasin Monitoring Plan (described in Chapter 3, Section 3.5), to be updated periodically, to address these data gaps and to monitor groundwater levels and water quality against the sustainability indicators defined and outlined in Chapter 3 of this GSP.

2.2.2.2 Estimate of Groundwater in Storage

The storage capacity based on stable groundwater levels before groundwater development began in the basin is estimated to have been about 5,500,000 AF (USGS 1982). Based upon subsequent study by Dr. David Huntley, the majority of readily available water to existing well users in the Borrego Valley exists in the upper and middle aquifer. The amount of groundwater within these two aquifers was estimated to be approximately 2,131,000 AF in 1945 and 1,900,500 AF in 1980 (Huntley 1993). The remaining water located within the lower aquifer is more difficult and costly to extract due to its low specific yield (estimated to be approximately 3%), its depth, and low specific capacity (estimated to be 5 gallons per minute/foot of drawdown or less) (County of San Diego 2010). As discussed in the following Section 2.2.3.3, it is estimated that 520,000 AF of water has been removed from storage over the period of model simulation, which begins in the pre-development period. The BVHM estimates that total storage loss from water year 1980 through water year 2016 is 334,293 AF. Therefore as of 2016, the volume of groundwater in storage within the upper and middle aquifers of the Subbasin is approximately 1,566,207 AF. It should be noted that the extent of the BVGB analyzed by the USGS (1982) was about 12% larger than the Plan Area, due to differences in the southeastern boundary of the study area along San Felipe Creek.

2.2.2.3 Seawater Intrusion

As an inland basin, the Borrego Springs Subbasin has no hydraulic connection to the Pacific Ocean. The Subbasin is more than 50 miles from the Pacific Ocean, more than 130 miles from the Gulf of California, and 15 miles from the Salton Sea, which is an inwardly draining sink. Additionally, the Salton Sea is geologically separated from the Subbasin by the Coyote Creek fault and Coyote Mountains. Therefore, sufficient data appears to demonstrate that seawater intrusion is not an applicable sustainability indicator[25] in the Plan Area.

2.2.2.4 Groundwater Quality

The most extensive water quality monitoring data within the Borrego Springs Subbasin comes from reporting by public water supply systems to the SWRCB Division of Drinking Water for the purpose of ensuring adequate drinking water quality. For example, the BWD routinely monitors approximately 12 wells to test pumped water for general minerals, aggregate properties, solids, metals, and nutrients at least every 3 years. In addition to historical water quality data available within the Subbasin, Table 2.2-4 shows the wells included in the GSA monitoring network for groundwater quality. Constituents to be monitored have been selected based on the results of prior monitoring activities in the Subbasin conducted primarily by DWR, USGS, and BWD. These monitoring activities along with USGS publications (USGS 2014, 2015) have summarized groundwater quality conditions in sufficient detail to identify arsenic, nitrate, sulfate, fluoride, TDS, and radionuclides as the Subbasin's main constituents of concern (COCs).

To provide some context for the groundwater quality results, concentrations of constituents measured in the untreated groundwater are compared with regulatory and non-regulatory health-based benchmarks established by the U.S. Environmental Protection Agency and SWRCB Division of Drinking Water. The primary metric for identifying undesirable results[26] related to groundwater quality within the Subbasin are exceedances of State of California Maximum

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[25] "Sustainability indicator" refers to any of the effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, cause undesirable results (California Water Code Section 10721(x)). Sustainability indicators as they relate to the Plan Area are discussed in Chapter 3.

[26] Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators defined by SGMA are caused by groundwater conditions occurring in one of the Subbasin's three management areas, or throughout the Subbasin. Undesirable results as they relate to the Plan Area are discussed in Chapter 3.

Contaminant Limits (MCLs)[27] (Title 17 CCR and Title 22 CCR). It should be noted that these regulatory benchmarks apply to water that is delivered to the consumer, not to untreated groundwater. Exceedances of MCLs within raw groundwater indicate potential threats to human health in untreated groundwater and the potential need for additional treatment steps to make groundwater suitable for potable use.

There are both anthropogenic and natural sources of the COCs in the Borrego Springs Subbasin. Anthropogenic sources that may contribute to degradation of the current water quality in the Subbasin include agricultural use of pesticides and fertilizers, salt accumulation resulting from agricultural irrigation practices, and household septic system return flows. Natural sources of COCs in the Subbasin include the rocks and minerals that comprise the aquifer matrix material. These naturally occurring COCs contain evaporite minerals, which can dissolve and increase TDS concentration in the aquifer; silicate minerals, which can contribute arsenic to the groundwater; and sulfate minerals, which can contribute sulfate to the groundwater. All are found in differing amounts in the upper, middle, and lower aquifers. Differences in the mineralogical composition of the aquifers can result in groundwater quality differences between the aquifers. Current and historical data was reviewed for COC concentrations exceeding applicable MCLs, and the Mann-Kendall test was applied in wells with sufficient data[28] to assess temporal trends in groundwater quality. The GSA, through development and implementation of this GSP, will further the goal of continuing to deepen the understanding of groundwater elevations and quality in the Subbasin.

Nitrate

Sources of nitrate in groundwater are typically associated with specific land use but they can also occur naturally. Nitrate is commonly associated with fertilizers and septic tanks; however, it can also be naturally occurring. Fertilizers and septic tanks are common anthropogenic sources of nitrate detected in groundwater. Potential natural sources of nitrate in groundwater may result from leaching of soil nitrate, which occurs by atmospheric deposition, and dissolution of evaporative minerals, igneous rocks, and deep geothermal fluids. In desert groundwater basins, the largest source of naturally occurring nitrates in groundwater occurs from incomplete utilization of nitrate by sparse vegetation. This nitrate accumulates in the unsaturated zone and may become mobile when surficial recharge percolates through the unsaturated zone (Walvoord et al. 2003). In arid environments, nitrate stored in the unsaturated zone may become mobilized by artificial recharge from irrigation return flow, septic effluent, and infiltration basins. Because the Borrego Springs Subbasin lacks appreciable evaporitic deposits, anthropogenic sources (irrigation and wastewater

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[27] MCLs are standards that are set by the U.S. Environmental Protection Agency and SWRCB for drinking water quality. An MCL is the legal threshold limit on the amount of a substance that is allowed in public water systems under the Safe Drinking Water Act (Federal and State).

[28] A minimum of four data points are required to calculate trend. Insufficient data indicates wells where no trend was established because either four data points were not available, or because the data reported was less than laboratory reporting limits.

return flows) are likely the main contributors of nitrates to groundwater. The California drinking water MCL is 10 mg/L for nitrate as (N) and can be expressed as 45 mg/L for nitrate (NO_3).

Figure 2.2-14A presents wellheads sampled for nitrate concentrations by aquifer, in terms of whether samples analyzed exceeded MCLs. Although there are no exceedances shown on Figure 2.2-14A, historical exceedances of nitrate concentration have occurred in five wells in the vicinity of Henderson Canyon Road in the northern part of the valley, adjacent to areas of agricultural use (USGS 2015). Nitrate concentrations in these wells ranged from above the MCL of 10 mg/L to 67 mg/L. The existing groundwater network indicates elevated nitrate at the State well ID 010S006E09N001S in the NMA and at the BWD's WWTP monitoring well.

Historical nitrate trends in the Subbasin show decreasing, increasing and neutral trends, depending on the well sampled. Wells exhibiting an increasing trend include BWD Wells ID4-11 and ID4-18 in the NMA, Well ID1-10 in the CMA, and Well ID1-8 in the SMA. All other wells that are currently monitored have a neutral or declining trend, or have insufficient historical data to establish a trend. Spatial concentration patterns of nitrate indicate the agricultural fields, golf courses, and the percolation ponds at the Rams Hill WWTP may represent anthropogenic sources of nitrate in groundwater. In the past, the BWD improvement district 4 (ID4) wells 1 and 4, Borrego Springs Water Company Well No. 1 (located at the BWD office), the Roadrunner Mobile Home Park and Santiago Estates wells had to be taken out of potable service due to elevated nitrate. The latter two developments were connected to municipal wells operated by the BWD as an alternative source of supply. Well ID4-4 was re-drilled and screened deeper at the same location and successfully accessed good water quality not impacted by nitrates. The Di Giorgio wells 11, 14 and 15 located north of Henderson Road have historical detections of nitrate and TDS above drinking water standards (BWD 2002).

Total Dissolved Solids

TDS is a measure of all dissolved solids in water including organic and suspended particles. Sources of TDS in groundwater include interaction of groundwater with the minerals that comprise the aquifer matrix material. Over time, TDS will increase as more minerals in contact with groundwater dissolve. In desert basins, evaporative enrichment near dry lake beds (playas) is known to naturally increase TDS in groundwater. This process also occurs in plants, both in agriculture and natural systems. Anthropogenic sources include synthetic fertilizers, manure, wastewater treatment facilities, and septic effluent. Repeated irrigation is also a known cause of elevated TDS, as minerals concentrate in the soil column with repeated evaporation. These increased concentrations can then be mobilized into the underlying groundwater table. The California drinking water secondary MCL for TDS is recommended at 500 mg/L with upper and short-term limits of 1,000 mg/L and 1,500 mg/L, respectively. TDS have been historically detected above the secondary MCL in some wells in the Subbasin. There is no primary MCL established for TDS.

Figure 2.2-14B presents wellheads sampled for TDS concentrations by aquifer, in terms of whether samples analyzed exceeded MCLs. The majority of wells sampled have TDS concentrations less than half the secondary MCL, of 500 mg/L. However, ID1-1 and MW-5A/B have TDS concentrations that exceed the secondary MCL. TDS concentrations in the Subbasin have historically ranged from less than 500 mg/L to 2,330 mg/L, and elevated TDS has occurred in wells that also have elevated nitrate concentrations (USGS 2015). The TDS concentrations are generally highest in the shallow aquifer and in the northern part of the Borrego Valley (USGS 2015). Historical TDS trends in the Subbasin show both decreasing, increasing and neutral trends, depending on the well sampled. Wells exhibiting an increasing trend include BWD ID1-1 and ID1-8 in the SMA. All other wells that are monitored have no trend, or have insufficient historical data to determine a trend.

Drilling of a dual screened monitoring well by DWR in the southern portion of Borrego Valley (northeast of Borrego Sink) shows poor water quality in shallow groundwater deteriorating with depth (DWR 2007). Groundwater samples collected from a dual screen monitoring well drilled by DWR (MW-5A and MW-5B) in the southern portion of the Borrego Valley (northeast of Borrego Sink) were analyzed for TDS and sulfate. The concentration of TDS in water collected from the upper completion (45 to 155 feet below ground surface) was 1,300 mg/L while the concentration of water collected from the lower completion (200–345 feet below ground surface) was 2,300 mg/L (DWR 2007). The measured concentrations of TDS and sulfate in these samples (MW-5A and MW-5B) are too high for drinking water supply without additional treatment. Elevated TDS appears to be associated with poorer water quality near the Borrego Sink, likely due to concentration of dissolved solids as a result of evaporation of water in the Borrego Sink and later leaching of naturally occurring evaporites (sediments formed by the evaporation of water). Furthermore, the differing TDS values provides supporting evidence that salinity increases with depth, and that treatment requirements may increase as users draw a higher percentage of water from the lower aquifer.

Sulfate

Natural sulfate sources include atmospheric deposition, sulfate mineral dissolution, and sulfide mineral oxidation of sulfur. Gypsum is an important source of natural sulfate near localized economically important deposits such as in the Ocotillo Wells Subbasin near Fish Creek Mountains in Imperial County. Fertilizers can also be a source of sulfate in groundwater but typically do not result in exceedance of drinking water standards. The California drinking water secondary MCL for sulfate is recommended at 250 mg/L, with upper and short-term limits of 500 mg/L and 600 mg/L, respectively.

Figure 2.2-14C presents wellheads sampled for sulfate by aquifer, in terms of whether samples analyzed exceeded MCLs. Although none of the samples analyzed as part of the USGS study had concentration of sulfate that exceeded the California secondary MCL for sulfate (USGS 2015), wells MW-4, MW-5A, MW-5B, and ID1-1 have had sulfate detected above the MCL with concentrations of 330 mg/L, 1,300 mg/L, 2,300 mg/L, and 650 mg/L, respectively. Historical sulfate trends in the Subbasin show both decreasing, increasing and neutral trends, depending on the well sampled. Wells exhibiting an increasing trend include BWD Wells ID1-1 and ID1-8 in the SMA. All other wells that are monitored have no trend, or have insufficient historical data to determine a trend. Based on the available data, it appears that elevated sulfate concentrations go hand in hand with elevated TDS concentrations around the Borrego Sink in the SMA as previously explained for dissolved solids.

Arsenic

Arsenic is naturally occurring, and concentrations of arsenic in Southern California groundwater basins commonly exceed California's drinking water MCL of 10 micrograms per liter (µg/L) (Anning et al. 2012; Welch et al. 2000). In semi-arid and arid groundwater basins, groundwater recharge is limited due to low precipitation and the residence time of the groundwater in the basin is high. The long residence time of the groundwater in the basin allows for more interaction between the groundwater and the minerals that comprise the aquifer matrix material. With time, arsenic desorbs from sediments and enters the groundwater. This process is more efficient in groundwater with higher pH. The groundwater in the Subbasin has a pH of 7.5 to 9.0, a range that is conducive for this transfer of arsenic from the sediment to the water. Arsenic concentrations have been demonstrated to increase as groundwater levels decrease for wells located in the SMA, and have been historically detected above laboratory reporting limits in some wells in the Borrego Springs Subbasin.

Figure 2.2-14D presents wellheads sampled for arsenic by aquifer, in terms of whether samples analyzed exceeded MCLs. Arsenic concentrations have been detected above laboratory reporting limits at several wells in the Borrego Springs Subbasin since the 1980s.[29] Arsenic has been detected in non-potable wells up to 22 µg/L in Rams Hill Golf Course well RH-4 (Dudek 2015a). Arsenic concentrations for wells located in the NMA were less than half the MCL (<5 µg/L) for wells screened in the upper, middle, and lower aquifers. Arsenic concentrations from 2016 for wells located in the CMA were less than half the MCL (<5 µg/L) for wells predominantly screened in the middle aquifer and less than the MCL (<10 µg/L) for wells predominantly screened in the lower aquifer. Arsenic concentrations from 2016 for wells located in the SMA ranged from less than half the MCL (<5 µg/L) to greater than the MCL (>10 µg/L). The screen intervals of wells in the SMA predominantly intercept the lower aquifer though most wells are partially screened in the middle aquifer as well.

Historical arsenic trends in the Subbasin show decreasing, increasing and neutral trends, depending on the well sampled. The only well exhibiting an increasing trend is BWD Well ID1-2 in the SMA. All other wells that are monitored have no trend, or have insufficient historical data to determine

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[29] Prior to the 1980s, laboratory detection limits for arsenic where often established at 10 µg/L or 50 µg/L and results were reported as below the laboratory detection limit.

a trend. Trends for most wells that have concentrations below the MCL were not determined due to results being below the laboratory reporting limits.

Fluoride

Fluoride is a naturally occurring element in groundwater resulting from the dissolution of fluoride-bearing minerals from the aquifer sediments and surrounding bedrock. Brown staining or mottling of teeth and resistance to tooth decay as a result of drinking water with high concentrations of fluoride has been known since the 1930s. While drinking fluoridated water at low concentrations (i.e., 0.7 parts per million) is beneficial to prevent tooth decay, excessive exposure to fluoride can result in dental and skeletal fluorosis. The California drinking water MCL for fluoride is 2 mg/L, and fluoride has historically been detected in some wells above this level in the Subbasin.

The USGS identified three wells with fluoride concentrations that exceed the California drinking water primary MCL of 2 µg/L. Fluoride concentrations in these wells ranged from 2.69 to 4.87 mg/L (USGS 2015). The Cocopah Well tested above the California drinking water standard at concentration of 2.2 mg/L (USGS 2015). Otherwise, fluoride concentrations within the Subbasin are typically below one-half the MCL. For wells with adequate data to analyze trends one well shows an increasing trend (Wilcox Well); for Wells ID1-1, ID1-2, and ID1-8, no trend is indicated.

Radionuclides

Radionuclides occur naturally in the mineralogy of sediment particles and become dissolved in groundwater as groundwater flows through the porous sediment matrix that contains trace levels of radioactive isotopes. Gross alpha and beta measurements are screening tools for quantification of radioactivity in groundwater, which is measured as activity units of picocuries per liter (pCi/L). The California drinking water primary MCL for gross alpha is 15 pCi/L based on a four-quarter average. Other radionuclides with California drinking water primary MCLs include radium-226 + radium-228 (5 pCi/L), strontium-90 (8 pCi/L), tritium (20,000 pCi/L) and uranium (20 pCi/L).

Limited radionuclide data is available for the Subbasin; however, gross alpha concentrations will be tracked to document and evaluate progress toward sustainability throughout development and implementation of the GSP. Gross alpha and gross beta results available for BWD indicate concentrations detected are below primary MCLs. Gross Alpha for Well ID4-11 was measured in Fall 2017 as being 5.24 pCi/L ± 1.68. Gross Alpha for Well ID1-16 was measured in Fall 2017 as being 0.751 pCi/L ± 0.872. Gross Alpha for Wilcox Well was measured in Fall 2017 as being 0.489 pCi/L ± 0.739. Gross Alpha for ID1-10 was measured in Fall 2017 as being 0.614 pCi/L ± 1.39. Gross Alpha for ID1-8 was measured in Fall 2017 as being 4.12 pCi/L ± 2.13.

Constituents of Concern Point Sources (Release Cases or Oil/Gas Wells)

Petroleum hydrocarbons and other contaminants can be released to the groundwater system as a result of leaking underground fuel tanks, disposal facilities, or poor management of activities on industrial sites and/or service commercial uses. The SWRCB's "Geotracker" database and the Department of Toxics Substances Control "Envirostor" database were reviewed to identify current and historical cleanup cases within the Subbasin. These case locations are shown on Figure 2.2-15. The potential media of concern for all the cases shown on Figure 2.2-15 is soil rather than groundwater, and all but two of the cases are identified as closed status, which indicates that the contamination issue has been verified to either be remediated or contained (i.e., prevented from migrating greater distances or to other media). The open cases include the Borrego Sites/Carrizo Impact Site (DOD100031200) and the Borrego Springs Landfill Class III Solid Waste Disposal Site (L10003017008). The Borrego Springs Landfill is in the Geotracker database as a solid waste facility subject to a WDR, and there is no contaminant release case associated with it. The landfill conducts semi-annual monitoring to ensure compliance with the terms of the WDR, developed to protect basin plan objectives for surface and groundwater (see Section 2.1.2).

The Borrego Sites/Carrizo Impact Site is a former military site used between 1942 and 1959 to train combat troops for desert warfare, to train mechanized artillery service units and staff, anti-aircraft training, and practice bombing training. Although the site is indicated on Figure 2.2-15 as a point location, it actually encompasses approximately 400 square miles (256,000 acres) of desert terrain and dry lakes, mostly outside of the Plan Area (in the Clark Valley and Ocotillo Wells area). The historic areas of activities within the Plan Area is Camp Ensign, a 1,918-acre site overlapping and south of the Borrego Springs Resort and Circle Club Resort. This site was used between 1942 to 1944 as a headquarters and bivouac/cantonment area in support of various training activities (ACOE 2011). The main issues of concern come from munitions debris and a historic dump site within the soil matrix. Soil sample sites were selected for testing of explosives, pH, and select metals (aluminum, antimony, copper, lead, and zinc) based on historical review of site activities. The site inspection report summarizing the testing results and risk assessment indicates the COC concentrations in soil do not present unacceptable human health or ecological risks and no further DOD was recommended (ACOE 2011). Since these activities occurred in the soil and no unacceptable concentrations of explosives or munitions-related metals were found, this site is not considered a current or potential future groundwater quality risk for the Borrego Springs Subbasin.

The SGMA GSP regulations also require identification of oil and gas wells within the groundwater basin. Such wells could be a concern if different aquifer units are cross contaminated. Information about oil and gas wells from the California Department of Oil, Gas, and Geothermal Resources was reviewed to identify whether the Subbasin has oil and/or gas resources. As shown on Figure 2.2-16, the closest oil and gas wells are located outside the Subbasin in and north of Ocotillo Wells. Note that there are no active oil extraction wells in the map extent; the well shown as active on

Figure 2.2-16 refers solely to the permit status as recorded in the California Department of Oil, Gas, and Geothermal Resources database.

Summary

In general, water quality has historically been good within BWD's wells with TDS at concentrations of less than 500 mg/L. The high proportion of sulfate in the surface water of Coyote Creek appears to dominate the character of groundwater in the northern and eastern parts of the basin (DWR 2014). The more bicarbonate waters of Borrego Palm Canyon and Big Spring influence the groundwater along the western and southern parts of the basin. Historical issues with elevated nitrate concentrations have been noted as evidenced by wells either taken out of production or drilled deeper including BWD Wells ID4-1 and ID4-4, and the Roadrunner Mobile Home Park well. ID4-4 was abandoned and drilled deeper at the same location to avoid nitrates in the upper aquifer. High salinity, poor-quality connate water is thought to occur in deeper formational materials in select areas of the aquifer as well as shallow groundwater in the vicinity of the Borrego Sink in the southern portion of the Plan Area.

Based on historical and contemporary water quality sampling, the trend of historical data, current concentration and background water quality concentrations for the identified COCs are listed by management area in Table 2.2-6.

Table 2.2-6
Management Area Background Water Quality

Constituent	Trend of Historical Data[a]	Current Concentration (2018)[b]	Background Concentration[c]
North Management Area			
Arsenic	No Trend	1.5 µg/L and 2.2 µg/L	0.0 µg/L (Range: 0.0–3.0 µg/L)
Fluoride	No Trend	0.66 mg/L (Range: 0.16–0.87 mg/L)	0.63 mg/L (Range: 0.11–1.3 mg/L)
Nitrate (as N)	Increasing	0.52 mg/L (Range: 0.1–15 mg/L)	0.63 mg/L (Range: 0–15 mg/L)
Sulfate	Decreasing	285 mg/L (Range: 110–440 mg/L)	147 mg/L (Range: 99–440 mg/L)
TDS	No Trend	675 mg/L (Range: 330–1,100 mg/L)	562 mg/L (Range: 295–1,100 mg/L)
Central Management Area			
Arsenic	No trend	2.1 µg/L (Range: 1.2–3.8 µg/L)	2.2 µg/L (Range: 0.0–12.2ug/L)
Fluoride	No Trend	0.46 mg/L (Range: 0.23–0.81 mg/L)	0.50 mg/L (Range: 0.00–1.40 mg/L)
Nitrate (as N)	No Trend	0.37 mg/L (Range: 0.1–1.3 mg/L)	0.97 mg/L (Range: 0.00–8.40 mg/L)
Sulfate	Decreasing	98 mg/L (Range: 19–300 mg/L)	89 mg/L (Range: 14–330 mg/L)
TDS	No trend	335 mg/L (Range: 230–610 mg/L)	325 mg/L (Range: 200–699 mg/L)
South Management Area			
Arsenic	No Trend	4.1 µg/L (Range: 1.6–15 µg/L)	4.8 µg/L (Range: 0.0–22.0 µg/L)
Fluoride	No Trend	0.51 mg/L (Range: 0.18–2.1 mg/L)	0.61 mg/L (Range: 0.00–2.10 mg/L)
Nitrate (as N)	No Trend	1.0 mg/L (Range: 0.1–20.0 mg/L)	1.2 mg/L (Range: 0.0–29.0 mg/L)

Table 2.2-6
Management Area Background Water Quality

Constituent	Trend of Historical Data[a]	Current Concentration (2018)[b]	Background Concentration[c]
Sulfate	Increasing	105 mg/L (Range: 24–700 mg/L)	86 mg/L (Range: 14–1,200 mg/L)
TDS	Increasing	640 mg/L (Range: 310–1,600 mg/L)	520 mg/L (Range: 230–1,600 mg/L)

Notes: µg/L = micrograms per liter; mg/L= milligrams per liter; N = nitrogen; TDS = total dissolved solids.

[a] Mann-Kendall analysis was used to determine trend in individual wells at the selected significance level of 0.05. For trend in management area, the trend in the majority of wells in the management area is reported.

[b] Median concentration and range from all samples collected within a management area in 2018.

[c] Median concentration and range from all samples collected within a management area on record in the data management system.

As indicated in the preceding discussion, water quality impacts may occur as decreased groundwater levels could induce flow of poor quality water (i.e., unsuitable for municipal uses) found in select deeper formational materials of the aquifer. This may eventually necessitate additional expensive treatment of groundwater to make the water suitable as a drinking water supply. Further, the preceding discussion indicated that water quality issues appear to be most extensive in the SMA. Well ID1-8 displays an increasing concentration trend from 1972 to present for nitrate, TDS, and sulfate; however, the current concentration is below the MCL for each constituent. It should be noted that well ID1-8 is down gradient from the Rams Hill golf course, which is a probable anthropogenic source of nitrates in the SMA in addition to the percolation ponds at the wastewater treatment plant. Rams Hill wells RH-5 and RH-6, which are located on the old golf course, indicate elevated nitrate as N concentrations at 3.8 mg/L and 3.2 mg/L (Dudek 2015b). Rams Hill will monitor groundwater quality annually from its wells as part of the Long-Term Cooperation Agreement with the BWD.

Data Gaps

The lateral distribution of the wells in the monitoring network that measure groundwater quality is limited, and does not extend to the outer portions of each management area. However, there is sufficient distribution to make reasonable interpretations of trends in groundwater elevations and groundwater quality in each of the three management areas. Vertical coverage of the BWD well network is similarly limited, as most of the wells are cross-screened in more than one aquifer. Deficiencies of this particular program as it relates to SGMA include limited vertical and horizontal spatial coverage and temporal deficiencies, since historical analytical data was only collected at approximately 3-year intervals for BWD wells. Of the more than 120 wells located in the Subbasin, approximately 12 were routinely monitored and sampled over multiple years prior to development of the GSA monitoring network. Based on the inconsistent analytical suites between wells and monitoring periods, this variability represents a significant data gap.

Additional routine analytical groundwater quality sampling is needed to establish long-term trends. As part of the GSP monitoring program (further described in Chapter 3, Section 3.5), the GSA will be sampling wells semi-annually rather than every 3 years as required by the Division of Drinking Water, at least for wells that indicate detections of COCs above one-half the drinking water MCL or where increasing concentration trend is indicated. In addition to conducting more frequent groundwater quality sampling, the GSA has standardized the analytical sampling suite and methods in accordance with the *Sampling and Analysis Plan and Quality Assurance Project Plan* included as part of Appendix E. The selection of which wells to monitor for groundwater quality represent a combination of factors, including the well's geographic location, the screen interval relative to three principal aquifers, accessibility, anticipated well longevity, and continuity of historical data.

As previously discussed, the GSA has been working to close these data gaps by identifying additional monitoring locations. Pursuant to the DWR's *BMPs for Sustainable Management of Groundwater, Monitoring Networks, and Identification of Data Gaps,* the GSA has developed the Borrego Springs Subbasin Monitoring Plan (described in Chapter 3, Section 3.5), to be updated periodically, in order to address these data gaps and to monitor groundwater levels and water quality against the sustainability indicators outlined in Chapter 3 of this GSP. The Monitoring Plan includes monitoring objectives and recommendations for collecting data that demonstrate short- and long-term trends in groundwater, and progress toward achieving measurable objectives. The Monitoring Plan is also designed to monitor impacts to beneficial uses of groundwater, and to quantify annual changes in water budget components.

2.2.2.5 Land Subsidence

Land subsidence can occur when long-term groundwater extractions result in the lowering of the groundwater table, which in turn increases the effective stress in the overlying aquifer matrix. This can cause the collapse of pore space within the matrix. Land subsidence can be either reversible (elastic), or irreversible (inelastic), depending on the soil characteristics of the aquifer. The USGS (2015) used two methods to evaluate land subsidence within the Plan Area. First, repeat GPS surveys were conducted over time, using 25 geodetic monuments as GPS stations. In addition to geodetic monuments, the USGS collected high-precision GPS elevation data from 79 groundwater wells in December 2008 and March 2009 to augment the evaluation of land subsidence. Second, interferometric synthetic aperture radar (InSAR) satellite data collected between 2003 and 2007 were reviewed. The difference between the two methods is that GPS is generally available over a longer period of time but has less spatial resolution, whereas InSAR has high spatial resolution but is only available for the recent past.

Land surface elevations from 1978 were compared with those collected in 2009 to estimate the degree of land subsidence in the Plan Area (USGS 2015). Analysis of the sources of error in the measured elevations indicated that the resolution of the data collected was approximately plus or minus 0.54 feet. This analysis included potential errors in the measurements associated with the GPS survey instrument, the error in the geoid, and the assumed errors associated with historical data. Land surface elevation changes within the Plan Area between 1978 and 2009 were found to be less than 0.54 feet, and included both increases and decreases (USGS 2015). Based on these observations, measurable land subsidence did not occur in the Plan Area between 1978 and 2009. InSAR was used to analyze data at a greater temporal and spatial scale, but over a shorter time period. Data from the European Space Agency’s Earth Remote Sensing 1 and 2 (ERS-1 and ERS-2) and ENVISAT satellites were used to detect changes in land surface elevations. Based on these data, the average maximum annual subsidence rate between 2003 and 2007 was found to be 0.2 inches per year, which is consistent with the subsidence findings using GPS data (USGS 2015). Analysis of the InSAR data revealed a small but consistent and seasonal pattern of elastic subsidence, in which land surface elevations decrease in the summer with increased pumping, and recover about half the decrease by the end of the year. The greatest area of subsidence detected between 2003 and 2007 is concentrated southeast of the agricultural fields in the Plan Area and amounts to 15 millimeters (or 0.59 inches), or 3.75 millimeters per year (or 0.15 inches per year).

The degree of land subsidence occurring in the Plan Area is minimal, has not substantially interfered with surface land uses in the past, and is not anticipated to substantially interfere with surface land uses in the foreseeable future. The minor amount of subsidence that has occurred when compared to over a hundred feet of groundwater level decline in the northern parts of the Plan Area indicate that the subsurface strata may be less sensitive to land subsidence due to its coarse-grained nature. There is sufficient data to qualify the subsidence criterion as insignificant, and not currently an undesirable result of groundwater overdraft (USGS 2015). Given the low sensitivity of subsurface strata to land subsidence in response to historical groundwater level declines, along with the lack of infrastructure in the Plan Area that may be sensitive to subsidence (i.e., linear infrastructure such as canals and high hazard pipelines), subsidence is also not expected to become an undesirable result over the planning and implementation horizon.

2.2.2.6 Groundwater–Surface Water connections

Streams interact with groundwater in three basic ways; streams gain water from inflow of groundwater through the streambed (gaining stream), they lose water to groundwater by outflow (losing stream), or they do both, gaining in some reaches and losing in other reaches. Streams or stream segments may also not interact at all with groundwater (disconnected stream). As shown on Figure 2.2-17, while surface water daylights in localized areas within the Subbasin as natural seeps and springs, the majority of springs and perennial[30] creeks occur outside the Plan Area within

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[30] Perennial streams typically flow continuously in all or part of its streambed during all of the calendar year as a result of groundwater discharge or surface runoff. However, during unusually dry years, a normally perennial stream may cease flowing, becoming intermittent until precipitation falls on the watershed.

the ABDSP. These surface water sources are topographically higher than the groundwater elevation of the underlying basin, in many cases hundreds of feet higher. Therefore, ongoing drawdown of groundwater elevations in the Subbasin does not appear to correlate to a depletion of interconnected surface water.

The environment that contributes to perennial flows in the region is that of springs and seeps emanating out of the basement rock in narrow stream valleys (outside the Plan Area), where the alluvium is both narrow and shallow, allowing at least some groundwater from the basement rock outside the boundaries of the Borrego Springs Subbasin to surface. The streams within the Plan Area are predominantly disconnected from the underlying groundwater table. This is because, when present, stream flows of moderate magnitude and short duration do not tend to percolate deeply enough to reach the underlying aquifer. Instead, water flowing upon and within the saturated alluvium beneath the stream bed is quickly lost to evaporation or transpiration. This is the case for most of the streams and washes in the Plan Area, and is typical of an arid desert environment.

Borrego Spring, shown on Figure 2.2-17, is no longer flowing. In 1963 (referring to Borrego Spring about one mile west of the Borrego Sink), Lester Reed wrote in *Old Time Cattlemen and Other Pioneers of the Anza-Borrego Area,*

> Since so much recent pumping of water in the Borrego Valley, the old spring no longer flows. This spring was one of the watering places upon which the Indians, and the old-timers could depend, although the water was of poor quality. The first time I visited Old Borrego Spring was just two or three days before Christmas 1913 when my brother Gilbert (Gib), and I were riding though on horseback from Imperial Valley to spend the holidays with our parents at the Mud Spring Ranch about fifteen miles southeast of Hemet. Since early boyhood, I heard old-timers talk about Borrego Springs water; so I thought I would try it. As I have said many times before, I found it to taste but very little better than the treated water we are expected to drink today.

Storm flows may occasionally be adequate in intensity and duration for recharge to be initiated through deep percolation of storm runoff. Figure 2.2-18 shows the Federal Emergency Management Agency mapping of the 100-year floodplain as an extreme scenario, where most of the valley north of Borrego Sink would be inundated by shallow floodwater (Zone AO), and a narrower portion of the valley along Borrego Palm Creek would have deep, higher velocity flooding (Zone A). The zones shown on Figure 2.2-18 are more accurately referred to as a flood with a 1% annual chance of occurring. It is peak rain events such as the 2-year or higher flood flows, or a prolonged series of storms, which contribute to the vast majority of recharge to the underlying aquifer, as further discussed in Section 2.2.3. However, not since the beginning of large-scale pumping in the Plan Area has groundwater (i.e., seeps, springs or gaining streams) been observed discharging onto the valley floor. The perennial portions of streams at the fringes of the

Subbasin are likely derived from springs, groundwater discharge from the basement rock and residual storm runoff outside the boundaries of the Borrego Springs Subbasin, or possibly the presence of perched groundwater.

Table 2.2-7 summarizes the watersheds and subwatersheds that overlap the Plan Area, as mapped by the USGS's watershed boundary dataset. The USGS National Hydrography Dataset, as well as mapping provided by ABDSP, were used to identify additional springs and the approximate extent of perennial creeks (commonly referred to as "blue-line" streams) versus those that are intermittent or ephemeral (Figure 2.2-17).[31] The perennial creeks in the Plan Area consist of a 1,000-foot section of Borrego Palm Creek as it exits the mountains and enters the Plan Area Boundary, as well as an approximately 2,000-foot portion of Coyote Creek in the northern part of the Subbasin. The GSA investigated the blueline stream mapped for Coyote Creek by the USGS National Hydrography Dataset, to validate whether it indeed represents a perennial stream. Field investigation found that grading of the creek bed near Seley Ranch causes stormwater to pond, resulting in the possible illusion that the reach has perennial flow.

Generally, the creeks and washes, once they exit the mountains and enter the Borrego Springs Subbasin, become disconnected from the alluvial groundwater table (i.e., 100% of their flow is attributable to surface runoff and not affected by fluctuations in the underlying groundwater table). However, for creek segments to be mapped as perennial in such an arid environment means at least some of the flow is likely attributable to groundwater discharge higher up in the watershed.

Table 2.2-7
U.S. Geological Survey Watersheds and Subwatersheds Overlapping the Plan Area

Watershed (size)	Subwatershed	Subwatershed Size (acres)	Acres in Plan Area (percent of subwatershed)	Primary Hydrologic Features within Plan Area
Coyote Creek (179 square miles)	Upper Coyote Creek	13,521	21 (0.2%)	Coyote Creek, Perrenial Sections; potential GDEs
	Lower Coyote Creek	21,197	10,541 (50%)	Coyote Creek, Primarily Ephemeral; Historical Mesquite Bosque Habitat
Borrego Valley – Borrego Sink Wash (158 square miles)	Borrego Valley	15,858	14,916 (94%)	Unnamed dry washes only; Historical Mesquite Bosque Habitat

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[31] Intermittent streams flow only seasonally or in response to runoff-generating precipitation.

Table 2.2-7
U.S. Geological Survey Watersheds and Subwatersheds Overlapping the Plan Area

Watershed (size)	Subwatershed	Subwatershed Size (acres)	Acres in Plan Area (percent of subwatershed)	Primary Hydrologic Features within Plan Area
	Borrego Sink Wash	36,565	25,657 (70%)	Unnamed dry washes and Borrego Sink (dry); Historical Mesquite Bosque Habitat; Old Borrego Spring
	Dry Canyon	12,082	2,222 (18%)	Unnamed dry washes
	Borrego Palm Canyon	36,875	7,449 (20%)	Borrego Palm Creek, partly perennial; Pup Fish Spring; potential GDEs
Upper San Felipe Creek (194 square miles)	Mine Wash – San Felipe Creek	31,560	1,922 (6%)	San Felipe Creek, ephemeral

Source: USGS 2017.
Notes: GDE = groundwater dependent ecosystem.

Groundwater Dependent Ecosystems

A GDE is a plant and animal community that requires groundwater to meet some or all water needs (TNC 2018). GDEs are defined under the SGMA as “ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface” (Title 23 CCR Section 351(m)). Groundwater is critical to sustaining springs, wetlands, and perennial flow (baseflow) in streams as well as to sustaining vegetation such as phreatophytes that directly tap groundwater. In response to SGMA, the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset was provided by DWR and TNC as a reference dataset and starting point for GSA’s to review and validate the mapped features and supplement the dataset as necessary with the GSA’s understanding of local surface water hydrology, groundwater conditions, and geology within the groundwater basin (TNC 2018). The Natural Communities dataset is comprised of 48 publicly available state and federal agency mapping datasets including but not limited to the following: VegCAMP – The Vegetation Classification and Mapping Program, California Department of Fish and Wildlife; CALVEG – Classification and Assessment with Landsat Of Visible Ecological Groupings, U.S. Department of Agriculture Forest Service; NWI V 2.0 – National Wetlands Inventory (Version 2.0), U.S. Fish and Wildlife Service; FVEG – California Department of Forestry and Fire Protection, Fire and Resources Assessment Program; USGS National Hydrography Dataset; and Mojave Desert Springs and Waterholes (Mojave Desert Spring Survey). After the previously described vegetation, wetland, seeps, and springs data were compiled into the Natural Communities dataset, data were screened to exclude vegetation and wetland types less likely to be associated with groundwater and retain types commonly associated with groundwater (TNC 2018).

The mapped vegetation types in the Plan Area considered to be potential GDEs are wetland and honey mesquite bosque (Figure 2.2-19). Because The Nature Conservancy's (TNC's) method for identifying potential GDEs does not assess or incorporate local groundwater conditions, the GSA has conducted a review, evaluation, and validation of the NCCAG dataset specific to the Subbasin and has evaluated whether there is a significant nexus between the regional groundwater aquifer and the potential GDEs identified in the NCCAG. Appendix D contains a detailed evaluation of the mapped GDEs, the local hydrology, geology and groundwater conditions that surround them, and a HCM to illustrate how the NCCAG are sustained.

The potential GDEs have been categorized into three discrete geographic units, described as follows.

GDE Unit 1 (Coyote Creek)

GDE Unit 1 occurs along the perennial section of Coyote Creek at the northern end of the Subbasin as shown in the inset map on Figure 2.2-19 (TNC 2010; ABDSP 2017). Both NCCAG wetlands and vegetation are mapped in this unit and are narrowly focused within the riparian corridors associated with Coyote Creek. GDE plant type mapped in association with Coyote Creek are desert willow (*Chilopsis linearis ssp. arcuata*), narrowleaf willow (*Salix exigua var. exigua*), honey mesquite, and catclaw acacia (*Senegalia greggii*) (drought deciduous, which lack leaves for most of the year). The nearest water well in the Subbasin to the mapped GDEs is the Horse Camp well owned by the ABDSP. The depth to groundwater at the Horse Camp well is 287.69 feet below top of casing (664.76 feet amsl) as measured in Spring 2018.

Coyote Creek Watershed encompasses approximately 180 square miles, as shown on Figure 2.2-17. The watershed is located almost entirely within the boundary of the Anza-Borrego Desert State Park and streamflow in the Coyote Creek Watershed has been documented by USGS as the number one source of recharge to the Subbasin via streamflow leakage (i.e., infiltration of surface water runoff). Approximately 65% of the surface water inflow to the Borrego Valley comes from Coyote Creek (USGS 1982). There are two streamgages along Coyote Creek located at the northernmost boundary of the Subbasin, one of which stopped recording streamflow in 1983, and the other stopped recording flow in 1993. USGS Station Number 1025580 (Upper–Northern) recorded daily discharge data from 1951–1983; at this station, annual average streamflow was measured to be 1,831 AFY (USGS 2017). USGS Station Number 10255805 (Lower–Southern) recorded daily discharge data from 1983–1993; at this station, annual average streamflow was measured to be 1,774 AFY (USGS 2017). Annual variability over the period measured ranges from 326 acre-feet to 10,715 acre-feet. This large annual variability is a function of large annual variability of precipitation falling on the Coyote Creek Watershed.

To begin to evaluate the GDEs associated with Coyote Creek, the GSA has investigated whether the perennial and ephemeral creek segments are gaining water or losing water to the underlying aquifer system. To complete this analysis, the GSA has begun to map the perennial extent of flow in to the Subbasin on a semi-annual basis (spring and fall). The upper historical streamgage is the GSA's manual monitoring point for Coyote Creek. At this location, the GSA manually measured an instantaneous streamflow of 0.46 cubic feet per second in Spring 2018, which converts to 206.5 gallons per minute. At that time, the former lower historical USGS stream gage station was observed to be dry.

In Spring 2018, the perennial extent of flow in Coyote Creek was documented to occur downstream of the third-crossing and upstream of the second crossing. No flow was observed in Spring 2018 at the lower inactive USGS stream gage, which is one of the permanent locations for manual flow readings. In Fall 2017, streamflow extended almost half-way from the second crossing to the first crossing. The crossings refer to where an unimproved road crosses the creek bed. In Fall 2017, there was a precipitation event in the Coyote Creek Watershed that produced runoff in Coyote Creek; however, no streamflow measurements are available for this event. Flow in the stream was observed to decrease incrementally from the upper inactive USGS stream gage to two locations measured downstream.

The evidence gathered thus far indicates that the reach of Coyote Creek that was mapped as potential GDE by DWR and TNC is a "losing" stream, and that this habitat, where it occurs, is supported by intermittent storm events and/or flows emanating from the upland watersheds and basins, rather than local discharge of groundwater from the Subbasin to the stream reach.

GDE Unit 2 (Palm Canyon)

GDE Unit 2 occurs along the perennial section of Borrego Palm Creek at the western boundary of the Plan Area (Figure 2.2-19) (TNC 2010; ABDSP 2017). The nearest water well in the Subbasin to GDE Unit 2 is the Anza-Borrego Desert State Park Well No. 3, owned by the ABDSP. The depth to groundwater at the Horse Camp well is 347.84 feet below top of casing as measured in Spring 2018. This indicates that GDE Unit 2 is supported by surface water flows originating outside the Subbasin (which can be storm fed and/or spring-fed) and entering the Subbasin through Borrego Palm Creek. Given the depth to groundwater within the Subbasin, there is no substantial nexus between pumping and GDE Unit 2.

GDE Unit 3 (Mesquite Bosque)

According to the USGS (2015), the Borrego Sink, a topographic low where the water table was within 10 feet of land surface, was the site of about 450 acres of honey mesquite bosque and other native phreatophytes[32], indicating that shallow groundwater and occasional accumulations of surface water was historically sufficient to support a GDE (Figure 2.2-19). Prior to development,

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[32] Phreatophytes are long-rooted water loving plants that obtain water supply from groundwater or the capillary fringe just above the water table.

honey mesquite, salt grass (*Distichlis spicata*), willow (*Salix*), and rushes were reported to be abundant in the valley (Mendenhall 1909 as cited in USGS 2015).

As stated in General Plan Update Groundwater Study completed by San Diego County (2010): "The mesquite bosque, a rare and sensitive groundwater-dependent habitat, is believed by many experts to be desiccating in portions of Borrego Valley, even though their taproots can reach down to 150 feet for water." The habitat covered an approximate four-square mile area. However, while mesquite bosque can have extremely deep taproots, the USGS (2015) notes that the deepest rooting depth for phreatophytes found in around the Borrego Sink and areas to the north was at 15.3 feet. Recent groundwater levels from wells adjacent to the main mapped habitat range from approximately 55 to 134 feet below the ground surface. The USGS (1988) and others estimated that prior to 1946, about 4,300 acre-feet of water was discharged from phreatophytes annually by evapotranspiration.

The honey mesquite bosque, shown as purple on Figure 2.2-19 north of the Borrego Sink, is considered a pre-2015 impact, because groundwater levels have declined to a level that no longer supports a viable habitat. Groundwater levels have long since declined below a level which can support the estimated rooting depth of the habitat, which is 15.3 feet (USGS 2015). Natural discharge determined from the BVHM attributable to evapotranspiration was approximately 6,500 AFY prior to development, but has been virtually zero in the last several decades (1990–2010) (USGS 2015). The green area on Figure 2.2-19 depicts the pre-pumping mapped historical extent of phreatophytes in the Subbasin by USGS (USGS 2015). The pink area depicts the mapped pre-January 1, 2015, extent of potential GDEs; (SANGIS 2017) and the orange area depicts the extent of mapped GDEs by the natural communities dataset (DWR 2018).

Pumping in the Subbasin has resulted in a groundwater level decline of about 44.1 feet over the last 65 years in the vicinity of the Borrego Sink. The average rate of decline over this 65-year period is approximately 0.67 feet per year. Because of the long-term imbalance of pumping with available natural recharge, an irreversible impact has occurred to the honey mesquite bosque, which was mostly desiccated prior to January 1, 2015. MW-5 is a multicompletion well that was constructed with BWD and DWR oversight. MW-5B is screened from 45 to 155 feet below ground surface and appears to sufficiently represent the depth of the groundwater table in the vicinity of the Borrego Sink, though it is possible that it represents a semi-confined potentiometric surface rather than the unconfined water table. MW-5A is screed from 200 to 340 feet and has a similar groundwater level to the shallower MW-5B suggesting potentially unconfined conditions in this part of the Subbasin; however, it is uncertain whether a good well seal was obtained during installation of the multicompletion monitoring well. The "Sink" wells shown on Figure 2.2-19 (i.e., 12G1 and 7N1) have become dry based on measurements recently performed by DWR. The overlap of a groundwater level measurement in 2009 of Sink Well 12G1 with MW-5B, which has a similar groundwater level elevation suggests that well MW-5B is sufficiently representative of depth to the groundwater table in the area of the Borrego Sink.

As indicated earlier, Borrego Spring located about 1 mile east of the Borrego Sink historically provided water to cattle prior to 1963. The Borrego Spring was located in the vicinity of the Desert Lodge anticline, which is evidenced by fold axes running perpendicular to the Veggie Line fault, the Coyote Creek fault and the Yaqui Ridge/San Felipe anticline associated with the San Jacinto fault zone (Steely et al. 2009). The faulting and folding effectively compartmentalize the deep sediments of the Borrego Springs Groundwater Subbasin and likely once resulted in 'daylighting' of groundwater at the Borrego Sink prior to interception of groundwater flow by pumping.

Other Potential GDEs

Other potential GDEs include Hellhole Palms, Tubb Canyon, Glorietta Canyon, and other minor or unnamed stream segments entering the Subbasin. Similar to Coyote Creek and Borrego Palm Canyon, these other potential GDEs are supported by surface water flows originating outside the Subbasin (which can be storm fed and/or spring-fed).

2.2.3 Water Budget

The water budget for the basin provides an accounting and assessment of the average annual volume of groundwater and surface water entering and leaving the basin. This section includes information on the historical and current water budget conditions, as well as the change in the volume of groundwater stored. The water budget provides detail sufficient to build local understanding of how historical changes to supply, demand, hydrology, population, land use, and climatic conditions have affected the applicable sustainability indicators in the basin. This information is used to predict how these same variables may affect or guide future management actions. Building a coordinated understanding of the interrelationship between changing water budget components and aquifer response will allow the GSA to effectively identify future management actions and projects most likely to achieve and maintain the sustainability goal for the basin (DWR 2016).

In order to estimate the groundwater budget for Borrego Valley, the GSA has leveraged the public domain numerical groundwater model produced by the USGS in 2015 (USGS 2015), also referred to as the BVHM. The BVHM has a period of simulation of 1945 through 2010. The USGS calibrated the model to groundwater levels that were measured throughout the period of simulation, but no model validation was completed as part of the original modeling process. In order to comply with GSP requirements, the GSA has updated the model to simulate water budget components up through Water Year 2016[33] and conducted a model validation. The 6-year period of measured groundwater level data including 2011 through 2016 was used to validate the model. As part of model validation, simulated groundwater levels were compared to measured groundwater levels including 2011 through 2016, with the resulting errors in groundwater levels being used to assess model uncertainty and support potential model revisions necessary to refine the water budget calculations.

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[33] See footnote 17. All references to years in this section are water years.

The model domain is defined by a finite-difference grid of uniform cells, or nodes, with each cell being 2,000-feet by 2,000-feet, or approximately 92 acres in area. The model domain includes 30 rows and 75 columns with 2,250 active cells (Figure 2.2-20). The total area simulated in the model is 73,876 acres, which is greater than the Plan Area, extending further southeast into the northwestern portion of the Ocotillo Wells Subbasin. Due to the resolution of the model grid, certain parts of the Borrego Springs Subbasin, namely its northern tip and small fringe areas of the Subbasin's southeastern boundary were not included in the model grid. This spatial discrepancy between the model grid and the Plan Area boundary is expected to have minimal effect on the water budget because the areas in question have minimal if any pumping. However, it should be noted that all references to the Borrego Springs Subbasin within this subsection refer specifically to the model domain rather than the Plan Area. The model was divided vertically into three layers, corresponding to the upper, middle and lower aquifers described in Section 2.2.1.3. A technical report—*Update to the United States Geological Survey Borrego Valley Hydrologic Model for the Borrego Valley Sustainability Agency*—goes into detail on the specific methods of analysis and model inputs and outputs, and is included in Appendix D of this GSP.

The following sections break down the water budget into components of inflow and outflow and summarizes the results of the BVHM update. The discussion below is summarized in Table 2.2-9A and Table 2.2-9B.

Table 2.2-9A
Borrego Valley Hydrologic Model Simulated Water Budget Components, Water Years 1945–2016

Component	Minimum (AF) (Water Year)	Maximum (AF) (Water Year)	71-Year Annual Average (AFY)	Standard Deviation (AFY)
Inflows				
Stream Recharge	112 (1947)	22,504 (1978)	3,905	4,965
Irrigation Return Flows	572 (1961)	3,706 (1978)	1,497	708
Subsurface Inflow	Constant (Specified) Flow		1,367	2
Annual Average Inflow			6,770	5,470
Outflows				
Pumping	996 (1945)	19,911 (2006)	10,597	4,744
Net Evaporation Losses	364 (2014)	9,998 (1945)	2,815	2,372
Subsurface Outflow	Constant (Specified) Flow		522	12
Annual Average Outflow			13,934	3,552
71-Year Average Annual Deficit			**(7,165)**	

Source: USGS 2015; Appendix D.
Notes: AF = acre-feet; AFY = acre-feet per year.

Table 2.2-9B
Borrego Valley Hydrologic Model Simulated Water Budget Components, Water Years 2006–2016

Component	Minimum (AF) (Water Year)	Maximum (AF) (Water Year)	10-Year Annual Average (AFY)	Standard Deviation (AFY)
Inflows				
Stream Recharge	234 (2009)	6,493 (2011)	1,928	1,680
Irrigation Return Flows	1,215 (2008)	1,919 (2011)	1,533	242
Subsurface Inflow	Constant (Specified) Flow		1,367	2
Annual Average Inflow			4,828	1,859
Outflows				
Pumping	14,759 (2011)	19,911 (2006)	16,945	1,630
Net Evaporation Losses	364 (2014)	946 (2005)	539	172
Subsurface Outflow	Constant (Specified) Flow		523	4
Annual Average Outflow			18,007	1,747
10-Year Average Annual Deficit			**(13,179)**	

Source: USGS 2015; Appendix D.
Notes: AF = acre-feet; AFY = acre-feet per year.

2.2.3.1 Inflow to Groundwater System

Stream Recharge

Infiltration from the ephemeral stream and washes entering the Borrego Valley from the adjacent mountains is the major component of recharge in the groundwater budget in the Plan Area. Within the Borrego Springs Subbasin, the natural recharge of underflow and surface water runoff from the adjoining watersheds was estimated from data obtained from the regional-scale USGS Basin Characterization Model (BCM). There are no known existing streamgages within the boundaries of the numerical groundwater model. There are three historical USGS streamgages located outside of the numerical model boundaries but within the boundaries of regional scale BCM, the most complete of which is the streamgage record on Borrego Palm Creek (USGS gage no. 10255810). Flows from streams into the model domain were estimated using the modeled streamflow from the BCM, which were calibrated using the USGS streamgages for the periods when data are available from the streamgages. The BVHM includes 84 stream segments where multiple segments were joined to represent streamflow in Coyote Creek, San Felipe Creek, Borrego Palm Creek, and other minor tributaries. The streams received inflow at 24 entry points that represented runoff from the adjoining upstream watersheds in the San Ysidro and Vallecitos Mountains, the general locations of which are shown on Figure 2.2-20.

Typically, there was little to no perennial streamflow into the Borrego Springs Subbasin from 1940 to 2016. Only after major wet seasons or large individual rainfall events did runoff to the Subbasin exceed 10,000 AFY or more. Stream recharge only occurred during 7 years in the 1940 to 2016 period (on average roughly once per decade). Runoff into the Subbasin from the 24 entry points modeled ranged from less than 10 AFY to 44,000 AFY with an average annual rate of 3,600 AFY. The BVHM includes perennial flow entering Coyote Creek at 0.014 cubic feet per second and an unnamed tributary at 0.002 cubic feet per second from a minor watershed to the southwest of the Subbasin. It should be noted that the BVHM also models runoff produced within the basin (as opposed to the 24 entry points) from direct precipitation.

Stream recharge ranged from 112 AF in 1947 to 22,500 AF in 1978. The annual average recharge rate from stream leakage between 1945 and 2016 was 3,831 AFY with a standard deviation of 4,690 AFY.

Irrigation Return Flows

Another component of inflow to the Subbasin, particularly as the valley became more developed, is return flow from applied irrigation within agricultural areas. USGS (2015) estimated recharge from irrigation return flows to be between 10%–30% agricultural and recreational pumping based on the results of the BVHM. This is consistent with the estimate of irrigation return flow by Netto (2001), who used a chloride mass balance technique at a citrus grove located northwest of the intersection of Di Giorgio Road and Henderson Canyon Road to estimate a return flow of 22%. Netto (2001) used a similar approach to estimate a return flow for golf course irrigation of 14%.

The BVHM calculated the amount of water from applied irrigation returning to the aquifer using the Farm Process (FMP) and Unsaturated Zone Package (UZP). The volume of applied water in excess of losses to evapotranspiration, irrigation inefficiencies, and surface runoff was simulated as infiltrating below the root zone and entering the unsaturated zone. An important update from earlier versions of the BVHM is that the Farm Process links to information on unsaturated flow, so that the considerable thickness of unsaturated sediment in the valley can be considered. This allows for a more realistic simulation of the years to decades it can take for irrigation return flow to pass through the unsaturated zone. Earlier versions of MODFLOW simulated an instantaneous contribution of infiltrating water from land surface to the water table.

Because irrigation efficiency has improved over the BVHM model period, the 10%–30% range for irrigation return flows cited by the USGS (2015) has both narrowed and decreased in the more recent past. By comparing model components that simulate return flows in the FMP and the UZF in the last 10 years, the UZF flows are approximately 10% of total pumping, and range from 7% to 13% (ENSI 2018). Combined agricultural and golf course irrigation represent approximately 80% of total pumping so these rates correspond to irrigation-specific return flow rates of approximately 9% to 16% (ENSI 2018).

Recharge from applied irrigation return flows ranged from 572 AF in 1961 to 3,706 AF in 1978. The annual average recharge rate from irrigation return flows between 1945 and 2016 was 1,473 AFY with a standard deviation of 683 AFY.

Subsurface Inflow

Underflow entering the Borrego Valley Subbasin from the adjoining upstream watersheds was simulated using the Flow Head Boundary package. Underflow from these watersheds was distributed over 44 cells aligned at the model domain boundaries with the San Ysidro and Vallecitos Mountains. The rate of underflow entering the BVHM for each cell was based on monthly data obtained from the BCM. The USGS defined an average rate of underflow at each cell to the model domain and held these rates constant throughout the simulation. The total underflow to the model domain was 3.7 acre-feet per day, or 1,367 AFY, and essentially held constant through the simulation period.

Henderson (2001) and Netto (2001) examined groundwater flow through bedrock in the surrounding watershed utilizing the computer program Recharg2, and found that on average between 1945 and the year 2000, bedrock recharge to the BVGB averaged 1,790 AFY (with a range of 0–19,860 AFY). Henderson (2001) found that 6 of the 15 drainage areas were expected to drain to the valley as surface flow rather than bedrock underflow due to the geologic stratigraphy and topography, which for some watersheds meant that the majority of bedrock groundwater was carried as surface flow to stream valleys of the adjoining watersheds. It should be noted that the study area for Henderson and Netto’s Masters’ theses was larger and encompassed the whole BVGB as opposed to the Borrego Springs Subbasin.

The USGS’s BVHM treatment of subsurface inflow as a constant rate of 1,367 AFY is reasonable when compared to the Master’s thesis findings (of an average of 1,790 AFY) and when considering their study areas were larger.

Other Inflows

Other inflows considered to be a negligible contribution to the water budget include septic system return flows and WWTF discharges. The USGS (2015) cited a previous study that estimated an average use of 100 gpd per household and assumed that 50% of the water used was lost to evaporation and transpiration. Therefore, the USGS estimated that return flow from septic tank systems in the valley was constant at 0.056 AFY per home, or $5.14e^{-7}$ cubic meters per day. The USGS identified residential and/or developed areas in the valley and estimated a number of septic tank systems associated with those land use types on a per node basis in the numerical model. The number of septic tank systems were periodically defined in the model and used for subsequent monthly stress periods until the next count. The last count of septic tank systems defined in the numerical model was based on development identified in 2009. The USGS (2015) reported that “the infiltration from irrigation of municipal lawns and treated and untreated wastewater was assumed to be negligible.”

The Rams Hill WWTF may also contribute to recharge of the basin, and though unquantified, the amount is thought to be limited. The BWD operates the facility under a waste discharge permit

(Order No. R7-2007-0053) issued by the California RWQCB, Region 7 – Colorado River Basin. The WWTF is a 250,000-gallons-per-day (gpd) extended aeration (oxidation ditch) plant with evaporation/percolation ponds for disposal. The WWTF serves approximately 20% of the community of Borrego Springs, specifically the Rams Hill residential community and the Town Center area, which includes hotels, a motel and small businesses along Palm Canyon Drive. The WWTF currently treats an annual average of flowrate of 74,000 gpd with low season (summer) flows down to approximately 20,000 gpd. Treated effluent from the Rams Hill WWTF is discharged into three evaporation-percolation ponds. Given the desert location and dry, hot conditions a portion of the treated effluent is evaporated and a portion percolates into the aquifer. Groundwater level monitoring at a 15-minute frequency using a pressure transducer installed in the WWTP-1 monitoring well indicates that treated effluent discharged into the percolation ponds does recharge the basin, however the volume has not been quantified. Discharge is approx. 50 AFY, with recharge roughly 25 AFY, and there is some mounding that shows water is reaching the groundwater table.

2.2.3.2 Outflows from Groundwater System

Groundwater Pumping

The BVHM simulated municipal pumping using metered data obtained from BWD, and simulated agricultural and recreational pumping using the FMP. Before 1944, groundwater pumping in the basin averaged less than 300 AFY, which was used mostly for domestic purposes (USGS 2015). No pumping was simulated in the BVHM from 1929 to 1943. Population growth in Borrego Valley after World War II led to increasing groundwater production with the majority of water produced for irrigation purposes. Figure 2.2-21A and Figure 2.2-21B show simulated groundwater pumping by aquifer and by sector (i.e., agricultural municipal and recreational), respectively, for the period from 1945 to 2016. Groundwater production ramped up from essentially 0 AFY in 1943 to over 10,000 AFY in 1955 (Figure 2.2-21A). Annual production declined to less than 7,000 AFY beginning in 1965 but began increasing again in the mid-1970s with a peak production of almost 20,000 AFY in 2006. USGS (2015) reported that, “about 70 percent of the groundwater used each year has been for agriculture, about 20 percent for golf courses and other recreational uses, and about 10 percent for municipal and domestic use (residential, commercial, and the Anza-Borrego Desert State Park)” (Figure 2.2-21B).

Outflow from groundwater pumping within the Subbasin ranged from a low of 996 AF in 1945 to a high of 19,909 AF in 2006. As shown on Figure 2.2-21A, the lower and middle aquifers have become utilized to a higher degree since the early 1990s, likely as a result of problems accessing available water or suitable water quality within the upper aquifer. As shown on Figure 2.2-21B, there has been a trend towards decreased municipal pumping in recent years relative to recreational and agricultural uses.

Evapotranspiration Losses

Monthly potential evapotranspiration (PET) data were obtained from the BCM and included as part of the water-balance calculations in the FMP. Direct evapotranspiration from groundwater was estimated in the FMP by calculating the monthly PET values by monthly crop coefficients assigned to each land-use type (e.g., phreatophytes, citrus, golf courses, native), the rooting depths defined for each land-use type, the depth to groundwater and height of capillary fringe. Phreatophytes, found mostly around the Borrego Sink, had the deepest rooting depth at 15.3 feet. They were responsible for most of the groundwater losses from the basin prior to the mid-1940s. Prior to development, mesquite trees, salt grass, willow and rushes were reported to be abundant in the valley (Mendenhall 1909). The USGS (1988) reported that approximately 4,300 AFY was lost via evapotranspiration from phreatophytes before 1946. The amount of water extracted by pumping from the basin surpassed losses by evapotranspiration by 1954 (USGS 2015). This was attributed to declining groundwater levels in the basin, which reduced the amount of water available for transpiration. Evapotranspiration losses were less than 2,000 AFY by 1990 and less than 1,000 AFY by 2000.

Outflow as a result of evapotranspiration has steadily decreased as the groundwater level decreased below the root zone of native phreatophytes. Evapotranspiration losses within the Subbasin ranged from a low of 364 AF in 2014 to a high of 9,998 AF in 1945. Currently, evapotranspiration losses estimated by the BVHM is dominated by losses from farms, golf courses, non-native tamarisk, and other land uses. As evaluated in Appendix D, water lost to evapotranspiration, even where in support of NCCAGs, come from percolating or perched groundwater, which means this component of the water budget does not represent water from the regional groundwater table, or water that is accessed by Subbasin pumping. This means that impacts to GDEs is a pre-2015 impact and is not currently an undesirable result applicable to the Subbasin.

Subsurface Outflow

A constant-head boundary condition was assigned to three cells marking the southern boundary of the BVHM model domain. This boundary was identified by the USGS based on groundwater level data from other sources that indicated this area was not influenced by groundwater level fluctuations and hydraulic conditions to the north. The average outflow at this boundary throughout the simulation was 1.4 acre-feet per day or 511 AFY. No water flowed into the model domain at this boundary.

Annual outflow from the Subbasin at the southern boundary of the model domain fluctuated slightly around 511 AF between 1945 and 2016.

2.2.3.3 Change in Annual Volume of Groundwater in Storage

Annual and cumulative changes in storage for the BVHM model domain were estimated using the USGS groundwater numerical model, and shown on Figure 2.2-22A and Figure 2.2-22B, respectively. The numerical model treats groundwater in storage as a separate reservoir from which water can be added or removed to satisfy the groundwater balance equation. For each period of model calculation, water may be added to storage in one part of the model and removed from storage in another part of the model. Therefore, change in storage values reported for the model represent the net change in storage over the entire model grid.

For the period of model simulation, including the model update (1945–2016), the annual change in storage ranged from a decrease in storage of approximately 18,000 AF in 2006 to an increase in storage of approximately 18,100 AF in 1978 (Figure 2.2-22B). On average, the Subbasin lost approximately 7,300 AFY from storage for the period between 1945 and 2016. When considering the average over the last 10 years only, the average loss increases to 13,137 AFY. Water was removed from storage in 63 of the 71 years simulated, with water generally being added to storage in years in which the frequency, intensity and/or duration of runoff events were sufficient to initiate substantial stream recharge (e.g., water years 1967, 1977, 1979, and 1992). As a result, a cumulative amount of approximately 520,000 acre-feet of water was removed from storage over the period of model simulation (Figure 2.2-22B).

Each year in the period of simulation has been assigned one of three water year types: wet, average or dry. Water year types were assigned by the USGS during model development based on the amount of precipitation in each year relative to the average over the period of model simulation (USGS 2015).

2.2.3.4 Discussion of Model Validation, Uncertainties, and Recommendations for Improvement

The sensitivity analysis conducted by the USGS indicated the greatest uncertainty in the numerical model was in agricultural pumping, streamflow leakage, and storage. The FMP estimates agricultural pumping using precipitation and evapotranspiration data obtained from the BCM, assumptions about soil types and their associated soil moisture characteristics, rooting depths, crop coefficients, overland runoff, and estimated efficiencies of applied irrigation. Additionally, the coarse uniform grid of the model domain may overstate the water demands of certain land-use types, like golf courses, and, consequently, overestimate the amount of groundwater pumped to meet the water demand.

The simulated hydraulic heads compared to observed hydraulic heads indicated a slight bias of the model in underestimating hydraulic heads. This may be the result of the model simulating too much pumping compared to actual usage, or underestimating storage values like specific yield for the upper aquifer, or underestimating the amount of recharge to the BVGB, or a combination of all three. To improve the accuracy of the BVHM in simulating actual conditions and provide greater confidence in predictive simulations, the GSA intends to undertake the following actions to obtain additional data and further study the hydrogeology of the basin:

- At GSP implementation, the GSA will require agricultural and golf course wells to be metered. This will allow collection of actual agricultural pumping data via existing or installing new flow meters at farm wells. The pumping data may be incorporated in the numerical model to calibrate the FMP to more accurately estimate the water demands for the various crops and golf courses being irrigated.

- At GSP implementation, the GSA intends to collect periodic manual streamflow measurements at major drainages that convey most of the surface water runoff to the valley, either from perennial flows or flash flows from major precipitation events. Collection of this information can be used to further verify the accuracy of the BCM used in the BVHM, and ultimately to provide a more accurate estimate of stream leakage.

- As future funding allows, the GSA intends to conduct aquifer tests at wells screened only in the upper aquifer and only in the middle aquifer to obtain site-specific estimates of hydraulic conductivity and specific yield for each aquifer unit. This information may be used to enhance the calibration of the model to these hydraulic properties and our understanding of storage in the BVGB.

2.2.3.5 Quantification of Overdraft

The average groundwater extraction calculated by the model for the 1945 though 2016 period of simulation was 10,750 AFY. This is approximately 5,000 AFY more than the natural recharge estimated by the USGS using the model (5,700 AFY; USGS 2015). The average groundwater extraction calculated by the model since 1980 is 14,130 AFY, approximately 8,400 AFY more than the estimated natural recharge. As shown in Figure 2.2-22, since 2007, the amount of groundwater pumped from the Subbasin has been in decline, due to a combination of water conservation efforts by BWD and agricultural irrigators, economic factors, and limited agricultural land fallowing.

Because groundwater is the sole source of water for the Subbasin, the inflows, outflows, and cumulative change in groundwater storage described in Sections 2.2.3.1 through 2.2.3.4, as well as Tables 2.2-9A and 2.2-9B represent past and current water supply and demand conditions. Future water supply conditions are anticipated to mirror the pumping reduction program being implemented under this GSP, meaning that water supply will be incrementally reduced from the current (2018) level of pumping (inclusive of all beneficial uses) of 19,656 acre-feet to the sustainable yield of 5,700 acre-feet by 2040. This is equivalent to an approximately 71% reduction in groundwater use.

2.2.3.6 Sustainable Yield Estimate

The average annual natural recharge of water reaching the saturated zone, which includes stream leakage and infiltrating water through the unsaturated zone, was 5,700 AFY for the full model simulation period from 1929 to 2010 (USGS 2015). In addition to natural recharge from stream leakage and infiltrating water (mostly from irrigation return flows), the Subbasin received underflow originating from the adjacent watersheds at an average annual rate of 1,400 AFY. Therefore, the combined average annual natural recharge to the BVGB is approximately 7,100 AFY. Recharge in the basin is bimodal, with the majority of recharge occurring on decadal basis in a few very wet years. Most years have significantly less natural recharge than the average. Given that this bimodal pattern introduces a level of uncertainty regarding the actual amount of recharge that could occur over the next 20 years, the GSA has determined that a target pumping rate of 5,700 AFY by 2040 would be consistent with the GSP's sustainability goal (discussed in Chapter 3).

2.2.3.7 Quantification of Current, Historical, and Projected Water Budget

The highest levels of uncertainty in the model were from agricultural pumping, specific yield, and streamflow entering the valley. Agricultural pumping (and to a lesser extent recreational pumping) was estimated using the FMP package, which calculates a water demand on a cell-by-cell basis for each land-use type. The water demand is based on an estimated water consumption factoring in evapotranspiration, applied water (via irrigation or rainfall), efficiencies of applied irrigation water, soil moisture content, rooting depth, and potential runoff. The following measures could be taken to improve the uncertainty in the model: (1) information on actual pumping for agricultural and recreational uses can be used to improve the accuracy of the FMP in estimating pumping, (2) long-term constant-rate aquifer tests in the upper and middle aquifer units would improve the estimates of specific yield, and (3) the installation of stream gaging stations or manual streamflow measurements in Coyote Creek and other major drainages to the valley would improve the estimates of runoff to the basin.

2.2.3.8 Surface Water Available for Groundwater Recharge or In-Lieu Use

Traditional projects and management actions to physically supplement groundwater supply have been determined to be generally infeasible. Specific examples are summarized as follows:

- *Imported water*: The importation of groundwater from outside the boundary of the Borrego Springs Groundwater Subbasin is not considered feasible at this time. The U.S. Bureau of Reclamation's *Summary Report—Southeast California Regional Basin Study* found that the structural alternatives evaluated did not produce benefits in excess of their costs (USBR 2015). Therefore, the U.S. Bureau of Reclamation found that importing water was not economically viable at the time of the study, in 2012, and did not recommend additional studies at that time. Additionally, BWD evaluated the feasibility of importing groundwater from the Clark Dry Lake, Ocotillo Wells Subbasin and Allegretti Farms (Ocotillo-Clark Valley Groundwater Basin) (Burzell 2006). The BWD evaluation found these projects to be economically infeasible, because the estimated project cost of $6,480,000 (2006 dollars) did not justify the estimated production of 1,900 AF.

- *Wastewater Treatment Plant Upgrades*: In some basins wastewater treatment plants can be upgraded or additional service connections can be added to increase effluent volumes usable for producing recycled water or effluent for groundwater recharge. However, the nature of the Borrego Springs community and distribution of potential service connections is such that the upgrades would not result in an appreciable increase in groundwater recharge due to the insufficient scale of the system. The Final Tertiary Treatment Project Feasibility Study concluded that the production of recycled water within the BWD is not feasible at this time, and the No Project Alternative is recommended (Dudek 2018).
- *Stormwater Capture and Infiltration*: The infrequent occurrence of rainfall in the region results in extended periods of zero-recharge. Additionally, design criteria for capturing and infiltrating desert flood events, as well as removal and disposition of accumulated sediment from large storm events, is costly (USBR 2015). Therefore, while this potential supply-side project requires additional analysis, the costs to construct this as a stand-alone project outweigh the benefits at this time. Stormwater retention will be evaluated on a case-by-case basis in conjunction with future development in the Subbasin.

Feasible and effective projects and management actions needed to achieve sustainability within the GSP’s implementation horizon are discussed in GSP Chapter 4.

2.2.4 Management Areas

The depth, elevation and quality of groundwater resources in the Plan Area appears to vary geographically from north to south and with depth in the aquifer based on present and historical data discussed in Section 2.2-1. Three Subbasin management areas (the NMA, CMA, and SMA) are proposed to contextualize baseline conditions, monitor the status of groundwater quality, and measure progress toward achieving sustainability goals pertaining to groundwater quality (Figure 2.2-23).

The boundaries of these areas are based on the distribution of the three aquifers underlying the Subbasin, geologic controls on groundwater movement, and differences in overlying land uses and associated groundwater pumping depressions. The two primary features that define the boundaries between Subbasin management areas are the West Salton detachment fault (between the NMA and the CMA) and the Desert Lodge anticline (between the CMA and SMA), shown on Figure 2.2-23. The shape and thickness of the aquifers and subsurface geological features such as the Desert Lodge anticline and the West Salton detachment fault appear to influence hydrologic communication between the northern, central, and southern parts of the Subbasin. Due to the variable thickness of the individual aquifers, extraction wells are predominantly cross-screened in the upper, middle, and lower aquifers in the northern part of the Subbasin, cross-screened in the middle and lower aquifers in the central part of the Subbasin, and cross-screened in the middle and lower aquifers in the southern part of the Subbasin. The justification for use of these three areas has been covered in earlier sections, which differentiate aquifer geometry, groundwater levels and groundwater quality laterally across the three management areas (Sections 2.2.1 and 2.2.2, previously outlined).

The use of management areas is optional under SGMA, and in this GSP, the definition of the three management areas are primarily for the purpose of groundwater quality management, since the end uses of groundwater differs substantially across the three management areas. Wells in the NMA serve primarily agricultural use whereas wells in the CMA primarily serve municipal use, and wells in the SMA primarily serve recreational use which means there may be different thresholds for undesirable results for potable versus non-potable uses. These are discussed in Chapter 3.

2.2.4.1 North Management Area

In terms of sustainability indicators, this management area is differentiated from the others primarily on the basis of water quality, but also incorporates differences in historical groundwater level declines and changes in predominant land use. The main land use in the NMA is agriculture but also includes domestic uses in the northwestern part of Borrego Springs (Figure 2.2-23). Accordingly, it has the greatest overall groundwater level declines when compared to the CMA and SMA.

2.2.4.2 Central Management Area

In terms of sustainability indicators, this management area is differentiated from the others primarily on the basis of water quality, but also incorporates differences in historical groundwater level declines and changes in predominant land use. The main land uses in the CMA are municipal and recreational (golf courses) but also include substantial undeveloped areas to the northeast. Like the NMA, water quality is generally good, and historical groundwater level declines are also high. The main differentiating factor between the NMA and CMA is the predominant beneficial use of groundwater.

2.2.4.3 South Management Area

The geological basis for differentiating the management areas are previously described (Section 2.2.4). In terms of sustainability indicators, this management area is differentiated from the others primarily on the basis of water quality, but also incorporates differences in historical groundwater level declines and changes in predominant land use. Additionally, the Desert Lodge anticline effectively compartmentalizes the SMA from the CMA (USGS 2015). The land use in the SMA is undeveloped open space, with the exception of the Rams Hill Country Club and Air Ranch. Unlike the NMA and CMA, arsenic is a water quality COC in groundwater and wells in this area tap the lower groundwater aquifer.

The minimum thresholds and measurable objectives for indicator wells within each management area, the rationale for selecting those thresholds, and the levels of monitoring and analysis for each management area are described in Chapter 3. The three management areas are shown in Figure 2.2-23 as well as included on the figure in in Chapter 3.

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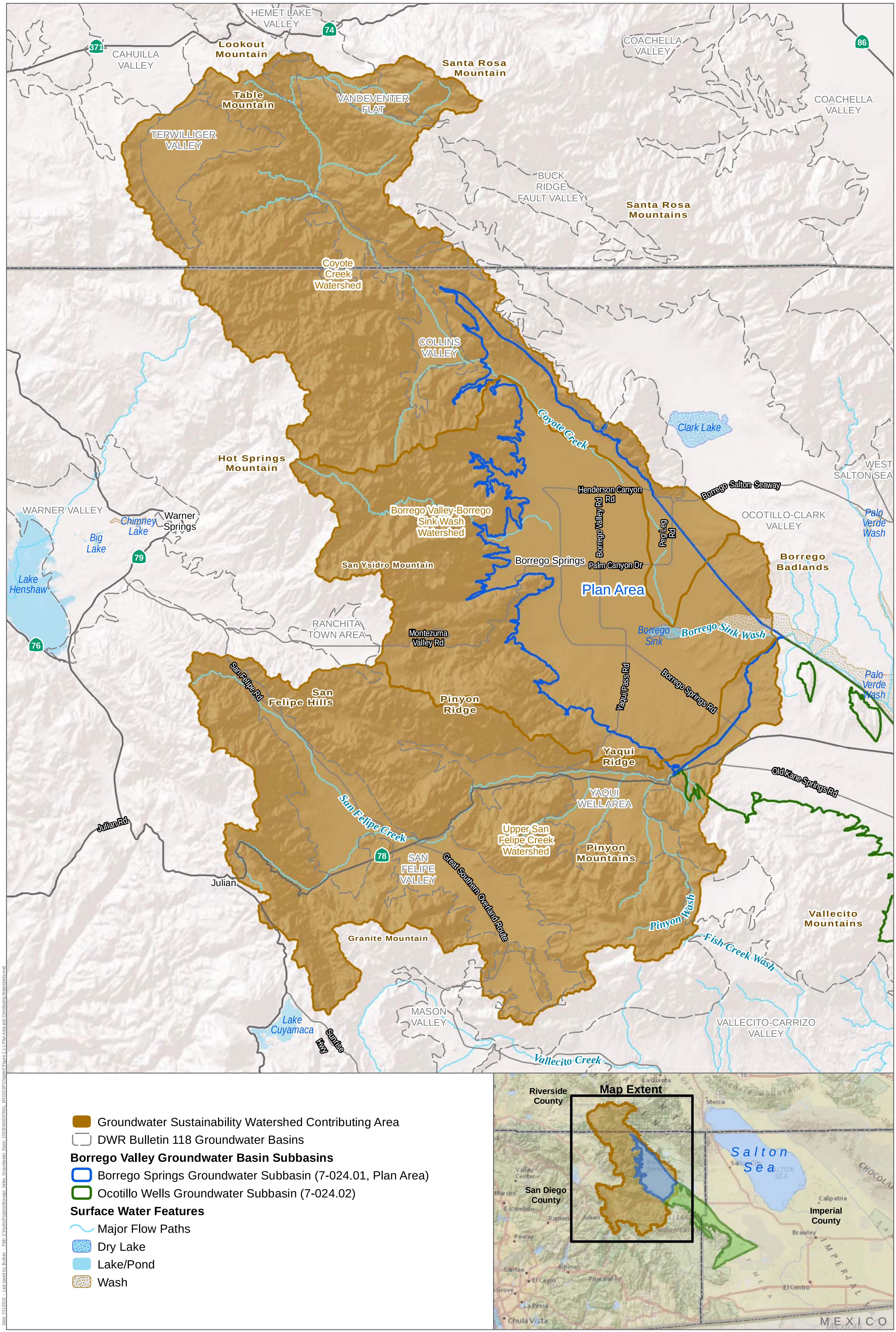

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DATUM: NAD 1983. DATA SOURCE: DWR 2015; SanGIS 2014; USGS NHD 2017

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Figure 2.1-1

Plan Area and Contributing Watersheds

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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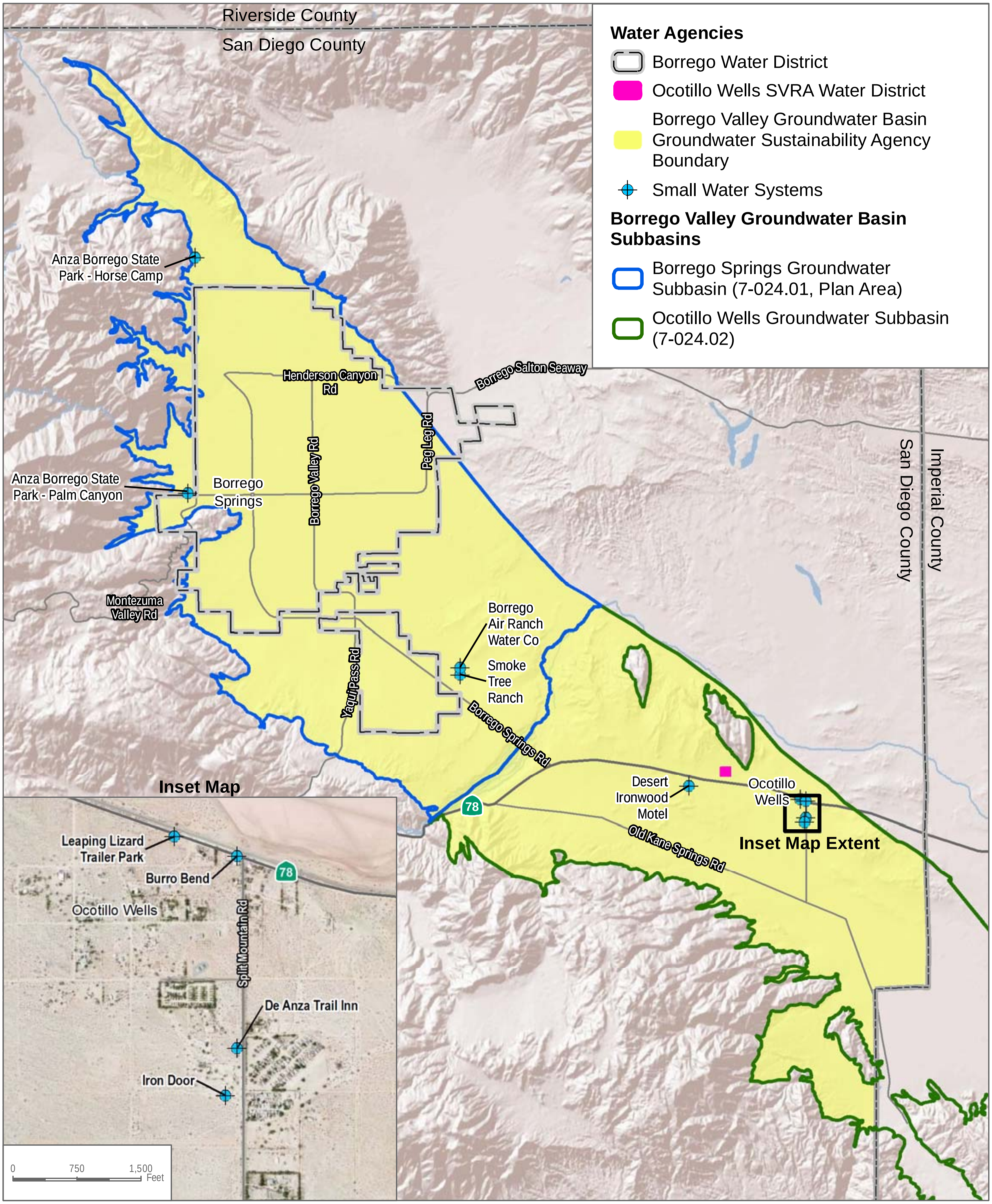

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Figure 2.1-2
Water Purveyors within the Groundwater Sustainability Agency Boundary

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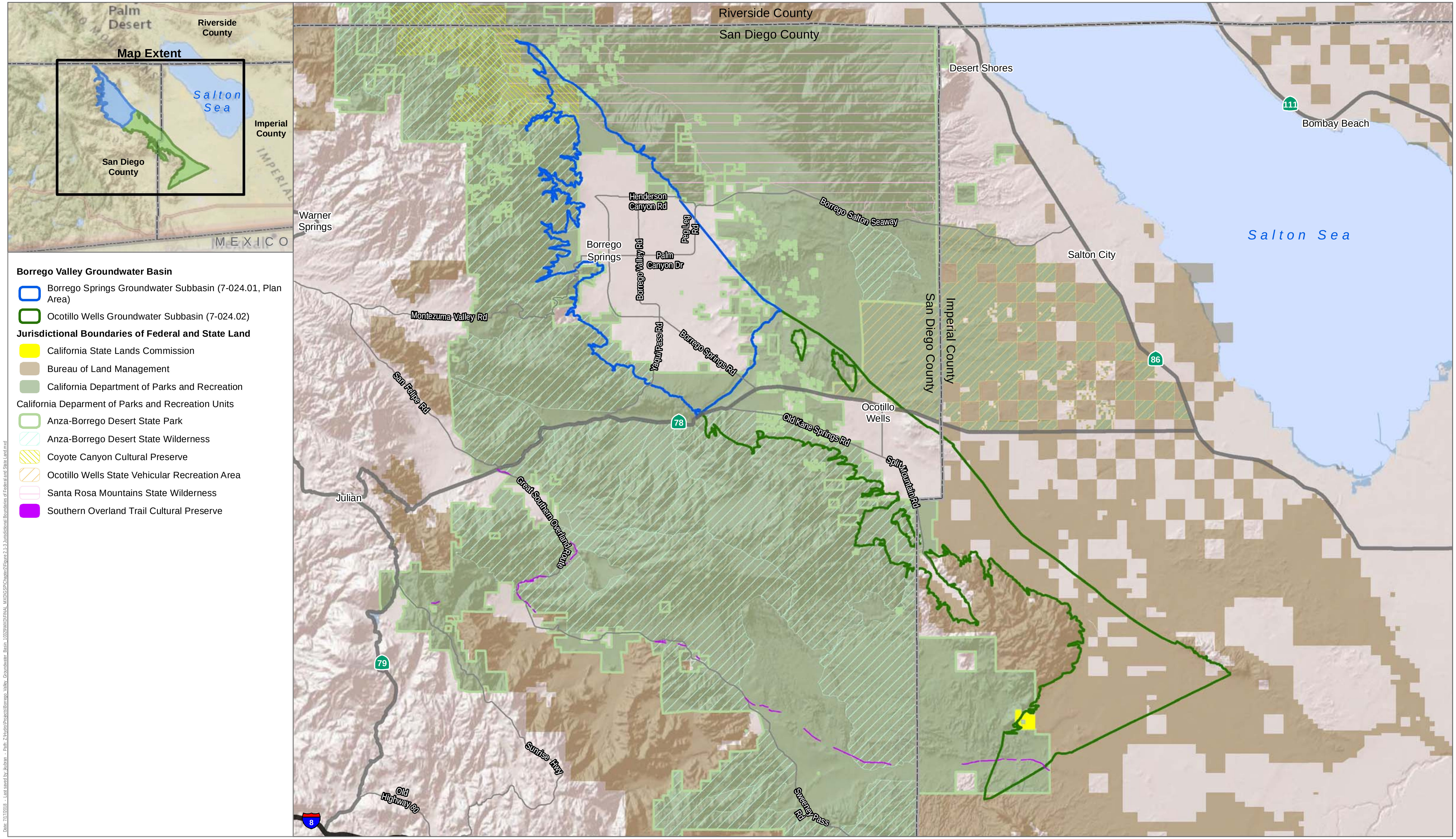

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Figure 2.1-3

Jurisdictional Boundaries of Federal and State Land

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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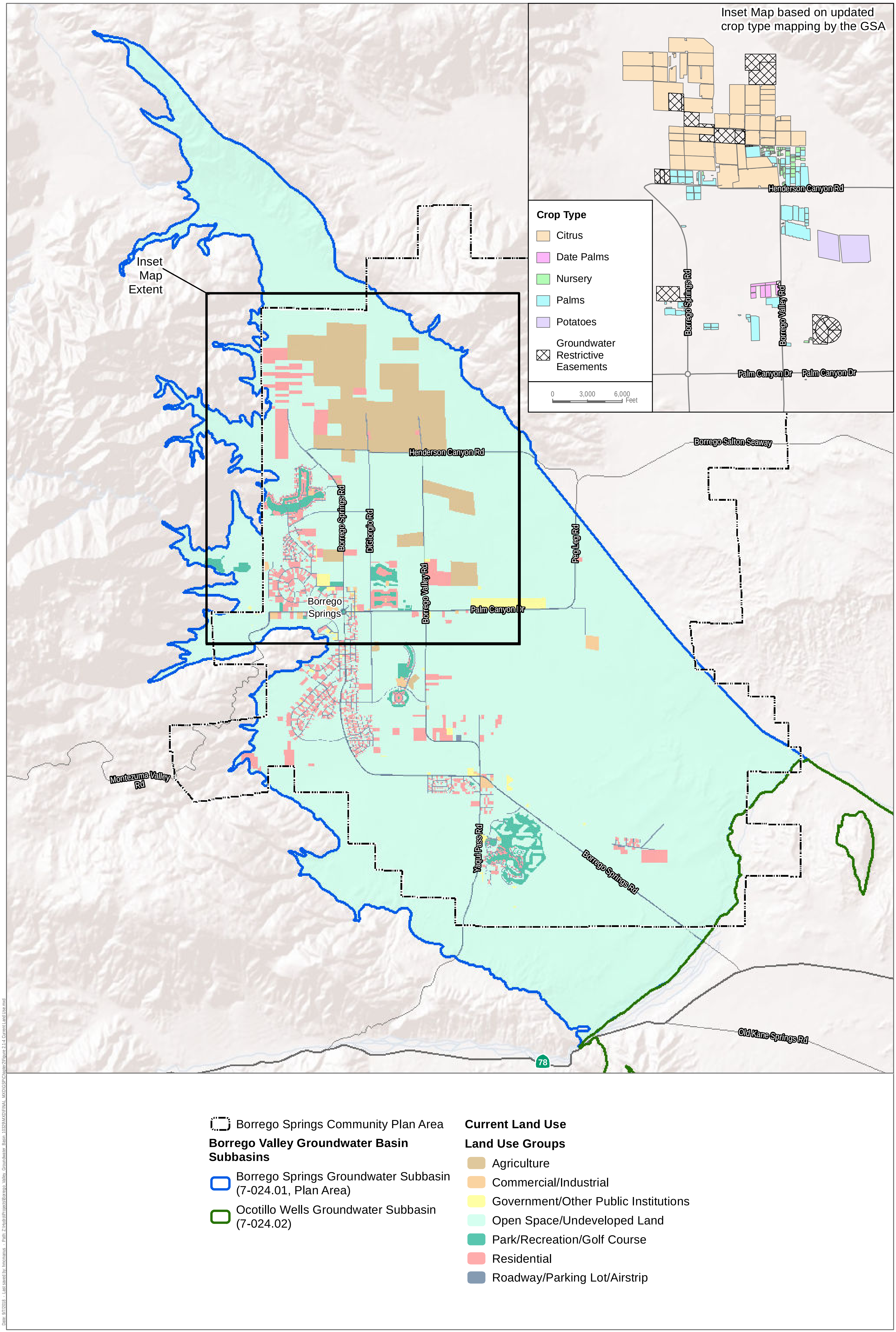

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DATUM: NAD 1983. DATA SOURCE: SanGIS 2017; Inset Map Source GSA 2018

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Figure 2.1-4
Current Land Use

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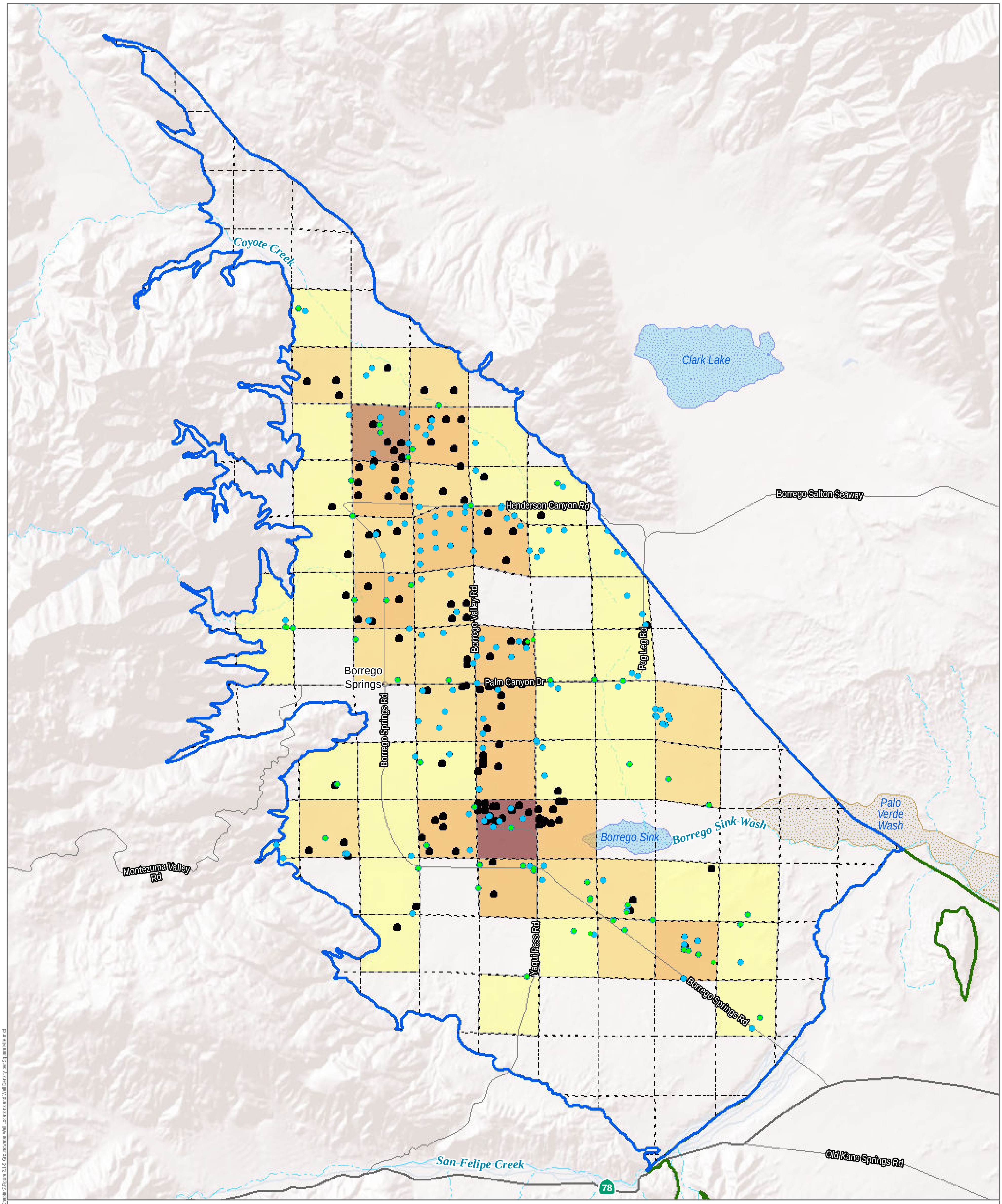

Borrego Valley Groundwater Basin Subbasins

- ▭ Borrego Springs Groundwater Subbasin (7-024.01, Plan Area)
- ▭ Ocotillo Wells Groundwater Subbasin (7-024.02)

Groundwater Well Locations

- ● Department of Water Resources Well Logs
- ● County of San Diego Well Permits
- ● Groundwater Sustainability Plan Wells

⬚ One Square Mile Sections

Well Density Per Square Mile

- 🟨 1 - 5
- 🟨 6 - 10
- 🟧 11 - 15
- 🟫 16 - 20
- 🟥 21 - 25

Surface Water Features

- ~ Major Flow Paths
- ▨ Dry Lake
- ▨ Wash

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DATUM: NAD 1983. DATA SOURCE: SanGIS 2017

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Figure 2.1-5

Groundwater Well Locations and Well Density per Square Mile

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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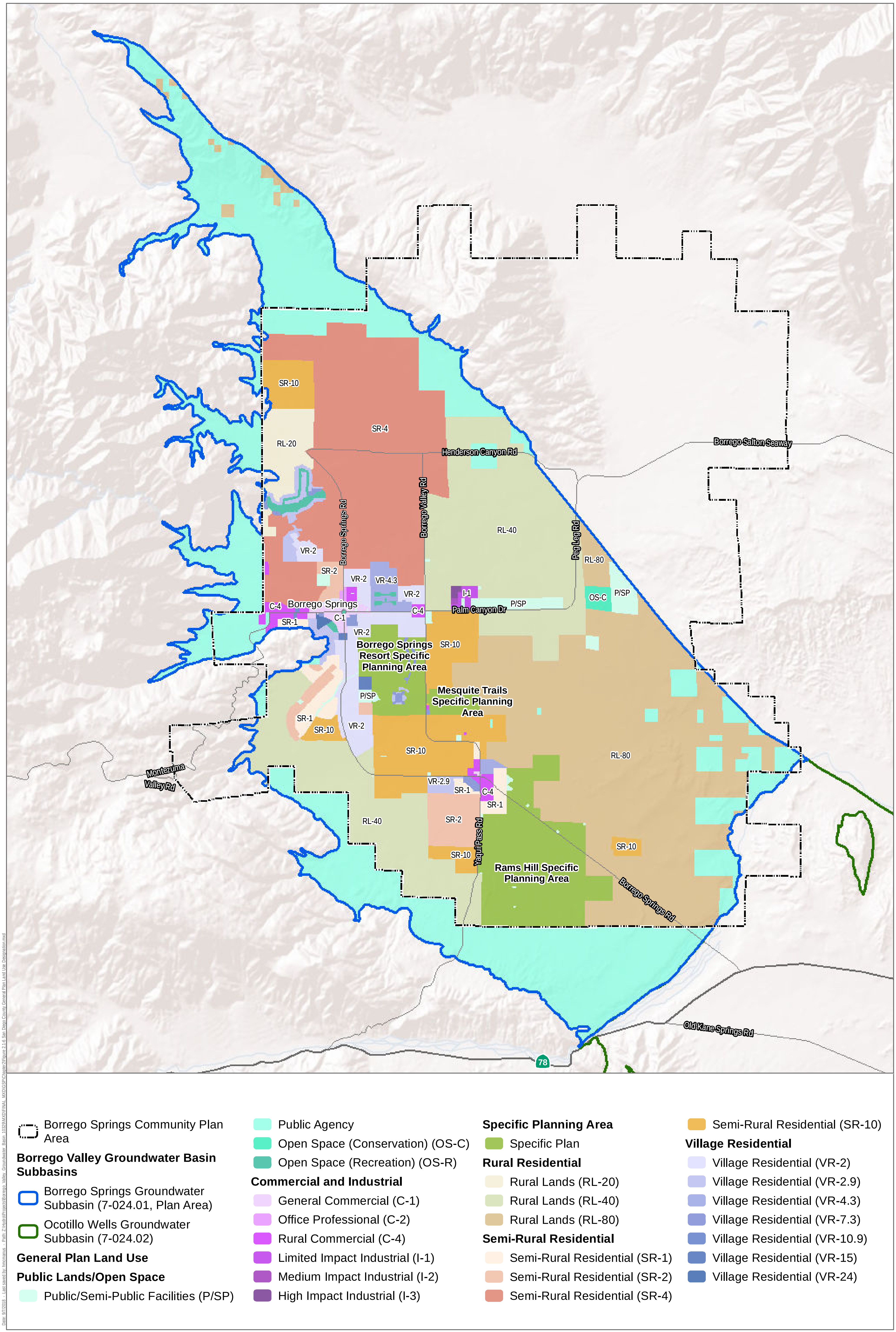

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Figure 2.1-6
San Diego County General Plan Land Use Designations

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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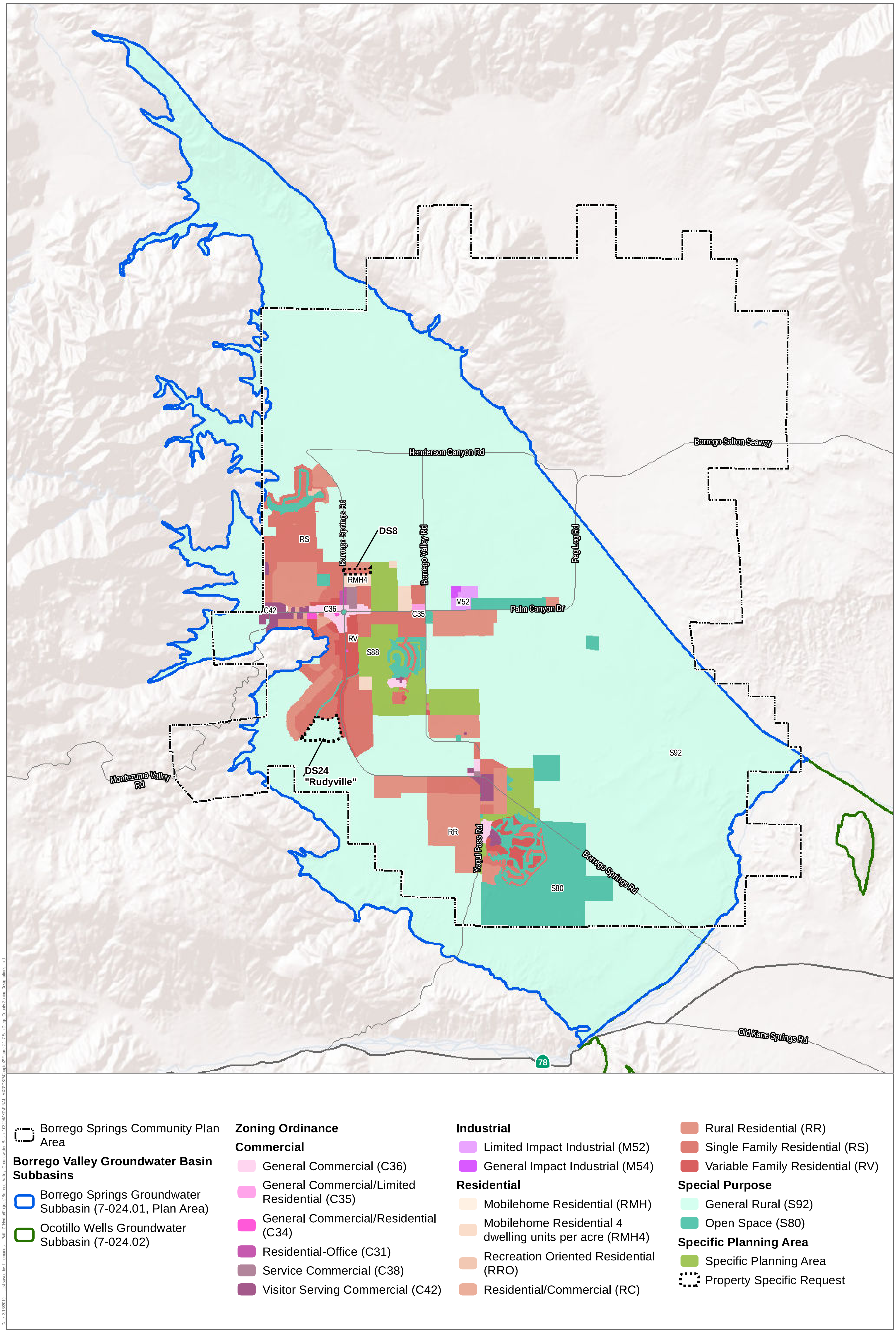

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Figure 2.1-7
San Diego County Zoning Designations

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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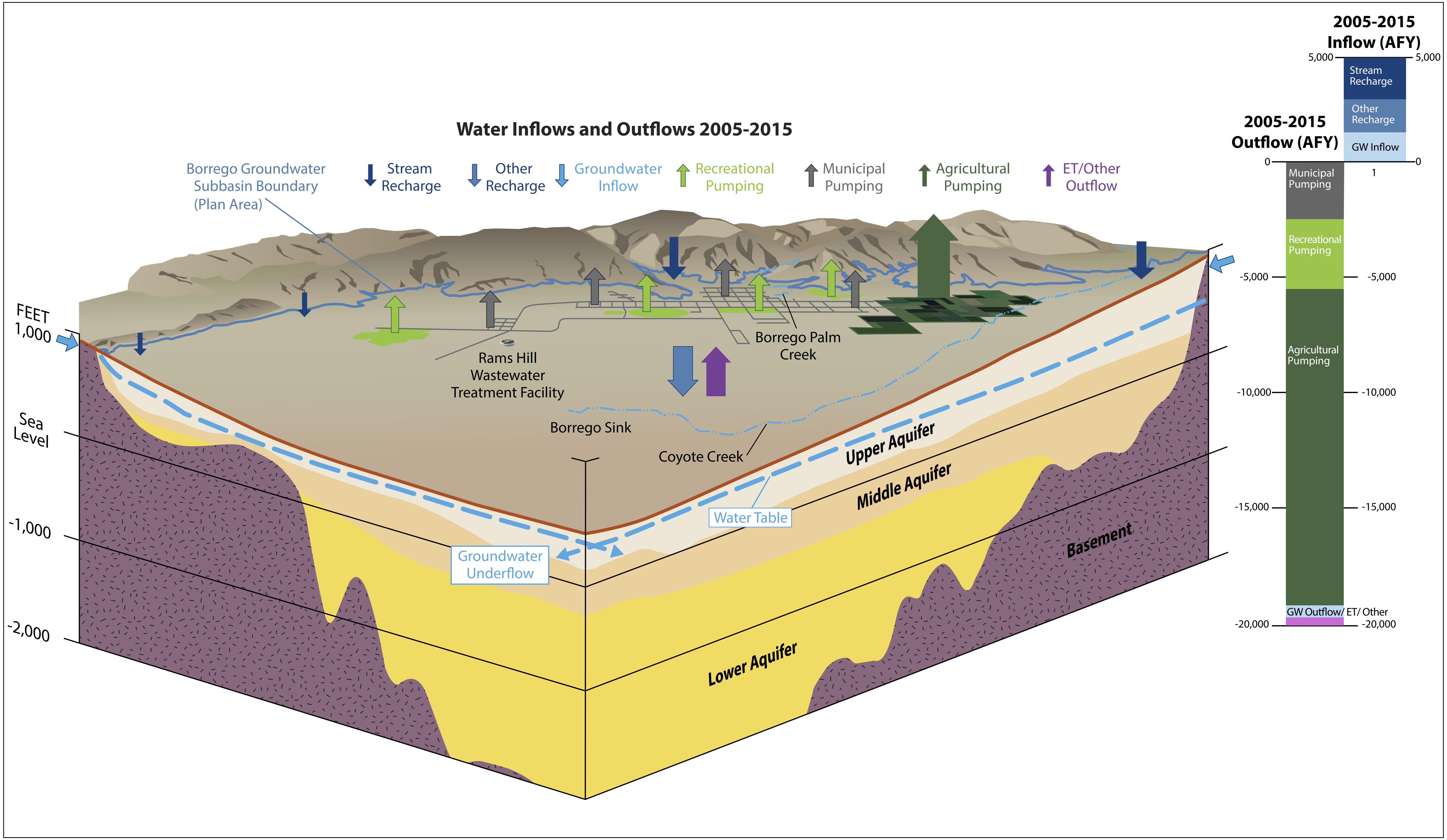

SOURCE: USGS 1982 and USGS 2015

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FIGURE 2.2-1

Hydrogeological Conceptual Model of the Plan Area

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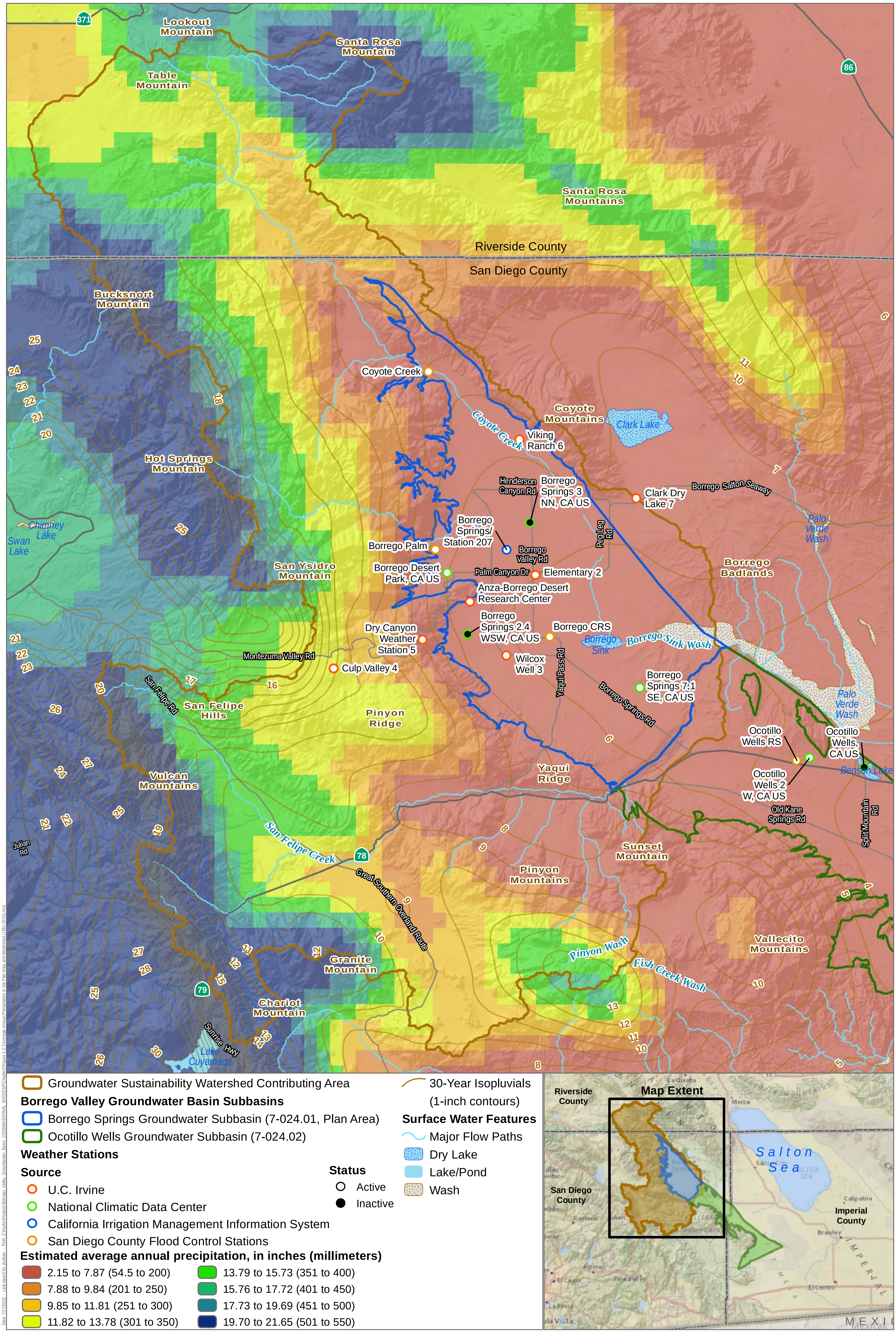

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DATUM: NAD 1983. DATA SOURCE: Flint and Others 2013

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Figure 2.2-2

Average Annual Precipitation in the Plan Area and Watershed (1981-2010)

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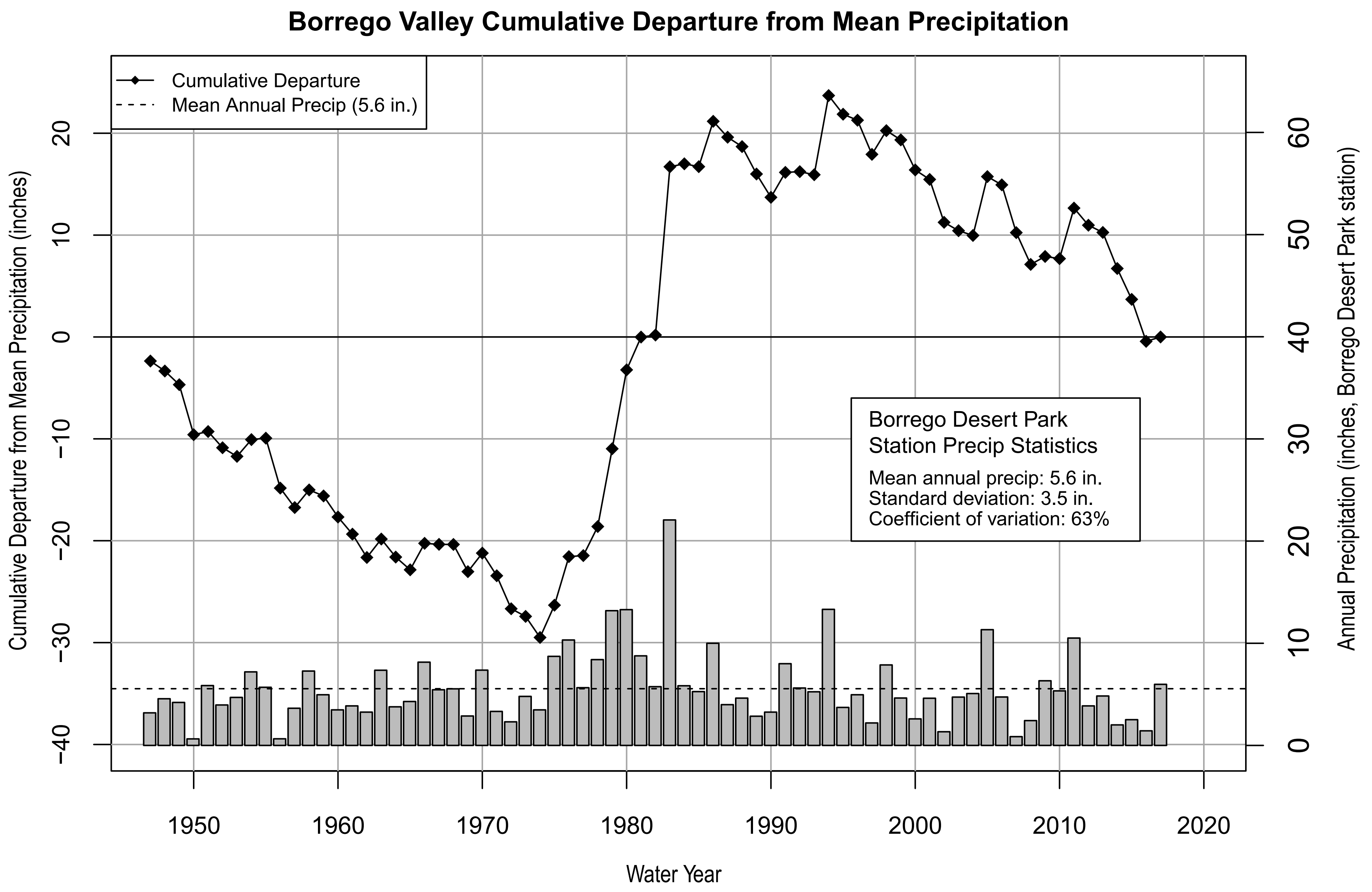

Path Z:\Hydro\Projects\Borrego_Valley_Groundwater_Basin_10329\PDF\FINAL_PDF\GSP\Chapter2\Graphics\Figure 2.2-3 Precipitation record

SOURCE: NOAA 2017

FIGURE 2.2-3

Precipitation Record for the Borrego Desert Park Station by Water Year (1947 - 2017)

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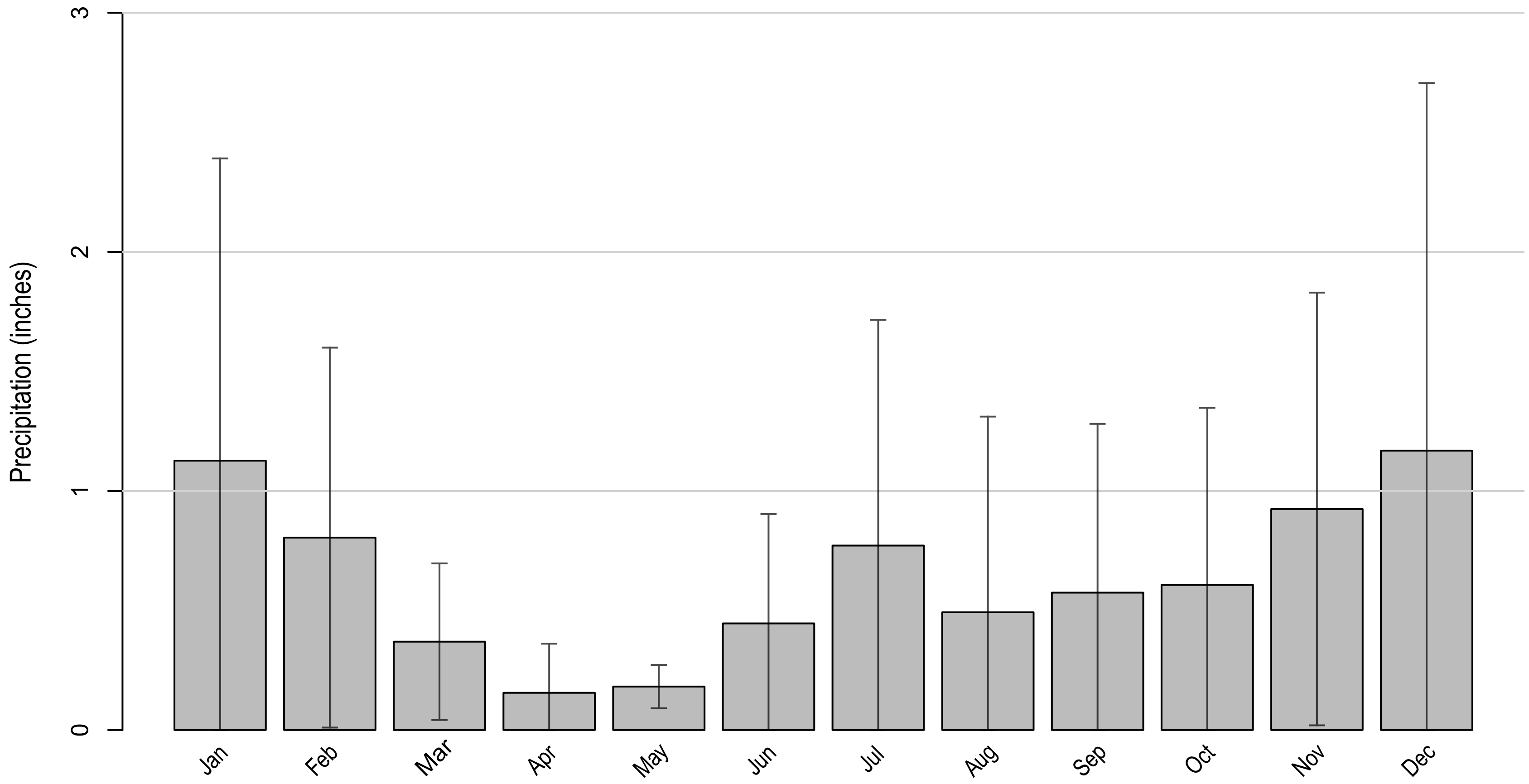
The standard deviation is based on the concept of a bell curve. One standard deviation give an estimate of the range of values around the average that occurs about 67% of the time. This means that 67% of the time, monthly precipitation will vary by one standard deviation from the long-term average.

The standard deviation provides a statistical estimate of precipitation variability. A larger standard deviation indicates a larger variability in precipitation from long-term average.



▨ Average Monthly Precipitation at Borrego Desert Park Station (1947 - 2017)

⌶ Tickmarks show one standard deviation above and below the mean monthly precipitation. Where a bottom tickmark is not shown, the standard deviation is greater than the mean for that month in the period of record.

FIGURE 2.2-4

Average Monthly Precipitation at Borrego Desert Park Station (1947 - 2017)

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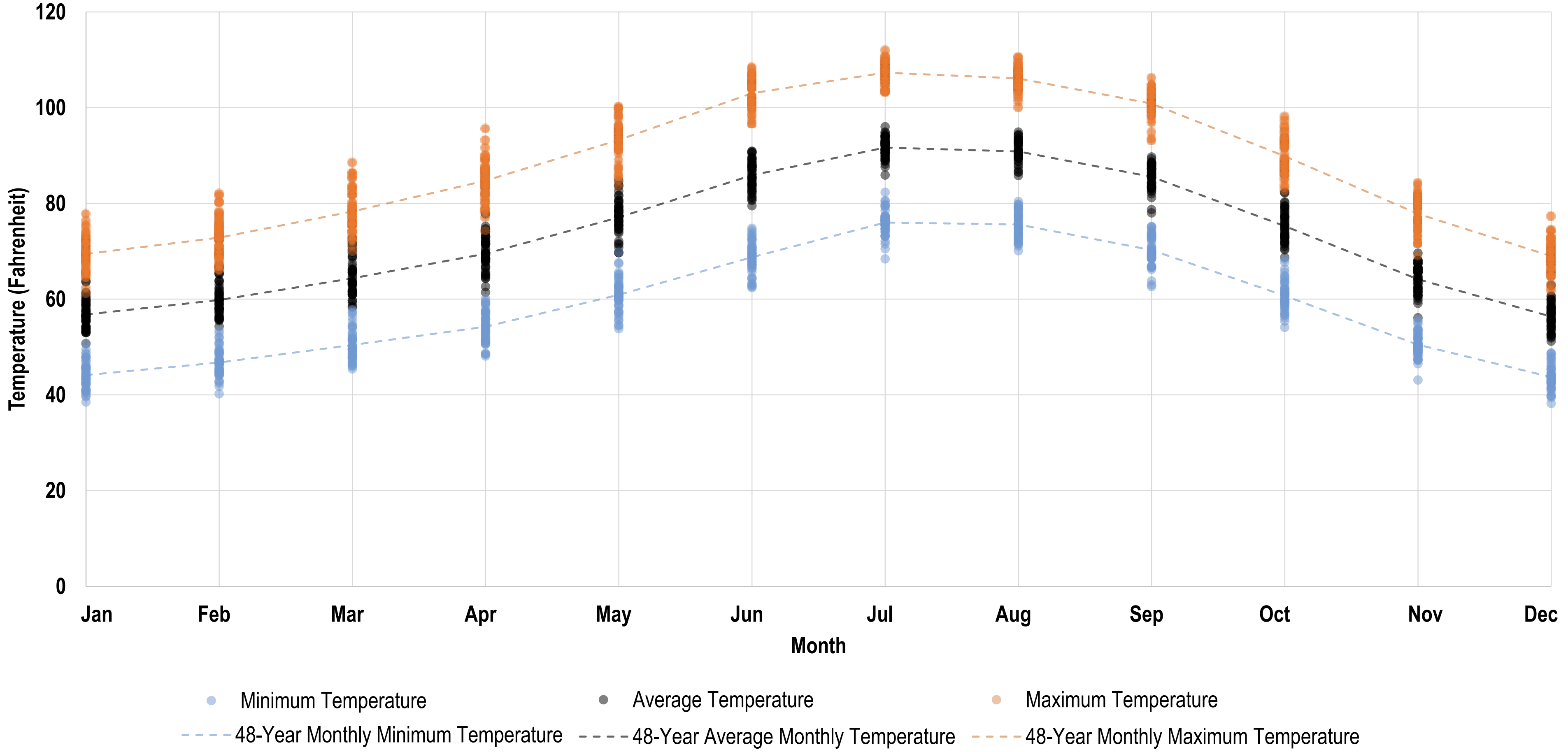

SOURCE: NOAA 2017

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FIGURE 2.2-5

Average Minimum and Maximum Air Temperatures at the Borrego Desert Park Station by Month (1968 - 2017)

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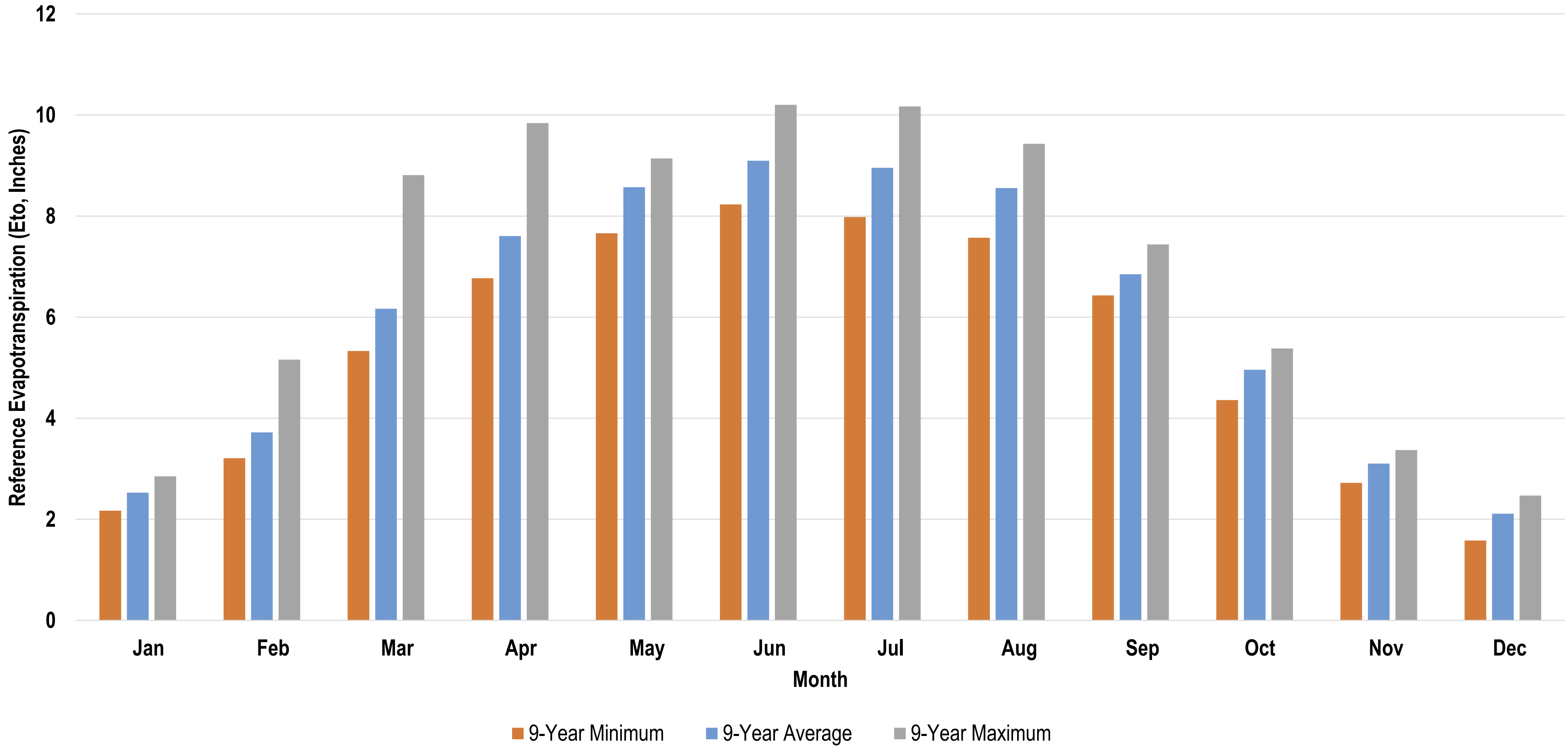
Annual 9-Year Minimum = 68.33 inches (5.69 feet) [2011]
Annual 9-Year Average = 72.21 inches (6.02 feet)
Annual 9-Year Maximum = 77.35 inches (6.45 feet) [2010]
Annual 9-Year Standard Deviation = 3.15 inches (0.26 feet)



Note: Data is from Borrego Springs CIMIS Station # 207 from available record 2008 - 2017. Monthly Eto from 2008 is excluded from the average as the record for that year is not complete.

SOURCE: CIMIS 2018

FIGURE 2.2-6

Average Minimum and Maximum Evapotranspiration at CIMIS Station 207 by Month (2009 - 2017)

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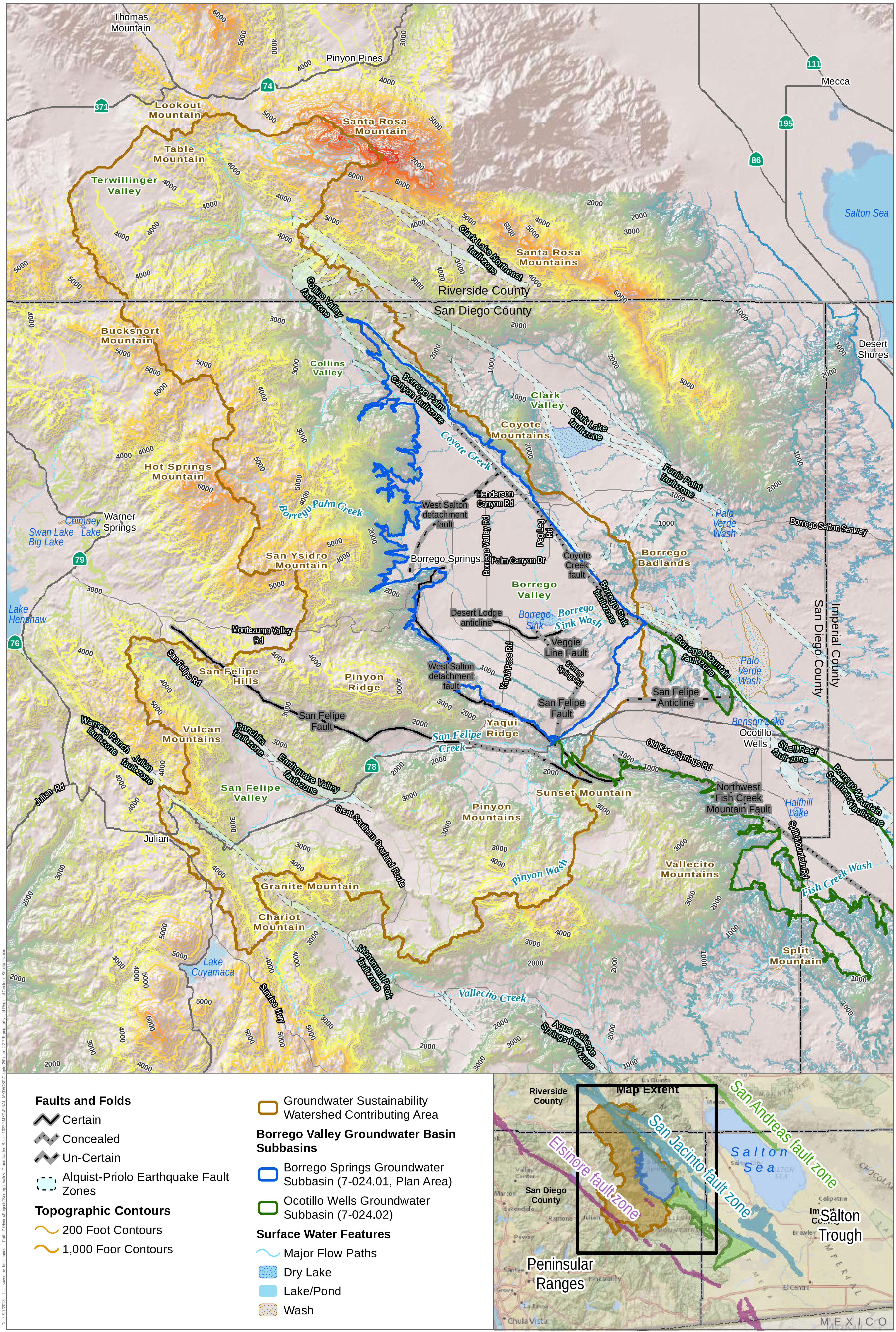

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DATUM: NAD 1983. DATA SOURCE: DWR 2015; USGS NHD 2017; USGS 2015; Steely et. al 2009; CGS 2012

DUDEK

0 1.75 3.5 Miles

Figure 2.2-7

Topography and Regional Geologic Structures

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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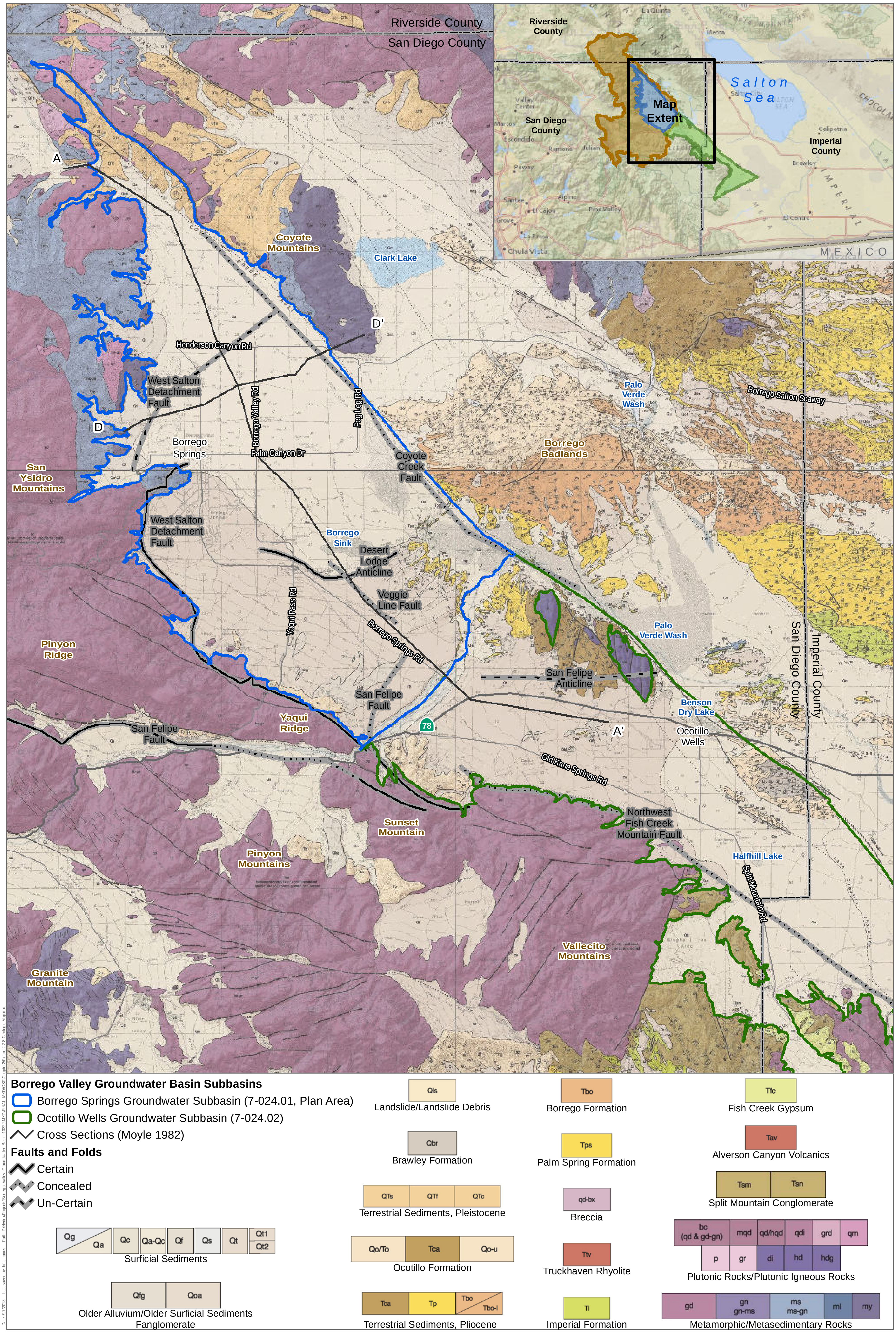

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DATUM: NAD 1983. DATA SOURCE: Dibblee 2008; USGS 2015; Steely et. al 2009; CGS 2012

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Figure 2.2-8
Geologic Map

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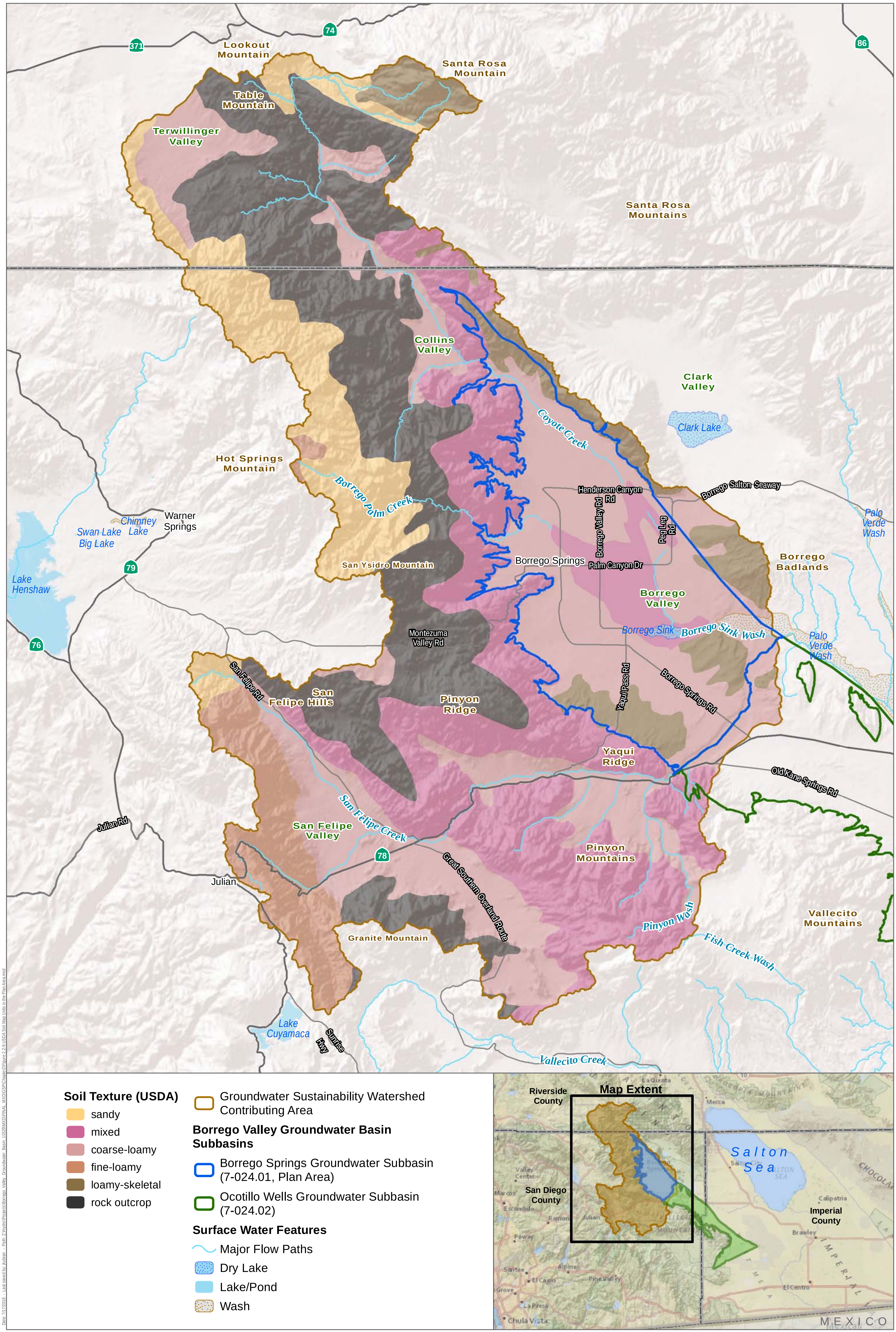

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DATUM: NAD 1983. DATASOURCE: DWR 2015; SanGIS 2014; USGS NHD 2017; USDASTATSGO 2

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0 1.5 3 Miles

Figure 2.2-9

USDA Soil Map Units in the Plan Area

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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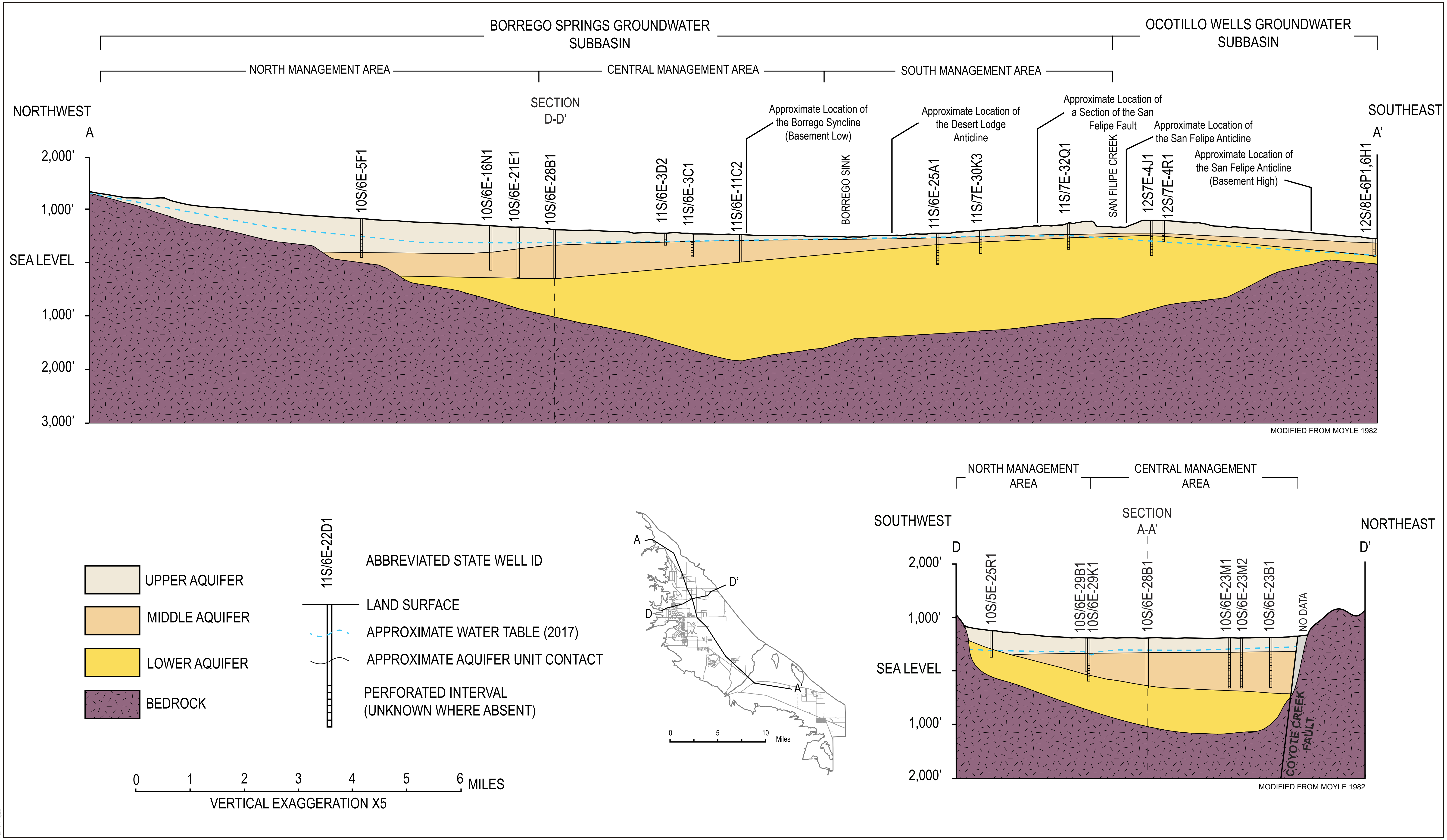

SOURCE: USGS 1982, 2015

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FIGURE 2.2-10

Hydrogeologic Cross Sections of the Plan Area

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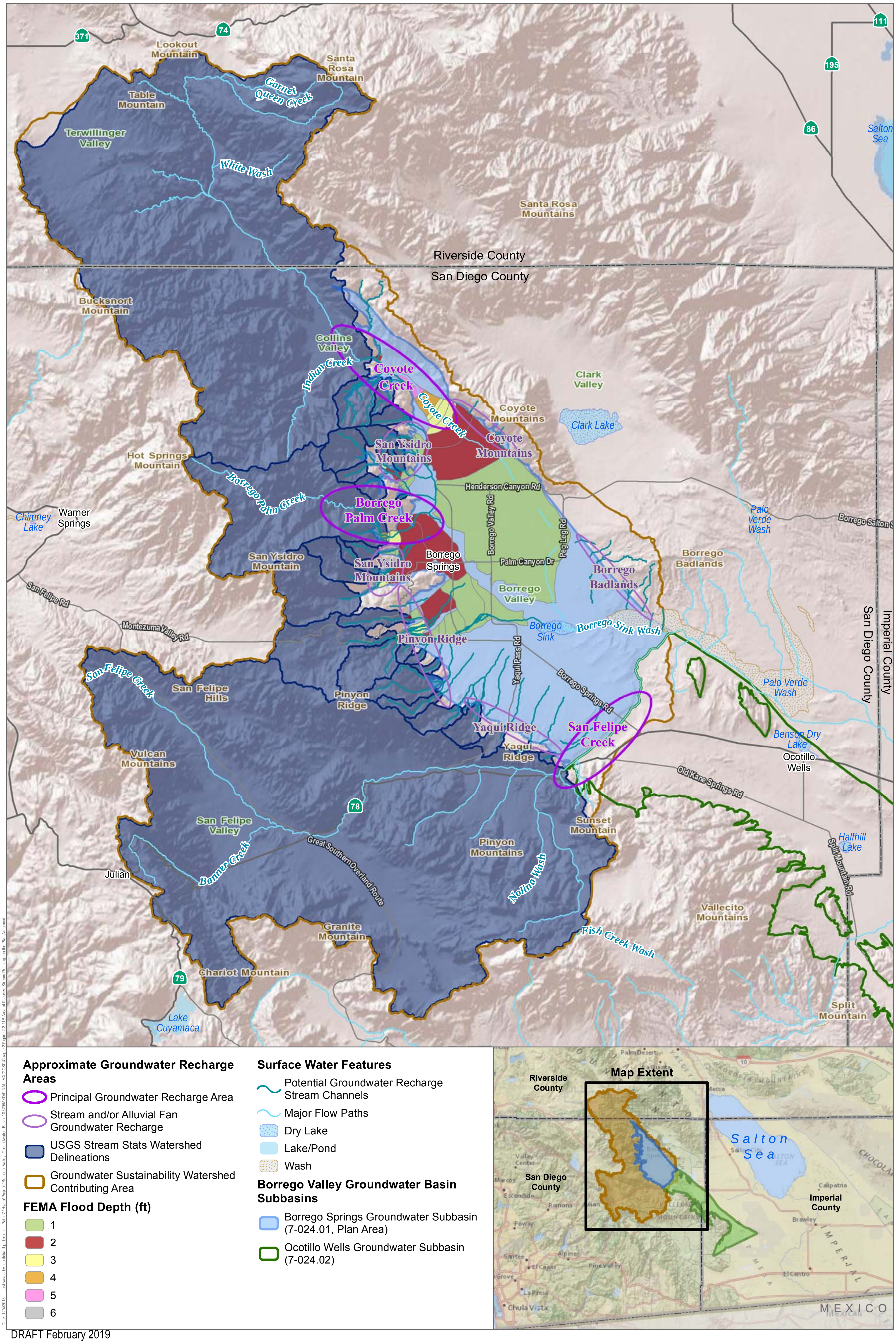

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DATUM: NAD 1983. DATA SOURCE: DWR 2015; USGS NHD 2017; USGS 2018; FEMA 2017

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0 1.5 3 Miles

Figure 2.2-11

Areas of Focused Stream Recharge in the Plan Area

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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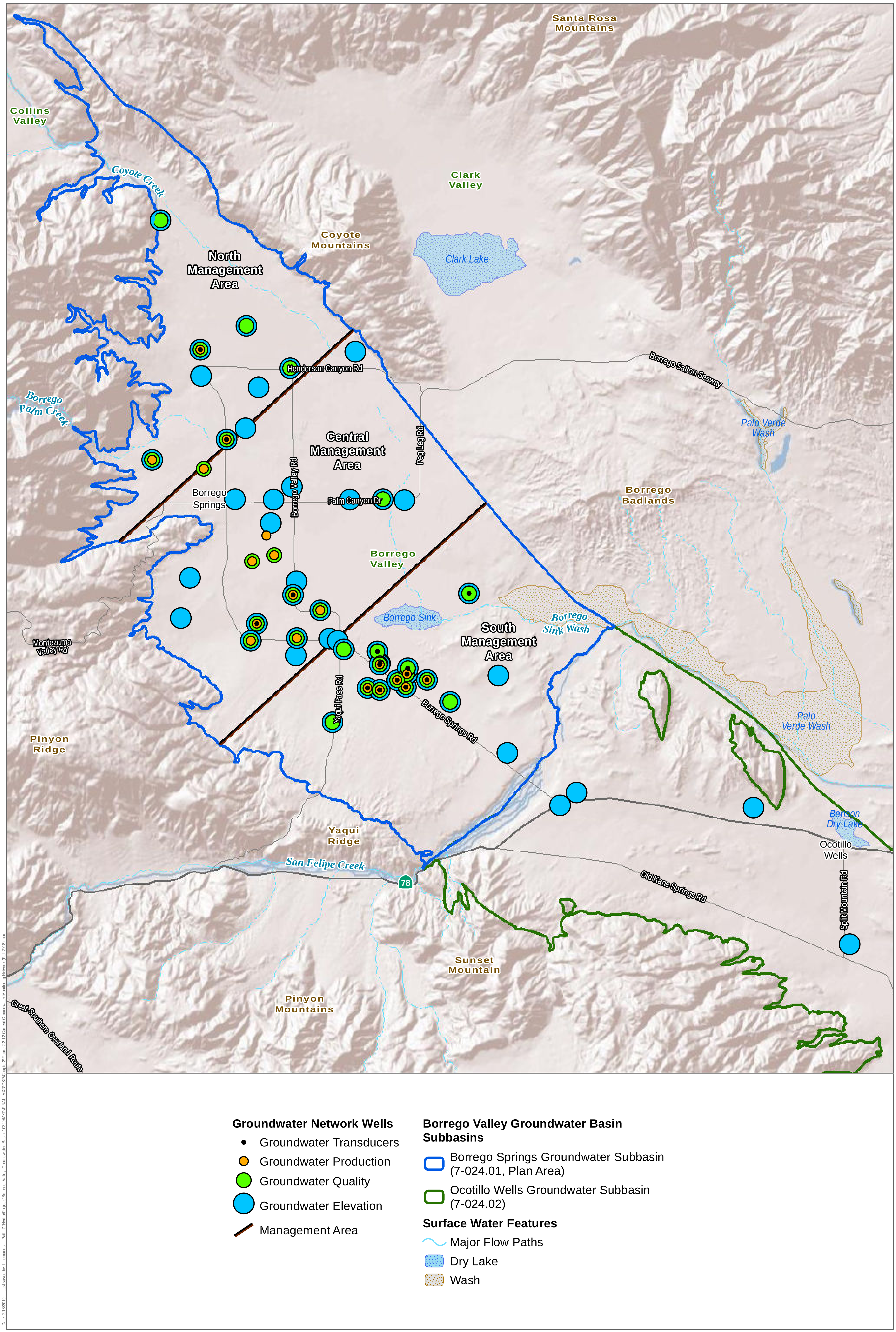

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DATUM: NAD 1983.

DUDEK

0 0.75 1.5 Miles

Figure 2.2-12
Current Groundwater Monitoring Network (Fall 2018)

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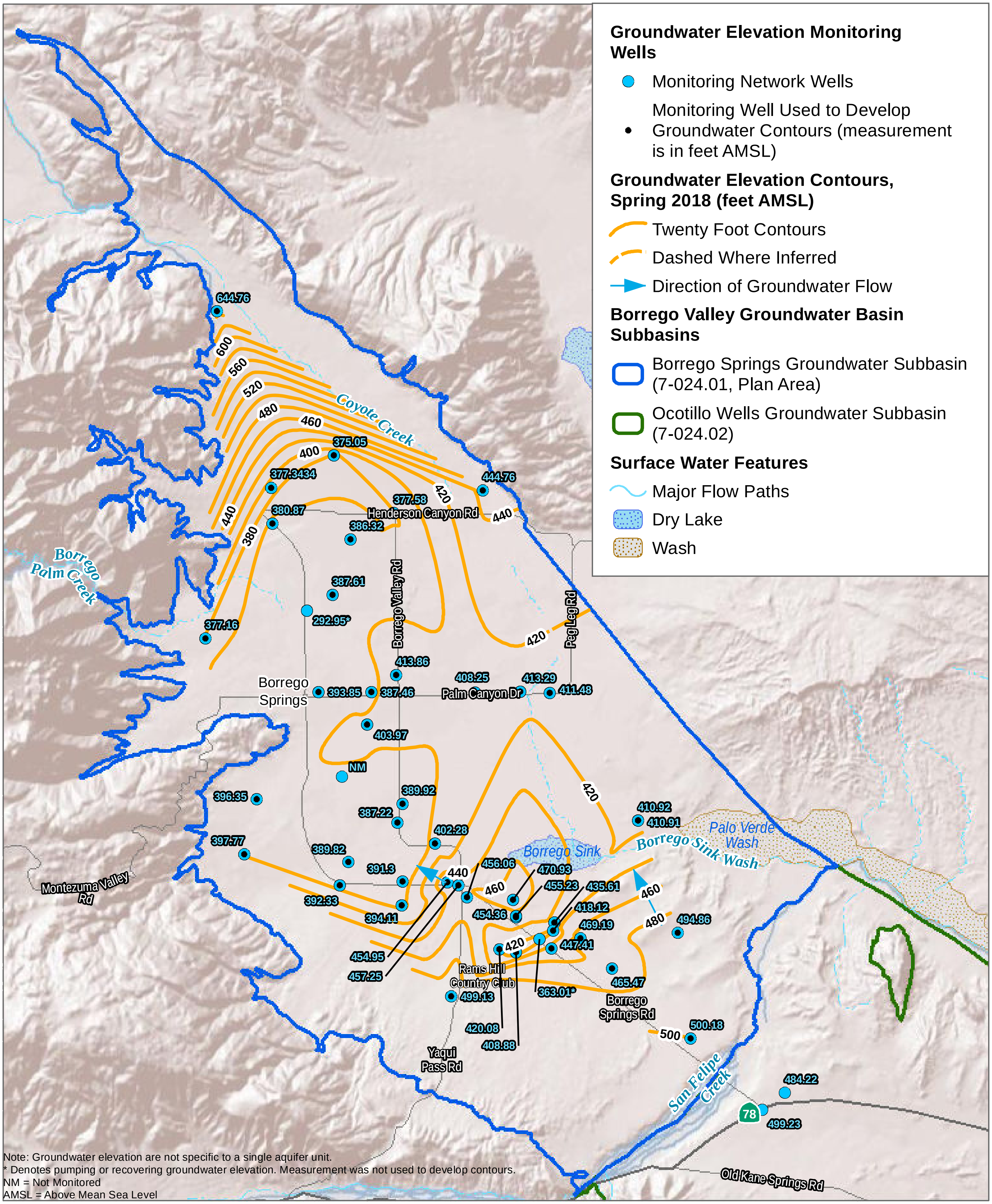

Note: Groundwater elevation are not specific to a single aquifer unit.
* Denotes pumping or recovering groundwater elevation. Measurement was not used to develop contours.
NM = Not Monitored
AMSL = Above Mean Sea Level

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: Dudek 2018

DUDEK

0 1 2 Miles

Figure 2.2-13A
Current Groundwater Levels in the Plan Area (Spring 2018)

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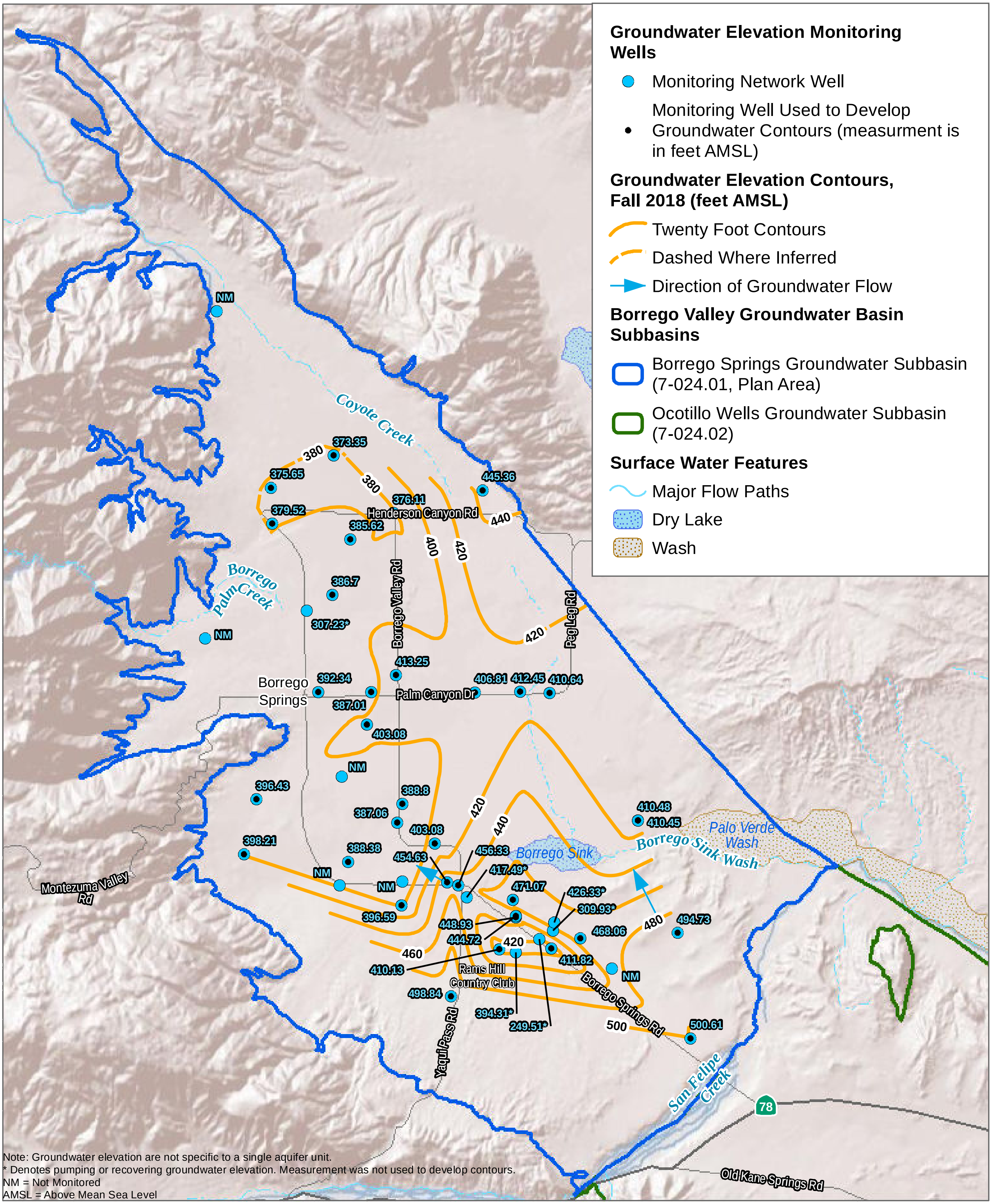

Note: Groundwater elevation are not specific to a single aquifer unit.
* Denotes pumping or recovering groundwater elevation. Measurement was not used to develop contours.
NM = Not Monitored
AMSL = Above Mean Sea Level

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: Dudek 2018

DUDEK

0 1 2 Miles

Figure 2.2-13B
Current Groundwater Levels in the Plan Area (Fall 2018)

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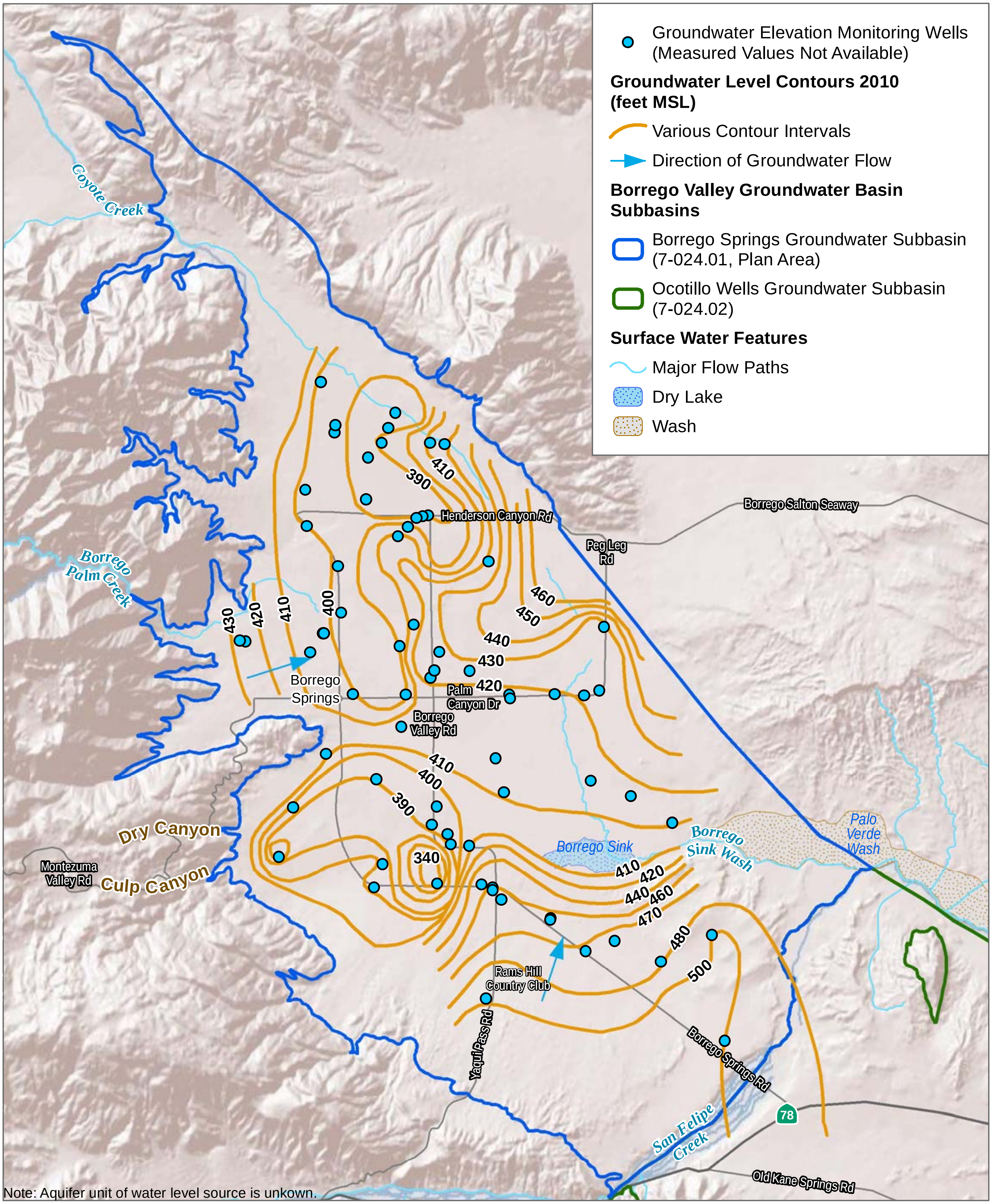

Note: Aquifer unit of water level source is unkown.

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: USGS 2015

DUDEK

0 1 2 Miles

Figure 2.2-13C
Historical Groundwater Levels in the Plan Area (2010)

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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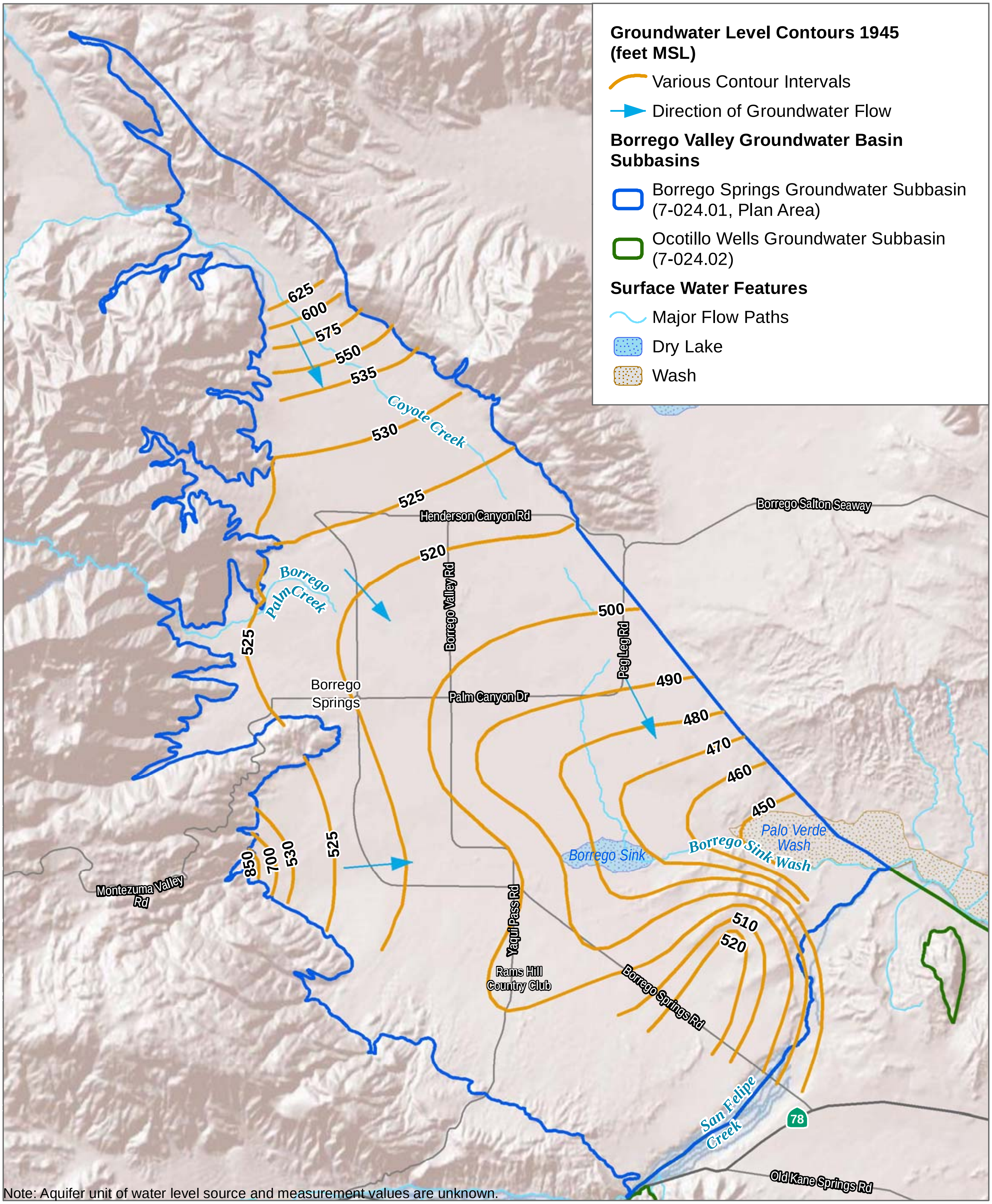

Note: Aquifer unit of water level source and measurement values are unknown.

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: USGS 2015

DUDEK

0 1 2 Miles

Figure 2.2-13D

Historical Groundwater Levels in the Plan Area (1945)

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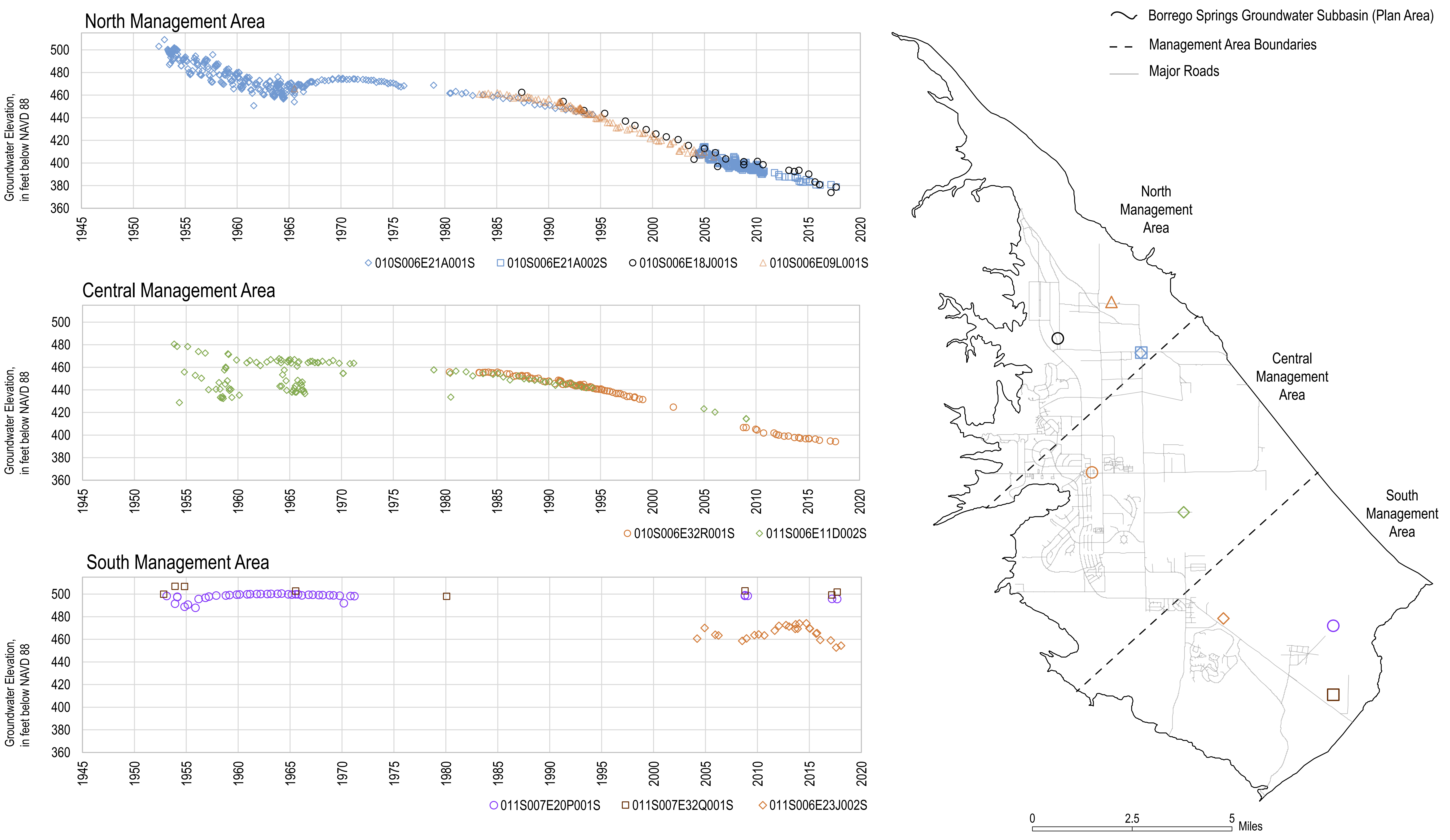

SOURCE: USGS 2015

DUDEK

FIGURE 2.2-13E

Groundwater Levels in Selected Wells in Parts of the Plan Area, 1952 - 2018

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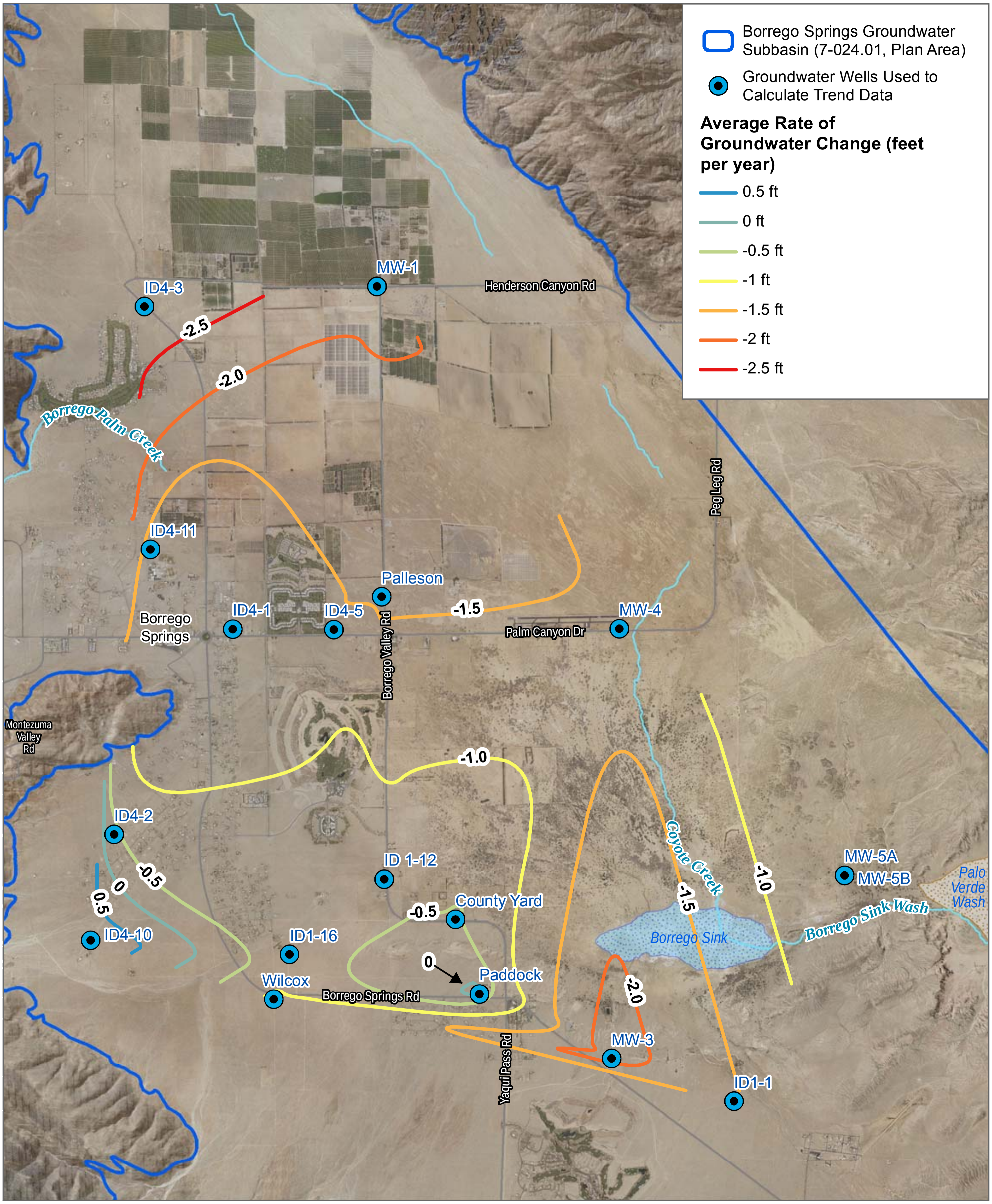

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: Dudek 2018

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Figure 2.2-13F
Contour Map of Average Rate of Groundwater Change (2010-2018)

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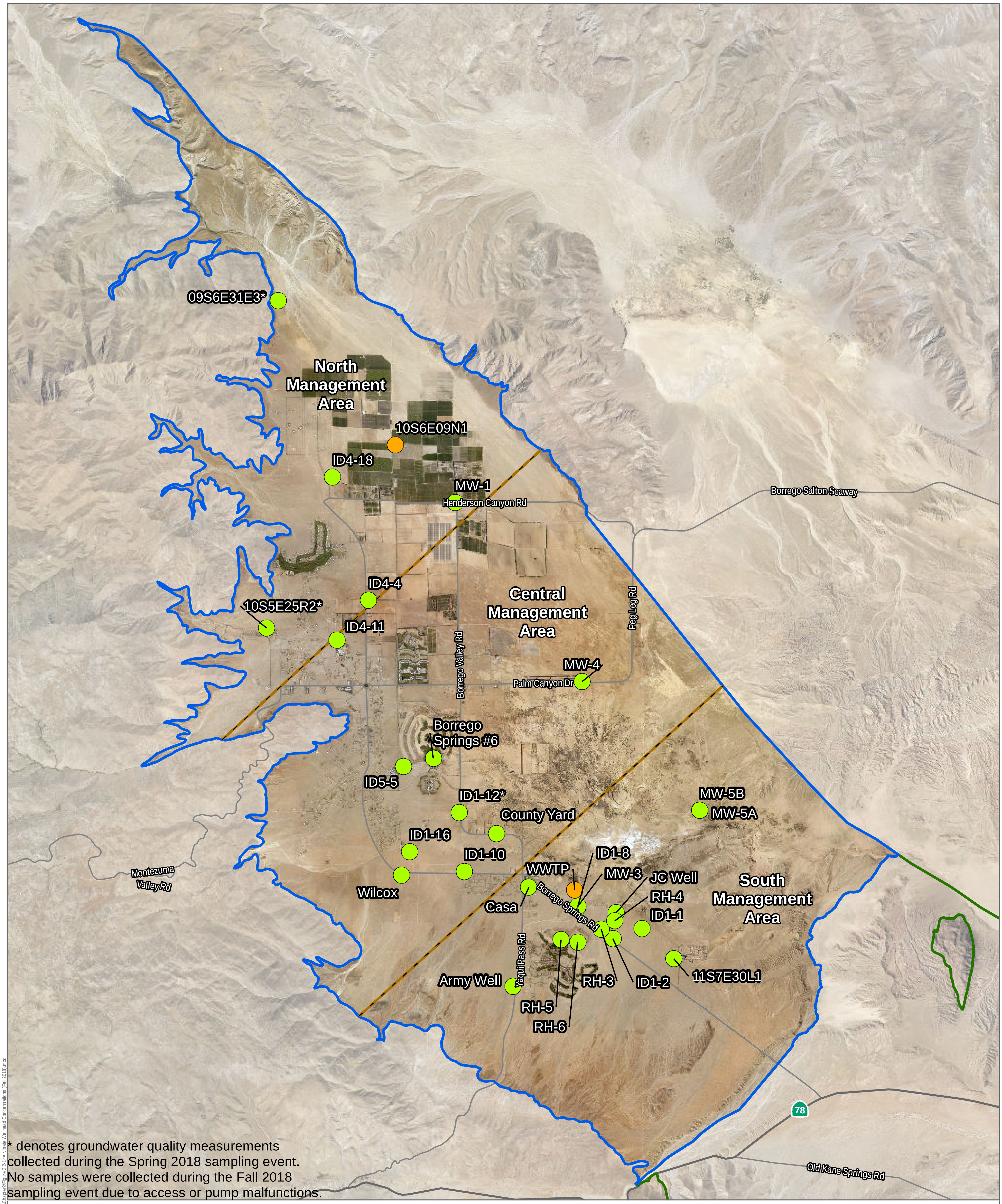

* denotes groundwater quality measurements collected during the Spring 2018 sampling event. No samples were collected during the Fall 2018 sampling event due to access or pump malfunctions.

Nitrate as Nitrogen (N) Wellhead Concentrations (Fall 2018)

- ● Less than 1/2 the MCL (5 mg/L)
- ● Greater than the MCL (10 mg/L)

Borrego Valley Groundwater Basin Subbasins

- ▭ Borrego Springs Groundwater Subbasin (7-024.01, Plan
- ▭ Ocotillo Wells Groundwater Subbasin (7-024.02)
- ⟋ Management Area Divisions

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: Dudek & Geosyntec 2018

DUDEK

0 0.75 1.5 Miles

Figure 2.2-14A

Nitrate Wellhead Concentrations

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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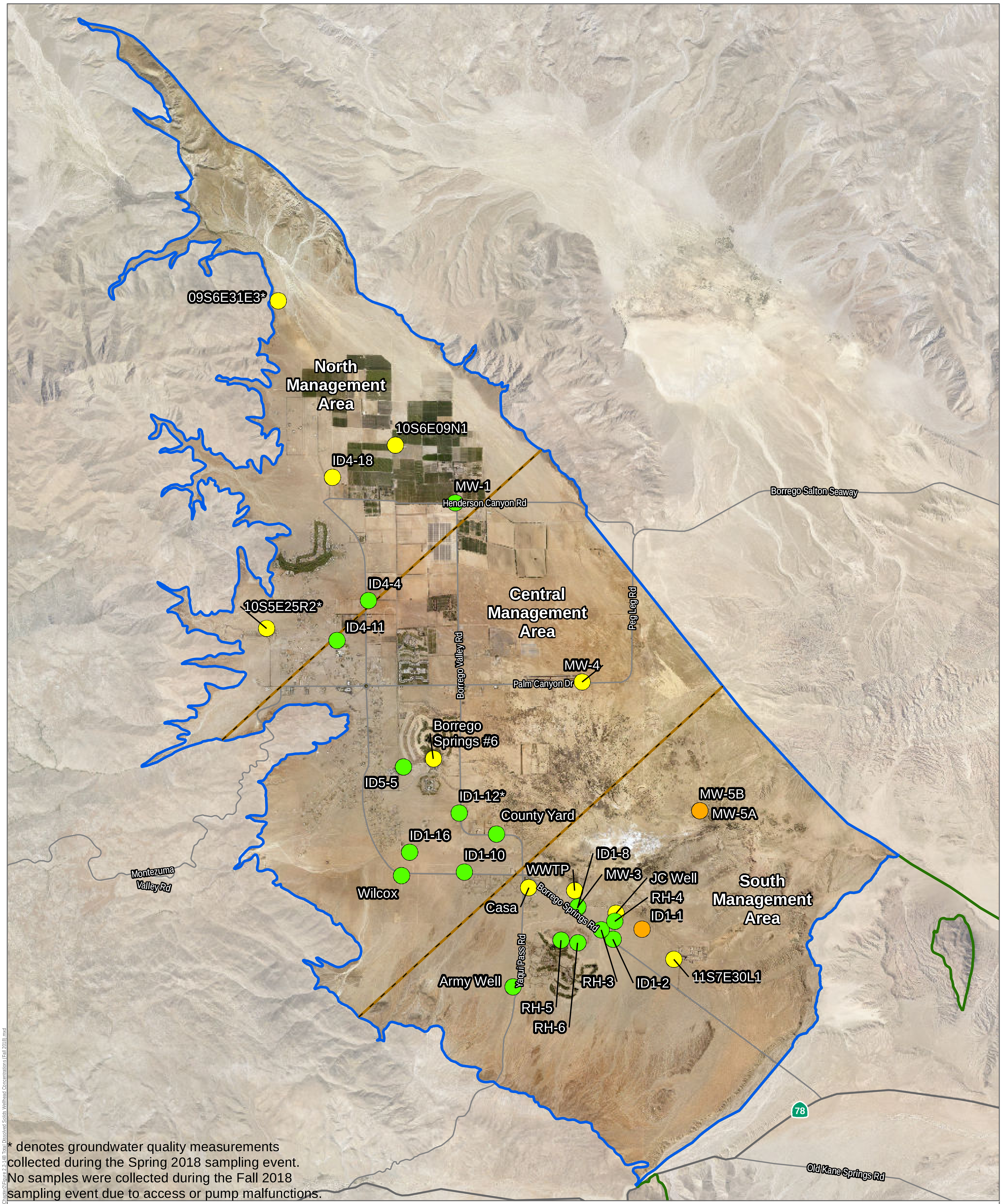

* denotes groundwater quality measurements collected during the Spring 2018 sampling event. No samples were collected during the Fall 2018 sampling event due to access or pump malfunctions.

Total Dissolved Solids (TDS) Wellhead Concentrations (Fall 2018)

- 🟢 Less than 1/2 the secondary MCL (500 mg/L)
- 🟡 Less than the secondary MCL (1,000 mg/L)
- 🟠 Greater than the secondary MCL (1,000 mg/L)

Borrego Valley Groundwater Basin Subbasins

- ▭ Borrego Springs Groundwater Subbasin (7-024.01, Plan Area)
- ▭ Ocotillo Wells Groundwater Subbasin (7-024.02)
- ⁄ Management Area Divisions

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: Dudek & Geosyntec 2018

DUDEK

0 0.75 1.5 Miles

Figure 2.2-14B
Total Dissolved Solids Wellhead Concentrations

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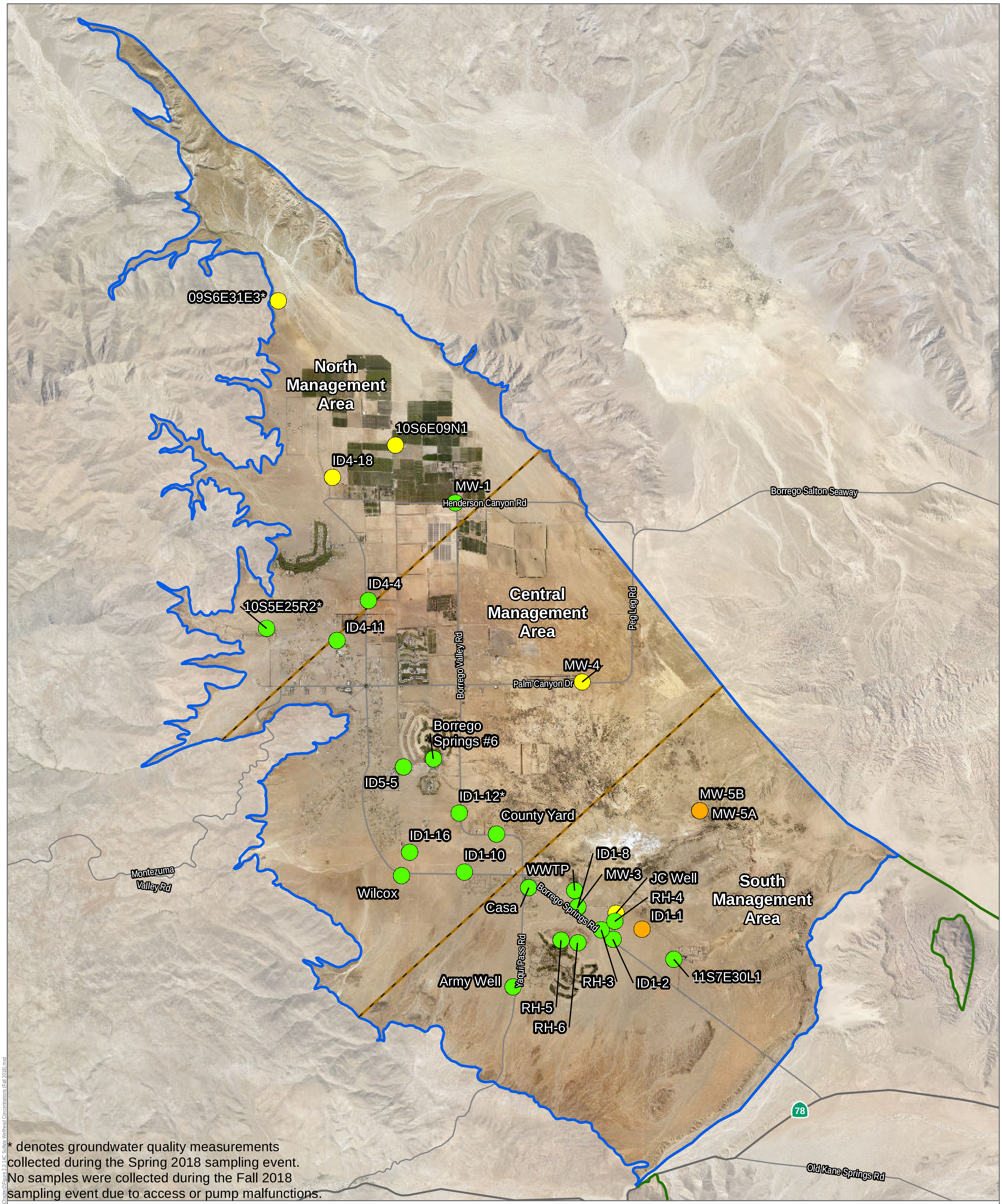

* denotes groundwater quality measurements collected during the Spring 2018 sampling event. No samples were collected during the Fall 2018 sampling event due to access or pump malfunctions.

Sulfate Wellhead Concentration (Fall 2018)
- 🟢 Less than 1/2 the Secondary MCL (250 mg/L)
- 🟡 Less than the Secondary MCL (500 mg/L)
- 🟠 Greater than the Secondary MCL (500 mg/L)

Borrego Valley Groundwater Basin Subbasins
- ▭ Borrego Springs Groundwater Subbasin (7-024.01, Plan
- ▭ Ocotillo Wells Groundwater Subbasin (7-024.02)
- ╱ Management Area Divisions

Date: 2/20/2019 - Last saved by: hmcmanus - Path: Z:\Hydro\Projects\Borrego Valley Groundwater Basin 10329\MXD\FINAL MXD\GSP\Chapter2\Figure 2.2-14C Sulfate Wellhead Concentrations (Fall 2018).mxd

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: Dudek & Geosyntec 2018

DUDEK

0 0.75 1.5 Miles

Figure 2.2-14C

Sulfate Wellhead Concentrations

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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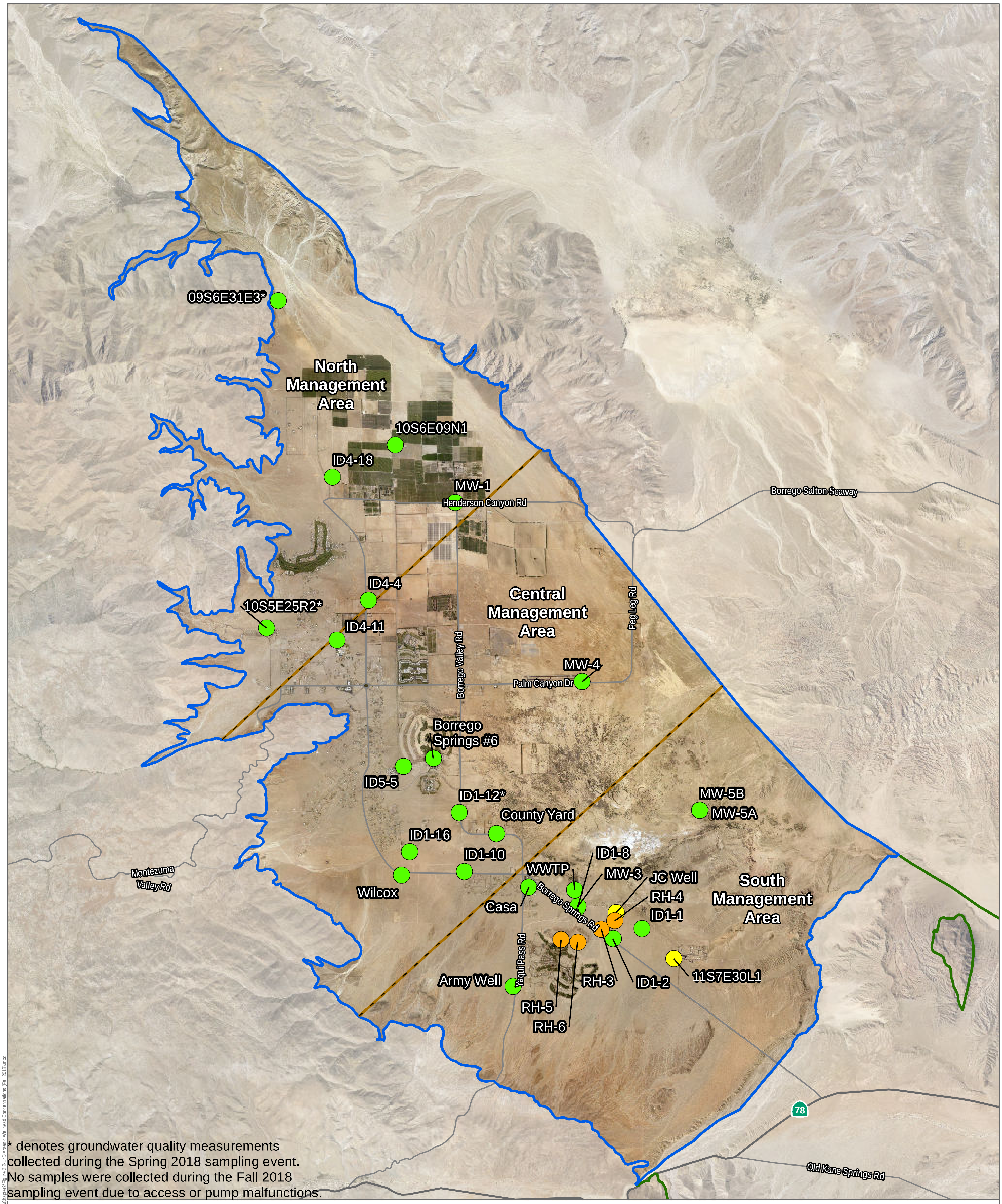

* denotes groundwater quality measurements collected during the Spring 2018 sampling event. No samples were collected during the Fall 2018 sampling event due to access or pump malfunctions.

Arsenic Wellhead Concentration (Fall 2018)

- 🟢 Less than 1/2 the MCL (5 ug/L)
- 🟡 Less than the MCL (10 ug/L)
- 🟠 Greater than the MCL (10 ug/L)

Borrego Valley Groundwater Basin Subbasins

- 🟦 Borrego Springs Groundwater Subbasin (7-024.01, Plan Area)
- 🟩 Ocotillo Wells Groundwater Subbasin (7-024.02)
- ╱ Management Area Divisions

Date: 2/20/2019 - Last saved by: hmcmanus - Path: Z:\Hydro\Projects\Borrego Valley Groundwater Basin 10329\MXD\FINAL MXD\GSP\Chapter2\Figure 2.2-14D Arsenic Wellhead Concentrations (Fall 2018).mxd

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: Dudek & Geosyntec 2018

DUDEK

N

0 0.75 1.5 Miles

Figure 2.2-14D

Arsenic Wellhead Concentrations

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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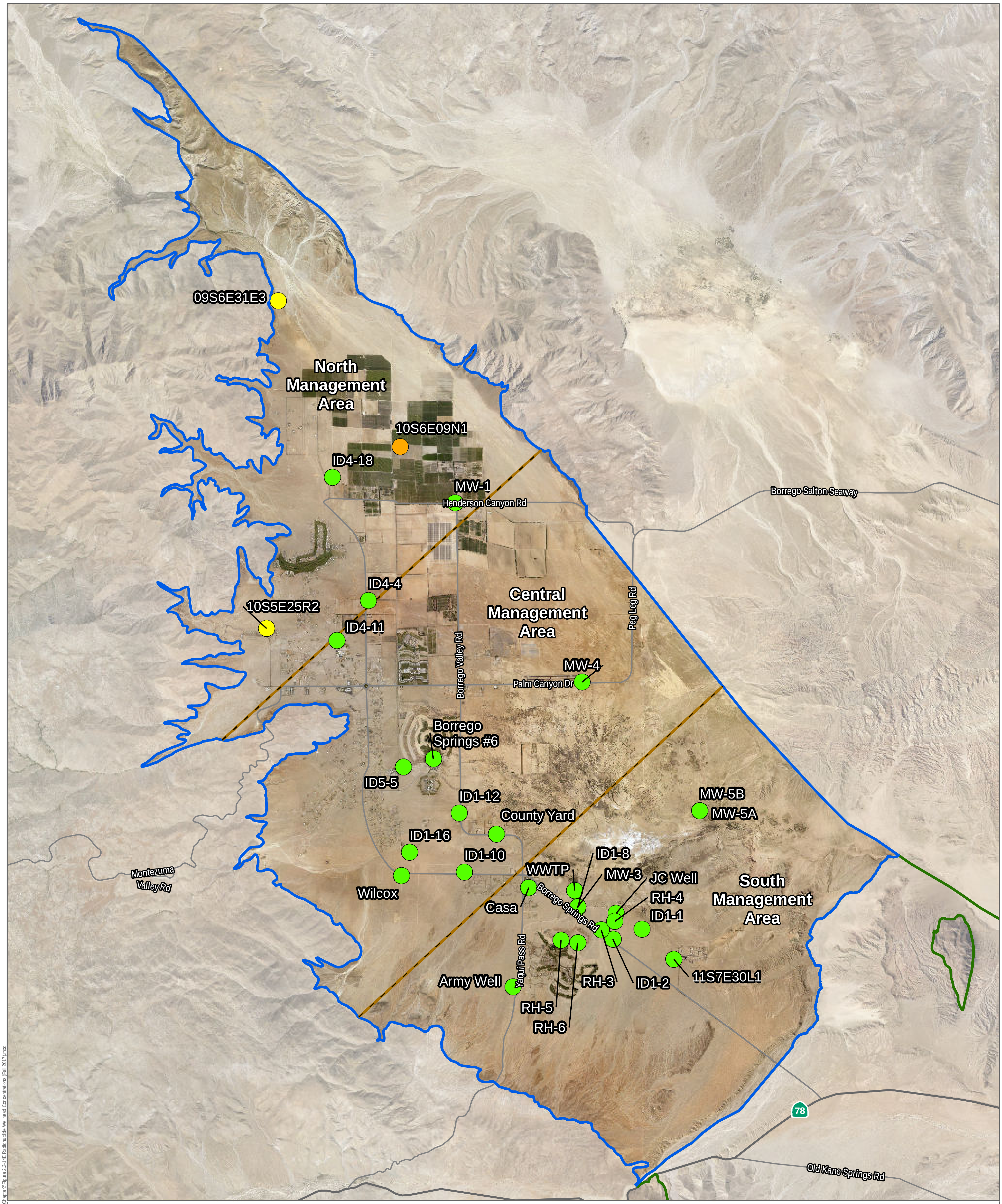

Radionuclide Well Head Concentration (Fall 2017)

Gross Alpa

- 🟢 Less than 1/2 the MCL (7.5 pCi/L)
- 🟡 Less than the MCL (15 pCi/L)
- 🟠 Greater than the MCL (15 pCi/L)

Borrego Valley Groundwater Basin Subbasins

- ▭ Borrego Springs Groundwater Subbasin (7-024.01, Plan
- ▭ Ocotillo Wells Groundwater Subbasin (7-024.02)
- ╱ Management Area Divisions

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: Dudek & Geosyntec 2017

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0 0.75 1.5 Miles

Figure 2.2-14E
Radionuclide Wellhead Concentrations

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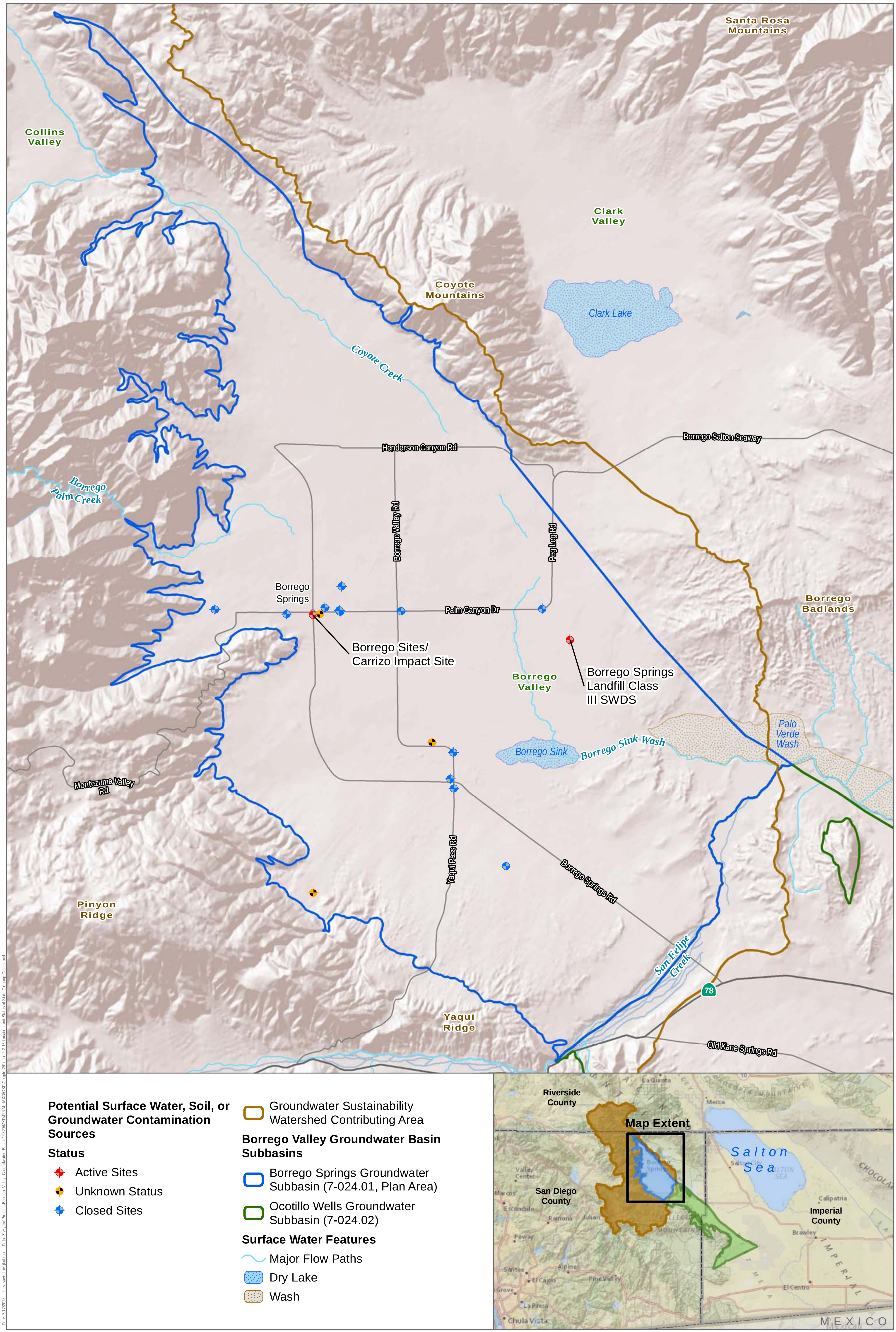

Date: 7/17/2018 - Last saved by: jkubran - Path: Z:\Hydro\Projects\Borrego_Valley_Groundwater_Basin_10329\MXD\FINAL_MXD\GSP\Chapter2\Figure 2.2-15 Location and Status of State Cleanup Cases.mxd

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: DWR 2016; GeoTracker 2017

Figure 2.2-15

Location and Status of State Cleanup Cases

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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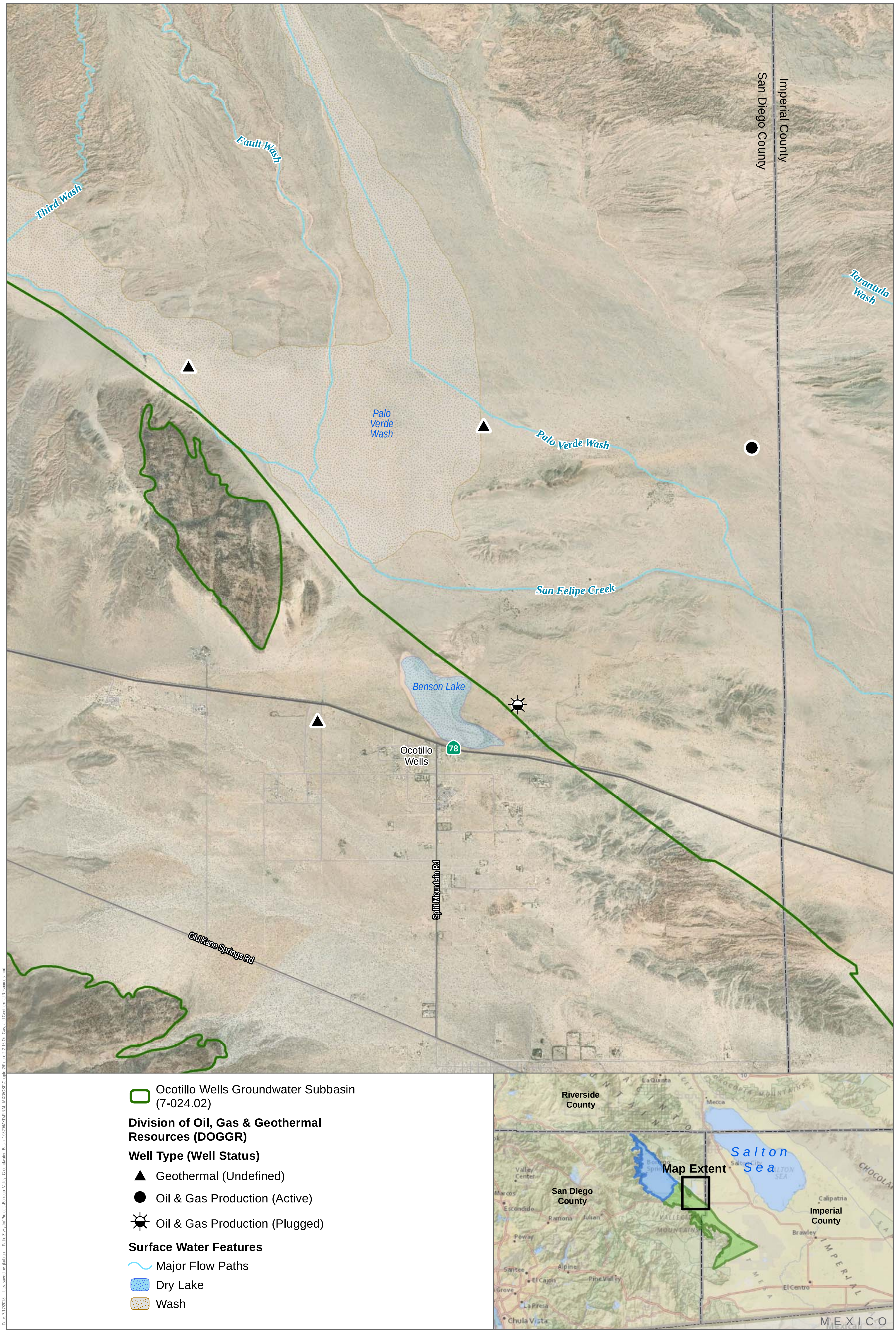

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: DOGGR 2017

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0 2,000 4,000 Feet

Figure 2.2-16

Oil, Gas, and Geothermal Resources

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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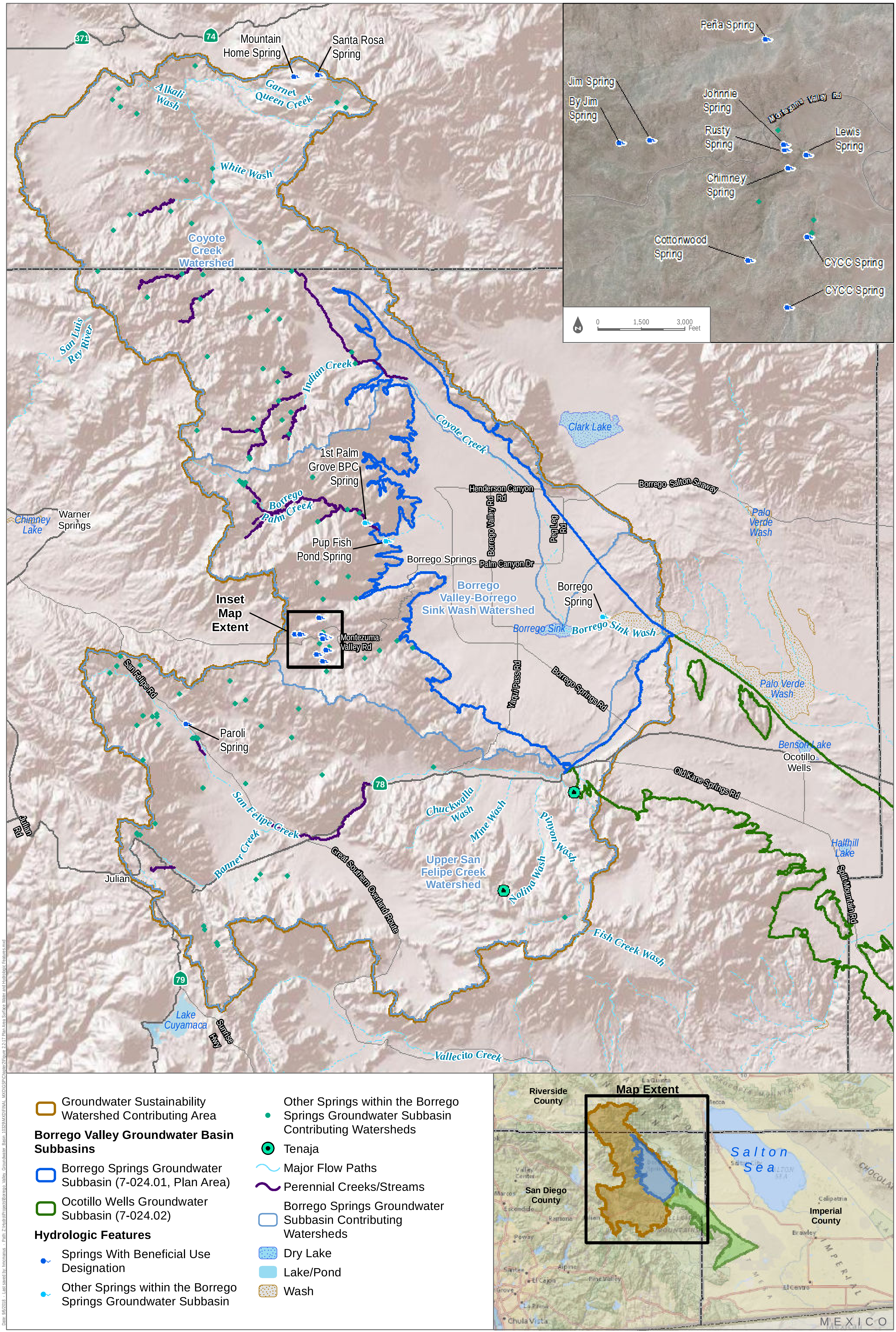

Date: 9/6/2018 - Last saved by: hmcmanus - Path: Z:\HydroProjects\Borrego_Valley_Groundwater_Basin_10329\MXD\FINAL_MXD\GSP\Chapter2\Figure 2.2-17 Plan Area Surface Water and Hydrologic Features.mxd

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: DWR 2015; USGS NHD 2017; State Parks 2017;

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0 1.5 3 Miles

Figure 2.2-17

Plan Area Surface Water and Hydrologic Features

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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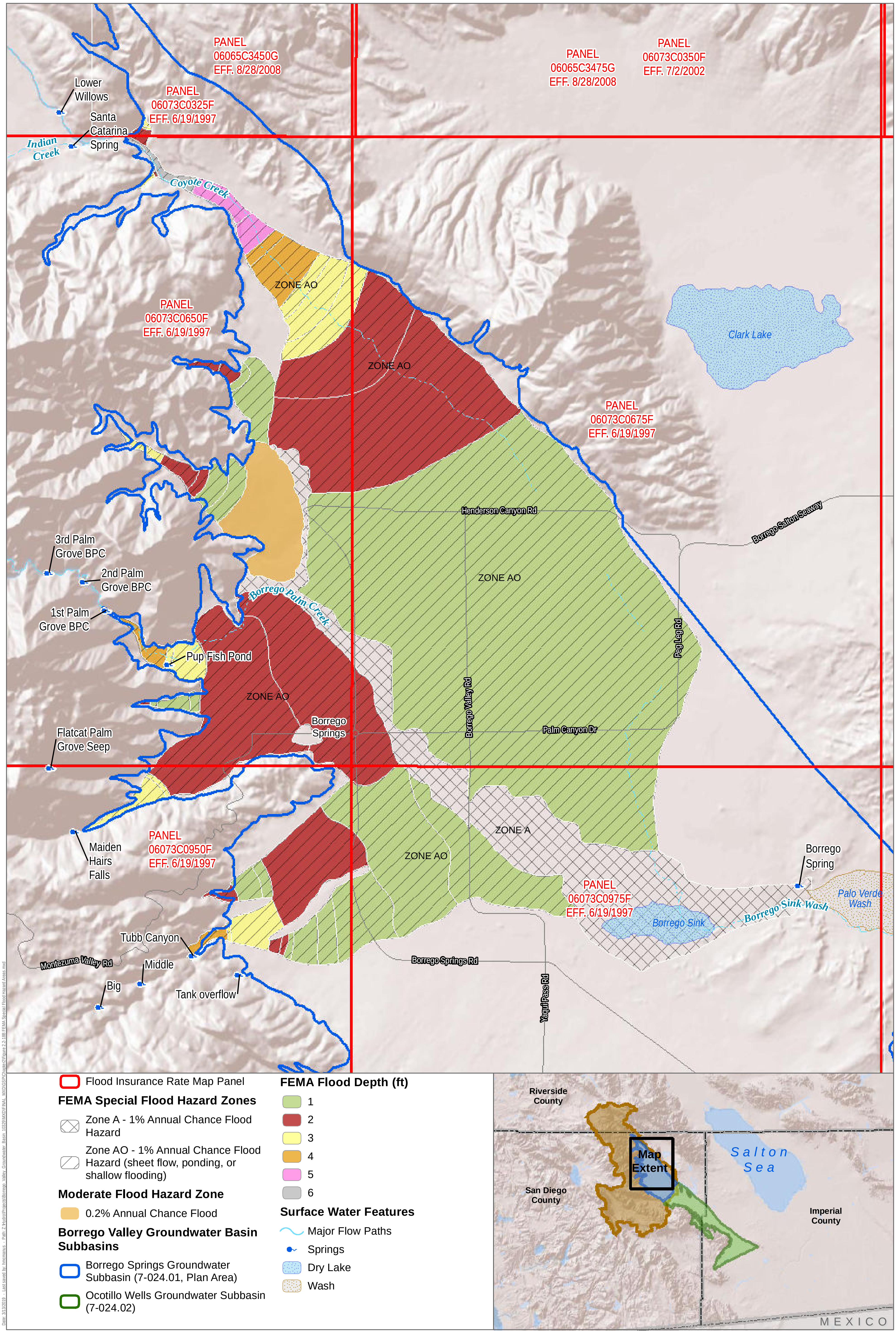

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DATUM: NAD 1983. DATA SOURCE: FEMA 2017

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Figure 2.2-18
FEMA Special Flood Hazard Areas

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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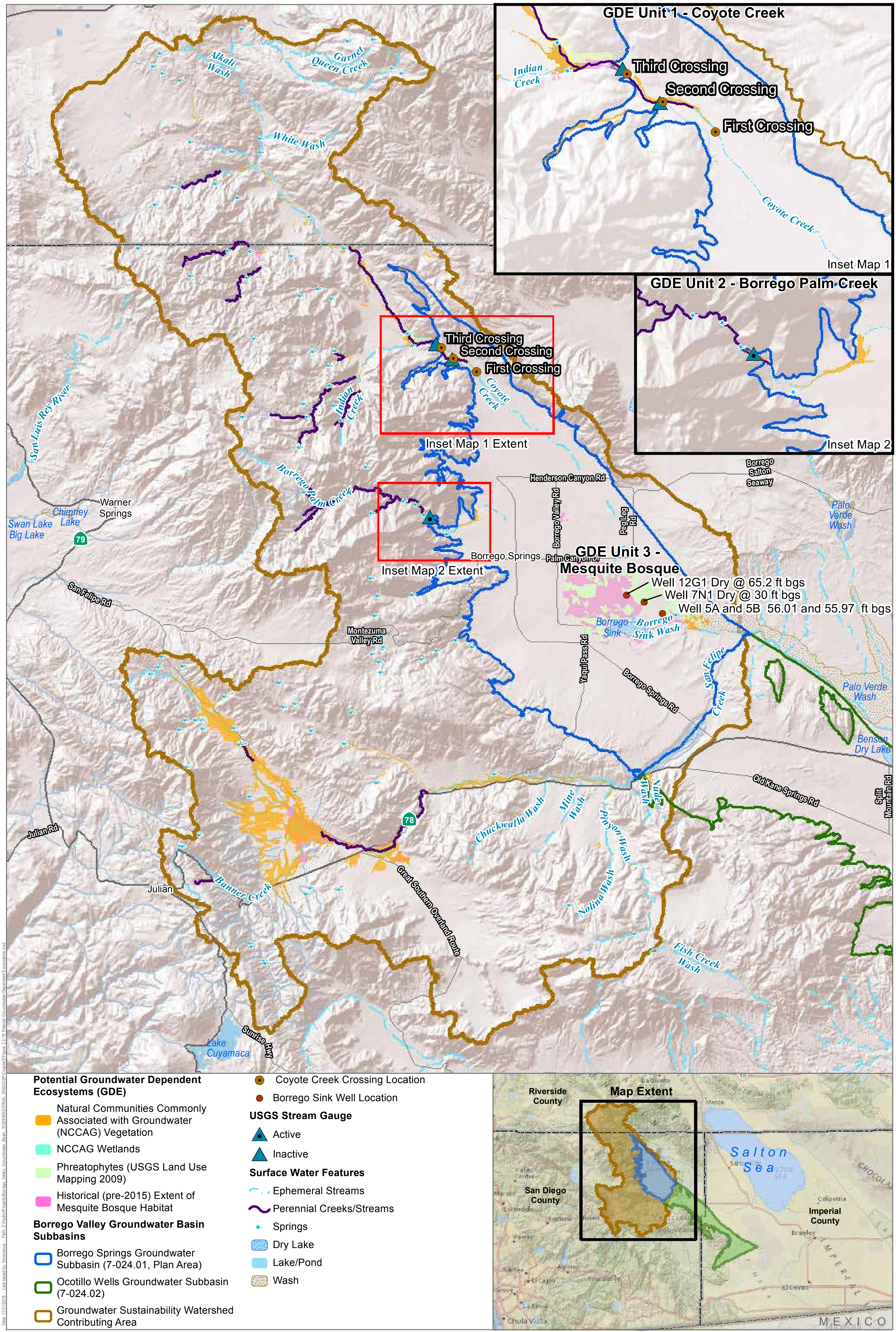

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: DWR 2018; USGS NHD 2017; State Parks 2017; SanGIS 2017

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0 1.5 3 Miles

Figure 2.2-19

Potential Groundwater Dependent Ecosystems

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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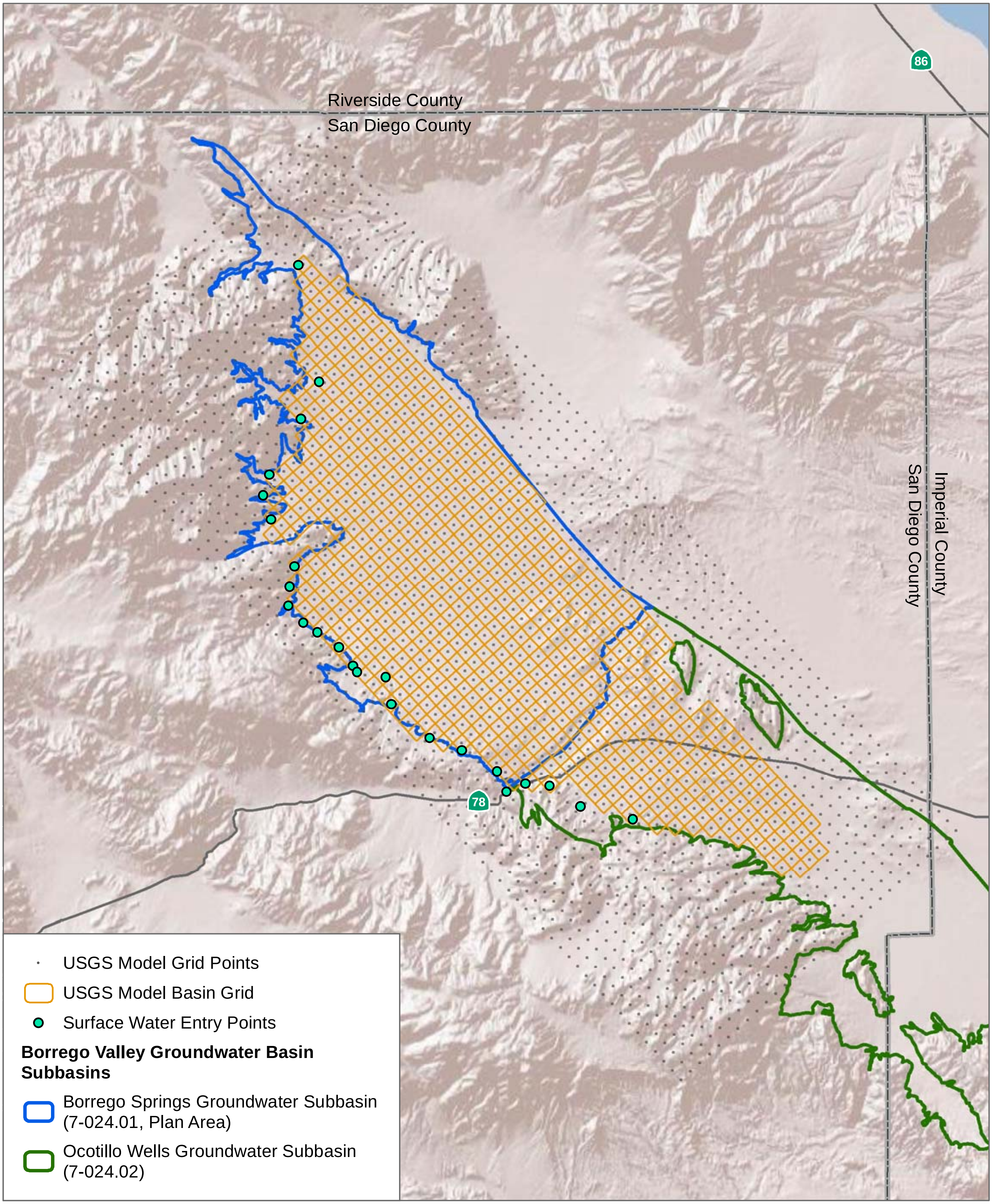

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DATUM: NAD 1983. DATA SOURCE: DWR 2015, USGS 2015

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Figure 2.2-20
Model Grid

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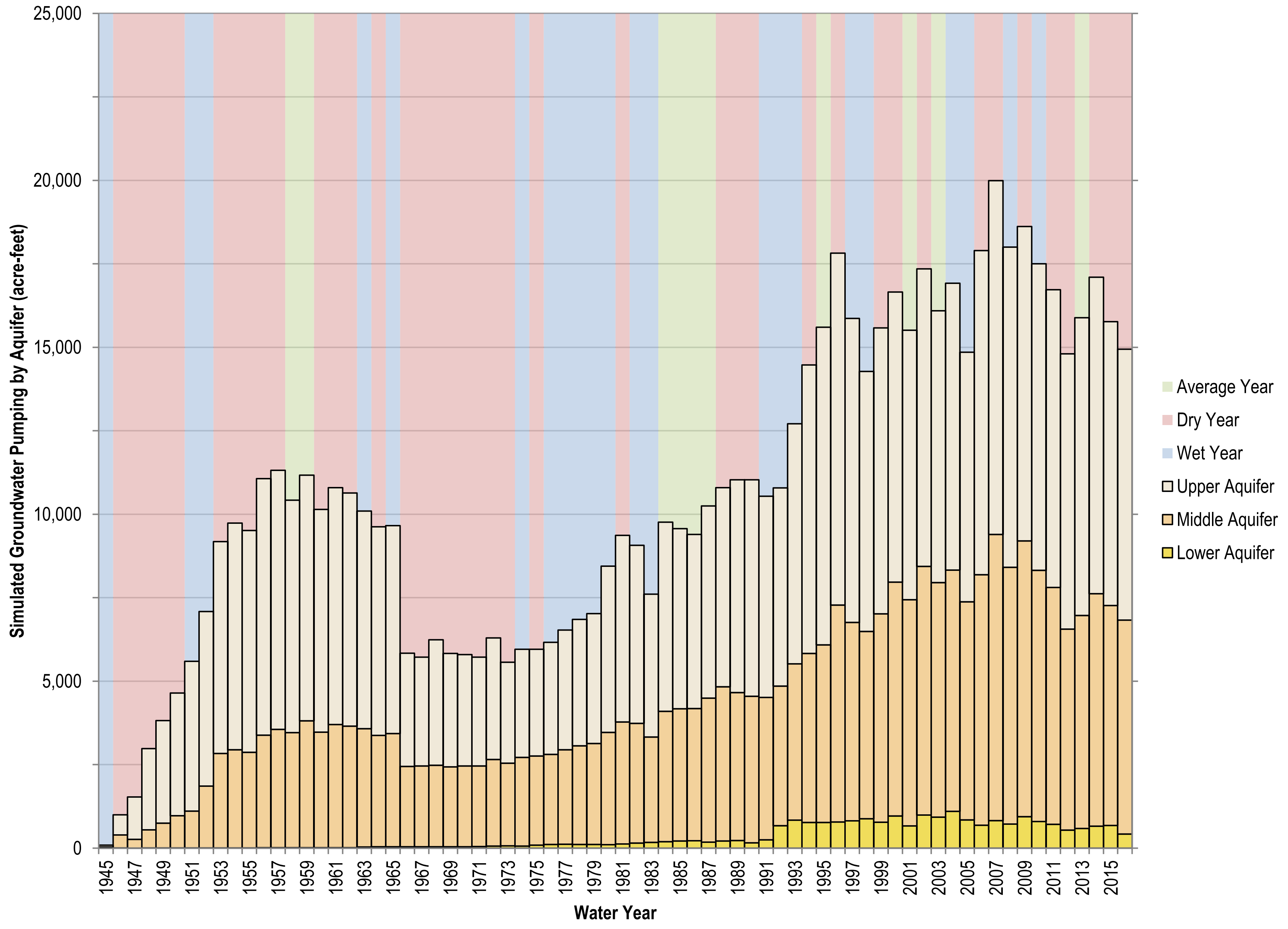

SOURCE: Modified from USGS 2015

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FIGURE 2.2-21A

Simulated Groundwater Pumpage by Aquifer (1945-2016)

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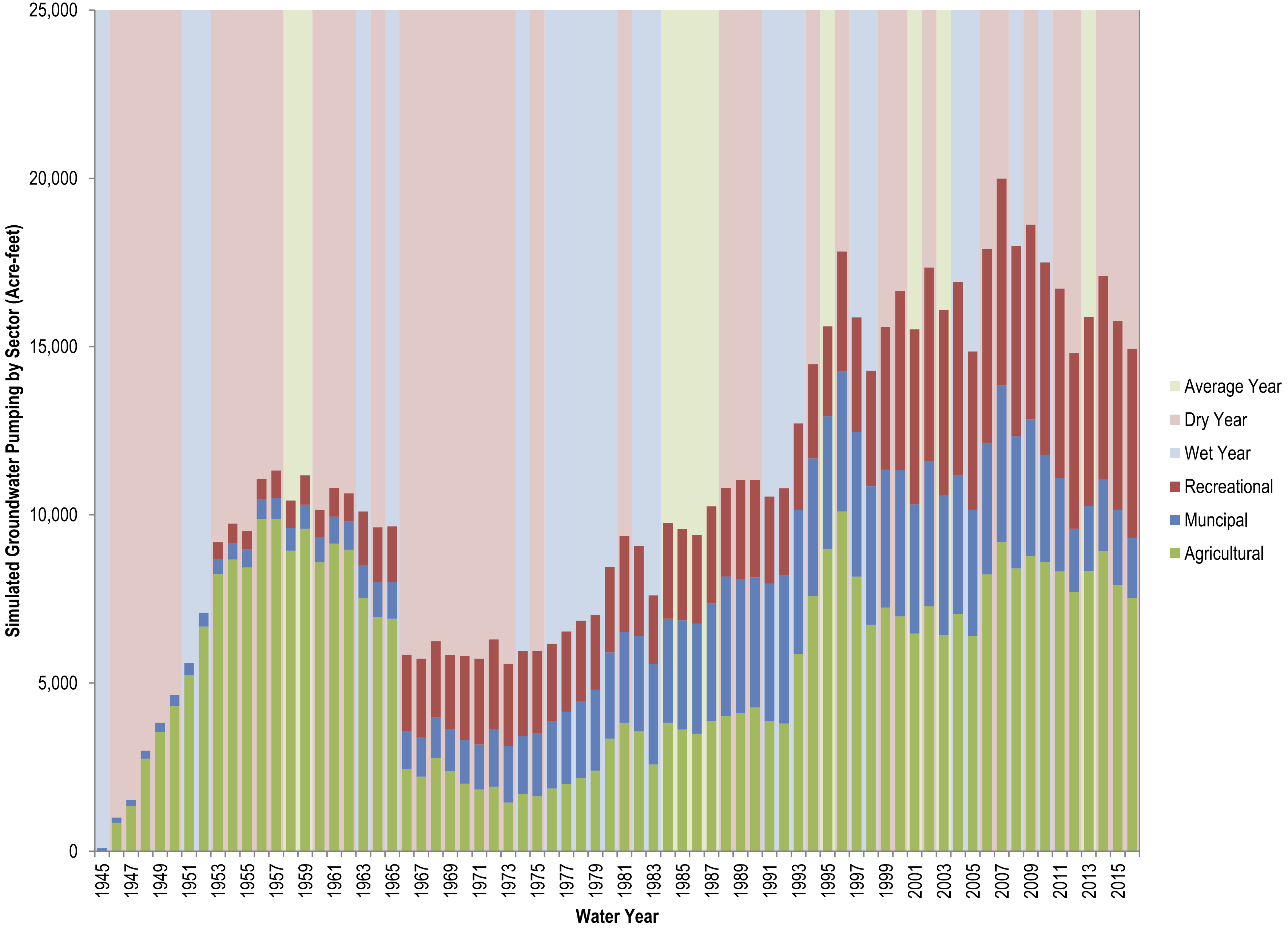

SOURCE: USGS 2015

FIGURE 2.2-21B

Estimated Water Use by Sector (1945 - 2016)

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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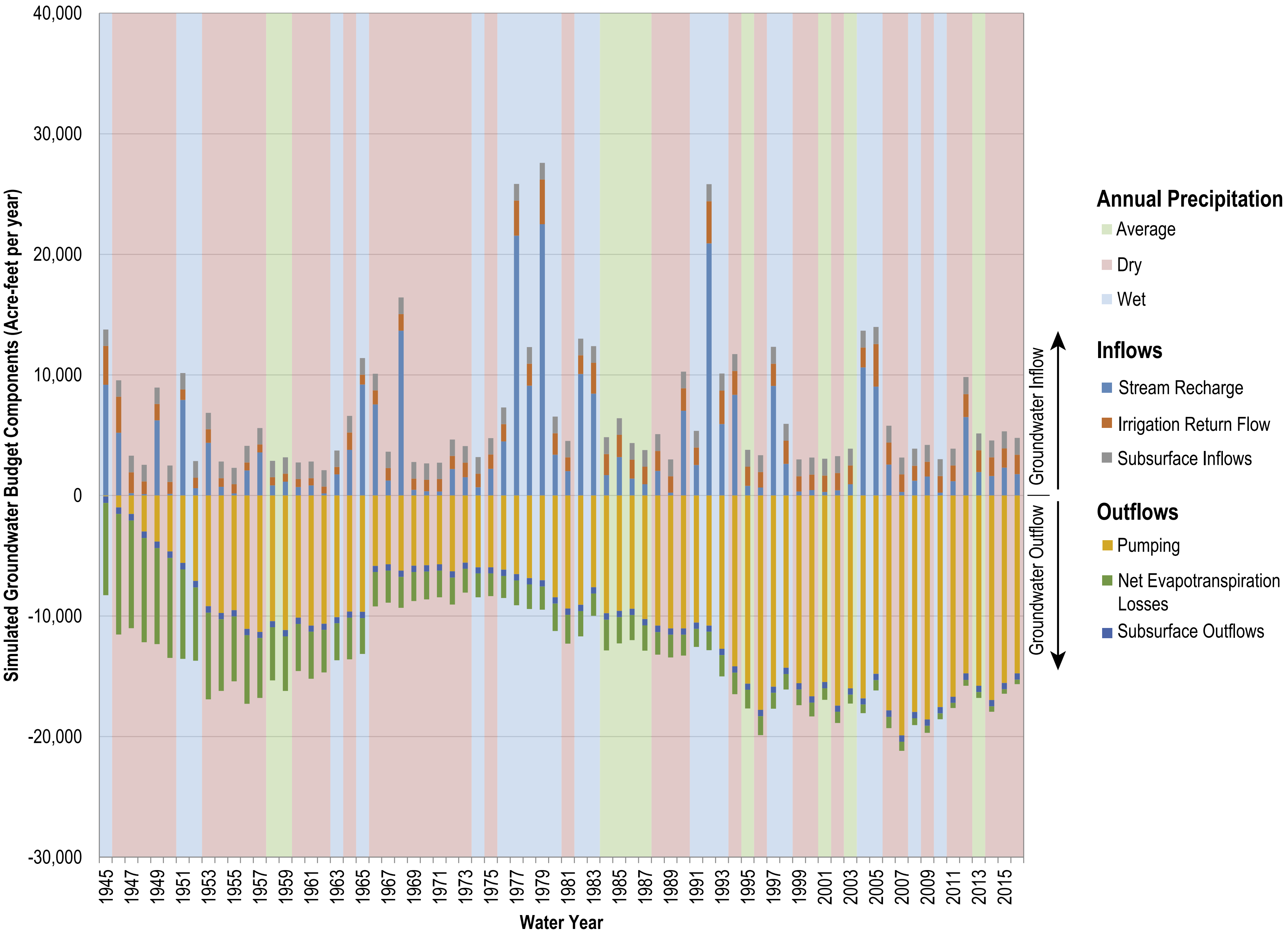

SOURCE: USGS 2015, Dudek 2017

DUDEK

FIGURE 2.2-22A

Groundwater Inflows and Outflows by Year (1945 - 2016)

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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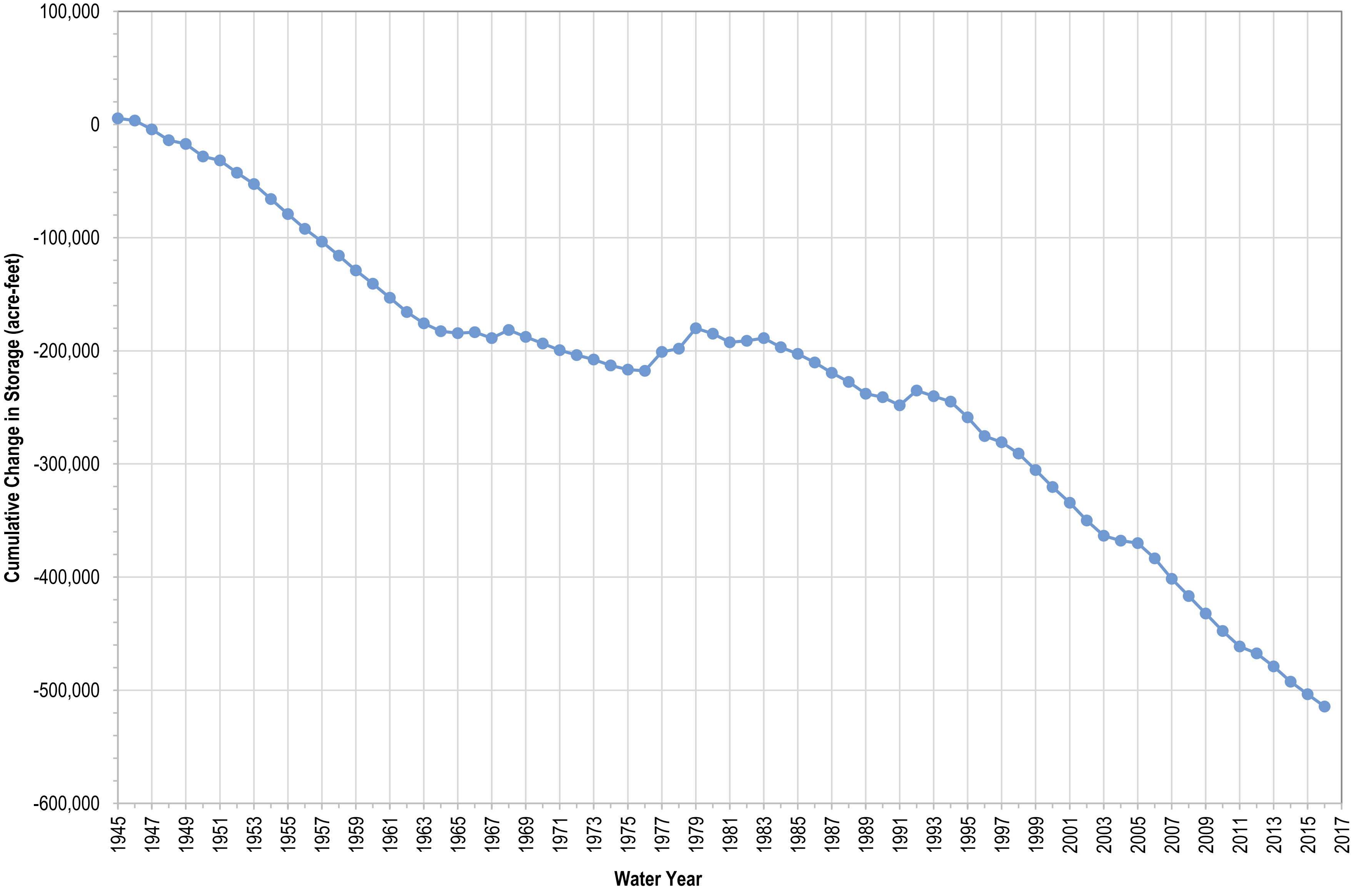

SOURCE: USGS 2015

DUDEK

FIGURE 2.2-22B

Cumulative Change in Storage by Year (1945 - 2016)

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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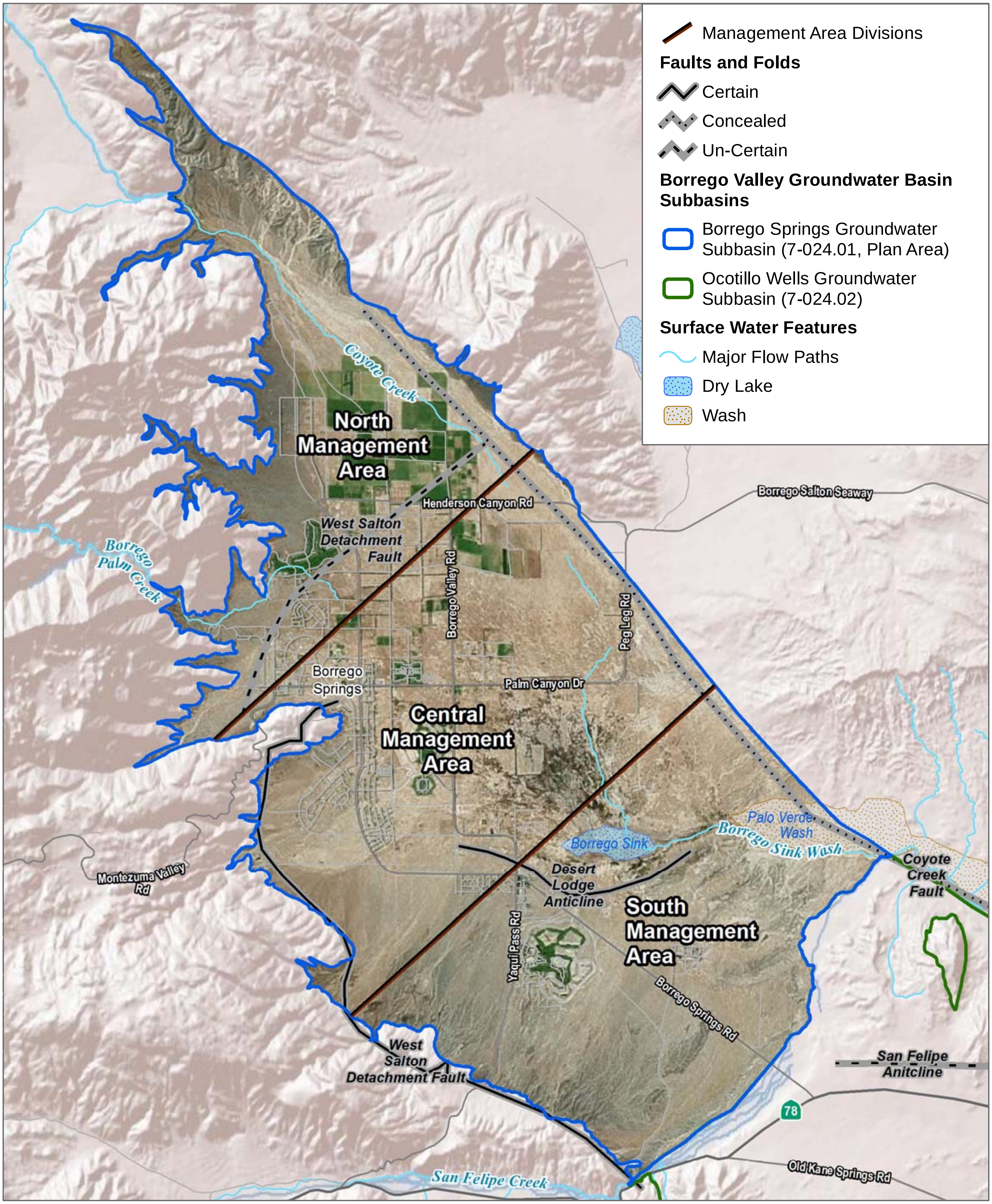

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: USGS; Steely et. al. 2009

DUDEK

0 1 2 Miles

Figure 2.2-23
Groundwater Management Areas

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CHAPTER 3
SUSTAINABLE MANAGEMENT CRITERIA

This chapter of the Groundwater Sustainability Plan (GSP, Plan) provides a discussion of the sustainability goal (Section 3.1), undesirable results (Section 3.2), minimum thresholds (Section 3.3), and the measurable objectives to avoid undesirable results (Section 3.4) applicable to the Borrego Springs Groundwater Subbasin (Subbasin, Plan Area).[1] Undesirable results occur when significant and unreasonable effects for any of the sustainability indicators[2] defined by the Sustainable Groundwater Management Act (SGMA) are caused by groundwater conditions occurring in one of the Subbasin's three management areas, or throughout the Subbasin. This chapter describes the criteria by which the Groundwater Sustainability Agency (GSA, Agency) defines undesirable results within the Subbasin, and identifies what constitutes sustainable groundwater management for the Subbasin, including the process by which the GSA establishes minimum thresholds[3] and measurable objectives[4] for each applicable sustainability indicator (Title 23 California Code of Regulations [CCR] Section 354.22). Accordingly, the following Sections 3.2, 3.3, and 3.4 are subdivided to address each groundwater sustainability indicator. Undesirable results can vary for each management area of the Subbasin, and the beneficial uses and users supported by the Subbasin's aquifers. Section 3.5 provides a description of the monitoring network to measure each applicable sustainability indicator.

The GSA will periodically evaluate this GSP, assess changing conditions in the Subbasin that may warrant modification of the Plan or management objectives, and may adjust components accordingly. The GSA will focus its evaluation on determining whether the actions under the Plan are meeting the Plan's management objectives and whether those objectives are meeting the sustainability goal in the Subbasin.

3.1 SUSTAINABILITY GOAL

3.1.1 Standards for Establishing the Sustainability Goal

A sustainability goal means the existence and implementation of one or more GSP's "that achieve sustainable groundwater management by identifying and causing the implementation of measures

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[1] A basin is a groundwater basin *or subbasin* [emphasis added] identified and defined in Bulletin 118 or as modified pursuant to a basin boundary modification approved by the Department of Water Resources (CWC Section 10721). In the context of this GSP, the word "basin" means the Borrego Springs Subbasin, unless otherwise specified.

[2] A sustainability indicator refers to "any of the effects caused by groundwater conditions occurring throughout the basin that, when significant and unreasonable, cause undesirable results" (Title 23 CCR Section 351(ah)).

[3] A minimum threshold means "a numeric value for each sustainability indicator used to define undesirable results" (Title 23 CCR Section 351(t)).

[4] A measurable objective means "specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin" (Title 23 CCR Section 351(s)).

targeted to ensure the . . . basin is operated within its sustainable yield[5]" (California Water Code [CWC] Section 10721(u))." "Sustainable groundwater management" means the "management and use of groundwater in a manner that can be maintained during the planning and implementation horizon without causing undesirable results" (CWC Section 10721(v)). Undesirable results include chronic lowering of groundwater levels indicating a significant and unreasonable depletion of supply, significant and unreasonable reduction of groundwater storage, significant and unreasonable degraded water quality, and depletions of interconnected surface water that have significant and unreasonable adverse impacts on beneficial uses of the surface water (CWC Section 10721(x)).

The California Department of Water Resources (DWR) SGMA GSP regulations (Title 23 CCR Section 350, et seq.) provide supplemental information about the sustainability goal. For example, the regulations state: "Each Agency shall establish in its Plan a sustainability goal for the basin that culminates in the absence of undesirable results within 20 years of the applicable statutory deadline. The Plan shall include a description of the sustainability goal, including:

- information from the basin setting used to establish the sustainability goal,
- a discussion of the measures that will be implemented to ensure that the basin will be operated within its sustainable yield, and
- an explanation of how the sustainability goal is likely to be achieved within 20 years of Plan implementation and is likely to be maintained through the planning and implementation horizon" (Title 23 CCR Section 354.24).

3.1.2 Background

The Borrego Springs community overlying the Subbasin relies on local groundwater resources as the sole source of municipal drinking water, domestic supply, and agricultural irrigation. Recreational water use in the Subbasin is entirely supported by groundwater. Groundwater also supports other beneficial uses, as described in Chapter 2, Plan Area and Basin Setting, of this GSP, including those set forth in the *Water Quality Control Plan for the Colorado River Basin* (Basin Plan). The current rate of groundwater production from the Subbasin is not sustainable and, if not moderated, threatens to impact the beneficial uses and users of groundwater in the Plan Area. Impacts to beneficial uses and users may include decreased well production rate, increased pumping costs, dry wells, and/or increasingly poor water quality. Without action, groundwater could become much more challenging and expensive to access and potentially insufficient in quantity and quality to support beneficial uses. The community of Borrego Springs is a small and

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[5] "Sustainable yield" means the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from a groundwater supply without causing an undesirable result [CWC Section 10721(w)].

severely disadvantaged community (DWR 2018a).[6] The continued overdraft of the basin at its present rate of pumping could cause severe economic hardship for the community.

Annual natural recharge to the Subbasin is small compared to the volume of groundwater available in storage. Since inception of large-scale pumping in the Subbasin in the 1940s, an imbalance of groundwater extraction exceeding recharge has occurred. In other words, annual groundwater extraction from the Subbasin has exceeded recharge over multiple decades resulting in a depletion or "mining" of the groundwater resource. According to the results of the Borrego Valley Hydrologic Model (BVHM) described in Sections 2.2.2.2 and 2.2.3, Water Budget, the cumulative volume of storage lost from the Subbasin between 1945 and 2016 is approximately 520,000 acre-feet (AF), which is a sum of the annual differences between Subbasin inflows and outflows. The storage capacity of the Borrego Valley Groundwater Basin (which includes the Ocotillo Wells Subbasin), based on stable groundwater levels before groundwater development began, is estimated to have been about 5,500,000 AF (USGS 1982). Based upon subsequent study by Dr. David Huntley, the majority of readily available water to existing well users in the Borrego Valley exists in the upper and middle aquifers. The amount of groundwater within these two aquifers within the Subbasin was estimated to be approximately 2,131,000 AF in 1945 and 1,900,500 AF in 1979 (Huntley 1993). The remaining water located within the lower aquifer is more difficult and costly to extract due to its low specific yield (estimated to be approximately 3%), its depth, and low specific capacity (estimated to be 5 gallons per minute/foot of drawdown or less) (County of San Diego 2010). Furthermore, as groundwater levels continue to drop in the Subbasin, an increasing percentage of water will be pumped from the lower aquifer, which has a lower yield, but is also likely to yield lower quality water (elevated total dissolved solids (TDS), sulfates, and arsenic), as discussed in Section 2.2.2.4. The BVHM estimates that total storage loss from water year 1980 through water year 2016 is 334,293 AF. Therefore as of 2016, the volume of groundwater in storage within the upper and middle aquifers of the Subbasin is approximately 1,566,207 AF.

Outright depletion (dewatering) of a groundwater resource is a serious condition for a community that is totally reliant on groundwater supply. Depletion also means that the groundwater resource has been effectively permanently removed, from storage without the ability to recover under current climate conditions and pumping volumes. In order to begin to bring the Subbasin back into balance, it is estimated that approximately 74% of the maximum baseline pumping in the Subbasin, on average, will need to be reduced over the GSP implementation period and through the planning an implementation horizon.

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[6] Severely disadvantaged communities are those census geographies with an annual median household income that is less than 60 percent of the Statewide annual median household income. The statewide median household income for 2012–2016 (the current dataset) is $63,783; therefore, the calculated severely disadvantaged community threshold is $38,270.

3.1.3 Sustainability Goal

The GSA's sustainability goal is to ensure that by 2040, and thereafter within the planning and implementation horizon of this GSP (50 years), the Subbasin is operated within its sustainable yield and does not exhibit undesirable results.

Meeting this goal requires achieving a balance of water demand with available water supply, while protecting water quality, by the end of the GSP implementation timeframe, carrying through the SGMA planning and implementation horizon. A good analogy is a prudent financial routine of "balancing the books" whereby the totals of debit (groundwater withdrawal) and credits (recharge) are brought into agreement to determine the profit or loss (change in groundwater storage) made during a period of time (annually or over a longer period of time such as a hydrologic cycle). Central to achieving this goal is a strong understanding of the local setting of the Subbasin described in Chapter 2. The Subbasin is totally groundwater dependent with no immediately viable alternative sources of water supply such as imported water, recycled water or groundwater from adjacent basins/subbasins (USBR 2015; Dudek 2018; BWD 2000, 2002).

Conditions within the Subbasin will be considered sustainable when the following sustainability goals are met:

- Long-term, aggregate groundwater use is less than or equal to the Subbasin's estimated sustainable yield, as defined by SGMA (Section 2.2.3.5, Sustainable Yield Estimate);
- The rate of groundwater level change within the Subbasin, averaged across indicator wells in the previous reporting period, is generally stable or increasing when compared to the contemporary groundwater level trend (i.e., 10-year trend 2010–2020 or trend based on available data) (Section 2.2.2.1, Groundwater Elevation Data);
- Groundwater levels are maintained at elevations necessary to avoid undesirable results. Lowering of groundwater levels potentially leading to significant and unreasonable depletions of available water supply for beneficial use could occur if groundwater levels fall below the top of screened intervals for key municipal water wells, or result in the loss of water availability for domestic well users (Section 2.2.2.1, Groundwater Elevation Data);
- Groundwater quality, as measured in municipal and domestic water wells, generally exhibits a stable and/or improving trend for identified contaminants of concern: arsenic, nitrate, sulfate, and TDS (Section 2.2.2.4, Groundwater Quality); and
- Groundwater quality is suitable for existing and future beneficial uses (Section 2.2.2.4, Groundwater Quality).

3.1.4 Sustainability Strategy

To ensure the Subbasin meets its sustainability goal by 2040, the GSA has proposed several projects and management actions (PMAs) detailed in Chapter 4, Projects and Management Actions, to address undesirable results. The PMAs expected to be implemented are: (1) Water Trading Program, (2) Water Conservation Program, (3) Pumping Reduction Program, (4) Voluntary Fallowing of Agricultural Land, (5) Water Quality Optimization, and (6) Intra-Subbasin Water Transfers. The overarching sustainability goal as well as the absence of undesirable results are expected to be achieved by 2040 through implementation of the PMAs. The sustainability goals will be maintained through proactive monitoring and management by the GSA as described in this and the following chapters.

Table 3-1 summarizes whether each of the six undesirables results has occurred, is occurring, or is expected to occur in the future in the Subbasin without GSP implementation, and shows the PMAs that have been developed to address each of the undesirable results presently occurring. The community of Borrego Springs has been acutely aware of its water problems for over 25 years, and the major drought period from 2012 through 2016 led to further heightened public awareness. Because supply augmentation through local and/or imported surface water is not a feasible option for the Subbasin at this time, the only tool available to the GSA to achieve groundwater sustainability is through demand reduction. The Borrego Water District (BWD) already implements a water conservation (shortage) policy, some golf courses have already implemented technologies and landscape practices that save water, and agricultural users have implemented increasingly efficient irrigation systems over the years. It is important to continue to implement and strengthen water conservation practices, as proposed in the water conservation PMA, because opportunity remains for further water savings, particularly with regard to the outdoor water use of BWD customers.

Considering the water conservation already achieved, and the diminishing returns in the volume of water that can be saved through conservation alone, the most critical PMAs to realize the pumping reductions needed to achieve the GSP’s sustainability goal are the voluntary fallowing of agricultural land, and the pumping reduction program. The pumping reduction program caps water use at the beginning of the implementation period (a total pumping allowance of 21,936 acre-feet per year (AFY)) and gradually reduces the cap to a level that matches the sustainable yield of the Subbasin (5,700 AFY) by 2040. Because agriculture accounts for approximately 70% of groundwater used in the Subbasin, such a drastic reduction cannot be achieved without continuing the permanent fallowing of agricultural land. The Water Trading Program is a PMA expected to replace the existing water credit program that assigned a water allocation for fallowing of primarily agricultural land based on crop or turf type and allowed for water credits to be transferred to new development to offset water demand. The water trading PMA ties into the pumping reduction program and voluntary fallowing of agricultural land by preserving the economic value of water as its availability is capped and reduced over time, and by providing for flexibility in the types of economic development or redevelopment that can occur, where consistent with water availability, general plan and zoning designations, and land use regulations.

Table 3-1
Summary of Undesirable Results Applicable to the Plan Area

Sustainability Indicator	Historical (Pre-2015)	Existing Conditions	Future Conditions Without GSP Implementation	PMAs implemented to meet the GSP's sustainability goal
Chronic Lowering of Groundwater Levels	✓	✓	✓	Water Trading Program, Water Conservation, Pumping Reduction Program, Voluntary Fallowing of Agricultural Land Intra-Subbasin Water Transfers
Reduction of Groundwater Storage	✓	✓	✓	
Seawater Intrusion	Not Applicable			
Degraded Water Quality	✓	✓	✓	Pumping Reduction Program, Voluntary Fallowing of Agricultural Land, Water Quality Optimization, Intra-Subbasin Water Transfers
Land Subsidence	Not Significant			
Depletions of Interconnected Surface Water	✓	*		

Notes: GSP = Groundwater Sustainability Plan; PMA = Projects and Management Action.
* See following Section 3.2.6.

3.2 UNDESIRABLE RESULTS

Standards for the Description of Undesirable Results

According to GSP Regulations, the GSP's description of undesirable results is to include the following:

1. The cause of groundwater conditions occurring throughout the basin that would lead to or has led to undesirable results based on information described in the basin setting, and other data or models as appropriate.
2. The criteria used to define when and where the effects of the groundwater conditions cause undesirable results for each applicable sustainability indicator. The criteria shall be based on a quantitative description of the combination of minimum threshold exceedances that cause significant and unreasonable effects in the basin.
3. Potential effects on the beneficial uses and users of groundwater, on land uses and property interests, and other potential effects that may occur or are occurring from undesirable results (Title 23 CCR Section 354.26(b)).

Under SGMA, undesirable results occur when the effects caused by groundwater conditions occurring throughout the basin cause significant and unreasonable impacts to any of the six sustainability indicators. That is, the "significant and unreasonable occurrence of any of the six sustainability indicators constitutes an undesirable result" (DWR, Draft Sustainable Management Criteria, Best Management Practice, Section 4, p. 5). These sustainability indicators are:

- Chronic lowering of groundwater levels
- Reduction of groundwater storage
- Seawater intrusion
- Degraded water quality
- Land subsidence
- Depletions of interconnected surface water

Application of Standards in the Borrego Subbasin

Each of the sustainability indicators for the Subbasin is discussed as follows, in the context of undesirable results.

3.2.1 Chronic Lowering of Groundwater Levels – Undesirable Results

Chronic lowering of groundwater levels in the Subbasin's aquifers has historically occurred and is ongoing due to groundwater production for agricultural, municipal, recreational and domestic use that exceeds the long-term sustainable yield of the Subbasin and the absence of any viable alternative source of water supply. The existing beneficial uses and users of Subbasin water are described in Section 2.1.5.1, Beneficial Uses and Users. The beneficial uses for groundwater for the Anza Borrego Hydrologic Unit are defined in the Basin Plan as Municipal and Domestic Supply (MUN), Industrial Service Supply (IND), and Agriculture Supply (AGR) as described in Section 2.1.2 (Water Resources Monitoring and Management Programs). SGMA requires that all beneficial uses and users of groundwater, including groundwater dependent ecosystems (GDEs), be considered in GSPs (CWC Section 10723.2). The honey mesquite bosque in the vicinity of the Borrego Sink is the primary GDE identified within the Plan Area that has historically been affected by pumping as described in Section 2.2.2.6, Groundwater-Surface Water Connections.

Undesirable results associated with chronic (i.e., persistent and long-term) lowering of groundwater levels are most directly indicated by loss of access to adequate water resources for support of current and/or potential future beneficial uses and users. As discussed in Section 2.2.2.1, Groundwater Elevation Data, the rate of groundwater level decline within the Subbasin is variable across the Plan Area, generally decreasing in magnitude from north to south. The North

Management Area (NMA) exhibits the steepest groundwater level declines since 1945 (average rate of 1.95 feet per year) due to pumping for primarily agricultural uses; the Central Management Area (CMA) exhibits substantial but somewhat less severe declines (average rate of 1.33 feet per year) due to pumping for primarily municipal, domestic and recreational uses; and the South Management Area (SMA) has up until 2014 exhibited minimal if any decline, though the resumption of groundwater pumping to support recreation at Rams Hill Golf Club resulted in a localized decline in groundwater levels, as shown by MW-3 in Figure 2.2-13F. Domestic users of groundwater, including customers of the BWD, are predominantly supplied groundwater produced from wells located within CMA, and to a lesser degree the SMA and NMA. Failure to address and reverse the current rate of groundwater level decline could put domestic, agricultural, recreational and water supply availability for other beneficial uses at risk.

Groundwater level declines indicating a significant and unreasonable depletion of supply, if continued over the SGMA planning and implementation horizon, can occur in several ways in the Subbasin. Depletions leading to a complete dewatering of the Subbasin’s upper aquifer in the CMA would be considered significant and unreasonable because beneficial users rely on this aquifer for water supply. Groundwater level declines would be significant and unreasonable if they are sufficient in magnitude to lower the rate of production of pre-existing groundwater extraction wells below that needed to meet the minimum required to support the overlying beneficial use(s), and that alternative means of obtaining sufficient groundwater resources are not technically or financially feasible. To the extent lowering groundwater levels impact *de-minimis*[7] pumpers, significant and unreasonable impacts to those pumpers could be avoided. For example, alternative means of obtaining water for *de-minimis* and domestic pumpers who can no longer pump may include connection to the municipal water system (i.e., BWD), groundwater well maintenance or rehabilitation (e.g., well pump lowering), or for some beneficial users, well redevelopment or deepening. However, use of these alternative means of supply, by themselves, do not necessarily offset undesirable results for lowering groundwater levels in the context of the Subbasin as a whole (as opposed to individual uses or users), because the ultimate source of supply remains groundwater pumped from the Subbasin, even if from another location.

Undertaking an evaluation for one particular use or user depends on the overlying beneficial use(s), the location within the basin, and the characteristics of the well(s) currently in use. Should a groundwater level decline cause the production rate of pre-existing groundwater wells to be insufficient for the applicable beneficial use, an undesirable result may be avoided for that particular user through the alternative means shown in Table 3-2. Table 3-2 acknowledges that certain beneficial users have greater flexibility and financial capacity to address lowering groundwater levels than others. For example, the BWD, as the municipal water system, has the ability to manage production from multiple extraction wells across its service area, normally

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[7] SGMA defines a de-minimis extractor as “a person who extracts, for domestic purposes, two acre-feet or less (of groundwater) per year.”

distributes the cost for well maintenance and development to its pool of customers, and can obtain grants for such work, if available. In contrast, domestic and *de-minimis* users can have geographic and financial constraints that may make well redevelopment and/or new well construction infeasible. Given the considerations previously outlined, domestic well users who are not in close proximity to existing BWD water service lines have the greatest sensitivity to and are consequently the most likely to experience the adverse effects of continued declining groundwater levels.

Table 3-2
Means of Addressing Decreasing Well Production by Use

	Municipal Uses	Agricultural Uses	Recreational Uses	Domestic/*De-Minimis* Uses
Connection to Municipal Water System	N/A		✓	*
Well Maintenance (e.g., brushing and bailing, pump lowering, repair or replacement)	✓	✓	✓	✓
Well Redevelopment/Deepening	✓	✓	✓	*
Well Abandonment/New Well Development	✓	✓	✓	*

Notes: N/A = not applicable.
* Domestic and *de-minimis* users may have geographic, financial, and technical constraints that limit the ability to modify or deepen wells. Furthermore, based on Borrego Water District's (BWD's) water supply pipeline distribution system, some – but not all – domestic and *de-minimis* users can be hooked into the BWD system.

The upper aquifer currently hosts the most accessible (i.e., shallowest) and highest-yielding wells within the Subbasin as a whole. Figure 3.2-1 shows the extent of the upper aquifer, and a representation of the percentage of the aquifer that remains saturated, based on the update of the BVHM discussed in Section 2.2.3. Also shown is the saturated thickness, in feet of the aquifer. The upper aquifer does not occur in the southern fringe of the CMA, nor in the southwestern portion of the SMA; in these areas, the middle or lower aquifers begin near the ground surface. The water table has dropped below the base of this aquifer in some parts of the Subbasin, particularly within the southwestern half of the CMA, which overlies the more developed portion of Borrego Springs that is served by the BWD with wells located in the CMA (Figure 3.2-1).

Up to 200 feet of the upper aquifer remains saturated in the east central part of the CMA, and roughly 50 feet, on average, of the upper aquifer remains saturated within portions of the SMA and CMA. Figure 3.2-2 and Figure 3.2-3 show the same information for the middle, and lower aquifers, respectively. Groundwater level declines, based on the percentage of the aquifer thickness that is saturated, have begun to drop below the top of the middle aquifer in the southwestern part of the NMA, and the western part of the CMA. Groundwater levels have also dropped below the top of the lower aquifer along the western fringes of the CMA, and SMA, where the upper aquifer boundary is much closer to the ground surface.

Because many of the domestic groundwater users not connected to BWD rely on continued access to the upper aquifer or upper portions of the middle aquifer, an important objective in this GSP is that access to the upper aquifer or upper middle aquifer be maintained, as much is practicable, in areas with *de minimis* and other domestic wells not currently served by municipal supply (Figure 3.2-1 and Figure 3.2-2). The lower aquifer is an important source of water supply to irrigation wells, municipal wells and some domestic wells mostly in the SMA. The lower aquifer is the thickest aquifer underlying the Plan Area (Figure 3.2-3). Figure 3.2-4 shows a map of township and range sections where well completion reports indicate domestic wells occur, along with an estimate of the average remaining water column, based on statistics gathered by DWR on well depths, and the results of the BVHM regarding depth to water as of September 2016.

The groundwater levels simulated by the BVHM were attached to township and range sections by averaging the groundwater levels of the overlapping model grid cells. Also shown in Figure 3.2-4 is BWD's water distribution system, because the feasibility of connecting domestic well users to the municipal water system, if needed, is related to the distance from BWD's existing infrastructure. Overall, there are 77 domestic wells in DWR's well completion report database. As shown Figure 3.2-4, four of the township and range sections have water levels estimated to be below the bottom of the well in the section. Furthermore, the difference between the average well depth and the average groundwater level is less than 50 feet in seven township and range sections, representing 20 domestic wells, which indicates a high likelihood that some may lack access to adequate water in existing wells. With groundwater levels expected to continue to decline early in the GSP implementation period, domestic users are currently experiencing undesirable results, which will be alleviated by 2040. The majority of the wells in this situation are close to the BWD water distribution system.

The undesirable results of chronic lowering of groundwater levels is expected to continue to occur absent management action to counteract the current trend, until the Subbasin water budget is brought into balance. BWD has had to abandon and re-drill wells in the past and expects to continue to do so within the GSP's implementation timeframe to continue to provide adequate groundwater access. For example, BWD well ID1-10 is being replaced and relocated in 2019 due to declining groundwater levels and production rate loss. The exact number of agricultural and domestic wells that have been abandoned and re-drilled deeper and/or relocated due to production rate loss from declining groundwater levels is not known. However, anecdotal information and field observations have confirmed that inactive wells exist throughout the Plan Area.

As discussed in Section 3.3, Minimum Thresholds, this GSP establishes thresholds for each Subbasin management area that would generally indicate the occurrence (or absence) of an undesirable result. These thresholds relate to known elevations that current and future groundwater levels can be compared against, such as the subsurface boundaries between the upper, middle and lower aquifers, and the prevailing elevations of the perforated intervals of groundwater wells in use, where known. The pumping reduction plan, the voluntary fallowing of agricultural land, and other PMAs described in this GSP are intended to limit production to meet all present beneficial uses and users of groundwater including the existing footprint of water intensive agriculture in the Subbasin. The proposed PMAs to mitigate potential effects to beneficial use and users are discussed in Chapter 4, Projects and Management Actions.

3.2.2 Reduction of Groundwater Storage – Undesirable Results

Reduction of groundwater storage in the Plan Area has the potential to impact the beneficial uses and users of groundwater in the Subbasin by limiting the volume of groundwater available for agricultural, municipal, recreational, industrial, and domestic use. In essence, the undesirable results of reductions in groundwater in storage are the same as those previously described for chronic lowering of groundwater levels, because within this Subbasin, these impacts go hand-in-hand. Continuing the current rate of loss of groundwater in storage could also impact other sustainability indicators, namely groundwater quality.

The primary cause of groundwater conditions in the Plan Area that would lead to reduction in groundwater storage is the ongoing groundwater production in excess of the estimated long-term sustainable yield of the Subbasin. Significant and unreasonable impacts with respect to groundwater in storage are indicated by a long-term deficit in the groundwater budget, which is described in Section 2.2.3, Water Budget. The usable quantity of groundwater in storage is large compared to average annual natural recharge to the Subbasin. On average, the Subbasin lost approximately 7,300 AFY from storage for the period between 1945 and 2015. Over the last 10 years, the Subbasin lost 13,137 AFY, based on the BVHM model results as described in Section 2.2.3. It is estimated from the BVHM that the cumulative volume of stored water lost from the Subbasin between 1945 and 2016 was approximately 520,000 AF. This volume is the cumulative difference between Subbasin inflows (e.g., natural recharge) and outflows (e.g., pumping) calculated by the BVHM over the 71-year timeframe.

An important concept relevant to the Subbasin is the high variability and the decadal periodicity of wet versus dry periods in the climatic record. A clear example of the variability inherent in the recharge values is that the 20-year period from 1955 to 1974 was one of the ‘driest’ on record and it immediately preceded one of the ‘wettest’ periods from 1975 to 1994 (ENSI 2018). The average annual recharge rates for these two periods of ‘dry’ and ‘wet’ precipitation were 3,975 and 11,907 AFY, respectively (ENSI 2018). The long-term groundwater supply highly depends on ‘wet’ years with high recharge rates; however, these occur on a decadal scale and may not coincide with the 20-year GSP implementation period.

Reduction in groundwater storage is significant and unreasonable if it is sufficient in magnitude to lower the rate of production of pre-existing groundwater wells below that needed to meet the minimum required to support the overlying beneficial use(s), and where means of obtaining sufficient groundwater or imported resources are not technically or financially feasible for the well owner to absorb, either independently or with assistance from the GSA, or other available assistance/grant program(s). Additionally, historical reductions in groundwater storage have desiccated GDEs (honey mesquite bosque) in the Subbasin prior to the effective date of SGMA, January 1, 2015 (USGS 1982, 2015; County of San Diego 2009). GDEs are discussed in more detail in Section 3.2.6, Depletions of Interconnected Surface Water.

Under the fixed pumping reduction plan described in Chapter 4 of this GSP, which would ramp down existing levels of pumping to meet the sustainable yield by 2040, it is estimated that an additional 72,000 AF of water would be removed from storage for the period 2020 through 2040. This estimate assumes that the historical climate from 1960 through 2010 repeats for the 50-year planning horizon from 2020 to 2070. Depending on the actual timing and magnitude of pumping reductions and the location and magnitude of future groundwater recharge, the amount of groundwater removed from storage will vary. The implementation of pumping reductions will limit water supply availability such that the present extent of water-intensive agriculture in the Subbasin will be substantially reduced (i.e., the existing trend of agricultural land fallowing will need to be maintained and likely accelerated). The proposed PMAs to mitigate potential effects to beneficial use and users are discussed in Chapter 4.

3.2.3 Seawater Intrusion – Undesirable Results

Undesirable results from seawater intrusion are not considered to be applicable to the Subbasin due to geographic isolation from the ocean. The Subbasin is more than 50 miles from the Pacific Ocean and more than 130 miles from the Gulf of California. As a result, this GSP does not establish criteria for seawater intrusion (Title 23 CCR Section 354.26(d)).

3.2.4 Degraded Water Quality – Undesirable Results

In general, the groundwater quality in the Subbasin meets California drinking water maximum contaminant levels (MCLs) without the need for treatment. As documented in Section 2.2.2.4, Groundwater Quality, naturally occurring poor water quality has been identified in specific areas: near the margins of the Subbasin where unconsolidated sediments are in contact with fractured bedrock; in parts of the SMA where certain wells that tap the lower aquifer have concentrations of arsenic above the drinking water MCL; and near the Borrego Sink where elevated sulfate and TDS are likely associated with dissolution of evaporites from the dry lake. Historical groundwater quality impairment for nitrates is noted for select portions of the Plan Area predominantly in the upper aquifer of the NMA underling the agricultural areas and near high density septic point sources. The source of nitrates is likely associated with either fertilizer applications or septic return flows. In desert environments artificial irrigation of the previously undisturbed desert floor can result in leaching of built up soil nitrate deposits (Walvoord et al. 2003). As discussed in Section 2.2.2.4, several potable wells in the Plan Area have been abandoned because of elevated nitrate above the drinking water MCL.

Degradation of groundwater quality in the upper aquifer has occurred as recharge to the aquifer has mobilized natural and anthropogenic sources of nitrate. The groundwater impacted by nitrate has the potential to migrate laterally as a result of pumping. One strategy successfully implemented to produce potable water in several areas of the Subbasin is to only screen the deeper sediments of the middle and lower aquifer to avoid nitrate that is likely concentrated in the upper aquifer. It should be noted that abandoned wells have the potential to provide a migration pathway of nitrate contaminants from the upper aquifer to the middle and lower aquifers. Hence, proactive abandonment of inactive wells will be considered by the GSA in order to preserve the existing potable water quality, especially where poor water quality has been identified.

Naturally occurring arsenic above the drinking water MCL has been detected in a subset of wells primarily screened in the lower aquifer of the SMA. Arsenic has not been detected at elevated concentrations in the NMA or CMA; however, semi-annual monitoring will track arsenic trends over time.

Degraded water quality is significant and unreasonable if the magnitude of degradation at pre-existing groundwater wells precludes the use of groundwater for existing beneficial use(s), including through migration of contaminant plumes that impair water supplies, where alternative means of treating or otherwise obtaining sufficient alternative groundwater resources are not technically or financially feasible. At a minimum, for municipal and domestic wells, water quality must meet potable drinking water standards specified in Title 22 of the CCR. For irrigation wells, water quality should generally be suitable for agriculture use. The Basin Plan has not established numerical objectives for groundwater quality in the Plan Area but recognizes that in most cases irrigation return flows return to the aquifer with an increase in mineral concentrations such as TDS and nitrate (Colorado River RWQCB 2017). The Basin Plan objective is to minimize quantities of contaminants reaching the aquifer by establishing stormwater and irrigation/fertilizer use best management practices.

Alternative means of obtaining water may consist of connection to the municipal water system (i.e., BWD), wellhead treatment, or for some beneficial users, well abandonment and new well development. Table 3-3 evaluates potential alternative means for addressing degraded water quality for each beneficial user type.

Table 3-3
Means of Addressing Degraded Water Quality

	Municipal Uses	Agricultural Uses	Recreational Uses	Domestic/*De-Minimis* Uses
Connection to Municipal Water System	N/A		✓	✓
Wellhead Treatment	✓	✓	✓	*
Blending Sources	✓	✓	✓	*
Well Abandonment/New Well Construction	✓	✓	✓	*

Notes: N/A = not applicable.

* Depending on water quality degradation, wellhead treatment for domestic/*de-minimis* uses may not be financially feasible in a severely disadvantaged community. Furthermore, domestic and *de-minimis* users may not have the flexibility, nor the technical or financial means to blend sources or drill new wells.

The proposed PMAs, including the Groundwater Quality Optimization Program are discussed in Chapter 4.

3.2.5 Land Subsidence – Undesirable Results

The undesirable result of land subsidence includes an irreversible reduction in groundwater storage, and differential settlement of the land surface that substantially interferes with surface land uses. The U.S. Geological Survey (USGS) evaluated subsidence in the Plan Area using geophysical and remote sensing techniques, including Global Positioning System (GPS) surveys, continuous GPS data collection, and interferometric synthetic aperture radar (InSAR) remote sensing techniques.

The USGS report indicates that GPS surveys are within the expected range of uncertainty, and that there has not been significant land-surface elevation change during the 41-year period from 1969 to 2009 (USGS 2015). The minor amount of subsidence that has occurred when compared to over a hundred feet of groundwater level decline in the northern parts of the Plan Area indicate that the subsurface strata may be less sensitive to land subsidence due to its coarse-grained nature. USGS (2015) also reported subsidence rates based on InSAR method, as described in Chapter 2 for the period from 2003 to 2007, in which the maximum rate of subsidence of 3.75 millimeters per year (or 0.15 inches per year) occurred in the NMA. This is not anticipated to cause undesirable results because the area lacks linear infrastructure that is most sensitive to small subsidence rates, such as canals or high hazard pipelines.

Given the low sensitivity of subsurface strata to land subsidence in response to historical groundwater level declines, along with the lack of infrastructure in the Plan Area that is most sensitive to subsidence, subsidence is also not expected to become an undesirable result within the planning and implementation horizon. If during the GSP implementation timeline, it becomes evident that minimum thresholds and measurable objectives for lowering of groundwater levels and groundwater in storage are not being met, the degree to which land subsidence may become an undesirable result will be re-evaluated.

3.2.6 Depletions of Interconnected Surface Water – Undesirable Results

Under SGMA, depletions of surface waters interconnected with water in the Subbasin that have significant and adverse impacts on beneficial uses of surface waters constitute an undesirable result (CWC Section 10721(x)(6)). This form of undesirable result had been ongoing since the 1940s in the Subbasin due to specific ecological impacts associated with lowering groundwater levels and associated depletion of surface water, including the loss of riparian habitats, and desiccation of GDEs such as the honey mesquite bosque located in the vicinity of the Borrego Sink, as described in Section 2.2.2.6, Groundwater-Surface Water Connections. Potential GDEs mapped along the margins of the Plan Area are disconnected from the Subbasin's groundwater aquifer for the reasons described in Section 2.2.2.6, are fed by surface water flow from outside the Subbasin, and thus are not considered to have a significant nexus to the water table within the Subbasin.

The only vegetation mapped in the basin as a potential GDE is found in and around the Borrego Sink wash (Figure 2.2-19; the Natural Communities Commonly Associated with Groundwater (NCCAG) dataset). The honey mesquite bosque, shown as purple in Figure 2.2-19 north of the Borrego Sink, is considered a pre-2015 impact, because groundwater levels declined many decades ago to a level no longer supporting a viable mesquite bosque habitat. Natural discharge—as determined from the BVHM—attributable to evapotranspiration “was approximately 6,500 acre-feet per year (AFY) prior to development, but has been virtually zero in the last several decades (1990–2010), because the groundwater levels in the basin dropped below the reach of the mesquite in the Subbasin” (USGS 2015). The green area in Figure 2.2-19 depicts the pre-pumping mapped historical extent of phreatophytes in the Subbasin by USGS (USGS 2015). The pink area depicts the mapped pre-January 1, 2015, extent of potential GDEs (SANGIS 2017), and the orange and light blue areas depict the extent of vegetation and wetland communities mapped in the NCCAG dataset (DWR 2018b). The honey mesquite experienced prolonged adverse impacts including desiccation, inability to regenerate and habitat loss well prior to 2015.

Pumping in the Subbasin has resulted in a groundwater level decline of about 44 feet over the last 65 years in the vicinity of the Borrego Sink. The average rate of decline over this 65-year period is approximately 0.67 feet per year. Because of the long-term imbalance of pumping with available natural recharge, an irreversible impact has occurred to the honey mesquite bosque. As discussed in Section 2.2.2.6, the remaining phreatophytes in the Subbasin are supported by periodic storm runoff, percolating surface water (i.e., above the static groundwater level), and/or locally perched layers of groundwater. Given groundwater levels underlying this area of the Subbasin now exceed 55 feet below ground surface, as measured at monitoring well MW-5, and that the estimated rooting depth of the habitat is a maximum of 15.3 feet (USGS 2015), it is unfeasible that any PMA developed by the GSA will result in recovery of the honey mesquite GDE. To restore the honey mesquite GDE, groundwater levels would have to rise by 30 to 40 feet over the course of the GSP implementation period. This is not possible even with cessation of all groundwater use in the basin. And, any such complete cessation of groundwater use would result in other significant and unreasonable impacts and undesirable results to groundwater users in the basin.

The GSA does not consider depletions of interconnected surface water as a current or future undesirable result, because this is a permanent impact that occurred early in the history of the Subbasin. As a result of the long-term trend of declining groundwater levels, the pumping wells in the Subbasin do not draw water that would otherwise support the remaining areas mapped by DWR as NCCAGs. Remaining NCCAGs are now supported by percolating surface water and locally perched layers of groundwater not accessed by pumping wells (Appendix D). Therefore, this GSP does not propose minimum thresholds or measurable objectives related to this sustainability indicator.

3.3 MINIMUM THRESHOLDS

A minimum threshold refers to a numeric value for each sustainability indicator used to define undesirable results (Title 23 CCR Section 351(t)). A GSP must establish minimum thresholds that quantify groundwater conditions for each applicable sustainability indicator at each monitoring site or representative monitoring site. The numeric value used to define minimum thresholds shall represent a point in the basin that, if exceeded, may cause undesirable results (Title 23 CCR Section 354.28(a)).

A GSA may establish a representative minimum threshold for groundwater elevation (GWE) to serve as the value for multiple sustainability indicators, where the GSA can demonstrate the representative value is a reasonable proxy for multiple individual minimum thresholds as supported by adequate evidence (Title 23 CCR Section 354.28(d)). Minimum thresholds are not required for sustainability indicators that are not present and not likely to occur in the Subbasin (Title 23 CCR Section 354.28(e)).

Per Title 23 CCR Section 354.28(b), the description of minimum thresholds shall include the following:

1. The information and criteria relied upon to establish and justify the minimum thresholds for each sustainability indicator. The justification for the minimum threshold shall be supported by information provided in the basin setting, and other data or models as appropriate, and qualified by uncertainty in the understanding of the basin setting.
2. The relationship between the minimum thresholds for each sustainability indicator, including an explanation of how the Agency has determined that basin conditions at each minimum threshold will avoid undesirable results for each of the sustainability indicators.
3. How minimum thresholds have been selected to avoid causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals.
4. How minimum thresholds may affect the interests of beneficial uses and users of groundwater or land uses and property interests.
5. How state, federal, or local standards relate to the relevant sustainability indicator. If the minimum threshold differs from other regulatory standards, the Agency shall explain the nature of and basis for the difference.
6. How each minimum threshold will be quantitatively measured, consistent with the monitoring network requirements described in [the GSP Regulations].

The following sections address minimum thresholds for each of SGMA’s sustainability indicators.

3.3.1 Chronic Lowering of Groundwater Levels – Minimum Thresholds

3.3.1.1 Minimum Threshold Justification

The GSP regulations provide that the "minimum threshold for chronic lowering of groundwater levels shall be the groundwater level indicating a depletion of supply at a given location that may lead to undesirable results" (Title 23 CCR Section 354.28(c)(2)).

Chronic lowering of groundwater levels in the Subbasin, as discussed in Section 3.2.1, Chronic Lowering of Groundwater Levels – Undesirable Results, cause significant and unreasonable declines if they are sufficient in magnitude to lower the rate of production of pre-existing groundwater wells below that necessary to meet the minimum required to support the overlying beneficial use(s), where alternative means of obtaining sufficient groundwater resources are not technically or financially feasible. In addition, GWEs will be managed under the minimum thresholds to ensure the several aquifers in the Subbasin are not depleted in a manner to cause significant and unreasonable impacts to other sustainability indicators. At the same time, the GSA is mindful that groundwater levels are anticipated to fall below 2015 levels before they are stabilized by the end of the GSP implementation period. Thus, the minimum thresholds have been designed with that circumstance in mind.

Maintaining groundwater levels above saturated screen intervals for pre-existing municipal wells during an anticipated multi-year drought circumstance was selected as the minimum desired threshold for GWEs that would be protective of beneficial uses in the Subbasin. This minimum threshold in most cases would also be protective of non-potable irrigation beneficial uses.

Explained as follows, these minimum thresholds are also intended to protect against significant and unreasonable impacts to groundwater storage volumes, water quality and the beneficial uses of interconnected surface water. The development of the minimum thresholds for chronic lowering of groundwater levels included review of the hydrogeologic conceptual model, climate, current historical groundwater conditions including groundwater level trends and groundwater quality, land subsidence data, groundwater-surface water connections and the water budget as discussed in various sections of Chapter 2.

The minimum thresholds for chronic lowering of groundwater levels are based principally on the documented screen intervals of key municipal water wells and domestic/*de-minimis* wells located in the Subbasin. Municipal wells are listed in Table 3-4 along with minimum thresholds corresponding to the top screened interval. Key indicator wells are also shown in Figure 3.3-1. Minimum thresholds are not considered applicable for wells that require replacement, or are not relied upon for a significant source of supply. These wells are as follows: (1) Well ID1-10 well is planned for replacement in 2019; (2) the Wilcox well is an emergency back-up well with no power supply (diesel generator only); (3)

ID1-16 will continue to be used but is planned to be replaced during the GSP implementation period; (4) ID4-18 is proposed for replacement in the future; and (5) ID1-8 is seldom used by the district, and is not anticipated to continue to serve BWD customers over the entire SGMA implementation period. Although the aforementioned wells are not key municipal wells and thus do not have an accompanying minimum threshold, they are included in Table 3-4 for informational purposes. Table 3-4 also lists the year drilled, well depth, blank casing intervals and a recent static depth to groundwater, GWE, aquifers screened, and management area for the BWD wells.

Table 3-4
Borrego Water District Well Screened Intervals and Key Municipal Well Minimum Thresholds

Well	Year Drilled	Well Depth (feet)	Screen Intervals (feet; bgs)	Minimum Threshold / Top of Well Screen (feet; bgs)	Depth to Groundwater (feet; bgs)*	Groundwater Elevation (feet MSL)*	Aquifer	Management Area	Existing Minimum Threshold Exceedance
Improvement District (ID) No. 1									
ID1-8	1972	830	72–240 260–830	72	77.76	448.93	Middle/ Lower	SMA	N/A
ID1-10	1972	392	162–372	N/A	204.2	390.94	Middle	CMA	N/A
ID1-12	1984	580	248–568	248	146.14	387.06	Middle/ Lower	CMA	No
ID1-16	1989	550	160–540	N/A	231.77	388.38	Middle/ Lower	CMA	N/A
Wilcox	1981	502	252–502	N/A	309.78	392.35	Lower	CMA	N/A
Improvement District (ID) No. 4									
ID4-4	1979	802	470–500 532–570 586–786	470	290.88	307.23	Middle/ Lower	NMA	No
ID4-11	1995	770	450–750	450	223.2	390.52	Middle/ Lower	NMA/CMA	No
ID4-18	1982	570	240–300 310–385 395–405 425–440 460–475 490–560	N/A	315.31	375.65	Upper/ Middle	NMA	N/A
Improvement District (ID) No. 5									
ID5-5	2000	700	400–700	400	182.1	394.7	Middle/ Lower	CMA	No

Notes: bgs = below ground surface; MSL = above mean sea level; SMA = South Management Area; N/A = not applicable; CMA = Central Management Area; NMA = North Management Area.

* Fall 2018 measured value, except ID4-11 and Wilcox, which are Spring 2018 measurements (due to active pumping or lack of access at time of Fall 2018 visit).

In Section 3.4, Measurable Objectives, this GSP establishes measurable objectives and interim milestones at the same locations as the minimum thresholds as required by the GSP Regulations (Title 23 CCR Sections 351(g) and 354.30) based on the assumption that the historical climate from 1960 through 2010 repeats for the period 2020 through 2070. A linear reduction in pumping from current levels to a target of 5,700 AFY between 2020 and 2040 was applied in the BVHM to forecast change in Subbasin groundwater storage (Figure 3.3-2). Figure 3.3-2 shows the cumulative change in storage for the entire Borrego Basin for several model runs including the cumulative change in storage from the original USGS model run (1945 through 2010) and the cumulative change in storage for the model update (2011 through 2016). In addition, the model was run to address six different future scenarios. Future scenarios can be divided into two groups:

1. Pumping remains the same as current levels, and
2. A linear reduction in pumping from current levels to a target of 5,700 AFY between 2020 and 2040. Three potential climate scenarios were run for each of the scenarios:
    a. Historical climate from 1960 through 2010 was repeated for the period 2020 through 2070,
    b. California DWR change factors for projected climate conditions in 2030 were applied to the historical period from 1960 through 2010 following the procedures outlined in the DWR climate guidance for GSPs, and
    c. DWR change factors for projected climate conditions in 2070 were applied to the historical period from 1960 through 2010 following the procedures outlined in the DWR climate guidance for GSPs (DWR 2018c).

Applying DWR climate change factors for projected climate conditions in 2030 and 2070 result in an estimated 79,000 AF and 87,000 AF of groundwater removed from storage or an increase of 9.7% and 20.8%, respectively as compared to assuming a repeat of the historical climate scenario. The results indicate that 5,700 AFY of sustainable yield appears to be an acceptable target for sustainable annual withdrawals from the Subbasin, and that changes in future climate conditions are just as likely as not to produce a small impact on storage in the Subbasin when compared to changes in pumping and historical climate variability.

Because water years in which significant natural recharge occurs are infrequent and unpredictable, identifying the degree of climate variability in the Subbasin is a more informative and consequential factor in understanding future conditions than the application of DWR climate change factors to a repeat of historical climate. Although Figure 3.3-2 shows that the difference between a repeat of past climate and the application of DWR climate change factors is notable, the range in future outcomes produced by climate variability is much more significant. Therefore, the GSA evaluated the potential future variability in recharge to the Subbasin over the 20-year implementation period based on the effect of time-varying recharge using a Monte Carlo

Simulation (MCS) uncertainty analysis (ENSI 2018). The BVHM recharge values produced over the model period from 1945 to 2010 served as the basis of the analysis. All of the simulations are based on the target pumping rate of 5,700 AFY being achieved in year 20 of GSP implementation. The MCS uncertainty analysis selected 20-year periods at random from the historical time series from 1945 to 2010. Alternatively, annual data could be randomly selected based on the distribution of values, but this was not done because review of the recharge values shows that there is periodicity within the time series (i.e., decadal dry, wet, and normal climatic periods).

The MCS uncertainty analysis provides for a series of 'what if' analyses where a 20-year SGMA attainment period could occur for any historical 20-year period modeled by the BVHM and thus examine the potential variability in the water balance as exhibited by the model. A total of 53 20-year periods from 1945 to 2016 are evaluated using the MCS uncertainty analysis. Figure 3.3-3 shows the MCS uncertainty analysis simulations in terms of the average and percentiles. Shown are the 20th through 80th percentiles. The 20th percentile line on Figure 3.3-3 indicates the value of the cumulative change in storage. The 20th percentile line represents a result which is higher than 20% of the simulations and lower than 80% of the simulations.

Since the simulations are looking at different time periods, the values translate to rate of occurrence. For example, values below the 20th percentile occur 20% of the time. The change in groundwater in storage, and corresponding change in groundwater level, associated with the 20th percentile was selected as the proposed minimum threshold for the Subbasin meaning that based on 53 20-year periods evaluated, values below the minimum threshold occur 20% of the time and values above the threshold occur 80% of the time. The uncertainty analysis demonstrates that variability in the historical climate and associated recharge is a critical factor to establish minimum thresholds.

In addition to minimum thresholds for BWD key indicator wells, the GSA has set minimum thresholds for key indicator wells throughout the Subbasin which are intended to be protective of beneficial uses and users of groundwater (Table 3-5). As previously mentioned, the climate in the Subbasin is both highly variable and has a decadal periodicity (ENSI 2018). A MCS uncertainty analysis was performed to estimate the effects of reaching a pumping target of 5,700 AFY through incremental reductions by 2040 under a wide range of potential climate scenarios (ENSI 2018). The minimum threshold is based on the estimated degree of groundwater level decline that would occur in each indicator well if the 20th percentile scenario for groundwater recharge were to be realized.

The GSA will evaluate the interim milestones and measurable objectives at least every 5 years based on the preceding GSP implementation period climate and actual realized pumping reductions to determine the likelihood that the Plan will attain sustainability goals. The GSA will adjust the rate of pumping reduction, revisit minimum thresholds, and/or evaluate additional PMAs if the minimum thresholds in Table 3-4 or Table 3-5 are exceeded or if the interim milestones in Table 3-7 are not being achieved. As described in Section 3.5, the GSP establishes a monitoring network in the Subbasin of 50 monitoring sites; however, only those representative sites listed in Table 3-4, Key Municipal Well Minimum Thresholds, and Table 3-5, Key Indicator Wells in Each Management Area, will be used to monitor compliance with the sustainability indicators for each management area, per Title 23 CCR Section 354.36(a). The thresholds in Table 3-4 are intended to establish groundwater level thresholds for municipal water system, whereas those in Table 3-5 are intended to be representative of Subbasin management areas, and reflect domestic, recreational and agricultural beneficial users not connected to the BWD system.

Table 3-5
Minimum Thresholds for Key Indicator Wells in Each Management Area

Management Area	Representative Monitoring Point Well ID	2018 Observed Groundwater Elevation (feet MSL)	Minimum Threshold Maximum allowable decline in groundwater levels as measured at the beginning of GSP Implementation through 2040
NMA	MW-1	377.91	-39
	ID4-3	381.4	-42
	SWID 010S006E09N001S	375.05	-46
	ID4-18	377.94	-44
CMA	ID4-1	393.88	-33
	Airport 2	407.51	-25
	ID1-16	389.75	-33
SMA	MW-5A	409.61	-14
	MW-5B	409.6	
	MW-3	454.38	-12
	Air Ranch	465.47	-9
	ID1-1	468.13	-9

Notes: MSL = above mean sea level; GSP = Groundwater Sustainability Plan; NMA = North Management Area; CMA = Central Management Area; SMA = South Management Area.

3.3.1.2 Relationship between the Established Minimum Thresholds and Sustainability Indicator(s)

a. Relationship between the established minimum thresholds and the Chronic Lowering of Groundwater Sustainability Indicator

The wells described in Table 3-4 and Table 3-5 are in locations that reflect a wide cross section of Subbasin conditions. These locations are representative of overall Subbasin conditions and conditions in each management area because they are spatially distributed throughout the Subbasin both vertically (across aquifers), and laterally. The GSA has determined that use of the minimum elevation thresholds at each of the listed monitoring site locations will help avoid the undesirable results of chronic lowering of groundwater levels because it will minimize the chance that access to adequate water resources for beneficial users within the Subbasin will be compromised.

b. Relationship between the established minimum thresholds and the three other sustainability indicators applicable to the Borrego Subbasin

In addition, and as described more fully as follows, use of GWEs at the cross section of wells outlined in Table 3-4 and Table 3-5, are also appropriate minimum thresholds for the following sustainability indicators: groundwater storage, groundwater quality degradation and, and depletion of interconnected surface waters. As established in Chapter 2, there are no regionally extensive aquitards, so lowering groundwater levels can reasonably be considered a proxy for decreases in groundwater in storage. Furthermore, the mechanism by which the GSA intends to address undesirable results is an incremental pumping reduction plan to reach the sustainable yield of 5,700 AFY by 2040. This measure would also minimize the degree of overdraft. The relationship between the chronic lowering of groundwater levels and water quality is not direct, but deeper groundwater may be the source of elevated arsenic concentrations in the SMA. Chronic lowering of groundwater levels may, therefore, result in the need to treat groundwater for municipal and domestic uses.

3.3.1.3 Minimum Threshold Impacts to Adjacent Basins

As described in the hydrogeologic conceptual model in Section 2.2.1, Hydrogeologic Conceptual Model, subsurface outflow from the Subbasin is minor (estimated at 511 AFY in the southern end of the BVHM model domain). The Coyote Creek fault is interpreted to act as a boundary to groundwater flow between the Subbasin and the Ocotillo-Clark Valley Groundwater Basin (USGS 2015). The adjacent Ocotillo-Clark Valley Groundwater Basin and Ocotillo Wells Subbasin are both “very low” priority basins not required to prepare GSPs. As such, they are not expected to develop descriptive undesirable results or quantitative minimum thresholds and measurable objectives. Thus, the minimum threshold of GWE selected to prevent chronic lowering of groundwater levels and to avoid triggering the other three applicable sustainability indicators in the Subbasin are not expected to cause undesirable results in adjacent basins or adversely affect the ability of adjacent basins to achieve sustainability goals.

3.3.1.4 Minimum Threshold Impact on Beneficial Uses

Beneficial uses and users of groundwater in the Subbasin are discussed in Section 2.1.5.1, Beneficial Uses and Users, and generally include three primary sets of pumpers: agriculture, municipal and recreation. Other Subbasin pumpers include small water systems and *de-minimis* users. The minimum thresholds developed represent points in the Subbasin that, if exceeded, may cause undesirable results (Title 23 CCR Section 354.28(a)). It is expected that, if GWEs fall below the established minimum thresholds, water supplies available to beneficial uses and users in the Subbasin will be limited or challenging to produce, and significant and unreasonable water quality and other adverse impacts to sustainability indicators may occur.

As a result, the PMA Section of the GSP (Chapter 4) describes the GSA's plan to establish: (1) Baseline Pumping Allocations for each non-*de-minimis* pumper of groundwater in the Subbasin, and (2) a ramp down schedule using a linear reduction in pumping to reach the planning sustainability target of 5,700 AFY. Once implemented, the latter is expected to require an approximate 19% reduction in pumping every 5 years from the Baseline Pumping Allocation of 21,963 AFY for a total estimated reduction of about 74%. Baseline Pumping Allocations were determined based on the maximum water use by individual (non-*de-minimis*) pumpers over the 5-year baseline period of January 1, 2010, to January 1, 2015. The Baseline Pumping Allocation also includes allocations for water credits issued in conjunction with the County/BWD program for sites fallowed prior to adoption of the GSP, municipal water use previously reduced through end use efficiency and conservation efforts, and recreation use curtailed prior to GSP adoption. The estimated water use by sector is 71.6% for agriculture, 18.5% for recreation, 9.7% for municipal, and 0.3% for other users based on the total Baseline Pumping Allocation.[8] Agricultural water use occurs over approximately 2,624 acres (according to updated estimates by the GSA in 2018), municipal water use includes 2,059 residential and commercial connections, and recreational water use includes six golf courses with approximately over 400 acres of irrigated turf.

As described in Chapter 4, the GSA proposes to develop water trading, water conservation and efficiency, land fallowing, and pumping reduction programs to mitigate the impacts of mandated pumping reductions. These programs will be designed to maximize beneficial uses while recognizing the finite availability of groundwater resources in the Subbasin. The proposed aggregate pumping allowance at each 5-year milestone and for achieving Subbasin sustainability is presented in Table 3-6.

Table 3-6
Proposed Aggregate Pumping

Year	Baseline Pumping Allocation (AFY)	Percent Reduced	Pumping Allowance (Percent)	Pumping Allowance (AFY)
0	21,938	0.0%	100%	21,938
5		18.5%	81.5%	17,879
10		37.1%	63.0%	13,819
15		55.6%	44.5%	9,760
20		74.1%	26.0%	5,700

Notes: AFY = acre-feet per year.

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[8] Water credits are currently not included in the Baseline Pumping Allocation but may be converted to Baseline Pumping Allocation during GSP implementation.

3.3.1.5 Comparison between Minimum Threshold and Relevant State, Federal, or Local Standards

The GSA is not aware of any other state, federal, or local standards specific to addressing the lowering of groundwater levels in the Subbasin. As part of the implementation of PMAs, additional biological analysis may be required in some circumstances and may have relevance to future iterations of the minimum thresholds. The California Environmental Quality Act (Guidelines Appendix G) has a requirement to examine whether a program or project would "substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)." However, the management criteria established in this GSP merely clarify the meaning of this requirement in the local context of the Subbasin, and are not conflicting or inconsistent.

With regard to local standards, there are no quantitative standards that define or limit specific GWEs or amount of allowable groundwater level decline. As further described in Chapter 2, when the County prepares a general plan (including community plan) update process, the GSP will be a key consideration with respect to related goals and policies. The implementation of this GSP and the County's general plan update process are separate but related processes. Future general plan and community plan updates should consider the sustainability goals of this GSP. This GSP may be referred to by reference within future general plan and community plan updates.

3.3.1.6 Minimum Threshold Measurement Method

The static groundwater level will be measured at each identified minimum threshold well (key indicator wells) at least two times per year to evaluate groundwater level elevation trends at anticipated seasonal low and seasonal high groundwater conditions. All measurements will comply with the Sampling and Analysis Plan and Quality Assurance Project Plan (Appendix E) and will be entered in to the GSA's data management system. The monitoring network is described in further detail in Section 3.5, Monitoring Network.

3.3.2 Reduction of Groundwater Storage – Minimum Thresholds

3.3.2.1 Minimum Threshold Justification

Reduction of groundwater in storage in the Subbasin as discussed in Section 3.2.2, Reduction of Groundwater Storage – Undesirable Results, is significant and unreasonable if it is sufficient in magnitude to lower the rate of production of active groundwater wells below the minimum required to support the overlying beneficial use(s), where an alternative means of obtaining sufficient groundwater resources is not technically or financially feasible. As discussed in Section 3.3.1, Chronic Lowering of

Groundwater Levels – Minimum Thresholds, domestic wells are generally located in areas that have a groundwater level substantially above the average depth of wells, with some exceptions shown in Figure 3.2-4. Furthermore, in most cases it would be technically and financially feasible to connect domestic and *de-minimis* users to the municipal water system, should they experience a significant loss in production rate attributable to groundwater level declines.

As discussed in Section 2.2.3.7, Surface Water Available for Groundwater Recharge or In-Lieu Use, neither imported nor recycled water is economically viable for alternative water supply. Stormwater capture and infiltration has limited potential in the Subbasin due to the arid environment and infrequent availability of stormwater runoff. The usable quantity of groundwater in storage is large compared to average annual natural recharge to the Subbasin. On average, the Subbasin lost approximately 7,300 AFY from storage for the period between 1945 and 2015. Over the last 10 years, the Subbasin lost approximately 13,137 AFY, based on the BVHM model results as described in Section 2.2.3, Water Budget. The long-term deficits in the groundwater budget resulted in an estimated 520,000 AF of water removed from storage from 1945 to 2016.

In order to reach the current target sustainability of 5,700 AFY, a linear pumping reduction is proposed to bring the basin into sustainability by 2040. The estimated pumping reduction over the applicable period is 74% from the Baseline Pumping Allocation. The Baseline Pumping Allocation is based on maximum annual groundwater extraction by each non-*de-minimis* pumper in the Subbasin during the period from January 1, 2010, to January 1, 2015. Hence, some pumping reductions, such as those for municipal end-use efficiency and water credits sites, have already been realized.

BVHM simulations that include a target pumping rate of 5,700 AFY in 2040, linear reduction in pumping, and an assumption that the historical climate from 1960 through 2010 was repeated for the period 2020 through 2070 to simulate future conditions, indicate a net deficit of 72,000 AF for groundwater in storage over the 20-year Plan implementation period. As discussed in Section 3.3.1.1, the change in groundwater in storage associated with the 20th percentile was selected as the proposed minimum threshold for the Subbasin meaning that based on fifty-three 20-year periods evaluated, values below the minimum threshold occur 20% of the time and values above the threshold occur 80% of the time (Figure 3.3-3).

The overdraft ‘curve’ that assumes a 5,700 AFY average annual recharge is approximately equal to the 55th percentile of the MCS analysis, meaning target sustainability occurs in 45% of the simulations. The GSA will evaluate the interim milestones and measurable objective at least every 5 years based on the preceding GSP implementation period climate and realized pumping reductions to determine the likelihood that the Plan will attain sustainability goals. If necessary, the GSA will adjust the rate of pumping reduction or evaluate additional PMAs if the minimum threshold is exceeded or the interim milestone is not being achieved.

3.3.2.2 Relationship between Minimum Threshold and Sustainability Indicator(s)

The minimum threshold for reduction of groundwater storage is related to the other applicable sustainability indicators, including chronic lowering of groundwater levels and degraded groundwater quality. The minimum threshold for reduction in groundwater storage, which will be directly correlated with the minimum threshold for chronic lowering of groundwater levels, will protect against losses of groundwater in storage sufficient to lower the rate of production of pre-existing groundwater wells below the minimum required to support the overlying beneficial use(s), as further described in Section 3.2.2.1, Minimum Threshold Justification.

3.3.2.3 Minimum Threshold Impacts to Adjacent Basins

As described in Section 3.3.1.3, Chronic Lowering of Groundwater Levels – Minimum Threshold, the minimum threshold selected for reduction of storage avoids causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals.

3.3.2.4 Minimum Threshold Impact on Beneficial Uses

The minimum thresholds developed will limit the availability of water supply to beneficial uses and users in the Subbasin as discussed in Section 3.3.1.4, Chronic Lowering of Groundwater Levels – Minimum Threshold. The minimum threshold impact on beneficial uses for both chronic lowering of groundwater level and reduction of groundwater storage is the same.

3.3.2.5 Comparison between Minimum Threshold and Relevant State, Federal, or Local Standards

The comparison between minimum threshold and relevant state, federal, or local standards is generally the same as previously discussed for Section 3.3.1.4, Chronic Lowering of Groundwater Levels – Minimum Threshold. The only difference is that San Diego County currently has cumulative analysis and mitigation standards for permitting discretionary projects with water demands in the Borrego Valley Exemption area, in which adequate water availability must be determined in consideration of surrounding uses and users. It is anticipated these standards will be superseded by this GSP and will be equally or more protective of groundwater in storage.

3.3.2.6 Minimum Threshold Measurement Method

Reduction in groundwater storage is not a parameter that can be directly measured; rather, change in storage will be regularly estimated based on either the Subbasin water budget or monitoring results derived from analysis of GWEs and aquifer properties as discussed in Section 3.5.2, Monitoring Protocols for Data Collection and Monitoring. To monitor the changes in storage to the Subbasin, the generalized water budget equation is as follows:

Sum of inflows – Sum of outflows = Change in storage

The water budget is an accounting framework used to quantify all inflows and outflows from the Subbasin over a given period of time, with the difference equating to the change in storage. The BVHM is used to estimate the water budget. The simulated water budget included water inputs from underflow, infiltrating rainfall, applied irrigation, and infiltrating surface water flows in creeks (i.e., losing streams); the water outputs included evapotranspiration, pumping, and subsurface flow out of the Subbasin. The water budget developed using the USGS model is an important tool to manage water resources and will be updated at least every 5 years to document progress toward achieving Subbasin sustainability.

On at least an annual basis, change in groundwater storage will be estimated based on change in GWEs. This involves documenting change in measured GWEs at all monitoring program wells in the Subbasin over a given period of time. The GWE change is then multiplied by the overlying Subbasin area and estimated specific yield of the aquifer sediments to determine the change in groundwater storage. Changes in storage in the Subbasin are determined from the generalized GWE and aquifer properties equation:

$$\text{Overlying Area} \times (GWE_{t0} - GWE_{t1}) \times \text{Specific Yield} = \text{Change in Storage}$$

Groundwater elevation surfaces will be created from measured GWE data using a geographic information system (GIS) for specific time periods (e.g., Spring 2020 and Spring 2021). Each surface represents a specific elevation of the groundwater table. The difference between the two surfaces multiplied by the surface area of the Subbasin represents the change in saturated volume of aquifer material between the two periods. This difference will be calculated using GIS and multiplied by the specific yield to estimate the change in groundwater storage. The reduction in groundwater storage will be calculated annually and reported by the GSA to document progress toward the sustainability goal.

Monitoring parameters for this sustainability indicator/minimum threshold include routine groundwater level measurements. Additionally, the hydrogeologic properties of the aquifer will be updated as additional pump test data becomes available.

3.3.3 Seawater Intrusion – Minimum Thresholds

As described in Section 3.2.3, Seawater Intrusion – Undesirable Results, seawater intrusion is not an applicable undesirable result in the Subbasin and a minimum threshold is not warranted.

3.3.4 Degraded Water Quality – Minimum Thresholds

Degraded water quality in the Subbasin, as discussed in Section 3.2.4, Degraded Water Quality – Undesirable Results, is significant and unreasonable if it is sufficient in magnitude to affect use of pre-existing groundwater wells such that the water quality precludes the use of groundwater to support the overlying beneficial use(s), and that alternative means of obtaining sufficient groundwater resources are not technically or financially feasible. For municipal and domestic wells, this means water quality that meets potable drinking water standards specified in Title 22 of the CCR. For irrigation wells, water quality should generally be suitable for agriculture use. As indicated in the Basin Plan, irrigation return flows and septic recharge returns to the aquifer with an increase in mineral concentrations such as TDS and nitrate. The Basin Plan objective is to minimize quantities of contaminants reaching the aquifer by establishing stormwater best management practices. A PMA to optimize water quality is discussed in Chapter 4.

3.3.4.1 Minimum Threshold Justification

The minimum threshold for degraded water quality is protective of existing and potential beneficial uses and users in the Subbasin. Alternative means of addressing degraded water quality such as wellhead treatment may also be technically and financially achievable.

3.3.4.2 Relationship between Minimum Threshold and Sustainability Indicator(s)

Degraded water quality is related to the sustainability indicators: chronic lowering of groundwater levels and reduction in groundwater storage. As groundwater levels decline and storage decreases there exists the potential for increased concentration of constituents of concern (COCs) as a result of poorer water quality identified in parts of the lower aquifer. Additionally, poor water quality associated with irrigation return flow and septic recharge that has percolated to the aquifer has the potential to migrate laterally as a result of pumping. Degraded water quality is not a predictor of other sustainability indicators. Rather, it is a potential response. As such, it is sufficient to establish the minimum threshold for degraded water quality in isolation from the other sustainability indicators.

3.3.4.3 Minimum Threshold Impacts to Adjacent Basins

As described in Section 3.3.1.3, Chronic Lowering of Groundwater Levels – Minimum Threshold, the minimum threshold selected for degraded water quality is protective of causing undesirable results in adjacent basins or affecting the ability of adjacent basins to achieve sustainability goals.

3.3.4.4 Minimum Threshold Impact on Beneficial Uses

The minimum threshold for degraded water quality maintains existing and potential future beneficial uses.

3.3.4.5 Comparison between Minimum Threshold and Relevant State, Federal, or Local Standards

The minimum threshold for degraded water quality is compliant with potable drinking water standards specified in Title 22 of the CCR and water quality objectives established in the Basin Plan.

Section 13241, Division 7 of the CWC, specifies that, "[e]ach regional board shall establish such water quality objectives in water quality control plans as in its judgement will ensure the reasonable protection of beneficial uses and the prevention of nuisance; however, it is recognized that it may be possible for the quality of water to be changed to some degree without unreasonably affecting beneficial uses..." The GSA is mindful that the Basin Plan indicates that investigative studies will be conducted to develop groundwater objectives and implementation plans for the Borrego Subarea.

3.3.4.6 Minimum Threshold Measurement Method

Groundwater quality will be monitored on a semi-annual basis at key, representative monitoring and extraction wells (shown in Table 3-4 and Table 3-5) located in each of the three management areas: NMA, CMA, and SMA. All measurements will comply with the *Sampling and Analysis Plan and Quality Assurance Project Plan* (Appendix E) and be recorded in the GSA's data management system. The monitoring network and monitoring protocols are described in Section 3.5, Monitoring Network, and Section 3.5.2, Monitoring Protocols for Data Collection and Monitoring. Groundwater quality trends will be evaluated semi-annually using the Mann-Kendall test to assess whether or not the historical dataset exhibits a trend with a selected significance level of 0.05 or confidence interval of 95%. Water quality results will be compared to background water quality objectives discussed in Section 3.4.4, Degraded Water Quality – Measurable Objectives, and potable drinking water standards specified in Title 22 of the CCR.

3.3.5 Land Subsidence – Minimum Thresholds

As explained in Section 3.2.5, Land Subsidence – Undesirable Results, land subsidence is not presently an applicable undesirable result in the Subbasin and a minimum threshold is not presently warranted.

3.3.6 Depletions of Interconnected Surface Water – Minimum Thresholds

As described in Section 3.2.6, Depletions of Interconnected Surface Water, the impact of groundwater pumping within the Subbasin to GDEs occurred prior to 2015 and thus a minimum threshold is not being proposed by the GSA.

3.4 MEASURABLE OBJECTIVES

Standards for Establishing Measurable Objectives

Under Chapter 6 of SGMA, a GSP is to include "measurable objectives, as well as interim milestones in increments of 5 years, to achieve the sustainability goal in the basin within 20 years of implementation of the plan" (CWC Section 10727.2(b)(1)). In addition, the plan is to describe "how the Plan helps meet each objective and how each objective is intended to achieve the sustainability goal for the basin for the long-term beneficial uses" (CWC Section 10727.2(b)(2)). The GSP Regulations define "measurable objectives" as "specific, quantifiable goals for the maintenance or improvement of specified groundwater conditions that have been included in an adopted Plan to achieve the sustainability goal for the basin" (Title 23 CCR Section 351(s)).

Per GSP Regulations (Title 23 CCR Section 354.30):

> a. Each Agency shall establish measurable objectives, including interim milestones in increments of five years, to achieve the sustainability goal for the basin within 20 years of Plan implementation and to continue to sustainably manage the groundwater basin over the planning and implementation horizon.
>
> b. Measurable objectives shall be established for each sustainability indicator, based on quantitative values using the same metrics and monitoring sites as are used to define the minimum thresholds.
>
> c. Measurable objectives shall provide a reasonable margin of operational flexibility under adverse conditions which shall take into consideration components such as historical water budgets, seasonal and long-term trends, and periods of drought, and be commensurate with levels of uncertainty.
>
> d. An Agency may establish a representative measurable objective for groundwater elevation to serve as the value for multiple sustainability indicators where the Agency can demonstrate that the representative value is a reasonable proxy for multiple individual measurable objectives as supported by adequate evidence. Each Plan shall describe a reasonable path to achieve the sustainability goal for the basin within 20 years of Plan implementation, including a description of interim milestones for each relevant sustainability indicator, using the same metric as the measurable objective, in increments of five years. The description shall explain how the Plan is likely to maintain sustainable.

The measurable objectives developed for each of the applicable sustainability indicators in this GSP are based on the current understanding of the Plan Area and basin setting as discussed in detail in Chapter 2. In particular, evaluation of the water budget as described in Section 2.2.3, Water Budget, concluded that the sustainable yield of the Subbasin is approximately 5,700 AFY and a 74% curtailment of pumping from the Baseline Pumping Allocation would be required to achieve the target sustainability goal. As discussed in Section 3.3.1, Chronic Lowering of Groundwater Levels – Minimum Threshold, a linear reduction in pumping from current levels to a target of 5,700 AFY between 2020 and 2040 was applied in the BVHM to forecast change in Subbasin groundwater storage and groundwater levels at each of the BWD wells and for key indicator wells in the Subbasin. Use of the BVHM to develop measurable objectives for chronic lowering of groundwater levels and reduction of groundwater in storage is discussed in the following sections. Additionally, the basis for establishing the measurable objective for degraded water quality and depletions of interconnected surface water are also described.

3.4.1 Chronic Lowering of Groundwater Levels – Measurable Objectives

A reasonable margin of operational flexibility under adverse conditions was factored in when developing minimum thresholds and measurable objectives for chronic lowering of groundwater levels. The minimum threshold is based on a statistical evaluation of historical climate and the probability of reoccurrence as discussed in Section 3.3.1, Chronic Lowering of Groundwater Levels – Minimum Threshold. The minimum threshold for chronic lowering of groundwater levels is based on the 20th percentile, meaning 20% of the time groundwater recharge is greater than the 53 20-year historical periods evaluated. For municipal wells, the minimum threshold is equivalent to the top of the well screen.

The reduction of groundwater in storage ‘curve’ that assumes a 5,700 AFY average annual recharge is approximately equal to the 55th percentile meaning target sustainability occurs for 45% of the simulations using historical climate.

The measurable objective for chronic lowering of groundwater levels is based on the average annual recharge. Table 3-7 presents observed groundwater levels, observed groundwater level trends, interim milestones and measurable objectives by Subbasin management area for key indicator wells, as well as key municipal wells. The difference between minimum thresholds, measurable objectives, and the current groundwater table level is visually depicted in Figure 2.4-1 for the key municipal wells. The methodology used to establish interim milestones assumes a consistent pumping reduction applied uniformly across all pumping wells in the Subbasin, and approximates average conditions based on the BVHM. Therefore, the GSA will evaluate progress toward meeting interim milestones based on average conditions by management area.

Table 3-7
Measurable Objectives for Groundwater Levels

Representative Monitoring Point Well ID	2018 Observed Groundwater Elevation (feet MSL)	Observed Groundwater Level Trend (feet per year)	2020 Interim Milestone (feet MSL)	2025 Interim Milestone (feet MSL)	2030 Interim Milestone (feet MSL)	2035 Interim Milestone (feet MSL)	Measurable Objective Value (feet MSL)
North Management Area							
MW-1	377.91	-2.14	373	367	364	363	363
ID4-3	381.4	-2.09	377	371	369	368	368
SWID 010S006E09N001S	375.05	-2.48	370	367	366	365	365
ID4-18	377.94	-2.31	373	369	367	367	367
Central Management Area							
ID4-1	393.88	-1.39	391	381	375	370	370
Airport 2	407.51	-1.67	404	394	387	382	382
ID1-16	389.75	-0.95	388	384	376	370	370
South Management Area							
MW-5A	409.61	-0.74	408	400	393	387	384
MW-5B	409.6	-0.74	408	400	393	387	384
MW-3	454.38	-5.84	443	440	437	434	433
Air Ranch	465.47	-0.50	464	462	460	458	458
ID1-1 (RH-1)	468.13	-0.94	466	463	460	457	456
BWD Key Municipal Indicator Wells							
ID4-4	305.33	-2.73	300	291	285	284	284
ID4-11	390.52	-2.29	386	366	358	355	355
ID1-12	386.81	-1.51	384	377	370	369	368
ID5-5	394.7	-0.85	393	384	378	377	377

Notes: MSL = above mean sea level; BWD = Borrego Water District.
Methodologies: The 2020 interim milestone is based on the spring 2018 observed groundwater elevation subtracted from the absolute value of the contemporary observed groundwater level trend multiplied by 2 years. The 2025, 2030, 2035 and measurable objective are based on the results of the BVHM estimates of change in groundwater in storage and corresponding change in groundwater head at each model node with linear fixed reduction to the estimated sustainable yield target of 5,700 acre-feet per year and the applied 2030 DWR climate change factors. In cases where there was a groundwater level increase between 2035 and 2040, the measurable objective was held at 2035 levels. Note SWID 010S006E09N001S has a limited groundwater level record and was determined by subtracting Spring 2018 measurement from the Spring 2017 measurement.

The interim milestones define the planned pathway to sustainability and are meant to track progress toward achieving sustainability.

The GSA recognizes that climate change enhances the probability, magnitude, and periodicity of extreme precipitation events and that recharge over the 20-year GSP implementation period is an estimation. As such, the interim milestones for chronic lowering of groundwater levels will be closely monitored to determine whether the Subbasin is on track to achieve its sustainability goals. The GSA will annually review actual Subbasin groundwater extraction, historical and contemporary groundwater level trends, changes in groundwater storage, and climatic condition (i.e., dry, normal, wet year/period) to determine whether metrics indicate the Subbasin is on track to achieve its sustainability goals.

The GSA will provide at a minimum a 5-year outlook for proposed pumping reductions and annually review the pumping allowance in terms of achieving sustainability goals. The GSA may amend the pumping allowance to achieve and maintain the sustainability goals. The intent of the 5-year outlook is to provide clear direction to the groundwater extractors regarding the availability of water supply over the next 5-year period. The GSA will provide 5-year outlooks for the start of GSP implementation and for each of the 5-year milestones. If the GSA amends the pumping allowance in any given year, they will provide a minimum 5-year outlook that will be reevaluated at the next 5-year milestone.

3.4.2 Reduction of Groundwater in Storage – Measurable Objectives

The reduction of groundwater in storage measurable objective was developed using the same methodology as chronic lowering of groundwater levels. The estimated reduction of groundwater in storage simulated using the BVHM was used to establish the interim milestones and measurable objective, as described in Section 3.4.1, Chronic Lowering of Groundwater Levels – Measurable Objective. The reduction of groundwater in storage measurable objectives are listed in Table 3-8 for the BVHM model domain.

Table 3-8
Reduction of Groundwater in Storage Interim Milestones and Measurable Objectives

Year	Percent Pumping Reduced	Pumping Allowance (percent)	Pumping Allowance (acre-feet per year)	Cumulative Reduction of Groundwater in Storage (acre-feet)
0 (Baseline)	0.0%	100%	21,938[a]	0
5 (Interim Milestone)	18.5%	81.5%	17,879	43,500
10 (Interim Milestone)	37.1%	63.0%	13,819	73,000
15 (Interim Milestone)	55.6%	44.5%	9,760	76,600
20 (Measurable Objective)	74.1%	26.0%	5,700	72,000

Notes:

[a] The Baseline Pumping Allocation currently does not include Water Credits that may be converted to Baseline Pumping Allocation during GSP implementation.

3.4.3 Seawater Intrusion

As explained in Section 3.2.3, Seawater Intrusion – Undesirable Results, seawater intrusion is not an applicable undesirable result in the Subbasin and a measurable objective is not warranted.

3.4.4 Degraded Water Quality – Measurable Objectives

Extraction wells in the Subbasin are generally screened in the upper, middle, or lower aquifers or cross-screened in multiple aquifers. These principal aquifers are discussed in Section 2.2.1.3, Principal Aquifers and Aquitards. Many extraction wells have long well screens intercepting multiple aquifers. Wellhead concentrations represent the average water quality of the formations producing flow to the well and in most cases do not represent the water quality of a specific aquifer or zone. As discussed Section 2.2.2.4, Groundwater Quality, the primary COCs identified in the Subbasin include arsenic, fluoride, nitrate, sulfate, and TDS.

As discussed in Section 3.3.4, Degraded Water Quality – Undesirable Results, the minimum threshold for degraded water quality is based on intended beneficial uses. For domestic or municipal supply (MUN), the minimum water quality means water quality that meets potable drinking water standards specified in Title 22 of the CCR. For irrigation wells, minimum water quality should generally be suitable for agriculture use. To develop a measurable objective for degraded water quality, the Basin Plan water quality objectives have been considered. The Regional Water Quality Control Board (RWQCB), Colorado River Region Basin Plan recognizes that, "[e]stablishment of numerical objectives for groundwater involves complex considerations since the quality of groundwater varies significantly with depth of well perforations, existing water levels, geology, hydrology and several other factors" (Colorado River RWQCB 2017). The Basin Plan does not have specific water quality objectives for groundwater. Groundwater quality suitability for agricultural use is industry and crop-specific, but can be gaged through conformance with generally accepted threshold limits for irrigation used by State Water Resources Control Board, and/or through continued engagement with growers within the Subbasin. If groundwater quality destined for irrigation is measured as meeting Title 22 standards, it would also be suitable for irrigation, as drinking water quality objectives are stricter than those that would make groundwater suitable for irrigation use.

Since the aforementioned standards are minimum thresholds, the GSA's measurable objective is for groundwater quality for the identified COCs within municipal and domestic wells exhibit stable or increasing trend, as measured at each 5-year evaluation. For irrigation wells, the measurable objective is the same as the minimum threshold (i.e., that water quality be of suitable quality for agricultural use).

3.4.5 Land Subsidence Measurable Objectives

As explained in Section 3.2.5, Land Subsidence – Undesirable Results, land subsidence is not presently an applicable undesirable result in the Subbasin and a measurable objective is not warranted at this time.

3.4.6 Depletions of Interconnected Surface Water – Measurable Objectives

As discussed in Section 3.3.6, Depletions of Interconnected Surface Water – Minimum Thresholds, there is not sufficient information at this time to establish a minimum threshold or measurable objective for depletions of interconnected surface water. Based on information provided by the DWR and best available data, actions implementable by the GSA such as pumping reductions and PMAs do not appear to have a substantial nexus with mitigating depletions of interconnected surface water. Specifically, a pre-SGMA impacted GDE associated with the honey mesquite bosque located in the vicinity of the Borrego Sink and potential GDEs located along the fringes of the Subbasin.

3.5 MONITORING NETWORK

Standards for Establishment of Monitoring Networks

Under SGMA, a GSP is to contain information regarding:

1. The monitoring and management of groundwater levels within the basin;
2. The monitoring and management of groundwater quality, groundwater quality degradation;
3. The type of monitoring sites, type of measurements, and the frequency of monitoring for each location monitoring groundwater levels, groundwater quality, subsidence, streamflow, precipitation, and evaporation, including a summary of monitoring information such as well depth, screened intervals, and aquifer zones monitored, and a summary of the type of well relied on for the information, including public, irrigation, domestic, industrial, and monitoring wells; and
4. Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin (CWC Section 10727.2).

According to GSP Regulations, the GSP is also to include descriptions of:

- How the monitoring network is capable of collecting sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative information about groundwater conditions as necessary to evaluate Plan implementation
- Monitoring network objectives including explanation of how the network will be developed and implemented to monitor:
  - Groundwater and related surface conditions
  - Interconnection of surface water and groundwater

- How implementation of the monitoring network objectives demonstrate progress toward achieving the measurable objectives, monitor impacts to beneficial uses or users of groundwater, monitor changes in groundwater conditions, and quantify annual changes in water budget components
- How the monitoring network is designed to accomplish the following for each sustainability indicator:
    - Chronic Lowering of Groundwater Levels. Demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features
    - Reduction of Groundwater Storage. Estimate the change in annual groundwater in storage
    - Seawater Intrusion. Monitor seawater intrusion
    - Degraded Water Quality. Determine groundwater quality trends
    - Land Subsidence. Identify the rate and extent of land subsidence
    - Depletions of Interconnected Surface Water. Calculate depletions of surface water caused by groundwater extractions
- How the monitoring plan provides adequate coverage of the sustainability indicators
- The density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends
- The scientific rational (or reason) for site selection
- Consistency with data and reporting standards
- For each well, the corresponding sustainability indicator, minimum threshold, measurable objective, and interim milestone
- The location and type of each monitoring site on a map (Title 23 CCR Section 354.34).

Monitoring Network

The overall objective of the monitoring network in the Borrego Springs Subbasin is to track and monitor parameters to demonstrate progress toward meeting the sustainability goals, including the minimum thresholds and measurable objectives defined in Section 3.3 and Section 3.4, respectively. In 2017, the GSA developed a *Sampling and Analysis Plan and Quality Assurance Project Plan* (SAP/QAPP), and in August 2018, the GSA developed a *Groundwater Extraction Metering Plan* (both included in Appendix E). The monitoring network is described in Chapter 2, Section 2.2.2.2, and the monitoring plan is described below in terms of each applicable sustainability indicator, including monitoring protocols and monitoring plan assessment and improvement. The monitoring plan described below will be re-evaluated periodically to address findings of the data and compliance criteria presented in this GSP. It is expected that data collected throughout implementation of this GSP may be used to validate and update the BVHM.

The monitoring plan was prepared pursuant to the DWR's *Best Management Practices for Sustainable Management of Groundwater, Monitoring Networks, and Identification of Data Gaps (BMP)* (DWR 2016), and considers relevant data and studies performed to date for the Subbasin. Consistent with the recommendations of the BMP, the monitoring plan includes monitoring objectives and recommendations for collecting data that demonstrate short- and long-term trends in groundwater, and progress toward achieving measurable objectives. The monitoring plan is also designed to monitor impacts to beneficial uses of groundwater, and to quantify annual changes in water budget components. Monitoring objectives, previous studies and ongoing monitoring programs, data quality objectives, and monitoring scope are described in detail below.

3.5.1 Description of Monitoring Network

The monitoring network is designed to collect sufficient data to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and provide representative information about Subbasin-wide groundwater conditions as necessary to evaluate Plan implementation. The most critical sustainability criteria to be monitored directly for the Subbasin are chronic lowering of groundwater levels and degraded water quality at the key indicator wells listed in Table 3-4 and Table 3-5 (Figure 3.3-1). Direct measurement of groundwater levels across the wider monitoring network described in Chapter 2 (Table 2.2-4) will be used to calculate and evaluate reductions in groundwater storage. No direct measurements of seawater intrusion, land subsidence, and depletions of interconnected surface water are proposed at this time.

The scope of monitoring is subdivided below consistent with the sustainability indicators.

3.5.1.1 Chronic Lowering of Groundwater Levels – Monitoring Network

As a critically overdrafted basin, groundwater levels in the Subbasin are the most obvious and important metric for basin sustainability, closely followed by water quality conditions. In addition, the effect of chronic lowering of groundwater levels will also be observed within each of the other sustainability indicators. The groundwater level-monitoring network currently consists of 50 wells, including 23 dedicated monitoring wells and 27 extraction wells. Of the 50 wells in the network, 46 are monitored for water levels, 30 are monitored for water quality, and 19 are monitored for production, as explained in Section 2.2.2, Current and Historical Groundwater Conditions, and shown on Figure 2.2-12. The Subbasin monitoring density for GWE is currently approximately 48 wells per 100 square miles (Plan Area is approximately 98 square miles). While there is no definitive rule for the density of groundwater monitoring points needed in a basin, for comparison the monitoring well density recommended by CASGEM Groundwater Elevation Monitoring Guidelines ranges from 1 to 10 wells per 100 square miles (DWR 2010). Per GSP Regulation

Section 354.2(a), the key indicator wells identified in Table 3-4 and Table 3-5 are proposed as the representative monitoring sites for the chronic lowering of groundwater sustainability indicator.

Wells were selected for monitoring based on a combination of factors, including geographic location, screen interval relative to the three principal aquifers, accessibility, well condition, and continuity of historical data. The groundwater level monitoring program incorporates all feasible wells in the Subbasin at this time; however, the network is expected to be further refined as access is gained to additional wells or new wells are drilled in the Subbasin. The GSA has recently inspected several private wells to determine potential to include into the monitoring network and is working with private property owners to gain access for long-term monitoring. In addition to tracking groundwater levels at key indicator wells in the Subbasin, collected data will also be used to update groundwater level elevation contour and direction of groundwater flow maps.

Groundwater production is currently recorded monthly for 11 active BWD wells and 12 golf course wells. Additionally, many private pumpers record groundwater production at monthly or annual intervals. Upon Plan adoption, all non-*de-minimis* groundwater extractors will be required to record monthly groundwater production and report to the GSA on an annual basis. The GSA secured Proposition 1 grant funding to install a limited number of flow meters at wells and is currently working with private well owners to get flow meters installed. It is expected that the property owner (or third-party contractor acceptable to the GSA) would monitor/read the meter on a monthly basis. A third-party contractor acceptable to the GSA would inspect and read the meter on a semi-annual basis to verify the accuracy of data including meter calibration. On behalf of the property owner, the third-party contractor would provide an annual statement to the GSA with verification of the total extraction in gallons from each well and verification that each flow meter is calibrated to within factory acceptable limits. The GSA will keep data confidential to the maximum extent allowed by law (California Govt. Code 6254(e)). The approach for well metering is detailed further in the *Groundwater Extraction Metering Plan* provided as Appendix E.

The current groundwater level monitoring network is capable of collecting data of sufficient accuracy and quantity to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions.

The entire groundwater monitoring network is shown in Figure 2.2-12, whereas the key indicator wells used to track progress towards interim milestones and measurable objectives are shown in Figure 3.3-1 and Figure 3.4-1.

- Short-term trends are tracked by pressure transducers currently installed and maintained in 17 wells that record groundwater levels at intervals of 15 minutes to 1 hour (sub-daily).
- Seasonal trends are tracked by semi-annual GWE monitoring of 46 wells in the spring and fall.

- Long-term trends are tracked by analysis of data from key indicator wells monitored semi-annually in each of the management areas with historical data dating back to the mid-1950s.

The groundwater level network is sufficiently representative of groundwater conditions in the Subbasin necessary to update the BVHM and track sustainability metrics discussed in the previous sections. As discussed in Section 2.2.1.3, Principal Aquifers and Aquitards, the groundwater system has been subdivided into three principal aquifers consisting of the upper, middle and lower aquifers. Most wells are cross-screened in more than one aquifer and aquifer-specific groundwater levels are limited. As described in Section 2.2.2.1, Geology and Geologic Structure, review of existing GWE data within the Plan Area suggests that although three distinct aquifers are delineated in varying thickness across the Subbasin, the effect of well screen lengths and intervals is potentially negligible with respect to measured depths to groundwater (i.e., potentiometric surface).

Therefore, although the GSA may not be able to obtain data from groundwater monitoring wells screened solely in each of the three aquifer units in each of the three management areas, these data gaps are not considered significant with regard to groundwater levels, given all the other available data points. As such, for the purposes of the GSP, the need for wells screened solely in each vertical aquifer unit independently does not appear to be necessary to achieve adequate spatial representation of GWEs in the Subbasin.

3.5.1.2 Reduction of Groundwater in Storage Monitoring Network

Reduction in groundwater storage is not a parameter that can be directly measured; rather, change in storage will be estimated based on the Subbasin water budget every 5 years and monitoring results derived from analysis of GWE changes annually (aquifer properties will be refined if there are additional pump tests performed within the Subbasin). The wider monitoring network shown in Table 2.2-4 will be used to update groundwater level elevation contour and direction of groundwater flow maps. Based on the availability of sufficient aquifer properties and GWE data, monitoring of groundwater levels in the Subbasin is a sufficient surrogate for evaluating reduction of groundwater in storage (Title 23 CCR Section 354.36(b)). The method for measurement of estimating annual reduction of groundwater in storage is described in Section 3.3.2.6, Minimum Threshold Measurement Method.

3.5.1.3 Degraded Water Quality Monitoring Network

The monitoring network currently includes sampling of 30 wells on a semi-annual basis to determine and track groundwater quality trends. Wells are monitored for potential COCs that were previously identified in part by the USGS and DWR, and a review of the historical data by the GSA. The COCs include arsenic, fluoride, nitrate, sulfate and TDS. Additionally, in Fall 2017, general minerals were analyzed to establish baseline water quality and for comparison of water quality type for all wells monitored. Radionuclides were also analyzed to determine baseline conditions but are not currently considered a COC.

Five additional wells are proposed to be added to the monitoring network in Fall 2018 to further evaluate both groundwater levels and groundwater quality in the CMA to better track trends in this more developed area of the Subbasin. Additionally, the GSA continues to work with private landowners to expand the monitoring network.

3.5.1.4 Seawater Intrusion Monitoring Network

As explained in Section 3.2.3, Seawater Intrusion – Undesirable Results, seawater intrusion is not an applicable undesirable result in the Subbasin and monitoring is not warranted.

3.5.1.5 Land Subsidence Monitoring Network

As explained in Section 3.2.5, Land Subsidence – Undesirable Results, land subsidence is not an applicable undesirable result in the Subbasin and monitoring is not warranted. If during the GSP implementation timeline, it becomes evident that minimum thresholds and measurable objectives for lowering of groundwater levels and groundwater in storage are not being met, the degree to which land subsidence may become an undesirable result will be re-evaluated.

3.5.1.6 Depletions of Interconnected Surface Water Monitoring Network

As explained in Section 3.2.6, Depletions of Interconnected Surface Waters – Undesirable Results, the impact of groundwater pumping within the Subbasin to GDEs occurred prior to 2015, is neither currently nor expected to become an undesirable result, and thus monitoring is not warranted.

3.5.2 Monitoring Protocols for Data Collection and Monitoring

Standards for Establishing Monitoring Protocols

“Under SGMA, the GSP must contain monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin. The CWC Section 10727.2(f). According to GSP Regulations, “Each Plan shall include monitoring protocols adopted by the Agency for data collection and management, as follows:

a. Monitoring protocols shall be developed according to best management practices.

b. The Agency may rely on monitoring protocols included as part of the best management practices developed by the Department, or may adopt similar monitoring protocols that will yield comparable data.

c. Monitoring protocols shall be reviewed at least every five years as part of the periodic evaluation of the Plan, and modified as necessary” (Title 23 CCR Section 352.2).

Protocols in the Borrego Subbasin

The protocols for data collection and monitoring are detailed in the SAP/QAPP (Appendix E). The SAP/QAPP will be updated periodically to address findings of the data and compliance criteria presented in this GSP. The SAP provides a sampling and analysis plan that includes sampling objectives, potential COCs, monitoring frequency, methods for GWE and quality monitoring, and sample handling. The QAPP defines roles and responsibilities, quality objectives and criteria, special training, documentation and records, field and laboratory analytical methods, field and laboratory quality control, assessments and response actions, data reduction, review, verification and validation, data evaluation roles and responsibilities, and data reporting. Technical standards, data collection methods and quality assurance are described in detail in the SAP/QAPP to ensure comparable data and methodologies (Appendix E).

3.5.3 Representative Monitoring

Standards for Representative Monitoring

The GSP Regulations provide that a GSA may designate a subset of monitoring sites as representative of conditions in the basin as follows:

1. Representative monitoring sites may be designated by the Agency as the point at which sustainability indicators are monitored, and for which quantitative values for minimum thresholds, measurable objectives, and interim milestones are defined.
2. Groundwater elevations may be used as a proxy for monitoring other sustainability indicators if the Agency demonstrates the following:
   a. (1) Significant correlation exists between groundwater elevations and the sustainability indicators for which groundwater elevation measurements serve as a proxy.
   b. (2) Measurable objectives established for groundwater elevation shall include a reasonable margin of operational flexibility taking into consideration the basin setting to avoid undesirable results for the sustainability indicators for which groundwater elevation measurements serve as a proxy.
3. The designation of a representative monitoring site shall be supported by adequate evidence demonstrating that the site reflects general conditions in the area (Title 23 CCR Section 354.36).

GWEs and water quality are the primary indicators to be directly measured and are the only sustainability indicators for which representative monitoring points are warranted at this time. GWEs are also a proxy for evaluation of storage as previously described in Section 3.5.1.2.

Measurement of other sustainability indicators (i.e., seawater intrusion, subsidence, and depletion of interconnected surface water) is not currently warranted as described in Section 3.5.1.

Representative monitoring points have been selected in each of the three management areas. Multiple representative monitoring points are warranted within each management area to address the diversity of land uses, proximity to pumping centers and recharge areas, elevation differences, etc. As such, selected representative monitoring points are anticipated to be updated as the Subbasin pumping centers evolve or other pertinent data are obtained over the GSP implementation period. Representative monitoring points are presented in Table 3-9 and plotted on Figure 3.3-1.

Table 3-9
Representative Monitoring Points

Management Area	Well ID	Rationale
North Management Area	MW-1	Dedicated monitoring well downgradient of agricultural pumping center, screened in the lower-middle/lower aquifers
	ID4-3	Proximal and cross-gradient of agricultural pumping center and golf course (De Anza). No log or well completion information is available.
	SWID 010S006E09N001S	Proximal to agricultural pumping center and suspected nitrate source areas, screened in the middle and lower aquifer
	ID4-18	Proximal and cross-gradient of agricultural pumping center and screened in the upper/upper-middle aquifers
	ID4-4	Key Municipal Water Well
Central Management Area	ID4-1	Located in central portion of community of Borrego Springs with predominantly drinking water beneficial use. No log or well completion information is available.
	Airport 2	Representative of eastern portion of CMA, screened in the middle and lower aquifer
	ID1-16	Representative of southwestern portion of CMA, screened in the middle and lower aquifers
	ID4-11	Key Municipal Water Well
	ID1-12	Key Municipal Water Well
	ID5-5	Key Municipal Water Well
South Management Area	MW-5A	Effective well pair to evaluate vertical differences (groundwater levels and water quality), located near Borrego Sink, screened in the middle/lower aquifers
	MW-5B	Effective well pair to evaluate vertical differences (groundwater levels and water quality), located near Borrego Sink, screened in the upper/middle aquifers
	MW-3	Dedicated monitoring well representative of pumping effects near golf course (Rams Hill) screened in the middle/upper-lower aquifers.
	Air Ranch Well 4	Representative of conditions in southeast SMA, screened in the lower aquifer

Notes: CMA = Central Management Area; SMA = South Management Area.

3.5.4 Assessment and Improvement of Monitoring Network

Standards for Assessment and Improvement of Monitoring Network

Section 354.38 of the GSP Regulations provide that a GSA should continue to assess and improve the monitoring network throughout the planning and implementation horizon, as follows:

1. Each Agency shall review the monitoring network and include an evaluation in the Plan and each 5-year assessment, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin.
2. Each Agency shall identify data gaps wherever the basin does not contain a sufficient number of monitoring sites, does not monitor sites at a sufficient frequency, or utilizes monitoring sites that are unreliable, including those that do not satisfy minimum standards of the monitoring network adopted by the Agency.
3. If the monitoring network contains data gaps, the Plan shall include a description of the following:

a. The location and reason for data gaps in the monitoring network.

b. Local issues and circumstances that limit or prevent monitoring.

4. Each Agency shall describe steps that will be taken to fill data gaps before the next five year assessment, including the location and purpose of newly added or installed monitoring sites.
5. Each Agency shall adjust the monitoring frequency and density of monitoring sites to provide an adequate level of detail about site-specific surface water and groundwater conditions and to assess the effectiveness of management actions under circumstances that include the following:

a. Minimum threshold exceedances.

b. Highly variable spatial or temporal conditions.

c. Adverse impacts to beneficial uses and users of groundwater.

3.5.4.1 Review and Evaluation of the Monitoring Network

The Subbasin monitoring network will be reviewed and evaluated for effectiveness annually and for each 5-year assessment. The review and evaluation will address uncertainty and data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin, and will consider localized effects that may not be represented throughout the respective management area. The evaluation is described in more detail in Section 5.4.5, Monitoring Network, of the GSP.

3.5.4.2 Identification of Data Gaps

Groundwater Elevation

Identification of data gaps for GWEs must consider vertical and lateral representation of the Subbasin and management areas. For vertical control, as discussed in Section 2.2.2, Current and Historical Groundwater Conditions, review of existing GWE data within the Plan Area suggests that although three distinct aquifers are delineated in varying thickness across the Subbasin, the effect of well screen lengths and intervals is potentially negligible with respect to measured depths to groundwater (i.e., potentiometric surface). Multicompletion wells or well clusters screened at discrete intervals in the upper, middle and lower aquifers would be required to determine potentiometric surface by aquifer unit. However, the average potentiometric surface measured at wells that are screened over one or more aquifer units appears to sufficiently represent groundwater conditions in the Subbasin with respect to monitoring the applicable sustainability indicators.

Laterally, the pattern of existing overlying land uses and beneficial uses of groundwater are well represented by the management areas, which the monitoring network covers. As conditions may change throughout GSP implementation, representation of overlying land uses and beneficial groundwater uses will be evaluated annually along with the network's reliability (i.e., access). Each monitoring well will be tracked and the need for alternative or additional monitoring wells will be evaluated as part of the annual and 5-year review processes, as described in Section 5.4.5, Monitoring Network, of the GSP.

As described in Section 3.5.1.1, based on the nature of the Subbasin and review of historical data, semi-annual monitoring is an appropriate monitoring frequency to continue to track seasonal trends and addresses the minimum standards of the monitoring network.

Groundwater Quality

As discussed in Section 2.2.2.4, Groundwater Quality, there are both anthropogenic and natural sources of the COCs in the Subbasin. All COCs are found in differing concentrations in the upper, middle, and lower aquifers. Extraction wells in the Subbasin are generally screened in the upper, middle, or lower aquifers or cross-screened in multiple aquifers. As such, water quality samples collected at the wellhead represent an average concentration of the formations screened and do not represent depth-discrete or aquifer specific conditions. Multicompletion wells or depth discrete water quality samples would be required to better characterize water quality by aquifer zone and depth in the Subbasin. For example, water quality results indicate that there is elevated arsenic detected at concentrations above drinking water standards in the lower aquifer of the SMA. As the occurrence of wells screened in discrete aquifer zones is limited, especially for the lower aquifer in the NMA and CMA, it is uncertain if elevated arsenic occurs at depth in these areas of the Subbasin. Additionally, there is limited contemporary data available for private wells located in the NMA and CMA to laterally and vertically delineate nitrate and TDS concentrations in the upper aquifer.

Regulatory Data Gaps

SGMA requires that the Plan consider relevant state, federal, and local standards. As such, pertinent regulatory agencies are considered stakeholders. Summaries of data gaps associated with relevant agencies are provided below:

- RWQCB – The Colorado River RWQCB has not established water quality objectives for the Region, and acknowledges that "[e]stablishment of numerical objectives for groundwater involves complex considerations since the quality of groundwater varies significantly with depth of well perforations, existing water levels, geology, hydrology and several other factors" (Colorado River RWQCB 2017).

Borrego Valley Hydrologic Model

SGMA requires that the GSA identify data gaps and uncertainty associated with key water budget components and model forecasts, and develop an understanding of how these gaps and uncertainty may affect implementation of proposed projects and water management actions.

As explained in the *Update to U.S. Geological Survey Borrego Valley Hydrologic Model for the Borrego Valley Sustainability Agency* (contained in Appendix D), the sensitivity analysis conducted by the USGS indicated the greatest uncertainty in the numerical model was in agricultural pumping, streamflow leakage, and storage. As new data are collected and an improved understanding of the basin is developed over time, through either additional characterization, monitoring efforts, or both, the predictive accuracy of the BVHM could be improved, as needed, at annual updates and the 5-year review process. This is because new data could allow for a refinement of the underlying model assumptions (aquifer properties, stratigraphy, boundary conditions, etc.) and/or a more robust calibration due to a larger database of calibration targets (groundwater levels, surface water flows, a more robust climatic dataset, etc.).

To improve the accuracy of the BVHM in simulating actual conditions and provide greater confidence in predictive simulations, the GSA intends to obtain additional data and further study the hydrogeology of the basin:

- Collect actual agricultural pumping data via existing or installation of new flow meters at farm wells. The pumping data may be incorporated in the numerical model to calibrate the Farm Process Package to more accurately estimate the water demands for the various crops and golf courses being irrigated.

- Collect periodic manual streamflow measurements at major drainages that convey most of the surface water runoff to the valley, either from perennial flows or flash flows from major precipitation events. Collection of this information can be used to further verify the accuracy of the Basin Characterization Model used in the BVHM, and ultimately to provide a more accurate estimate of stream leakage.

Additional data gaps noted within this GSP, which would improve the accuracy of the BVHM, but may not be necessary to adequately apply sustainable management criteria include:

- Conduct aquifer tests at wells with screen intervals isolated to only the upper aquifer or the middle aquifer to obtain site-specific estimates of hydraulic conductivity and specific yield for each aquifer unit. This information may be used to enhance the calibration of the model to these hydraulic properties and our understanding of storage in the Subbasin.
- Evaluate subsurface inflow and outflow along the Coyote Creek fault. Currently, the Coyote Creek fault is interpreted to act as a boundary to groundwater flow between the Subbasin and the Ocotillo-Clark Valley Groundwater Basin. However, supplemental analysis of boundary conditions may be warranted to estimate a value of underflow to substantiate the working assumption regarding the negligible effect on the Subbasin water balance across this portion of the Subbasin boundary.

3.5.4.3 Description of Steps to Fill Data Gaps

The process for addressing identified data gaps is for the GSA to evaluate the potential significance of the data gaps, anticipated duration, costs, and overall benefit to the effectiveness of the GSP. Initial tasks to address existing data gaps include the following:

- If the Colorado River RWQCB develops interim water quality measurable objectives, the GSA will coordinate for determination of defensible water quality objectives.
- The GSA will evaluate opportunities for gathering additional data on existing or new monitoring wells screened in the upper aquifer of the NMA to determine the nature and extent of nitrate concentrations in the upper aquifer underlying areas of historical agricultural fertilizer application.
- The GSA will evaluate opportunities for gathering additional data on existing or new monitoring wells screened in the lower aquifer of the NMA and CMA to determine if poor water quality occurs with depth in the Subbasin, such as the elevated arsenic detected in the lower aquifer of the SMA.

3.5.4.4 Description of Monitoring Frequency and Density of Sites

Based on Subbasin conditions, as described in GSP Chapter 2; Section 3.5.1.1, Chronic Lowering of Groundwater Levels Monitoring Network; and the monitoring plan (described above), semi-annual monitoring of water quality and water elevations is considered adequate to demonstrate short-term, seasonal, and long-term trends in groundwater and related surface conditions, and yield representative data to compare to measurable objectives and minimum thresholds.

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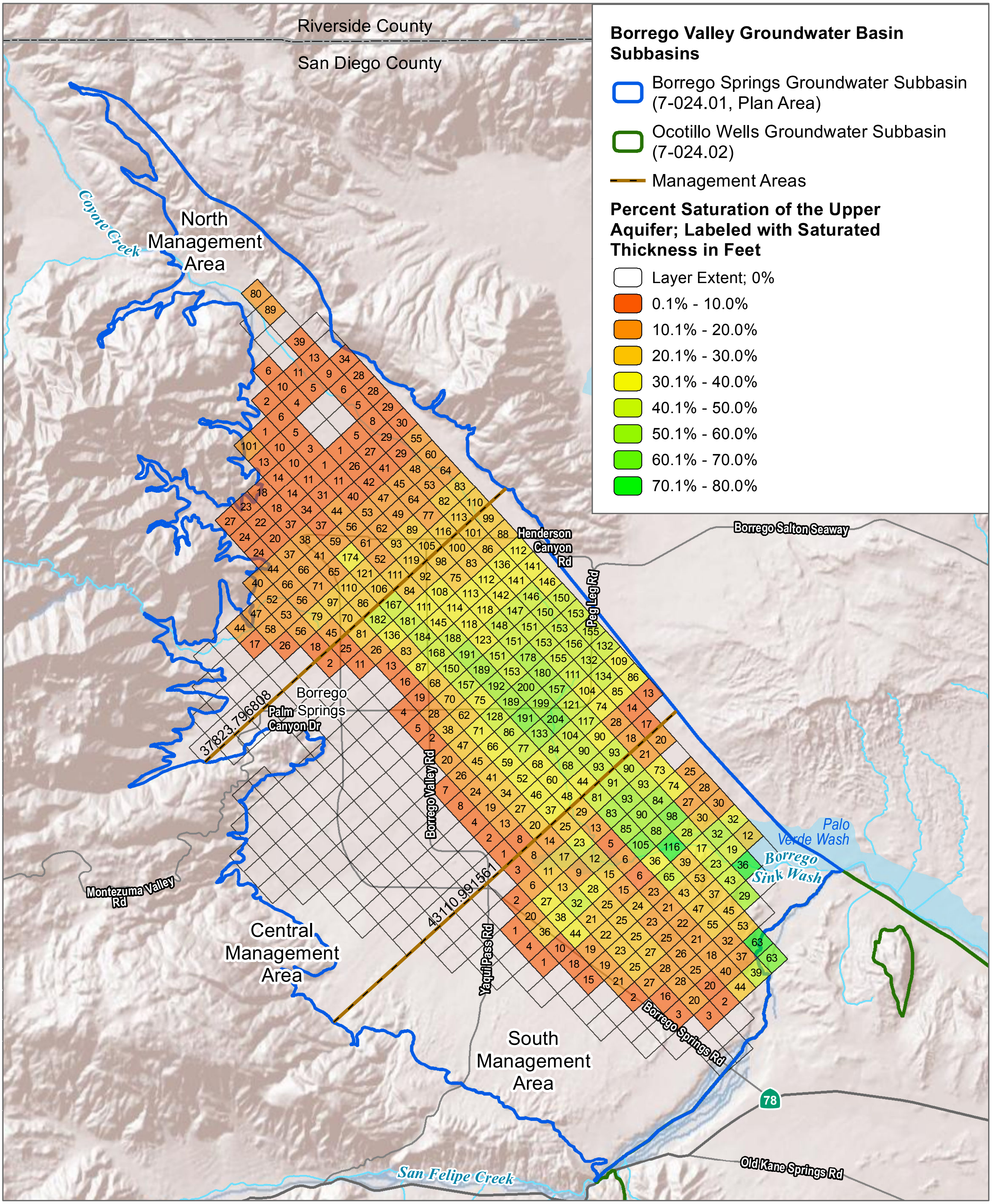

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: DWR 2015, USGS 2015

DUDEK

0 1 2 Miles

Figure 3.2-1
Model Upper Aquifer Saturated Thickness - September 2016

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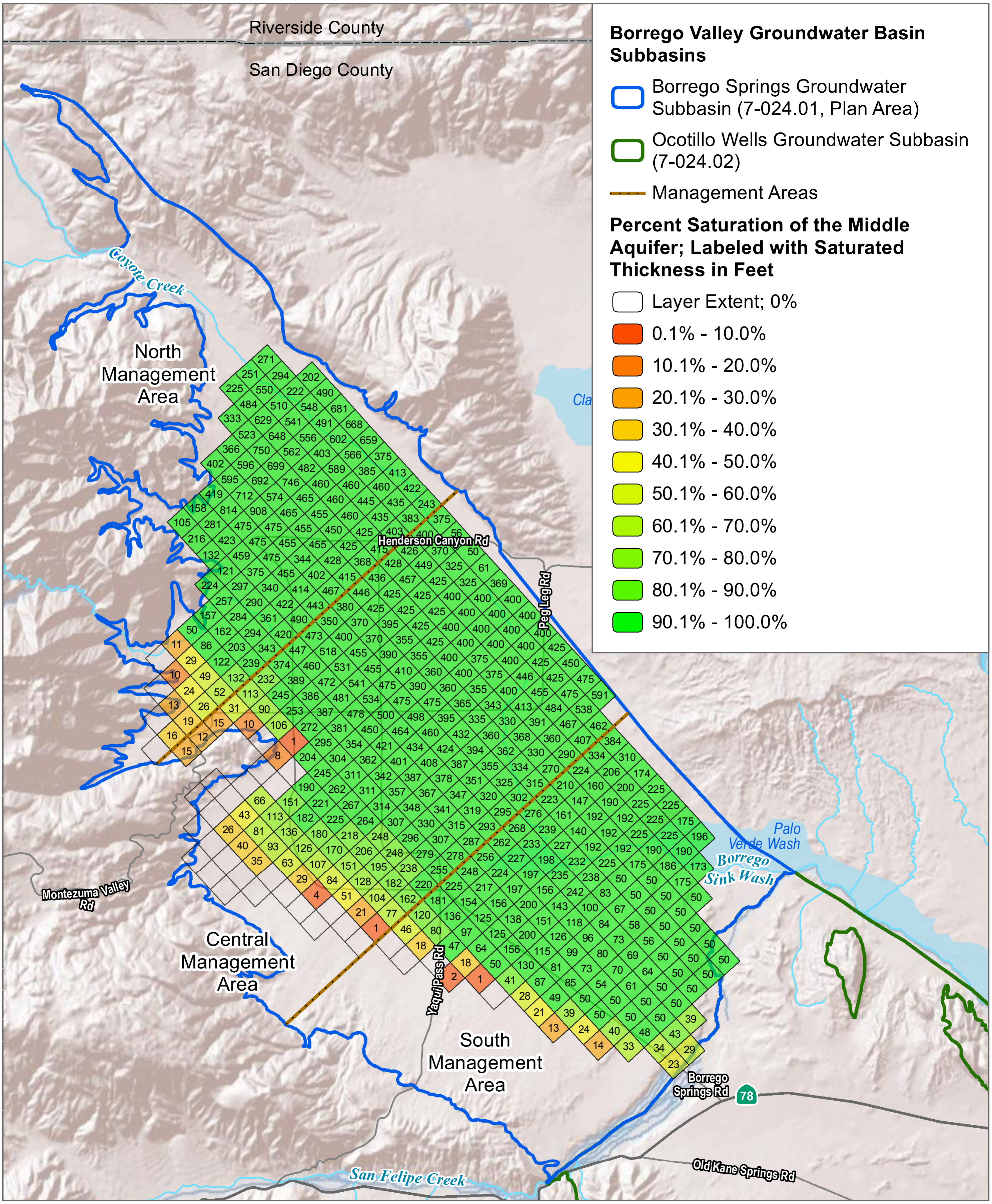

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DATUM: NAD 1983. DATA SOURCE: DWR 2015, USGS 2015

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Figure 3.2-2

Model Middle Aquifer Saturated Thickness - September 2016

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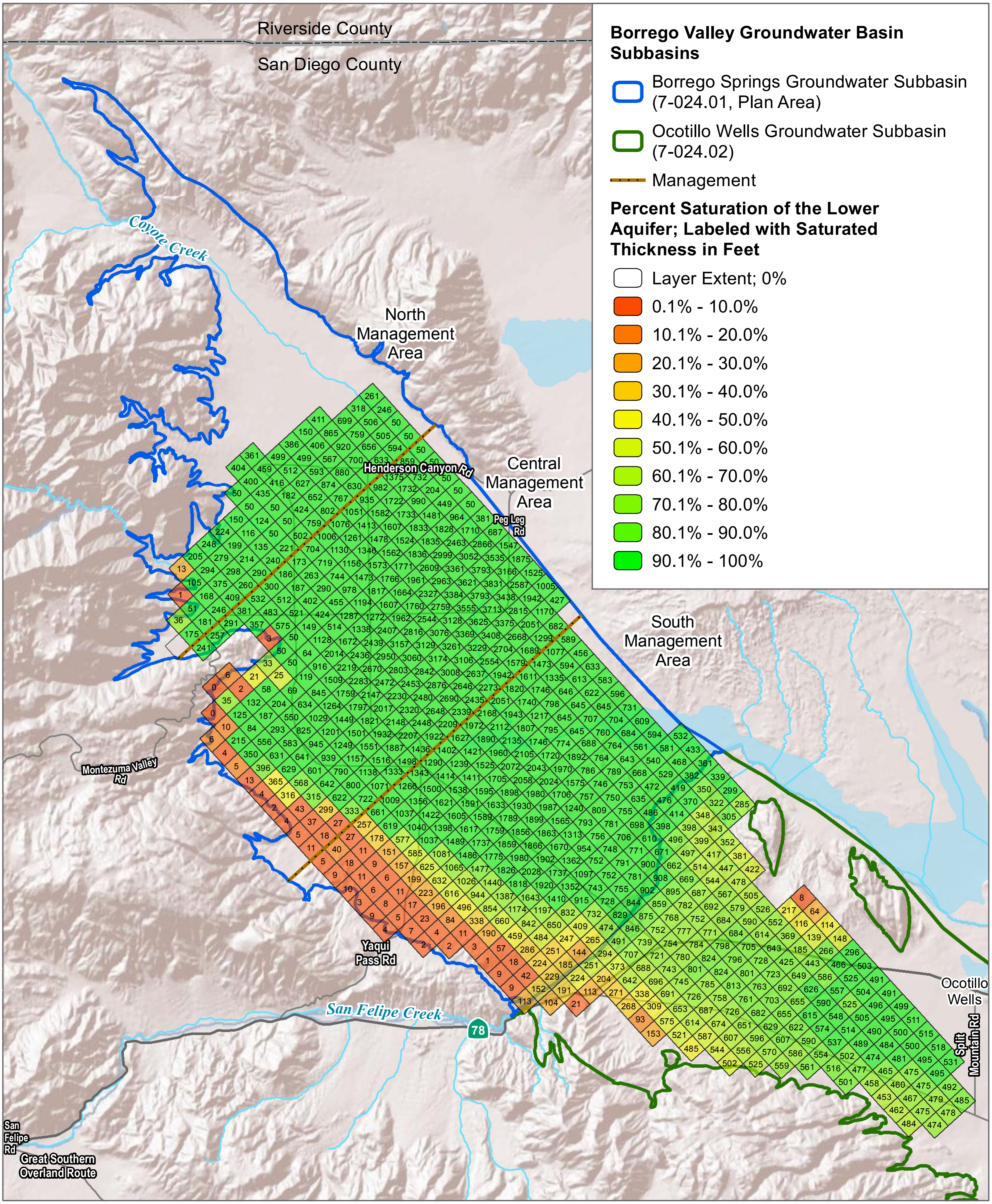

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DATUM: NAD 1983. DATA SOURCE: DWR 2015, USGS 2015

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0 1.25 2.5 Miles

Figure 3.2-3
Model Lower Aquifer Saturated Thickness - September 2016

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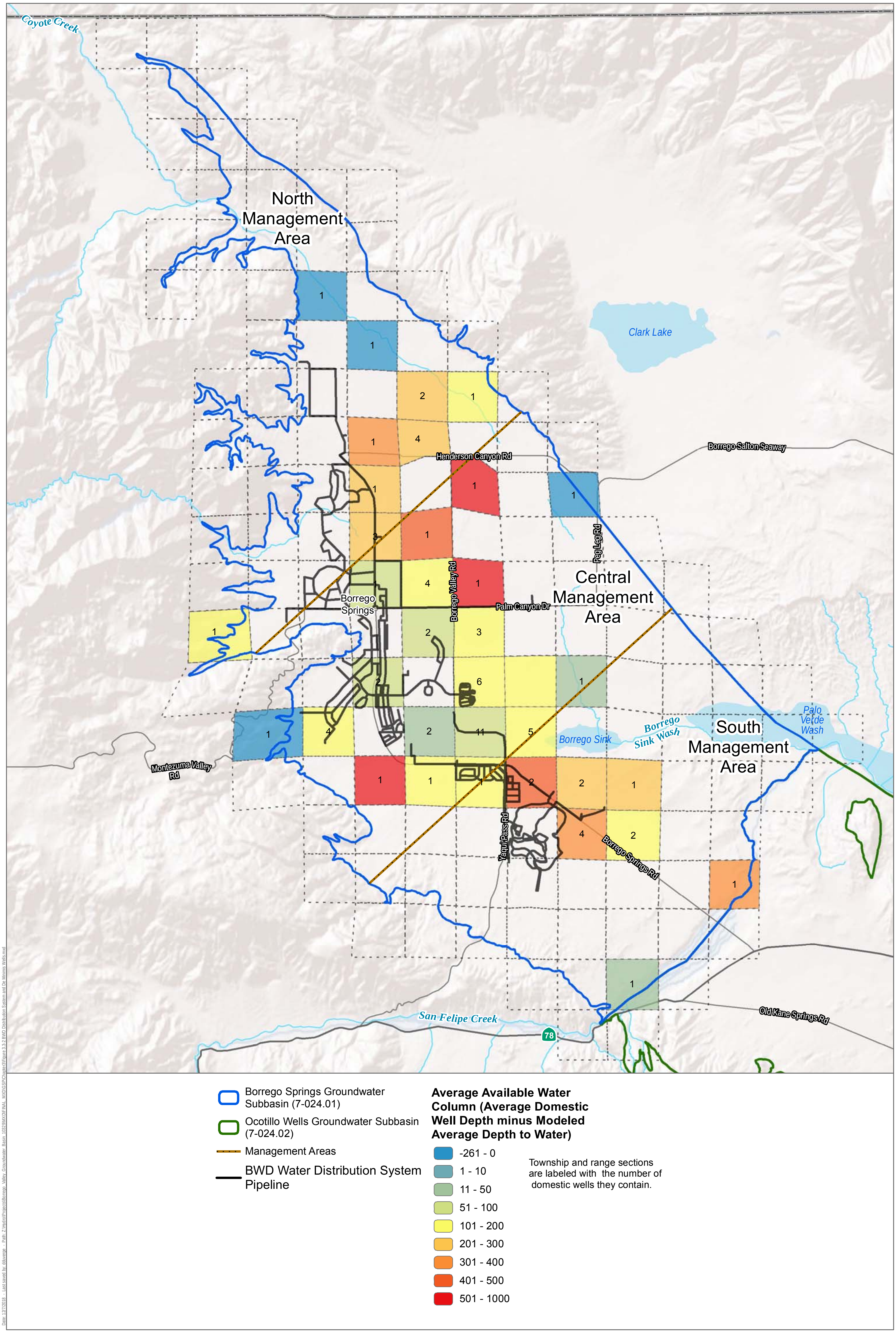

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DATUM: NAD 1983. DATA SOURCE: SanGIS 2017, BWD, DWR 2018

0 0.75 1.5 Miles

Figure 3.2-4

BWD Distribution System and De Minimis Users

Borrego Valley Groundwater Basin Groundwater Sustainability Plan

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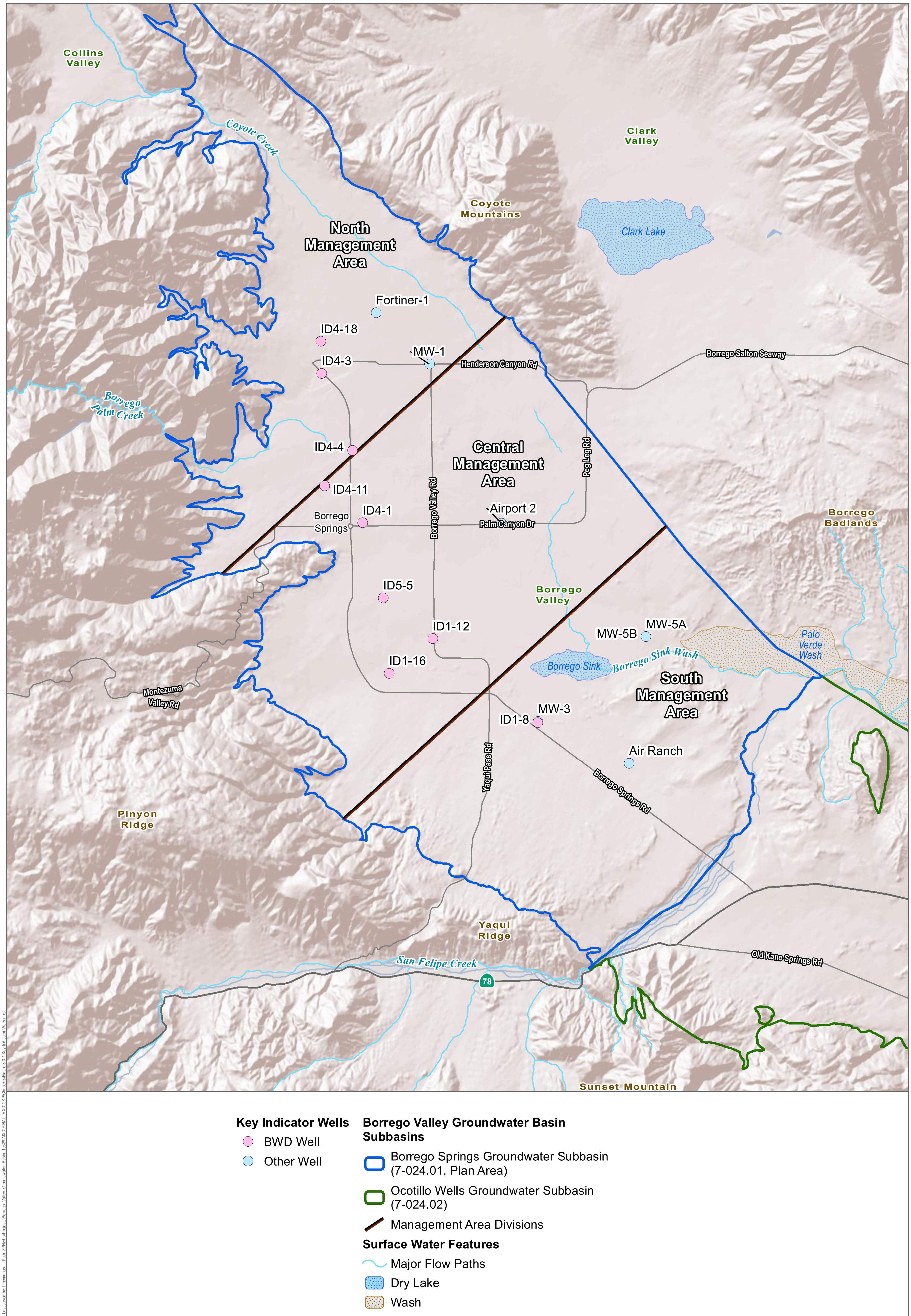

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DATUM: NAD 1983.

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0 0.75 1.5 Miles

Figure 3.3-1
Key Indicator Wells

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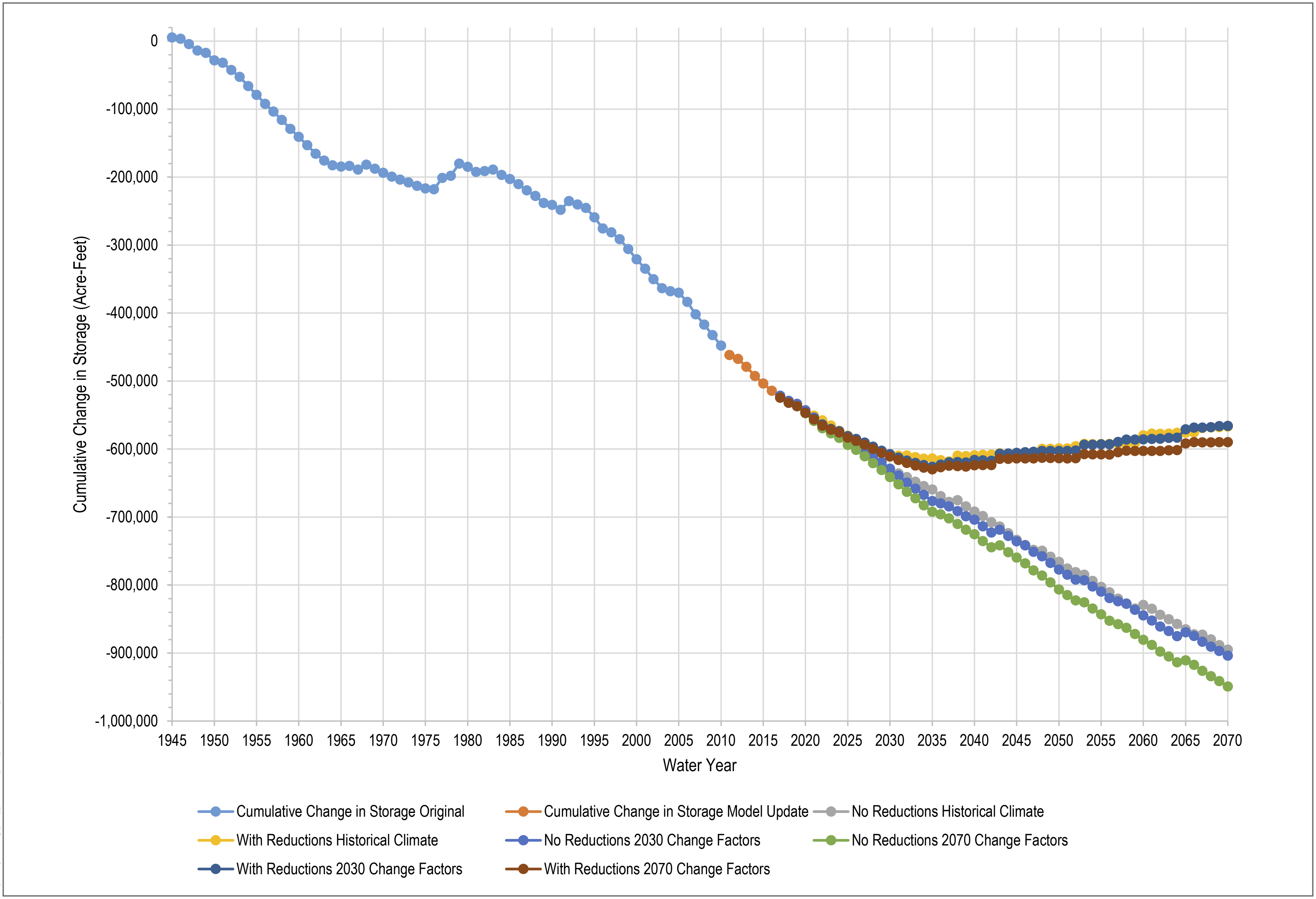

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FIGURE 3.3-2

BVHM Model Runs Addressing Future Climate and Pumping Reductions

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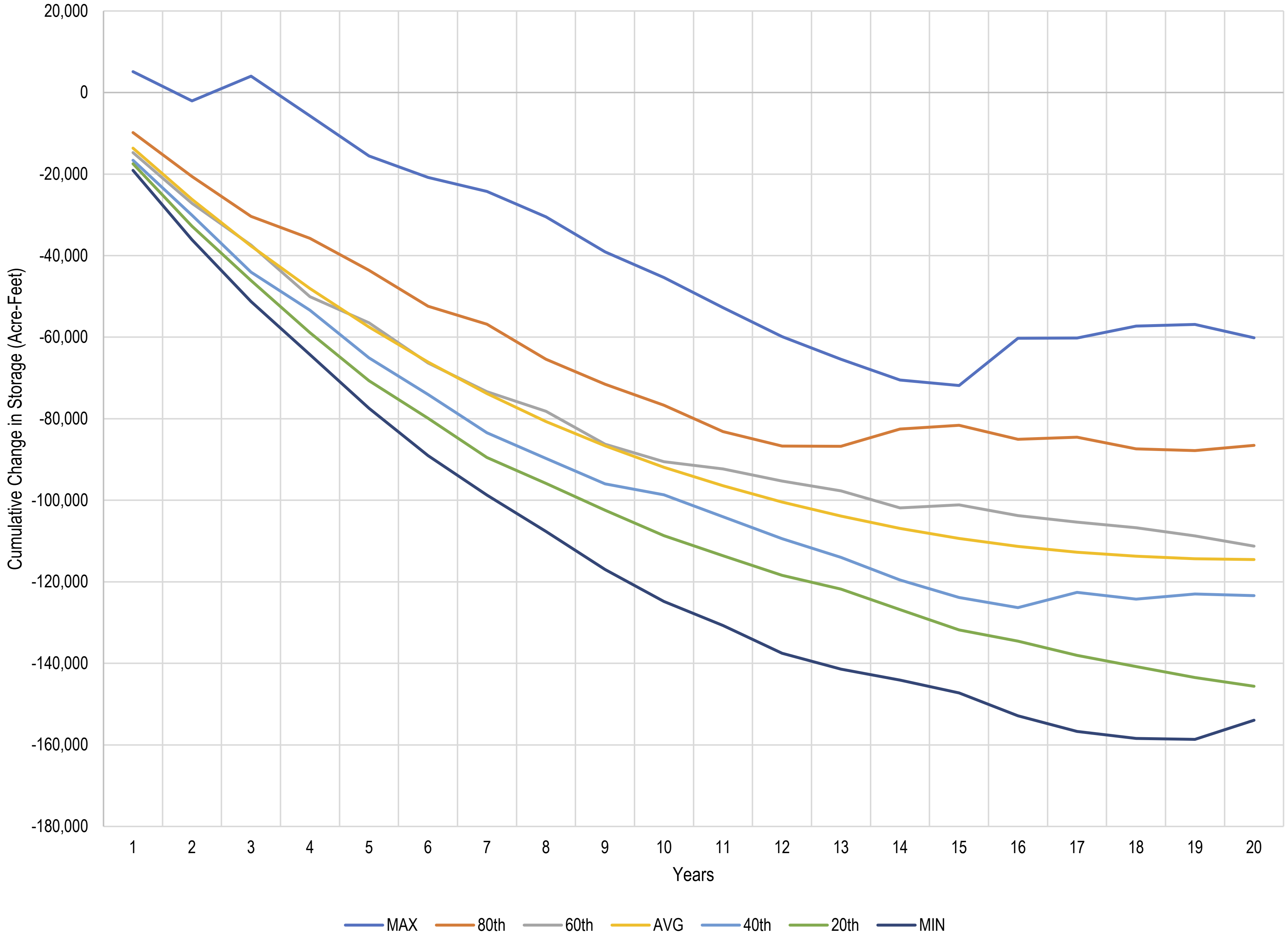

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SOURCE: ENSI 2018

DUDEK

FIGURE 3.3-3

Monte Carlo Simulation Time Varying Recharge 1945 to 2010 and Forcasted Cumulative Overdraft

DRAFT Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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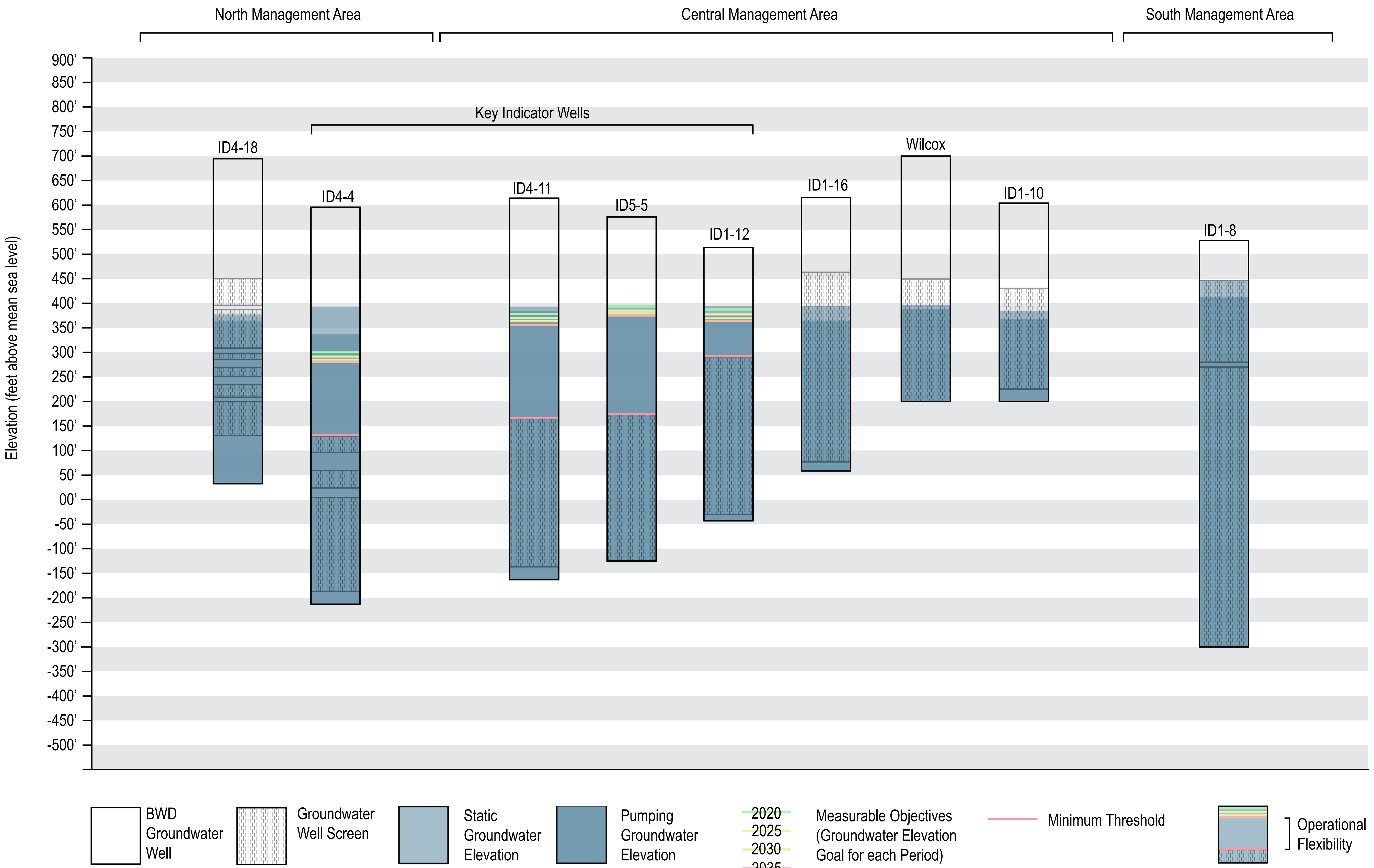

Static and pumping groundwater elevations recorded by Pump Check on 3/16/2018

SOURCE: Pump Check 2018

FIGURE 3.4-1

BWD Municipal Well Screens Relative to 2018 Groundwater Elevations

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CHAPTER 4
PROJECTS AND MANAGEMENT ACTIONS

4.0 PROJECTS AND MANAGEMENT ACTIONS TO ACHIEVE SUSTAINABILITY GOAL

Standards for Projects and Management Actions

Under the Regulations, the Groundwater Sustainability Plan (GSP, Plan) is to include the following:

1. "Each Plan shall include a description of the projects and management actions the Agency [Groundwater Sustainability Agency (GSA)] has determined will achieve the sustainability goal for the basin, including projects and management actions to respond to changing conditions in the basin.
2. Each Plan shall include a description of the projects and management actions that include the following:
    a. A list of projects and management actions proposed in the Plan with a description of the measurable objective that is expected to benefit from the project or management action. The list shall include projects and management actions that may be utilized to meet interim milestones, the exceedance of minimum thresholds, or where undesirable results have occurred or are imminent. The Plan shall include the following:
        i. A description of the circumstances under which projects or management actions shall be implemented, the criteria that would trigger implementation and termination of projects or management actions, and the process by which the Agency shall determine that conditions requiring the implementation of particular projects or management actions have occurred.
        ii. The process by which the Agency shall provide notice to the public and other agencies that the implementation of projects or management actions is being considered or has been implemented, including a description of the actions to be taken.
    b. If overdraft conditions are identified through the analysis required by California Code of Regulations (CCR) Section 354.18 [Water Budget], the Plan shall describe projects or management actions, including a quantification of demand reduction or other methods, for the mitigation of overdraft.
    c. A summary of the permitting and regulatory process required for each project and management action.
    d. The status of each project and management action, including a time-table for expected initiation and completion, and the accrual of expected benefits.

   e. An explanation of the benefits that are expected to be realized from the project or management action, and how those benefits will be evaluated.
   f. An explanation of how the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.
   g. A description of the legal authority required for each project and management action, and the basis for that authority within the Agency.
   h. A description of the estimated cost for each project and management action and a description of how the Agency plans to meet those costs.
   i. A description of the management of groundwater extractions and recharge to ensure that chronic lowering of groundwater levels or depletion of supply during periods of drought is offset by increases in groundwater levels or storage during other periods.
3. Projects and management actions shall be supported by best available information and best available science.
4. An Agency shall take into account the level of uncertainty associated with the basin setting when developing projects or management actions" (CCR Section 354.44).

Further, a GSA "has and may use the powers [in the Sustainable Groundwater Management Act (SGMA)] to provide the maximum degree of local control and flexibility consistent with the sustainability goals of [SGMA]" (California Water Code (CWC), Section 10725(b)). "A groundwater sustainability agency may perform any act necessary or proper to carry out the purposes of [SGMA]" (CWC, Section 10725.2(a)).

4.1 INTRODUCTION TO PROJECTS AND MANAGEMENT ACTIONS

Projects and management actions (PMAs) have been developed to address sustainability goals, measurable objectives, and undesirable results identified for the Borrego Springs Subbasin (Subbasin), with a view towards reducing the potential socioeconomic impacts associated with actions required to sustainably manage the Subbasin. The applicable undesirable results are chronic lowering of groundwater levels, reduction of groundwater storage, and degradation of water quality as explained in Section 3.2, Undesirable Results. In addition, groundwater dependent ecosystems (GDEs), which suffered significant and unreasonable adverse impacts well before January 1, 2015 (CWC, Section 10727.2(b)(4), were also evaluated, quantified, and considered. The Plan PMAs addressing chronic lowering of groundwater levels, reduction of groundwater storage, and degradation of water quality are anticipated to provide ancillary benefits to interconnected surface waters and GDEs.

The PMAs have been selected and developed with consideration of the arid climate that affords few opportunities for capture of excess precipitation. The Subbasin is remote to potential sources of imported water and totally dependent on groundwater for its water supply as described in Section 2.2.3.7, Surface Water Available for Groundwater Recharge or In-Lieu Use. In addition, water uses by volume within the Subbasin are primarily for agriculture and recreation with lesser amounts for municipal, domestic and industrial uses as described in Section 2.1.5.1, Beneficial Uses and Users. Water quality degradation is attributable to overlying land uses and the mobilization of naturally occurring contaminants from the underlying geologic formations as described in Section 3.2.4, Degraded Water Quality – Undesirable Results. Finally, the magnitude of the overdraft, estimated to be almost 400% above sustainable yield, is a primary factor in the selection of PMAs and the degree to which they will need to be implemented to achieve Subbasin sustainability.

The PMAs determined to achieve the sustainability goals for the Subbasin are: (1) Water Trading Program, (2) Water Conservation, (3) Pumping Reduction Program, (4) Voluntary Fallowing of Agricultural Land, (5) Water Quality Optimization, and (6) Intra-Subbasin Water Transfers. These proposed PMAs have been developed using preexisting basin studies and vetted through a public outreach and agency collaboration process as described in Section 2.1.5, Notice and Communication.

The identified PMAs are interrelated in many respects and the benefits of each may be augmented by co-implementation. The following are prospective examples of interrelated PMA benefits:

- PMA No. 1 – Water Trading Program incentivizes PMA No. 2 – Water Conservation.
- Water use reductions from PMA No. 3 – Pumping Reduction Program and PMA No. 4 – Voluntary Fallowing of Agricultural Land may mitigate groundwater quality as part of PMA No. 5 – Water Quality Optimization.
- PMA No. 6 – Intra-Subbasin Water Transfers may be used to match water quality to its potable and non-potable beneficial uses in accordance with PMA No. 5 – Water Quality Optimization.

4.2 PROJECTS AND MANAGEMENT ACTION NO. 1 – WATER TRADING PROGRAM

In 2005, the Borrego Water District (BWD) implemented a water credits program as described in Section 2.1.2, Water Resources Monitoring and Management Programs, that assigned a water allocation for fallowing of primarily agricultural land based on crop or turf type and allowed for water credits to be transferred to new development to offset water demand. The program was initiated in response to overdraft conditions within the groundwater basin and was designed to encourage water conservation and reduce high water consumptive land uses.

4.2.1 Water Trading Program Description

The GSP Water Trading Program will have a similar intent as the existing Water Credit Program but be informed by the pumping allocations developed in conjunction with the GSP, and the estimated sustainable yield of the Subbasin, and be administered by the GSA. The program will enable permanent transfer and potentially long-term or short-term lease of baseline pumping allocations (BPA) (as reduced over time) and may replace the existing Water Credits Program. The program is intended to allow groundwater users or new development to purchase needed groundwater allocation from others to maintain economic activities in the Subbasin, encourage and incentivize water conservation, and facilitate adjustment of pumping allocations as water demands and basin conditions fluctuate during the 20-year GSP implementation period.

Upon adoption and implementation of the Water Trading Program, the GSA will issue “water shares” to non-*de minimis* pumpers consistent with the finalized BPA (see PMA No. 3 – Pumping Reduction Program). Each year during GSP implementation, the GSA will publish the annual pumping allowance as a percentage of the BPA (e.g., in Year 5 of the GSP implementation period, the pumping allowance is anticipated to be set at approximately 81% of the BPA using annual reductions through 2040 to reach the target sustainability of 5,700 acre-feet per year (AFY) for the Subbasin as a whole). Every 5 years, the GSA is required to report progress toward achieving the Subbasin’s sustainability goals to Department of Water Resources (DWR). Shareholders may be able to privately negotiate terms of prospective trades with willing purchasers, within the confines of the Water Trading Program and rules developed for the program. Upon agreement, a proposed trade would be submitted to the GSA for review and approval, or separate mechanisms may be established regarding trades. If approved, the shareholder parties would be notified, the trade certified, and the GSA would update the official, publicly accessible register to notate the trade and the updated annual pumping allowances.

The GSA will agree upon and approve details of the Water Trading Program which may include either temporary or permanent water transfers, or both. Each water share will represent and entitle a shareholder to extract a reduced volume of groundwater (i.e., pumping allowance) over time, commensurate with the pumping reduction schedule developed by the GSA. The water trade review process by the GSA is intended to be structured to prevent unintended consequences, such as hoarding, collusion, or speculation. For example, to prevent hoarding, the GSA could cap the number of “water shares” held by an individual at a maximum percentage of the total shares. If warranted, the Water Trading Program Policy and/or rules will be reviewed annually during GSP review, and updated as needed to address unintended consequences or other unanticipated program deficiencies.

Summary of Process to Adopt Program and How Program Will be Accomplished

The anticipated development approach of the Water Trading Program by the GSA is as follows:

- Identify stakeholders/participants and conduct interviews and meetings to receive input and identify concerns to be addressed in program development.
- Evaluate existing programs in other basins and guidance from the DWR.
- Identify potential unintended consequences of the Water Trading Program to be addressed in development of governing documents (e.g., hoarding, speculation, price fixing, collusion, etc.).
- Present findings of the interviews and provide recommendations to the GSA.
- Develop a consolidation/replacement plan for the replacement of existing groundwater restrictive easements and Water Credits Program.
- Draft preliminary regulations for the Water Trading Program (e.g., allowable frequency and amount of water to be traded), allowable water uses (e.g., Area of Origin restriction as described in Section 4.2.2), fees and penalties requirements, accounting scope, etc.
- Collaborate with pending shareholders and GSA to develop Water Trading Program.
- Develop a governing structure for water trades and program administration.
- Develop an enforcement structure.
- Develop and test an accounting/register system to track BPA, pumping allowance, water trades and compliance though metering of groundwater production.
- Determine applicability of California Environmental Quality Act (CEQA) review to Water Trading Program.
- Finalize the details of the initial Water Trading Program into a comprehensive Water Trading Program Policy document to be approved by the GSA.
- Adopt Water Trading Program implementing regulations.

Legal Authority and Regulatory Process

It is the established policy of the State of California “to facilitate the voluntary transfer of water and water rights where consistent with the public welfare” (CWC, Section 109(a)). “The Legislature hereby finds and declares that voluntary water transfers between water users can result in a more efficient use of water, benefitting both the buyer and the seller” (CWC, Section 475). To these ends, BWD has previously duly adopted and implemented a Demand Offset Mitigation Water Credits Policy. That policy has been implemented under the umbrella of a 2013 Memorandum of Agreement Between the BWD and the County of San Diego Regarding Water

Credits and Section 67.720 (Chapter 7) of the County Groundwater Ordinances. Thus, in addition to the authority described as follows, each of the members of the GSA has independent legal authority to implement water transfer programs in their respective jurisdictions under existing law and they have done so.

Under SGMA, the GSA has authority to "authorize temporary and permanent transfers of groundwater extraction allocations within the [GSA's] boundaries, if the total quantity of groundwater extracted in any water year is consistent with the provisions of the [GSP]" CWC, Section 10726.4(a)(3). The GSA also has authority to "provide for a program of voluntary fallowing of agricultural lands or validate an existing program" (CWC, Section 10726.2(c)).

The Water Trading Program identified in this chapter carries forward the policy of the state and satisfies SGMA requirements by establishing a voluntary program that encourages water within the Subbasin to be transferred to beneficial uses of water in a manner designed to achieve the sustainability goals and to protect against undesirable results. The Water Trading Program is expected to operate in parallel with the Voluntary Fallowing of Agricultural Land Program described in Section 4.5, Projects and Management Action No. 4 – Voluntary Fallowing of Agricultural Land.

4.2.2 Water Trading Program Relationship to Sustainability Criteria

The Water Trading Program is intended to avoid undesirable results in the Subbasin by providing incentives for water conservation, the transfer of water to other beneficial uses and the reduction of water intensive land uses. The Water Trading Program will be implemented in a manner consistent with the baseline production allocations and the schedule of ramp downs necessary to achieve the sustainability objectives developed for the GSP. This program will help achieve stabilization of groundwater levels and groundwater in storage, and potentially limit water quality degradation.

Relationship to Measurable Objectives

The Water Trading Program primarily provides for the potential voluntary reallocation of available water supplies to other beneficial uses of water. Reallocation of available water supplies may result in changes to the existing distribution of pumping in the Subbasin that could result in direct effects primarily to the chronic lowering of groundwater levels and reduction of groundwater in storage measurable objectives. The Water Trading Policy will explicitly consider the direct effects to measurable objectives when evaluating proposed water trades. For instance, an area of origin of pumping requirement (i.e., North Management Area) may be required for trades. PMA No. 6 – Intra-Subbasin Transfers is being evaluated to address and optimize the distribution of pumping in the Subbasin as a result of implementation of PMAs. The Water Trading Program is also expected to provide ancillary benefits to GDEs.

Relationship to Minimum Thresholds

Consistent with the measurable objective, the Water Trading Program may result in direct, positive effects primarily to the chronic lowering of groundwater levels and reduction of groundwater in storage minimum thresholds. The Water Trading Policy will explicitly consider the direct effects to minimum thresholds when evaluating proposed water trades.

4.2.3 Expected Benefits of the Water Trading Program

The Water Trading Program will provide an economic incentive for conserving water and promoting beneficial uses of water and land uses by providing for the potential to monetize voluntary water conservation or the elimination of water intensive uses. For example, the Water Trading Program provides the ability for replacement of water intensive crop types with other land uses such as residential development, lower water use hydroponics, or solar projects. It may also encourage restoration of land for use as open or recreational space in accordance with the Voluntary Fallowing of Agricultural Land Program (see Section 4.5). It may also serve to shift pumping from areas and aquifers of depressed groundwater levels or poorer quality groundwater to those more favorable for additional pumping. PMA No. 5 – Water Quality Optimization and PMA No. 6 – Intra-Subbasin Water Transfers have been selected to evaluate and mitigate the potential effects of shifting pumping in the Subbasin (see Sections 4.6 and 4.7).

4.2.4 Timetable for Implementation of the Water Trading Program

Preparation of the Water Trading and Policy document is intended to begin upon adoption of the GSP and the appropriate CEQA review (if needed). It is anticipated that development of the Water Trading Program will require approximately six to nine months to conduct the appropriate stakeholder outreach, draft the policy development, public comment, legal review, accounting system development, and finalization of an initial Water Trading Program Policy. The timetable for implementation of the Water Trading Program is dependent on the schedule to complete CEQA review should it be determined that implementation of the program requires CEQA review.

4.2.5 Metrics for Evaluation of Water Trading Program Effectiveness

The Water Trading Program will include both direct and indirect metrics to evaluate its effectiveness. Program effectiveness is primarily related to Subbasin sustainability goals that are quantified through the development of measurable objectives and minimum thresholds in this Plan. As such, groundwater levels and corresponding changes in Subbasin groundwater storage are potentially the most representative metric to evaluate Program effectiveness. Additionally, comparison of metered or estimated historical water use versus metered water use after GSP adoption is integral to implement the program. Pursuant to the Metering Plan, all non-*de minimis* groundwater extractors will be required to register their wells during GSP implementation and report metered production data. In addition, BPA, pumping reduction, temporary or permanent water trades, voluntary fallowing of agricultural land and other land use changes will be documented. Water budget components, when combined with water quality, demographic information, and project costs may be used as an indirect measure of the effectiveness of the Water Trading Program as shown in Table 4-1.

Table 4-1
Metrics for Evaluating Water Trading Program Effectiveness

PMA No.	PMA Name	Direct Metrics	Indirect Metrics
No. 1	Water Trading Program	1. Groundwater levels 2. Groundwater storage 3. Metered groundwater extraction 4. Baseline pumping allocation (BPA) 5. Pumping reduction (ramp down) 6. Water trades 7. Area of irrigated land and crop type 8. Used and unused BPA	1. Water budget components 2. Water quality 3. Subbasin demographics 4. Cost

Notes: PMA = Projects and Management Action.

4.2.6 Economic Factors and Funding Sources for Water Trading Program

Planning-level development cost for establishing the Water Trading Program is estimated to be approximately $122,000 and separate from development of this GSP.

As part of consideration and adoption of the Water Transfer Program Policy and/or rules, transaction fees or other form of participation fees will be considered in order to support and implement the program. State grant funding may be available for capital or planning expenditures. Other potential sources of funding for the Water Trading Program components include pumping fees, application fees, water rates, parcel taxes, and other mechanisms as described in Section 5.1.7, Funding Sources.

4.2.7 Water Trading Program Uncertainty

Elements of uncertainty associated with the Water Trading Program include the impact of voluntary fallowing of agricultural land and changing land use to the overall economy of the Subbasin, the relationship of the program to existing property and water rights, and how program compliance will be enforced. It is anticipated that program design and stakeholder outreach will reduce this level of uncertainty.

4.3 PROJECTS AND MANAGEMENT ACTION NO. 2 – WATER CONSERVATION

The BWD has historically implemented measures to encourage efficient water use. These include a tiered water rate structure and other incentive programs (BWD 2009). In the past, rebate programs were established for purchase of low flow toilets, low water use washing machines, and high water use turf removal. Additionally, the BWD provided rate payer irrigation system audits and may pay a portion of recommended irrigation system improvements as described in Section 2.1.2, Water Resource Monitoring and Management Programs. The Borrego Springs Community Plan (County 2013) includes a policy requiring the continuation of "…aggressive, multi-faceted water conservation programs to reduce existing agricultural, golf course, commercial and residential [water] use."

The agricultural sector has made significant investment in end use efficiency technologies such as drip irrigation. Some golf courses have invested in control technologies to optimize the timing and application of irrigation. Use of lower water demand native plants has also been incorporated into non-turf areas for some of the golf courses. BWD has also adopted a water conservation (shortage) policy (BWD 2018). In addition, the County of San Diego adopted and enforces an ordinance containing groundwater use reduction measures for new development. San Diego County Code of Regulatory Ordinances (County Code) Section 67.720.

4.3.1 Water Conservation Program Description

The GSP Water Conservation Program would consist of separate components for the three primary sectors: agricultural, municipal, and recreation. Programs for each sector would follow a similar approach consisting of reviewing historical programs and projects, identifying areas and methods for greatest potential water savings, outreach and coordination with potential participants, developing project cost estimates, competitively evaluating project alternatives implementing projects, and acquiring follow-up metrics.

Legal Authority and Regulatory Process

California Constitution Article X, Section 2 and CWC Section 100 provide that because of conditions prevailing in the state, it is the declared policy of the state that the general welfare requires that the water resources of the state shall be put to beneficial use to the fullest extent of which they are capable, the waste or unreasonable use of water shall be prevented, and the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and the public welfare.

Additionally, in May 2016, Governor Brown signed Executive Order B-37-16 that set a policy of making water conservation a California way of life and ordered state agencies to establish permanent changes so Californians use water more efficiently. It set a framework for moving the state from temporary, emergency water conservation measures to a more permanent approach customized to the unique local conditions. In April 2017, DWR, the State Water Resources Control Board, the California Public Utilities Commission, the California Department of Food and Agriculture, and the California Energy Commission issued a report entitled "Making Water Conservation a California Way of Life, Implementing Executive Order B-37-16" to establish a long-term framework for water conservation and drought planning (DWR et al. 2017).

In May 2018, Governor Brown signed Senate Bill 606 and Assembly Bill 1668, which stem from the Governor's Executive Order and report to implement it. The legislation establishes a foundation for long-term improvements in water conservation and drought planning to adapt to climate change and the resulting longer and more intense droughts. Most of the legislation applies to conservation measures for urban water suppliers, but the legislation recognizes that small water suppliers and rural communities require guidance from the state to improve drought and conservation planning (CWC, Section 10609.40.) Accordingly, DWR and the State Water Resources Control Board must propose to the Governor and Legislature by January 1, 2020, recommendations and guidance relating to the development and implementation of countywide drought and water shortage contingency plans to address the planning needs of small water suppliers and rural communities (CWC, Section 10609.42). The County and thus the GSA may be able to adopt additional conservation measures that result from the forthcoming recommendations.

The State of California has set standards for water efficiency in landscaping since 1990. These requirements are currently set forth in the Water Conservation in Landscaping Act, Government Code Sections 65591 et seq. The DWR adopted and periodically amended a Model Water Efficient Landscape Ordinance (MWELO). The MWELO is currently codified in Title 23 CCR Sections 490 et seq. The County is at all times required to adopt an ordinance as effective as the MWELO at conserving water or apply the MWELO. The County adopted and has enforced its own water efficient landscape regulations since the first MWELO became effective on January l, 1993. In response to prolonged drought conditions in the state, Governor Brown, by Executive Order B-29-15 issued April l, 2015, directed the DWR to amend the MWELO to increase water efficiency standards for new and existing landscapes and to limit the use of turf. The DWR revised the MWELO in accordance with the Executive Order and the California Water Commission approved the revised MWELO on July 15, 2015. Consistent with the requirements of the Water Conservation in Landscaping Act, the County amended its water efficient landscape requirements set forth at Sections 86.701 et seq. of the County Code to ensure that the County's requirements are as effective as the current MWELO at conserving water.

Public noticing will be an integral part of the conservation program implementation. To be most effective, the availability of optional water conservation program services such as water audits and rebate programs will be widely advertised through billing inserts, websites, or mailings to BWD customers and other members of the public. In addition, water conservation outreach will be discussed at public meetings conducted by the GSA.

Agricultural Sector

Agricultural extractions from the Subbasin are estimated to be about 15,729 AFY based on the BPA making agriculture the largest potential sector for water savings in the Subbasin. Potential agricultural water savings are from reduction of applied water to crops, planting lower water use crops and/or increased efficiency of irrigation systems. Efficiencies in fertilizer or pesticide use can serve to limit degradation of groundwater quality potentially caused by agricultural return flows. The primary element of the agricultural conservation program will be water audits to be performed by the GSA or third-party contractors such as the Resource Conservation District of Greater San Diego County, which may have the following components:

- Pre-audit analysis of historical water use, topography, climate data, and land use
- Analysis of distribution uniformity (amount of water supplied by irrigation system to each plant), crop density, and crop types
- Analysis of irrigation efficiency (amount of water used beneficially by crop compared to the total water applied)
- Analysis of soil grain size and texture, agronomic soil suitability including salinity, drainage, and water retention properties
- Analysis of irrigation system water use efficiency, pressure, and maintenance
- Pesticide and Fertilizer application and use
- A report containing recommendations for improving efficiency and crop yield
- Follow up analysis of measures implemented actions/practices and savings obtained

The steps to implement the audit program will consist of the following:

1. Historical project analysis – Compile and analyze information from previously conducted audit programs and estimate cost and water savings achieved
2. Analysis of potential acreage, land use, and water savings – Geographic information systems (GIS) analysis of Subbasin agriculture, land use, and property ownership in order to determine scope and design of program and to target appropriate landowners for outreach efforts
3. Program design – Design and select program components based on crop types, program cost, and potential water savings; may include irrigation audits, equipment rebates, and cost sharing
4. Program Outreach – Contact, inform, and coordinate with potential program participants to determine needs and constraints
5. Conduct Audits – Each audit will include a report documenting "pre" conditions, recommendations for implementing water savings measures, and potential quantified benefits

6. Follow up on Audit Results – Return to each audit location after a suitable amount of time to document recommendations implemented and other metrics

Municipal Sector

Approximately 1,700 AFY of water is currently supplied for municipal purposes within the Subbasin and about 75% of that is used out of doors. Therefore, outdoor water use has great potential for municipal water savings. There is potential for water savings associated with turf removal or replacement and irrigation system upgrades for homeowner associations (HOAs). However, indoor conservation measures will be implemented to raise awareness of the value of the resource as well as for the water savings they provide.

Potential programs to be included in the municipal water conservation sector include landscape irrigation audits, rebates for turf replacement, efficient landscape irrigation equipment and indoor water fixtures. Smart irrigation controllers may be encouraged in order to automatically adjust landscape irrigation based on real-time, local weather conditions. A BWD and/or GSA-dedicated water conservation website would give water users voluntary access to free water conservation information such as a landscape watering calculator, a watering index, and a water efficient plant database. See the San Diego County Water Authority conservation website for example projects and programs (https://www.watersmartsd.org/tools).

The BWD and/or GSA may sponsor an accreditation program for gardeners and landscapers that complete a training program that may include water efficiency, green waste reduction, pesticide reduction, and fertilizer management. The individuals and companies that receive certification may be included in a conservation website list, to be contacted by those interested in hiring “environmentally responsible” landscaping professionals. Professionals could include those primarily employed in the agricultural sector as part of a job retraining program.

The following steps will be conducted as part of implementation of the Municipal water conservation program:

- A conservation and efficiency analysis will be performed to identify Best Management Practices for water conservation for residential and commercial stakeholders.
- The scope, feasibility, and impact of a landscape restrictive ordinance for existing development will be evaluated in addition to water efficient landscape requirements set forth at Section 86.701 et seq. of the County Code for new development.
- Determination of the applicability of conservation requirements for existing water users (BWD Conservation Program) versus new development (i.e., County water efficient landscape requirements).

- The nature of a potential conservation incentive program will be evaluated, which may include incentives for turf removal, installation of efficient water fixtures, etc.
- Development of an updated program to provide voluntary home inspections to assist residents with identifying water conservation and efficiency opportunities.
- Preparation of a Municipal Water Conservation and Efficiency Plan to convey the findings of the previously referenced assessments, present resources to be made available to stakeholders, and document requirements of the plan, if any.

Recreation Sector

Opportunities for water savings in the recreational sector are primarily from golf courses. Changes in golf course irrigation practices, turf types, irrigated area, and adjacent landscaping afford opportunities for significant water savings. The physical and operational improvements to golf course irrigation systems may include modification of irrigation types and schedules, and the installation of soil moisture and evapotranspiration sensors (Mann 2014).

The following tasks will be implemented for the development of a Recreation Water Conservation and Efficiency Plan:

- Identify stakeholders/participants and conduct interviews to receive input and identify concerns to be addressed in the program development. Additionally, the interviews would be used to solicit suggestions for specific resources that will assist the recreational sector with improving efficiency.
- Assessment of each golf course's irrigation practices and irrigated acreage to identify areas where more efficient irrigation practices could be applied, and the potential cost/benefit of the action for the operator.
- Independent of specific property evaluations, a variety of irrigation practices, alternative turf types or management actions should be evaluated to recommend the best methods for increasing irrigation efficiency and groundwater conservation in the Subbasin.
- Preparation of a Recreational Water Conservation and Efficiency Plan to convey the findings of the previously referenced assessments, present resources to be made available to stakeholders, and document requirements of the plan, if any.

4.3.2 Water Conservation Program Relationship to Sustainability Criteria

The specific components of a water conservation program to be implemented within the Subbasin will be developed through a process of outreach, data compilation, and program design for each sector. By reducing the amount of water consumed within each sector, the program will reduce the water produced, thereby directly addressing the requirement to ramp down groundwater production to meet the sustainability goals. Chronic lowering of groundwater levels and reduction of groundwater in storage will be addressed by a reduction of pumping from the Subbasin. In addition, agriculture and landscape audits may result in a reduction in fertilizer and pesticide use needed for crops and turf, thereby limiting the amount of primarily nitrate and total dissolved solids (TDS) infiltrating to the aquifer.

Relationship to Measurable Objectives

The Water Conservation Program will incrementally reduce water demand in the Subbasin and is an option worth considering to achieve measurable objectives during Plan implementation and throughout the planning period. The Water Conservation Program is directly related to the chronic lowering of groundwater levels and reduction of groundwater in storage measurable objectives.

Relationship to Minimum Thresholds

Consistent with the measurable objective, the program serves as an incremental, direct physical action to maintain sustainability indicators, including groundwater levels and groundwater storage, above minimum thresholds to avoid undesirable results. The Water Conservation Program also has the potential to improve water quality by augmenting the quantity and quality of return flows.

4.3.3 Expected Benefits of the Water Conservation Program

In addition to the potential for incremental water savings estimated at 1,455 AFY for all sectors, the conservation program will raise awareness of the value of water as a resource and help modify the culture of water use. Therefore, the benefits of the program will accumulate as a larger segment of the local population becomes more educated about water conservation and modifies behavior over time. By taking a proactive role in water efficiency issues, the BWD and GSA will lead by example.

Agricultural audits are commonly performed by agencies throughout California. They are generally recognized as beneficial for increasing efficiency, reducing water use, and increasing crop yields. Audits are often conducted by Resource Conservation Districts with funding provided by counties or state grant programs. A previous study of the Subbasin completed by Roger Mann for DWR and BWD identified several individual actions and estimated costs for reducing water use (Mann 2014). This study estimated potential water savings of 365 AFY by maximizing agricultural irrigation efficiency. Potential water conservation savings for the municipal sector of 255 AFY assumes 20% water savings on BWD outdoor water use. An updated recreation sector water conservation estimate of 835 AFY was developed based on the assumptions made by Mann and interviews with several golf course landscape professionals with experience in Borrego Springs. Estimated water savings by sector as a result of implementing water conservation programs are listed in Table 4-2.

Table 4-2
Estimated Potential Water Savings by Sector for Water Conservation Programs

Water Sector/Crop	Potential Water Savings Acre-Feet Per Year
Agriculture	365[a]
Municipal	255[b]
Recreation	835[c]
Total	**1,455**

Source: Mann 2014

Notes:

[a] From Mann 2014. Potential water savings for agriculture is less than 2% of the BPA and there may be potential for additional savings.

[b] Assumes 20% savings of outdoor water use that is about 75% of total BWD demand.

[c] Based on 2018 interviews and/or previous assumptions by Mann.

Recreation Sector

Potential water savings for golf courses are achievable by two primary activities: 1) converting turf to desert landscaping or low water use xeriscaping, and 2) optimizing golf course irrigation system management. Estimated potential water savings for golf courses by implementing turf conversion is provided in Tables 4-3.

Table 4-3
Estimated Potential Water Savings by Sector for Water Conservation Programs

Golf Course	Estimated Turf Acres[a]	Estimated Convertible Acres[b]	Potential Water Savings Acre-Feet Per Year
Borrego Springs Resort	106.00	32.0[c]	192.6
Club Circle	23.00	3.9	23.5
De Anza	146.76	24.9	149.9
Ram's Hill[d]	96.75	0.0	—
Road Runner Golf and Country Club	46.23	7.9	
The Springs	42.45	7.2	43.3
Total	**461.19**	**75.9**	**456.9**

Notes:

[a] Turf area based on aerial analysis of GIS.

[b] Assumes 17% of irrigated turf is convertible and 90 irrigated turf acres per 18-hole golf course, except where golf course specific information was provided. Water savings assume average water demand of 6.02 acre-feet per year per acre of turf.

[c] Borrego Springs Resort has indicated that up to 32 acres of turf is potentially convertible to desert landscaping based on their preliminary evaluation (Bambach, pers. comm. 2018).

[d] Rams Hill Golf Course has indicated that it is unlikely that they have any convertible turf. However, they have implemented irrigation system improvements and conversion of non-turf areas to native landscaping and are working with irrigation professionals to identify future water savings projects (Smith, pers. comm. 2018).

The average cost of turf conversion per acre for golf courses is $20,000. Conversion cost assumes turf removal and fine grading with sand or decomposed granite to match grade of adjacent turf.

No irrigation replacement or plant material is included. Conversion to desert landscaping from turf would be approximately $2.86 per square foot or $125,000 per acre (Smith, pers. comm. 2018).

Optimizing golf course irrigation system management is another management strategy that may result in water savings. This involves installation of new controllers and sprinkler heads, soil moisture sensors, and weather stations to improve irrigation efficiency. For instance some golf courses are required to turn on multiple sprinklers covering a large area even when only a small portion of the golf course requires irrigation. Estimated potential water savings for golf courses by optimizing golf course irrigation system management is provided in Table 4-4.

Table 4-4
Golf Course Irrigation System Management

Golf Course	Estimated Managed Acres of Irrigated Turf[a]	Potential Water Savings Acre-Feet Per Year at 0.82 AF/ acre/year[b]
Borrego Springs Resort	106.00	86.92
Club Circle	23.00	18.86
De Anza	146.76	120.34
Ram’s Hill	96.75	79.34
Road Runner Golf and Country Club	46.23	37.91
The Springs	42.45	34.81
Total	**461.19**	**378.18**

Notes: AFY = acre-feet per year; AF = acre-feet.

[a] Turf area based on aerial analysis of geographic information system (GIS).

[b] Mann 2014.

The average cost of optimizing a golf course irrigation system is approximately $400 per acre per year (Mann 2014). For 100 acres of turf that works out to $40,000 per year; however, it should be noted that there are substantial upfront capital costs to install irrigation system infrastructure and train staff to use software and maintain equipment. Actual costs and potential water savings will vary, and require detailed evaluation and study of each golf course’s existing irrigation system.

Municipal Sector

The Borrego Springs HOA implemented turf replacement projects in the last 5 years, which indicate the potential costs and benefits that may be achieved through additional turf replacement programs. Approximate data for historical turf replacement projects are presented in Table 4-5.

Table 4-5
Historical Turf Replacement Projects, Borrego Springs

Year	Area Replaced (square feet)	Total Cost	Cost/Square Foot	Estimated Outdoor HOA Water Savings (%)
Club Circle West, Borrego Springs HOA				
2013	38,800	$125,250	$3.23	37
2017	3,438	$8,695	$2.53	7
2018	2,770	$7,756	$2.80	7
2018	6,700	$15,000	$2.24	NA
Total	**51,708**	**$156,701**	**$3.03**[a]	**51**

Source: Duncan, pers. comm. 2018a, 2018b.
Notes: HOA = homeowner association; NA = not applicable.
[a] Average cost per square foot.

Based on the Borrego Springs HOA turf replacement projects, the average cost is approximately $3.00 per square foot or $131,000 per acre. Actual costs and water savings will be determined by specific program configuration and funding sources. Previous estimates indicate that HOA turf replacement and irrigation efficiency projects, if implemented throughout the Subbasin, have the potential to save approximately 90 AFY (Mann 2014).

Graywater Guidance Programs

In recent years, state regulations for the use of graywater have been relaxed, making it easier to utilize wastewater from showers, clothes washers, and wash basins for irrigation of certain types of landscaping (CWC, Chapter 15). “Laundry to Landscape” systems conforming to certain requirements do not currently require a state permit. The County Department of Environmental Health (DEH) administers graywater systems in unincorporated areas of the County. No construction permit is required for clothes washer systems provided the system is installed in accordance with the Graywater System Requirements for a Single Clothes Washer (County 2015). Larger graywater systems, which require more extensive plumbing modifications, require a permit. The County DEH has developed guidance for the design, installation, operation and maintenance of graywater systems to ensure subsurface irrigation systems discharging graywater will not contaminate surface water or groundwater or create public health hazards (County 2015b). The guidance also explains the permitting procedures and inspection of graywater systems. The DEH graywater systems webpage can be found at: https://www.sandiegocounty.gov/content/sdc/deh/lwqd/lu_graywater_systems.html

Installation of an individual graywater system in Borrego Springs is feasible provided a graywater system meets the requirements outlined in the guidance. There is an average of about 40 gallons per person per day available for graywater recycling and the average family can reduce their freshwater use by as much as 30% by using graywater for irrigation (SOW 2019).

4.3.4 Timetable for Implementation of Water Conservation Program

Because water conservation is a beneficial component of sustainable water supply planning, it is intended that the water conservation program will be enacted within the first few years of GSP implementation and continue indefinitely recognizing that all of the sectors have historically implemented or are in the process of evaluating water conservation and efficiency projects. It is anticipated that development of the program parameters will require approximately nine to twelve months to conduct stakeholder outreach, efficiency audits, draft document development, public comment, and finalization of the three Water Conservation and Efficiency Program components. Projects currently in planning development could potentially be implemented sooner if a viable funding source is identified.

4.3.5 Metrics for Evaluation of Water Conservation Program

The Water Conservation Program will include both direct and indirect metrics to evaluate the effectiveness of the program. Program effectiveness is primarily related to Subbasin sustainability goals that are quantified through the development of measurable objectives and minimum thresholds is this Plan. As such, groundwater levels and corresponding changes in Subbasin groundwater storage are potentially the most representative metrics to evaluate Program effectiveness. Additionally, the metrics available for evaluation of the Water Conservation Program are dependent on the water use sector and specific programs to be evaluated. Direct metrics will include groundwater levels and corresponding groundwater storage, and metered pumping records, effective after adoption of the GSP.

BWD water supply records will be used to directly evaluate water supply reduction for specific water accounts that have implemented water conservation program components. The number and types of water conservation projects implemented with quantification of water saved will also be documented. Indirect metrics may also include follow up evaluation of water users having received water audits to see which recommended measures were implemented and the associated estimated water savings. For water efficient fixture give-away or rebate programs, records of the number and type of fixtures will be used to approximate water savings. Similarly, follow up evaluation of turf replacement projects will allow for an approximation of water savings related to irrigation reduction. Water budget components, when combined with water quality, demographic information, and project costs may be used as an indirect measure of the effectiveness of the Water Trading Program as shown in Table 4-6.

Table 4-6
Metrics for Evaluating Water Conservation Program Effectiveness

PMA No.	PMA Name	Direct Metrics	Indirect Metrics
No. 2	Water Conservation	1. Groundwater levels 2. Groundwater storage 3. Metered groundwater extraction 4. Number/type of projects implemented 5. Quantification of water saved	1. Water budget components 2. Water quality 3. Subbasin demographics 4. Cost 5. Audits

Notes: PMA = Projects and Management Action.

4.3.6 Economic Factors and Funding Sources for Water Conservation Program

Planning-level development cost for establishing the Water Conservation Program is estimated to be approximately $130,000 and separate from development of this GSP.

Potential sources of funding for the Water Conservation Program components include state grants, transaction fees from trades, pumping fees, water rates, parcel taxes, and other mechanisms as described in Section 5.1.7, Funding Sources.

4.3.7 Water Conservation Program Uncertainty

Only high level estimates of the cost and benefits of the water conservation program are possible until there is a detailed plan for project components, stakeholder interest, and quantification of benefits for each sector. Some benefits such as stakeholder awareness and level of participation in voluntary programs are difficult to predict or quantify. Other components of uncertainty are the extent to which conservation measures have already been implemented and how to incentivize or require participation in specific components of the conservation programs.

4.4 PROJECTS AND MANAGEMENT ACTION NO. 3 – PUMPING REDUCTION PROGRAM

The Pumping Reduction Program is the central tool for the GSA to implement the GSP and achieve the sustainability goal for the Subbasin. The pumping reduction program is based on the establishment of each respective user’s “share” of the estimated sustainable yield of the Subbasin. To implement the program, the GSA has been working with the groundwater extractors in the Subbasin to determine individual BPA. Once the program is implemented, BPAs will be ramped down over time to bring pumping in the Subbasin within its sustainable yield by 2040. As described in SGMA, any limitation on extractions by the GSA “shall not be construed to be a final determination of rights to extract groundwater from the basin or any portion of the basin” (CWC, Section 10726.4(a)(2)).

The GSA has determined that adoption and implementation of the ramp down component of the pumping reduction program in the Subbasin described herein is likely to fall outside of the CEQA exemption set forth in SGMA (CWC, Section 10728.6). That provision states that: "Nothing in this part shall be interpreted as exempting from [CEQA] . . . a project that would implement actions taken pursuant to a plan adopted pursuant to this chapter." The GSA has decided to prepare CEQA environmental documentation in advance of considering the formal adoption and implementation of any ramp downs and a precise ramp down schedule for the Subbasin. The GSA anticipates consideration of an ordinance or other mechanism to adopt and implement a ramp down within 24 months of adoption of this GSP. An agreement among the Pumpers or GSA adoption of an interim ramp down schedule are two possible scenarios where pumping reductions could start prior to CEQA review completion.

4.4.1 Pumping Reduction Program Description

It is anticipated that the Pumping Reduction Program will consist of the following general components: (1) estimation of the Subbasin sustainable yield, (2) determination of BPAs for each non-*de-minimis* pumper, and (3) pumping allocation reduction recommendations over the implementation period to reach the estimated sustainable yield by 2040. In summary, each non-*de minimis* groundwater user within the Subbasin will be assigned an allocation based on their historical groundwater use. That allocation will be reduced incrementally as necessary until 2040 such that the total extraction from the Subbasin will be equal to the estimated sustainable yield at the end of that period. Each component of the program is discussed in greater detail as follows.

Estimation of the Subbasin Sustainable Yield

A water budget approach has been used to establish the estimated sustainable yield for the Subbasin as explained in Section 2.2.3, Water Budget, and Section 2.2.3.5, Sustainable Yield Estimate. Based on existing data, the estimated sustainable yield of the Subbasin is 5,700 AFY, which is an approximately 74% reduction from historical water use of up to 21,938 AFY as established by the BPA. The estimated sustainable yield is the target amount to which groundwater is to be reduced over the implementation period. It should be noted that the 5,700 AFY sustainable yield value is an estimate that depends on a number of climate and hydrological factors that will be re-evaluated concurrent with the GSP 5-year updates.

Determination of Baseline Pumping Allocation

BPAs have been determined for pumpers in each of the three sectors: recreational, municipal, and agricultural. The "baseline pumping allocation" is defined as the maximum annual production, in AFY, for each well owner over the baseline pumping period. The baseline pumping period is the 5-year period from January 1, 2010, to January 1, 2015. In addition to the three water use sectors, there are two small water use systems and two non-potable irrigators, the baseline allocations for which were considered separately. These are the Anza-Borrego Desert State Park (ABDSP) and the Borrego Air Ranch Water Co. The two non-potable irrigators are the Borrego Springs Unified School District (Elementary School) and La Casa Del Zoro Resort and Spa (La Casa Del Zoro).

The BPA is determined to be the maximum annual groundwater extraction during the baseline pumping period. Metered historical data is the most accurate method of determining maximum historical use. Therefore, metered data has been used when available. Metered data was available for the ABDSP, a limited number of private pumpers and for all of BWD's production. Where metered data was unavailable, including for golf courses and a large proportion of agriculture, water use is estimated using plant-specific evapotranspiration rates during the baseline period.

The evapotranspiration method requires the determination of irrigated areas and plant types and the application of a water use factor. Irrigated area and plant types have been determined from aerial photographs, limited field reconnaissance, GIS analysis tools and correspondence with pumpers. The water use factor is an annual estimate of water use in feet of water that includes plant type, climate, irrigation system efficiency, and for some crops such as citrus, the leaching of salts from the soils. The BPA methodology developed for the Subbasin is detailed in Appendix F.

Pumping Allocation Reduction

Water budget modeling has calculated an estimated sustainable yield of 5,700 AFY. This is approximately 26% of the historical extraction levels of about 21,938 AFY resulting in a required reduction in pumping of 74%.

Because many of the parameters used to determine water use and sustainable yield estimate are modeled or estimated, it is anticipated that adjustments will be required to achieve the sustainability goals. Therefore, the reduction allocation will be reviewed at least every 5 years in relation to groundwater levels, groundwater in storage and other sustainability criteria. Adjustments to the program will be made when necessary in the future by the GSA.

Pumping Overage Charges

The SGMA legislation allows for charging fees for pumping in excess of allocations or non-compliance with other GSA regulations (CWC Section 10732 (a)). The GSA will consider the adoption of fees and/or other penalties for violations of pumping allowance and/or reporting during the GSP implementation period.

4.4.2 Pumping Reduction Program Relationship to Sustainability Criteria

Permanent reduction in pumping directly relates to all of the sustainability criteria. Pumping reductions will serve to stabilize declining groundwater levels and prevent loss of groundwater storage.

Degradation of water quality may be limited as a result of a reduction in fertilizer use needed for crops and turf, thereby limiting the amount of primarily nitrate and TDS infiltrating to the aquifer.

Relationship to Measurable Objectives

The pumping reduction program will serve as a significant, direct physical action to meet the measurable objectives of chronic lowering of groundwater levels and the reduction in groundwater storage. Further, it is anticipated to provide ancillary benefits to GDEs and support certain measurable objectives to protect against degradation of water quality.

Relationship to Minimum Thresholds

Consistent with the measurable objectives, the program serves as a significant, direct physical action to maintain sustainability indicators, including groundwater levels and groundwater storage, above minimum thresholds to avoid undesirable results. Additionally, improvements to water quality are expected as a result of reduction of fertilizer use and return flows to the aquifer.

4.4.3 Expected Benefits of the Pumping Reduction Program

As the central component to achieving sustainability within the Subbasin, the Pumping Reduction Program will result in the avoidance of undesirable results including chronic lowering of groundwater levels, reduction of groundwater in storage, and potentially degraded water quality. Peripheral benefits may include potential investment in alternate land uses or taking advantage of the water trading or land fallowing management programs. To achieve the required reductions, the sectors may implement conservation measures resulting in more efficient use of water and greater resiliency to long-term climate variability.

4.4.4 Timetable for Implementation of the Pumping Reduction Program

Individual allocations have been provided by the GSA to each existing user. Metering will be required with implementation of this GSP and are anticipated to be required within 90 days of GSP adoption. As the central component of the GSP, the Pumping Reduction Program is anticipated to be implemented once CEQA review of the GSP is completed. As such, it is expected that the Pumping Reduction Program will be implemented approximately 24 months after the adoption of this GSP. The program will be ongoing throughout the GSP implementation period as annual adjustments to the pumping allocations are made. It is anticipated that the ramp down schedule will be revisited during the 5-year GSP updates.

4.4.5 Metrics for Evaluation of Effectiveness of Pumping Reduction Program

The Pumping Reduction Program will include both direct and indirect metrics to evaluate the effectiveness of the program. Program effectiveness is primarily related to Subbasin sustainability goals that are quantified through the development of measurable objectives and minimum thresholds in this Plan. As such, groundwater levels and corresponding changes in Subbasin groundwater storage are probably the most representative metrics to evaluate effectiveness. Water metering will be required to implement this GSP, so that extractions from wells will be directly measured as specified in the Metering Plan (Appendix E3). Establishment of the BPA and pumping reduction or ramp down rates is required to be developed to implement the Pumping Reduction Program. The area of irrigated land and crop types should also be directly tracked to monitor program effectiveness. Water budget components, when combined with water quality, demographic information, and project costs may be used as an indirect measure of the effectiveness of the Pumping Reduction Program as shown in Table 4-7.

Table 4-7
Metrics for Evaluating Pumping Reduction Program Effectiveness

PMA No.	PMA Name	Direct Metrics	Indirect Metrics
No. 3	Pumping Reduction Program	1. Groundwater levels 2. Groundwater storage 3. Metered groundwater extraction 4. Baseline pumping allocation (BPA) 5. Pumping reduction (ramp down) 6. Area of irrigated land and crop types 7. Used and unused BPA	1. Water budget components 2. Water quality 3. Subbasin demographics 4. Cost

Notes: PMA = Projects and Management Action.

4.4.6 Economic Factors and Funding Sources for Pumping Reduction Program

Planning-level development cost for establishing the Pumping Reduction Program is estimated to be approximately $82,000 and separate from development of this GSP.

Potential sources of funding for the Pumping Reduction Program components include pumping fees, water rates, parcel taxes, and other mechanisms as described in Section 5.1.7, Funding Sources.

4.4.7 Pumping Reduction Program Uncertainty

Uncertainty associated with the Pumping Reduction Program is related to the method of establishing the estimated sustainable yield and baseline allocations. As described in Section 2.2.3, Water Budget, and previously in Section 4.4.1, it has been necessary to estimate historical groundwater use where direct measurement was unavailable. Therefore, evaluation and as-needed adjustment to the Program parameters will be conducted every 5 years, at a minimum.

Legal authority and Regulatory Process

SGMA provides the GSA with authority to: "control groundwater extractions by regulating, limiting, or suspending extractions from individual groundwater wells or extractions from groundwater wells in the aggregate, . . . or otherwise establishing groundwater extraction allocations" (CWC, Section 10726.4(a)). Also,

> in addition to any other authority granted to a groundwater sustainability agency by this part or other law, a groundwater sustainability agency may enter into written agreements and funding with a private party to assist in, or facilitate the implementation of, a groundwater sustainability plan or any elements of the plan (CWC, Section 10726.5).

Further, the powers outlined in SGMA are in addition to, and not a limitation on the authority granted to local agencies under any other law (CWC, Section 10725(a), 10726.8(a)). And, counties have independent authority under their police powers to act to protect groundwater and other related resources (Envt'l Law Foundation v. State Water Resources Control Board (Aug. 29, 2018), 3rd District Court of Appeal case no. C083239; Allegretti & Co. v. County of Imperial (2006) 138 Cal.App.4th 1261; Baldwin v. County of Tehama (1994) 31 Cal.App.4th 166).

In addition, under SGMA, "no extraction of groundwater between January 1, 2015, and the date of adoption of the plan pursuant to this part . . . may be used as evidence of, or to establish or defend against, any claim of prescription" (CWC, Section 10720.5(a)). The protection of the Subbasin and the achievement of the sustainability goals could be put at significant and unreasonable risk were the establishment of BPA's delayed until a later date. Failure to approve the BPA's at the time of GSP adoption could encourage pumpers to pump more groundwater in order to establish or defend against prescription. Accordingly, the GSA has determined that adopting the BPA's immediately, as part of the GSP, is the most protective of the Subbasin and in compliance with SGMA and other laws.

4.5 PROJECTS AND MANAGEMENT ACTION NO. 4 – VOLUNTARY FALLOWING OF AGRICULTURAL LAND

4.5.1 Program Description of Voluntary Fallowing of Agricultural Land

The voluntary Fallowing Program will constitute a mechanism to facilitate the conversion of high water use irrigated agriculture to low water use open space, public land, or other development on a voluntary basis. Due to the extent of the overdraft within the Subbasin and the infeasibility of increasing water production or tapping imported supplies, land fallowing is a necessary and principal management action to achieve sustainability. Although some fallowing programs in California are short term to address a specific drought or shortage, the program proposed for the Subbasin is primarily for long-term or permanent fallowing or conversion to other land uses. Approximately 2,480 acres of land in the Subbasin have been fallowed in the last several decades and another 600 acres were recently fallowed as part of the water credit program as described in Section 2.1.2, Water Resources Monitoring and Management Program.

Currently, there are about 2,624 acres of active agriculture within the Subbasin. It is anticipated that each of these lands/landowners with water demands during 2010–2014 will receive freely transferable BPA's as part of the GSP that, in turn, will encourage cultivated lands to be fallowed. Factors that will be considered for the fallowing program include the current extent of agriculture land and water use, the intended land and water use after fallowing, and the potential environmental impacts associated with fallowing. These include airborne emissions through wind-blown dust, the introduction or spreading of invasive plant species, and changes to the landscape that could adversely affect visual quality. The land uses proximal to the fallowing projects will affect the processes utilized and best management practices associated with fallowing proposals will be developed as part of this management action. For example, there could be differing levels of site stabilization or restoration needed or required based on the land use intended post- fallowing. Temporary stabilization will be less expensive and may be appropriate for properties to be developed for other use in the near term. A passive restoration approach may be applied if the goal is for the property to eventually return to native habitat, and active restoration may be applied for relatively near-term restoration to native habitat with the goal of providing open space, parks, or public trails.

The initial program phase will be to evaluate key issues associated with program development as follows:

- Evaluation and compliance with jurisdictional regulations already in place for vacant land
- Identification of existing prospective fallowing opportunities and anticipated environmental impacts and unintended consequences from unmanaged fallowed land
- Identification of land restoration goals
- Land management, inspection, and enforcement procedures
- Evaluation of future land use alternatives
- Evaluation of easements and appropriate easement language
- Development of a regulatory document
- Cost–benefit analyses
- Programmatic and/or project-based CEQA review

Legal Authority and Regulatory Process

Preparation of a CEQA evaluation for a fallowing program will identify potential environmental impacts and identify feasible alternatives or feasible mitigation measures. Establishment of a voluntary land fallowing program is expressly authorized under SGMA (CWC, Section 10726.2(c)). The fallowing program including program standards will be developed and undergo CEQA review as necessary.

4.5.2 Voluntary Fallowing of Agricultural Land Program Relationship to Sustainability Criteria

The Fallowing Program will address each of the undesirable results that have been identified for the Subbasin by reducing the amount of groundwater consumed from existing uses and reduced application of fertilizers or other agrichemicals. Reduced pumping will help to stabilize groundwater levels and increase groundwater in storage. Degradation of water quality may be limited to the extent that land fallowing or changes in land use reduces the amount of fertilizers applied for the former land uses.

Relationship to Measurable Objectives

The land fallowing program will serve as a significant, direct physical action to meet the measurable objectives of chronic lowering of groundwater levels and the reduction in groundwater storage. Further, it is anticipated to support certain measurable objectives for degradation of water quality, most notably for nitrate and TDS associated with agricultural return flows.

Relationship to Minimum Thresholds

Consistent with the measurable objective, the program serves as a significant, direct physical action to maintain sustainability indicators, including groundwater levels, groundwater storage, and water quality above minimum thresholds to avoid undesirable results.

4.5.3 Expected Benefits from Voluntary Fallowing of Agricultural Land Program

In addition to the benefits derived directly from reduced pumping, the program will allow for a level of land use and community planning for converted properties not otherwise available. Depending on the nature of land uses implemented, the program could result in increased recreational space or potential economic benefits from conversion of land use types. For example, the conversion of previously fallowed land to a land restoration project that is expected to improve infiltration of stormwater runoff along the Coyote Creek wash is currently being evaluated.

4.5.4 Timetable for Implementation of Voluntary Fallowing of Agricultural Land Program

The initial phase of the program will be focused on program design, policy development, and stakeholder outreach. This phase can begin immediately and is anticipated to take from 4 to 6 months. Full implementation of the program is anticipated following CEQA review, if needed. Once implemented, the program will result in immediate groundwater savings, which may increase with addition of fallowed lands and fluctuate depending on the nature and timing of converted land use.

4.5.5 Metrics for Evaluation of Voluntary Fallowing of Agricultural Land Program

The Voluntary Fallowing of Agricultural Land Program will include both direct and indirect metrics to evaluate the effectiveness of the program. Program effectiveness is primarily related to Subbasin sustainability goals that are quantified through the development of measurable objectives and minimum thresholds in this Plan. As such, groundwater levels and corresponding changes in Subbasin groundwater storage are the ultimate metrics to evaluate effectiveness. Direct metrics by which to evaluate the success of the fallowing program include comparison of pre- and post-pumping records for fallowed or converted properties, to the extent available. The area of irrigated land and crop types should also be directly tracked to monitor program effectiveness. Additionally, the number of fallowing projects implemented, active and or planned are to be tracked. Water budget components, when combined with water quality, demographic information, and project costs may be used as an indirect measure of the effectiveness of the Voluntary Fallowing of Agricultural Land Program as shown in Table 4-8.

Table 4-8
Metrics for Evaluating Voluntary Fallowing of Agricultural Land Program Effectiveness

PMA No.	PMA Name	Direct Metrics	Indirect Metrics
No. 4	Voluntary Fallowing of Agricultural Land	1. Groundwater levels 2. Groundwater storage 3. Metered groundwater extraction 4. Area of irrigated land and crop type 5. Area of fallowed land 6. Number of implemented/active/planned projects	1. Water budget components 2. Water quality 3. Subbasin demographics 4. End-use of fallowed land 5. Stabilization of site soils 6. Cost

Notes: PMA = Projects and Management Action.

4.5.6 Economic Factors and Funding Sources for Voluntary Fallowing of Agricultural Land Program

Planning-level development cost for establishing the Voluntary Fallowing of Agriculture Program is estimated to be approximately $103,000 and separate from development of this GSP.

Potential sources of funding for the Voluntary Fallowing of Agriculture Program components include state grants, pumping fees, water rates, parcel taxes, and other mechanisms as described in Section 5.1.7, Funding Sources.

Ongoing program costs will be determined through the initial task of developing a fallowing plan. These potential costs are related to the conformance inspections, economic value of fallowed land, the cost for site stabilization, and restoration. Additionally, wells that will no longer be used will have costs to be properly destroyed. Preliminary estimation for site stabilization and restoration is as follows:

- Level 1: Site Stabilization: Sites planned to be left fallow which could be used for future development would benefit from site stabilization. This approach to fallowing orchards should include stabilizing the land surface, avoiding the blight of dead tree stands, reducing weed growth, and reducing dust emissions.
    - Cutting and chipping orchard trees and spreading over the surface. **Cost estimate: $1,000–$5,000 per acre**
- Level 2: Passive Restoration: If the ultimate goal of the site is to convert to natural habitat which can allow for a relatively long period of time to establish future open space (e.g., Anza-Borrego Desert State Park (ABDSP) land), a passive restoration approach could be implemented in some areas of the Subbasin such as those influenced by the floodwaters of Coyote Creek wash. This approach would establish the fundamental site conditions that would put the site on a trajectory towards reestablishment of native habitat. This approach could include tree removal, site contouring, soil decompaction, and native seed collection and application. It does not include maintenance and monitoring. A passive restoration approach can take many years, and even decades, in a desert environment. **Cost estimate: $10,000–$25,000 per acre**
- Level 3: Active Restoration: An active restoration approach would be appropriate if the goal of the site is to restore site to natural habitat in a relatively short period for future open space (e.g., ABDSP land, open space trails). This approach would require full restoration of the site including site preparation as described for passive restoration, plus horizontal/vertical mulch, supplemental seeding, maintenance, monitoring, and remedial actions and goals. While active restoration is more labor intensive and expensive than passive restoration, it could take as little as 3–5 years to establish and meet success criteria. **Cost estimate: $25,000–$50,000 per acre**

The cost per acre-foot saved will depend on the historical land use and the method of fallowing or conversion.

Preliminary Estimation for Costs to Properly Destroy Wells

Well Destruction Permit: For each fallowing transaction, the GSA may request the property owner to obtain a Well Destruction Permit from the County of San Diego Department of Environmental Health (DEH) for any wells that will no longer be used after the land is fallowed. Alternatively, the GSA may consider utilizing wells for groundwater monitoring. As of July 1, 2018, the fee for a Well Destruction Permit for a single water well is $334. DEH updates the fees on an annual basis and should be contacted to determine the current fee required to be collected for the permit. The Well Destruction Permit must be obtained by a California C57 Licensed Contractor who is listed on the DEH approved Well Driller’s List. The DEH water wells webpage can be found at: https://www.sandiegocounty.gov/content/sdc/deh/lwqd/lu_water_wells.html

Costs to Properly Destroy Wells

An Engineers Estimate was obtained to properly abandon a 16-inch diameter, 500 feet deep well. It is $33,500 assuming the well needs to be pressure grouted with cement, and prevailing wage applies. For each additional foot of well depth an additional $41 should be added to the cost. Costs for narrower diameter wells would be less expensive.

The Engineers Estimate to pull a turbine pump installed to a depth up to 500 feet is $6,800 assuming prevailing wage applies.

Thus, the Engineers Estimate to properly destroy wells is $40,300 per well assuming prevailing wage applies. Non-prevailing wage well destructions could be initiated by private landowners.

4.5.7 Voluntary Fallowing of Agricultural Land Program Uncertainty

Program uncertainty is related to the willingness of property owners to participate in the program and the water consumption of future, post fallowing, post transfer land uses. These parameters will be evaluated during the first phase of the implementation.

4.6 PROJECTS AND MANAGEMENT ACTION NO. 5 – WATER QUALITY OPTIMIZATION

Groundwater is extracted for multiple beneficial uses in the Subbasin including municipal and domestic use, and for irrigation. At a minimum, for municipal and domestic wells, the water quality must meet potable drinking water standards specified in Title 22 of the CCR. For irrigation wells, water quality should generally be suitable for agriculture use. Water quality optimization is primarily focused on ensuring potable water quality for municipal and domestic use. Additionally, water quality optimization will evaluate the potential to match water quality for intended uses such as the potential to use groundwater with elevated nitrate concentrations or other constituents of concern for irrigation.

In general, the groundwater quality in the Subbasin is good and meets California drinking water maximum contaminant levels without the need for treatment. As documented in Section 2.2.2.4, Groundwater Quality, naturally occurring poor water quality has been identified in specific areas: near the margins of the Subbasin where unconsolidated sediments are in contact with fractured bedrock; for select wells screened predominantly in the lower aquifer of the South Management Area that have concentrations of arsenic above the drinking water maximum contaminant level; and near the Borrego Sink where elevated sulfate and TDS are likely associated with dissolution of evaporites from the dry lake. Historical groundwater quality impairment for nitrates is noted for select portions of the Subbasin predominantly in the upper aquifer of the North Management Area underling the agricultural areas and near high density of septic point sources. The source of nitrates is likely associated with either fertilizer applications or septic return flows.

A robust groundwater quality monitoring program is essential to the implementation of the "Water Quality Optimization Program." Analysis of the existing monitoring program and data gaps has revealed lateral, vertical, and temporal limitations to water quality data availability. These data gaps will be addressed with collection and analysis of additional data and implementation of this GSP as described in Section 3.5, Monitoring Network.

4.6.1 Water Quality Optimization Program Description

Implementation of the Water Quality Optimization Program is to be initially conducted at the planning level. However, preliminary evaluations have already been conducted for several water quality optimization options. These are presented briefly following the section on planning considerations as follows.

Water Quality Optimization Planning

Development of the Groundwater Quality Optimization Program is anticipated to include three general phases: (1) investigation to identify the sources, nature, and extent of existing and potential future water quality impairments; (2) as needed, development of work plans to implement mitigation strategies; and (3) implementation of water quality mitigation projects.

The initial program phase will be to evaluate key issues associated with program development as follows:

- Evaluate existing data for gaps related to identification of contaminant sources (e.g., well construction information in areas with suspected surficial contaminant sources).
- Perform outreach with applicable stakeholders to obtain input regarding pertinent practices or anticipated future activities and vulnerabilities (e.g., meeting with farmers regarding fertilizer application practices).
- Scope investigations to fill data gaps or refine preliminary findings.

- Evaluate proactive abandonment of inactive wells to minimize migration pathways.
- As needed, prepare recommended mitigation alternatives for GSA consideration, with associated cost-benefit analyses.
- Identify potential funding sources.
- Consider costs and benefits for combined treatment projects and methods.
- As needed, scope a feasibility study for outlining the procedures for characterizing and mitigating degraded groundwater quality in the Subbasin.
- Prepare a Groundwater Quality Optimization Plan.

BWD Water Quality Optimization Options

Both direct treatment and indirect options have been considered to optimize groundwater quality and its use. Direct treatment of some types of groundwater contaminants may not be cost effective. There are indirect methods that may be more cost effective such as blending of poor quality water with better quality water, the construction of new wells in areas or aquifers with better quality water, transfer of water to areas where water use is better suited to a particular water quality as described in Section 4.7, PMA No. 6 – Intra-Subbasin Water Transfers, and reallocation of pumping production between wells.

Direct Treatment Options

The BWD has investigated the treatment of arsenic and nitrates on a preliminary basis. Treatment and cost considerations are presented *in Water Replacement and Treatment Cost Analysis for the Borrego Valley Groundwater Basin* (Dudek 2015). The feasibility of treatment is dependent on several factors including the contaminant concentration, quantity of water to be treated, the type of treatment facilities, and the operation and maintenance cost associated with particular treatment methods. Wellhead treatment systems yielded a wide range of total costs based on the level of uncertainty. The costs have been estimated to be between $227 and $548 per acre-foot for municipal production wells (Dudek 2015). Treatment system costs have not been evaluated for domestic wells because there have been no known detections of arsenic above drinking water standards reported for domestic wells. If private wells were to become impacted by water quality degradation, the feasibility of direct treatment would be evaluated.

Indirect Treatment Methods

Indirect treatment methods considered include various blending scenarios, the construction of new wells and delivery facilities, and re-allocation of pumping among existing wells.

Blending

Arsenic levels above the maximum contaminant level have historically been documented in one active BWD well and several private irrigation wells in the South Management Area; however, all BWD wells currently meet drinking water standards. There is a potential that continued decline in groundwater levels may result in increased arsenic concentrations. If increased arsenic concentrations do occur in BWD wells in the future, blending of water from these wells with BWD wells that do not have elevated arsenic is potentially a low-cost alternative to direct treatment. The cost associated with blending is highly variable and will depend on proximity of wells and the water quality of the blending source well. Additionally, the Division of Drinking Water would need to review and approve any potential blending plan, and it may not be possible to meet Division of Drinking Water standards because blending is not a preferred permanent alternative due to the potential for variability in the concentration of arsenic at the well-head over time.

New Well and Pipeline

This option would require the construction of new extraction wells in a part of the basin with acceptable water quality (potentially the North Management Area or Central Management Area). In addition to well construction costs associated with this alternative, costs to be evaluated include the cost of distribution pipelines, ongoing maintenance costs, and project power. The BWD is currently locating, designing and constructing up to three new potable extraction wells as part of its current Capital Improvement Plan.

Reallocation of Pumping from Existing Wells

Another option in the future is to re-allocate production from wells with higher levels of constituents of concern and potential for future water quality degradation, with production from more reliable wells with better water quality. The feasibility of this mitigation measure would be based on availability of water resources from wells in other parts of the Subbasin. If private wells were to become impacted by water quality degradation, the feasibility of drilling new wells or connecting to the BWD distribution system would be evaluated.

4.6.2 Water Quality Optimization Relationship to Sustainability Criteria

The Water Quality Optimization Program will address the undesirable result of water quality degradation. Avoiding undesirable results to water quality benefits the whole Subbasin to the benefit of all pumpers. Depending on the methods selected to optimize water quality, the Water Quality Optimization Program could potentially help to alleviate declining groundwater levels in particular areas of the basin by relocating pumping to other parts or management areas.

Relationship to Measurable Objectives

The Water Quality Optimization Program will be implemented to meet the measurable objectives for water quality.

Relationship to Minimum Thresholds

Consistent with the measurable objectives, the program serves as a direct physical action to maintain water quality above minimum thresholds to avoid undesirable results.

4.6.3 Expected Benefits of Water Quality Optimization

The primary benefit of the Water Quality Optimization Program is the existing and future maintenance of high quality water produced by groundwater extractors. Associated benefits may include lower long-term water costs to customers and reduction of future degradation of water quality.

4.6.4 Timetable for Implementation of the Water Quality Optimization

It is anticipated that the Water Quality Optimization Program will require a significant analysis and planning component prior to the implementation of specific water quality projects. Such planning has already started and the entire planning component is expected to take from 18 to 24 months after adoption of the GSP. The need for specific water quality optimization projects will be evaluated annually based on the results of the monitoring network described in Section 3.5, Monitoring Network.

4.6.5 Metrics for Evaluation of Water Quality Optimization

Water Quality Optimization will include both direct and indirect metrics to evaluate the effectiveness of the program. Effectiveness is primarily related to Subbasin sustainability goals that are quantified through the development of measurable objectives and minimum thresholds in this Plan. As such, groundwater quality in the Subbasin is the ultimate metric to evaluate effectiveness. Water quality evaluation has been included in the data gaps analysis and groundwater monitoring plan as described in Section 3.5, Monitoring Network. Specific metrics will include monitoring for the constituents most likely to be of concern in the basin, including arsenic, nitrate, sulfate, fluoride, and TDS. Metered groundwater extraction, groundwater levels and corresponding changes in groundwater storage will be monitored as they potentially relate to the potential for leaching of contaminants from subsurface geology. Active and implemented optimization projects will be tracked, and the need for new projects will be identified. Water budget components, when combined with demographic information and project costs may be used as an indirect measure of the effectiveness of the Water Quality Optimization as shown in Table 4-9.

Table 4-9
Metrics for Evaluating Water Quality Optimization Effectiveness

PMA No.	PMA Name	Direct Metrics	Indirect Metrics
No. 5	Water Quality Optimization	1. Groundwater levels 2. Groundwater storage 3. Metered groundwater extraction 4. Water quality 5. Active projects/identification of need for projects 6. List of implemented projects	1. Water budget components 2. Subbasin demographics 3. Cost

Notes: PMA = Projects and Management Action.

4.6.6 Economic Factors and Funding Sources for Water Quality Optimization Program

Planning-level development cost for establishing the Water Quality Optimization Program is estimated to be approximately $124,000 and separate from development of this GSP.

Potential sources of funding for the Water Quality Optimization program components include state grants, pumping fees, water rates, parcel taxes, and other mechanisms as described in Section 5.1.7, Funding Sources.

4.6.7 Water Quality Optimization Program Uncertainty

Program uncertainty includes unknown existing and future water quality, and the costs and efficacy associated with projects selected to address water quality degradation. These costs are dependent on a more thorough characterization of the severity and location of existing and potential future water quality impairments. Additionally, there is uncertainty regarding the availability of funding to implement the Water Quality Optimization Program.

4.7 PROJECTS AND MANAGEMENT ACTION NO. 6 – INTRA-SUBBASIN WATER TRANSFERS

4.7.1 Intra-Subbasin Water Transfers Program Description

The purpose of Intra-Subbasin Transfer Program is to mitigate existing and future reductions in groundwater storage and groundwater quality impairment by establishing conveyance of water from higher to lower production alternative areas in the Subbasin. This PMA will evaluate the feasibility and effectiveness of utilizing new or existing well sites in the Subbasin where groundwater conditions are more favorable for continued groundwater extraction. Currently, the BWD is the only entity in the Subbasin with a large water distribution system. The BWD distribution system supplies only potable water. All other water users in the Subbasin only have small, private conveyance restricted to limited areas of land. These include both potable and non-potable systems for domestic and irrigation use.

The GSA has designated three Subbasin management areas as described in Section 2.2.4, Management Areas. The management areas are based primarily for the purpose of groundwater quality management since the end uses of groundwater differs substantially across the three management areas. Wells in the North Management Area (NMA) serve primarily agricultural use whereas wells in the Central Management Area (CMA) primarily serve municipal use, and wells in the South Management Area (SMA) primarily serve recreational use which means there may be different thresholds for undesirable results for potable versus non-potable uses. For example, groundwater pumped in the NMA, with potentially elevated nitrate levels from irrigation return flow, might be beneficially used to irrigate golf course turf in the CMA or SMA. Conveyance of non-potable water in the Subbasin would require construction of a new non-potable distribution system. A non-potable distribution system could benefit all pumpers in the Subbasin because it would preserve areas of the Subbasin where water meets drinking water standards. Additionally, because the Desert Lodge anticline effectively compartmentalizes the SMA from the CMA, it may be necessary to convey water between management areas to achieve location specific measurable objectives for groundwater levels and groundwater in storage. The need for transfer of pumped groundwater may be of benefit to other areas of the Subbasin depending on the timing and location of pumping reductions. For instance, if a sizable area of land were fallowed in the NMA, there is the potential to use existing wells to supply water to the CMA or SMA.

As part of this PMA, current system infrastructure, condition, and needs as well as identify potential siting for new wells and conveyance facilities will be evaluated.

Development of the Intra-Subbasin transfer program will include the following steps:

- Inventory of existing infrastructure with considerations for capacity, condition, and vulnerabilities.
- Identification and prioritization of specific extraction wells that warrant mitigation/replacement.
- Preliminary opportunities and constraints analysis.
- Identification of current and potential future water blending opportunities and limitations.
- Estimated costs for anticipated future water treatment requirements (i.e., arsenic, nitrate, TDS) for the existing well network.
- Cost-benefit analysis for various selected project alternatives.
- Development of a more specific Intra-Subbasin Water Transfer Plan.

Legal Authority and Regulatory Process

A GSA has the power to "perform any act necessary or proper to carry out the purposes of [SGMA]" (CWC Section 10725.2(a)). A GSA may also "authorize temporary and permanent transfers of groundwater extraction allocations within the agency's boundaries, if the total quantity of groundwater extracted in any water year is consistent with the provisions of the groundwater sustainability plan." A GSA also has the power to "(e) Transport, reclaim, purify, desalinate, treat, or otherwise manage and control polluted water, wastewater, or other waters for subsequent use in a manner that is necessary or proper to carry out the purposes of this part" (CWC, Section 10726.2(e)).

4.7.2 Intra-Subbasin Water Transfers Program Relationship to Sustainability Criteria

The Intra-Subbasin Transfer Program will potentially address multiple undesirable results identified for the Subbasin. Groundwater level declines may be addressed by the transfer of water from parts of the Subbasin with stable groundwater levels to those with pumping depressions or groundwater level declines. Water transfers may also allow for selective pumping of the middle or lower aquifers as opposed to the upper aquifer, which is likely more susceptible to water quality impacts as a result of septic and irrigation return flows. Use of groundwater resources may be optimized by the transport of water for uses to which the water quality is compatible, thereby potentially preserving good water quality for potable use. For example, transfer of high nitrate groundwater for irrigation may reduce the reliance on potable water.

Relationship to Measurable Objectives

The Intra-Subbasin Transfer Program is intended to optimize water supply and demand for beneficial users in the Subbasin. This program will evaluate the distribution of pumping in the Subbasin that could result in direct effects to the chronic lowering of groundwater levels and reduction of groundwater in storage measurable objectives.

Relationship to Minimum Thresholds

Consistent with the measurable objective, the program serves as a direct physical action to manage groundwater levels, groundwater in storage and water quality above minimum thresholds to avoid undesirable results.

4.7.3 Expected benefits of the Intra-Subbasin Water Transfers Program

The primary benefit of the Intra-Subbasin Transfer Program is that it will provide flexibility in regard to where groundwater is produced and consumed. In particular, it provides a potential mechanism to convey both potable and non-potable water to end users. This would allow for conveyance of groundwater of specific water quality for purposes to which its use is compatible. Additionally, it could provide an additional tool to reduce groundwater extraction from areas of declining groundwater levels. It is expected that Intra-Subbasin Transfer Program would help achieve measurable objectives for groundwater levels, groundwater in storage and water quality.

4.7.4 Timetable for Implementation of the Intra-Subbasin Water Transfers Program

It is anticipated that the planning part of the Intra-Subbasin Transfer and analysis plan will require approximately 9–12 months but potentially be required to be initiated during GSP implementation based on the results of the monitoring network as described in Section 3.5, Monitoring Network.

4.7.5 Metrics for Evaluation of the Intra-Subbasin Water Transfers Program

The Intra-Subbasin Water Transfer Program will include both direct and indirect metrics to evaluate the effectiveness of the program. Program effectiveness is primarily related to Subbasin sustainability goals that are quantified through the development of measurable objectives and minimum thresholds. As such, groundwater levels, corresponding changes in Subbasin groundwater storage, and water quality are probably the most representative metrics to evaluate effectiveness. Direct metrics by which to evaluate the success of the metrics for the evaluation of the Intra-Subbasin Transfer Program include area and aquifer-specific measurement of groundwater levels and corresponding changes in groundwater storage, metering of groundwater production and monitoring water quality. Active and implemented projects will be tracked, and the need for new projects will be identified. Water budget components, when combined with demographic information and project costs, may be used as an indirect measure of the effectiveness of the Intra-Subbasin Water Transfers as shown in Table 4-10.

Table 4-10
Metrics for Evaluating Intra-Subbasin Water Transfers Effectiveness

PMA No.	PMA Name	Direct Metrics	Indirect Metrics
No. 6	Intra-Subbasin Water Transfers	1. Groundwater levels 2. Groundwater storage 3. Metered groundwater production 4. Water quality 5. Active projects/identification of need for projects 6. List of implemented projects	1. Water budget components 2. Subbasin demographics

Notes: PMA = Projects and Management Action.

4.7.6 Economic Factors and Funding Sources for Intra-Subbasin Water Transfers Program

Planning-level development cost for establishing the Intra-Subbasin Water Transfers Program is estimated to be approximately $90,000 and separate from development of this GSP.

Potential sources of funding for the Intra-Subbasin Water Transfers Program components include state grants, pumping fees, water rates, parcel taxes, and other mechanisms as described in Section 5.1.7, Funding Sources.

4.7.7 Intra-Subbasin Water Transfers Program Uncertainty

Program uncertainty associated with intra-subbasin water transfers includes the cost and availability of land for infrastructure and facilities construction, level of participation of water users, and water quality suitability for contributing and receiving uses, some of which activities may require CEQA compliance. Intra-subbasin water transfers may require construction of new pipeline conveyance systems, siting and construction of new extraction wells, and additional analysis of water quality.

4.8 GROUNDWATER SUSTAINABILITY PLAN COORDINATION WITH GENERAL PLAN UPDATE

SGMA (CWC, Sections 10727.2(g), 10726.9) requires coordination of GSPs with General Plan Updates in order to promote consistency within the planning documents. In this case, the County is a member of the GSA and, thus, this task of coordination is more streamlined than it may be with the development of other GSPs.

The sustainability goals of the GSP are anticipated to play a central role in the County's next General Plan update process, which encompasses updates to the Borrego Springs Community Plan (see Chapter 2, Basin Setting). The GSA has prepared a *Planning, Permitting and Ordinance Review Technical Report* that identifies key issues of current County plans and policies that may need to be changed or updated to ensure consistency with the long-term sustainability goal and sustainable management criteria of the GSP.

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CHAPTER 5
PLAN IMPLEMENTATION

5.1 GROUNDWATER SUSTAINABILITY PLAN IMPLEMENTATION AND ESTIMATED COSTS

This Groundwater Sustainability Plan (GSP, Plan) will be implemented by the Borrego Valley Groundwater Sustainability Agency (GSA, Agency). The following sections include cost estimates for Plan implementation including annual reporting, periodic updates, monitoring protocols, and projects and management actions (PMAs). Potential funding sources and mechanisms are presented along with a tentative schedule for implementing the Plan's primary components. In addition, annual reporting and 5-year update procedures for the Borrego Springs Groundwater Subbasin (Subbasin, Plan Area) are described.

Standards for Plan Implementation

Under the GSP Regulations (23 California Code of Regulations (CCR) Section 350, et seq.), the GSP is to include the following:

- An estimate of the cost of implementing the Plan and a general description of how the Agency plans to meet those costs (23 CCR Section 354.6(e)).
- Schedule for Implementation (23 CCR Sections 352.4(c)(2) and 355.4(b)(2)).

Annual Reporting

The GSA shall submit an annual report to the Department by April 1 of each year following the adoption of the Plan. The annual report shall include the following components for the preceding water year:

1. General information, including an executive summary and a location map depicting the basin covered by the report.
2. A detailed description and graphical representation of the following conditions of the basin managed in the Plan:
    a. Groundwater elevation data from monitoring wells identified in the monitoring network shall be analyzed and displayed as follows:
        i. Groundwater elevation contour maps for each principal aquifer in the basin illustrating, at a minimum, the seasonal high and seasonal low groundwater conditions.
        ii. Hydrographs of groundwater elevations and water year type using historical data to the greatest extent available, including from January 1, 2015, to current reporting year.
    b. Groundwater extraction for the preceding water year. Data shall be collected using the best available measurement methods and shall be presented in a table that summarizes

   groundwater extractions by water use sector, and identifies the method of measurement (direct or estimate) and accuracy of measurements, and a map that illustrates the general location and volume of groundwater extractions.

   c. Surface water supply used or available for use, for groundwater recharge or in-lieu use shall be reported based on quantitative data that describes the annual volume and sources for the preceding water year.
   d. Total water use shall be collected using the best available measurement methods and shall be reported in a table that summarizes total water use by water use sector, water source type, and identifies the method of measurement (direct or estimate) and accuracy of measurements.
   e. Change in groundwater in storage shall include the following:
      i. Change in groundwater in storage maps for each principal aquifer in the basin.
      ii. A graph depicting water year type, groundwater use, the annual change in groundwater in storage, and the cumulative change in groundwater in storage for the basin based on historical data to the greatest extent available, including from January 1, 2015, to the current reporting year.

3. A description of progress towards implementing the Plan, including achieving interim milestones, and implementation of projects or management actions since the previous annual report (CCR Section 356.2).

5-Year Evaluation

The GSA shall evaluate its Plan at least every 5 years and whenever the Plan is amended, and provide a written assessment to the Department. The assessment shall describe whether the Plan implementation, including implementation of PMAs, are meeting the sustainability goal in the basin, and shall include the following:

1. A description of current groundwater conditions for each applicable sustainability indicator relative to measurable objectives, interim milestones and minimum thresholds.
2. A description of the implementation of any projects or management actions, and the effect on groundwater conditions resulting from those projects or management actions.
3. Elements of the Plan, including the basin setting, management areas, or the identification of undesirable results and the setting of minimum thresholds and measurable objectives, shall be reconsidered and revisions proposed, if necessary.
4. An evaluation of the basin setting in light of significant new information or changes in water use, and an explanation of any significant changes. If the Agency's evaluation shows that the basin is experiencing overdraft conditions, the Agency shall include an assessment of measures to mitigate that overdraft.

5. A description of the monitoring network within the basin, including whether data gaps exist, or any areas within the basin are represented by data that does not satisfy the requirements of the GSP Regulations (23 CCR Sections 352.4 and 354.34(c)). The description shall include the following:
    a. An assessment of monitoring network function with an analysis of data collected to date, identification of data gaps, and the actions necessary to improve the monitoring network, consistent with the requirements of Section 354.38.
    b. If the Agency identifies data gaps, the Plan shall describe a program for the acquisition of additional data sources, including an estimate of the timing of that acquisition, and for incorporation of newly obtained information into the Plan.
    c. The Plan shall prioritize the installation of new data collection facilities and analysis of new data based on the needs of the basin.
6. A description of significant new information that has been made available since Plan adoption or amendment, or the last 5-year assessment. The description shall also include whether new information warrants changes to any aspect of the Plan, including the evaluation of the basin setting, measurable objectives, minimum thresholds, or the criteria defining undesirable results.
7. A description of relevant actions taken by the Agency, including a summary of regulations or ordinances related to the Plan.
8. Information describing any enforcement or legal actions taken by the Agency in furtherance of the sustainability goal for the basin.
9. A description of completed or proposed Plan amendments.
10. Where appropriate, a summary of coordination that occurred between multiple Agencies in a single basin, Agencies in hydrologically connected basins, and land use agencies.
11. Other information the Agency deems appropriate, along with any information required by the Department to conduct a periodic review as required by California Water Code (CWC) Section 10733 (CCR Section 356.4).

5.1.1 Groundwater Sustainability Agency Annual Budget

The GSA has performed substantial work toward estimating the cost of GSP implementation. Summaries of the tasks and costs are provided in the following subsections.

5.1.1.1 Operations and Monitoring Costs

Annual operations include semi-annual monitoring of groundwater levels, water quality, and streamflow monitoring, and annual review of land subsidence data, if necessary, in accordance with the monitoring plan (described in Chapter 3, Section 3.5). Other tasks include data management system maintenance, update of the groundwater model, and monitoring equipment maintenance. The required annual report will be produced in accordance with Section 356.2 of the GSP Regulations. The total annual cost of these tasks is estimated to be $303,261 per year starting in fiscal year (FY) 2020; however, some tasks such as the Borrego Valley Hydrologic Model update or land subsidence review may not occur annually throughout GSP implementation but have been included annually to provide a conservative estimate. A task list and related estimated annual costs are provided in Table 5-1.

Table 5-1
Operations and Monitoring Costs

Expense Item		Estimated Annual Costs (FY 2020)
Task 1:	Semi-Annual Groundwater Level Monitoring	$29,616
Task 2:	Semi-Annual Water Quality Monitoring	$69,131
Task 3:	Semi-Annual Stream Monitoring	$11,302
Task 4:	Pump Metering	$10,927
Task 5:	Land Subsidence Review	$9,168
Task 6:	Operation and Maintenance	$20,739
Task 7:	Data Management System	$19,508
Task 8:	Annual Groundwater Model Update	$79,375
Task 9:	Annual Comprehensive DWR Reporting	$16,444
Task 10:	Project Management and Coordination	$37,051
	Total	**$303,261**

Notes: FY = fiscal year; DWR = Department of Water Resources.

A summary of the scope of each task is as follows:

1. **Semi-Annual Groundwater Level Monitoring** Monitoring of groundwater levels conducted semi-annually throughout the well network within the Subbasin. This may consist of multiple days of field monitoring annually in which trained professionals will manually measure depth to groundwater, or, collect data from transducer data loggers. Management of data, as well as annual preparation of groundwater level monitoring summary memorandum.
2. **Semi-Annual Water Quality Monitoring** Collection, testing, and analysis of groundwater samples from designated monitoring wells on a semi-annual basis. A trained professional will visit designated wells, perform field testing of select water quality parameters, collect samples, and send samples to laboratory for water quality testing. Test results will be tabulated and reported per the GSP guidelines. Management of data, as well as annual preparation of water quality monitoring summary.

3. **Semi-Annual Stream Monitoring** Inspection and monitoring of streams within basin on a semi-annual basis. Tasks may include measuring flow rates, visual inspection of streams, noting changes in geomorphology, and preparation of stream monitoring summary.
4. **Pump Metering** Quality assurance and quality control of supplied metering data of groundwater extraction, annual meter reads (non-self-reporting wells), meter calibration and validation, and new meter installations in accordance with the Metering Plan (Appendix E). Preparation of annual groundwater extraction summary.
5. **Land Subsidence Monitoring** Evaluation of existing monument survey to examine and estimate any changes in land subsidence. Management of data and preparation of periodic land subsidence summary, if necessary.
6. **Operation and Maintenance** Maintenance and minor repairs to various monitoring instruments including: transducers, dataloggers, well heads, etc. This task may also include inspections of fallowed lands.
7. **Data Management System** Maintenance and hosting of data management system. Updates and quality assurance of organization and viability of stored data.
8. **Annual Groundwater Model Update** Annual updates to groundwater model as a result of new and higher resolution data within the Subbasin. Preparation of periodic groundwater model summary, as necessary.
9. **Annual Comprehensive Department of Water Resources (DWR) Reporting** Preparation of draft DWR annual reports as outlined in the GSP. Review and edits of draft annual reports. Preparation and submittal of final DWR annual reports as outlined in the GSP.
10. **Project Management and Coordination** Correspondence between GSA and consultants, including GSA and Borrego Town Hall or GSP implementation update meetings. Project management and as-needed correspondence to complete annual GSP requirements.

5.1.1.2 Management, Administration, and Other Costs

The GSA will incur additional costs for internal management and administration by Borrego Water District (BWD) and County staff. The level of effort in fulltime equivalent (FTE) employees and corresponding fully burdened rates is still being estimated, but at this state the GSA estimates it will require two FTEs at a fully burdened rate of $120,000 per FTE. The GSA may also incur costs related to repair and replacement of capital assets such as well meters, vehicles, equipment, and supplies, as well as potential legacy costs of well abandonment. It is assumed that the GSA will lease office and other space from BWD for operations and administration. Rent is roughly estimated at $500 per month or $6,000 per year. Legal fees are estimated at $30,000 per year based on legal fees currently paid to develop the GSP. Other expenses include audit services, insurance, office supplies, etc. and are roughly estimated based on comparable agency costs. Cost estimates for these items require additional evaluation; however, these other expenses are expected to be a fraction of personnel and legal expenses. Additional variable costs include engineering services, permits and fees, and land management/stewardship expenses that are expected to be incurred once PMAs are fully developed. Once PMAs are developed the GSA will update annual management, administration and other costs. Table 5-2 provides a comprehensive list of line item expense types that the GSA expects to incur.

Table 5-2
Management, Administration, and Other Costs

Expense Item		Estimated Annual Costs (FY 2020)
1	Administrative Personnel (two FTE)	$240,000
2	Rent/Leases (BWD space)	$6,000
3	Utilities	$500
4	Consulting Services	$10,000
5	Audit and Professional Services	$5,000
6	Legal	$30,000
7	Insurance	$3,750
8	Public Outreach	$6,000
9	Repairs and Maintenance	$1,500
10	Supplies and Equipment	$750
11	Office Supplies	$500
12	Miscellaneous Expenses	$1,500
	Total	**$305,500**

Notes: FY = fiscal year; FTE = fulltime equivalent; BWD = Borrego Water District.

5.1.2 Reserves and Contingencies

In addition to covering the operations budget, the GSA should consider adoption of a reserves policy which is expressly authorized by the Sustainable Groundwater Management Act (SGMA) (CWC Sections 10730(a) and 10730.2(a)(1)). Reasonable and achievable reserves are a prudent financial tool to aid in cash flow timing and unforeseen expenditures. Generally, a reserve for operations targets a specific percentage of annual operating costs or days of cash on hand. The reserve target is influenced by several factors including the frequency of billing and the recurrence of expenses. Comparable agencies use a reserve percentage of 50% of operating budget if billing semi-annually, less if more frequent. The bases and values for reserves are presented in the GSP Finance Plan. Additionally, for budgeting purposes the GSA has included a 10% contingency to FY cost estimates.

5.1.3 Periodic (5-Year) Groundwater Sustainability Plan Update Costs

Every fifth year of GSP implementation and whenever the GSP is amended, the GSA is required to prepare and submit an Agency Evaluation and Assessment Report to the DWR together with the annual report for that year. The assessment and report will be prepared as described in California Code of Regulations (CCR) Section 356.10. Table 5-3 provides a list of tasks and estimated cost that the GSA expects to incur to complete 5-year updates.

Table 5-3
Groundwater Sustainability Plan 5-Year Update Costs

Expense Item		Estimated 5-Year Additional Costs
Task 1	Updated Water Budget, Groundwater Model and Sustainable Yield	$31,430
Task 2	Assessment of Pumping Allocations	$14,450
Task 3	5-Year Plan Evaluation and Assessment Report	$19,120
	Total	**$65,000**

5.1.4 Projects and Management Actions Development Costs

Details of the proposed PMAs are presented in Chapter 4, Projects and Management Actions. Task descriptions and estimated costs associated with development of each PMA are summarized in Table 5-4. Proposed PMAs are presented at the planning level and additional costs will be incurred with full implementation.

Table 5-4
Projects and Management Actions Development Costs

PMA Number	PMA	Estimated Cost	Level of Project Development
1	Water Trading Program	$122,065	Planning and trading system development
2	Water Conservation Program (Demand Management)	$130,390	Planning, field surveys and cost development
3	Pumping Reduction Program	$82,430	Planning and outreach
4	Voluntary Fallowing of Agricultural Land	$103,175	Planning and outreach
5	Water Quality Optimization	$124,060	Planning and preliminary engineering
6	Intra-Basin Transfers	$89,545	Planning and preliminary engineering

Notes: PMA = Projects and Management Action.

5.1.5 Total Costs

Annual implementation costs may vary from year to year as a result of the status of PMAs, significance of new data, and increased milestone reporting requirements every fifth year of implementation. For planning purposes, the estimated annual budget for GSA operations and monitoring have been adjusted for annual inflation assumed at 2.8% per year to determine the total GSP implementation cost. The estimated GSP implementation cost for the anticipated 20-year implementation period for operations and monitoring, management, administration and other costs, 5-year annual reviews and 10% contingency is approximately $19,200,000 as summarized in Table 5-5.

Table 5-5
Groundwater Sustainability Plan Estimated Implementation Cost Through 2040

Fiscal Year	Operations and Monitoring Costs	Management, Administration and Other Costs	5-Year Annual Reviews	10% Contingency	Total
2020	$303,261	$305,500	$0	$60,876	$669,637
2021	$311,752	$314,054	$0	$62,581	$688,387
2022	$320,481	$322,848	$0	$64,333	$707,662
2023	$329,455	$331,887	$0	$66,134	$727,476
2024	$338,680	$341,180	$0	$67,986	$747,846
2025	$348,163	$350,733	$72,592	$77,149	$848,636
2026	$357,911	$360,554	$0	$71,846	$790,311
2027	$367,933	$370,649	$0	$73,858	$812,440
2028	$378,235	$381,027	$0	$75,926	$835,188
2029	$388,825	$391,696	$0	$78,052	$858,574
2030	$399,712	$402,664	$83,340	$88,572	$974,287
2031	$410,904	$413,938	$0	$82,484	$907,327
2032	$422,410	$425,528	$0	$84,794	$932,732
2033	$434,237	$437,443	$0	$87,168	$958,849
2034	$446,396	$449,692	$0	$89,609	$985,696
2035	$458,895	$462,283	$95,679	$101,686	$1,118,543
2036	$471,744	$475,227	$0	$94,697	$1,041,668
2037	$484,953	$488,533	$0	$97,349	$1,070,835
2038	$498,532	$502,212	$0	$100,074	$1,100,818
2039	$512,490	$516,274	$0	$102,876	$1,131,641
2040	$526,840	$530,730	$109,846	$116,742	$1,284,157
	$8,511,809	**$8,574,653**	**$361,456**	**$1,744,792**	**$19,192,710**

Notes: Assumes inflation factor of 2.8% per year.

Estimated total GSP implementation costs assumes the following general components:

- Data collection, management, and evaluation
- Annual reporting
- 5-year review assessment and reporting
- Data gap analysis and additional evaluation
- PMAs development and implementation of components as funding allows
- Management, administration, and other costs
- 10% contingency assumed over 20-year plan implementation period

In addition to the $19,200,000 required for 20-year GSP implementation costs, an additional $652,000 is estimated to be required for PMA development costs as previously provided in Table

5-4. In addition, $500,000 has been budgeted for preparation of the Environmental Impact Report (EIR) for GSP implementation. Budget for the EIR has been secured though funding provided by Proposition 1 Severely Disadvantaged Community grant. Thus, the current total estimated GSP implementation cost is $20,352,000, including a contingency of $1,745,000. It is emphasized that this estimate does not include the implementation of all PMAs or final costs incurred by BWD for internal management and administration. BWD intends to request reimbursement from the GSA for some of its GSA creation and GSP development related expenses and these costs are not included in the estimates. Additional budget will be required to implement PMAs once they have been developed. Implementation of PMAs such as the water conservation program will be highly dependent upon securing funding such as through state or federal grants. Administrative costs to implement the primary water reduction programs that include the Water Trading Program, Pumping Reduction Program and Voluntary Fallowing of Agricultural Land is expected to be covered by the costs estimated in Table 5-5.

5.1.6 Funding Sources

In general, the GSA plans to fund GSP implementation using a combination of groundwater extraction charges, including monthly fixed charges and variable pumping fees, assessments/parcel taxes, and grants. Because of Constitutional limitations imposed through California Propositions 13, 218, and 26, there are strict rules about what constitutes a fee versus a tax. Taxes and assessments require voter approval. Water rates passed under Proposition 218 are subject to mandatory noticing and a potential majority protest. Regulatory fees identified as an exemption from taxes under Proposition 26 can be passed by the vote of the governing body of the agency imposing the fee. An example is a $/AF pumping charge levied by a groundwater management agency. Assessments for special benefit are also governed by Proposition 218 and can be assessed to pay for a public improvement or service if it provides a special benefit to the properties. A benefit nexus is required to determine the amount of special benefit to each property. Grants from DWR have funded the majority of the GSP costs to date and it is expected that grants available from general obligation bonds such as Proposition 68 will be available to fund GSP implementation and development of PMAs. Potential funding sources specific to PMAs are presented in Chapter 4.

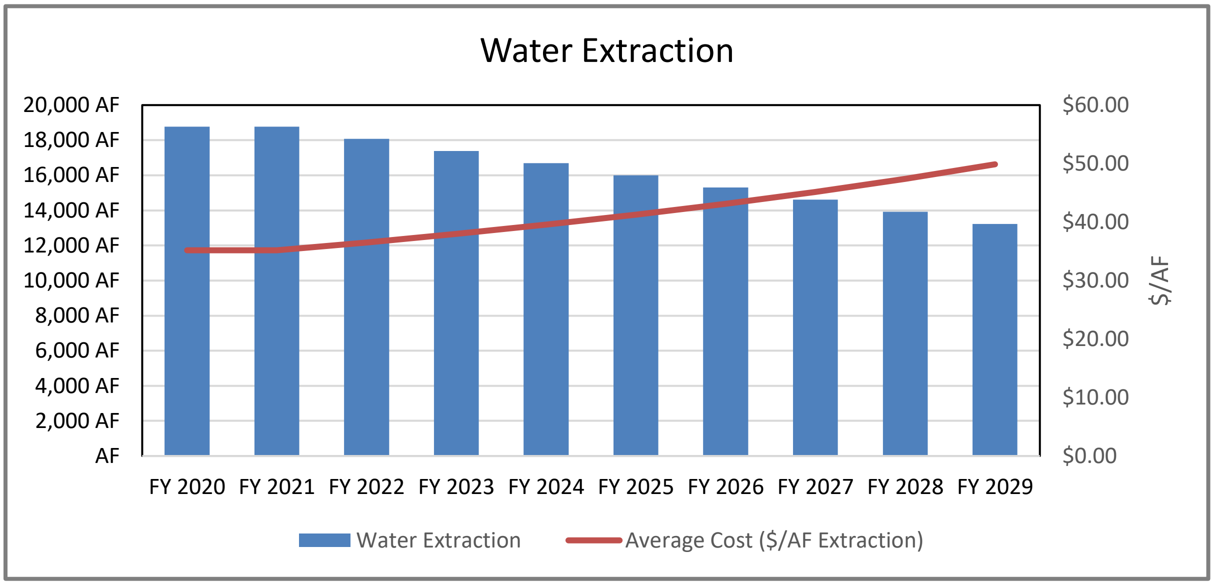
The GSA performed a preliminary financing plan options evaluation to determine a funding structure to fund the proposed GSA activities and expected financial commitments throughout GSP implementation. Development of the funding mechanism(s) is critical to facilitate successful implementation of the GSP consistent with the requirements of SGMA. A key success factor is preparing a cost allocation that is equitable to GSA members and stakeholders. Subsequent to the evaluation of financing plan options, a preliminary financing model was developed to determine revenue required to fund the operating plan, reserve balances and to evaluate required adjustments to the fee structure over time as pumping ramps down to the estimated sustainable yield.

The working draft Financing Plan identifies the following proposed cost allocation structure:

- Monthly fixed charge based on well meter size (i.e., specific meter fee based on meter pipe diameter; 0–2 inches, 2–4 inches, 4–6 inches, 6–8 inches, and more than 8 inches; all non-*de minimis* extraction wells to be registered with the GSA)
- Variable pumping fee based on volume of groundwater extracted (all non *de-minimis* wells to be metered)

It is expected that a portion of the pumping cost will be apportioned though the monthly meter fee and a portion applied at least semi-annually based on metered production. The intent of the meter fee is to provide regular cash flow to the GSA in order for it to meet its financial obligations. Monthly regular cash flow will also minimize the reserve target that would need to be greater if based solely on variable pumping revenues. Over the first 10 years of plan implementation, it is expected that up to $50/AF will be required to cover operations and monitoring costs, management, administration and other costs such as reserves (Exhibit 1). This cost does not include additional potential fees required to implement specific PMAs nor internal management and administration by BWD. Additional PMA planning, stakeholder outreach and detailed cost development is required to determine additional costs associated with PMAs implementation. Cost per acre-foot to cover GSA expenses is expected to continue to increase through 2040 as required revenue is spread over less groundwater extraction as a result of pumping ramp down. Exhibit 1 shows the estimated groundwater extracted and average cost per acre-foot.

Exhibit 1. Estimated Groundwater Extracted and Average Cost (dollar per acre-foot)



Notes: AF = acre-feet; FY = fiscal year.
FY 2020 groundwater extraction is estimated based on recent agriculture, municipal, recreation, and other non-*de minimis* pumping. Pumping is assumed to ram down annually over time to the estimated sustainable yield. The cost per acre-foot pumped increases as revenue is spread over less groundwater extraction.

5.2 IMPLEMENTATION SCHEDULE

Pursuant to SGMA, the GSP will be adopted no later than January 31, 2020. Figure 5.2-1 through 5.2.-4 provides a preliminary schedule for implementation of the primary GSP components. The schedule may shift as the process proceeds. Each annual and periodic report will include a reevaluation and update of the schedule components based on progress toward the sustainability goal or other factors.

Routine annual and 5-year reporting of GSP progress will be performed in accordance with SGMA requirements. Annual Reports will be prepared and submitted to the DWR by April 1 of each year. Periodic Reports (5-Yearly or following substantial GSP amendments) will be submitted to the DWR by April 1 at least every 5 years (i.e., 2025, 2030, 2035, and 2040). The contents of Annual and Periodic Reports are described in the following Sections 5.3 and 5.4.

The six PMAs and their implementation schedules are presented in Figure 5.2-3. Activities that might cause physical change to the environment requires California Environmental Quality Act (CEQA) review. There are CEQA exemptions that could apply for some of these activities. Regardless, the GSA will still need to go through the process of CEQA review to determine which exemptions would apply, and then file for the exemption. PMA No. 1 – Water Trading Program, PMA No. 3 – Pumping Reduction Program, and PMA No. 4 – Voluntary Fallowing of Agricultural Land, all are considered as activities to undergo CEQA. It is likely an Environmental Impact Report (EIR) will be required to be prepared and adopted. It is anticipated an EIR would take approximately two years to develop. 2. PMA No. 5 – Water Quality Optimization and PMA No. 6 – Intra-Subbasin Water Transfer, have no definitive timeframe for implementation. The GSA will evaluate projects on a case-by-case basis to determine CEQA requirements.

5.3 ANNUAL REPORTING

The annual report will, at a minimum, include the components described as required pursuant to CCR Section 356.2. In addition to being available from DWR, the GSA will make annual reports available to the public and stakeholders through the methods described in Chapter 2 (Section 2.1.5, Notice and Communication), primarily through the County's SGMA website, but also through email announcements, newsletters/columns, and/or water bill inserts.

5.3.1 General Information

An executive summary will be prepared to summarize the findings of the Annual Report and include a location map similar to Figure 1-1. This section will include a description of significant progress and pertinent findings of the reporting period and key recommendations for going forward.

5.3.2 Description and Graphical Representations of Groundwater Information

Groundwater Elevation Data

Detailed descriptions and graphical representations will be included to demonstrate the following conditions of the Subbasin in accordance with the monitoring plan and monitoring network described in Section 3.5, and attached as Appendix E. Groundwater elevation data for each management area will be depicted and summarized using groundwater contour maps similar to those included as Figures 2.2-13A. The contour maps will include delineation of the primary aquifers (Figure 2.2-10) and groundwater contours for seasonal high and low conditions. Hydrographs depicting current and historical data for each management area will be included (Figure 2.2-13E). The written section will include a description and interpretation of the data shown in the figures and a discussion of observed data gaps and recommendations for modifications to the monitoring network, if warranted.

Groundwater Extraction

Groundwater extraction information for the preceding water year will be presented. Data sources will include BWD pumping records and metered extraction data from private agricultural, golf courses and other non-*de minimis* wells (i.e., pumpers extracting greater than 2 acre-feet per year). All non-*de minimis* groundwater users will be required to register their wells with the GSA upon GSP adoption in accordance with the Metering Plan (Appendix E). Data will be presented in a table that summarizes groundwater extractions by water use sector and management area, and identifies the measurement method (direct or estimated) and accuracy of measurements. A map of general location and volume of groundwater extractions will be provided. Groundwater extraction will be documented in conformance with the Metering Plan (Appendix E).

Surface Water Supply

Currently, there are only natural sources of groundwater recharge to the basin. The annual report will note developments or studies in regard to surface water supplies. The contribution from natural sources of recharge are presented in Section 2.2.3, Water Budget, and will be quantified as part of the water budget.

Sources of imported water and recycled water from wastewater treatment plant upgrades have been evaluated and determined to be infeasible at this time as explained in Section 2.2.3.7, Surface Water Available for Groundwater Recharge or In-Lieu Use.

Total Water Use

The total water use for the Basin will be reported in tabular format including water use by sector (agriculture, recreation, and municipal) and geographically by management area. Sources of data will include BWD production and delivery records and metered well use for the private sector. Where direct measurement is not possible, indirect methods will be used to estimate water use.

Changes in Groundwater Storage

Estimated changes in storage will be evaluated for each management area and each principal aquifer and this information will be depicted on maps. This section will include a graph of climate, groundwater use, and annual and cumulative change in storage for the period of available record through the reporting period.

5.3.3 Plan Implementation Progress

A description of progress toward implementing the GSP will be included, including achieving interim milestones and implementation of PMAs since the previous report. Current progress will be compared to the planned schedule using the chart shown in Figures 5.2-1 through 5.2-4.

5.4 PERIODIC EVALUATION AND REPORTING

The Borrego Valley GSA will evaluate its Plan at least every 5 years and whenever the Plan is amended and provide a written assessment to the DWR. The evaluation will include the elements of the annual reports and an assessment of the progress toward the sustainability goal as defined in Section 3.1.3, Sustainability Goal. At a minimum, the Periodic Evaluations will include the elements required Pursuant to CCR Section 356.4. In addition to being available from DWR, the GSA will make periodic evaluations available to the public and stakeholders through the methods described in Chapter 2 (Section 2.1.5, Notice and Communication), primarily through the County's SGMA website, but also through email announcements, newsletters/columns, and/or water bill inserts. In addition, the assessment will include the following components:

5.4.1 Current Groundwater Conditions

A description of current groundwater conditions will be included for each applicable sustainability indicator relative to measurable objectives, interim milestones, and minimum thresholds defined in Section 3.2, Undesirable Results. For example, hydrographs showing groundwater elevations for key wells in relation to the measurable objective and minimum threshold will be prepared.

5.4.2 Implementation of Projects or Management Actions

A description will be provided to summarize the implementation and status of PMAs, and the effect on groundwater conditions or other socioeconomic effects resulting from those PMAs. The success of PMAs will be evaluated in terms of whether implementation is achieving Subbasin sustainability goals. If not, PMAs would require re-evaluation or potentially accelerated implementation. Major deviations to the PMAs implementation schedule would be coordinated with the Subbasin stakeholders through an outreach process.

5.4.3 Plan Elements

Elements of this Plan, including the basin setting, management areas, or the identification of undesirable results and the setting of minimum thresholds and measurable objectives, will be reconsidered and revisions proposed, if necessary. Such considerations will include the extent to which this Plan is progressing toward achievement of the sustainability goal and meeting interim milestones.

5.4.4 Basin Evaluation

Each Periodic Evaluation will include an assessment of unanticipated changes that have occurred, or new information impacting water use, and how they may impact the plan implementation and achievement of the sustainability goal. Such changes may include unanticipated climate extremes. Changes will be evaluated in regard to impacts on overdraft conditions and adjustments made to mitigate overdraft and conditions contributing to undesirable effects.

Water Balance Review

The data collected to date will be reviewed to determine whether a revision in the estimated sustainable yield value is warranted.

If warranted, the report will describe the impact of revised sustainable yield value on the following:

- Pumping allowances
- Measurable objectives/interim milestones
- Other pertinent components of the GSP

5.4.5 Monitoring Network

The periodic evaluation will include a description of the monitoring network within the Basin, including whether data gaps exist, or whether areas within the Basin are represented by data that do not satisfy the Data and Reporting Standards. The descriptions shall include the following:

- An assessment of monitoring network function with an analysis of data collected to date, identification of data gaps, and the actions necessary to improve the monitoring network, consistent with the requirements of CWC Section 354.38.
  - The periodic evaluation will provide an update of data gaps. The evaluation shall include options for obtaining additional data sources, an estimate of timing to obtain new data sources, and for potential incorporation of newly obtained information into the GSP.

  - The evaluation will prioritize the installation of new data collection facilities and analysis of new data based on the needs of the Basin.
- An assessment of whether areas within the Basin are represented by data that does not satisfy the requirements of CCR Section 352.4 and Section 354.34(c), Data and Reporting Standards.

5.4.6 Pumping Allowance

The primary mechanism for achieving sustainability in the Basin is establishing Baseline Pumping Allocations and pumping ramp down though preparation of an annual Pumping Allowance. A summary will be provided to describe the status of pumping allocations and allowance in the Basin, including adjustments based on potential changes in the estimated sustainable yield of the Basin.

5.4.7 New Information

A description will be provided for significant new information that has been made available since GSP adoption or amendment, or the last 5-year assessment. The description will also include whether new information warrants changes to any aspect of the GSP, including the evaluation of the Basin setting, measurable objectives, minimum thresholds, or the specific criteria defining undesirable results.

5.4.8 Relevant Actions

A description will be provided for relevant actions taken by the GSA since the prior Periodic Report (or GSP adoption for the initial Periodic Report). Relevant actions may include regulations or ordinances related to the GSP, development of additional PMAs, or other actions pertinent to the implementation of the GSP.

5.4.9 Enforcement or Legal Actions

Information will be provided to describe enforcement or legal actions taken by the GSA in furtherance of the sustainability goal for the Basin. Information will include a description of enforcement or legal actions, penalties, resolutions, or any other relevant information.

5.4.10 Plan Amendments

Descriptions will be provided for completed or proposed GSP amendments.

5.4.11 Summary of Coordination

Where appropriate, a summary will be provided to describe coordination activities that occurred during the reporting period with local agencies.

At the time of GSP adoption, no other GSAs exist within the BVGB or adjoining basins. Therefore, if new GSAs are subsequently formed in these relevant areas a summary will be provided in the Periodic Report.

Coordination with the County of San Diego is anticipated throughout implementation of PMAs, including CEQA review and approval, and modification of land use designations, local ordinances, etc. This section will provide detailed summaries of relevant coordination with the County of San Diego as the land use agency.

5.4.12 Other Information

The Periodic Report should include other information the GSA deems appropriate and relevant, along with any information required by the DWR to conduct a periodic review as required by CWC Section 10733.

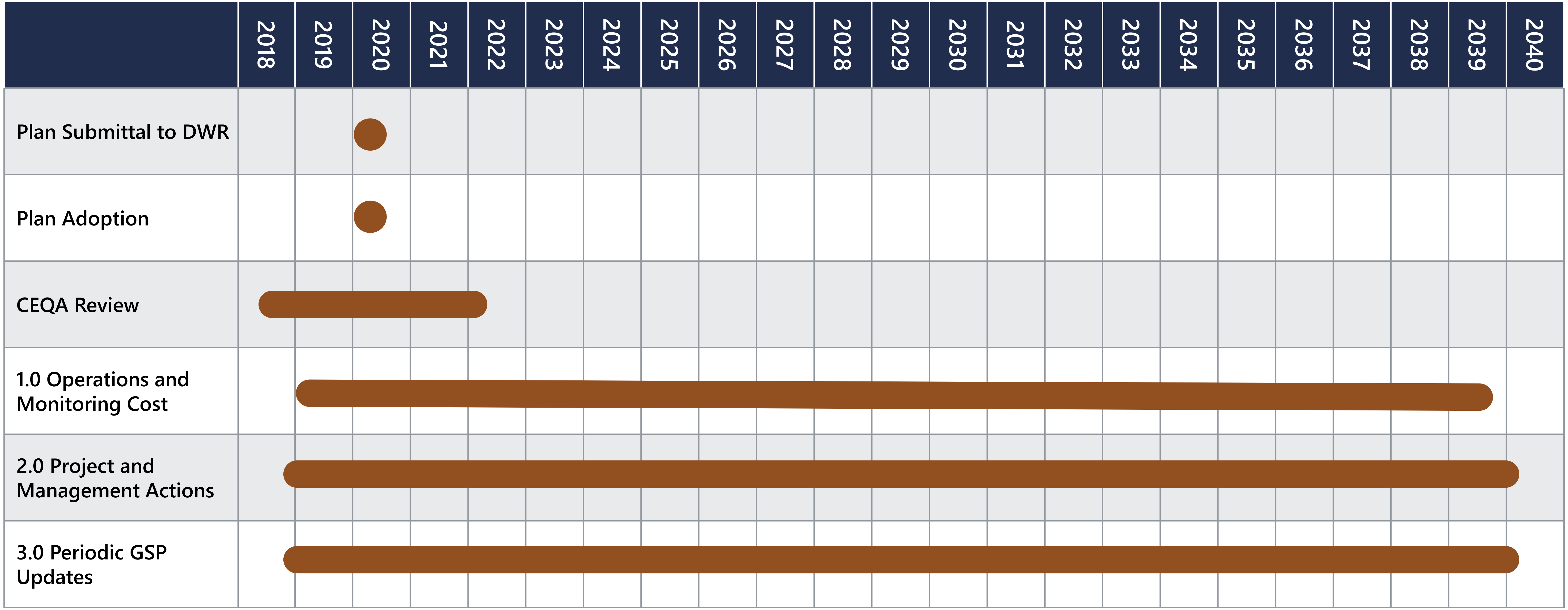


FIGURE 5.2-1

Schedule for Implementation - Overview

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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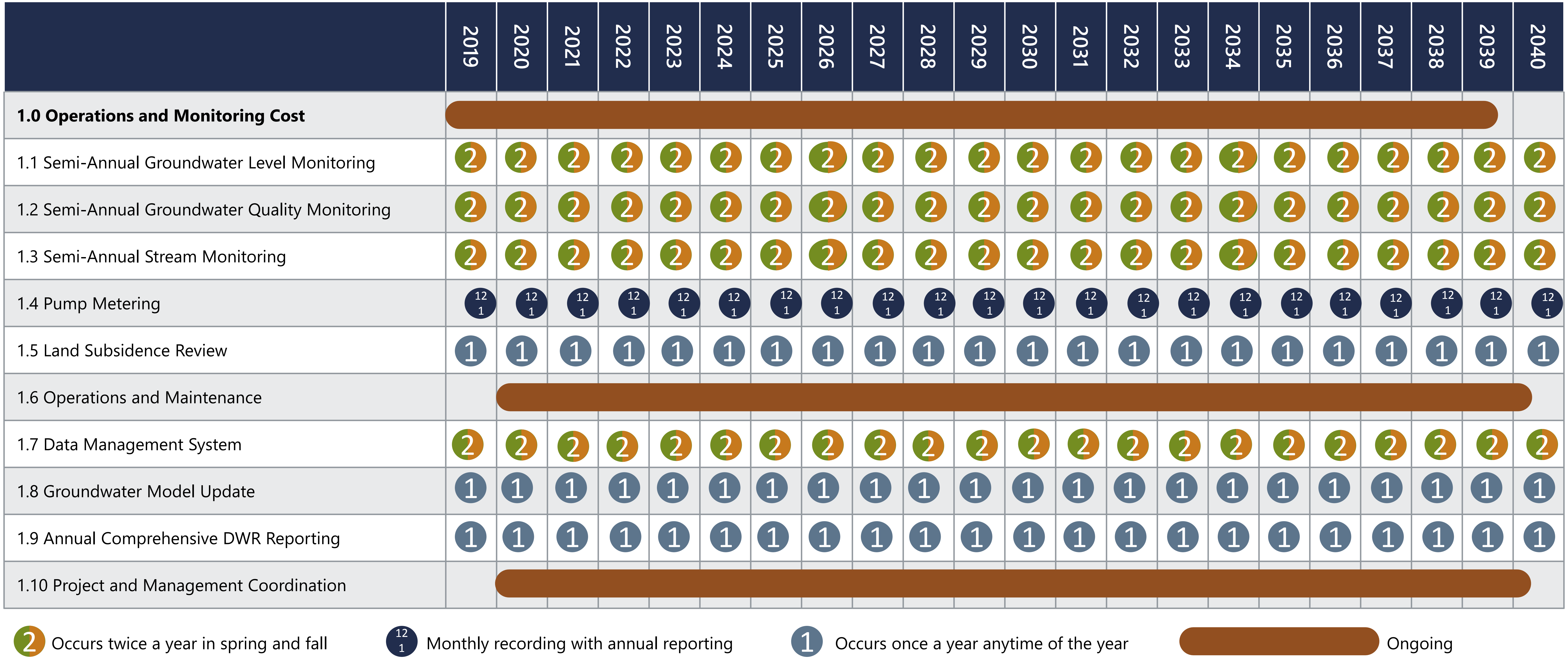

	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
1.0 Operations and Monitoring Cost	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	
1.1 Semi-Annual Groundwater Level Monitoring	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1.2 Semi-Annual Groundwater Quality Monitoring	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1.3 Semi-Annual Stream Monitoring	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1.4 Pump Metering	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1	12 1
1.5 Land Subsidence Review	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.6 Operations and Maintenance		▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬
1.7 Data Management System	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1.8 Groundwater Model Update	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.9 Annual Comprehensive DWR Reporting	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1.10 Project and Management Coordination		▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬

2 Occurs twice a year in spring and fall

12 1 Monthly recording with annual reporting

1 Occurs once a year anytime of the year

▬ Ongoing

FIGURE 5.2-2

Schedule for Implementation - Operations and Monitoring Cost

Groundwater Sustainability Plan for the Borrego Valley Groundwater Basin

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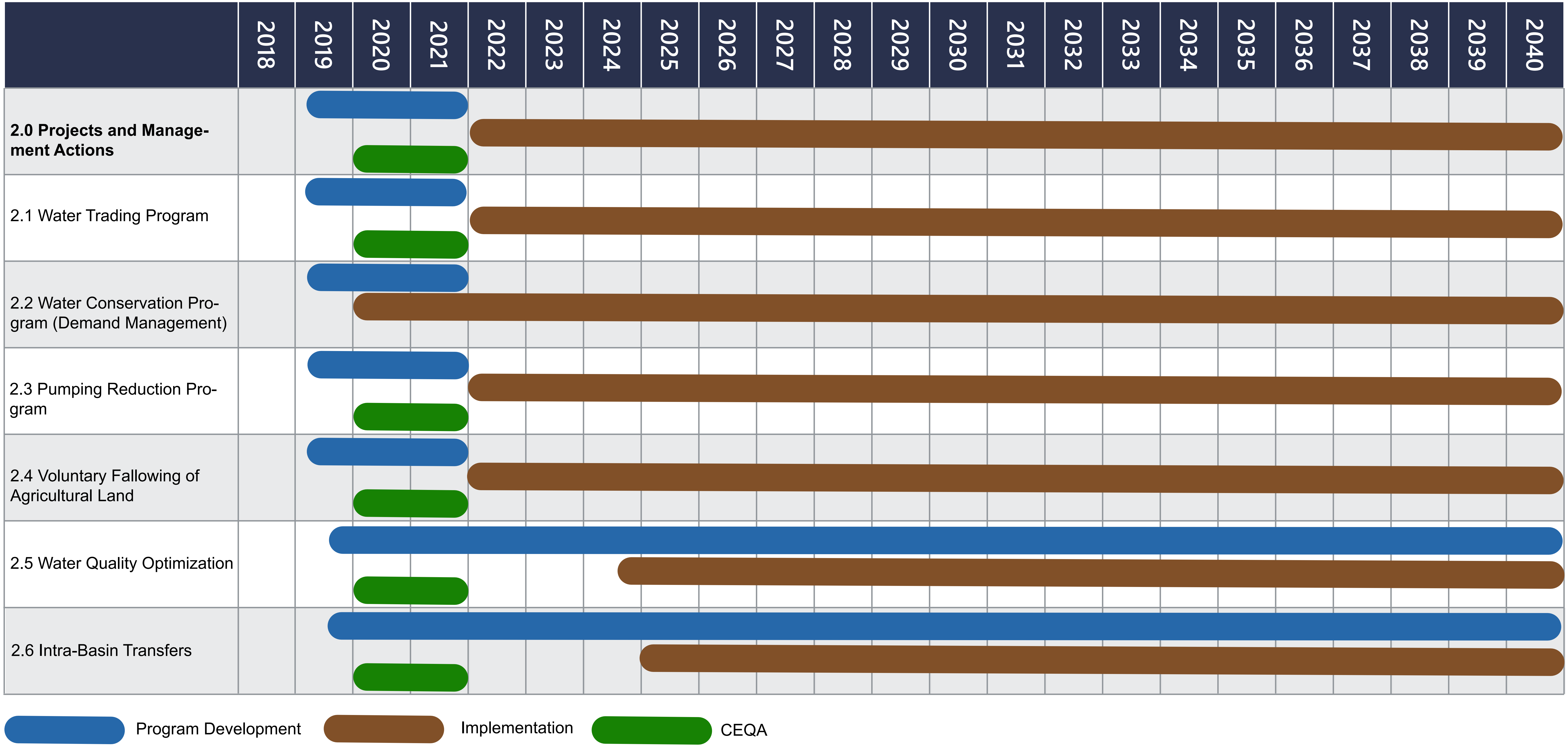

FIGURE 5.2-3

Schedule for Implementation - Project and Management Actions

Groundwater SUstainability Plan for the Borrego Valley Groundwater Basin

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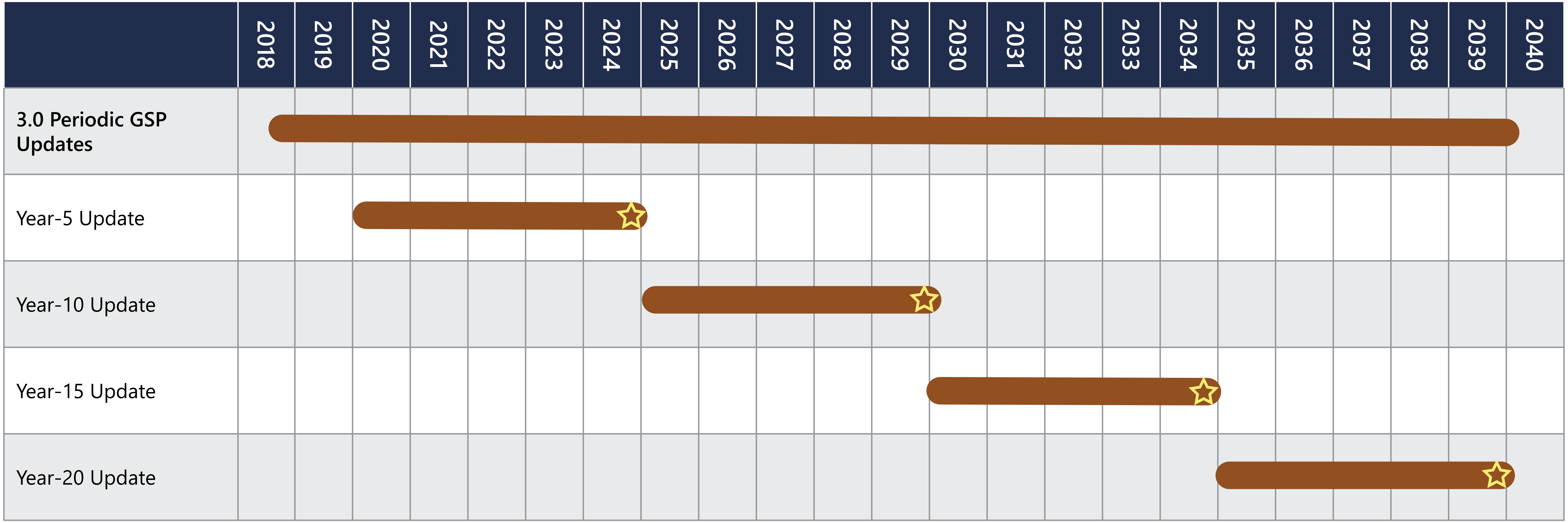

* All updates will include the following: Update Budget, Groundwater Model, and Sustainable Yield; Assessment of Pumping Allocations; Five-year Plan Evaluation and Assessment

☆ Deliverable Milestone for Submittal of 5-year Updates

DUDEK

FIGURE 5.2-4

Schedule for Implementation - Periodic GSP Updates

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APPENDIX A

DWR Preparation Checklist for GSP Submittal

Appendix A - DWR Preparation Checklist for GSP Submittal

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
Article 3. Technical and Reporting Standards				
352.2		Monitoring Protocols	· Monitoring protocols adopted by the GSA for data collection and management · Monitoring protocols that are designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence for basins for which subsidence has been identified as a potential problem, and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater extraction in the basin	Section 3.5, Section 5.4.5, and Appendix E
Article 5. Plan Contents, Subarticle 1. Administrative Information				
354.4		General Information	· Executive Summary · List of references and technical studies	Chapter ES, and "References Cited" section at end of each Chapter.
354.6		Agency Information	· GSA mailing address · Organization and management structure · Contact information of Plan Manager · Legal authority of GSA · Estimate of implementation costs	Section 1.3 and Appendix B
354.8(a)	10727.2(a)(4)	Map(s)	· Area covered by GSP · Adjudicated areas, other agencies within the basin, and areas covered by an Alternative · Jurisdictional boundaries of federal or State land · Existing land use designations · Density of wells per square mile	Figures 2.1-1 through 2.1-6
354.8(b)		Description of the Plan Area	· Summary of jurisdictional areas and other features	Section 2.1.1
354.8(c) 354.8(d)	10727.2(g)	Water Resource Monitoring and Management Programs	· Description of water resources monitoring and management programs · Description of how the monitoring networks of those plans will be incorporated into the GSP	Section 2.1.2

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
354.8(e)			· Description of how those plans may limit operational flexibility in the basin	
			· Description of conjunctive use programs	Section 2.1.6
354.8(f)	10727.2(g)	Land Use Elements or Topic Categories of Applicable General Plans	· Summary of general plans and other land use plans	Section 2.1.3
			· Description of how implementation of the GSP may change water demands or affect achievement of sustainability and how the GSP addresses those effects · Description of how implementation of the GSP may affect the water supply assumptions of relevant land use plans	Section 2.1.3
			· Summary of the process for permitting new or replacement wells in the basin	Section 2.1.2
			· Information regarding the implementation of land use plans outside the basin that could affect the ability of the Agency to achieve sustainable groundwater management	Section 2.1.2 and Section 2.1.3
354.8(g)	10727.4	Additional GSP Contents	Description of Actions related to:	
			· Control of saline water intrusion	Section 2.1.6 and Section 2.2.2.3
			· Wellhead protection	Section 2.1.6 and Section 2.2.2.4
			· Migration of contaminated groundwater	Section 2.1.6, 2.2.2.4, and 2.2.4.1
			· Well abandonment and well destruction program	Section 2.1.2 and 2.1.6
			· Replenishment of groundwater extractions	Section 2.1.6 and 2.2.3.7
			· Conjunctive use and underground storage	Section 2.1.6 and Chapter 4
			· Well construction policies	Section 2.1.2

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			· Addressing groundwater contamination cleanup, recharge, diversions to storage, conservation, water recycling, conveyance, and extraction projects	Section 2.1.6 , 2.2.2.4, 2.2.3, and 4.7.5
			· Efficient water management practices	Section 2.1.6, and Section 4.3
			· Relationships with State and federal regulatory agencies	Section 2.1.2 and 2.1.6
			· Review of land use plans and efforts to coordinate with land use planning agencies to assess activities that potentially create risks to groundwater quality or quantity	Sections 2.1.2, 2.1.3, and 2.1.6
			· Impacts on groundwater dependent ecosystems	Sections 2.1.6, 2.2.2.6, and 2.2.2.7; and Appendix D4
354.1		Notice and Communication	· Description of beneficial uses and users	Section 2.1.4
			· List of public meetings	Appendix C
			· GSP comments and responses	Appendix G
			· Decision-making process · Public engagement · Encouraging active involvement	Section 2.1.5
			· Informing the public on GSP implementation progress	Section 2.1.5 and Section 5.4
Article 5. Plan Contents, Subarticle 2. Basin Setting				
354.14		Hydrogeologic Conceptual Model	· Description of the Hydrogeologic Conceptual Model	Section 2.2.1 and Figure 2.2-1
			· Two scaled cross-sections	Figure 2.2-10
			· Map(s) of physical characteristics: topographic information, surficial geology, soil characteristics, surface water bodies, source and point of delivery for imported water supplies	Figure 2.2-1 through Figure 2.2-9

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
354.14(c)(4)	10727.2(a)(5)	Map of Recharge Areas	· Map delineating existing recharge areas that substantially contribute to the replenishment of the basin, potential recharge areas, and discharge areas	Figure 2.2-11
	10727.2(d)(4)	Recharge Areas	· Description of how recharge areas identified in the plan substantially contribute to the replenishment of the basin	Sections 2.2.1.4, 2.2.2.6, and 2.2.3.1
354.16	10727.2(a)(1) 10727.2(a)(2)	Current and Historical Groundwater Conditions	· Groundwater elevation data · Estimate of groundwater storage · Seawater intrusion conditions · Groundwater quality issues · Land subsidence conditions · Identification of interconnected surface water systems · · Identification of groundwater-dependent ecosystems	Section 2.2.2
354.18	10727.2(a)(3)	Water Budget Information	· Description of inflows, outflows, and change in storage · Quantification of overdraft · Estimate of sustainable yield · Quantification of current, historical, and projected water budgets	Section 2.2.3
	10727.2(d)(5)	Surface Water Supply	· Description of surface water supply used or available for use for groundwater recharge or in-lieu use	Section 2.2.3.8
354.2		Management Areas	· Reason for creation of each management area · Minimum thresholds and measurable objectives for each management area · Level of monitoring and analysis · Explanation of how management of management areas will not cause undesirable results outside the management area	Section 2.2.4, and Sections 3.3.1.3, 3.3.2.3, and 3.3.4.3

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			· Description of management areas	
Article 5. Plan Contents, Subarticle 3. Sustainable Management Criteria				
354.24		Sustainability Goal	· Description of the sustainability goal	Section 3.1.3
354.26		Undesirable Results	· Description of undesirable results · Cause of groundwater conditions that would lead to undesirable results · Criteria used to define undesirable results for each sustainability indicator · Potential effects of undesirable results on beneficial uses and users of groundwater	Section 3.2, Appendix D4
354.28	10727.2(d)(1)	Minimum Thresholds	· Description of each minimum threshold and how they were established for each sustainability indicator	Sections 3.3.1.1, 3.3.2.1, and 3.3.4.1
	10727.2(d)(2)		· Relationship for each sustainability indicator	Sections 3.3.1.2, 3.3.2.2, and 3.3.4.2
			· Description of how selection of the minimum threshold may affect beneficial uses and users of groundwater	Sections 3.3.1.4, 3.3.2.4, and 3.3.4.4
			· Standards related to sustainability indicators	Section 3.3
			· How each minimum threshold will be quantitatively measured	Sections 3.3.1.6, 3.3.2.6, and 3.3.4.6
354.3	10727.2(b)(1)	Measureable Objectives	· Description of establishment of the measureable objectives for each sustainability indicator	Sections 3.4.1, 3.4.2, and 3.4.4
	10727.2(b)(2)		· Description of how a reasonable margin of safety was established for each measureable objective	Sections 3.4.1, 3.4.2, and 3.4.4
	10727.2(d)(1) 10727.2(d)(2)		· Description of a reasonable path to achieve and maintain the sustainability goal, including a description of interim milestones	Sections 3.4.1, 3.4.2, and 3.4.4
Article 5. Plan Contents, Subarticle 4. Monitoring Networks				
354.34	10727.2(d)(1)	Monitoring Networks	· Description of monitoring network	Section 2.2.2, Section 3.5 and Appendix E

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
	10727.2(d)(2)		· Description of monitoring network objectives	Section 3.5 and Appendix E
	10727.2(e)		· Description of how the monitoring network is designed to: demonstrate groundwater occurrence, flow directions, and hydraulic gradients between principal aquifers and surface water features; estimate the change in annual groundwater in storage; monitor seawater intrusion; determine groundwater quality trends; identify the rate and extent of land subsidence; and calculate depletions of surface water caused by groundwater extractions	Section 3.5.1
	10727.2(f)		· Description of how the monitoring network provides adequate coverage of Sustainability Indicators	Section 3.5.1
			· Density of monitoring sites and frequency of measurements required to demonstrate short-term, seasonal, and long-term trends · Scientific rational (or reason) for site selection · Consistency with data and reporting standards	Section 3.5, Appendix E
			· Corresponding sustainability indicator, minimum threshold, measureable objective, and interim milestone	Section 3.3, 3.4, 3.5, and Appendix E
			· Location and type of each monitoring site within the basin displayed on a map, and reported in tabular format, including information regarding the monitoring site type, frequency of measurement, and the purposes for which the monitoring site is being used	Section 2.2.2, Table 2.2-4, Table 2.2-5, and Figure 2.2-12

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			· Description of technical standards, data collection methods, and other procedures or protocols to ensure comparable data and methodologies	Section 3.5, Appendix E
354.36		Representative Monitoring	· Description of representative sites	Section 3.5.3 and Figure 3.3-1
			· Demonstration of adequacy of using groundwater elevations as proxy for other sustainability indicators	Section 3.5.3 and Figure 3.3-1
			· Adequate evidence demonstrating site reflects general conditions in the area	Section 3.5.3 and Figure 3.3-1
354.38		Assessment and Improvement of Monitoring Network	· Review and evaluation of the monitoring network · Identification and description of data gaps · Description of steps to fill data gaps · Description of monitoring frequency and density of sites	Section 3.5.4
Article 5. Plan Contents, Subarticle 5. Projects and Management Actions				
354.44		Projects and Management Actions	· Description of projects and management actions that will help achieve the basin's sustainability goal	Sections 4.2.1, 4.3.1, 4.4.1, 4.5.1, 4.6.1, and 4.7.1
			· Measureable objective that is expected to benefit from each project and management action	Sections 4.2.2, 4.3.2, 4.4.2, 4.5.2, 4.6.2, and 4.7.2
			· Circumstances for implementation	Sections 2.1.2 and 2.1.5; and Appendix C
			· Public noticing	
			· Permitting and regulatory process	
			· Time-table for initiation and completion, and the accrual of expected benefits	Sections 4.2.4, 4.3.4, 4.4.4, 4.5.4, 4.6.4, and 4.7.4
			· Expected benefits and how they will be evaluated	Sections 4.2.3, 4.3.3

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			· How the project or management action will be accomplished. If the projects or management actions rely on water from outside the jurisdiction of the Agency, an explanation of the source and reliability of that water shall be included.	Sections 4.2.3, 4.3.3, 4.4.3, 4.5.3, 4.6.3, and 4.7.3; and Sections 4.2.5, 4.3.5, 4.4.5, 4.5.5, 4.6.5, and 4.7.5
			· Legal authority required	Section 1.3.2; and Appendix B
			· Estimated costs and plans to meet those costs	Section 5.1.4, and Sections 4.2.6, 4.3.6, 4.4.6, 4.5.6, 4.6.6, and 4.7.6
			· Management of groundwater extractions and recharge	Chapter 4
354.44(b)(2)	10727.2(d)(3)		· Overdraft mitigation projects and management actions	
Article 8. Interagency Agreements				
357.4	10727.6	Coordination Agreements - Shall be submitted to the Department together with the GSPs for the basin and, if approved, shall become part of the GSP for each participating Agency.	Coordination Agreements shall describe the following:	
			· A point of contact · Responsibilities of each Agency · Procedures for the timely exchange of information between Agencies · Procedures for resolving conflicts between Agencies · How the Agencies have used the same data and methodologies to coordinate GSPs · How the GSPs implemented together satisfy the requirements of SGMA · Process for submitting all Plans, Plan amendments, supporting information, all monitoring data and other pertinent information, along with annual reports and periodic evaluations	Cahpter 1, Appendix B, and Chapter 5. Organizational structure of the GSA (County and BWD) is simple, and there are no adjacent basins that are required to or expected to develop a GSP under SGMA

GSP Regulations Section	Water Code Section	Requirement	Description	Section(s) or Page Number(s) in the GSP
			· A coordinated data management system for the basin · Coordination agreements shall identify adjudicated areas within the basin, and any local agencies that have adopted an Alternative that has been accepted by the Department	GSP under SGMA.

APPENDIX B

GSA Formation and Interagency Agreement Documentation

APPENDIX B1

Advisory Committee Bylaws

BORREGO VALLEY
GROUNDWATER SUSTAINABILITY PLAN
ADVISORY COMMITTEE
BY-LAWS

Adopted and approved at the June 29, 2017 Borrego Valley GSP Advisory Committee Meeting:

Article 1 PURPOSE AND FORMATION of the ADVISORY COMMITTEE

Section A – On September 20, 2016, the Board of Directors of the Borrego Water District (District) approved a Memorandum of Understanding (MOU) between the County of San Diego (County) and the District, which memorialized each agency's role and responsibilities for developing a Groundwater Sustainability Plan (GSP) for the Borrego Valley Groundwater Basin (Borrego Basin). On October 19, 2016, the Board of Supervisors of the County also approved the MOU, thereby establishing a multiple-agency Groundwater Sustainability Agency (GSA) responsible for developing and implementing a GSP for the Borrego Basin. The MOU establishes a Core Team comprised of County and District staff tasked with coordinating the activities of the Borrego Basin GSP Advisory Committee (AC).

Section B – In consideration of the interests of all beneficial uses and users of groundwater in the basin, stakeholder engagement and education of both stakeholders and the general public will be conducted in part via the deliberations of the AC pursuant to California Water Code Section 10723.2. The purpose of the AC is to provide input to aid in the development of the planning and policy recommendations contained in the GSP. As information supporting the GSP is prepared by the GSA, these items will be brought before the AC for discussion, analysis, and recommendations.

Section C – The AC is a non-partisan, non-sectarian, non-profit advisory organization. The AC is not empowered by ordinance, establishing authority, or policy to render a binding decision of any kind.

Section D – The AC is advisory to the Core Team. The Core Team will develop a GSP that meets the requirements of SGMA and is acceptable to the District and to the County. The GSP shall include, but not be limited to, groundwater use enforcement measures, a detailed breakdown of each GSA Party's responsibilities for Plan implementation, anticipated costs of implementing the Plan, and cost recovery mechanisms, if necessary.

Article 2 MEMBERSHIP AND TERM OF OFFICE

Section A – The AC shall consist of individuals with backgrounds in developing, deliberating, planning, and/or advocating for sustainable use of groundwater in the Borrego Basin, under the requirements of SGMA.

Section B – The AC is limited to nine (9) members as established in the MOU. Potential representatives shall be nominated by the following six (6) Stakeholder Organizations and shall be apportioned as follows:

(1) Four members nominated by the Borrego Water Coalition and filling the following representative roles- 1 agricultural member; 1 recreation member; 1 independent pumper; 1 at large member,
(2) One member nominated by the Borrego Springs Community Sponsor Group,
(3) One member nominated by the Borrego Valley Stewardship Council,
(4) One member nominated by the Borrego Water District Board of Directors who is not an employee or elected official –to represent ratepayers/property owners,
(5) One member nominated by the County of San Diego who is not an employee or elected official –to represent the Farm Bureau, and
(6) One member nominated by the California State Parks, Colorado Desert Region – to represent the Anza-Borrego Desert State Park.

Each person nominated to the AC by the above Stakeholder Organizations must be endorsed by the Board of Directors of the District and the Director of Planning & Development Services (PDS) of the County before serving on the AC. Substitution of an alternate for an endorsed AC Member is not permitted. Only endorsed Members may serve on the AC.

Section C – Each AC Member shall serve a term, which shall run concurrently with the development and completion of the GSP.

Section D - A vacancy shall be recognized for any AC Member who: (1) dies; (2) resigns; (3) has unexcused absences from more than three of the scheduled AC meetings within a single calendar year; (4) misses three meetings in a row; (5) regularly fails to abide by the discussion covenants of the AC; (6) violates the Ralph M. Brown Act; or (7) fails to exercise the purpose and authority of the AC as described in Article 1 above. The AC shall notify the Core Team if a position is deemed vacant pursuant to items 1-4 above, or if the AC recommends the removal of a member as related to items 5–7 above. If a vacancy occurs, the Stakeholder Organization may nominate another AC member appointee for that position that must then be endorsed by the District Board and County Director of PDS. The new appointee member shall serve through the development and completion of the GSP.

Article 3 DUTIES

The AC shall have the following duties and responsibilities:

(1) Serve as a resource to the Core Team on GSP development issues for the Borrego Basin;

(2) Advise in the formation of the planning and policy recommendations to be included in the GSP. This may include reviewing technical materials and providing comment, data, and relevant local information to the GSA related to Plan development; assisting in communicating concepts and requirements to the stakeholder constituents that they represent; providing comments on materials and reports prepared; assisting the Core Team to anticipate short- and long-term future events that may impact groundwater sustainability, trends and conditions that will impact groundwater management;

(3) Participate in AC and Core Team public decision-making meetings, expected to occur on an approximately quarterly basis or as needed during GSP development.

Article 4 STRUCTURE

Section A – AC meetings will be facilitated by a facilitator from the California State University, Sacramento, Center for Collaborative Policy ("CCP") or other such facilitator acceptable to the Core Team. The Facilitator shall convene the meeting, establish the existence of a quorum and oversee the meeting to insure the timely completion of the published agenda. If for any reason, the Facilitator cannot facilitate at a particular meeting, a Core Team member shall assume the facilitation responsibilities assigned above to the facilitator.

Section B – The Facilitator, in consultation with the AC, shall assign coordinating duties and/or specific tasks to subcommittees of the AC as necessary. The Facilitator will work with the Core Team to determine a meeting schedule, develop meeting materials, coordinate communications to the AC in advance of meetings, and other similar organizational responsibilities.

Section C – The District shall assign staff to record the minutes of all AC meetings, maintain a list of all active representatives, handle committee correspondence, and keep records of actions as they occur at each meeting. It is the responsibility of the Core Team staff assigned to the AC to assure that posting of meeting notices in a publicly accessible place for 72 hours prior to an AC meeting, to keep a record of such posting, and to reproduce and distribute the AC notices and minutes of all meetings.

Article 5 ORGANIZATIONAL PROCEDURES

Section A – Robert's Rules of Order govern the operation of the AC in all cases not covered by these by-laws, the AC may formulate specific procedural rules of order to govern the conduct of its meetings.

Section B – Any voting is on the basis of one vote per AC member. No proxy or absentee voting is permitted.

Section C – All AC recommendations regarding the GSP shall be made by consensus. Consensus is achieved when AC participants indicate that they are at Levels 1-4 (not Levels 5 or 6) as described below. If after multiple attempts, the AC deems consensus improbable among the AC members on a particular matter, the issue will be returned to the Core Team without a recommendation.

Levels of consensus are as follows:

1. I can say an **unqualified 'yes'** to the decision. I am satisfied that the decision is an expression of the wisdom of the group.
2. I find the decision **acceptable**. It is the best of the real options we have available to us.
3. I can **live with** the decision. However, I'm not enthusiastic about it.
4. I do not fully agree with the decision and need to register my view about it. However, I do not choose to block the decision and will **stand aside**. I am willing to support the decision because I trust the wisdom of the group.
5. We need to **do more work** before consensus can be achieved.

6. I do not agree with the decision and feel the need to **block** the decision being accepted as consensus.

Section D – AC meetings shall be held under the following discussion covenants:

- Focus on the future as much as possible.
- All perspectives are valued. You are not required to defend your perspective, but you are asked to share it and to provide supporting rationale.
- All ideas have value. If you believe another approach is better, offer it as a constructive alternative.
- Everyone will have an equal opportunity to participate.
- Everyone will be encouraged to talk.
- One person speaks at a time.
- No side conversations.
- View disagreements as problems to be solved rather than battles to be won.
- Avoid ascribing motives to or judging the actions of others. Please speak about your experiences, concerns, and suggestions. Treat each other with respect.
- Avoid right-wrong paradigms.
- When communicating outside of the AC, Members are asked to speak only for themselves when asked about AC progress unless there has been adoption of concepts or recommendations by the full body.

Section E – A majority of the AC members currently appointed shall constitute a quorum. A quorum is required for an Official Meeting to occur. No consensus vote of the AC shall be considered as reflecting an official recommendation by the AC unless a vote was taken at an Official Meeting.

Section F – All meetings of the AC and its subcommittees are open to the public to the extent required by the Ralph M. Brown Act. Meetings are to be held in accessible, public places in Borrego Springs, California. Notice of all AC meetings shall be posted in a publicly accessible place for a period of 72 hours prior to the meeting. A majority of the AC members shall not use a series of communications of any kind, directly or through intermediaries, to discuss, deliberate, or take action on any AC-related business outside of a public meeting in violation of the Ralph M. Brown Act.

Section G –All members of the AC must abide by these by-laws. The County and District reserve the right to remove members that do not abide by the by-laws.

Article 6 COMPENSATION

Members of the AC shall serve without compensation.

APPENDIX B2

Notice of Intent to Develop a Groundwater Sustainability Plan

County of San Diego

MARK WARDLAW
DIRECTOR

PLANNING & DEVELOPMENT SERVICES
5510 OVERLAND AVENUE, SUITE 310, SAN DIEGO, CA 92123
www.sdcounty.ca.gov/pds
PHONE (858) 694-2962 FAX (858) 694-2555

March 22, 2017

Trevor Joseph, SGM Section Chief
Department of Water Resources
901 P Street, Room 213
Post Office Box 942836
Sacramento, CA 94236

Delivery via E-Mail
(Trevor.Joseph@water.ca.gov)

NOTICE OF INTENT TO DEVELOP A GROUNDWATER SUSTAINABILITY PLAN FOR THE BORREGO VALLEY GROUNDWATER BASIN

Dear Mr. Joseph:

The purpose of this letter is to notify you that the Borrego Valley Groundwater Sustainability Agency (GSA), which comprises the County of San Diego (County) and Borrego Water District (District), intends to develop a Groundwater Sustainability Plan (GSP) for the Borrego Valley Groundwater Basin (BVGB) [Attachment 1] pursuant to California Water Code (Water Code) Section 10727.8. In November 2016, the Department of Water Resources (DWR) acknowledged resolution of the overlapping GSA status of the County and District through the adoption of a Memorandum of Understanding (MOU) between the two agencies, and approved the Borrego Valley GSA as the Exclusive Multi-Agency GSA for the BVGB (DWR Bulletin 118 Groundwater Basin Number 7-24).

To determine the best way to consider the interests of all beneficial uses and users of groundwater, pursuant to Water Code Sections 10723.2 and 10723.4, the Borrego Valley GSA established an ad-hoc advisory committee (AC) to aid in developing and implementing the GSP. The first meeting of the Borrego Valley Sustainable Groundwater Management Act (SGMA) AC occurred on March 6, 2017. In accordance with Water Code Section 10727.8(a), interested parties may participate in the development and implementation of the GSP by attending AC meetings in Borrego Valley and may sign up to receive information about AC meetings and GSP development at the County's SGMA webpage located at: http://www.sandiegocounty.gov/content/sdc/pds/SGMA/borrego-valley.html. AC meeting notices will also be posted at the Borrego Post Office, provided to the *Borrego Sun*, and posted to the District's website at: http://borregowd.org/.

The Borrego Valley GSA reviewed the Emergency Regulations for Groundwater Sustainability Plans and Alternatives that were adopted by the California Water

Commission on May 18, 2016 (California Code of Regulations Title 23. Division 2. Chapter 1.5. Subchapter 2. Groundwater Sustainability Plans) and developed a scope of work to comply with these regulations. The GSP will include, among other components, a groundwater model and projects/management actions that will be required to sustainably manage groundwater in the BVGB. The Borrego Valley GSA anticipates compiling and assessing existing data in the coming weeks and finalizing the GSP prior to the January 2020 SGMA-mandated deadline.

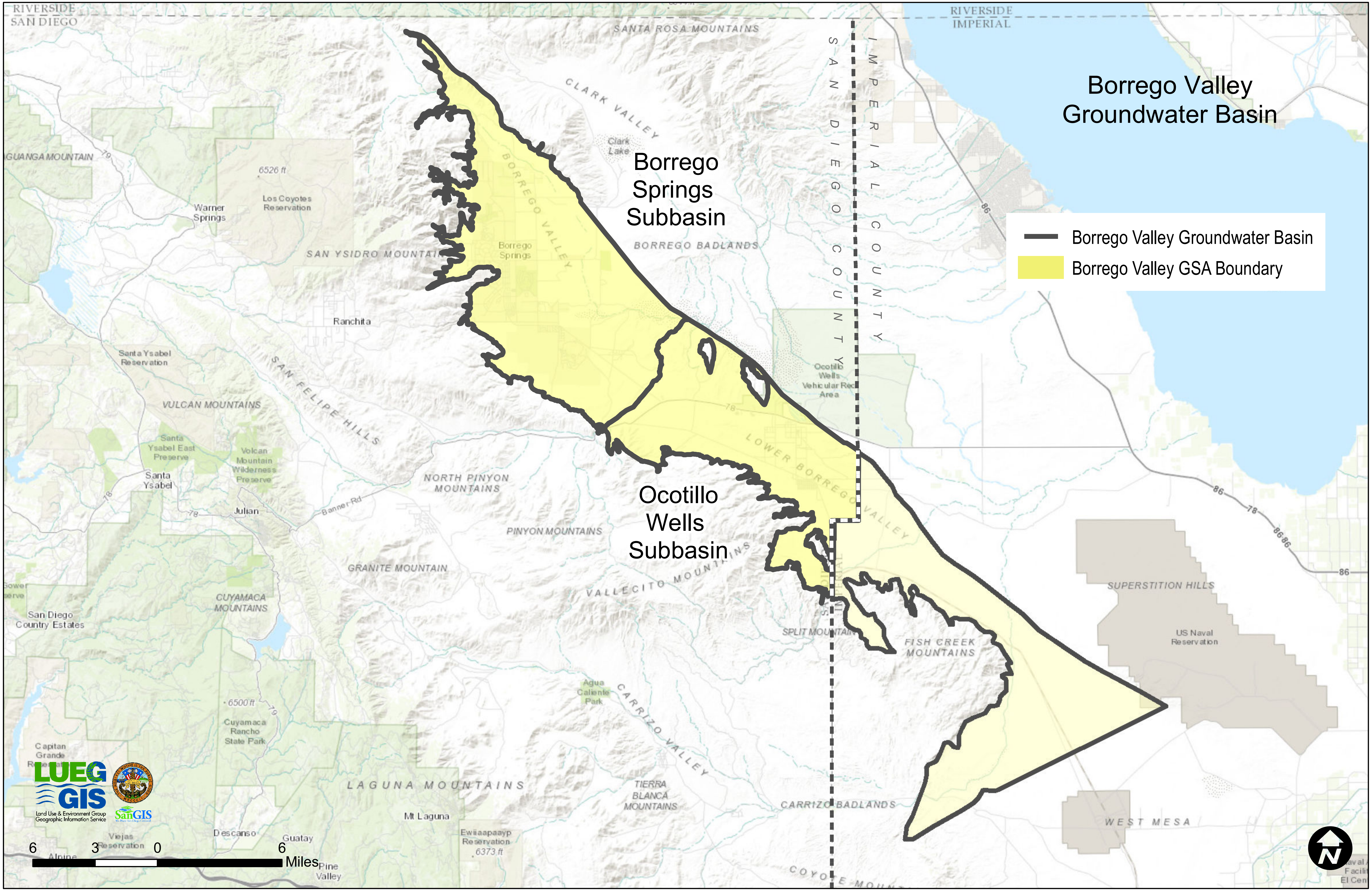
If you have any questions, or require additional information, please contact me at (858) 694-3820.

Sincerely,

JIM BENNETT, Groundwater Geologist
Planning & Development Services

Attachments:
Attachment 1 – Borrego Valley Groundwater Basin Map

cc.
Geoff Poole, General Manager, Borrego Water District
(geoff@borregowd.org)



Path: P:\20151020_Borrego_Valley_basin\GSA_Borrego_color_v2.mxd – Date: 3/14/2017

APPENDIX B3

GSA Notification (Amended)

County of San Diego

MARK WARDLAW
DIRECTOR

PLANNING & DEVELOPMENT SERVICES
5510 OVERLAND AVENUE, SUITE 310, SAN DIEGO, CA 92123
www.sdcounty.ca.gov/pds
PHONE (858) 694-2962 FAX (858) 694-2555

March 22, 2017

Mark Nordberg, GSA Project Manager
Senior Engineering Geologist
Department of Water Resources
901 P Street, Room 213A
Post Office Box 942836
Sacramento, CA 94236

Delivery via E-Mail
(Mark.Nordberg@water.ca.gov)

GSA NOTIFICATION (AMENDED): MEMORANDUM OF UNDERSTANDING FOR THE BORREGO VALLEY GROUNDWATER SUSTAINABILITY AGENCY

Dear Mr. Nordberg:

Pursuant to California Water Code (Water Code) Section 10723.8, the County of San Diego (County) provided notice on January 13, 2016 to the California Department of Water Resources (DWR) of the County's decision to become a Groundwater Sustainability Agency (GSA) for the Borrego Valley Groundwater Basin (BVGB) [Attachment 1]. Since Borrego Water District (BWD) also provided notice to become a GSA for BVGB (DWR Basin No. 7-24), the County and BWD collaborated on a Memorandum of Understanding (MOU) to eliminate any overlap in the areas proposed to be managed. This MOU (Attachment 2) was approved by BWD on September 20, 2016 and by the County Board of Supervisors on October 19, 2016 and establishes the Borrego Valley GSA, which is a multi-agency GSA for the BVGB.

In October 2016, DWR released final 2016 modifications to California's basin boundaries (Bulletin 118 Basins [2016 Edits]), which included the subdivision of the BVGB into two separate subbasins (Borrego Springs and Ocotillo Wells). As such, this notification includes a map and GIS files of the proposed Borrego Valley GSA boundary within the limits of the revised basin in San Diego County (Attachment 1).

In addition to eliminating the overlap, the MOU serves to memorialize each agency's roles and responsibilities for developing a single Groundwater Sustainability Plan (GSP) that complies with the requirements of the Sustainable Groundwater Management Act (SGMA) to sustainably manage groundwater in the BVGB. As indicated in the initial notices, the County and BWD intend to work cooperatively to jointly manage groundwater in the basin.

Both agencies remain committed to considering the interests of all beneficial uses and users of groundwater, as well as those responsible for implementing a GSP. Each agency further anticipates working collaboratively with stakeholders to develop and implement the GSP for the Borrego Valley Groundwater Basin. To aid this effort, the County and BWD established an advisory committee in spring 2017. In accordance with Water Code Section 10727.8(a), interested parties may participate in the development and implementation of the GSP by attending advisory committee meetings in Borrego Valley and may sign up to receive information about GSP development at the County's SGMA webpage located at: http://www.sandiegocounty.gov/pds/SGMA.html.

The County and BWD concur that this agreement does not involve a material change from the information in the posted notices from BWD and the County, yet eliminates the overlap as required by California Water Code Section 10723.8(c).

If you have any questions, or require additional information, please contact the County Groundwater Geologist, Jim Bennett, at (858) 694-3820.

Sincerely,

MARK WARDLAW, Director
Planning & Development Services

Attachments:
Attachment 1 – Borrego Valley Groundwater Basin Map
Attachment 2 – MEMORANDUM OF UNDERSTANDING FOR THE BORREGO VALLEY GROUNDWATER SUSTABILITY AGENCY

cc.
Jim Bennett, Groundwater Geologist, County of San Diego
(jim.bennett@sdcounty.ca.gov)
Geoff Poole, General Manager, Borrego Water District
(geoff@borregowd.org)

APPENDIX B4

Signed Memorandum of Understanding

MEMORANDUM OF UNDERSTANDING
DEVELOPMENT OF A GROUNDWATER SUSTAINABILITY PLAN FOR THE BORREGO VALLEY GROUNDWATER BASIN

This Memorandum of Understanding for the Development of a Groundwater Sustainability Plan ("Plan") for the Borrego Valley Groundwater Basin ("MOU") is entered into and effective this 24th day of October, 2016 by and between the Borrego Water District ("District") and the County of San Diego ("County"). The District and the County are each sometimes referred to herein as a "Party" and are collectively sometimes referred to herein as the "Parties."

RECITALS

WHEREAS, on September 16, 2014, Governor Jerry Brown signed into law Senate Bills 1168 and 1319 and Assembly Bill 1739, known collectively as the Sustainable Groundwater Management Act (Act);

WHEREAS, Act went into effect on January 1, 2015;

WHEREAS, Act seeks to provide sustainable management of groundwater basins, enhance local management of groundwater; establish minimum standards for sustainable groundwater management; and provide local groundwater agencies the authority and the technical and financial assistance necessary to sustainably manage groundwater;

WHEREAS, the Parties have each declared to be a Groundwater Sustainability Agency (GSA) overlying portions of Borrego Valley Groundwater Basin (Borrego Basin), identified as Basin Number 7.24, a Bulletin 118 designated (medium-priority) basin;

WHEREAS, each Party has statutory authorities that are essential to groundwater management and Act compliance;

WHEREAS, Section 10720.7 of Act requires all basins designated as high- or medium-priority basins designated in Bulletin 118 be managed under a Plan or coordinated Plans pursuant to Act;

WHEREAS, Section 10720.7 of Act requires all critically over drafted basins be managed under a Plan by January 31, 2020;

WHEREAS, the California Department of Water Resources (DWR) has identified the Borrego Basin as critically over drafted;

WHEREAS, the Parties intend to eliminate overlap of the Parties by collectively developing and implementing a single Plan to sustainably manage Borrego Basin pursuant to section 10727 et seq. of Act;

WHEREAS, the Parties wish to use the authorities granted to them pursuant to the Act and utilize this MOU to memorialize the roles and responsibilities for developing the Plan;

WHEREAS, it is the intent of the Parties to complete the Plan as expeditiously as possible in a manner consistent with Act and its implementing regulations;

WHEREAS, it is the intent of the Parties to cooperate in the successful implementation of the Plan not later than the date as required by the Act for the Borrego Basin;

WHEREAS, the Parties wish to memorialize their mutual understandings by means of this MOU; and

NOW, THEREFORE, in consideration of the promises, terms, conditions, and covenants contained herein, the Borrego Water District and the County of San Diego hereby agree as follows:

I. Purposes and Authorities.

This MOU is entered into by the Parties for the purpose of establishing a cooperative effort to develop and implement a single Plan to sustainably manage the Borrego Basin that complies with the requirements set forth in the Act and its associated implementing regulations. The Parties recognize that the authorities afforded to a GSA pursuant to Section 10725 of the Act are in addition to and separate from the statutory authorities afforded to each Party individually. The Parties intend to memorialize roles and responsibilities for Plan implementation during preparation of the Plan.

II. Definitions.

As used in this Agreement, unless context requires otherwise, the meanings of the terms set forth below shall be as follows:

1. "Act" refers to the Sustainable Groundwater Management Act.
2. "Advisory Committee" refers to the stakeholder group created in Section III of the MOU.
3. "Core Team" refers to the working group created in Section III of the MOU.
4. "County" refers to the County of San Diego, a Party to this MOU. The County has designated the Director, Planning & Development Services, or his designee(s), as the County department representative to carry out the terms of this MOU for the County.
5. "District" refers to the Borrego Water District, a Party to this MOU.
6. "DWR" refers to the California Department of Water Resources.
7. "Effective Date" means the date on which the last Party executes this Agreement.
8. "Governing Body" means the legislative body of each Party: the District Board of Directors and the County Board of Supervisors, respectively.
9. "Groundwater Sustainability Plan (Plan)" is the basin plan for the Borrego Basin that the parties to this MOU are seeking to develop and implement pursuant to the Act.
10. "Memorandum of Understanding (MOU)" refers to this agreement.
11. "Party" or "Parties" refer to the County of San Diego and Borrego Water District.

12. "Plan Funding" is the funding necessary for the preparation and implementation of the Plan.
13. "Plan Schedule" includes all the tasks necessary to complete the Plan and the date scheduled for completion.
14. "State" means the State of California.
15. "SWRCB" refers to the State Water Resources Control Board.
16. "Undesirable Result" shall be defined as in the Act Section 10721(x) 1-6

III. Agreement.

This section establishes the process for the Borrego Basin Plan Core Team and the Advisory Committee.

1. Establishment and Responsibilities of the Plan Core Team (Core Team).
   a. The Core Team shall jointly develop a coordinated Plan. The Plan shall include, but not be limited to, enforcement measures, a detailed breakdown of each Parties responsibilities for Plan implementation, anticipated costs of implementing the Plan, and cost recovery mechanisms (if necessary).
   b. The Core Team will consist of representatives from each Party to this MOU working cooperatively together to achieve the objectives of the Act. Core Team members serve at the pleasure of their appointing Party and may be removed/changed by their appointing Party at any time. A Party must notify all other Parties to this MOU in writing if that Party removes or replaces Core Team members.
   c. Each member of the Core Team shall be responsible for keeping his/her respective management and governing board informed of the progress towards the development of the Plan and for obtaining any necessary approvals from management/governing board. Each member of the Core Team shall keep the other member reasonably informed as to all material developments so as to allow for the efficient and timely completion of the Plan.
   d. Each Core Team member's compensation for their service on the Core Team is the responsibility of the appointing Party.
   e. The Core Team shall develop and implement a stakeholder participation plan that involves the public and area stakeholders in an Advisory Committee role to aid in developing and implementing the Plan.
   f. The Core Team will cooperatively work with the Advisory Committee to develop bylaws for the governance of the Advisory Committee. These bylaws are subject to approval by the Core team prior to adoption by the Advisory Committee. The Core Team may establish an appointment process and other administrative procedures for the Advisory Committee, in accordance with District and County policies intended to promote active participation in local

government, and requirements to include stakeholders in the development of the Plan as established in the Act.

   g. The Core Team will be the primary liaison with the Advisory Committee; and will guide Advisory Committee activities.

2. Core Team Meetings.

   a. The Core Team will establish a meeting schedule and choice of locations for regular meetings to discuss Plan development and implementation activities, assignments, milestones and ongoing work progress.

   b. The Core Team may establish and schedule meetings of the Advisory Committee to coordinate development and implementation of the Plan.

   c. Attendance at all Core Team meetings may be augmented to include staff or consultants to ensure that the appropriate expertise is available.

3. Establishment and Role of the Advisory Committee

   a. The Parties shall establish an Advisory Committee. The Advisory Committee will provide input to the Core Team on Plan development, including providing recommendations on basin sustainability measures, and the planning, financing, and implementation of the Plan. The Parties will agree on the composition of the Advisory Committee and acknowledge that the Advisory Committee must meet the requirements established in the Act.

   b. Advisory Committee members will not be compensated for activities associated with the Advisory Committee, Plan development or any activity conducted under this agreement.

   c. The Advisory Committee that is formed through this process shall be subject to and abide by the California open meeting laws under Government Code sections 54950 et seq., otherwise known as the "Brown Act," in order for the Parties to accept an Advisory Committee's recommendations.

   d. Meetings of the Advisory Committee shall be held in Borrego Springs, CA.

IV. <u>Interagency Communication.</u>

1. To provide for consistent and effective communication between parties, each Party agrees that a single member from each Party's Core Team will be their central point of contact on matters relating to this MOU. Additional representatives may be appointed to serve as points of contact on specific actions or issues.

2. The Core Team shall appoint a single representative to communicate actions conducted under this agreement to DWR. The appointee shall not communicate formal actions or decisions without prior written approval from the Core Team. This is not intended to discourage informal communications between the Parties

and DWR.

V. Roles and Responsibilities of the Parties.

1. The Parties are responsible for developing a coordinated Plan that meets the requirements of the Act.
2. The Parties will jointly establish their roles and responsibilities for implementing a coordinated Plan for the Borrego Basin in accordance with the Act.
3. The Parties will jointly work in good faith and coordinate all activities to meet the objectives of this MOU. The Parties shall cooperate with one another and work as efficiently as possible in the pursuit of all activities and decisions described in the MOU.
4. Each of the Parties will provide expertise, guidance, and data on those matters for which it has specific expertise or statutory authority, as needed to carry out the objectives of this MOU. Further development of roles and responsibilities of each Party will occur during Plan development.
5. After execution of this MOU as soon as reasonably possible, the Core Team shall mutually develop a timeline that describes the anticipated tasks to be performed under this MOU and dates to complete each task (Plan Schedule); and scope(s) of work and estimated costs for Plan development. The Plan Schedule will allow for the preparation of a legally defensible Plan acceptable to the Parties and include allowances for public review and comment, and approval by governing boards prior to deadlines required in the Act. Due to the critical nature of the Borrego Basin overdraft, both Parties shall make every effort to complete the draft Plan as soon as possible but no later than July 1, 2019. The Plan Schedule shall become part of this MOU through reference. The Plan Schedule will be referred and amended as necessary to conform to developing information, permitting, and other requirements. Therefore, this Plan Schedule may be revised from time to time upon mutual agreement of the Core Team. Costs shall be funded and shared as outlined in Section VI.
6. The Parties recognize that they may disagree as to the composition of the Plan and/or the timelines/methods for implementing the Plan. In the event that the Parties have attempted, in good faith, to resolve the matter on their own and are unsuccessful, the Parties agree to jointly seek to use the non-binding mediation services provided by the DWR to address disputes arising under the Act, to the extent that such services are available. If non-binding mediation from the DWR is not available or if either Party believes it would be more useful to consult with the State Water Resources Control Board ("SWRCB"), the Parties agree to request non-binding mediation from the Chair of the SWRCB or another Member designated by the Chair who is acceptable to both Parties. The Parties recognize that the failure to timely complete a Plan or to achieve any of the other milestones in the Act may result in intervention by the SWRCB.

VI. Contracting and Funding for Plan Development.

1. The Parties shall mutually develop a scope of work, budget, cost sharing agreement and cost recovery plan ("Plan Funding") for the work to be undertaken pursuant to this MOU. The Plan Funding shall be included and adopted in the final Borrego Basin Plan. Both the budget and cost sharing agreement shall be determined prior to any substantial financial expenditures or incurrence of any financial obligations related to consultant costs.
2. Specifically, to fulfill the requirements of the Act, the Core Team will jointly prepare and agree upon a scope of work for the consultants needed to prepare the Plan. The Parties agree that any work contracted for the purpose of developing the Plan shall be a cooperative effort.
3. The County shall hire consultant(s) to complete required components of the Plan. The contracting shall be subject to the County's competitive bid process and be subject to auditing by the County's Auditor and Controller.
4. Within the parameters of the County's contracting regulations, policies and procedures, the Core Team will be cooperatively involved in the evaluation, selection and oversight of the consultant(s).
5. Each Party is free to retain other consultants for its own purposes and at its own cost, *provided that* each Party consults with the other Party before conducting such work. The scope of any such work may not conflict with or duplicate work performed under this MOU. Nothing in this agreement prohibits either Party from exercising its statutory authorities afforded to each Party individually.
6. The Parties agree that each Party will bear its own staff costs to develop the Plan.

VII. Approval.

1. The Parties agree to make best efforts to adhere to the required Plan Schedule and will forward a final Borrego Basin Plan to their respective governing boards for approval and subsequent submission to DWR for evaluation as provided for in Act.
2. Approval and amendments will be obtained from the District Board of Directors prior to submission to the County Board of Supervisors.
3. Each Governing Board retains full authority to approve, amend, or reject the proposed Plan, provided the other Governing Board subsequently confirms any amendments, but both Parties also recognize that the failure to adopt and submit a Plan for the Basin to DWR by January 31, 2020 risks allowing for state intervention in managing the Basin.
4. The Parties agree that they will use good-faith efforts to resolve any issues that one or both Governing Boards may have with the final proposed Plan for the Basin in a timely manner so as to avoid the possibility of state intervention. An amendment to this MOU is anticipated upon acceptance of the Borrego Basin Plan by both Governing Boards.

VIII. Staffing.

Each Party agrees that it will devote sufficient staff time and other resources to actively participate in the development of the Plan for the Basin, as set forth in this MOU.

IX. Indemnification.

1. Claims Arising From Sole Acts or Omissions of County.
   The County of San Diego (County) hereby agrees to defend and indemnify the District, its agents, officers and employees (hereinafter collectively referred to in this paragraph as "District"), from any claim, action or proceeding against District, arising solely out of the acts or omissions of County in the performance of this MOU. At its sole discretion, District may participate at its own expense in the defense of any claim, action or proceeding, but such participation shall not relieve County of any obligation imposed by this MOU. The District shall notify County promptly of any claim, action or proceeding and cooperate fully in the defense.

2. Claims Arising From Sole Acts or Omissions of the District.
   The District hereby agrees to defend and indemnify the County of San Diego, its agents, officers and employees (hereafter collectively referred to in this paragraph as 'County') from any claim, action or proceeding against County, arising solely out of the acts or omissions of District in the performance of this MOU. At its sole discretion, County may participate at its own expense in the defense of any such claim, action or proceeding, but such participation shall not relieve the District of any obligation imposed by this MOA. County shall notify District promptly of any claim, action or proceeding and cooperate fully in the defense.

3. Claims Arising From Concurrent Acts or Omissions.
   The County of San Diego ("County") hereby agrees to defend itself, and the District hereby agrees to defend itself, from any claim, action or proceeding arising out of the concurrent acts or omissions of County and District. In such cases, County and District agree to retain their own legal counsel, bear their own defense costs, and waive their right to seek reimbursement of such costs, except as provided in paragraph 5 below.

4. Joint Defense.
   Notwithstanding paragraph 3 above, in cases where County and District agree in writing to a joint defense, County and District may appoint joint defense counsel to defend the claim, action or proceeding arising out of the concurrent acts or omissions of District and County. Joint defense counsel shall be selected by mutual agreement of County and District. County and District agree to share the costs of such joint defense and any agreed settlement in equal amounts, except as provided in paragraph 5 below. County and District further agree that neither party may bind the other to a settlement agreement without the written consent of both County and District.

5. Reimbursement and/or Reallocation.
   Where a trial verdict or arbitration award allocates or determines the comparative fault of the parties, County and District may seek reimbursement and/or reallocation

of defense costs, settlement payments, judgments and awards, consistent with such comparative fault.

X. Litigation.

In the event that any lawsuit is brought against either Party based upon or arising out of the terms of this MOU by a third party, the Parties shall cooperate in the defense of the action. Each Party shall bear its own legal costs associated with such litigation.

XI. Books and Records.

Each Party shall have access to and the right to examine any of the other Party's pertinent books, documents, papers or other records (including, without limitation, records contained on electronic media) relating to the performance of that Party's obligations pursuant to this Agreement, *providing that* nothing in this paragraph shall be construed to operate as a waiver of any applicable privilege.

XII. Notice.

All notices required by this Agreement will be deemed to have been given when made in writing and delivered or mailed to the respective representatives of County and the District at their respective addresses as follows:

For the District:	For the County:
General Manager Borrego Water District PO Box 1870 806 Palm Canyon Drive Borrego Springs, CA 92004	San Diego County Administrative Officer San Diego County 1600 Pacific Highway San Diego, CA 92101
With a copy to:	With a copy to:
David Aladjem Downey Brand LLP 621 Capitol Mall, 18th Floor Sacramento, CA 95814	Justin Crumley, Senior Deputy Office of County Counsel 1600 Pacific Highway, Rm 355 San Diego, CA 92101

Any party may change the address or facsimile number to which such communications are to be given by providing the other parties with written notice of such change at least fifteen (15) calendar days prior to the effective date of the change.

All notices will be effective upon receipt and will be deemed received through delivery if personally served or served using facsimile machines, or on the fifth (5th) day following deposit in the mail if sent by first class mail.

XIII. Miscellaneous.

1. Term of Agreement. This MOU shall remain in full force and effect until the date upon which the Parties have both executed a document terminating the provisions of this MOU.
2. No Third Party Beneficiaries. This Agreement is not intended to, and will not be construed to, confer a benefit or create any right on a third party, or the power or right to bring an action to enforce any of its terms.
3. Amendments. This Agreement may be amended only by written instrument duly signed and executed by the County and the District.
4. Compliance with Law. In performing their respective obligations under this MOU, the Parties shall comply with and conform to all applicable laws, rules, regulations and ordinances.
5. Jurisdiction and Venue. This MOU shall be governed by and construed in accordance with the laws of the State of California, except for its conflicts of law rules. Any suit, action, or proceeding brought under the scope of this MOU shall be brought and maintained to the extent allowed by law in the County of San Diego, California.
6. Waiver. The waiver by either party or any of its officers, agents or employees, or

the failure of either party or its officers, agents or employees to take action with respect to any right conferred by, or any breach of any obligation or responsibility of this Agreement, will not be deemed to be a waiver of such obligation or responsibility, or subsequent breach of same, or of any terms, covenants or conditions of this Agreement, unless such waiver is expressly set forth in writing in a document signed and executed by the appropriate authority of the County and the District.

7. Authorized Representatives. The persons executing this Agreement on behalf of the parties hereto affirmatively represent that each has the requisite legal authority to enter into this Agreement on behalf of their respective party and to bind their respective party to the terms and conditions of this Agreement. The persons executing this Agreement on behalf of their respective party understand that both parties are relying on these representations in entering into this Agreement.
8. Successors in Interest. The terms of this Agreement will be binding on all successors in interest of each party.
9. Severability. The provisions of this Agreement are severable, and the adjudicated invalidity of any provision or portion of this Agreement shall not in and of itself affect the validity of any other provision or portion of this Agreement, and the remaining provisions of the Agreement shall remain in full force and effect, except to the extent that the invalidity of the severed provisions would result in a failure of consideration or would materially adversely affect either party's benefit of its bargain. If a court of competent jurisdiction were to determine that a provision of this Agreement is invalid or unenforceable and results in a failure of consideration or materially adversely affects either party's benefit of its bargain, the parties agree to promptly use good faith efforts to amend this Agreement to reflect the original intent of the parties in the changed circumstances.
10. Construction of Agreement. This Agreement shall be construed and enforced in accordance with the laws of the United States and the State of California.
11. Entire Agreement.
    a. This Agreement constitutes the entire agreement between the County and the District and supersedes all prior negotiations, representations, or other agreements, whether written or oral.
    b. In the event of a dispute between the parties as to the language of this Agreement or the construction or meaning of any term hereof, this Agreement will be deemed to have been drafted by the parties in equal parts so that no presumptions or inferences concerning its terms or interpretation may be construed against any party to this Agreement.

IN WITNESS WHEREOF, the parties hereto have set their hand on the date first above written.

BORREGO WATER DISTRICT

By: Beth A Hart
Beth A. Hart
President, Board of Directors

COUNTY OF SAN DIEGO,
a political subdivision of
the State of California

By:
Clerk of the Board of Supervisors

DATE: 10/24/16

APPROVED AS TO FORM AND LEGALITY
BY COUNTY COUNSEL

By: 10/19/16
Senior Deputy

Approved and/or authorized by the
Board of Supervisors of the County of San Diego.
Meeting Date: 10/19/16 Minute Order No. 1
By: Date: 10/24/16
Deputy Clerk of the Board Supervisors

APPENDIX B5

County of San Diego Notice of Election to Become a Groundwater Sustainability Agency

County of San Diego

MARK WARDLAW
DIRECTOR
PHONE (858) 694-2962
FAX (858) 694-2555

PLANNING & DEVELOPMENT SERVICES
5510 OVERLAND AVENUE, SUITE 310, SAN DIEGO, CA 92123
www.sdcounty.ca.gov/pds

DARREN GRETLER
ASSISTANT DIRECTOR
PHONE (858) 694-2962
FAX (858) 694-2555

January 13, 2016

Mark Nordberg, GSA Project Manager
Senior Engineering Geologist
Department of Water Resources
901 P Street, Room 213A
Post Office Box 942836
Sacramento, CA 94236

Delivery via E-Mail and US Mail
(MarkNordberg@water.ca.gov)

NOTICE OF ELECTION TO BECOME A GROUNDWATER SUSTAINABILITY AGENCY FOR THE BORREGO VALLEY GROUNDWATER BASIN

Dear Mr. Nordberg:

Pursuant to California Water Code Section 10723.8, the County of San Diego (County), a political subdivision of the State of California, gives notice to the California Department of Water Resources (DWR) of the County's decision to become a Groundwater Sustainability Agency (GSA) and to undertake sustainable groundwater management in the portion of the Borrego Valley Groundwater Basin (DWR Basin No. 7-24) within the boundary of San Diego County. The County overlies a portion of the basin as indicated on the attached map (Exhibit A of Attachment 1).

On January 6, 2016, the County Board of Supervisors held a public hearing in accordance with California Water Code Section 10723(b). The public hearing was noticed in the Daily Transcript in accordance with Government Code Section 6066 (Attachment 2).

After holding the public hearing, the County Board of Supervisors adopted Resolution Number 16-001 (Attachment 1) electing to become a GSA over the portion of the Borrego Valley Groundwater Basin within the boundary of San Diego County. No new bylaws, ordinances, or authorities were adopted by the County at that time.

The County is coordinating with Borrego Water District (BWD), which also submitted notice of election to DWR to become a GSA over the Borrego Valley Groundwater Basin within San Diego County. The County and BWD intend to work cooperatively to jointly manage groundwater in the basin. The County of Imperial and Imperial Irrigation District provided notice of election to DWR to become GSAs over the portion of the basin within

Imperial County. It should be noted that BWD and the County intend to submit a basin boundary adjustment under separate cover which will request that DWR adjust the basin boundaries in Bulletin 118-2003.

The County Board of Supervisors authorized the Director of Planning & Development Services to negotiate inter-agency agreements with BWD, the County of Imperial, Imperial Irrigation District, and/or other agencies or entities utilizing groundwater in the Borrego Valley Groundwater Basin, as necessary for the purpose of implementing a cooperative and coordinated governance structure to sustainably manage the basin.

Pursuant to California Water Code Section 10723.2, the County will consider the interests of all beneficial uses and users of groundwater, as well as those responsible for implementing a Groundwater Sustainability Plan (GSP). An initial list of stakeholders and interested parties include, but are not limited to, the following:

a) Holders of overlying groundwater rights, including:
    1) Agricultural users – 17 property owners encompassing about 3,976 acres.
    2) Domestic well owners – About 275 wells within the GSA boundary.
b) Municipal well operators – No incorporated cities within the GSA boundary.
c) Public water systems – Borrego Water District.
d) Local land use planning agencies – County of San Diego and Borrego Springs Community Sponsor Group.
e) Environmental users of groundwater – Anza-Borrego Desert State Park.
f) Surface water users, if there is a hydrologic connection between surface and groundwater bodies – No hydrologic connection.
g) The federal government, including, but not limited to, the military and managers of federal lands – None.
h) California Native American tribes – None.
i) Disadvantaged communities, including, but not limited to, those served by private domestic wells or small community water systems – Borrego Water District ratepayers and domestic well owners.
j) Entities listed in Section 10927 that are monitoring and reporting groundwater elevations in all or a part of a groundwater basin managed by the groundwater sustainability agency – The BWD and County have filed and maintain California Statewide Groundwater Elevation Monitoring (CASGEM) monitoring data with the DWR.

The County intends to work cooperatively with stakeholders to develop and implement the GSP for the Borrego Valley Groundwater Basin and will maintain a list of interested parties to be included in the formation of the GSP. By this notification, the County has provided DWR with all applicable information in California Water Code Section

10723.8(a). If you have any questions, or require additional information, please contact the County Groundwater Geologist, Jim Bennett, at (858) 694-3820.

Sincerely,

Mark Wardlaw

MARK WARDLAW, Director
Planning & Development Services

Attachments:
Attachment 1 – Resolution No. 16-001 (with Exhibit A – Borrego Valley Groundwater Basin Map)
Attachment 2 – Proof of Publication

Attachment 1 – Resolution No. 16-001 (with Exhibit A – Borrego Valley Groundwater Basin Map)

Resolution No.:16-001
Meeting Date: 1/6/16 (1)

RESOLUTION OF THE BOARD OF SUPERVISORS OF THE COUNTY OF SAN DIEGO TO BECOME A GROUNDWATER SUSTAINABILITY AGENCY OVER BORREGO VALLEY GROUNDWATER BASIN.

WHEREAS, on September 16, 2014, the Sustainable Groundwater Management Act (SGMA) was signed into law and adopted into the California Water Code, commencing with Section 10720, and became effective on January 1, 2015;

WHEREAS, the legislative intent of the SGMA is to provide for sustainable management of groundwater basins and sub-basins defined by the California Department of Water Resources (DWR), to enhance local management of groundwater, to establish minimum standards for sustainable groundwater management, and to provide local groundwater agencies with the authority and the technical and financial assistance necessary to sustainably manage groundwater;

WHEREAS, Water Code Section 10723(a) authorizes local land use authorities, water suppliers, and certain other local agencies, or a combination of local agencies, overlying a groundwater basin to elect to become a Groundwater Sustainability Agency (GSA) for the basin;

WHEREAS, San Diego County (County) is a local agency qualified to become a GSA under SGMA;

WHEREAS, the County overlies a portion of Borrego Valley (DWR Basin No. 7-24), a DWR-designated medium-priority, non-adjudicated groundwater basin, as shown on the map at Exhibit "A" attached to this Resolution.

WHEREAS, California Water Code Section 10723.8 requires that a local agency electing to serve as a GSA notify DWR of its election to form the GSA and undertake sustainable groundwater management within a basin;

WHEREAS, California Water Code Section 10723.8 mandates that within 90 days of the posting of a notice by DWR of an entity's election to form a GSA, that entity shall be presumed to be the exclusive GSA for that area unless another entity provides notice to DWR of its intent to form a GSA, or notice that the entity has formed a GSA;

WHEREAS, on August 11, 2015 the County of Imperial provided notice to DWR of election to form a GSA within the portion of Borrego Valley that lies within their jurisdiction;

WHEREAS, on October 27, 2015 Borrego Water District (BWD) provided notice to DWR of its election to form a GSA within the portion of Borrego Valley that lies within its jurisdiction;

WHEREAS, California Water Code Section 10724(a) states that if there is an area within the basin that is not within the management area of another entity, the County will be presumed to be the GSA for that area;

WHEREAS, no other entities have jurisdiction over the Borrego Valley Groundwater Basin in its entirety within San Diego County;

WHEREAS, the County intends to work cooperatively with the BWD, the County of Imperial, and community interests to form a GSA over Borrego Valley Groundwater Basin;

WHEREAS, the County is uniquely qualified to become the GSA over that portion of Borrego Valley Groundwater Basin located within the County as a result of its;

- current jurisdiction over the entire extent of Borrego Valley Groundwater Basin within the County of San Diego (reference Exhibit "A");
- experience in regulating groundwater through the San Diego County Groundwater Ordinance (San Diego County Code Title 6, Division 7, Chapter 7 Groundwater), and groundwater monitoring via the County's role of administering and enforcing State standards and local ordinances pertaining to the construction or destruction of any well or boring within the County (Article 4, Section 67 of the San Diego County Code and the California Well Standards Bulletin 74-90); and
- experience regulating groundwater use by making land use decisions based on the availability of groundwater for project use and whether or not the project will negatively impact groundwater quantity or quality.

WHEREAS, establishing the County as a GSA will enable the County to coordinate well permitting and extraction allocations with Groundwater Sustainability Plan (GSP) requirements, apply uniform basin management requirements, and ensure diverse stakeholder interests are represented during GSP development;

WHEREAS, the County is committed to the management of its groundwater resources to create and promote sustainable groundwater use for the residents of the State of California, the County of San Diego, and Borrego Valley, in particular;

WHEREAS, the County held a public hearing on January 6, 2016 after publication of notice pursuant to Government Code Section 6066 to consider adoption of this Resolution; and

WHEREAS, no new bylaws were adopted in conjunction with this Resolution and the County's existing Board of Supervisors will serve for governance purposes of the GSA or until the County and BWD cooperatively adopt a governing structure for a unified GSA; and

WHEREAS, adoption of this Resolution does not constitute a "Project" under the California Environmental Quality Act (CEQA) pursuant to 15060(c)(3) and 15378(b)(5) of the State CEQA Guidelines because it is an administrative action that does not result in any direct or indirect physical change in the environment.

THEREFORE, BE IT RESOLVED that the Board of Supervisors of the County of San Diego does hereby elect to become a GSA for the portion of DWR Basin No. 7-24 within the jurisdiction of the County of San Diego, pursuant to California Water Code Section 10723, as shown on Exhibit "A" attached to this Resolution.

BE IT FURTHER RESOLVED that the County shall develop an outreach program to ensure that all beneficial uses and users of groundwater are considered.

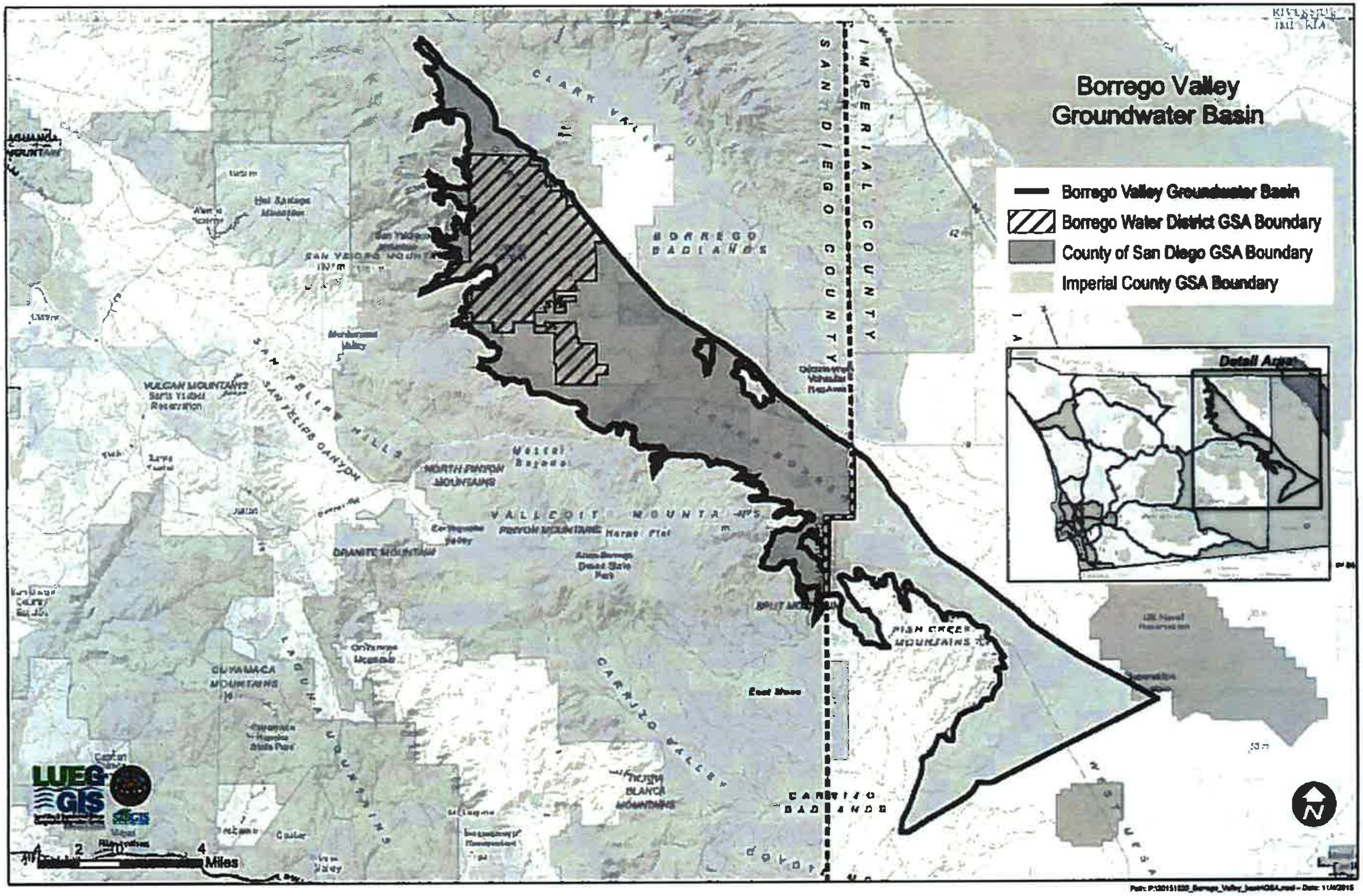
BE IT FURTHER RESOLVED that the Clerk of the Board of Supervisors is hereby directed to submit to DWR, on behalf of the County, a notice of this action to become a GSA and undertake sustainable groundwater management in accordance with SGMA for the portion of DWR Basin No. 7-24 within the jurisdiction of the County of San Diego.

BE IT FURTHER RESOLVED that the notification to DWR shall include the boundary of the portion of DWR Basin No. 7-24 within the jurisdiction of the County of San Diego that the County intends to sustainably manage, a copy of this Resolution, and the initial list of interested parties developed pursuant to California Water Code Section 10723.2, including an explanation of how their interests will be considered in the development and implementation of the GSP.

Approved as to form and legality

Senior Deputy County Counsel
By: Justin Crumley

Exhibit A


Borrego Valley
Groundwater Basin
Borrego Valley Groundwater Basin
Borrego Water District GSA Boundary
County of San Diego GSA Boundary
Imperial County GSA Boundary
Detail Area
IMPERIAL COUNTY
SAN DIEGO COUNTY
CLARK VALLEY
BORREGO BADLANDS
SAN FELIPE HILLS
SAN FELIPE CANYON
NORTH PINYON MOUNTAINS
VALLECITO MOUNTAINS
PINYON MOUNTAINS
GRANITE MOUNTAIN
VULCAN MOUNTAINS
CUYAMACA MOUNTAINS
LAGUNA MOUNTAINS
CARRIZO VALLEY
FISH CREEK MOUNTAINS
CARRIZO BADLANDS
TIERRA BLANCA MOUNTAINS
Anza-Borrego Desert State Park
Horse Flat
Split Mountain
East Mesa
WEST MESA
N
2
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LUEG GIS

ON MOTION of Supervisor D. Roberts, seconded by Supervisor Jacob, the above Resolution was passed and adopted by the Board of Supervisors, County of San Diego, State of California, on this 6th day of January, 2016, by the following vote:

AYES: Cox, Jacob, D. Roberts, R. Roberts, Horn

\- - -

STATE OF CALIFORNIA)
County of San Diego)SS

I hereby certify that the foregoing is a full, true and correct copy of the Original Resolution entered in the Minutes of the Board of Supervisors.

DAVID HALL
Clerk of the Board of Supervisors

By:
Elizabeth Miller, Deputy

Resolution No. 16-001
Meeting Date: 01/06/16 (1)

Attachment 2 – Proof of Publication

THE DAILY TRANSCRIPT

2652 4TH AVE 2ND FL, SAN DIEGO, CA 92103
Telephone (619) 232-3486 / Fax (619) 270-2503

This space for filing stamp only

Jim Bennett
SD CO CLERK OF THE BOARD
1600 PACIFIC HWY., RM. 402
SAN DIEGO, CA - 92101

PROOF OF PUBLICATION

(2015.5 C.C.P.)

State of California)
County of SAN DIEGO) ss

Notice Type: GOV - GOVERNMENT LEGAL NOTICE

Ad Description:

AUTHORIZATION TO BECOME A GROUNDWATER SUSTAINABILITY AGENCY OVER

I am a citizen of the United States and a resident of the State of California; I am over the age of eighteen years, and not a party to or interested in the above entitled matter. I am the principal clerk of the printer and publisher of THE DAILY TRANSCRIPT, a newspaper published in the English language in the city of SAN DIEGO, and adjudged a newspaper of general circulation as defined by the laws of the State of California by the Superior Court of the County of SAN DIEGO, State of California, under date of 05/13/2003, Case No. GIC808715. That the notice, of which the annexed is a printed copy, has been published in each regular and entire issue of said newspaper and not in any supplement thereof on the following dates, to-wit:

12/21/2015, 12/28/2015

Executed on: 12/28/2015
At Los Angeles, California

I certify (or declare) under penalty of perjury that the foregoing is true and correct.

Signature

A000003967003

SD#: 2825264

NOTICE IS HEREBY GIVEN that the Board of Supervisors of the County of San Diego (County) will consider whether to elect to become a Groundwater Sustainability Agency (GSA) for the Borrego Valley Groundwater Basin. Pursuant to California Government Code section 6066 and California Water Code section 10723, the resolution to become a GSA will be considered for adoption on January 6, 2016. After the public hearing, the Board may elect to submit a notice of intent for the County to become a GSA to the California Department of Water Resources (DWR). The notice of intent shall be posted by DWR pursuant to Water Code Section 10733.3 and will include a description of the proposed boundaries of the basin for which the County will be the GSA. The Board of Supervisors meets at 9:00 a.m. in Room 310, County Administration Center, 1600 Pacific Highway, San Diego, California. Interested persons are encouraged to review the text of the proposed resolution. A copy of the full text is posted in the office of the Clerk of the Board of Supervisors, Room 402, of the County Administration Center.
12/21, 12/28/15

SD-2825264#

APPENDIX B6

Borrego Water District Notice of Election to Serve as Groundwater Sustainability Agency

BORREGO WATER
DISTRICT

October 26, 2015

Mark Nordberg, GSA Project Manager Senior Engineering Geologist
California Department of Water Resources
P.O. Box 942836
Sacramento, CA 94236
Mark.Nordberg@water.ca.gov

RE: Notice of Election to Serve as a Groundwater Sustainability Agency

Dear Mr. Nordberg:

Pursuant to Water Code section 10723.8, the Borrego Water District (District), provides this notice of its election to serve as the Groundwater Sustainability Agency (GSA) for the portion of the Borrego Valley Groundwater Basin (number 7-24) within the boundaries of the District and wholly within the County of San Diego, as identified in the attached Exhibit A.

The District is a California Water District formed and operating under the provisions of the California Water Code 35565 and has the authority to exercise powers related to groundwater management. The District adopted an AB3030 Groundwater Management Plan is 2002. The District territory lies entirely within San Diego County and is the sole source water supply for the unincorporated community of Borrego Springs.

On October 20, 2015, the District held a public hearing to consider applying for the GSA status. The District noticed this hearing in both the bi-weekly Borrego Sun and the daily San Diego Union Tribune newspapers, as required by Water Code section 10723(b). A copy of the notice is provided in Exhibit B.

The District also mailed courtesy copies to the Counties of Imperial and San Diego which are the only other local agencies with groundwater authority in the Bulletin 118-2003 configuration of the Borrego Valley Groundwater Basin. A copy of the resolution through which the District elected to become a GSA is attached as Exhibit C. Please note that, under separate cover, the District, the County of Imperial, and the County of San Diego will jointly request the Department of Water Resources adjust the basin boundaries in Bulletin 118-2003 so as to split the basin so that the District and the County of San Diego will manage the portion within the County of San Diego and the County of Imperial will manage the portion within its boundaries.

The District will work cooperatively with the two Counties, along with all interested stakeholders pursuant to Water Code 10723.2. These interested parties include, but are not limited to, the following:

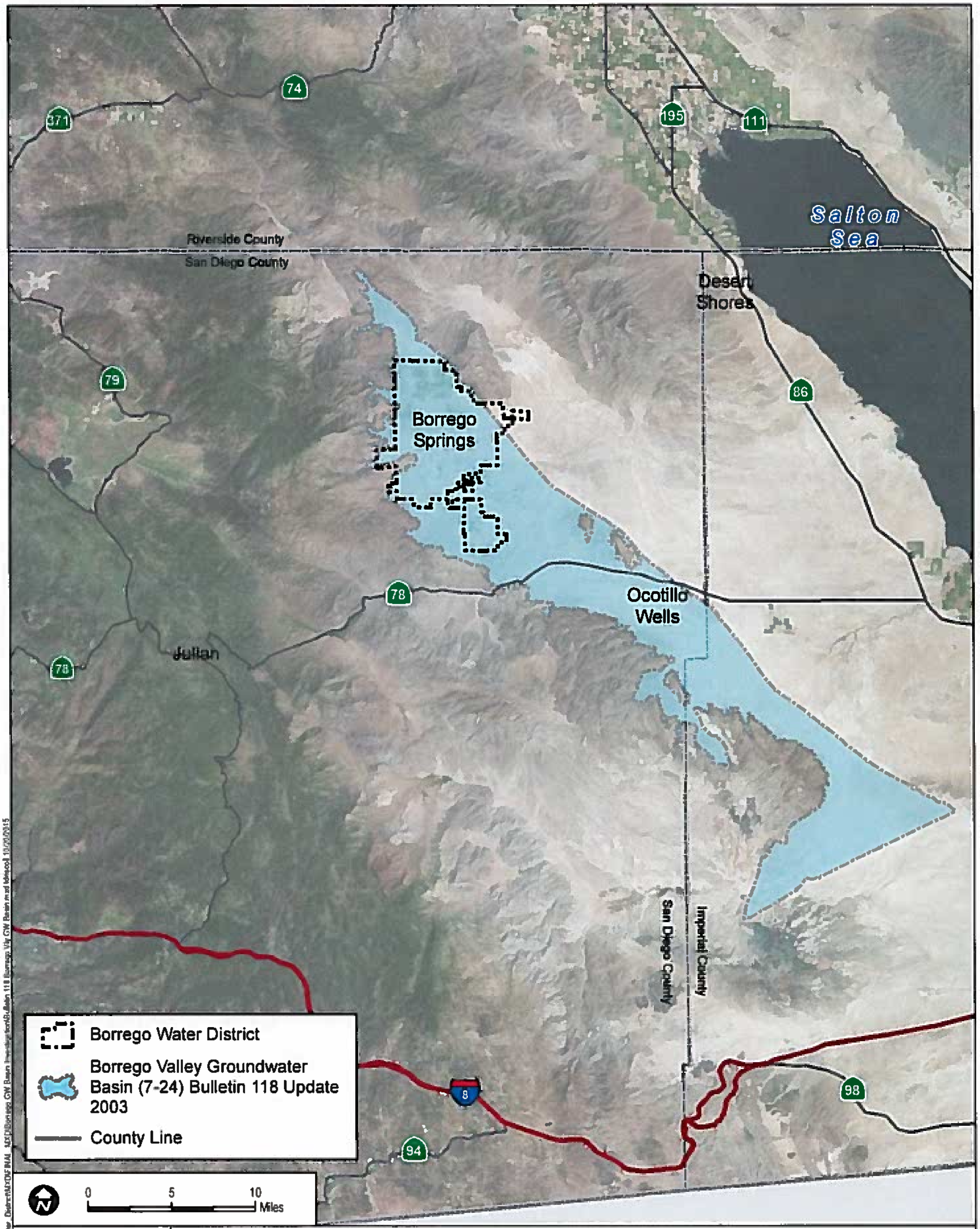
a) Holders of overlying groundwater rights
  1) agricultural users - 17 property owners encompassing 3,976 acres
  2) domestic well owners - approximately 75 wells located within the District boundary
b) Municipal well operators - no incorporated cities within District boundary
c) Public water systems - Borrego Water District
d) Local land planning agencies - San Diego County Department of Planning and Development Services, Borrego Springs Community Sponsor Group
e) Environmental users of groundwater - Anza-Borrego Desert State Park
f) surface water users - Anza-Borrego Desert State park
g) The federal government - none
h) California Native American Tribes - none
i) Disadvantaged Communities - all ratepayers of the Borrego Water District
j) Entities listed in Section 10927 - the Borrego Water District has filed and maintains CASGEM monitoring data with the Department of Water Resources.

The District will consider the interests of all users of groundwater within its boundaries and will maintain a list of interested parties to be included in the formation of the Groundwater Sustainability Plan.

If the DWR has any question, or requires additional information regarding this notification, please feel free to contact me.

Sincerely,

Jerry Rolwing
General Manager
760/767-5806
jerry@borregowd.org



DUDEK

OCTOBER 2015

SOURCE: BING 2014; DWR 2003

FIGURE 1
Borrego Valley Groundwater Basin (7-24)

Borrego Water District

RESOLUTION 2015-10-02

Electing to Become a Groundwater Sustainability Agency

WHEREAS the Legislature recently adopted the Sustainable Groundwater Management Act of 2014, which authorizes local agencies to manage groundwater in a sustainable fashion; and

WHEREAS, in order to use the authority granted in the Sustainable Groundwater Management Act, a local agency must elect to become a groundwater sustainability agency; and

WHEREAS, where more than one local agency overlies a groundwater basin, the Sustainable Groundwater Management Act calls on local agencies to cooperate to manage the groundwater basin in a sustainable manner for the common good; and

WHEREAS, the District together with the Counties of Imperial and San Diego overlies the Borrego Valley groundwater basin; and

WHEREAS, it is the intent of the District to work cooperatively with community interests (including but not limited to the Borrego Water Coalition), the County of Imperial, and the County of San Diego, to manage the Borrego Valley groundwater basin in a sustainable fashion; and

WHEREAS, the District has provided informal notice of its intent to serve as a groundwater sustainability agency for the Borrego Valley Groundwater Basin (the "Basin" as defined in DWR Bulletin 118-80) by means of written communications to the Borrego Water Coalition and the Counties of Imperial and San Diego; and

WHEREAS, on October 5th and October 12th, 2015, the District caused notice of its election to serve as a groundwater sustainability agency for the Basin in the San Diego *Union-Tribune*; and

WHEREAS, on October 20, 2015, the District held a public hearing to consider whether it should elect to become a groundwater sustainability agency for the Basin.

NOW, THEREFORE, BE IT RESOLVED by the Board of Directors of the Borrego Water District as follows:

1. The District hereby elects to become a groundwater sustainability agency for the Basin.

2. District staff are hereby directed to provide notice of this election to the California Department of Water Resources in the manner required by law.

3. District staff are hereby directed to promptly meet with the Borrego Water Coalition and the Counties of Imperial and San Diego in order to begin the process of developing a groundwater sustainability plan for the Basin. District staff are further directed to develop that plan in consultation and close coordination with the California Department of Water Resources,

the Regional Water Quality Control Board, the State Water Resources Control Board, and other interested stakeholders, as contemplated by the Sustainable Groundwater Management Act.

4. District staff are hereby directed to report back to the Board of Directors at least quarterly on the progress toward developing the groundwater sustainability plan for the Basin. The Board of Directors wishes to move forward aggressively to complete the development of this plan as quickly as may be feasible and to ensure that the groundwater basin will be managed in a sustainable fashion at the earliest possible date.

ADOPTED, SIGNED AND APPROVED this 20th day of October, 2015.

Beth A Hart

Beth Hart, President
Board of Directors of Borrego Water District

ATTEST:

Joseph Tatusko

Joseph Tatusko, Secretary
Board of Directors of Borrego Water District

{Seal}

STATE OF CALIFORNIA)
) ss.
COUNTY OF SAN DIEGO)

I, Joseph Tatusko, Secretary of the Board of Directors of the Borrego Water District, do hereby certify that the foregoing resolution was duly adopted by the Board of Directors of said District at a regular meeting held on the 20th day of October, 2015, and that it was so adopted by the following vote:

AYES: DIRECTORS: Hart, Brecht, Tatusko, Delahay

NOES: DIRECTORS:

ABSENT: DIRECTORS: Estep

ABSTAIN: DIRECTORS:

Joseph Tatusko

Joseph Tatusko, Secretary of the Board of Directors
of Borrego Water District

STATE OF CALIFORNIA)
) ss.
COUNTY OF SAN DIEGO)

I, Joseph Tatusko, Secretary of the Board of Directors of the Borrego Water District, do hereby certify that the above and foregoing is a full, true and correct copy of RESOLUTION NO. 2015-10-2, of said Board, and that the same has not been amended or repealed.

Dated: October 20, 2015

Joseph Tatusko

Joseph Tatusko, Secretary of the Board of Directors
of Borrego Water District

APPENDIX C

Stakeholder Engagement

C1: Stakeholder Engagement Plan

C2: List of Public Meetings

APPENDIX C1

Stakeholder Engagement Plan

STAKEHOLDER ENGAGEMENT PLAN

BORREGO VALLEY GROUNDWATER BASIN (7-24)
SAN DIEGO COUNTY, CALIFORNIA

SUSTAINABLE GROUNDWATER MANAGEMENT ACT (SGMA) PROGRAM

Prepared for

BORREGO WATER DISTRICT
EST. 1962

Prepared by

County of San Diego
Planning & Development Services
5510 Overland Avenue, Suite 310
San Diego, CA 92123

March 20, 2017

TABLE OF CONTENTS

TABLE

1 INTRODUCTION

This Stakeholder Engagement Plan (Engagement Plan) summarizes the strategies to educate and involve stakeholders (those individuals and representatives of organizations who have a direct stake in the outcome of the planning process) and other interested parties in the preparation of a Groundwater Sustainability Plan (GSP) for the Borrego Valley Groundwater Basin (Borrego Basin). This GSP will be prepared in accordance with the Sustainable Groundwater Management Act (SGMA), which was signed by Governor Brown in September 2014 and became effective January 1, 2015.

SGMA provides a framework to regulate groundwater for the first time in California's history. The intent of SGMA is to strengthen local management of specified groundwater basins that are most critical to the state's water needs by regulating groundwater and land use management activities. SGMA also aims to preserve the jurisdictional authorities of cities, counties and water agencies within groundwater basins while protecting existing surface water and groundwater rights.

The County of San Diego (County) and Borrego Water District (the District) elected to become a Multi-Agency Groundwater Sustainability Agency (GSA) for the Borrego Basin – Department of Water Resources (DWR) Basin No. 7-24. The primary purpose of a GSA under SGMA is to develop a GSP to achieve long-term groundwater sustainability. Additionally, SGMA requires and directs GSAs to involve stakeholders and interested parties in the process to regulate groundwater.

2 PURPOSE

The purpose of the outreach activities described in this Engagement Plan is to provide individual stakeholders and stakeholder organizations, and other interested parties an opportunity to be involved in the development and evaluation of the GSP for the Borrego Basin. As a Multi-Agency GSA, the County and the District intend to develop and implement a basin-specific GSP for the Borrego Basin. This GSP is required under SGMA to be completed by no later than January 31, 2020. The projects and management actions necessary to implement the GSP could affect numerous individuals and groups who have a stake in ensuring the basin is sustainably managed as required by SGMA.

In an effort to understand and involve stakeholders and their concerns in the decision-making and activities of the GSA, the County and the District have prepared this Engagement Plan to achieve broad, enduring and productive involvement during the GSP development and implementation phases. This Engagement Plan will assist the County and the District in providing timely information to stakeholders and receive input from interested parties during GSP development. This Engagement Plan will identify stakeholders who have an interest in groundwater in the Borrego Basin, and recommend outreach, education and communication strategies for engaging those stakeholders during the development and implementation of the GSP. The plan also includes an approach for evaluating the overall success of stakeholder engagement and education of both stakeholders and the general public. In consideration of the interests of all beneficial uses and users of groundwater in the basin, this Engagement Plan has been developed pursuant to California Water Code Section 10723.2.

3 GENERAL INFORMATION

The following personnel at the County will serve as contacts for the public during preparation of the GSP.

3.1 SGMA Coordinator

The County's SGMA Coordinator will serve as the central contact for stakeholders and the public. For information on the GSP, contact:

Jim Bennett, Groundwater Geologist
Planning & Development Services
County of San Diego
PDS.groundwater@sdcounty.ca.gov
(858) 694-3820

3.2 Media Contact

Media inquiries should be addressed to:

Alex Bell, Group Communications Officer
Land Use and Environment Group
County of San Diego
Alex.Bell@sdcounty.ca.gov
(619) 531-5410

4 OUTREACH ACTIVITIES

The County and the District will implement the following outreach activities to maximize stakeholder involvement during the development of the GSP and throughout SGMA implementation.

4.1 Public Notices

To ensure that the general public is apprised of local activities and allow stakeholders to access information, SGMA specifies several public notice requirements for GSAs. Refer to Table 1 for a summary of statutory requirements. Three sections of the California

Water Code require public notice before establishing a GSA, adopting (or amending) a GSP, or imposing or increasing fees:

- Section 10723(b). Before electing to be a groundwater sustainability agency, and after publication of notice pursuant to Section 6066 of the Government Code, the local agency or agencies shall hold a public hearing in the county or counties overlying the basin.

- Section 10728.4. A groundwater sustainability agency may adopt or amend a groundwater sustainability plan after a public hearing, held at least 90 days after providing notice to a city or county within the area of the proposed plan or amendment.

- Section 10730(b)(1). Prior to imposing or increasing a fee, a groundwater sustainability agency shall hold at least one public meeting, at which oral or written presentations may be made as part of the meeting….(3) At least 10 days prior to the meeting, the groundwater sustainability agency shall make available to the public data upon which the proposed fee is based.

In accordance with California Water Code Section 10723(b), the following was noticed to the public:

- On October 20, 2015, the District held a public hearing to consider becoming a GSA for the portion of the Borrego Basin within their boundaries. The District noticed the hearing in both the bi-weekly Borrego Sun and the daily San Diego Union Tribune newspapers.

- On January 6, 2016, the County Board of Supervisors held a public hearing to consider becoming a GSA over the portion of the Borrego Basin within San Diego County. The public hearing was noticed in the Daily Transcript in accordance with Government Code Section 6066.

- On September 20, 2016, the District held a public hearing to consider adopting a Memorandum of Understanding (MOU) between the District and the County. The District noticed the hearing in both the bi-weekly Borrego Sun and the daily San Diego Union Tribune newspapers.

- On October 19, 2016, the County Board of Supervisors held a public hearing to also consider adopting a MOU between the District and the County. The public hearing was noticed in the Daily Transcript in accordance with Government Code Section 6066.

Future noticing will occur as required by SGMA.

4.2 Stakeholder Identification

SGMA mandates that a GSA establish and maintain a list of persons interested in receiving notices regarding plan preparation, meeting announcements, and availability of draft plans, maps, and other relevant documents. The County and the District compiled a list of interested persons wishing to receive information that will be maintained throughout the GSA formation and GSP development phases. An initial list of stakeholders and interested parties include, but are not limited to, the following:

a) Holders of overlying groundwater rights, including:
    1) Agricultural users.
    2) Domestic well owners.
    3) Borrego Water District – From the purchase of private water companies

b) Municipal well operators – No incorporated cities within the GSA boundary.

c) Public water systems – Borrego Water District.

d) Local land use planning agencies – County of San Diego and Borrego Springs Community Sponsor Group.

e) Environmental users of groundwater – Anza-Borrego Desert State Park.

f) Surface water users, if there is a hydrologic connection between surface and groundwater bodies – No hydrologic connection.

g) The federal government, including, but not limited to, the military and managers of federal lands – None.

h) California Native American tribes – None.

i) Disadvantaged communities, including, but not limited to, those served by private domestic wells or small community water systems – Borrego Water District ratepayers and domestic well owners.

j) Entities listed in Section 10927 that are monitoring and reporting groundwater elevations in all or a part of a groundwater basin managed by the groundwater sustainability agency – The District and County have filed and maintain California Statewide Groundwater Elevation Monitoring (CASGEM) monitoring data with the DWR.

The County intends to work cooperatively with stakeholders and interested parties to develop and implement the GSP for the Borrego Basin and will maintain a list of stakeholders and interested parties to be included in the formation of the GSP.

4.3 Town Hall Meetings

The District hosts an annual town hall meeting for the public each March. The County and the District will continue outreach efforts to identify stakeholders and interested parties and conduct a stakeholder assessment during the town hall meeting on March 29, 2017. Some key questions for the stakeholder assessment will be:

- What are their interests, concerns, and priorities?
- What is the best way to communicate with them?
- How involved would they like to be in development of the GSP?
- What information would be helpful for engagement of stakeholders and interested parties to better participate in the development and/or implementation of the GSP?

4.4 Planning Group

The Borrego Springs Community Sponsor Group is actively involved in the community on matters dealing with planning and land use in Borrego Valley. Since this group provides a forum for the discussion of land use planning that directly impacts GSP issues that are important to the community, it is important for this group to be well informed throughout GSP development. County/District team members will attend these meetings at key milestones to provide up-to-date information and hear feedback from group members.

4.5 Public Hearings/Meetings

4.5.1 Planning Commission

On April 22, 2016, County staff presented an informational item about SGMA to the County's Planning Commission. The presentation served to inform the commission and community on SGMA and what impacts the legislation has on San Diego County. Periodic updates on SGMA implementation will be provided to the commission and the public will be invited to listen. No action will be taken during these meetings. Planning Commission hearings can be viewed online at: http://www.sandiegocounty.gov/pds/PC/sop/PCHearing_stream.html.

4.5.2 District Board Hearings and Meetings

On October 20, 2015, the Board of Directors for the District held a public hearing and voted to become a GSA for the portion of the Borrego Basin within their boundaries. On September 20, 2016, the District held a public hearing and adopted a MOU between the District and the County, which serves to memorialize each agency's role and responsibilities for developing a GSP. SGMA has been, and will continue to be, an agenda item at the regular meetings of the District's Board of Directors. These meetings are held every third Tuesday and fourth Wednesday of the month at 9:00 a.m. at the District office, 806 Palm Canyon Drive, Borrego Springs, CA. Each meeting has a scheduled time for public comments. Information about upcoming meetings can be found on the District's website (http://www.borregowd.org/). Additionally, on most third Tuesdays of each month, an informal workshop is held for the public to discuss SGMA and GSP-related issues.

4.5.3 County Board of Supervisors Hearings

On January 6, 2016, the County Board of Supervisors held a public hearing and voted to become a GSA over the portion of the Borrego Basin within San Diego County. On October 19, 2016, the County Board of Supervisors held a public hearing to also consider adopting a MOU between the District and the County. Additional Board of Supervisors Hearings will be scheduled at key stages during SGMA implementation, including adoption of the GSP for Borrego Basin. Hearings can be viewed online at: http://www.sandiegocounty.gov/content/sdc/general/board-meeting-video.html.

4.6 Direct Mailings/Email

Advisory committee meetings and project information will be disseminated through email. This communication will provide information for the Borrego Valley community, public agencies, and other interested persons/organizations about milestones, meetings, and the progress of GSP development. Property owners with groundwater wells within the basin will be notified via email and/or direct mailings about the establishment of an interested persons list and given the opportunity to receive future notices.

4.7 Newsletters/Columns

Recurring updates in the *Borrego Sun* newspaper and County Planning & Development Services (PDS) newsletter, *eBlast*, will be provided to advise, educate, and inform the public on SGMA implementation in Borrego Valley. The latest County PDS *eBlast* can be found online at http://www.sandiegocounty.gov/pds/.

4.8 SGMA Website

A variety of information about SGMA and groundwater conditions will be produced by the County and the District. This information will include maps, timelines, frequently asked questions, groundwater information, and schedules/agenda of upcoming meetings and milestones. This information will be accessible on the County's SGMA webpage located at: http://www.sandiegocounty.gov/pds/SGMA.html. County staff will update the website regularly and invite users to request information or be added to the interested persons list. Additionally, the District maintains a repository of groundwater, economic, and GSP-related technical studies on its website at: http://www.borregowd.org/Groundwater_Management_EY7H.php.

4.9 Database

To distribute information about GSP development, a mailing list and email list has been compiled into a database of interested persons and stakeholders. The database will be updated regularly to add names of attendees at sponsor group or town hall meetings along with those requesting information via email or through the SGMA website.

4.10 Advisory Committee

Comprehensive stakeholder involvement will include the establishment of an Advisory Committee to aid in developing and implementing the GSP. In addition to signing up to receive information about GSP development at the County's SGMA webpage, interested parties may participate in the development and implementation of the GSP by attending public Advisory Committee meetings in Borrego Springs, in accordance with Water Code Section 10727.8(a). The Multi-Agency GSA approved nine-member Borrego Valley Advisory Committee (Advisory Committee) comprises the following members:

- Borrego Water Coalition - 1 agricultural member; 1 recreation member; 1 independent pumper; 1 at large member,
- 1 member Borrego Springs Community Sponsor Group,
- 1 member Borrego Valley Stewardship Council,
- 1 member District representative for ratepayers/property owners,
- 1 member San Diego County Farm Bureau, and
- 1 member California State Parks, Colorado Desert Region.

The Borrego Water Coalition represents a broad cross-section of groundwater pumpers and users of the Borrego Basin who together represent approximately 80% of annual withdrawals from the Borrego Basin. The Borrego Springs Community Sponsor Group is the officially appointed representative body charged with addressing land use issues to the County. The Borrego Valley Stewardship Council represents community groups associated with the Anza-Borrego Desert State Park and geotourism economic development initiative. The District represents over 2,000 ratepayers/property owners in Borrego Springs. Through the Agricultural Alliance for Water and Resource Education (AAWARE), the San Diego County Farm Bureau represents farming interests in Borrego Springs who, at present, collectively use approximately 70% of annual withdrawals from the Borrego Basin. The California State Parks represent the approximately 600,000 acre Anza-Borrego Desert State Park that surrounds Borrego Springs.

5 EVALUATION

To determine the level of success of the Engagement Plan, the County and the District will implement the following measures:

5.1 Attendance/Participation

A record of those attending public and Advisory Committee meetings will be maintained throughout the GSP development process. The County and the District will utilize sign-in sheets and request feedback from attendees to determine adequacy of public education and productive engagement in the GSP development and implementation process. Meeting minutes will also be prepared and will be provided on the SGMA website once approved.

5.2 Adherence to Schedule

Public participation in developing projects and management actions for inclusion in the GSP is instrumental to the success of the GSP. Keeping these tasks on schedule will be an important indicator of stakeholder involvement. Early identification of milestones and due dates will be important in ensuring a commitment from Advisory Committee members.

6 REFERENCES

Community Water Center. 2015. *Collaborating for Success: Stakeholder Engagement for Sustainable Groundwater Management Act Implementation.* July.

TABLE

Table 1. Summary of Statutory Requirements for Stakeholder Engagement in SGMA[1]

During GSA Formation:	
"Before electing to be a groundwater sustainability agency… the local agency or agencies shall hold a public hearing."	Water Code Sec. 10723 (b)
"A list of interested parties [shall be] developed [along with] an explanation of how their interests will be considered."	Water Code Sec. 10723.8.(a)(4)
During GSP Development and Implementation:	
"A groundwater sustainability agency may adopt or amend a groundwater sustainability plan after a public hearing".	Water Code Sec. 10728.4
"Prior to imposing or increasing a fee, a groundwater sustainability agency shall hold at least one public meeting".	Water Code Sec. 10730(b)(1)
"The groundwater sustainability agency shall establish and maintain a list of persons interested in receiving notices regarding plan preparation, meeting announcements, and availability of draft plans, maps, and other relevant documents".	Water Code Sec. 10723.4
"Any federally recognized Indian Tribe… may voluntarily agree to participate in the preparation or administration of a groundwater sustainability plan or groundwater management plan… A participating Tribe shall be eligible to participate fully in planning, financing, and management under this part".	Water Code Sec. 10720.3(c)
"The groundwater sustainability agency shall make available to the public and the department a written statement describing the manner in which interested parties may participate in the development and implementation of the groundwater sustainability plan".	Water Code Sec. 10727.8(a)
Throughout SGMA Implementation:	
"The groundwater sustainability agency shall consider the interests of all beneficial uses and users of groundwater".	Water Code Sec. 10723.2
"The groundwater sustainability agency shall encourage the active involvement of diverse social, cultural, and economic elements of the population within the groundwater basin".	Water Code Sec. 10727.8(a)

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[1] Source: Community Water Center. *Collaborating for Success: Stakeholder Engagement for Sustainable Groundwater Management Act Implementation.* July 2015.

APPENDIX C2

List of Public Meetings

Appendix C2 - List of Public Meetings

Date	Location	Start Time	End Time	Topics (Not listed are opening/closing procedures and certain administrative/informational items)	Meeting Type	Attendance			
						Advisory Committee Members	Core Team Members	Staff	Public / Stakeholders
3/6/2017	Borrego High School	10:00 AM	2:25 PM	Brown Act Training; Collaborative Problem Solving and Consensus Decision Making; Draft Advisory Committee Bylaws	Advisory Committee	8	4		10
4/10/2017	Borrego High School	10:00 AM	2:55 PM	Support for A/C Members; Review, Discussion and Possible Adoption of A/C By-Laws; GSP Update, Overview and Informational Presentation	Advisory Committee	7	5	2	9
5/15/2017	Borrego Water District	10:00 AM	3:10 PM	Review, Discussion and Possible Adoption of A/C By-Laws ; Review and Discussion of Draft A/C Agenda Development Schedule and Interaction with Constituent Group (CG); Borrego Valley Stewardship Council (BVSC); Receive Updates from A/C Members on CG Engagement; Presentation on the Borrego Basin Groundwater Sustainability Plan	Advisory Committee	8	4	2	13
6/29/2017	Borrego Water District	10:00 AM	2:45 PM	Review, Discussion and Possible Adoption of A/C By-Laws; Proposition 1 Grant Funding Opportunity – Flow Metering; Groundwater Sustainability Plan: Discuss Proposed Management Areas; Receive A/C Input on Roger Mann Study; 2018 Statewide Water Bond Update; Receive Updates from A/C Members on Constituent Group Discussions	Advisory Committee	8	5	3	3

Appendix C2 - List of Public Meetings

Date	Location	Start Time	End Time	<u>Topics</u> (Not listed are opening/closing procedures and certain administrative/informational items)	Meeting Type	Attendance			
						Advisory Committee Members	Core Team Members	Staff	Public / Stakeholders
7/27/2017	Borrego Water District	10:00 AM	3:00 PM	Continued Discussion and Potential Actions: Proposition 1 Grant Funding Opportunity; Requiring the Metering of all Wells in Borrego Springs Subbasin and Proposed Monitoring Program; Benchmarking under SGMA Presentation; Policy on Projects Creating Additional Water Use post January 1, 2015 Pending Determination of Existing Allocations; Review Timeline for GSP Development and Milestones for AC Input/Recommendations on High-level Topics	Advisory Committee	7	4	3	7
9/28/2017	Borrego Water District	10:00 AM	3:00 PM	Metering Requirements for Non-de Minimis Wells; Baseline Pumping Allocations; Sustainability Indicators, Measurable Objectives, and Minimum Thresholds; Proposition One Grant Application Update; Revisions to SGMA Frequently Asked Questions (FAQ) Document	Advisory Committee	7	4	4	14
10/26/2017	Steele/Burnand Anza-Borrego Desert Research Center	10:00 AM	2:50 PM	Metering Requirements for Non-de Minimis Wells; Baseline Pumping Allocation; Water Budget and Reduction Period; Proposition One Grant Application Update	Advisory Committee	8	4	3	16
11/27/2017	Steele/Burnand Anza-Borrego Desert Research Center	10:00 AM	2:50 PM	Metering Requirements for Non-de Minimis Wells; Baseline Pumping Allocation; Pumping Allowance; Sustainability Period and Reduction Period; Streamflow	Advisory Committee	9	4	4	7

Appendix C2 - List of Public Meetings

Date	Location	Start Time	End Time	Topics (Not listed are opening/closing procedures and certain administrative/informational items)	Meeting Type	Attendance			
						Advisory Committee Members	Core Team Members	Staff	Public / Stakeholders
1/25/2018	Steele/Burnand Anza-Borrego Desert Research Center	10:00 AM	3:00 PM	Sustainability Indicators; Water Credits Program; Projects and Management Actions to be Considered; Water Quality Presentation	Advisory Committee	9	4	5	8
3/5/2018	Steele/Burnand Anza-Borrego Desert Research Center	5:30 PM	7:30 PM	SGMA Overview, GSP Timeline, Prop 1 Grant, community outreach, Community Q/A/C Session	Community Meeting	8	5	7	85
3/16/2018	Steele/Burnand Anza-Borrego Desert Research Center	5:30 PM	7:30 PM	Rising water rates; Economic impacts; Land use designations; Water use allocations; Sustainability strategies; Water quality; Environmental impacts; GSP development; Community meetings	Community Meeting	8	5	7	102
3/29/2018	Steele/Burnand Anza-Borrego Desert Research Center	10:00 AM	2:50 PM	Considering Human Right to Water Use; Municipal Allocations; Projects and Management Actions to be Considered	Advisory Committee	8	4	5	12
4/27/2018	Borrego Springs Library	1:00 PM	3:00 PM	Ad Hoc Committee on Severely Disadvantaged Community (SDAC) Involvement	SDAC	Unkown			
5/31/2018	Steele/Burnand Anza-Borrego Desert Research Center	10:00 AM	3:05 PM	Baseline Pumping Allocation Update; Projects and Management Actions to be Considered; Well Metering Plan; Groundwater Dependent Ecosystems Presentation	Advisory Committee	8	4	4	11

Appendix C2 - List of Public Meetings

Date	Location	Start Time	End Time	<u>Topics</u> (Not listed are opening/closing procedures and certain administrative/informational items)	Meeting Type	Attendance			
						Advisory Committee Members	Core Team Members	Staff	Public / Stakeholders
7/26/2018	Borrego Springs Resort	10:00 AM	3:00 PM	Review of GSP Development Progress Over Last Year; Baseline Pumping Allocation Update; Groundwater Monitoring Network Spring 2018 Results; Socioeconomic Efforts; Groundwater Dependent Ecosystems	Advisory Committee	8	5	5	7
8/30/2018	Steele/Burnand Anza-Borrego Desert Research Center	10:00 AM	12:00 PM	Baseline Pumping Allocations & Reductions; CEQA Process Presentation; BWD SDAC Grant Tasks 2 and 3 Presentation; Community Engagement Efforts; Water Vulnerability & New Extraction Well Site Feasibility Analysis Presentation	Advisory Committee (SDAC	8	3	6	8
8/31/2018	Steele/Burnand Anza-Borrego Desert Research Center	10:00 AM		Model/Water Budget Presentation	Technical Meeting	Unkown			
9/19/2018	Borrego Springs Unified School District	5:00 PM	8:00 PM	Rising water rates; Economic impacts; Land use designations; Water use allocations; Sustainability strategies; Water quality; Environmental impacts; GSP development; Community meetings	Community Meeting	1	1	3	34
10/4/2018	Steele/Burnand Anza-Borrego Desert Research Center	10:00 AM	2:40 PM	Socioeconomic Efforts: Community Engagement Efforts Update; EIR and CEQA Process; GSP Ch. 1-3 Presentation	Advisory Committee	8	5	5	14

Appendix C2 - List of Public Meetings

Date	Location	Start Time	End Time	Topics (Not listed are opening/closing procedures and certain administrative/informational items)	Meeting Type	Attendance			
						Advisory Committee Members	Core Team Members	Staff	Public / Stakeholders
11/29/2018	Steele/Burnand Anza-Borrego Desert Research Center	10:00 AM	3:00 PM	Review of Chapters 2 & 3: Key Concept Slides from Oct. 4th AC Meeting; Opportunity to Clarify Technical/Informational Material presented on 10-04-2018; Ch. 4 Presentation	Advisory Committee	7	5	4	11
1/24/2019	LIVE LIST TO BE UPDATED								

Full list, agenda and meeting mintes at available on County website at: https://www.sandiegocounty.gov/content/sdc/pds/SGMA/borrego-valley.html

APPENDIX D

Technical Appendices

D1: Update to the USGS Borrego Valley Hydrologic Model

D2: BWD Water Quality Review and Assessment

D3: Groundwater Hydrographs

D4: Borrego Springs Subbasin Groundwater Dependent Ecosytems

APPENDIX D1

Update to the USGS Borrego Valley Hydrologic Model

DRAFT

Update to United States Geological Survey Borrego Valley Hydrologic Model for the Borrego Valley Sustainability Agency

Prepared for:

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TABLE OF CONTENTS

Section **Page No.**

APPENDICES

FIGURES

1 INTRODUCTION

In 2009, the United States Geological Survey (USGS) initiated a study of the Borrego Valley Groundwater Basin (BVGB) with the Borrego Water District (BWD). The goals of the study were to enhance the understanding of groundwater conditions in BVGB, and develop a numerical model as a tool to manage groundwater resources and evaluate possible future conditions in the basin. The USGS used the MODFLOW numerical modeling code One-Water Hydrologic Flow Model, or MF-OWHM, to simulate the interaction between surface water (e.g., stream flow and applied irrigation) and groundwater in Borrego Valley. From a Sustainable Groundwater Management Act (SGMA) perspective, MF-OWHM provides a fully integrated numerical modelling system capable of simulating the full hydrologic cycle to evaluate potential undesirable effects like declining groundwater storage, declining groundwater levels in areas with groundwater-dependent habitat, subsidence, and seawater intrusion.

2 2015 BORREGO VALLEY HYDROLOGIC MODEL

The Borrego Valley Hydrologic Model (BVHM) was developed as part of a cooperative study between the USGS and the BWD. The study began in 2009, with the objectives of 1) improving the understanding groundwater conditions and land subsidence, 2) incorporating this improved understanding into a model that would assist in the management of groundwater resources in the BVGB, and 3) using this model to test several management scenarios (Faunt et al., 2015). The BVHM simulates the use, movement, and storage of water throughout the BVGB through time. The BVHM is a finite-difference groundwater model that was developed using the MODFLOW numerical code MF-OWHM. It was anticipated the model developed as part of the study would be used to help the BWD quantify the relative benefits of various groundwater management options that would need to be undertaken in the basin in order to comply with SGMA.

2.1 Simulation Period

The BVHM simulated conditions using monthly stress periods from October 1929 to December 2010. There were 975 monthly stress periods in the simulation. Faunt et al., (2015) noted that, “the first 192 stress periods (years 1930-45) are considered a model spin-up period, and the model calibration as well as the target simulation period used for analysis was October 1945 through December 2010.” The 16-year “spin-up” was used in the model to “eliminate significant effects caused by uncertainty in the initial conditions” defined in the model. Because there was groundwater development and irrigation before the simulation period, the initial conditions defined in the model, per groundwater levels mapped in 1945, may not have represented steady-state conditions.

Each monthly stress period has two time steps, with the exception of the first stress period with 16 time steps. The time step multiplier was 0.75 for each stress period, meaning that the duration of the first time step (excluding the first stress period) ranged from 16 days to 17.7 days depending on the number of days in the month. The second time step ranged from 12 days to 13.3 days.

2.2 Model Domain

The boundaries of the active model domain of the BVHM were defined by the Coyote Creek fault on the northeast and east of the alluvial valley, the Vallecito Mountains to the south, and the San Ysidro Mountains to the west and northwest. The southeastern boundary of the model was defined at a surface-water divide southwest of Ocotillo Wells. This boundary marks an area of the alluvial valley where subsurface flow leaves the basin.

The model domain is defined by a finite-difference grid of uniform cells, or nodes, with each cell being 2,000-feet by 2,000-feet, or approximately 92 acres in area. The model domain includes 30 rows and 75 columns with 2,250 active cells (Figure 1). The total area simulated in the model is 73,876 acres. The model was divided vertically into three layers. The top layer represents the upper unconfined aquifer unit consisting of Quaternary alluvium. The thickness of the top layer ranged from 50 feet to 643 feet. The middle aquifer unit (Layer 2) is Pleistocene age continental deposits with a thickness ranging from 50 feet to 908 feet. The lower aquifer unit (Layer 3) includes the lower Palm Spring and Imperial Formations with a thickness ranging from 50 feet to 3,831 feet.

2.3 Hydrogeological Characteristics

Layer 1 represents the upper unconfined aquifer, which historically has been the main source of water in the valley with well yields as high as 2,000 gallons per minute (GPM). The upper aquifer includes unconsolidated gravel, sand silt and clay of Holocene to Pleistocene age. Layer 2 represents the middle aquifer, which includes Pleistocene age continental deposits of gravel to silt with moderate amounts of consolidation and cementation. The middle aquifer yields moderate amounts of water north of San Felipe Creek. Layer 3 represents the lower aquifer and includes deposits of the lower Palm Springs and Imperial Formations. It is comprised of sandstone, siltstone, and conglomerate with low well yields. All three layers were simulated as convertible between unconfined and confined, meaning that when the water table declines below the top elevation of a layer that was fully saturated (i.e., confined), then the layer was converted to unconfined to account for a change in the saturated thickness and unsaturated portion of the layer.

The USGS used a geostatistical approach on grain size and texture characterized from various lithologic and geophysical logs recorded in Borrego Valley to simulate the heterogeneity of the aquifer units in the Borrego Basin. The textural map was based on the percentage of coarse-grain material described in each lithologic log. Coarse-grained sediments were characterized with having primarily boulders, cobbles, pebbles, gravel, and sand.

The distribution of coarse-grain sediment across the basin was interpolated between locations of borings and geophysical logs using kriging or cokriging algorithms over a grid matching the finite-difference gird utilized in the BVHM. Coarse-grain sediments were predominantly defined at the base of the foothills in the alluvial valley, and along major streambeds like Coyote Creek. The upper aquifer had the largest percentage of coarse-grain sediment, which reflected the depositional and geomorphic environments originating from the watersheds and drainages tributary to Borrego Valley. The middle and lower aquifers had finer sediments.

2.3.1 Hydraulic Conductivity

Hydraulic conductivity in the BVHM was defined based on the distribution of coarse-grain sediments defined by the textural map created from lithologic and geophysical logs. Horizontal hydraulic conductivity was "calculated as the weighted arithmetic mean of the hydraulic conductivities of the coarse-grained and fine-grained lithologic end members and the distribution of sediment texture for each model cell" (USGS, 2015). Faunt et al., (2015) noted that, "hydraulic conductivities generally decrease with depth and with increasing distances from the original source of the sediments in adjacent mountain ranges and river channels, which is consistent with the fining-down and fining-toward-the-basin-center sequences observed in the aquifer sediments and texture model. Coarser grained sediments were assumed to be present near stream channels in the alluvium in the upper reaches of all three aquifers."

The saturated horizontal hydraulic conductivity in the upper aquifer ranged from 0.3 feet per day (ft/day) to 184 ft/day. The highest hydraulic conductivities were defined in the central portion of the valley where sand deposits of Quaternary age were characterized and older fan deposits at the base of the San Ysidro and Vallecito Mountains (Figure 2). Lower hydraulic conductivities were identified in areas characterized with younger fan deposits and consolidated continental deposits. The Borrego Sink was characterized with a uniform hydraulic conductivity of 6 ft/day in all three aquifer units. The saturated hydraulic conductivity in the middle and lower aquifer units ranged from 0.02 ft/day to 7 ft/day. The lower hydraulic conductivity in the middle and lower aquifers relative to the upper aquifer were based on a lower energy depositional environment to the valley prior to activity along the Coyote Creek fault that opened the northern portion of the valley to sediment deposition from Coyote Creek.

Faunt et al., (2015) reported estimated hydraulic conductivities based on previous aquifer tests conducted in the valley. Four constant-rate aquifer tests yielded an estimated hydraulic conductivity of 2 ft/day in a clay interbedded with sand to 336 ft/day in a coarse sand unit. The lower aquifer unit, which included the Palm Springs Formation characterized with cemented interbedded clays and gravels, had an estimated hydraulic conductivity of 10 ft/day. A previous numerical model included hydraulic conductivities that ranged from 0.1 to 178 ft/day, with a ratio of horizontal to vertical hydraulic conductivity at 10 for the upper and middle aquifers, and 1 for the lower aquifer.

2.3.2 Storage Properties

Specific yield, which represents unconfined aquifer storage and equals the percentage of bulk aquifer volume that would drain under gravity, ranged from 12% to 17% (average was 15%) for the upper aquifer. Specific yield was defined in the BVHM similarly to how hydraulic conductivity was defined using a textural map to simulate the heterogeneity of the aquifer units. The specific yield for the middle aquifer ranged from 15% to 21% with an average of 17.5% (Figure 3). The specific yield for the lower aquifer ranged from 0.7% to 5.6% with an average of 3%. A specific yield was defined for each aquifer unit because they were simulated as convertible between confined and unconfined layers based on hydraulic head in relation to the top elevation at each model node.

Faunt et al., (2015) reported that the specific storage defined for each aquifer unit under confined conditions ranged from 5.1×10^{-7} in the upper aquifer to 1.6×10^{-6} in the middle aquifer. The specific storage terms were defined uniformly for each layer.

2.4 Boundary Conditions

The boundaries of the model domain were mostly defined as no-flow boundaries coinciding with the Coyote Creek fault and the foothills of the San Ysidro and Vallecitos mountains. There were a few exceptions: specified fluxes were defined at 44 cells representing underflow originating from the upstream watersheds draining to Borrego Valley, twenty-four (24) stream flow entry points were defined at nodes representing the locations where stream flow entered the valley via Coyote Creek, San Felipe Creek, Borrego Palm Creek, and other drainages, and three constant-head boundary nodes simulating the outflow of groundwater at the southern end of the BVHM. The natural recharge of underflow and surface water runoff from the adjoining watersheds was estimated from data obtained from the regional-scale USGS Basin Characterization Model (BCM).

2.4.1 Basin Characterization Model

The BCM was developed by the USGS in 2004 and provides a “deterministic water-balance approach to estimate recharge and runoff in a basin” on a regional scale. The BCM “uses the distribution of precipitation, snow accumulation and melt, [potential evapotranspiration] PET, soil-water storage, and bedrock permeability to estimate a monthly water balance for the groundwater system” (Faunt et al., 2015). The result is an estimate of water recharging a basin (of which some may leave the basin as underflow to an adjacent basin) and potential runoff. Potential underflow and runoff to Borrego Valley was estimated from the BCM using the watersheds surrounding Borrego Valley. Water entering BVGB via underflow was represented by 44 cells along the mountain boundaries in the valley each defined with a constant specified flux based on estimates from the BCM. Water entering BVGB via surface water runoff was represented by 24 cells defined as entry points to the stream segments defined in the stream-flow routing (SFR) package (Figure 4).

Runoff and underflow entering the BVGB, as estimated by the BCM, were “simulated for the watersheds draining into the Borrego Valley on a monthly basis for years 1940 – 2007 as spatially distributed among the watersheds draining into Borrego Basin” (Faunt, 2015). The average annual underflow entering the BVGB was approximately 10% of the estimated recharge to the adjacent watersheds, or approximately 900 acre-feet per year. Typically, there was little to no stream flow to the BVGB from 1940 to 2007. Only after major wet seasons or large individual rainfall events did runoff to BVGB exceed 10,000 acre-feet per year or more. This only occurred during 7 years in the 1940 to 2007 period. Runoff to the BVGB ranged from less than 10 acre-feet per year to 44,000 acre-feet per year with an average annual rate of 3,600 acre-feet per year. The BVHM includes perennial flow entering Coyote Creek at 0.014 cubic feet per second (cfs) and an unnamed tributary at 0.002 cfs from a minor watershed to the southwest of the BVGB.

2.5 Farm Process

MF-OWHM is a fully coupled integrated hydrologic numerical modeling code capable of simulating all interactions of surface water and groundwater in the hydrosphere. Integrated within MF-OWHM is the Farm Process Package, or FMP, which simulates the movement of water over a landscape. Water may originate from natural (e.g., rainfall) and/or anthropogenic sources (e.g., applied irrigation) and move via surface water runoff, evapotranspiration, and infiltration into the unsaturated zone. A landscape is characterized by a land-use type (e.g. farm, golf course) with certain characteristics defined, like rooting depth, soil moisture characteristics, and application inefficiencies defined for irrigation and precipitation. The FMP simulates the water budget over a landscape defined at each cell, or node, in the model domain. Water inputs may include rainfall, applied irrigation, and stream flow. Water outputs may include evapotranspiration, surface water runoff, and, when coupled with MODFLOW, infiltration in the unsaturated zone and groundwater pumping from the saturated zone.

The USGS (2015) defined fifty-two (52) water-balance subregions (WBS), or “farms,” in the BVHM. These 52 farms were defined based on a parcel map showing land ownership from 2010. The definition of these farms in the model domain were held constant throughout the simulation. Each farm was assigned one or more land-use types, of which there were 15 classifications that included golf course, urban, fallow, native, and certain crop types like grapes, citrus, and palm. The USGS redefined land-use types on a near annual basis, with some land uses changing due to urbanization, zoning, and/or farming restrictions through the simulation. For example, Faunt et al., (2015) noted that “before development, about 10 percent of land use consisted of phreatophytes, and 90 percent was other types of native vegetation and bare ground. In 2009, 78 percent was natural vegetation (6 percent phreatophytes and 72 percent other native types), 11 percent residential/municipal, 8 percent developed agricultural land, and about 3 percent recreational uses (golf courses).”

Land-use type was assigned on a cell-by-cell basis (Figure 5). The coarse grid of the BVHM, with cells of uniform dimensions of 2,000-feet by 2,000-feet (or 92 acres), however, meant that the land-use type that comprised the largest fraction of a cell was assigned to that cell. For example, the farm representing Rams Hill Golf Course included 10 cells comprising a total of 920 acres, but only two of those cells (total of 184 acres) were assigned a golf course land-use type after 2009. The other 8 cells were assigned a “native classes” land-use type designation.

Pumping data for agricultural uses was not available to the USGS when designing the BVHM. The FMP estimates agricultural pumping by calculating estimated water demands for the various crop types receiving applied irrigation. The FMP calculates the water demand for a specific crop using potential evapotranspiration (PET) provided by the BCM and crop coefficients assigned to each crop type simulated in the BVHM. The FMP then calculates a crop irrigation requirement (CIR), or residual water demand, after accounting for water supplied via precipitation and root uptake via groundwater. The CIR was increased to compensate for evaporative losses and estimated inefficiencies of delivering water for irrigation supply. The result is a total farm delivery requirement (TFDR) that is satisfied in the BVHM via estimated pumping in the FMP.

2.6 Water Budget

An annual water budget was calculated for the BVGB for every water year. A water year spans the year from October 1 to the subsequent September 30.

2.6.1 Inflow from Stream Leakage

Faunt et al., (2015) noted that "the primary source of natural recharge to the basin is infiltration from the ephemeral stream and washes entering the Borrego Valley from the adjacent mountains." Surface water runoff entering the model domain was simulated using the SFR package. The SFR package is a head-dependent boundary condition that can simulate stream flow routing, groundwater discharges in reaches characterized as gaining streams, stream flow leakage in reaches characterized as losing streams, and the capture and conveyance of surface runoff. The BVHM includes 84 stream segments defined in the SFR package, where multiple segments were joined to represent stream flow in Coyote Creek, San Felipe Creek, Borrego Palm Creek, and other minor tributaries. The streams received inflow at 24 entry points that represented runoff from the adjoining upstream watersheds in the San Ysidro and Vallecitos mountains.

Recharge from stream leakage ranged from 97 acre-feet (AF) in 1929 to 22,500 AF in 1978 (Figure 6). The annual average recharge rate from stream leakage was 4,016 acre-feet per year (AFY) with a standard deviation of 4,853 AFY.

2.6.2 Inflow from Applied Irrigation Return Flows

Another source of inflow to the basin, particularly as the valley became more developed, was return flow from applied irrigation at agricultural areas. Applied irrigation at agricultural areas was estimated using the FMP. The volume of applied water in excess of losses to evapotranspiration, irrigation inefficiencies, and surface runoff was simulated as infiltrating below the root zone and entering the unsaturated zone. The FMP was linked to the unsaturated zone flow package, or UZF, of MODFLOW. The UZF simulates the movement of water through the unsaturated zone based on soil moisture characteristics and a uniform definition of vertical hydraulic conductivity in the unsaturated zone.

Early versions of MODFLOW simulated an instantaneous contribution of infiltrating water from land surface to the water table. However, water does not infiltrate instantaneously, but moves through an unsaturated zone where the movement of water is a function of soil moisture content (i.e., degree of saturation) and highly variable hydraulic conductivities based on the moisture content. Faunt et al., (2015) noted, "depending on the unsaturated-zone thickness, permeability, and residual moisture content, it can take years to decades for irrigation return flow to pass through the unsaturated zone." The UZF provides a more realistic estimation of irrigation return flows in the BVHM.

Recharge from applied irrigation return flows ranged from 572 AF to 5,703 AF (Figure 6). The annual average recharge rate from stream leakage was 1,657 AFY with a standard deviation of 973 AFY.

2.6.3 Septic System Return Flows

The USGS cited a previous study that estimated an average use of 100 gallons per day per household and assumed that 50% of the water used was lost to evaporation and transpiration. Therefore, the USGS estimated that return flow from septic tank systems in the valley was constant at 0.056 AFY per home, or $5.14e^{-7}$ cubic meters per day (m^3/day). The USGS identified residential and/or developed areas in the valley and estimated a number of septic tank systems associated with those land use types on a per node basis in the numerical model. The number of septic tank systems were periodically defined in the model and used for subsequent monthly stress periods until the next count. The last count of septic tank systems defined in the numerical model was based on development identified in 2009. The USGS reported that, “the infiltration from irrigation of municipal lawns and treated and untreated wastewater was assumed to be negligible.”

2.6.4 Inflow from Subsurface Flow

Underflow entering the BVGB from the adjoining upstream watersheds was simulated using the Flow Head Boundary (FHB) package. Underflow from these watersheds was distributed over 44 cells aligned at the model domain boundaries with the San Ysidro and Vallecitos mountains. The rate of underflow entering the BVHM for each cell was based on monthly data obtained from the BCM. The USGS defined an average rate of underflow at each cell to the model domain and held these rates constant throughout the simulation. The total underflow to the model domain was 3.7 acre-feet per day, or 1,367 AFY (Figure 6).

Inflow from subsurface flow (i.e., underflow) ranged from 1,366 AF to 1,370 AF. The annual average recharge rate from stream leakage was 1,367 AFY with a standard deviation of 2 AFY.

2.6.5 Outflow via Pumping

The BVHM simulated municipal pumping using metered data obtained from BWD, and agricultural and recreational pumping estimated using the FMP. Before 1944, groundwater pumping in the basin averaged less than 300 AFY, which was used mostly for domestic purposes (USGS, 2015). No pumping was simulated in the BVHM from 1929 to 1943. Population growth in Borrego Valley after World War II led to increasing groundwater production with the majority of water produced for irrigation purposes. Groundwater production ramped up from essentially 0 AFY in 1943 to over 10,000 AFY in 1955 (Figure 7). Annual production declined to less than 7,000 AFY beginning in 1965, but began increasing again in the mid-1970s with a peak production of almost 20,000 AFY in 2006. Faunt et al., (2015) reported that, “about 70 percent of the groundwater used each year has been for agriculture, about 20 percent for golf courses and other recreational uses, and about 10 percent for municipal and domestic use (residential, commercial, and the Anza-Borrego Desert State Park).”

Pumping for agricultural, recreational and municipal uses were simulated using the MODFLOW multi-node well package (MNW2). The MNW2 package simulates the effects of pumping from wells that intersect multiple aquifer units that contribute flow under different hydraulic heads. A number of wells were completed in more than one of the aquifer units in Borrego Valley. Faunt et al., (2015) identified up to 82 wells operating in the basin. Seventy of those wells were assigned to farms identified in the model domain with pumping determined from the FMP package. These wells represented pumping for agricultural and recreational uses in Borrego Valley. Municipal pumping, which was based on metered data, was provided by BWD.

2.6.6 Outflow via Evapotranspiration

Monthly potential evapotranspiration data was obtained from the BCM and included as part of the water-balance calculations in the FMP. Direct evapotranspiration from groundwater was estimated in the FMP by calculating the monthly PET values by monthly crop coefficients assigned to each land-use type (e.g. phreatophytes, citrus, golf courses, native, etc.), the rooting depths defined for each land-use type, the depth to groundwater and height of capillary fringe. Phreatophytes, found mostly in the northern part of Borrego Valley and around the Borrego Sink, had the deepest rooting depth at 15.3 feet. They were responsible for most of the groundwater losses from the basin prior to the mid-1940s. Faunt et al., (2015) reported that approximately 4,300 AFY was lost via evapotranspiration from phreatophytes before 1946. The amount of water extracted by pumping from the basin surpassed losses by evapotranspiration by 1954 (Figure 7). This was attributed to declining water levels in the basin, which reduced the amount of water available for transpiration. Evapotranspiration losses were less than 2,000 AFY by 1990 and less than 1,000 AFY by 2000.

2.6.7 Outflow at Southern Boundary of BVGB

A constant-head boundary condition was assigned to three cells marking the southern boundary of the BVGB. This boundary was identified by the USGS based on water level data from other sources that indicated this area was not influenced by water level fluctuations and hydraulic conditions to the north. The average outflow at this boundary throughout the simulation was 1.4 acre-feet per day. No water flowed into the model domain at this boundary.

Annual outflow from the BVGB at the southern boundary of the basin ranged from 499 AF to 573 AF. The annual average was 525 AFY with a standard deviation of 15 AFY.

2.6.8 Water Balance

The BVGB has experienced more in water losses via pumping and evapotranspiration than inflows from stream leakage and underflow from the adjoining watersheds since the 1929-1930 water year (Figure 8). The exceptions were during more-than-normal wet years, like 1976, 1978, and 1991, when stream flow leakage was a significant contributor of inflow to the basin. In those years, there was a net influx of 13,000 to 18,000 AF of water to the basin. Outside of those wet years, the average annual loss from the basin was approximately 13,100 AFY. The average annual loss from the basin from the 2004-2005 water year to the 2009-2010 water year was 19,000 AFY (Appendix A).

Faunt et al., (2015) reported that the average annual natural recharge of water reaching the saturated zone, which includes stream leakage and infiltrating water through the unsaturated zone, was 5,700 AFY. This estimate was derived from the full simulation period from 1929 to 2010. In addition to natural recharge from stream leakage and infiltrating water (mostly from irrigation return flows), the BVGB received underflow originating from the adjacent watersheds at an average annual rate of 1,400 AFY. Therefore, the average annual recharge to the BVGB is approximately 7,100 AFY.

The average annual loss in storage in the BVGB from 1929 to 2010 was approximately 6,000 AFY.

2.7 Model Calibration and Sensitivity

2.7.1 Calibration

The model was calibrated to observed hydraulic heads (i.e. measured groundwater levels at wells) collected from 1945 to 2010. Faunt et al., (2015) reported that 2,224 groundwater level measurements were obtained from databases maintained by BWD, USGS, and California Department of Water Resources. The groundwater level data was collected at 73 wells in the basin. Model calibration was evaluated by calculating the difference (i.e. residual) between the observed groundwater level measured at a well to the corresponding simulated groundwater level. The USGS employed a combination of manual modifications and the use of an automated parameterization algorithm, or parameter estimation tool (PEST), to adjust parameters (e.g. hydraulic conductivity, storage, stream inflows) over a series of simulation runs to minimize the residuals between observed and simulated hydraulic heads.

Faunt et al., (2015) reported that “the overall model fit for groundwater-level comparisons is generally good when the simulated head values are compared against the measured groundwater levels. About 90 percent of the residuals were between -20 and +20 feet, and more than 50 percent were between -5 and +5 feet” (Appendix C). The mean residual from 1945 to 2010 was

+2.41 feet (from 2,258 residuals ranging from -249.48 to +235.9 feet), indicating that the model tended to underestimate hydraulic heads compared to observed values (Figure 9).

A plot of simulated versus observed hydraulic heads from 1945 to 2010 shows a bias of the model to overestimate lower observed hydraulic heads and underestimate higher observed hydraulic heads (Figure 10). A perfect match of simulated heads with observed heads would yield a uniform slope. A linear trend line fitted to the observed and simulated hydraulic head data had a slope of 0.65, which may indicate a flatter hydraulic gradient simulated across the basin than one estimated from the observed hydraulic heads.

A measure of the average error in the model simulating observed hydraulic heads is indicated by the root mean squared error (RMSE) of the residuals. The RMSE is the best measure of error if the residuals are normally distributed in the basin. An acceptable error is gaged by the magnitude of the change in hydraulic head in the simulation compared to the RMSE. The RMSE was 17.88 feet between observed and simulated hydraulic heads from 1945 to 2010. Hydraulic heads declined 10 feet to 130 feet from the 1950s to 2010 with an average decline of 57.3 feet. The ratio of the RMSE (17.88 feet) to the average decline in hydraulic head in the basin (57.3 feet) is 0.31, which is an acceptable level of error given the coarse grid (2,000 feet by 2,000 feet) and layer thicknesses of 50 feet to 643 feet in the upper aquifer (layer 1) of the model domain.

2.7.2 Sensitivity

The parameter estimation process using PEST was used to evaluate the sensitivity of the BVHM to parameters defined in the model. A sensitivity analysis, as conducted by the USGS for the BVHM, provides a measure of the uncertainty in the model results arising from the assumptions made in defining the hydrogeology and parameters in the model. Faunt et al., (2015) reported that the BVHM was most sensitive to scaling factors used in estimating runoff from precipitation and applied irrigation, crop coefficients, and irrigation efficiency, all of which were included in the FMP and contribute to calculating the water demand for the various land-use types defined in the model. The next most sensitive parameters were specific yield and scaling factors used to adjust the amount of runoff and underflow estimated by the BCM that entered the BVGB.

The highest levels of uncertainty in the model were from agricultural pumping, specific yield, and stream flow entering the valley. Agricultural pumping (and to a lesser extent recreational pumping) was estimated using the FMP package, which calculates a water demand on a cell-by-cell basis for each land-use type. The water demand is based on an estimated water consumption factoring in evapotranspiration, applied water (via irrigation or rainfall), efficiencies of applied irrigation water, soil moisture content, rooting depth, and potential runoff. The following measures could be taken to improve the uncertainty in the model: 1) information on actual pumping for agricultural and recreational uses can be used to improve the accuracy of the FMP in estimating pumping; 2) long-term constant-rate aquifer tests in the upper and middle aquifer units would improve the estimates of specific yield; and 3) the installation of stream gaging stations in Coyote Creek and other major drainages to the valley would improve the estimates of runoff to the basin.

3 UPDATE OF THE BORREGO VALLEY HYDROLOGIC MODEL

The BVHM was updated to extend the simulation period to September 2016. This required increasing the number of monthly stress periods from 975 to 1,044. The additional stress periods were configured with the same number of time steps (2) and time-step multiplier (0.75) used in the original stress periods of the model. Inflow from subsurface flow representing underflow to the basin and outflow represented by the constant-heads at the southern end of the basin were maintained at their same respective rates and heads from January 2011 to September 2016. No changes were made to hydraulic properties like saturated hydraulic conductivity and storativity (specific yield and specific storage) and to hydraulic properties of the unsaturated zone.

Monthly precipitation and evapotranspiration data for January 2011 to September 2016 were obtained from the BCM. The Farm Process package was updated to incorporate the monthly precipitation and evapotranspiration data, and changes to land-use type were made in the FMP based on a review of aerial imagery and documented fallowed land through the BWD and County of San Diego (County) Water Credits Program. Municipal pumping by District wells from January 2011 to September 2016 was included in the updated files.

3.1 Updating the Farm Process Package

3.1.1 Land Use Types

Land use types were updated after reviewing aerial imagery of the Borrego Valley from 2011 to 2016, and reviewing Water Credits filed with the County. The following modifications were made to the last land use type characterization from the original file: in September 2013, the land use at one cell was changed from citrus to fallow; in August 2014, one cell was changed from native to residential; in December 2014, one cell was changed from citrus to fallow; in July 2015, one cell was changed from palms to fallow; and in May 2016, one cell was changed from citrus to fallow. All other land-use types defined in the original model remained the same.

3.1.2 Precipitation and Evapotranspiration

Monthly precipitation and evapotranspiration data were obtained from the BCM for January 2011 to September 2016. The precipitation and evapotranspiration data were compiled in separate files for each month. The FMP was updated to read each precipitation and evapotranspiration data file corresponding to the additional stress periods in the updated model.

The FMP used the monthly precipitation and evapotranspiration data to calculate a water balance on a cell-by-cell basis. The data from the BCM are in units of millimeters per month. The FMP includes a multiplier of $3.29e^{-5}$ that is applied to each value from the BCM to convert it to units of meters per day.

3.2 Stream Flow

Runoff to the 24 stream flow entry points were taken from historical stream gage and precipitation data. An attempt was made to repeat the methodology the USGS used in defining runoff to the 24 stream flow entry points using BCM data, but the process utilized by the USGS was not understood and could not be discerned when comparing BCM data to runoff values used in the numerical model for earlier stress periods.

Therefore, stream flow entering the valley after December 2010 was simulated based on historical rainfall compared to runoff. Precipitation data recorded at climatic stations from 2011 to 2016 in the BVGB were compared to historical (i.e. pre-2011) monthly precipitation data recorded at the same climatic stations to find months with similar precipitation. These months were then used to pull stream gage data from stream gages on Coyote Creek, Palm Canyon Creek, and San Filipe Creek during historical periods when these stream gages were active. These monthly values were added to the appropriate stress periods for the extended model simulation.

3.3 Pumping

Monthly municipal pumping data from January 2011 to September 2016 was obtained from BWD. The pumping data was converted from acre-feet per month to cubic meters per day and incorporated in the updated BVHM. The average monthly pumping rates for municipal wells ranged from 0 m^3/day to 2,011 m^3/day at well ID4-11. Agricultural and recreational pumping continued to be estimated using the FMP.

3.4 Septic System Return Flows

The number of septic tank systems were periodically defined in the model and used for subsequent monthly stress periods until the next count. The last count of septic tank systems defined in the numerical model was based on development identified in 2009. The updated model repeated this information from 2009 during the extended period from January 2011 to September 2016.

4 WATER BALANCE OF UPDATED MODEL

An annual water balance from the 2010-2011 to 2015-2016 water years was calculated for the BVGB using the updated BVHM. Stream leakage was the largest contributor of inflow to the basin, which ranged from 1,180 AF to 6,500 AF. The 6,500 AF occurred during the winter of 2011. The average annual inflow from stream leakage was 2,550 AFY. Recharge from irrigation return flows averaged 1,630 AFY. Underflow was held constant from the original model and averaged 1,400 AFY. The average annual total inflow, or recharge, to the BVGB was 5,550 AFY from the 2010-2011 to 2015-2016 water years (Appendix B).

Pumping was the largest outflow component from the basin. The average annual outflow via pumping from the basin was 15,800 AFY. Other sources of outflow included evapotranspiration (435 AFY) and the southern constant-head boundary of the basin (520 AFY). Pumping constituted 94% of the total outflow. The average annual total outflow from the BVGB was 16,700 AFY from the 2010-2011 to 2015-2016 water years.

The average annual water balance from the 2010-2011 to 2015-2016 water years was a deficit of 11,000 AFY, which further contributed to a decline in groundwater storage in the BVGB (Figure 8).

5 MODEL VALIDATION

All hydraulic head and stream flow data collected up through 2010 were used to calibrate the numerical model. No exercise was conducted by the USGS to verify, or validate, the results of the BVHM. Model validation is a means of establishing greater confidence in the model and its accuracy in predicting future conditions. “A model is verified if its accuracy and predictive capability have been proven to lie within acceptable limits of error by tests independent of the calibration data” (Anderson, 1992). Updating the BVHM with data collected outside the calibration period from January 2011 to September 2016 presented the opportunity of validating the model. As described previously, only climatic parameters (precipitation, evapotranspiration, stream flow) and metered pumping were added to the additional stress periods defined in the updated model. Parameters defining hydraulic properties (hydraulic conductivity, storage) and uniform boundary conditions (constant underflow and heads at the southern boundary) were consistent in the updated model.

The simulation results from January 2011 to September 2016 were compared to observed hydraulic heads recorded in this period to validate the numerical model. The mean residual from October 2010 to September 2016, which included the 2010-2011 to 2015-2016 water years, was +6.18 feet (from 225 residuals ranging from -55.72 to +52.71 feet), indicating that the model continued to underestimate hydraulic heads compared to observed values (Figure 6, Appendix C).

A plot of simulated versus observed hydraulic heads from 1945 to September 2016 continues to show a bias of the model to overestimate lower observed hydraulic heads and underestimate higher observed hydraulic heads (Figure 7). A linear trend line fitted to the observed and simulated hydraulic head data from January 2011 to September 2016 was parallel (slope of 0.65) to the linear trend line matched to the 1945 to 2010 data. The BVHM, updated with recent data outside the calibration period, provided similar results with similar error.

The RMSE between observed and simulated hydraulic heads from January 2011 to September 2016 was 18.78 feet, which was comparable to the RMSE of 17.88 feet calculated for the residuals from 1945 to 2010. Hydraulic heads declined an additional 2 to 18.5 feet from 2011 to 2016 with an average decline of 9.3 feet over the 6 year period.

6 RECOMMENDATIONS

The sensitivity analysis conducted by the USGS indicated the greatest uncertainty in the numerical model was in agricultural pumping, stream flow leakage, and storage. The FMP estimates agricultural pumping using precipitation and evapotranspiration data obtained from the BCM, assumptions about soil types and their associated soil moisture characteristics, rooting depths, crop coefficients, overland runoff, and estimated efficiencies of applied irrigation. Additionally, the coarse uniform grid of the model domain may overstate the water demands of certain land-use types, like golf courses, and, consequently, overestimate the amount of groundwater pumped to meet the water demand.

The simulated hydraulic heads compared to observed hydraulic heads indicated a slight bias of the model in underestimating hydraulic heads. This may be the result of the model simulating too much pumping compared to actual usage, or underestimating storage values like specific yield for the upper aquifer, or underestimating the amount of recharge to the BVGB, or a combination of all three. To improve the accuracy of the BVHM in simulating actual conditions and provide greater confidence in predictive simulations, the following are recommended actions to undertake to obtain additional data and further study the hydrogeology of the basin:

- Collect actual agricultural pumping data via existing or installing new flow meters at farm wells. The pumping data may be incorporated in the numerical model to calibrate the FMP to more accurately estimate the water demands for the various crops and golf courses being irrigated.

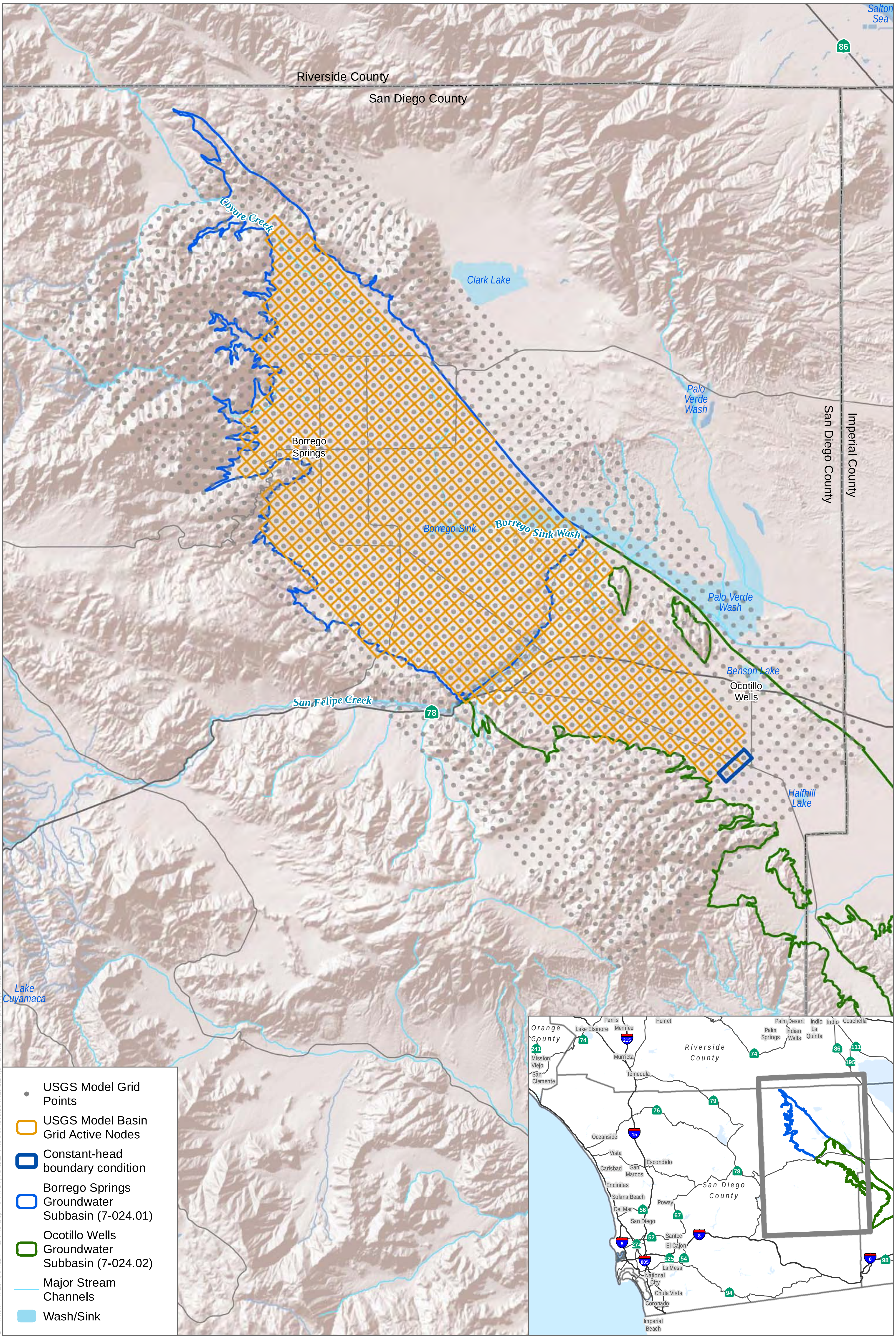
- Install stream gaging stations at major drainages that convey most of the surface water runoff to the valley, either from perennial flows or flash flows from major precipitation events. The goal would be to install two gaging streams in the same creek to measure differences in flow. This information would provide a more accurate estimate of stream leakage.

- Conduct aquifer tests at wells screened only in the upper aquifer and only in the middle aquifer to obtain site-specific estimates of hydraulic conductivity and specific yield for each aquifer unit. This information may be used to enhance the calibration of the model to these hydraulic properties and our understanding of storage in the BVGB.

7 REFERENCES

Anderson, M.P., & Woessner, W.W. (1992). *Applied Groundwater: Modeling Simulation of Flow and Advective Transport*. San Diego: Academic Press, Inc.

Faunt, C.C., Stamos, C.L., Flint, L.E., Wright, M.T., Burgess, M.K., Sneed, Michelle, Brandt, Justin, Martin, Peter, and Coes, A.L., 2015. Hydrogeology, hydrologic effects of development, and simulation of groundwater flow in the Borrego Valley, San Diego County, California: U.S. Geological Survey Scientific Investigations Report 2015-5150, 135 p.



SOURCE: Faunt et al., 2015

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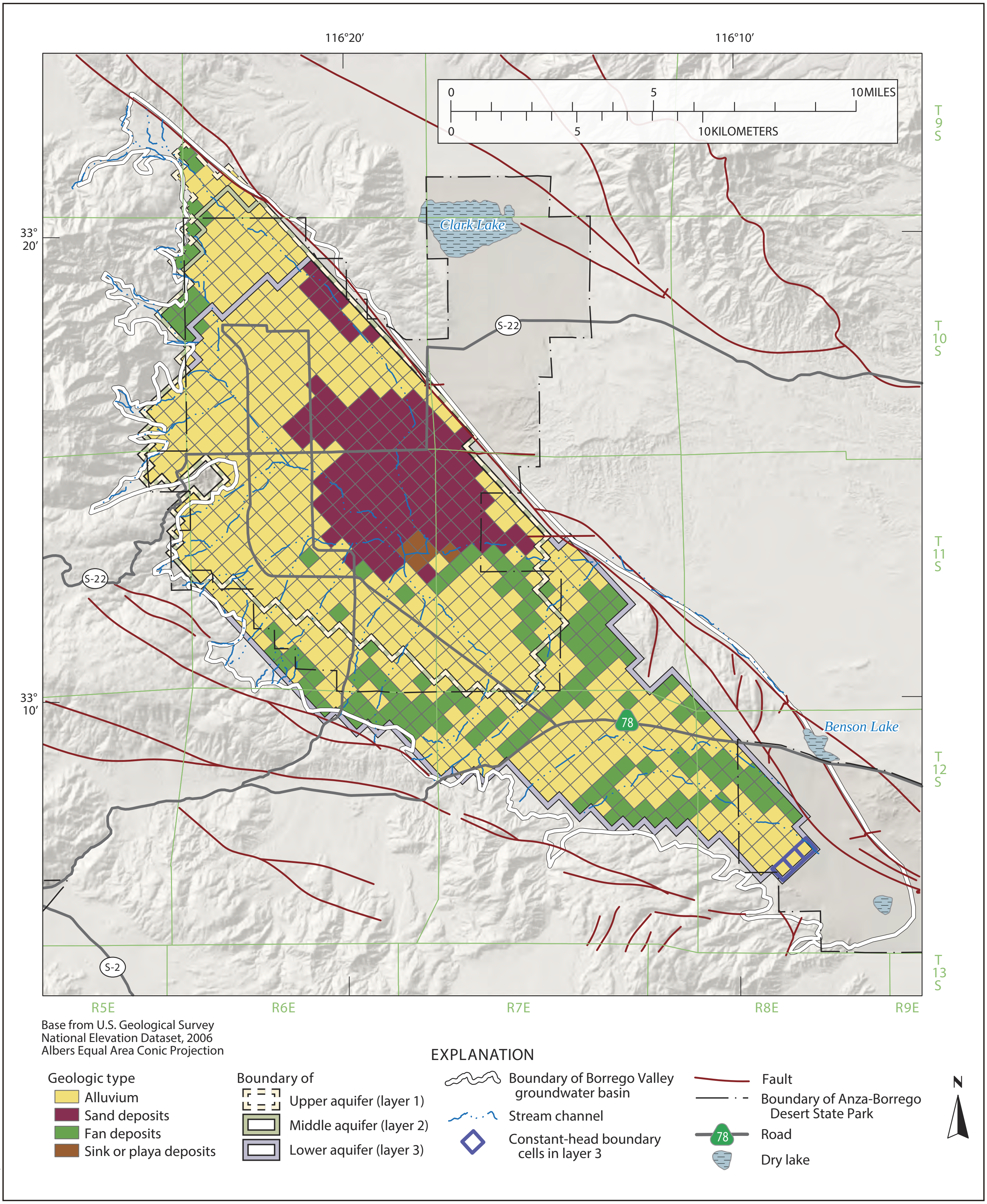
Figure 1

Model Domain for Borrego Valley Hydrologic Model

Update to United States Geologic Survey Borrego Valley Hydrologic Model

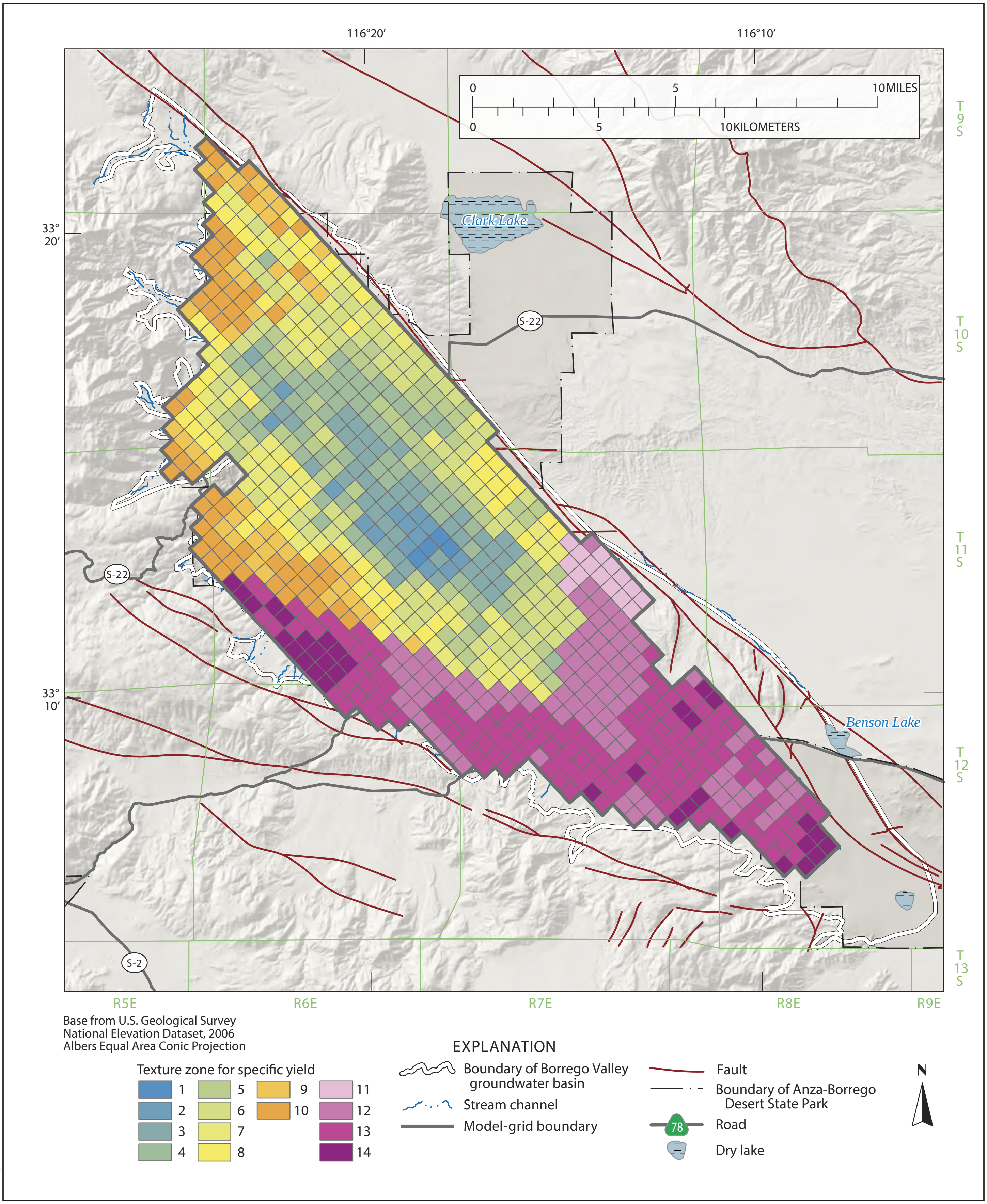


SOURCE: Faunt et al., 2015

FIGURE 2

Hydrogeologic Parameter Zones in Borrego Valley Hydrologic Model

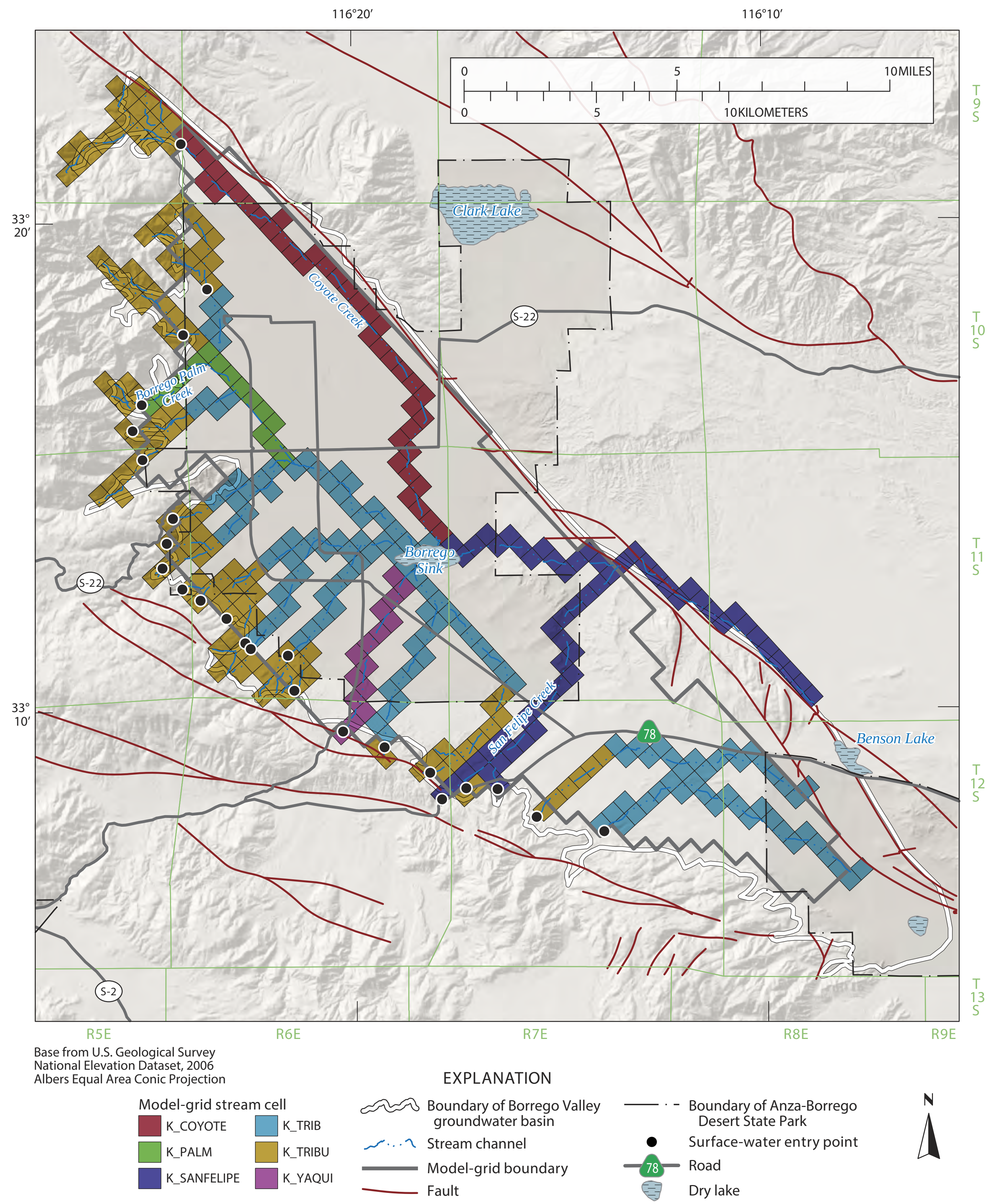
Update to United States Geologic Survey Borrego Valley Hydrologic Model



SOURCE: Faunt et al., 2015

FIGURE 3

Textural Map of Specific Yield in Borrego Valley Hydrologic Model



Model-grid stream cell explanation

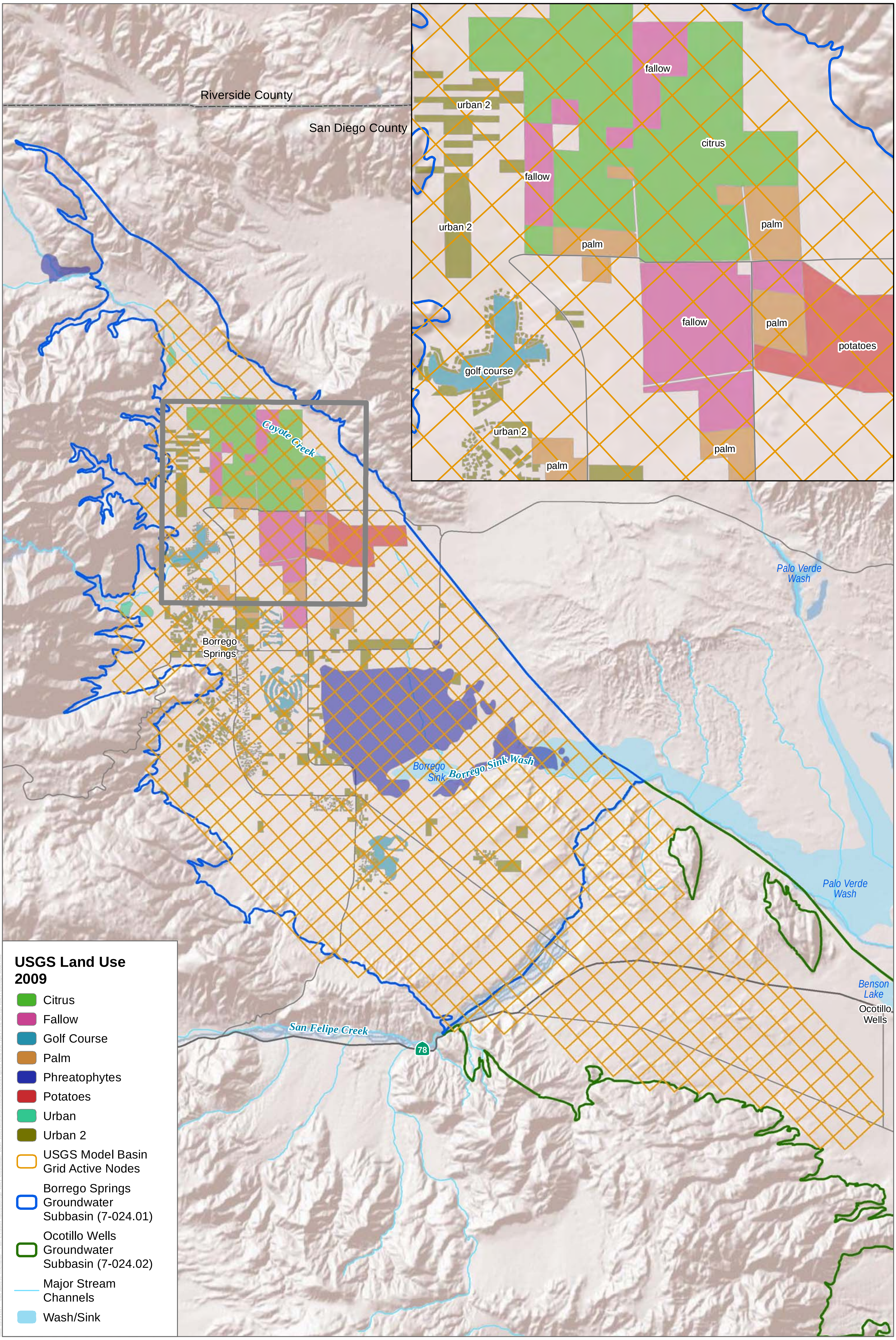
K, hydraulic conductivity; Kᵥ, vertical hydraulic conductivity; COYOTE, Coyote Creek; PALM, Borrego Palm Creek; SANFELIPE, San Felipe Creek; TRIB, unidentified tributary streams; TRIBU, upper portions of unidentified tributary streams; YAQUI, Yaqui Creek

SOURCE: Faunt et al., 2015

FIGURE 4

Simulated Stream Flow in Borrego Valley Hydrologic Model

Update to United States Geological Survey Borrego Valley Hydrologic Model



SOURCE: Faunt et al., 2015

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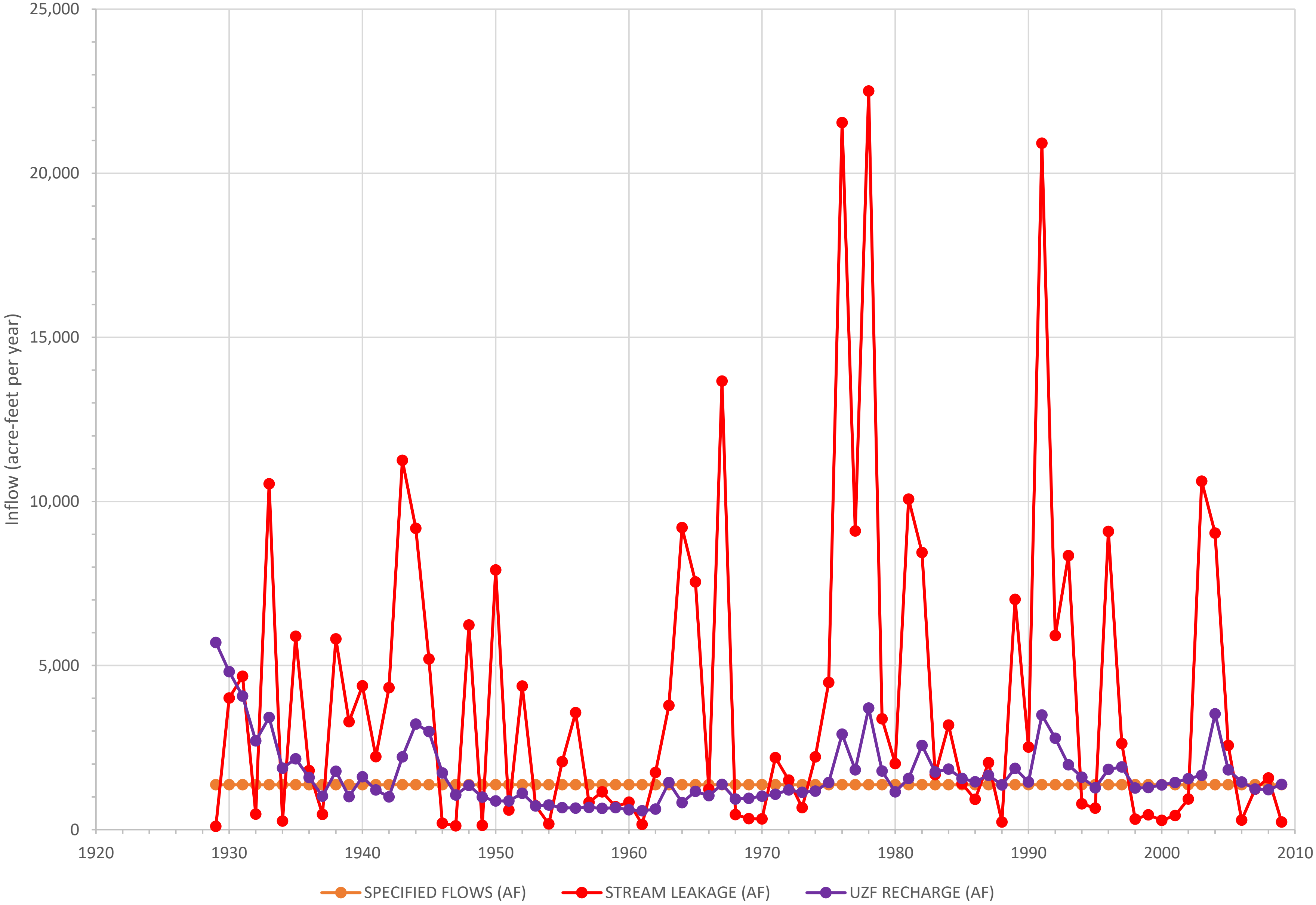
0 5,000 10,000
Feet

Figure 5

Land-Use Types in the Borrego Valley Hydrologic Model

Update to United States Geologic Survey Borrego Valley Hydrologic Model

Figure 6. Inflows to Borrego Valley Groundwater Basin



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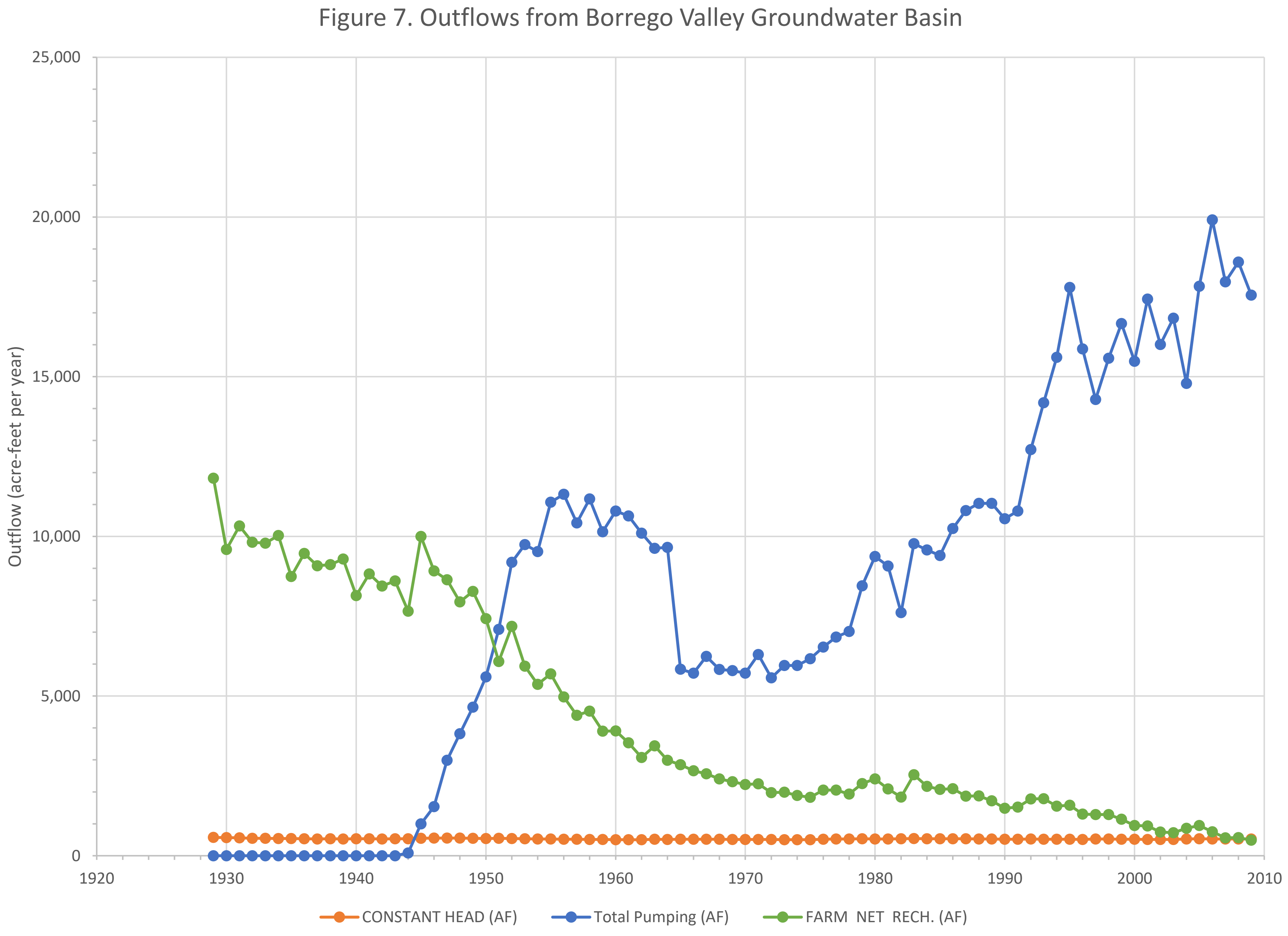

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Figure 8. Cumulative Change in Storage in Borrego Valley Groundwater Basin from 1945 to 2010

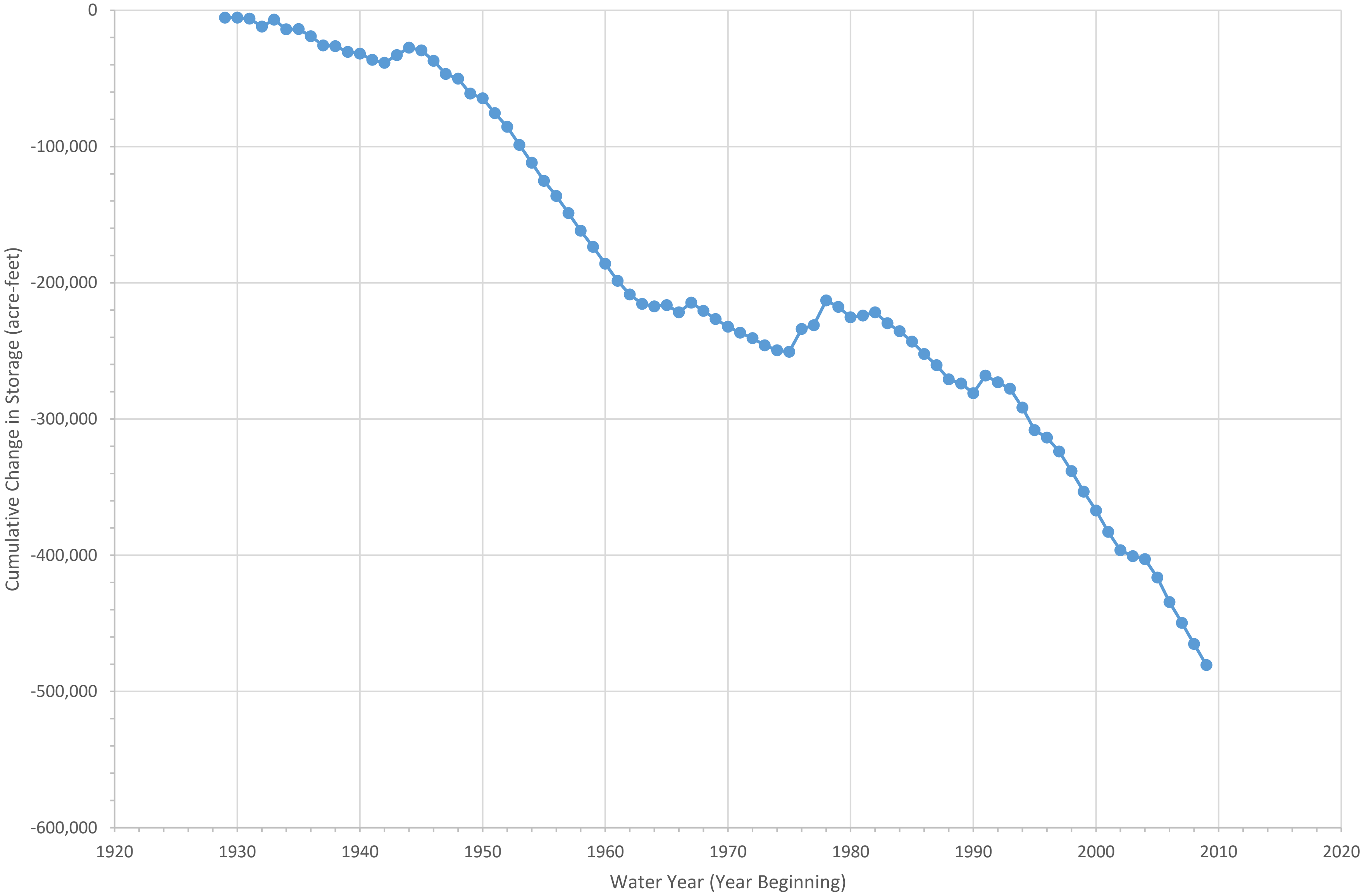

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Figure 9. Observed - Simulated Hydraulic Heads (Residuals) from 1945 to 2010

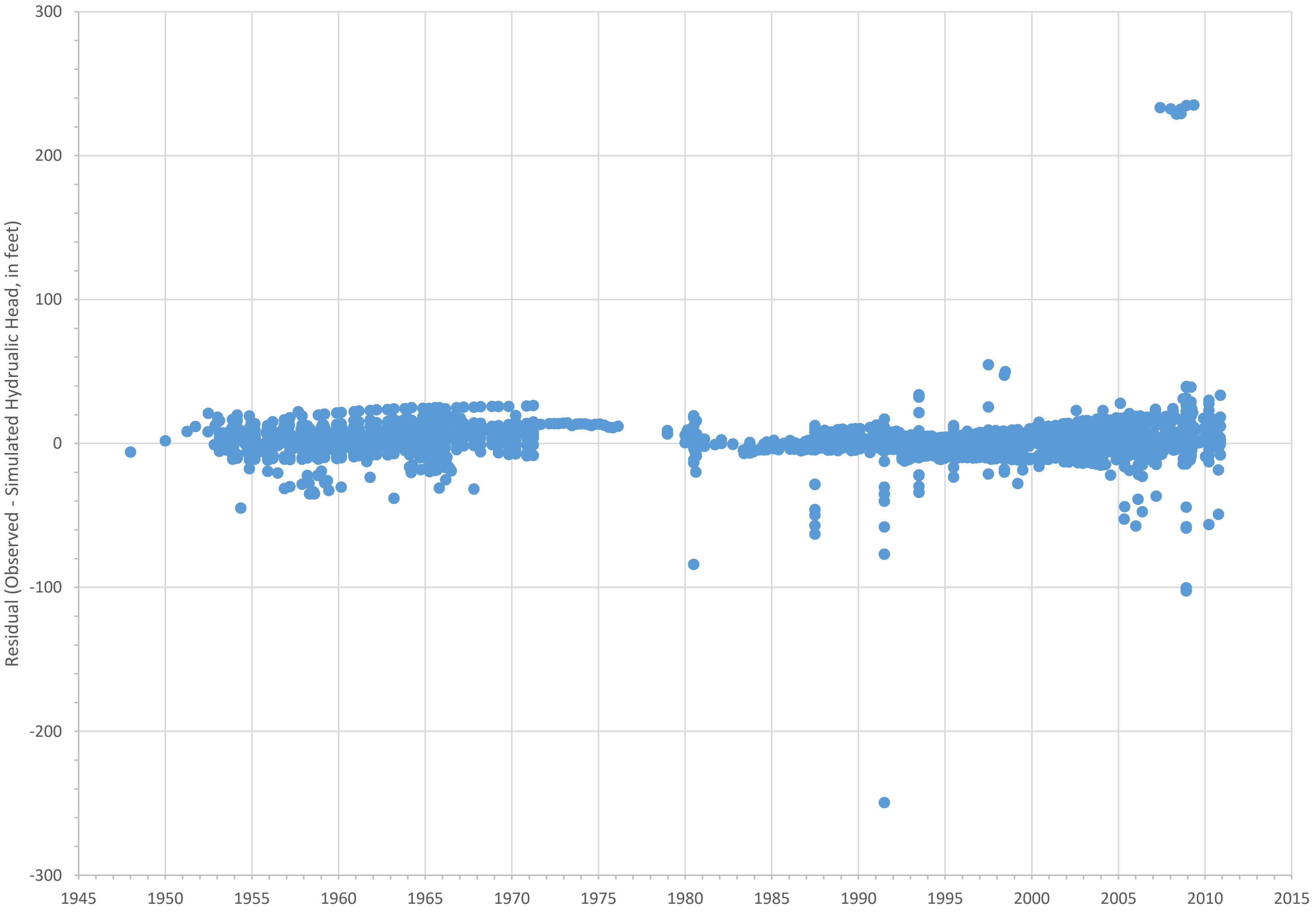

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Figure 10. Observed vs. Simulated Hydraulic Heads in the Borrego Valley Groundwater Basin from 1945 to 2010

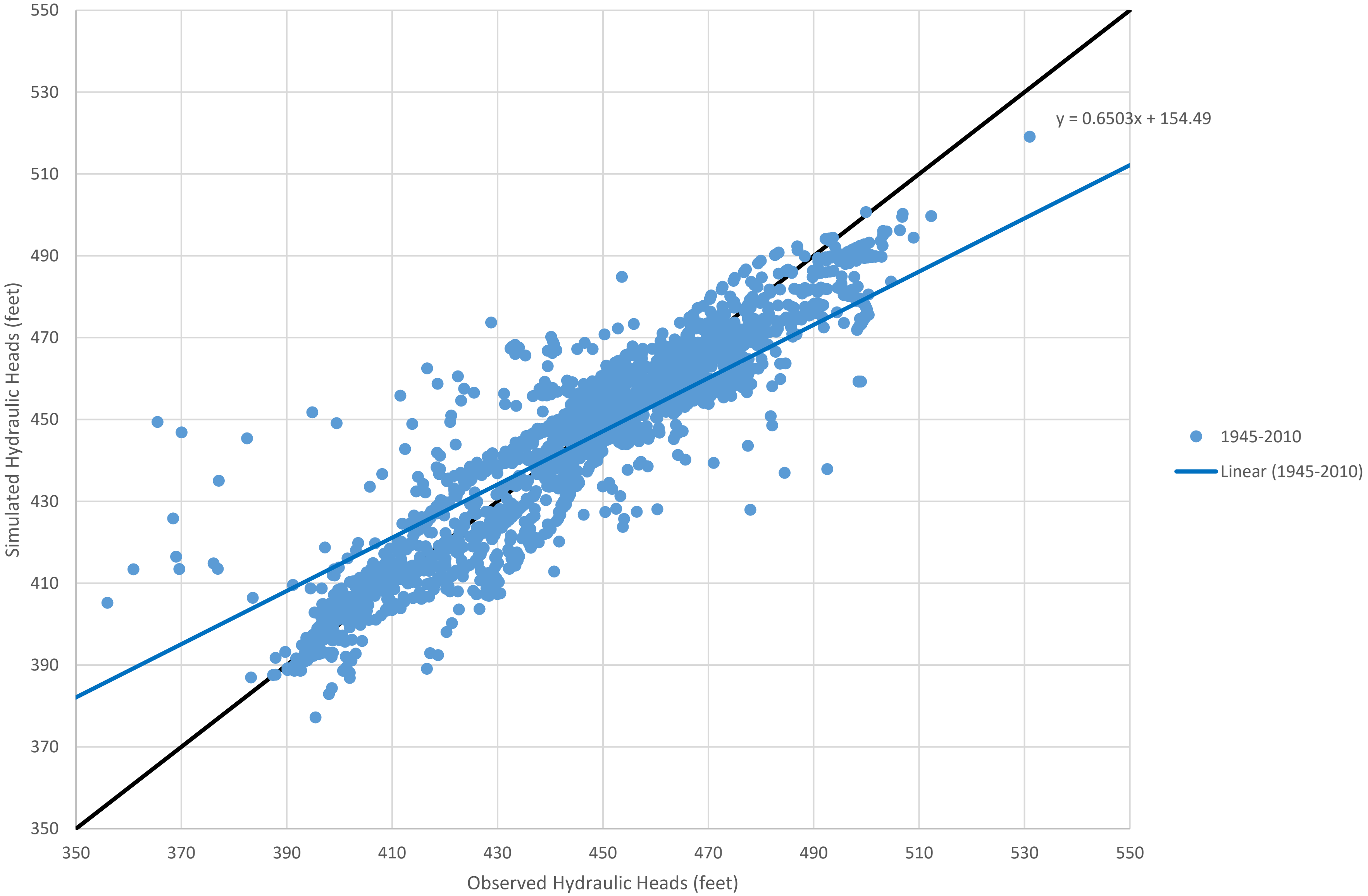

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Figure 11. Observed - Simulated Hydraulic Heads (Residuals) from 1945 to 2016

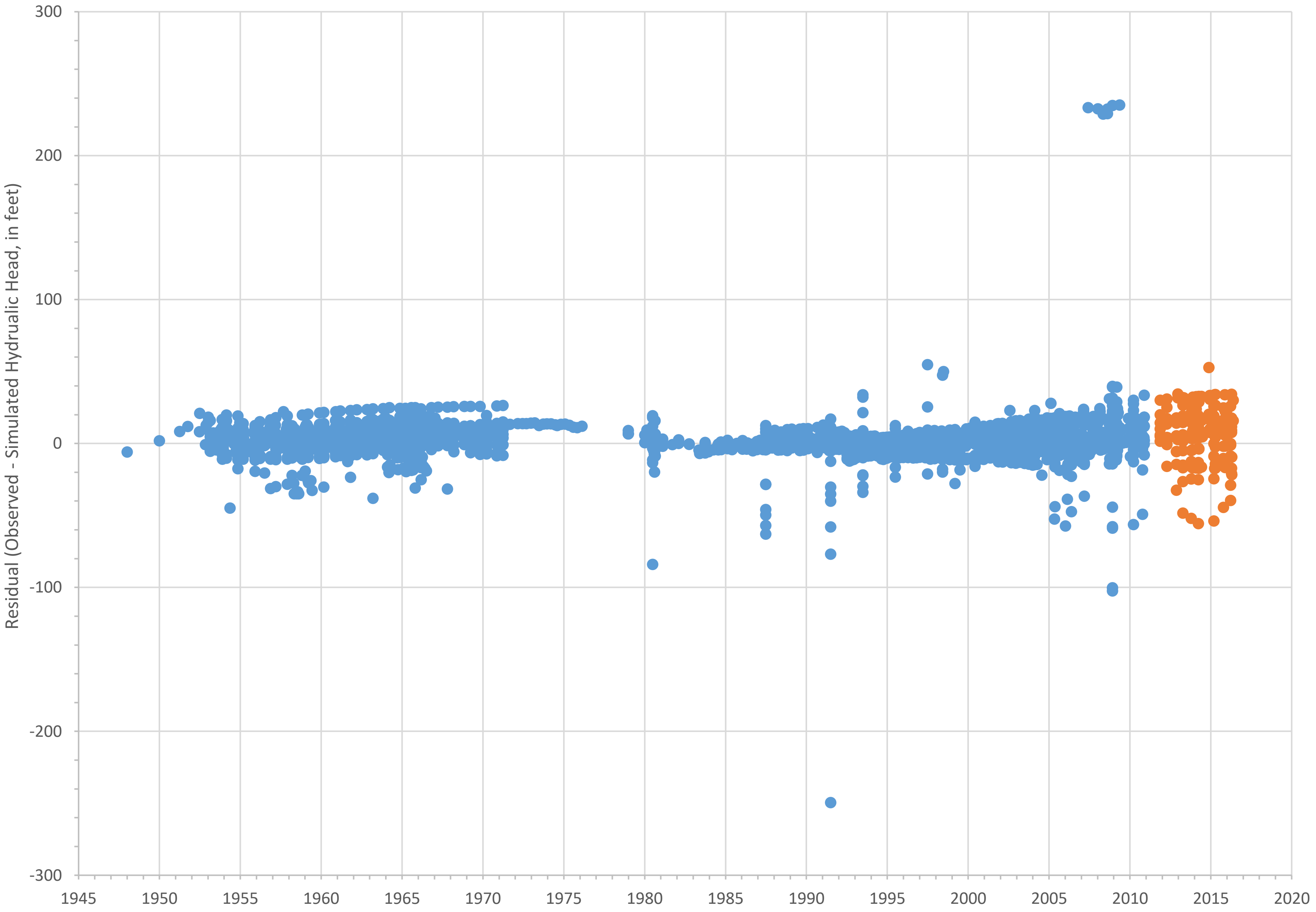

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Figure 12. Observed vs. Simulated Hydraulic Heads in the Borrego Valley Groundwater Basin from 1945 to 2016

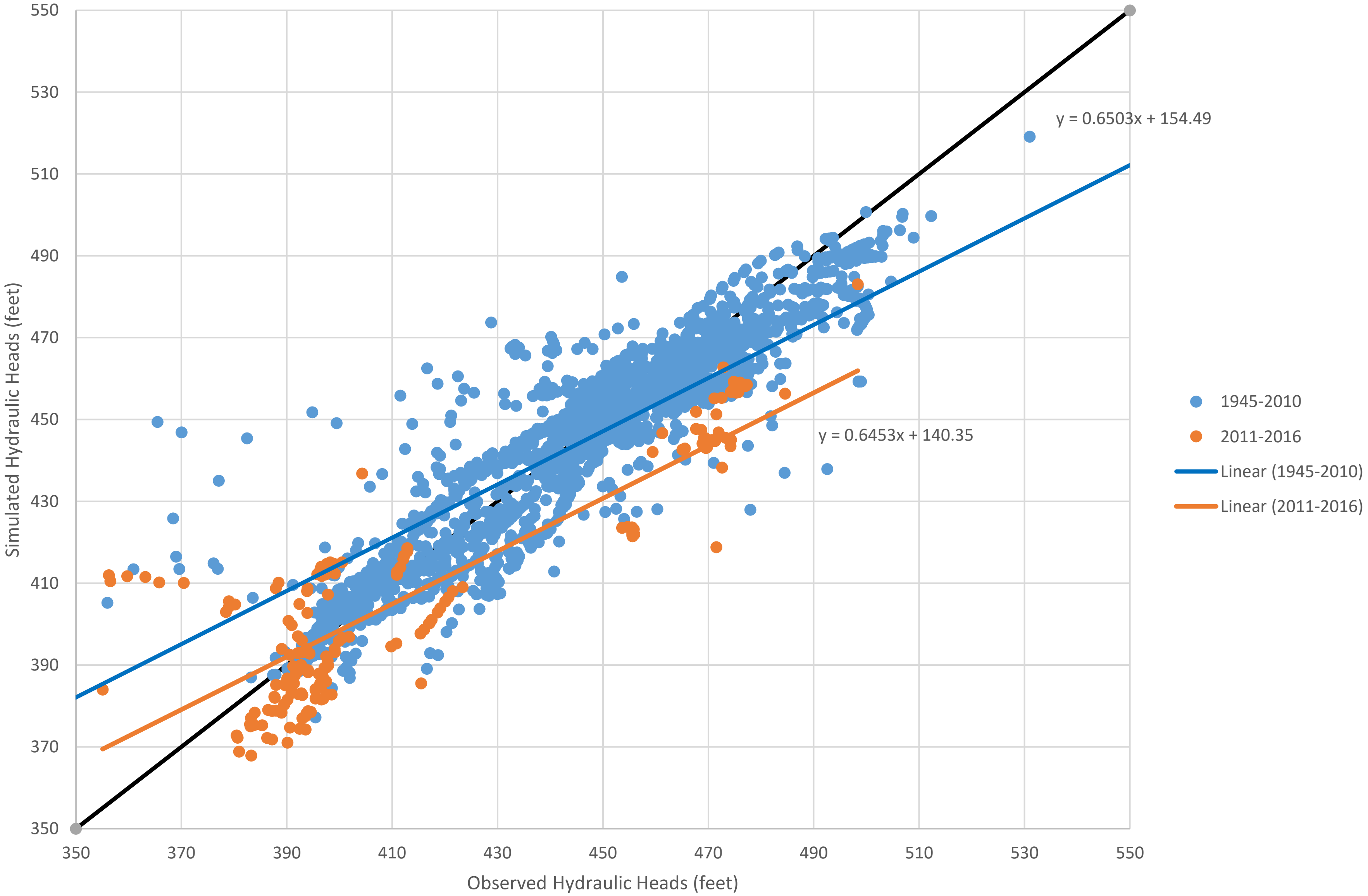

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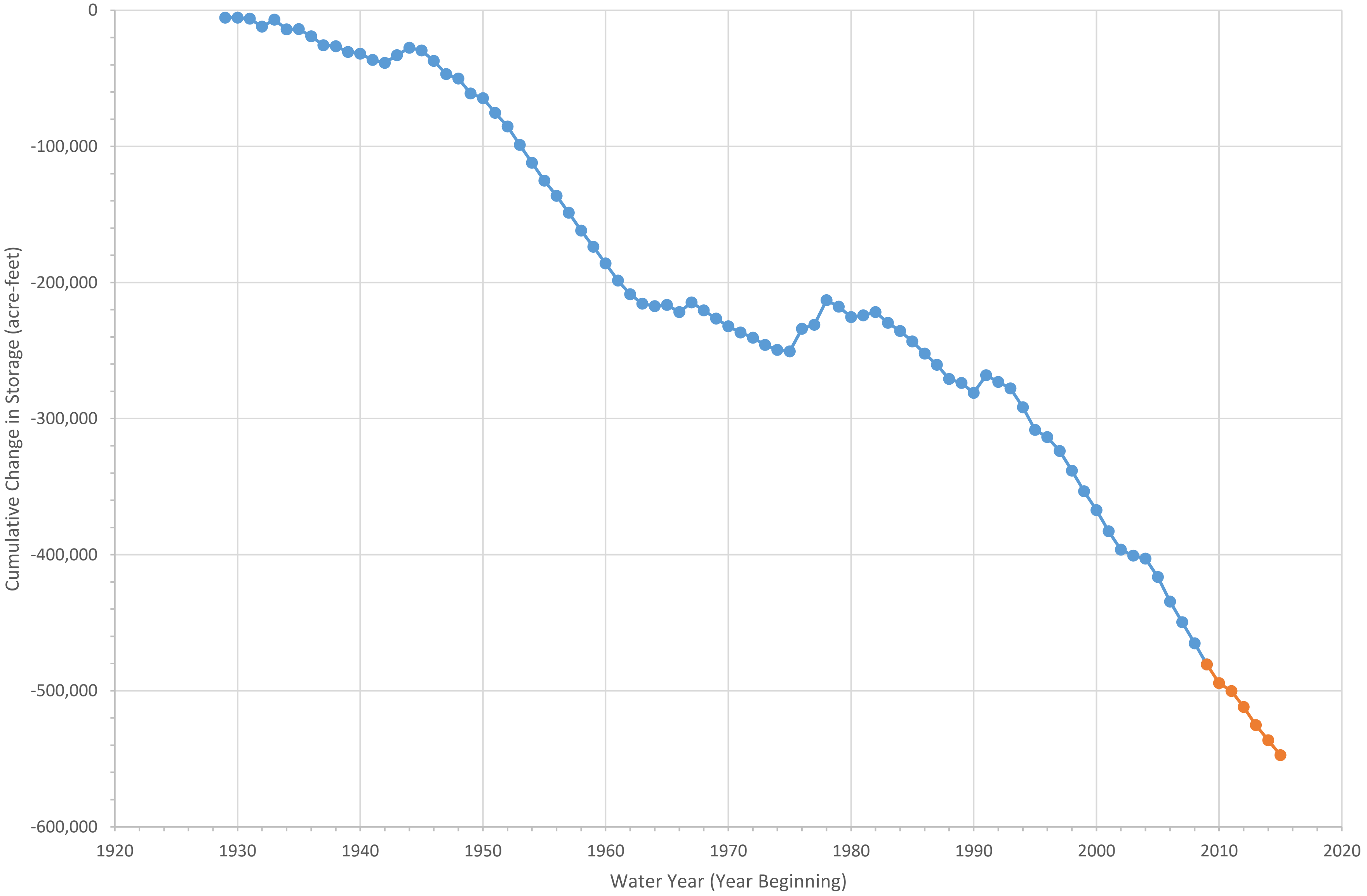
Figure 13. Cumulative Change in Storage in Borrego Valley Groundwater Basin from 1945 to 2016



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Appendix A. Annual Water Balance for Borrego Valley Hydrologic Model

Water Year Beginning	`							OUTFLOWS								Water Balance	Δ Storage
	STORAGE (AF)	SPECIFIED FLOWS (AF)	STREAM LEAKAGE (AF)	UZF RECHARGE (AF)	MNW2 (AF)	TOTAL IN (AFY)	Natural Recharge (AF)	STORAGE (AF)	CONSTANT HEAD (AF)	MNW2 (AF)	FARM WELLS (AF)	Total Pumping (AF)	FARM NET RECH. (AF)	Total Out (AF)	Discharge (AF)		
1929	11,164.65	1,366.27	97.40	5,702.64	0.00	18,330.95	7,166.30	5,730.49	573.29	0.00	0.00	0.00	11,822.97	18,126.75	12,396.26	-5,229.96	-5,434.16
1930	6,564.56	1,366.27	4,006.82	4,815.95	0.00	16,753.60	10,189.04	6,587.16	566.45	0.00	0.00	0.00	9,589.55	16,743.15	10,155.99	33.05	22.60
1931	7,727.41	1,370.01	4,671.00	4,069.45	0.00	17,837.87	10,110.46	6,963.86	559.46	0.00	0.00	0.00	10,325.88	17,849.20	10,885.34	-774.87	-763.55
1932	7,489.29	1,366.27	470.35	2,704.38	0.00	12,030.29	4,541.00	1,745.51	545.31	0.00	0.00	0.00	9,816.30	12,107.12	10,361.61	-5,820.61	-5,743.78
1933	8,391.33	1,366.27	10,540.11	3,422.88	0.00	23,720.59	15,329.26	13,392.66	544.34	0.00	0.00	0.00	9,789.97	23,726.97	10,334.31	4,994.95	5,001.33
1934	8,687.88	1,366.27	259.12	1,869.70	0.00	12,182.96	3,495.08	1,670.78	535.83	0.00	0.00	0.00	10,028.54	12,235.15	10,564.36	-7,069.28	-7,017.09
1935	7,055.88	1,370.01	5,893.96	2,154.58	0.00	16,474.44	9,418.56	7,207.68	537.00	0.00	0.00	0.00	8,739.95	16,484.63	9,276.95	141.61	151.80
1936	8,147.76	1,366.27	1,802.50	1,585.55	0.00	12,902.08	4,754.32	2,938.35	532.92	0.00	0.00	0.00	9,464.21	12,935.47	9,997.13	-5,242.81	-5,209.41
1937	8,229.59	1,366.27	466.59	1,019.48	0.00	11,081.93	2,852.33	1,523.34	526.04	0.00	0.00	0.00	9,078.35	11,127.72	9,604.38	-6,752.05	-6,706.25
1938	8,007.00	1,366.27	5,807.98	1,777.60	0.00	16,958.85	8,951.85	7,330.01	529.87	0.00	0.00	0.00	9,114.70	16,974.59	9,644.57	-692.73	-676.99
1939	8,323.85	1,370.01	3,291.39	1,002.93	0.00	13,988.19	5,664.34	4,200.11	526.55	0.00	0.00	0.00	9,292.28	14,018.95	9,818.84	-4,154.50	-4,123.74
1940	6,902.92	1,366.27	4,380.06	1,607.52	0.00	14,256.77	7,353.85	5,596.57	527.83	0.00	0.00	0.00	8,142.31	14,266.71	8,670.14	-1,316.29	-1,306.35
1941	7,727.33	1,366.27	2,222.73	1,206.88	0.00	12,523.21	4,795.88	3,191.10	529.21	0.00	0.00	0.00	8,821.64	12,541.96	9,350.85	-4,554.98	-4,536.23
1942	7,872.03	1,366.27	4,324.76	994.25	0.00	14,557.31	6,685.28	5,613.54	525.80	0.00	0.00	0.00	8,441.68	14,581.03	8,967.49	-2,282.21	-2,258.49
1943	8,781.49	1,370.01	11,249.22	2,215.77	0.00	23,616.49	14,835.00	14,475.99	532.46	0.00	0.00	0.00	8,608.10	23,616.55	9,140.56	5,694.44	5,694.50
1944	6,743.86	1,366.27	9,181.62	3,212.55	1.27	20,505.56	13,760.43	12,220.58	532.26	88.63	0.00	88.63	7,658.60	20,500.07	8,279.49	5,482.21	5,476.72
1945	10,236.99	1,366.27	5,201.31	2,988.91	1.71	19,795.20	9,556.49	8,252.91	549.24	996.16	0.00	996.16	9,998.39	19,796.71	11,543.80	-1,985.59	-1,984.08
1946	9,334.75	1,366.27	196.05	1,730.47	1.77	12,629.31	3,292.79	1,627.18	550.88	1,534.08	0.00	1,534.08	8,917.02	12,629.16	11,001.99	-7,707.43	-7,707.57
1947	10,922.73	1,370.01	112.19	1,059.47	0.93	13,465.33	2,541.68	1,287.80	550.77	2,770.43	215.03	2,985.45	8,642.13	13,466.16	12,178.36	-9,635.75	-9,634.93
1948	10,476.17	1,366.27	6,232.29	1,350.82	0.68	19,426.23	8,949.37	7,099.47	555.20	3,589.05	231.55	3,820.60	7,949.71	19,424.98	12,325.50	-3,375.45	-3,376.70
1949	12,127.20	1,366.27	126.71	989.46	0.64	14,610.27	2,482.44	1,141.28	546.61	4,425.95	223.31	4,649.26	8,274.42	14,611.58	13,470.29	-10,987.22	-10,985.91
1950	11,335.03	1,366.27	7,915.42	871.22	0.50	21,488.43	10,152.90	7,926.75	541.98	5,260.83	336.44	5,597.27	7,421.59	21,487.60	13,560.84	-3,407.44	-3,408.27
1951	13,059.68	1,370.01	594.36	876.51	0.80	15,901.37	2,840.89	2,189.66	542.09	6,596.19	493.44	7,089.63	6,079.95	15,901.33	13,711.67	-10,869.98	-10,870.02
1952	15,186.40	1,366.27	4,375.11	1,108.86	1.63	22,038.27	6,850.24	5,129.63	538.02	8,173.89	1,012.42	9,186.31	7,183.63	22,037.59	16,907.96	-10,056.09	-10,056.76
1953	14,817.73	1,366.27	724.52	718.10	3.68	17,630.29	2,808.89	1,419.82	530.85	8,633.96	1,109.13	9,743.09	5,937.38	17,631.14	16,211.32	-13,398.76	-13,397.90
1954	14,477.67	1,366.27	174.09	749.18	4.06	16,771.27	2,289.55	1,359.66	524.91	8,462.30	1,059.26	9,521.56	5,366.80	16,772.94	15,413.28	-13,119.68	-13,118.00
1955	15,506.87	1,370.01	2,067.48	669.49	2.76	19,616.61	4,106.98	2,335.93	520.56	9,896.81	1,173.85	11,070.66	5,692.14	19,619.28	17,283.36	-13,173.61	-13,170.94
1956	14,959.72	1,366.27	3,565.63	656.46	2.78	20,550.86	5,588.36	3,745.89	515.57	9,945.73	1,371.60	11,317.32	4,972.94	20,551.72	16,805.83	-11,214.69	-11,213.83
1957	14,065.91	1,366.27	828.34	676.13	2.99	16,939.64	2,870.74	1,605.74	512.90	8,979.94	1,443.77	10,423.71	4,397.77	16,940.12	15,334.38	-12,460.65	-12,460.18
1958	14,598.36	1,366.27	1,150.74	644.93	2.61	17,762.91	3,161.93	1,550.67	508.96	9,518.32	1,655.41	11,173.73	4,531.07	17,764.42	16,213.75	-13,049.21	-13,047.69
1959	13,640.41	1,370.01	695.95	669.55	2.77	16,378.69	2,735.51	1,829.93	509.20	8,642.83	1,501.45	10,144.28	3,903.23	16,386.64	14,556.71	-11,818.42	-11,810.47
1960	13,760.82	1,366.27	835.39	607.24	2.18	16,571.90	2,808.90	1,378.33	504.82	9,197.43	1,598.39	10,795.83	3,905.18	16,584.16	15,205.82	-12,394.74	-12,382.48
1961	13,546.30	1,366.27	162.71	572.10	2.19	15,649.57	2,101.08	970.00	501.92	9,071.85	1,568.97	10,640.82	3,538.32	15,651.06	14,681.06	-12,577.79	-12,576.30
1962	12,212.91	1,366.27	1,741.39	622.76	2.04	15,945.36	3,730.41	2,279.58	498.78	8,628.29	1,469.48	10,097.77	3,075.17	15,951.29	13,671.72	-9,939.27	-9,933.33
1963	12,227.76	1,370.01	3,785.26	1,438.11	3.15	18,824.29	6,593.38	5,239.41	515.77	8,152.32	1,471.47	9,623.79	3,444.70	18,823.67	13,584.26	-6,987.73	-6,988.35
1964	11,695.82	1,366.27	9,204.15	820.80	5.73	23,092.77	11,391.22	9,935.95	510.02	8,163.31	1,494.93	9,658.23	2,988.73	23,092.93	13,156.98	-1,760.04	-1,759.87
1965	8,827.72	1,366.27	7,548.36	1,165.22	7.21	18,914.78	10,079.85	9,702.20	516.95	4,400.06	1,441.40	5,841.46	2,852.77	18,913.38	9,211.18	875.88	874.48
1966	7,302.93	1,366.27	1,230.53	1,035.33	3.91	10,938.96	3,632.13	2,044.91	516.18	4,244.66	1,474.20	5,718.86	2,659.44	10,939.38	8,894.48	-5,258.44	-5,258.02
1967	8,257.79	1,370.01	13,665.71	1,378.84	9.31	24,681.67	16,414.57	15,356.16	515.97	4,860.43	1,380.11	6,240.54	2,566.51	24,679.18	9,323.02	7,100.86	7,098.37
1968	8,646.63	1,366.27	458.96	933.04	5.98	11,410.88	2,758.27	2,671.12	514.10	4,493.98	1,338.48	5,832.46	2,404.05	11,421.73	8,750.62	-5,986.37	-5,975.52
1969	6,974.17	1,366.27	337.26	951.13	4.10	9,632.93	2,654.66	1,014.47	512.40	4,193.85	1,602.89	5,796.74	2,318.17	9,641.78	8,627.31	-5,968.55	-5,959.70
1970	6,678.45	1,366.27	330.25	1,016.85	3.59	9,395.42	2,713.37	948.17	508.73	4,065.23	1,654.84	5,720.07	2,227.37	9,404.34	8,456.17	-5,739.21	-5,730.29
1971	6,932.95	1,370.01	2,192.97	1,076.44	3.21	11,575.57	4,639.41	2,519.07	509.38	4,578.80	1,720.91	6,299.70	2,250.31	11,578.45	9,059.38	-4,416.76	-4,413.88
1972	6,091.90	1,366.27	1,511.96	1,211.05	3.28	10,184.47	4,089.29	2,135.59	506.74	3,976.97	1,593.72	5,570.68	1,977.73	10,190.74	8,055.16	-3,962.59	-3,956.31
1973	6,402.21	1,366.27	670.80	1,139.95	4.02	9,583.24	3,177.01	1,145.68	504.91	4,317.47	1,641.45	5,958.92	1,987.13	9,596.64	8,450.96	-5,269.93	-5,256.54
1974	6,105.25	1,366.27	2,215.20	1,170.82	3.47	10,861.01	4,752.29	2,528.92	503.19	4,358.26	1,598.76	5,957.02	1,888.94	10,878.07	8,349.14	-3,593.38	-3,576.33
1975	6,430.62	1,370.01	4,482.20	1,432.99	4.53	13,720.35	7,285.19	5,220.02	505.38	4,678.19	1,488.74	6,166.93	1,828.76	13,721.09	8,501.07	-1,211.34	-1,210.61
1976	7,221.49	1,366.27	21,545.32	2,910.56	10.00	33,053.63	25,822.15	23,955.63	514.80	4,975.02	1,558.62	6,533.64	2,056.57	33,060.65	9,105.02	16,727.13	16,734.15
1977	8,608.59	1,366.27	9,100.41	1,822.69	10.69	20,908.65	12,289.36	11,482.01	522.51	5,287.61	1,562.36	6,849.97	2,051.80	20,906.29	9,424.28	2,875.78	2,873.42
1978	9,980.94	1,366.27	22,504.37	3,706.44	12.78	37,570.81	27,577.08	28,103.65	521.61	5,569.13	1,456.47	7,025.60	1,931.97	37,582.82	9,479.17	18,110.69	18,122.71
1979	11,578.46	1,370.01	3,372.44	1,784.84	10.35	18,116.10	6,527.29	6,864.35	528.64	6,728.95	1,720.93	8,449.88	2,260.29	18,103.16	11,238.81	-4,701.17	-4,714.11
1980	10,116.67	1,366.27	2,010.57	1,147.53	5.82	14,646.86	4,524.37	2,367.07	524.58	7,415.02	1,956.47	9,371.49	2,402.89	14,666.03	12,298.96	-7,768.78	-7,749.60
1981	8,678.39	1,366.27	10,070.52	1,555.96	6.25	21,677.39	12,992.75	9,994.00	521.12	7,238.96	1,834.55	9,073.51	2,095.53	21,684.16	11,690.16	1,308.84	1,315.61
1982	8,301.78	1,366.27	8,442.66	2,562.94	20.54	20,694.18	12,371.87	10,715.07	529.12	6,183.12	1,427.62	7,610.74	1,838.47	20,693.41	9,978.34	2,414.07	2,413.29
1983	10,566.72	1,370.01	1,678.92	1,755.96	19.09	15,390.69	4,804.88	2,547.39	538.13	7,815.70	1,954.79	9,770.48	2,540.05	15,396.06	12,848.67	-8,024.69	-8,019.32

Appendix A. Annual Water Balance for Borrego Valley Hydrologic Model

Water Year Beginning	`							OUTFLOWS								Water Balance	Δ Storage
	STORAGE (AF)	SPECIFIED FLOWS (AF)	STREAM LEAKAGE (AF)	UZF RECHARGE (AF)	MNW2 (AF)	TOTAL IN (AFY)	Natural Recharge (AF)	STORAGE (AF)	CONSTANT HEAD (AF)	MNW2 (AF)	FARM WELLS (AF)	Total Pumping (AF)	FARM NET RECH. (AF)	Total Out (AF)	Discharge (AF)		
1984	9,629.04	1,366.27	3,182.71	1,841.77	18.69	16,038.47	6,390.74	3,761.00	533.87	7,722.91	1,849.74	9,572.65	2,172.11	16,039.63	12,278.63	-5,869.20	-5,868.03
1985	9,910.09	1,366.27	1,402.37	1,559.51	20.46	14,258.70	4,328.15	2,251.65	533.98	7,588.52	1,810.21	9,398.73	2,074.40	14,258.76	12,007.11	-7,658.50	-7,658.44
1986	10,375.36	1,366.27	926.43	1,454.34	19.45	14,141.85	3,747.04	1,266.15	530.20	8,282.97	1,966.51	10,249.48	2,096.30	14,142.13	12,875.97	-9,109.48	-9,109.21
1987	10,934.85	1,370.01	2,038.69	1,654.10	22.53	16,020.18	5,062.80	2,820.28	531.26	8,983.53	1,822.15	10,805.67	1,863.77	16,020.97	13,200.70	-8,115.36	-8,114.57
1988	11,506.53	1,366.27	233.41	1,364.98	23.74	14,494.92	2,964.65	1,064.87	524.27	9,030.12	2,005.64	11,035.76	1,872.89	14,497.78	13,432.91	-10,444.52	-10,441.66
1989	10,826.51	1,366.27	7,016.01	1,868.39	24.50	21,101.68	10,250.67	7,827.69	521.45	9,069.61	1,965.15	11,034.76	1,721.44	21,105.34	13,277.65	-3,002.48	-2,998.81
1990	10,636.74	1,366.27	2,515.30	1,453.41	19.05	15,990.77	5,334.98	3,434.20	518.06	8,772.85	1,776.15	10,549.00	1,489.41	15,990.68	12,556.48	-7,202.45	-7,202.54
1991	11,707.80	1,370.01	20,913.16	3,494.77	36.82	37,522.57	25,777.94	24,694.41	513.90	9,018.37	1,778.19	10,796.56	1,520.21	37,525.08	12,830.67	12,984.10	12,986.60
1992	14,569.90	1,366.27	5,915.43	2,785.29	44.27	24,681.15	10,066.99	9,666.34	521.54	10,959.33	1,755.96	12,715.29	1,777.29	24,680.47	15,014.12	-4,902.87	-4,903.56
1993	12,610.91	1,366.27	8,347.66	1,978.52	29.77	24,333.13	11,692.44	7,845.73	517.77	12,333.54	1,847.84	14,181.38	1,788.13	24,333.00	16,487.28	-4,765.06	-4,765.18
1994	15,805.11	1,366.27	787.19	1,592.92	31.50	19,582.99	3,746.37	1,903.71	516.31	13,780.52	1,828.68	15,609.20	1,553.51	19,582.72	17,679.01	-13,901.14	-13,901.40
1995	17,536.31	1,370.01	656.24	1,277.18	30.93	20,870.67	3,303.42	973.73	515.34	15,772.36	2,022.79	17,795.15	1,581.69	20,865.91	19,892.18	-16,557.82	-16,562.58
1996	14,585.62	1,366.27	9,087.98	1,834.52	28.05	26,902.44	12,288.78	9,214.69	511.86	14,041.17	1,826.88	15,868.05	1,307.77	26,902.36	17,687.67	-5,370.85	-5,370.93
1997	14,384.23	1,366.27	2,625.43	1,909.47	36.17	20,321.56	5,901.16	4,221.20	523.49	12,565.50	1,718.59	14,284.08	1,292.65	20,321.42	16,100.23	-10,162.89	-10,163.03
1998	15,335.63	1,366.27	317.60	1,268.15	27.95	18,315.60	2,952.01	935.58	520.86	13,650.77	1,926.98	15,577.76	1,291.44	18,325.64	17,390.05	-14,410.09	-14,400.05
1999	16,190.26	1,370.01	450.22	1,280.74	34.00	19,325.23	3,100.97	1,014.02	519.23	14,507.72	2,155.29	16,663.01	1,146.80	19,343.05	18,329.04	-15,194.07	-15,176.24
2000	15,569.67	1,366.27	283.49	1,362.17	29.63	18,611.23	3,011.93	1,659.64	515.78	13,413.67	2,067.40	15,481.07	950.13	18,606.61	16,946.98	-13,905.41	-13,910.03
2001	16,905.68	1,366.27	428.29	1,434.40	33.98	20,168.62	3,228.96	1,292.43	512.82	15,108.61	2,320.53	17,429.14	934.45	20,168.84	18,876.41	-15,613.47	-15,613.25
2002	15,642.91	1,366.27	931.91	1,551.15	33.38	19,525.63	3,849.33	2,265.52	510.42	13,675.08	2,331.81	16,006.89	744.89	19,527.72	17,262.20	-13,379.49	-13,377.39
2003	15,308.80	1,370.01	10,614.50	1,655.06	35.78	28,984.15	13,639.57	10,928.22	509.89	14,373.88	2,454.67	16,828.55	719.22	28,985.88	18,057.66	-4,382.31	-4,380.58
2004	15,596.97	1,366.27	9,034.46	3,529.99	45.84	29,573.53	13,930.71	13,394.40	527.26	12,873.56	1,916.17	14,789.73	862.87	29,574.25	16,179.86	-2,203.30	-2,202.58
2005	16,951.16	1,366.27	2,563.05	1,820.33	34.10	22,734.91	5,749.64	3,423.90	529.56	15,473.65	2,359.42	17,833.08	946.16	22,732.70	19,308.81	-13,525.06	-13,527.26
2006	19,091.07	1,366.27	291.71	1,448.80	31.62	22,229.47	3,106.78	1,040.39	524.86	17,389.64	2,521.67	19,911.31	752.59	22,229.15	21,188.76	-18,050.35	-18,050.68
2007	17,754.85	1,370.01	1,228.89	1,239.57	35.87	21,629.19	3,838.48	2,579.28	522.74	15,650.88	2,316.60	17,967.48	562.38	21,631.88	19,052.60	-15,178.26	-15,175.57
2008	18,160.59	1,366.27	1,572.16	1,215.03	37.57	22,351.62	4,153.46	2,665.27	522.44	16,220.74	2,370.20	18,590.94	571.12	22,349.77	19,684.50	-15,493.47	-15,495.32
2009	17,393.45	1,366.27	234.31	1,378.10	35.75	20,407.88	2,978.68	1,868.07	520.48	15,179.83	2,377.39	17,557.21	487.48	20,433.23	18,565.17	-15,550.73	-15,525.38

MIN (1929 - 2009)	6,092	1,366	97	572	0	9,395	2,101	936	499	0	0		487	9,404	8,055	-18,050	-18,051
MAX (1929 - 2009)	19,091	1,370	22,504	5,703	46	37,571	27,577	28,104	573	17,390	2,522		11,823	37,583	21,189	18,111	18,123
AVG (1929 - 2009)	11,292	1,367	4,016	1,657	12	18,344	7,040	5,358	525	6,982	1,271		4,212	18,348	12,990	-5,937	-5,933
STDEV (1929 - 2009)	3,556	2	4,853	973	14	5,681	5,363	5,487	15	5,053	824		3,298	5,676	3,577	7,175	7,175

MIN (1944 - 2009)	6,092	1,366	112	572	1	9,395	2,101	936	499	89	0	89	487	9,404	8,055	-18,050	-18,051
MAX (1944 - 2009)	19,091	1,370	22,504	3,706	46	37,571	27,577	28,104	555	17,390	2,522	19,911	9,998	37,583	21,189	18,111	18,123
AVG (1944 - 2009)	12,024	1,367	4,028	1,486	15	18,919	6,881	5,240	522	8,569	1,560	10,128	3,032	18,922	13,682	-6,786	-6,783
STDEV (1944 - 2009)	3,518	2	5,142	737	14	5,884	5,673	5,811	13	4,198	614	4,672	2,361	5,883	3,597	7,490	7,489

Appendix B. Annual Water Budget from 1929 to 2016 for Borrego Valley Hydrologic Model

Water Year Beginning	INFLOWS							OUTFLOWS								Water Balance	Δ Storage
	STORAGE (AF)	SPECIFIED FLOWS (AF)	STREAM LEAKAGE (AF)	UZF RECHARGE (AF)	MNW2 (AF)	TOTAL IN (AFY)	Natural Recharge (AF)	STORAGE (AF)	CONSTANT HEAD (AF)	MNW2 (AF)	FARM WELLS (AF)	Total Pumping (AF)	FARM NET RECH. (AF)	Total Out (AF)	Discharge (AF)		
1929	11,164.65	1,366.27	97.40	5,702.64	0.00	18,330.95	7,166.30	5,730.49	573.29	0.00	0.00	0.00	11,822.97	18,126.75	12,396.26	-5,229.96	-5,434.16
1930	6,564.56	1,366.27	4,006.82	4,815.95	0.00	16,753.60	10,189.04	6,587.16	566.45	0.00	0.00	0.00	9,589.55	16,743.15	10,155.99	33.05	22.60
1931	7,727.41	1,370.01	4,671.00	4,069.45	0.00	17,837.87	10,110.46	6,963.86	559.46	0.00	0.00	0.00	10,325.88	17,849.20	10,885.34	-774.87	-763.55
1932	7,489.29	1,366.27	470.35	2,704.38	0.00	12,030.29	4,541.00	1,745.51	545.31	0.00	0.00	0.00	9,816.30	12,107.12	10,361.61	-5,820.61	-5,743.78
1933	8,391.33	1,366.27	10,540.11	3,422.88	0.00	23,720.59	15,329.26	13,392.66	544.34	0.00	0.00	0.00	9,789.97	23,726.97	10,334.31	4,994.95	5,001.33
1934	8,687.88	1,366.27	259.12	1,869.70	0.00	12,182.96	3,495.08	1,670.78	535.83	0.00	0.00	0.00	10,028.54	12,235.15	10,564.36	-7,069.28	-7,017.09
1935	7,055.88	1,370.01	5,893.96	2,154.58	0.00	16,474.44	9,418.56	7,207.68	537.00	0.00	0.00	0.00	8,739.95	16,484.63	9,276.95	141.61	151.80
1936	8,147.76	1,366.27	1,802.50	1,585.55	0.00	12,902.08	4,754.32	2,938.35	532.92	0.00	0.00	0.00	9,464.21	12,935.47	9,997.13	-5,242.81	-5,209.41
1937	8,229.59	1,366.27	466.59	1,019.48	0.00	11,081.93	2,852.33	1,523.34	526.04	0.00	0.00	0.00	9,078.35	11,127.72	9,604.38	-6,752.05	-6,706.25
1938	8,007.00	1,366.27	5,807.98	1,777.60	0.00	16,958.85	8,951.85	7,330.01	529.87	0.00	0.00	0.00	9,114.70	16,974.59	9,644.57	-692.73	-676.99
1939	8,323.85	1,370.01	3,291.39	1,002.93	0.00	13,988.19	5,664.34	4,200.11	526.55	0.00	0.00	0.00	9,292.28	14,018.95	9,818.84	-4,154.50	-4,123.74
1940	6,902.92	1,366.27	4,380.06	1,607.52	0.00	14,256.77	7,353.85	5,596.57	527.83	0.00	0.00	0.00	8,142.31	14,266.71	8,670.14	-1,316.29	-1,306.35
1941	7,727.33	1,366.27	2,222.73	1,206.88	0.00	12,523.21	4,795.88	3,191.10	529.21	0.00	0.00	0.00	8,821.64	12,541.96	9,350.85	-4,554.98	-4,536.23
1942	7,872.03	1,366.27	4,324.76	994.25	0.00	14,557.31	6,685.28	5,613.54	525.80	0.00	0.00	0.00	8,441.68	14,581.03	8,967.49	-2,282.21	-2,258.49
1943	8,781.49	1,370.01	11,249.22	2,215.77	0.00	23,616.49	14,835.00	14,475.99	532.46	0.00	0.00	0.00	8,608.10	23,616.55	9,140.56	5,694.44	5,694.50
1944	6,743.86	1,366.27	9,181.62	3,212.55	1.27	20,505.56	13,760.43	12,220.58	532.26	88.63	0.00	88.63	7,658.60	20,500.07	8,279.49	5,482.21	5,476.72
1945	10,236.99	1,366.27	5,201.31	2,988.91	1.71	19,795.20	9,556.49	8,252.91	549.24	996.16	0.00	996.16	9,998.39	19,796.71	11,543.80	-1,985.59	-1,984.08
1946	9,334.75	1,366.27	196.05	1,730.47	1.77	12,629.31	3,292.79	1,627.18	550.88	1,534.08	0.00	1,534.08	8,917.02	12,629.16	11,001.99	-7,707.43	-7,707.57
1947	10,922.73	1,370.01	112.19	1,059.47	0.93	13,465.33	2,541.68	1,287.80	550.77	2,770.43	215.03	2,985.45	8,642.13	13,466.16	12,178.36	-9,635.75	-9,634.93
1948	10,476.17	1,366.27	6,232.29	1,350.82	0.68	19,426.23	8,949.37	7,099.47	555.20	3,589.05	231.55	3,820.60	7,949.71	19,424.98	12,325.50	-3,375.45	-3,376.70
1949	12,127.20	1,366.27	126.71	989.46	0.64	14,610.27	2,482.44	1,141.28	546.61	4,425.95	223.31	4,649.26	8,274.42	14,611.58	13,470.29	-10,987.22	-10,985.91
1950	11,335.03	1,366.27	7,915.42	871.22	0.50	21,488.43	10,152.90	7,926.75	541.98	5,260.83	336.44	5,597.27	7,421.59	21,487.60	13,560.84	-3,407.44	-3,408.27
1951	13,059.68	1,370.01	594.36	876.51	0.80	15,901.37	2,840.89	2,189.66	542.09	6,596.19	493.44	7,089.63	6,079.95	15,901.33	13,711.67	-10,869.98	-10,870.02
1952	15,186.40	1,366.27	4,375.11	1,108.86	1.63	22,038.27	6,850.24	5,129.63	538.02	8,173.89	1,012.42	9,186.31	7,183.63	22,037.59	16,907.96	-10,056.09	-10,056.76
1953	14,817.73	1,366.27	724.52	718.10	3.68	17,630.29	2,808.89	1,419.82	530.85	8,633.96	1,109.13	9,743.09	5,937.38	17,631.14	16,211.32	-13,398.76	-13,397.90
1954	14,477.67	1,366.27	174.09	749.18	4.06	16,771.27	2,289.55	1,359.66	524.91	8,462.30	1,059.26	9,521.56	5,366.80	16,772.94	15,413.28	-13,119.68	-13,118.00
1955	15,506.87	1,370.01	2,067.48	669.49	2.76	19,616.61	4,106.98	2,335.93	520.56	9,896.81	1,173.85	11,070.66	5,692.14	19,619.28	17,283.36	-13,173.61	-13,170.94
1956	14,959.72	1,366.27	3,565.63	656.46	2.78	20,550.86	5,588.36	3,745.89	515.57	9,945.73	1,371.60	11,317.32	4,972.94	20,551.72	16,805.83	-11,214.69	-11,213.83
1957	14,065.91	1,366.27	828.34	676.13	2.99	16,939.64	2,870.74	1,605.74	512.90	8,979.94	1,443.77	10,423.71	4,397.77	16,940.12	15,334.38	-12,460.65	-12,460.18
1958	14,598.36	1,366.27	1,150.74	644.93	2.61	17,762.91	3,161.93	1,550.67	508.96	9,518.32	1,655.41	11,173.73	4,531.07	17,764.42	16,213.75	-13,049.21	-13,047.69
1959	13,640.41	1,370.01	695.95	669.55	2.77	16,378.69	2,735.51	1,829.93	509.20	8,642.83	1,501.45	10,144.28	3,903.23	16,386.64	14,556.71	-11,818.42	-11,810.47
1960	13,760.82	1,366.27	835.39	607.24	2.18	16,571.90	2,808.90	1,378.33	504.82	9,197.43	1,598.39	10,795.83	3,905.18	16,584.16	15,205.82	-12,394.74	-12,382.48
1961	13,546.30	1,366.27	162.71	572.10	2.19	15,649.57	2,101.08	970.00	501.92	9,071.85	1,568.97	10,640.82	3,538.32	15,651.06	14,681.06	-12,577.79	-12,576.30
1962	12,212.91	1,366.27	1,741.39	622.76	2.04	15,945.36	3,730.41	2,279.58	498.78	8,628.29	1,469.48	10,097.77	3,075.17	15,951.29	13,671.72	-9,939.27	-9,933.33
1963	12,227.76	1,370.01	3,785.26	1,438.11	3.15	18,824.29	6,593.38	5,239.41	515.77	8,152.32	1,471.47	9,623.79	3,444.70	18,823.67	13,584.26	-6,987.73	-6,988.35
1964	11,695.82	1,366.27	9,204.15	820.80	5.73	23,092.77	11,391.22	9,935.95	510.02	8,163.31	1,494.93	9,658.23	2,988.73	23,092.93	13,156.98	-1,760.04	-1,759.87
1965	8,827.72	1,366.27	7,548.36	1,165.22	7.21	18,914.78	10,079.85	9,702.20	516.95	4,400.06	1,441.40	5,841.46	2,852.77	18,913.38	9,211.18	875.88	874.48
1966	7,302.93	1,366.27	1,230.53	1,035.33	3.91	10,938.96	3,632.13	2,044.91	516.18	4,244.66	1,474.20	5,718.86	2,659.44	10,939.38	8,894.48	-5,258.44	-5,258.02
1967	8,257.79	1,370.01	13,665.71	1,378.84	9.31	24,681.67	16,414.57	15,356.16	515.97	4,860.43	1,380.11	6,240.54	2,566.51	24,679.18	9,323.02	7,100.86	7,098.37
1968	8,646.63	1,366.27	458.96	933.04	5.98	11,410.88	2,758.27	2,671.12	514.10	4,493.98	1,338.48	5,832.46	2,404.05	11,421.73	8,750.62	-5,986.37	-5,975.52
1969	6,974.17	1,366.27	337.26	951.13	4.10	9,632.93	2,654.66	1,014.47	512.40	4,193.85	1,602.89	5,796.74	2,318.17	9,641.78	8,627.31	-5,968.55	-5,959.70
1970	6,678.45	1,366.27	330.25	1,016.85	3.59	9,395.42	2,713.37	948.17	508.73	4,065.23	1,654.84	5,720.07	2,227.37	9,404.34	8,456.17	-5,739.21	-5,730.29
1971	6,932.95	1,370.01	2,192.97	1,076.44	3.21	11,575.57	4,639.41	2,519.07	509.38	4,578.80	1,720.91	6,299.70	2,250.31	11,578.45	9,059.38	-4,416.76	-4,413.88
1972	6,091.90	1,366.27	1,511.96	1,211.05	3.28	10,184.47	4,089.29	2,135.59	506.74	3,976.97	1,593.72	5,570.68	1,977.73	10,190.74	8,055.16	-3,962.59	-3,956.31
1973	6,402.21	1,366.27	670.80	1,139.95	4.02	9,583.24	3,177.01	1,145.68	504.91	4,317.47	1,641.45	5,958.92	1,987.13	9,596.64	8,450.96	-5,269.93	-5,256.54
1974	6,105.25	1,366.27	2,215.20	1,170.82	3.47	10,861.01	4,752.29	2,528.92	503.19	4,358.26	1,598.76	5,957.02	1,888.94	10,878.07	8,349.14	-3,593.38	-3,576.33
1975	6,430.62	1,370.01	4,482.20	1,432.99	4.53	13,720.35	7,285.19	5,220.02	505.38	4,678.19	1,488.74	6,166.93	1,828.76	13,721.09	8,501.07	-1,211.34	-1,210.61
1976	7,221.49	1,366.27	21,545.32	2,910.56	10.00	33,053.63	25,822.15	23,955.63	514.80	4,975.02	1,558.62	6,533.64	2,056.57	33,060.65	9,105.02	16,727.13	16,734.15
1977	8,608.59	1,366.27	9,100.41	1,822.69	10.69	20,908.65	12,289.36	11,482.01	522.51	5,287.61	1,562.36	6,849.97	2,051.80	20,906.29	9,424.28	2,875.78	2,873.42
1978	9,980.94	1,366.27	22,504.37	3,706.44	12.78	37,570.81	27,577.08	28,103.65	521.61	5,569.13	1,456.47	7,025.60	1,931.97	37,582.82	9,479.17	18,110.69	18,122.71
1979	11,578.46	1,370.01	3,372.44	1,784.84	10.35	18,116.10	6,527.29	6,864.35	528.64	6,728.95	1,720.93	8,449.88	2,260.29	18,103.16	11,238.81	-4,701.17	-4,714.11
1980	10,116.67	1,366.27	2,010.57	1,147.53	5.82	14,646.86	4,524.37	2,367.07	524.58	7,415.02	1,956.47	9,371.49	2,402.89	14,666.03	12,298.96	-7,768.78	-7,749.60
1981	8,678.39	1,366.27	10,070.52	1,555.96	6.25	21,677.39	12,992.75	9,994.00	521.12	7,238.96	1,834.55	9,073.51	2,095.53	21,684.16	11,690.16	1,308.84	1,315.61
1982	8,301.78	1,366.27	8,442.66	2,562.94	20.54	20,694.18	12,371.87	10,715.07	529.12	6,183.12	1,427.62	7,610.74	1,838.47	20,693.41	9,978.34	2,414.07	2,413.29
1983	10,566.72	1,370.01	1,678.92	1,755.96	19.09	15,390.69	4,804.88	2,547.39	538.13	7,815.70	1,954.79	9,770.48	2,540.05	15,396.06	12,848.67	-8,024.69	-8,019.32

Appendix B. Annual Water Budget from 1929 to 2016 for Borrego Valley Hydrologic Model

Water Year Beginning	INFLOWS							OUTFLOWS								Water Balance	Δ Storage
	STORAGE (AF)	SPECIFIED FLOWS (AF)	STREAM LEAKAGE (AF)	UZF RECHARGE (AF)	MNW2 (AF)	TOTAL IN (AFY)	Natural Recharge (AF)	STORAGE (AF)	CONSTANT HEAD (AF)	MNW2 (AF)	FARM WELLS (AF)	Total Pumping (AF)	FARM NET RECH. (AF)	Total Out (AF)	Discharge (AF)		
1984	9,629.04	1,366.27	3,182.71	1,841.77	18.69	16,038.47	6,390.74	3,761.00	533.87	7,722.91	1,849.74	9,572.65	2,172.11	16,039.63	12,278.63	-5,869.20	-5,868.03
1985	9,910.09	1,366.27	1,402.37	1,559.51	20.46	14,258.70	4,328.15	2,251.65	533.98	7,588.52	1,810.21	9,398.73	2,074.40	14,258.76	12,007.11	-7,658.50	-7,658.44
1986	10,375.36	1,366.27	926.43	1,454.34	19.45	14,141.85	3,747.04	1,266.15	530.20	8,282.97	1,966.51	10,249.48	2,096.30	14,142.13	12,875.97	-9,109.48	-9,109.21
1987	10,934.85	1,370.01	2,038.69	1,654.10	22.53	16,020.18	5,062.80	2,820.28	531.26	8,983.53	1,822.15	10,805.67	1,863.77	16,020.97	13,200.70	-8,115.36	-8,114.57
1988	11,506.53	1,366.27	233.41	1,364.98	23.74	14,494.92	2,964.65	1,064.87	524.27	9,030.12	2,005.64	11,035.76	1,872.89	14,497.78	13,432.91	-10,444.52	-10,441.66
1989	10,826.51	1,366.27	7,016.01	1,868.39	24.50	21,101.68	10,250.67	7,827.69	521.45	9,069.61	1,965.15	11,034.76	1,721.44	21,105.34	13,277.65	-3,002.48	-2,998.81
1990	10,636.74	1,366.27	2,515.30	1,453.41	19.05	15,990.77	5,334.98	3,434.20	518.06	8,772.85	1,776.15	10,549.00	1,489.41	15,990.68	12,556.48	-7,202.45	-7,202.54
1991	11,707.80	1,370.01	20,913.16	3,494.77	36.82	37,522.57	25,777.94	24,694.41	513.90	9,018.37	1,778.19	10,796.56	1,520.21	37,525.08	12,830.67	12,984.10	12,986.60
1992	14,569.90	1,366.27	5,915.43	2,785.29	44.27	24,681.15	10,066.99	9,666.34	521.54	10,959.33	1,755.96	12,715.29	1,777.29	24,680.47	15,014.12	-4,902.87	-4,903.56
1993	12,610.91	1,366.27	8,347.66	1,978.52	29.77	24,333.13	11,692.44	7,845.73	517.77	12,333.54	1,847.84	14,181.38	1,788.13	24,333.00	16,487.28	-4,765.06	-4,765.18
1994	15,805.11	1,366.27	787.19	1,592.92	31.50	19,582.99	3,746.37	1,903.71	516.31	13,780.52	1,828.68	15,609.20	1,553.51	19,582.72	17,679.01	-13,901.14	-13,901.40
1995	17,536.31	1,370.01	656.24	1,277.18	30.93	20,870.67	3,303.42	973.73	515.34	15,772.36	2,022.79	17,795.15	1,581.69	20,865.91	19,892.18	-16,557.82	-16,562.58
1996	14,585.62	1,366.27	9,087.98	1,834.52	28.05	26,902.44	12,288.78	9,214.69	511.86	14,041.17	1,826.88	15,868.05	1,307.77	26,902.36	17,687.67	-5,370.85	-5,370.93
1997	14,384.23	1,366.27	2,625.43	1,909.47	36.17	20,321.56	5,901.16	4,221.20	523.49	12,565.50	1,718.59	14,284.08	1,292.65	20,321.42	16,100.23	-10,162.89	-10,163.03
1998	15,335.63	1,366.27	317.60	1,268.15	27.95	18,315.60	2,952.01	935.58	520.86	13,650.77	1,926.98	15,577.76	1,291.44	18,325.64	17,390.05	-14,410.09	-14,400.05
1999	16,190.26	1,370.01	450.22	1,280.74	34.00	19,325.23	3,100.97	1,014.02	519.23	14,507.72	2,155.29	16,663.01	1,146.80	19,343.05	18,329.04	-15,194.07	-15,176.24
2000	15,569.67	1,366.27	283.49	1,362.17	29.63	18,611.23	3,011.93	1,659.64	515.78	13,413.67	2,067.40	15,481.07	950.13	18,606.61	16,946.98	-13,905.41	-13,910.03
2001	16,905.68	1,366.27	428.29	1,434.40	33.98	20,168.62	3,228.96	1,292.43	512.82	15,108.61	2,320.53	17,429.14	934.45	20,168.84	18,876.41	-15,613.47	-15,613.25
2002	15,642.91	1,366.27	931.91	1,551.15	33.38	19,525.63	3,849.33	2,265.52	510.42	13,675.08	2,331.81	16,006.89	744.89	19,527.72	17,262.20	-13,379.49	-13,377.39
2003	15,308.80	1,370.01	10,614.50	1,655.06	35.78	28,984.15	13,639.57	10,928.22	509.89	14,373.88	2,454.67	16,828.55	719.22	28,985.88	18,057.66	-4,382.31	-4,380.58
2004	15,596.97	1,366.27	9,034.46	3,529.99	45.84	29,573.53	13,930.71	13,394.40	527.26	12,873.56	1,916.17	14,789.73	862.87	29,574.25	16,179.86	-2,203.30	-2,202.58
2005	16,951.16	1,366.27	2,563.05	1,820.33	34.10	22,734.91	5,749.64	3,423.90	529.56	15,473.65	2,359.42	17,833.08	946.16	22,732.70	19,308.81	-13,525.06	-13,527.26
2006	19,091.07	1,366.27	291.71	1,448.80	31.62	22,229.47	3,106.78	1,040.39	524.86	17,389.64	2,521.67	19,911.31	752.59	22,229.15	21,188.76	-18,050.35	-18,050.68
2007	17,754.85	1,370.01	1,228.89	1,239.57	35.87	21,629.19	3,838.48	2,579.28	522.74	15,650.88	2,316.60	17,967.48	562.38	21,631.88	19,052.60	-15,178.26	-15,175.57
2008	18,160.59	1,366.27	1,572.16	1,215.03	37.57	22,351.62	4,153.46	2,665.27	522.44	16,220.74	2,370.20	18,590.94	571.12	22,349.77	19,684.50	-15,493.47	-15,495.32
2009	17,393.45	1,366.27	234.31	1,378.10	35.75	20,407.88	2,978.68	1,868.07	520.48	15,179.83	2,377.39	17,557.21	487.48	20,433.23	18,565.17	-15,550.73	-15,525.38
2010	16,130.33	1,366.27	1,181.97	1,302.35	34.87	20,015.79	3,850.58	2,417.32	516.93	14,400.91	2,294.19	16,695.10	424.42	20,053.78	17,636.46	-13,751.00	-13,713.01
2011	13,210.35	1,370.01	6,492.76	1,919.11	35.17	23,027.41	9,781.88	7,214.16	528.96	12,638.51	2,126.67	14,765.18	494.37	23,002.67	15,788.51	-5,971.46	-5,996.20
2012	14,318.19	1,366.27	1,947.54	1,801.13	29.37	19,462.48	5,114.93	2,682.44	524.77	13,544.96	2,246.37	15,791.33	488.45	19,486.99	16,804.55	-11,660.26	-11,635.75
2013	14,970.90	1,366.27	1,617.06	1,542.79	29.50	19,526.52	4,526.12	1,596.00	522.11	14,584.80	2,380.29	16,965.08	464.46	19,547.65	17,951.66	-13,396.04	-13,374.90
2014	13,948.97	1,366.27	2,312.90	1,594.99	35.10	19,258.23	5,274.16	2,819.32	520.15	13,388.54	2,166.69	15,555.23	364.41	19,259.11	16,439.79	-11,130.52	-11,129.64
2015	14,067.64	1,370.01	1,768.14	1,603.61	29.27	18,838.67	4,741.76	3,184.87	522.85	12,634.53	2,124.42	14,758.95	373.53	18,840.20	15,655.32	-10,884.29	-10,882.77

MIN (2010 - 2015)	13,210	1,366	1,182	1,302	29	18,839	3,851	1,596	517	12,635	2,124	14,759	364	18,840	15,655	-11,760.44	-11,614.36
MAX (2010 - 2015)	16,130	1,370	6,493	1,919	35	23,027	9,782	7,214	529	14,585	2,380	16,965	494	23,003	17,952	-8,171.36	-8,916.18
AVG (2010 - 2015)	14,441	1,368	2,553	1,627	32	20,022	5,548	3,319	523	13,532	2,223	15,755	435	20,032	16,713	-11,132.26	-11,122.05
STDEV (2010 - 2015)	1,005	2	1,966	214	3	1,521	2,134	1,981	4	835	102	934	57	1,508	943	1,186.39	976.70

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
7/21/1965	145.59	144.07	-1.52	5E25R010008
7/21/1965	145.04	144.02	-1.02	5E36A010009
4/27/1987	142.49	142.86	0.37	5E36A010010
7/27/1987	142.26	142.77	0.51	5E36A010011
11/19/1987	142.00	142.37	0.37	5E36A010012
1/20/1988	141.90	142.22	0.32	5E36A010013
4/1/1988	141.77	142.04	0.27	5E36A010014
6/8/1988	141.63	141.92	0.29	5E36A010015
10/25/1988	141.24	141.55	0.31	5E36A010016
8/8/1989	140.61	140.82	0.21	5E36A010017
10/26/1989	140.42	140.64	0.21	5E36A010018
2/6/1990	140.21	140.82	0.61	5E36A010019
9/1/1990	141.06	139.75	-1.31	5E36A010020
1/14/1991	140.66	140.27	-0.39	5E36A010021
2/19/1991	140.52	140.27	-0.25	5E36A010022
3/5/1991	140.48	140.27	-0.21	5E36A010023
3/19/1991	140.43	140.24	-0.19	5E36A010024
4/11/1991	140.37	140.24	-0.13	5E36A010025
5/9/1991	140.29	139.48	-0.81	5E36A010026
5/30/1991	140.24	139.51	-0.73	5E36A010027
7/23/1991	140.69	139.36	-1.34	5E36A010028
1/7/1992	140.52	139.26	-1.26	5E36A010029
3/12/1992	140.29	139.33	-0.97	5E36A010030
5/12/1992	140.37	139.11	-1.26	5E36A010031
7/7/1992	142.37	139.02	-3.35	5E36A010032
9/2/1992	142.62	138.87	-3.75	5E36A010033
10/13/1992	142.39	138.87	-3.53	5E36A010034
12/8/1992	142.06	138.69	-3.37	5E36A010035
1/12/1993	141.94	138.93	-3.01	5E36A010036
2/3/1993	142.03	139.02	-3.01	5E36A010037
2/12/1993	142.04	139.08	-2.96	5E36A010038
2/24/1993	142.03	139.17	-2.85	5E36A010039
3/11/1993	141.98	139.26	-2.71	5E36A010040
3/27/1993	141.91	139.39	-2.52	5E36A010041
4/16/1993	141.83	139.36	-2.47	5E36A010042
5/11/1993	141.72	139.42	-2.30	5E36A010043
7/2/1993	141.49	139.30	-2.19	5E36A010044
8/19/1993	141.28	139.23	-2.05	5E36A010045
10/20/1993	141.03	139.08	-1.95	5E36A010046
12/24/1993	140.79	139.08	-1.71	5E36A010047
2/11/1994	140.63	139.02	-1.61	5E36A010048
3/25/1994	140.51	139.26	-1.25	5E36A010049
5/25/1994	140.94	139.36	-1.58	5E36A010050
8/24/1994	142.13	138.84	-3.29	5E36A010051
10/6/1994	142.01	138.66	-3.35	5E36A010052
12/21/1994	141.57	138.44	-3.13	5E36A010053
2/24/1995	141.24	138.38	-2.86	5E36A010054
4/4/1995	141.07	138.56	-2.51	5E36A010055

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/21/1995	140.75	138.53	-2.21	5E36A010056
10/2/1995	140.31	138.20	-2.11	5E36A010057
12/28/1995	139.95	137.86	-2.09	5E36A010058
4/11/1996	139.59	137.53	-2.06	5E36A010059
8/9/1996	139.17	137.16	-2.01	5E36A010060
10/23/1996	138.88	136.67	-2.20	5E36A010061
1/3/1997	138.60	136.67	-1.93	5E36A010062
9/3/1997	139.12	135.79	-3.33	5E36A010063
12/3/1997	138.88	135.64	-3.24	5E36A010064
5/13/1998	138.27	135.30	-2.97	5E36A010065
11/12/1998	137.60	135.09	-2.51	5E36A010066
3/12/1999	137.20	135.09	-2.11	5E36A010067
5/17/1999	137.02	134.24	-2.78	5E36A010068
11/22/1999	136.48	133.38	-3.10	5E36A010069
3/24/2000	136.15	133.14	-3.01	5E36A010070
6/29/2000	135.92	132.71	-3.21	5E36A010071
12/18/2000	135.45	132.10	-3.35	5E36A010072
11/14/2001	134.65	130.76	-3.89	5E36A010073
2/22/2002	134.40	130.49	-3.91	5E36A010074
8/30/2002	133.95	129.88	-4.07	5E36A010075
12/13/2002	133.66	129.48	-4.18	5E36A010076
3/17/2003	133.42	129.45	-3.97	5E36A010077
6/30/2003	133.18	128.93	-4.25	5E36A010078
10/6/2003	132.96	128.57	-4.40	5E36A010079
12/29/2003	132.76	128.20	-4.56	5E36A010080
2/12/2004	132.65	128.17	-4.48	5E36A010081
4/8/2004	132.55	128.14	-4.41	5E36A010082
7/23/2004	134.47	127.74	-6.73	5E36A010083
8/23/2005	133.46	127.74	-5.72	5E36A010084
1/5/2006	133.09	127.68	-5.41	5E36A010085
6/14/2006	132.60	129.11	-3.49	5E36A010086
2/24/1993	139.54	137.45	-2.09	6E04Q010087
6/25/1998	130.43	145.68	15.25	6E04Q010088
4/10/2005	125.43	123.74	-1.69	6E04Q010089
2/23/2006	123.62	122.53	-1.09	6E04Q010090
5/12/2008	119.40	118.22	-1.18	6E04Q010091
12/1/2008	118.12	118.08	-0.04	6E04Q010092
12/2/2008	118.14	118.22	0.08	6E04Q010093
10/1/1951	158.23	161.84	3.61	6E05F010094
12/4/2008	118.69	122.31	3.63	6E05F010095
11/28/1955	149.19	150.99	1.79	6E08B010096
11/16/1956	147.78	151.70	3.91	6E08B010097
11/16/1956	147.78	138.26	-9.53	6E08B010098
11/26/1957	147.02	150.98	3.96	6E08B010099
3/15/1958	147.30	150.95	3.66	6E08B010100

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/5/1958	145.92	144.76	-1.16	6E08B010101
11/24/1959	144.60	148.64	4.04	6E08B010102
2/27/1960	144.90	149.08	4.19	6E08B010103
11/22/1960	143.51	148.36	4.85	6E08B010104
3/8/1961	143.54	148.11	4.58	6E08B010105
10/26/1961	142.20	147.15	4.94	6E08B010106
3/15/1962	142.46	142.10	-0.36	6E08B010107
11/2/1962	141.13	143.05	1.92	6E08B010108
3/15/1963	141.30	146.39	5.08	6E08B010109
10/31/1963	140.42	143.04	2.62	6E08B010110
3/20/1964	140.63	144.42	3.79	6E08B010111
11/12/1964	139.55	145.24	5.69	6E08B010112
3/19/1965	139.81	145.74	5.94	6E08B010113
7/23/1965	140.61	144.81	4.20	6E08B010114
10/26/1965	140.68	144.79	4.10	6E08B010115
3/3/1966	141.28	144.78	3.49	6E08B010116
10/26/1966	142.55	144.57	2.01	6E08B010117
3/23/1967	142.35	144.63	2.28	6E08B010118
10/24/1967	142.02	144.57	2.56	6E08B010119
3/13/1968	141.60	144.82	3.23	6E08B010120
11/8/1968	143.92	144.56	0.65	6E08B010121
3/27/1969	143.86	145.13	1.27	6E08B010122
10/28/1969	142.87	145.09	2.22	6E08B010123
3/23/1970	142.71	145.33	2.63	6E08B010124
11/12/1970	141.91	145.17	3.26	6E08B010125
3/30/1971	141.77	145.32	3.56	6E08B010126
12/5/2008	117.90	122.52	4.62	6E08F010127
3/12/2009	118.29	122.52	4.23	6E08F010128
3/25/2010	116.71	121.31	4.60	6E08F010129
11/18/2010	114.98	120.54	5.56	6E08F010130
12/2/2008	117.95	116.81	-1.15	6E09C010129
7/26/1965	140.59	141.92	1.33	6E09L010130
5/26/1983	142.61	140.51	-2.09	6E09L010131
9/30/1983	142.39	140.39	-2.00	6E09L010132
12/11/1983	142.27	140.51	-1.76	6E09L010133
4/6/1984	142.02	140.73	-1.30	6E09L010134
7/19/1984	141.53	140.27	-1.26	6E09L010135
2/18/1985	141.16	140.82	-0.35	6E09L010136
5/26/1985	140.86	140.58	-0.29	6E09L010137
1/20/1986	140.38	140.36	-0.02	6E09L010138
4/22/1986	140.30	140.06	-0.25	6E09L010139
9/11/1986	139.65	139.42	-0.23	6E09L010140
12/8/1986	139.51	139.78	0.27	6E09L010141
4/27/1987	139.30	139.75	0.46	6E09L010142
7/27/1987	138.84	139.42	0.58	6E09L010143

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/15/1987	138.59	139.54	0.95	6E09L010144
1/20/1988	138.62	139.78	1.17	6E09L010145
4/1/1988	138.47	139.63	1.16	6E09L010146
6/8/1988	138.12	139.42	1.30	6E09L010147
10/25/1988	137.39	138.93	1.54	6E09L010148
2/3/1989	137.36	139.14	1.79	6E09L010149
8/8/1989	136.51	138.47	1.96	6E09L010150
10/26/1989	136.22	138.23	2.01	6E09L010151
2/6/1990	136.16	139.23	3.07	6E09L010152
9/1/1990	137.35	137.53	0.18	6E09L010153
1/14/1991	136.76	138.20	1.43	6E09L010154
2/19/1991	136.75	138.26	1.51	6E09L010155
3/5/1991	136.76	138.44	1.68	6E09L010156
3/19/1991	136.73	138.47	1.75	6E09L010157
4/11/1991	136.60	138.38	1.78	6E09L010158
5/9/1991	136.35	138.17	1.82	6E09L010159
5/30/1991	136.17	137.19	1.02	6E09L010160
7/23/1991	135.71	136.64	0.93	6E09L010161
10/31/1991	135.43	136.84	1.41	6E09L010162
1/7/1992	135.65	137.25	1.61	6E09L010163
3/12/1992	135.83	137.41	1.57	6E09L010164
5/12/1992	136.30	136.86	0.56	6E09L010165
7/7/1992	139.64	136.51	-3.13	6E09L010166
9/2/1992	139.03	136.06	-2.97	6E09L010167
10/13/1992	138.69	135.94	-2.75	6E09L010168
12/8/1992	138.47	136.43	-2.04	6E09L010169
1/21/1993	138.63	136.61	-2.01	6E09L010170
2/3/1993	138.70	136.52	-2.18	6E09L010171
2/12/1993	138.69	136.80	-1.89	6E09L010172
2/24/1993	138.67	136.70	-1.96	6E09L010173
3/11/1993	138.51	136.55	-1.96	6E09L010174
3/27/1993	138.31	136.43	-1.88	6E09L010175
4/16/1993	138.03	136.22	-1.81	6E09L010176
5/11/1993	137.68	136.06	-1.61	6E09L010177
7/2/1993	136.92	135.58	-1.34	6E09L010178
8/19/1993	136.29	135.12	-1.17	6E09L010179
10/20/1993	135.92	135.00	-0.92	6E09L010180
12/24/1993	135.93	135.24	-0.69	6E09L010181
2/11/1994	135.84	135.06	-0.78	6E09L010182
3/25/1994	135.67	135.03	-0.64	6E09L010183
5/25/1994	136.15	135.03	-1.12	6E09L010184
8/24/1994	135.14	133.99	-1.15	6E09L010185
10/6/1994	134.87	133.87	-1.00	6E09L010186
12/21/1994	134.99	134.21	-0.79	6E09L010187
2/24/1995	135.15	134.54	-0.61	6E09L010188
4/12/1995	134.89	134.33	-0.56	6E09L010189
6/21/1995	133.84	133.87	0.03	6E09L010190
10/2/1995	132.59	132.80	0.21	6E09L010191

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
12/26/1995	132.61	132.83	0.23	6E09L010192
4/11/1996	132.22	132.71	0.49	6E09L010193
8/9/1996	130.45	131.43	0.98	6E09L010194
10/23/1996	130.09	131.43	1.34	6E09L010195
1/3/1997	130.34	131.74	1.40	6E09L010196
9/3/1997	130.22	130.85	0.64	6E09L010197
12/3/1997	130.49	131.19	0.70	6E09L010198
5/13/1998	130.40	131.16	0.76	6E09L010199
11/12/1998	129.05	130.03	0.98	6E09L010200
3/12/1999	129.12	129.88	0.76	6E09L010201
5/17/1999	128.63	130.09	1.46	6E09L010202
11/22/1999	127.53	128.47	0.94	6E09L010203
2/17/2000	127.71	129.63	1.93	6E09L010204
3/24/2000	127.66	129.05	1.40	6E09L010205
6/29/2000	126.58	128.02	1.44	6E09L010206
9/15/2000	126.04	127.77	1.73	6E09L010207
12/18/2000	126.27	128.05	1.78	6E09L010208
10/17/2001	124.89	126.98	2.09	6E09L010209
11/14/2001	124.99	127.23	2.24	6E09L010210
2/22/2002	125.17	127.65	2.48	6E09L010211
8/30/2002	123.41	125.12	1.71	6E09L010212
9/27/2002	123.42	125.15	1.73	6E09L010213
12/13/2002	123.79	125.70	1.91	6E09L010214
3/17/2003	124.09	126.49	2.40	6E09L010215
6/30/2003	123.00	124.60	1.60	6E09L010216
12/29/2003	122.97	124.97	2.00	6E09L010217
2/12/2004	123.11	125.46	2.35	6E09L010218
4/8/2004	122.92	124.63	1.72	6E09L010219
11/18/2004	124.41	124.15	-0.27	6E09L010220
2/10/2005	125.18	124.85	-0.33	6E09L010221
1/5/2006	123.33	123.60	0.26	6E09L010222
	140.31	134.49	-5.82	6E09N010223
2/12/2004	124.50	127.38	2.88	6E10L010224
2/10/2005	125.93	126.77	0.84	6E10L010225
1/5/2006	124.39	129.66	5.28	6E10L010226
8/23/1980	143.33	148.15	4.81	6E10M010227
2/12/2004	124.21	131.22	7.01	6E10M010228
2/10/2005	125.83	134.33	8.50	6E10M010229
5/5/2005	125.33	130.77	5.43	6E10M010230
8/24/2005	124.09	130.40	6.31	6E10M010231
1/5/2006	124.14	129.85	5.71	6E10M010232
5/15/2009	119.20	122.61	3.41	6E17J010235
6/30/1987	138.54	140.96	2.42	6E18J010236

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/30/1991	135.31	138.52	3.21	6E18J010237
6/30/1993	136.04	136.08	0.04	6E18J010238
6/30/1995	134.09	135.29	1.20	6E18J010239
6/30/1997	130.49	133.22	2.73	6E18J010240
6/2/1998	130.71	132.03	1.32	6E18J010241
6/29/1999	128.76	130.93	2.17	6E18J010242
6/5/2000	127.71	129.74	2.03	6E18J010243
6/8/2001	126.65	128.98	2.33	6E18J010244
7/29/2002	124.77	128.22	3.45	6E18J010245
7/31/2003	123.81	126.66	2.86	6E18J010246
2/10/2004	123.64	122.95	-0.69	6E18J010247
2/12/2005	125.18	125.81	0.63	6E18J010248
3/3/2006	123.78	124.68	0.91	6E18J010249
5/21/2006	123.42	120.96	-2.46	6E18J010250
3/8/2007	122.15	123.01	0.85	6E18J010251
12/1/2008	119.48	121.47	1.98	6E18J010252
12/3/2008	119.50	122.29	2.79	6E18J010253
3/25/2010	118.48	122.37	3.89	6E18J010254
10/12/2010	117.14	121.48	4.34	6E18J010255
4/9/2013	115.06	119.96	4.90	6E18J010256
10/18/2013	114.12	119.62	5.50	6E18J010257
3/28/2014	114.07	119.96	5.89	6E18J010258
3/10/2015	113.09	118.92	5.83	6E18J010259
10/12/2015	112.13	116.82	4.69	6E18J010260
3/23/2016	112.42	116.12	3.70	6E18J010261
6/30/1980	142.69	144.68	1.99	6E18R010254
6/30/1987	138.40	140.72	2.32	6E18R010255
6/30/1991	135.33	138.28	2.95	6E18R010256
6/30/1993	136.02	134.62	-1.40	6E18R010257
6/30/1995	134.26	134.95	0.69	6E18R010258
6/30/1997	131.16	133.86	2.70	6E18R010259
6/2/1998	130.91	131.88	0.97	6E18R010260
6/29/1999	129.60	130.96	1.36	6E18R010261
6/5/2000	128.30	132.82	4.52	6E18R010262
7/31/2003	124.55	128.10	3.55	6E18R010263
5/13/2005	125.21	124.87	-0.34	6E18R010264
3/3/2006	124.23	124.62	0.39	6E18R010265
5/21/2006	123.87	116.91	-6.96	6E18R010266
3/8/2007	122.84	122.88	0.04	6E18R010267
12/1/2008	120.74	121.93	1.20	6E18R010268
12/3/2008	120.75	122.64	1.89	6E18R010269
5/14/2009	120.67	123.24	2.57	6E18R010270
3/25/2010	119.72	122.86	3.14	6E18R010271
11/18/2010	118.44	122.13	3.69	6E18R010272
11/14/2012	116.36	120.98	4.62	6E18R010273
4/9/2013	116.30	120.88	4.58	6E18R010274
11/13/2013	115.37	120.26	4.89	6E18R010275

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/25/2013	115.39	120.26	4.87	6E18R010276
2/5/2014	115.44	120.10	4.66	6E18R010277
4/9/2014	115.25	120.00	4.75	6E18R010278
6/3/2014	114.90	119.77	4.87	6E18R010279
4/15/2015	114.21	119.05	4.84	6E18R010280
11/19/2015	113.33	118.02	4.69	6E18R010281
4/12/2016	113.44	117.74	4.30	6E18R010282
7/27/1987	138.41	140.73	2.32	6E20L010271
11/19/1987	138.23	140.54	2.31	6E20L010272
1/20/1988	138.26	141.06	2.81	6E20L010273
4/1/1988	138.15	140.30	2.15	6E20L010274
6/8/1988	137.87	140.33	2.46	6E20L010275
10/25/1988	137.31	140.24	2.93	6E20L010276
2/3/1989	137.26	140.30	3.04	6E20L010277
8/8/1989	136.66	139.69	3.04	6E20L010278
10/26/1989	136.46	139.63	3.17	6E20L010279
2/6/1990	136.40	139.57	3.17	6E20L010280
9/1/1990	135.84	139.23	3.39	6E20L010281
1/14/1991	135.94	139.84	3.90	6E20L010282
2/19/1991	136.06	139.78	3.73	6E20L010283
3/5/1991	136.09	139.87	3.79	6E20L010284
3/19/1991	136.09	139.81	3.73	6E20L010285
4/11/1991	136.07	139.72	3.65	6E20L010286
5/30/1991	135.95	138.87	2.92	6E20L010287
7/23/1991	135.80	137.53	1.73	6E20L010288
10/31/1991	135.68	137.44	1.76	6E20L010289
1/7/1992	135.75	138.11	2.36	6E20L010290
3/12/1992	135.83	138.41	2.59	6E20L010291
5/12/1992	135.72	137.53	1.81	6E20L010292
7/7/1992	135.75	137.04	1.29	6E20L010293
9/2/1992	135.79	137.01	1.22	6E20L010294
12/8/1992	136.16	137.47	1.31	6E20L010295
1/21/1993	136.43	138.02	1.58	6E20L010296
2/3/1993	136.52	138.02	1.49	6E20L010297
2/12/1993	136.56	138.08	1.52	6E20L010298
2/24/1993	136.62	138.11	1.49	6E20L010299
3/11/1993	136.65	138.02	1.37	6E20L010300
3/27/1993	136.67	137.83	1.17	6E20L010301
4/16/1993	136.67	137.50	0.83	6E20L010302
5/11/1993	136.65	137.19	0.54	6E20L010303
7/2/1993	136.52	136.98	0.46	6E20L010304
8/19/1993	136.35	136.89	0.54	6E20L010305
10/20/1993	136.21	136.95	0.74	6E20L010306
12/24/1993	136.17	137.19	1.02	6E20L010307
2/11/1994	136.15	137.34	1.19	6E20L010308
3/25/1994	136.11	137.71	1.60	6E20L010309
5/25/1994	135.92	137.10	1.18	6E20L010310

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
8/24/1994	135.67	136.67	1.01	6E20L010311
10/6/1994	135.60	136.64	1.04	6E20L010312
12/21/1994	135.61	136.67	1.07	6E20L010313
2/24/1995	135.66	137.01	1.35	6E20L010314
4/12/1995	135.60	136.70	1.10	6E20L010315
6/21/1995	135.29	136.16	0.86	6E20L010316
10/2/1995	134.74	135.94	1.20	6E20L010317
12/25/1995	134.53	136.06	1.53	6E20L010318
4/11/1996	134.26	135.82	1.56	6E20L010319
8/9/1996	133.52	134.97	1.45	6E20L010320
10/23/1996	133.16	134.94	1.78	6E20L010321
1/3/1997	132.99	135.09	2.10	6E20L010322
5/9/1997	132.60	134.48	1.87	6E20L010323
9/3/1997	132.16	134.05	1.89	6E20L010324
12/3/1997	132.21	134.24	2.02	6E20L010325
5/13/1998	132.20	133.93	1.73	6E20L010326
11/12/1998	131.61	133.23	1.62	6E20L010327
3/12/1999	131.45	133.17	1.72	6E20L010328
5/17/1999	131.24	132.74	1.50	6E20L010329
11/22/1999	130.54	131.98	1.44	6E20L010330
2/17/2000	130.40	131.98	1.58	6E20L010331
3/24/2000	130.33	132.01	1.68	6E20L010332
6/29/2000	129.89	131.16	1.26	6E20L010333
9/15/2000	129.56	131.25	1.69	6E20L010334
12/18/2000	129.39	131.04	1.64	6E20L010335
5/17/2001	129.12	130.88	1.76	6E20L010336
10/17/2001	128.49	130.67	2.18	6E20L010337
11/14/2001	128.44	129.48	1.04	6E20L010338
2/22/2002	128.30	129.88	1.58	6E20L010339
8/30/2002	127.50	128.63	1.13	6E20L010340
12/13/2002	127.31	128.66	1.34	6E20L010341
3/17/2003	127.21	128.78	1.57	6E20L010342
6/30/2003	126.80	128.05	1.25	6E20L010343
10/6/2003	126.42	127.93	1.51	6E20L010344
12/29/2003	126.31	127.83	1.53	6E20L010345
2/12/2004	126.27	127.80	1.54	6E20L010346
7/23/2004	125.91	126.80	0.89	6E20L010347
2/10/2005	126.38	127.35	0.97	6E20L010348
8/23/2005	125.93	126.34	0.41	6E20L010349
1/5/2006	125.74	126.34	0.60	6E20L010350
6/14/2006	125.28	125.46	0.18	6E20L010351
1/10/2007	124.53	125.09	0.57	6E20L010352
6/4/2007	123.97	123.60	-0.37	6E20L010353
9/21/2007	123.39	122.47	-0.92	6E20L010354
1/8/2008	123.18	122.44	-0.74	6E20L010355
5/8/2008	122.84	122.32	-0.53	6E20L010356
8/12/2008	122.36	122.32	-0.05	6E20L010357
12/1/2008	122.06	122.73	0.67	6E20L010358

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
12/3/2008	122.06	123.08	1.02	6E20L010359
4/15/2009	121.87	123.13	1.27	6E20L010360
2/5/2014	116.63	119.77	3.14	6E20L010361
6/24/1952	150.88	153.37	2.48	6E21A010361
1/3/1953	150.70	155.14	4.44	6E21A010362
5/1/1953	150.33	152.56	2.23	6E21A010363
5/15/1953	150.20	152.25	2.05	6E21A010364
5/28/1953	150.09	152.03	1.94	6E21A010365
6/11/1953	149.96	151.83	1.86	6E21A010366
6/25/1953	149.83	151.62	1.78	6E21A010367
7/1/1953	149.78	148.42	-1.37	6E21A010368
7/3/1953	149.75	151.50	1.75	6E21A010369
7/11/1953	149.63	151.29	1.66	6E21A010370
7/25/1953	149.43	151.14	1.71	6E21A010371
8/3/1953	149.33	151.41	2.08	6E21A010372
8/5/1953	149.31	148.82	-0.49	6E21A010373
8/19/1953	149.23	150.39	1.16	6E21A010374
9/2/1953	149.15	151.36	2.21	6E21A010375
9/17/1953	149.14	151.45	2.31	6E21A010376
10/1/1953	149.13	151.81	2.68	6E21A010377
10/16/1953	149.17	151.96	2.79	6E21A010378
10/21/1953	149.18	149.60	0.42	6E21A010379
10/29/1953	149.20	152.28	3.09	6E21A010380
11/11/1953	149.23	152.47	3.24	6E21A010381
11/19/1953	149.24	150.03	0.79	6E21A010382
11/25/1953	149.26	152.70	3.44	6E21A010383
12/10/1953	149.29	152.92	3.63	6E21A010384
12/17/1953	149.31	150.27	0.97	6E21A010385
12/21/1953	149.31	152.93	3.61	6E21A010386
1/6/1954	149.36	152.74	3.38	6E21A010387
1/7/1954	149.36	152.72	3.36	6E21A010388
1/21/1954	149.42	152.40	2.98	6E21A010389
2/3/1954	149.46	152.55	3.09	6E21A010390
2/18/1954	149.46	150.95	1.50	6E21A010391
2/24/1954	149.46	152.62	3.17	6E21A010392
3/4/1954	149.45	152.26	2.81	6E21A010393
3/17/1954	149.43	152.20	2.77	6E21A010394
4/2/1954	149.41	152.39	2.98	6E21A010395
4/15/1954	149.29	151.23	1.94	6E21A010396
5/17/1954	149.01	150.08	1.07	6E21A010397
5/28/1954	148.92	149.62	0.70	6E21A010398
8/13/1954	148.18	148.11	-0.07	6E21A010399
8/27/1954	148.08	148.08	0.00	6E21A010400
10/21/1954	148.05	149.60	1.55	6E21A010401
11/9/1954	148.09	149.76	1.67	6E21A010402
11/19/1954	148.13	150.03	1.90	6E21A010403
12/17/1954	148.18	150.27	2.10	6E21A010404

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
1/12/1955	148.23	150.49	2.26	6E21A010405
2/10/1955	148.29	149.66	1.37	6E21A010406
3/7/1955	148.25	149.30	1.05	6E21A010407
3/16/1955	148.20	149.39	1.20	6E21A010408
4/14/1955	148.02	147.32	-0.71	6E21A010409
5/19/1955	147.76	146.34	-1.42	6E21A010410
6/29/1955	147.42	145.73	-1.69	6E21A010411
7/20/1955	147.18	145.92	-1.26	6E21A010412
8/3/1955	147.04	146.10	-0.94	6E21A010413
9/20/1955	146.85	146.80	-0.05	6E21A010414
10/25/1955	146.85	149.18	2.32	6E21A010415
11/28/1955	146.89	150.09	3.20	6E21A010416
11/29/1955	146.89	150.12	3.23	6E21A010417
1/4/1956	146.97	150.73	3.76	6E21A010418
2/7/1956	147.00	149.76	2.76	6E21A010419
3/8/1956	146.95	148.84	1.89	6E21A010420
3/18/1956	146.89	148.23	1.34	6E21A010421
4/4/1956	146.80	148.51	1.71	6E21A010422
5/3/1956	146.61	146.83	0.22	6E21A010423
6/6/1956	146.32	145.82	-0.49	6E21A010424
7/2/1956	146.09	145.67	-0.43	6E21A010425
8/2/1956	145.71	145.55	-0.16	6E21A010426
9/4/1956	145.51	146.74	1.23	6E21A010427
10/3/1956	145.49	148.20	2.71	6E21A010428
11/1/1956	145.55	148.84	3.29	6E21A010429
11/16/1956	145.58	149.21	3.63	6E21A010430
12/3/1956	145.61	149.51	3.90	6E21A010431
1/3/1957	145.68	149.91	4.23	6E21A010432
2/4/1957	145.80	149.39	3.59	6E21A010433
3/1/1957	145.80	149.63	3.84	6E21A010434
3/15/1957	145.72	147.87	2.15	6E21A010435
3/27/1957	145.67	147.29	1.62	6E21A010436
4/25/1957	145.48	145.70	0.22	6E21A010437
5/27/1957	145.25	145.34	0.09	6E21A010438
6/26/1957	144.99	144.24	-0.76	6E21A010439
7/24/1957	144.65	143.75	-0.90	6E21A010440
8/22/1957	144.42	143.75	-0.67	6E21A010441
9/3/1957	144.35	151.10	6.75	6E21A010442
9/26/1957	144.36	146.04	1.68	6E21A010443
11/6/1957	144.51	147.50	2.99	6E21A010444
11/26/1957	144.56	147.98	3.42	6E21A010445
12/11/1957	144.60	148.29	3.69	6E21A010446
1/7/1958	144.68	148.57	3.89	6E21A010447
2/11/1958	144.78	148.14	3.36	6E21A010448
3/15/1958	144.84	148.62	3.78	6E21A010449
4/21/1958	144.74	145.70	0.96	6E21A010450
5/5/1958	144.66	145.55	0.89	6E21A010451
6/23/1958	144.28	143.78	-0.50	6E21A010452

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
7/23/1958	143.99	143.54	-0.45	6E21A010453
8/14/1958	143.81	143.26	-0.55	6E21A010454
9/23/1958	143.67	143.11	-0.56	6E21A010455
10/20/1958	143.70	145.64	1.94	6E21A010456
11/5/1958	143.72	146.21	2.49	6E21A010457
11/12/1958	143.73	146.13	2.40	6E21A010458
12/3/1958	143.76	145.55	1.79	6E21A010459
1/5/1959	143.82	147.10	3.28	6E21A010460
1/26/1959	143.87	146.49	2.62	6E21A010461
2/18/1959	143.95	146.28	2.34	6E21A010462
3/12/1959	143.93	147.29	3.36	6E21A010463
3/19/1959	143.89	147.26	3.36	6E21A010464
4/16/1959	143.77	146.25	2.48	6E21A010465
5/12/1959	143.64	144.60	0.97	6E21A010466
6/11/1959	143.46	144.00	0.53	6E21A010467
7/28/1959	143.09	144.09	1.00	6E21A010468
8/11/1959	143.01	143.05	0.04	6E21A010469
9/8/1959	142.90	141.89	-1.01	6E21A010470
10/6/1959	142.88	144.97	2.09	6E21A010471
11/10/1959	142.94	145.76	2.83	6E21A010472
11/24/1959	142.95	145.76	2.81	6E21A010473
12/10/1959	142.99	145.76	2.77	6E21A010474
12/29/1959	143.05	146.25	3.20	6E21A010475
1/13/1960	143.09	145.70	2.61	6E21A010476
2/11/1960	143.15	144.85	1.69	6E21A010477
2/27/1960	143.18	145.13	1.96	6E21A010478
3/8/1960	143.15	146.37	3.23	6E21A010479
3/23/1960	143.08	146.22	3.14	6E21A010480
4/4/1960	143.04	144.76	1.72	6E21A010481
4/21/1960	142.95	143.81	0.86	6E21A010482
5/2/1960	142.90	142.38	-0.52	6E21A010483
5/17/1960	142.81	142.59	-0.21	6E21A010484
6/2/1960	142.71	142.84	0.12	6E21A010485
6/16/1960	142.62	141.83	-0.79	6E21A010486
6/30/1960	142.54	142.20	-0.34	6E21A010487
7/14/1960	142.40	142.23	-0.17	6E21A010488
8/11/1960	142.18	142.59	0.41	6E21A010489
9/19/1960	142.07	143.63	1.56	6E21A010490
10/21/1960	142.07	144.12	2.05	6E21A010491
11/17/1960	142.11	144.48	2.37	6E21A010492
11/22/1960	142.12	144.53	2.41	6E21A010493
12/16/1960	142.15	145.06	2.92	6E21A010494
1/16/1961	142.18	144.88	2.70	6E21A010495
2/14/1961	142.20	143.60	1.40	6E21A010496
3/8/1961	142.17	143.78	1.61	6E21A010497
3/13/1961	142.15	144.94	2.79	6E21A010498
5/5/1961	141.90	141.62	-0.29	6E21A010499
5/29/1961	141.77	141.62	-0.15	6E21A010500

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/28/1961	141.58	140.73	-0.84	6E21A010501
8/20/1961	141.17	137.35	-3.82	6E21A010502
10/8/1961	141.09	143.05	1.96	6E21A010503
10/26/1961	141.10	143.43	2.33	6E21A010504
11/30/1961	141.12	143.02	1.90	6E21A010505
12/28/1961	141.19	143.14	1.95	6E21A010506
1/30/1962	141.25	141.83	0.58	6E21A010507
3/6/1962	141.28	144.18	2.90	6E21A010508
3/15/1962	141.24	144.12	2.88	6E21A010509
4/6/1962	141.16	141.74	0.58	6E21A010510
6/28/1962	140.68	140.58	-0.10	6E21A010511
7/25/1962	140.43	140.34	-0.09	6E21A010512
8/23/1962	140.24	140.31	0.07	6E21A010513
9/25/1962	140.16	141.53	1.36	6E21A010514
10/22/1962	140.18	142.90	2.72	6E21A010515
11/2/1962	140.18	143.26	3.07	6E21A010516
1/10/1963	140.28	142.62	2.34	6E21A010517
2/12/1963	140.32	141.82	1.50	6E21A010518
3/11/1963	140.30	143.81	3.51	6E21A010519
3/15/1963	140.29	144.07	3.78	6E21A010520
4/10/1963	140.20	142.29	2.09	6E21A010521
5/7/1963	140.07	141.17	1.10	6E21A010522
6/18/1963	139.81	140.49	0.68	6E21A010523
7/2/1963	139.73	139.97	0.24	6E21A010524
7/9/1963	139.66	140.12	0.47	6E21A010525
7/15/1963	139.59	140.15	0.56	6E21A010526
7/16/1963	139.58	140.28	0.69	6E21A010527
8/1/1963	139.44	139.97	0.54	6E21A010528
8/8/1963	139.42	140.18	0.76	6E21A010529
8/15/1963	139.40	139.70	0.29	6E21A010530
9/1/1963	139.35	140.00	0.65	6E21A010531
9/4/1963	139.35	140.31	0.96	6E21A010532
9/16/1963	139.38	141.22	1.84	6E21A010533
10/3/1963	139.40	142.01	2.61	6E21A010534
10/8/1963	139.43	142.26	2.82	6E21A010535
10/15/1963	139.48	142.01	2.54	6E21A010536
10/31/1963	139.56	143.47	3.91	6E21A010537
11/1/1963	139.56	142.65	3.09	6E21A010538
11/12/1963	139.59	142.93	3.34	6E21A010539
11/15/1963	139.59	142.87	3.28	6E21A010540
12/1/1963	139.62	143.14	3.52	6E21A010541
12/5/1963	139.63	143.37	3.74	6E21A010542
12/15/1963	139.64	145.15	5.51	6E21A010543
1/2/1964	139.67	143.17	3.50	6E21A010544
1/6/1964	139.68	142.74	3.07	6E21A010545
1/15/1964	139.69	142.93	3.23	6E21A010546
2/1/1964	139.72	142.01	2.29	6E21A010547
2/5/1964	139.72	142.00	2.28	6E21A010548

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
2/18/1964	139.73	140.83	1.09	6E21A010549
3/1/1964	139.74	143.08	3.34	6E21A010550
3/9/1964	139.72	143.31	3.59	6E21A010551
3/15/1964	139.71	143.17	3.46	6E21A010552
3/20/1964	139.70	144.02	4.32	6E21A010553
4/1/1964	139.67	141.07	1.40	6E21A010554
4/3/1964	139.66	141.07	1.41	6E21A010555
4/15/1964	139.60	141.71	2.11	6E21A010556
5/1/1964	139.53	140.64	1.12	6E21A010557
5/8/1964	139.48	140.37	0.88	6E21A010558
5/11/1964	139.47	141.34	1.88	6E21A010559
5/15/1964	139.44	140.06	0.62	6E21A010560
6/1/1964	139.35	139.73	0.38	6E21A010561
6/3/1964	139.34	139.61	0.27	6E21A010562
6/15/1964	139.27	139.42	0.16	6E21A010563
6/30/1964	139.18	139.15	-0.03	6E21A010564
7/7/1964	139.12	140.25	1.13	6E21A010565
7/23/1964	138.96	139.48	0.52	6E21A010566
8/5/1964	138.86	139.48	0.61	6E21A010567
9/11/1964	138.73	140.58	1.85	6E21A010568
9/30/1964	138.72	141.51	2.79	6E21A010569
11/2/1964	138.76	142.54	3.78	6E21A010570
12/1/1964	138.87	143.14	4.27	6E21A010571
1/6/1965	138.89	143.18	4.29	6E21A010572
2/1/1965	138.92	142.72	3.80	6E21A010573
3/3/1965	138.93	143.40	4.47	6E21A010574
3/16/1965	138.97	141.80	2.84	6E21A010575
4/5/1965	139.15	143.47	4.33	6E21A010576
5/5/1965	139.37	140.93	1.56	6E21A010577
5/24/1965	139.38	141.71	2.33	6E21A010578
6/29/1965	139.30	141.48	2.18	6E21A010579
7/7/1965	139.25	141.72	2.47	6E21A010580
7/20/1965	139.15	140.28	1.12	6E21A010581
7/22/1965	139.14	138.39	-0.75	6E21A010582
8/3/1965	139.06	140.89	1.82	6E21A010583
10/4/1965	138.94	142.66	3.72	6E21A010584
10/25/1965	138.96	142.72	3.76	6E21A010585
10/26/1965	138.96	142.82	3.87	6E21A010586
11/5/1965	138.98	143.00	4.02	6E21A010587
12/10/1965	139.14	143.18	4.03	6E21A010588
1/4/1966	139.23	143.00	3.77	6E21A010589
2/1/1966	139.31	143.00	3.68	6E21A010590
3/3/1966	139.38	142.93	3.55	6E21A010591
3/10/1966	139.40	142.94	3.55	6E21A010592
4/5/1966	139.46	142.32	2.86	6E21A010593
5/3/1966	139.66	142.39	2.73	6E21A010594
6/2/1966	139.94	141.13	1.19	6E21A010595
7/6/1966	140.12	142.32	2.20	6E21A010596

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
8/1/1966	140.18	142.67	2.49	6E21A010597
9/7/1966	140.21	142.82	2.61	6E21A010598
10/5/1966	140.22	143.11	2.90	6E21A010599
10/26/1966	140.22	143.32	3.11	6E21A010600
1/13/1967	140.23	143.72	3.49	6E21A010601
2/13/1967	140.24	143.84	3.60	6E21A010602
3/7/1967	140.24	143.75	3.51	6E21A010603
3/23/1967	140.24	143.87	3.64	6E21A010604
4/24/1967	140.23	143.78	3.55	6E21A010605
8/17/1967	140.14	143.45	3.30	6E21A010606
10/13/1967	140.10	143.78	3.68	6E21A010607
3/13/1968	140.07	144.33	4.26	6E21A010608
6/27/1968	141.15	144.12	2.96	6E21A010609
11/8/1968	142.08	144.15	2.07	6E21A010610
3/26/1969	141.76	144.39	2.63	6E21A010611
3/27/1969	141.76	144.60	2.85	6E21A010612
10/3/1969	141.32	144.48	3.16	6E21A010613
10/28/1969	141.27	144.79	3.51	6E21A010614
1/29/1970	141.14	144.45	3.32	6E21A010615
3/23/1970	141.07	144.76	3.68	6E21A010616
4/3/1970	141.06	144.51	3.45	6E21A010617
8/6/1970	140.89	144.42	3.54	6E21A010618
11/10/1970	140.74	144.48	3.74	6E21A010619
3/30/1971	140.61	144.60	3.99	6E21A010620
5/19/1971	140.56	144.54	3.99	6E21A010621
9/1/1971	140.41	144.48	4.07	6E21A010622
3/1/1972	140.22	144.42	4.20	6E21A010623
6/15/1972	140.11	144.33	4.22	6E21A010624
9/7/1972	139.99	144.18	4.19	6E21A010625
12/20/1972	139.90	144.21	4.30	6E21A010626
3/16/1973	139.89	144.24	4.35	6E21A010627
6/21/1973	139.86	143.66	3.80	6E21A010628
9/25/1973	139.78	143.90	4.13	6E21A010629
12/14/1973	139.72	143.90	4.18	6E21A010630
3/20/1974	139.67	143.84	4.17	6E21A010631
6/20/1974	139.57	143.54	3.97	6E21A010632
8/6/1974	139.50	143.29	3.79	6E21A010633
10/29/1974	139.40	143.48	4.07	6E21A010634
1/30/1975	139.36	143.45	4.09	6E21A010635
5/8/1975	139.28	143.14	3.86	6E21A010636
8/5/1975	139.16	142.62	3.47	6E21A010637
10/31/1975	139.08	142.44	3.36	6E21A010638
2/17/1976	139.04	142.72	3.67	6E21A010639
12/26/1978	140.80	142.86	2.06	6E21A010640
7/22/1980	142.20	140.70	-1.50	6E21A010641
8/25/1980	142.00	140.76	-1.24	6E21A010642
2/12/1981	141.76	141.19	-0.57	6E21A010643
9/22/1981	140.77	140.53	-0.23	6E21A010644

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
2/4/1982	140.84	140.86	0.02	6E21A010645
10/1/1982	140.23	140.12	-0.11	6E21A010646
9/27/1983	140.56	140.31	-0.25	6E21A010647
9/17/1984	139.92	139.66	-0.25	6E21A010648
2/26/1985	140.03	140.19	0.15	6E21A010649
9/12/1985	139.28	139.28	0.00	6E21A010650
5/7/1986	139.24	139.33	0.09	6E21A010651
2/18/1987	138.75	139.43	0.68	6E21A010652
9/17/1987	137.91	138.16	0.26	6E21A010653
3/10/1988	138.09	138.70	0.62	6E21A010654
9/27/1988	137.16	137.55	0.40	6E21A010655
3/31/1989	137.05	137.74	0.69	6E21A010656
9/27/1989	136.20	137.21	1.00	6E21A010657
3/13/1990	136.16	137.51	1.35	6E21A010658
9/27/1990	136.28	136.65	0.37	6E21A010659
3/11/1991	136.44	137.12	0.68	6E21A010660
9/23/1991	135.47	136.22	0.76	6E21A010661
3/16/1992	135.61	136.60	0.99	6E21A010662
9/24/1992	137.42	135.75	-1.67	6E21A010663
4/12/1993	137.40	135.65	-1.75	6E21A010664
9/17/1993	136.21	135.20	-1.00	6E21A010665
4/28/1994	135.60	135.00	-0.60	6E21A010666
7/15/2004	125.40	124.56	-0.84	6E21A020667
8/1/2004	125.35	124.23	-1.12	6E21A020668
8/15/2004	125.33	124.20	-1.13	6E21A020669
9/1/2004	125.30	124.02	-1.28	6E21A020670
9/15/2004	125.32	124.59	-0.72	6E21A020671
10/1/2004	125.33	124.41	-0.92	6E21A020672
10/15/2004	125.46	124.41	-1.05	6E21A020673
11/5/2004	125.65	124.83	-0.83	6E21A020674
11/15/2004	125.72	124.98	-0.74	6E21A020675
12/1/2004	125.81	124.98	-0.83	6E21A020676
12/15/2004	125.90	125.53	-0.37	6E21A020677
1/1/2005	126.01	126.11	0.10	6E21A020678
1/15/2005	126.08	126.30	0.21	6E21A020679
2/1/2005	126.17	126.00	-0.17	6E21A020680
2/10/2005	126.21	125.68	-0.53	6E21A020681
2/15/2005	126.23	126.08	-0.15	6E21A020682
3/1/2005	126.29	126.33	0.03	6E21A020683
3/15/2005	126.23	124.99	-1.24	6E21A020684
4/1/2005	126.15	124.19	-1.96	6E21A020685
4/16/2005	126.06	124.39	-1.67	6E21A020686
5/1/2005	125.97	124.23	-1.73	6E21A020687
5/16/2005	125.84	124.45	-1.39	6E21A020688
5/31/2005	125.72	124.29	-1.43	6E21A020689
6/15/2005	125.60	124.20	-1.40	6E21A020690
7/1/2005	125.47	123.54	-1.93	6E21A020691

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
7/15/2005	125.37	123.09	-2.27	6E21A020692
8/1/2005	125.25	123.09	-2.16	6E21A020693
8/15/2005	125.19	123.99	-1.19	6E21A020694
9/1/2005	125.11	122.73	-2.38	6E21A020695
9/15/2005	125.07	122.72	-2.35	6E21A020696
9/30/2005	125.02	122.83	-2.19	6E21A020697
10/15/2005	125.08	123.32	-1.76	6E21A020698
10/25/2005	125.12	123.97	-1.15	6E21A020699
12/23/2005	125.17	124.13	-1.04	6E21A020700
12/31/2005	125.17	123.95	-1.22	6E21A020701
1/15/2006	125.15	124.12	-1.03	6E21A020702
1/26/2006	125.13	123.90	-1.23	6E21A020703
2/16/2006	125.09	123.81	-1.28	6E21A020704
3/1/2006	125.06	123.96	-1.10	6E21A020705
3/15/2006	125.04	124.60	-0.44	6E21A020706
3/30/2006	125.01	123.44	-1.57	6E21A020707
5/6/2006	124.80	122.88	-1.93	6E21A020708
5/15/2006	124.72	122.83	-1.90	6E21A020709
6/1/2006	124.59	122.04	-2.54	6E21A020710
6/15/2006	124.47	121.84	-2.63	6E21A020711
7/1/2006	124.34	122.10	-2.23	6E21A020712
7/15/2006	124.22	122.13	-2.09	6E21A020713
8/1/2006	124.08	121.75	-2.33	6E21A020714
8/9/2006	124.03	121.72	-2.31	6E21A020715
10/6/2006	123.81	122.11	-1.70	6E21A020716
10/20/2006	123.80	123.26	-0.54	6E21A020717
10/31/2006	123.78	123.33	-0.45	6E21A020718
11/15/2006	123.79	122.25	-1.54	6E21A020719
11/30/2006	123.79	122.42	-1.37	6E21A020720
12/15/2006	123.79	122.47	-1.32	6E21A020721
12/31/2006	123.78	122.52	-1.27	6E21A020722
1/15/2007	123.77	122.13	-1.64	6E21A020723
1/31/2007	123.76	122.36	-1.40	6E21A020724
2/15/2007	123.72	122.14	-1.58	6E21A020725
2/28/2007	123.69	122.37	-1.32	6E21A020726
3/15/2007	123.62	121.63	-1.99	6E21A020727
3/27/2007	123.57	121.77	-1.80	6E21A020728
4/12/2007	123.47	121.39	-2.07	6E21A020729
5/16/2007	123.19	121.13	-2.06	6E21A020730
5/21/2007	123.14	121.04	-2.10	6E21A020731
5/31/2007	123.05	121.35	-1.71	6E21A020732
6/14/2007	122.92	121.14	-1.78	6E21A020733
6/30/2007	122.78	120.47	-2.31	6E21A020734
7/12/2007	122.67	120.82	-1.86	6E21A020735
8/9/2007	122.44	120.86	-1.58	6E21A020736
8/14/2007	122.41	120.91	-1.49	6E21A020737
8/31/2007	122.29	121.19	-1.10	6E21A020738
9/13/2007	122.25	121.05	-1.20	6E21A020739

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
12/5/2007	122.21	123.32	1.11	6E21A020740
12/14/2007	122.23	123.61	1.39	6E21A020741
12/31/2007	122.25	122.49	0.23	6E21A020742
1/15/2008	122.32	122.83	0.51	6E21A020743
1/31/2008	122.40	123.20	0.81	6E21A020744
2/14/2008	122.37	122.80	0.43	6E21A020745
2/21/2008	122.35	122.53	0.18	6E21A020746
2/29/2008	122.33	122.10	-0.23	6E21A020747
3/14/2008	122.26	121.82	-0.44	6E21A020748
3/20/2008	122.23	121.81	-0.43	6E21A020749
4/11/2008	122.09	121.41	-0.68	6E21A020750
4/15/2008	122.06	121.57	-0.49	6E21A020751
4/30/2008	121.95	120.91	-1.04	6E21A020752
5/14/2008	121.85	121.25	-0.59	6E21A020753
5/31/2008	121.73	120.73	-0.99	6E21A020754
6/14/2008	121.60	120.64	-0.96	6E21A020755
6/30/2008	121.45	120.85	-0.61	6E21A020756
7/15/2008	121.33	120.92	-0.41	6E21A020757
7/31/2008	121.21	120.74	-0.47	6E21A020758
8/14/2008	121.12	120.39	-0.73	6E21A020759
8/31/2008	121.02	120.31	-0.71	6E21A020760
9/11/2008	120.98	120.80	-0.19	6E21A020761
9/16/2008	120.97	120.54	-0.43	6E21A020762
9/30/2008	120.92	120.54	-0.38	6E21A020763
10/14/2008	120.91	120.00	-0.90	6E21A020764
10/31/2008	120.89	120.44	-0.45	6E21A020765
11/15/2008	120.90	120.82	-0.08	6E21A020766
11/30/2008	120.92	121.58	0.66	6E21A020767
12/1/2008	120.92	120.88	-0.04	6E21A020768
12/2/2008	120.93	120.87	-0.06	6E21A020769
12/5/2008	120.94	120.88	-0.07	6E21A020770
12/14/2008	121.00	121.22	0.22	6E21A020771
12/29/2008	121.09	121.82	0.74	6E21A020772
1/14/2009	121.09	121.48	0.39	6E21A020773
1/29/2009	121.07	121.48	0.41	6E21A020774
2/14/2009	121.07	122.09	1.02	6E21A020775
2/28/2009	121.08	121.38	0.30	6E21A020776
3/14/2009	121.03	120.88	-0.15	6E21A020777
3/31/2009	120.96	120.72	-0.24	6E21A020778
4/14/2009	120.86	120.79	-0.07	6E21A020779
4/30/2009	120.76	120.99	0.24	6E21A020780
5/15/2009	120.62	120.52	-0.10	6E21A020781
5/31/2009	120.47	120.35	-0.11	6E21A020782
6/15/2009	120.34	120.48	0.14	6E21A020783
6/30/2009	120.21	120.68	0.47	6E21A020784
7/14/2009	120.09	120.54	0.45	6E21A020785
7/31/2009	119.94	120.04	0.10	6E21A020786
8/14/2009	119.85	120.01	0.16	6E21A020787

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
8/31/2009	119.73	120.11	0.38	6E21A020788
9/14/2009	119.70	120.08	0.38	6E21A020789
9/30/2009	119.66	119.88	0.22	6E21A020790
10/14/2009	119.66	120.03	0.38	6E21A020791
10/31/2009	119.65	120.28	0.63	6E21A020792
11/15/2009	119.67	120.34	0.67	6E21A020793
11/30/2009	119.69	120.72	1.03	6E21A020794
12/25/2009	119.77	120.89	1.12	6E21A020795
12/31/2009	119.79	120.99	1.20	6E21A020796
1/15/2010	119.78	120.46	0.68	6E21A020797
1/31/2010	119.77	121.20	1.43	6E21A020798
2/15/2010	119.78	121.54	1.76	6E21A020799
2/28/2010	119.79	121.31	1.51	6E21A020800
3/15/2010	119.75	121.31	1.56	6E21A020801
3/31/2010	119.69	120.53	0.85	6E21A020802
4/15/2010	119.59	120.39	0.80	6E21A020803
4/30/2010	119.50	120.25	0.75	6E21A020804
5/14/2010	119.37	119.92	0.55	6E21A020805
5/31/2010	119.22	120.06	0.83	6E21A020806
6/15/2010	119.10	119.88	0.78	6E21A020807
6/30/2010	118.98	119.50	0.52	6E21A020808
7/15/2010	118.86	119.31	0.46	6E21A020809
7/31/2010	118.72	119.30	0.58	6E21A020810
8/15/2010	118.63	118.91	0.28	6E21A020811
8/31/2010	118.53	119.22	0.69	6E21A020812
9/15/2010	118.49	118.91	0.42	6E21A020813
9/30/2010	118.46	119.29	0.83	6E21A020814
10/15/2010	118.45	119.32	0.87	6E21A020815
10/31/2010	118.44	119.67	1.22	6E21A020816
11/15/2010	118.46	119.70	1.23	6E21A020817
11/18/2011	117.50	119.29	1.79	6E21A020818
4/17/2012	117.49	118.78	1.29	6E21A020819
5/3/2012	117.38	118.26	0.88	6E21A020820
11/14/2012	116.51	118.15	1.64	6E21A020821
4/9/2013	116.44	118.18	1.75	6E21A020822
11/13/2013	115.46	118.02	2.56	6E21A020823
11/25/2013	115.48	118.25	2.78	6E21A020824
2/5/2014	115.52	117.79	2.27	6E21A020825
4/9/2014	115.32	117.02	1.70	6E21A020826
6/3/2014	114.94	116.80	1.86	6E21A020827
8/6/2014	114.45	116.75	2.30	6E21A020828
12/9/2014	114.37	117.44	3.07	6E21A020829
3/30/2015	114.40	116.97	2.57	6E21A020830
4/15/2015	114.31	116.78	2.47	6E21A020831
11/19/2015	113.46	116.03	2.57	6E21A020832
4/12/2016	113.62	115.97	2.35	6E21A020833
11/9/1954	148.23	147.74	-0.49	6E21B010817

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
2/12/2004	125.38	127.62	2.25	6E21B010818
8/25/1980	142.05	139.41	-2.64	6E21B020819
2/12/2004	125.60	124.06	-1.54	6E21B020820
2/10/2005	125.79	123.51	-2.28	6E21B020821
5/5/2005	125.73	123.48	-2.26	6E21B020822
8/23/2005	125.06	122.53	-2.52	6E21B020823
1/5/2006	124.99	122.68	-2.31	6E21B020824
6/14/2006	124.46	121.86	-2.60	6E21B020825
8/25/1980	142.04	141.92	-0.12	6E21F010826
7/26/1965	138.91	141.93	3.02	6E23M010827
3/25/1994	136.72	134.68	-2.05	6E23M010828
8/24/1994	136.35	134.34	-2.01	6E23M010829
10/6/1994	136.27	134.40	-1.86	6E23M010830
12/21/1994	136.13	134.22	-1.91	6E23M010831
4/12/1995	135.60	134.25	-1.35	6E23M010832
6/21/1995	135.02	134.13	-0.89	6E23M010833
10/2/1995	134.61	133.92	-0.69	6E23M010834
12/28/1995	134.55	134.07	-0.48	6E23M010835
4/11/1996	134.29	133.31	-0.98	6E23M010836
8/9/1996	133.64	133.18	-0.46	6E23M010837
10/23/1996	133.50	134.01	0.51	6E23M010838
1/3/1997	133.49	133.28	-0.21	6E23M010839
5/9/1997	132.97	132.30	-0.67	6E23M010840
9/3/1997	132.67	132.15	-0.53	6E23M010841
12/3/1997	132.97	132.36	-0.61	6E23M010842
5/13/1998	132.74	132.21	-0.54	6E23M010843
11/12/1998	132.32	131.90	-0.41	6E23M010844
3/12/1999	132.16	123.67	-8.48	6E23M010845
5/17/1999	131.91	131.26	-0.64	6E23M010846
11/12/1999	131.56	130.99	-0.57	6E23M010847
9/15/2000	131.04	129.89	-1.15	6E23M010848
12/18/2000	130.85	129.80	-1.05	6E23M010849
5/17/2001	130.29	130.38	0.09	6E23M010850
10/17/2001	130.17	129.65	-0.53	6E23M010851
11/14/2001	130.13	129.83	-0.30	6E23M010852
2/12/2002	129.82	129.19	-0.63	6E23M010853
8/30/2002	129.28	129.16	-0.12	6E23M010854
12/13/2002	129.12	129.04	-0.08	6E23M010855
3/17/2003	128.77	128.86	0.08	6E23M010856
6/30/2003	128.30	128.79	0.50	6E23M010857
10/6/2003	128.36	128.76	0.40	6E23M010858
12/29/2003	128.18	128.64	0.46	6E23M010859
2/12/2004	128.01	128.86	0.85	6E23M010860
4/8/2004	127.57	128.25	0.67	6E23M010861
11/18/2004	127.81	128.15	0.34	6E23M010862

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
2/10/2005	127.95	128.49	0.54	6E23M010863
8/24/2005	127.27	127.79	0.52	6E23M010864
1/5/2006	127.04	127.94	0.90	6E23M010865
6/14/2006	126.08	127.21	1.13	6E23M010866
8/17/2006	126.28	126.14	-0.13	6E23M010867
1/10/2007	125.93	126.42	0.48	6E23M010868
6/1/2007	124.94	125.87	0.93	6E23M010869
9/21/2007	125.07	126.11	1.05	6E23M010870
5/8/2008	123.86	126.17	2.31	6E23M010871
8/12/2008	123.96	125.62	1.66	6E23M010872
5/13/1998	134.68	135.31	0.62	6E25R010890
11/12/1998	134.40	135.15	0.75	6E25R010891
3/12/1999	134.20	134.97	0.77	6E25R010892
5/17/1999	134.10	134.94	0.84	6E25R010893
11/22/1999	133.77	134.39	0.62	6E25R010894
3/24/2000	133.55	134.48	0.93	6E25R010895
6/29/2000	133.37	134.24	0.87	6E25R010896
9/15/2000	133.22	133.99	0.77	6E25R010897
12/18/2000	133.04	134.03	0.98	6E25R010898
5/17/2001	132.75	133.81	1.06	6E25R010899
10/17/2001	132.45	135.79	3.35	6E25R010900
11/17/2001	132.39	135.76	3.38	6E25R010901
2/12/2002	132.21	135.64	3.43	6E25R010902
8/20/2002	131.82	133.29	1.47	6E25R010903
12/13/2002	131.57	133.20	1.63	6E25R010904
3/17/2003	131.37	133.05	1.68	6E25R010905
6/30/2003	131.15	132.87	1.72	6E25R010906
10/6/2003	130.94	132.75	1.80	6E25R010907
12/29/2003	130.77	132.56	1.79	6E25R010908
2/12/2004	130.67	132.47	1.80	6E25R010909
4/8/2004	130.55	132.38	1.83	6E25R010910
11/18/2004	130.22	132.17	1.95	6E25R010911
5/5/2005	129.98	131.80	1.82	6E25R010912
8/23/2005	129.77	131.59	1.82	6E25R010913
10/12/2005	129.67	131.54	1.87	6E25R010914
1/5/2006	129.56	130.61	1.05	6E25R010915
2/22/2006	129.47	131.37	1.90	6E25R010916
6/12/2006	129.25	131.22	1.98	6E25R010917
6/14/2006	129.24	131.31	2.07	6E25R010918
8/17/2006	129.11	131.31	2.21	6E25R010919
1/10/2007	128.79	130.89	2.10	6E25R010920
2/12/2004	128.59	129.71	1.11	6E28Q010921
2/21/2008	124.89	127.45	2.56	6E28Q010922
12/1/2008	123.96	126.91	2.95	6E28Q010923
12/3/2008	123.97	127.11	3.14	6E28Q010924
5/20/2016	116.66	121.47	4.81	6E28Q010925

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/30/1980	140.65	140.99	0.33	6E29K020925
6/30/1987	138.11	141.90	3.79	6E29K020926
6/30/1991	135.99	139.46	3.47	6E29K020927
6/30/1993	136.61	134.71	-1.90	6E29K020928
6/30/1997	133.46	150.13	16.67	6E29K020929
6/2/1998	133.18	147.66	14.48	6E29K020930
6/29/1999	132.22	132.15	-0.07	6E29K020931
6/5/2000	131.25	131.60	0.35	6E29K020932
6/8/2001	130.27	130.62	0.36	6E29K020933
7/29/2002	129.42	128.58	-0.84	6E29K020934
7/31/2003	127.98	127.97	-0.01	6E29K020935
2/10/2004	127.75	127.67	-0.08	6E29K020936
2/12/2005	127.73	126.91	-0.82	6E29K020937
2/17/2006	126.90	126.57	-0.33	6E29K020938
5/21/2006	126.44	126.51	0.07	6E29K020939
3/8/2007	125.23	125.20	-0.03	6E29K020940
12/1/2008	122.92	123.13	0.21	6E29K020941
12/3/2008	122.91	123.45	0.54	6E29K020942
3/25/2010	121.68	122.51	0.83	6E29K020943
10/12/2010	120.70	121.53	0.83	6E29K020944
4/9/2013	118.37	119.49	1.12	6E29K020945
10/18/2013	118.39	119.49	1.10	6E29K020946
3/28/2014	117.58	119.15	1.57	6E29K020947
3/10/2015	116.27	118.91	2.64	6E29K020948
3/23/2016	115.33	118.57	3.24	6E29K020949
11/19/1952	152.31	156.15	3.84	6E29N010943
11/19/1953	151.26	154.34	3.08	6E29N010944
2/3/1954	151.21	153.37	2.16	6E29N010945
2/24/1954	151.16	153.57	2.41	6E29N010946
11/9/1954	150.11	153.34	3.23	6E29N010947
11/29/1955	148.96	150.85	1.89	6E29N010948
3/18/1956	148.80	151.40	2.60	6E29N010949
11/16/1956	147.82	150.97	3.15	6E29N010950
3/15/1957	147.76	149.29	1.53	6E29N010951
11/26/1957	146.90	149.96	3.06	6E29N010952
3/15/1958	146.86	149.30	2.44	6E29N010953
11/5/1958	145.81	145.78	-0.03	6E29N010954
11/24/1959	144.68	148.04	3.37	6E29N010955
2/27/1960	144.76	147.75	2.99	6E29N010956
11/22/1960	143.71	147.19	3.48	6E29N010957
3/8/1961	143.65	146.75	3.10	6E29N010958
10/26/1961	142.69	146.33	3.63	6E29N010959
3/15/1962	142.69	146.09	3.41	6E29N010960
11/2/1962	141.68	146.34	4.66	6E29N010961
3/15/1963	141.65	145.58	3.93	6E29N010962
10/31/1963	140.95	146.14	5.19	6E29N010963

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
3/20/1964	140.94	145.87	4.93	6E29N010964
11/12/1964	140.03	144.91	4.88	6E29N010965
3/19/1965	140.45	145.32	4.87	6E29N010966
7/29/1965	140.40	141.27	0.87	6E29N010967
7/30/1965	140.39	141.27	0.88	6E29N010968
10/26/1965	140.05	144.41	4.37	6E29N010969
3/3/1966	140.24	144.58	4.34	6E29N010970
10/26/1966	140.14	144.36	4.22	6E29N010971
3/23/1967	140.23	144.46	4.24	6E29N010972
10/24/1967	139.98	144.33	4.35	6E29N010973
3/13/1968	140.07	144.35	4.27	6E29N010974
11/8/1968	140.69	144.34	3.65	6E29N010975
3/27/1969	140.77	144.51	3.74	6E29N010976
10/28/1969	140.54	144.57	4.03	6E29N010977
3/23/1970	140.62	144.68	4.07	6E29N010978
11/10/1970	140.33	144.59	4.26	6E29N010979
3/30/1971	140.39	144.65	4.26	6E29N010980
3/10/2009	123.60	125.67	2.07	6E29N020981
6/30/1995	137.68	137.69	0.01	6E32D010982
6/30/1997	135.19	135.55	0.36	6E32D010983
6/2/1998	135.04	134.46	-0.59	6E32D010984
6/29/1999	133.19	133.51	0.32	6E32D010985
6/5/2000	132.54	132.38	-0.16	6E32D010986
6/8/2001	131.75	131.35	-0.40	6E32D010987
7/29/2002	129.19	130.07	0.88	6E32D010988
7/31/2003	128.19	128.24	0.04	6E32D010989
5/13/2005	127.13	127.60	0.47	6E32D010990
5/21/2006	127.42	126.99	-0.44	6E32D010991
10/12/2010	120.61	122.24	1.63	6E32D010992
4/9/2013	119.52	121.15	1.63	6E32D010993
10/18/2013	116.67	121.15	4.48	6E32D010994
3/28/2014	117.65	121.15	3.50	6E32D010995
3/10/2015	117.08	120.54	3.46	6E32D010996
3/23/2016	116.38	120.54	4.16	6E32D010997
6/30/1980	139.95	138.93	-1.02	6E32R010992
5/10/1983	140.23	138.81	-1.42	6E32R010993
5/26/1983	140.21	138.75	-1.46	6E32R010994
9/30/1983	140.46	138.81	-1.65	6E32R010995
12/11/1983	140.34	138.87	-1.47	6E32R010996
4/6/1984	140.26	138.90	-1.36	6E32R010997
7/19/1984	140.11	138.75	-1.36	6E32R010998
9/21/1984	140.01	138.72	-1.29	6E32R010999
2/16/1985	140.00	138.90	-1.10	6E32R011000
5/26/1985	139.89	138.59	-1.29	6E32R011001
1/20/1986	139.65	138.44	-1.20	6E32R011002

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
4/22/1986	139.60	138.41	-1.19	6E32R011003
9/11/1986	139.33	137.77	-1.56	6E32R011004
12/8/1986	139.24	137.92	-1.32	6E32R011005
4/27/1987	139.13	137.83	-1.30	6E32R011006
6/30/1987	139.01	138.02	-0.99	6E32R011007
7/27/1987	138.95	137.74	-1.21	6E32R011008
11/19/1987	138.83	137.89	-0.94	6E32R011009
1/20/1988	138.81	137.92	-0.88	6E32R011010
4/1/1988	138.75	137.34	-1.40	6E32R011011
6/8/1988	138.63	137.28	-1.35	6E32R011012
10/25/1988	138.33	137.10	-1.23	6E32R011013
2/3/1989	138.21	137.25	-0.95	6E32R011014
8/8/1989	137.90	136.40	-1.50	6E32R011015
10/26/1989	137.73	136.31	-1.42	6E32R011016
2/6/1990	137.59	136.49	-1.10	6E32R011017
9/1/1990	137.78	135.85	-1.93	6E32R011018
1/14/1991	137.36	136.73	-0.63	6E32R011019
2/19/1991	137.30	136.40	-0.90	6E32R011020
3/5/1991	137.28	136.61	-0.67	6E32R011021
3/19/1991	137.27	136.49	-0.78	6E32R011022
4/11/1991	137.24	136.48	-0.76	6E32R011023
5/30/1991	137.16	135.63	-1.52	6E32R011024
6/30/1991	137.10	135.58	-1.52	6E32R011025
10/31/1991	136.88	135.67	-1.21	6E32R011026
1/7/1992	136.81	135.85	-0.96	6E32R011027
3/12/1992	136.78	135.97	-0.80	6E32R011028
5/12/1992	136.91	135.55	-1.37	6E32R011029
7/7/1992	137.73	135.39	-2.34	6E32R011030
9/2/1992	137.44	135.23	-2.22	6E32R011031
10/13/1992	137.26	135.21	-2.05	6E32R011032
12/8/1992	137.10	135.30	-1.80	6E32R011033
1/21/1993	137.32	135.52	-1.80	6E32R011034
2/3/1993	137.48	135.52	-1.96	6E32R011035
2/12/1993	137.49	135.52	-1.97	6E32R011036
2/24/1993	137.48	135.55	-1.94	6E32R011037
3/11/1993	137.45	135.39	-2.06	6E32R011038
3/27/1993	137.41	135.18	-2.23	6E32R011039
4/16/1993	137.35	135.09	-2.27	6E32R011040
5/11/1993	137.29	135.09	-2.20	6E32R011041
6/30/1993	137.16	135.58	-1.58	6E32R011042
7/2/1993	137.15	134.88	-2.28	6E32R011043
8/19/1993	137.03	134.81	-2.22	6E32R011044
10/20/1993	136.91	134.75	-2.16	6E32R011045
12/24/1993	136.85	134.75	-2.10	6E32R011046
2/11/1994	136.82	134.97	-1.86	6E32R011047
3/25/1994	136.81	134.85	-1.96	6E32R011048
5/25/1994	137.13	134.54	-2.59	6E32R011049
8/24/1994	137.00	134.36	-2.65	6E32R011050

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
10/6/1994	136.87	134.36	-2.52	6E32R011051
12/21/1994	136.74	134.27	-2.47	6E32R011052
2/24/1995	136.71	134.36	-2.35	6E32R011053
4/4/1995	136.68	134.21	-2.48	6E32R011054
6/21/1995	136.57	133.96	-2.61	6E32R011055
10/2/1995	136.36	133.84	-2.52	6E32R011056
12/28/1995	136.24	133.75	-2.49	6E32R011057
4/11/1996	136.10	133.47	-2.62	6E32R011058
8/9/1996	135.76	133.14	-2.62	6E32R011059
10/23/1996	135.53	133.14	-2.39	6E32R011060
1/3/1997	135.36	133.11	-2.25	6E32R011061
5/9/1997	135.11	132.71	-2.40	6E32R011062
9/3/1997	135.23	132.32	-2.92	6E32R011063
12/3/1997	135.04	132.38	-2.66	6E32R011064
5/13/1998	134.78	132.04	-2.74	6E32R011065
6/2/1998	134.72	132.19	-2.53	6E32R011066
11/12/1998	134.20	131.61	-2.59	6E32R011067
3/12/1999	133.92	131.49	-2.43	6E32R011068
2/22/2002	130.87	129.48	-1.38	6E32R011069
12/5/2008	124.16	123.96	-0.19	6E32R011070
3/11/2009	124.02	123.96	-0.06	6E32R011071
2/9/2010	122.90	123.51	0.61	6E32R011072
3/25/2010	122.80	123.29	0.49	6E32R011073
11/18/2010	121.93	122.49	0.56	6E32R011074
11/18/2011	120.97	122.48	1.51	6E32R011075
2/6/2012	120.88	122.08	1.20	6E32R011076
5/3/2012	120.67	121.88	1.21	6E32R011077
11/14/2012	120.07	121.64	1.57	6E32R011078
4/9/2013	119.83	121.66	1.83	6E32R011079
11/13/2013	119.18	121.24	2.06	6E32R011080
4/9/2014	118.84	121.26	2.42	6E32R011081
6/3/2014	118.67	121.05	2.37	6E32R011082
12/9/2014	118.09	120.94	2.86	6E32R011083
3/30/2015	117.87	121.00	3.13	6E32R011084
4/15/2015	117.83	120.91	3.08	6E32R011085
11/18/2015	117.23	120.85	3.62	6E32R011086
3/23/2016	117.04	108.22	-8.82	6E32R011087
4/12/2016	117.00	120.53	3.53	6E32R011088
2/12/2004	128.49	126.19	-2.30	6E33C021072
2/10/2005	127.92	126.16	-1.76	6E33C021073
12/1/2008	123.45	122.77	-0.68	6E33C021074
12/3/2008	123.48	123.30	-0.18	6E33C021075
2/12/2004	128.54	131.85	3.31	6E33J011076
2/10/2005	127.90	132.88	4.98	6E33J011077
10/12/2005	127.27	132.18	4.91	6E33J011078
2/17/2006	127.08	129.98	2.91	6E33J011079

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
2/22/2006	127.07	132.22	5.15	6E33J011080
6/12/2006	126.80	131.87	5.07	6E33J011081
1/23/2007	126.07	131.72	5.65	6E33J011082
1/26/2007	126.07	131.75	5.69	6E33J011083
2/22/2007	126.04	131.76	5.72	6E33J011084
9/28/2007	125.28	131.02	5.74	6E33J011085
2/13/2008	125.05	131.13	6.08	6E33J011086
2/21/2008	125.05	131.08	6.03	6E33J011087
12/1/2008	124.16	130.61	6.45	6E33J011088
12/2/2008	124.16	131.05	6.89	6E33J011089
4/14/2009	124.03	130.57	6.53	6E33J011090
3/25/2010	123.05	130.02	6.97	6E33J011091
5/20/2016	117.50	126.65	9.15	6E33J011092
6/30/1980	138.70	140.20	1.50	6E33Q011090
6/30/1987	137.73	140.81	3.08	6E33Q011091
6/30/1991	135.92	134.41	-1.51	6E33Q011092
6/30/1993	135.92	132.89	-3.04	6E33Q011093
6/30/1995	135.45	132.89	-2.57	6E33Q011094
2/12/2004	127.45	125.66	-1.79	6E33Q011095
2/10/2005	127.23	125.36	-1.88	6E33Q011096
2/21/2008	123.81	122.88	-0.93	6E33Q011097
12/1/2008	122.74	122.50	-0.24	6E33Q011098
3/25/2010	121.74	121.56	-0.18	6E33Q011099
11/18/2010	120.06	120.80	0.74	6E33Q011100
11/18/2011	119.72	120.19	0.47	6E33Q011101
4/17/2012	119.76	119.52	-0.24	6E33Q011102
12/21/2012	118.87	119.70	0.83	6E33Q011103
4/9/2013	118.77	119.24	0.47	6E33Q011104
11/13/2013	117.87	118.91	1.03	6E33Q011105
6/25/2014	117.36	118.80	1.44	6E33Q011106
12/9/2014	116.79	119.15	2.36	6E33Q011107
3/30/2015	116.76	119.71	2.95	6E33Q011108
4/15/2015	116.70	119.56	2.86	6E33Q011109
11/19/2015	115.93	118.73	2.80	6E33Q011110
4/12/2016	115.94	118.72	2.78	6E33Q011111
2/16/1985	139.15	139.82	0.67	6E34D011099
5/26/1985	139.10	138.42	-0.68	6E34D011100
1/20/1986	138.86	139.48	0.62	6E34D011101
4/22/1986	138.83	138.08	-0.75	6E34D011102
9/11/1986	138.66	138.51	-0.15	6E34D011103
12/8/1986	138.56	138.97	0.40	6E34D011104
4/27/1987	138.46	138.57	0.11	6E34D011105
7/27/1987	138.34	138.63	0.29	6E34D011106
11/19/1987	138.18	138.72	0.54	6E34D011107
1/20/1988	138.15	139.30	1.15	6E34D011108
4/1/1988	138.11	137.78	-0.33	6E34D011109

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/8/1988	138.03	137.14	-0.89	6E34D011110
10/25/1988	137.80	136.31	-1.49	6E34D011111
2/3/1989	137.67	137.20	-0.47	6E34D011112
8/8/1989	137.37	137.56	0.19	6E34D011113
10/26/1989	137.22	138.17	0.96	6E34D011114
2/6/1990	137.08	137.99	0.91	6E34D011115
9/1/1990	136.74	137.81	1.06	6E34D011116
1/14/1991	136.61	139.00	2.38	6E34D011117
2/19/1991	136.60	138.78	2.18	6E34D011118
3/5/1991	136.59	139.21	2.62	6E34D011119
3/19/1991	136.59	138.65	2.06	6E34D011120
4/11/1991	136.58	138.91	2.33	6E34D011121
5/9/1991	136.56	138.95	2.39	6E34D011122
5/30/1991	136.53	138.36	1.82	6E34D011123
7/23/1991	136.46	138.48	2.02	6E34D011124
10/31/1991	136.32	138.69	2.38	6E34D011125
1/7/1992	136.25	138.69	2.44	6E34D011126
3/12/1992	136.21	138.65	2.43	6E34D011127
5/12/1992	136.16	138.45	2.29	6E34D011128
7/7/1992	136.18	137.84	1.66	6E34D011129
9/2/1992	136.25	137.84	1.59	6E34D011130
10/13/1992	136.30	137.78	1.47	6E34D011131
12/8/1992	136.38	137.96	1.58	6E34D011132
1/21/1993	136.46	138.30	1.84	6E34D011133
2/3/1993	136.49	138.20	1.72	6E34D011134
2/12/1993	136.51	138.23	1.73	6E34D011135
2/24/1993	136.53	138.20	1.67	6E34D011136
3/11/1993	136.56	137.96	1.40	6E34D011137
3/27/1993	136.58	137.90	1.32	6E34D011138
4/16/1993	136.61	137.44	0.84	6E34D011139
5/11/1993	136.63	137.69	1.06	6E34D011140
7/2/1993	136.63	137.72	1.08	6E34D011141
8/19/1993	136.61	137.87	1.26	6E34D011142
10/20/1993	136.57	137.99	1.42	6E34D011143
12/24/1993	136.55	138.05	1.51	6E34D011144
2/11/1994	136.53	138.05	1.52	6E34D011145
3/25/1994	136.52	137.29	0.77	6E34D011146
5/25/1994	136.48	136.71	0.23	6E34D011147
8/24/1994	136.39	136.68	0.29	6E34D011148
10/6/1994	136.33	136.95	0.62	6E34D011149
12/21/1994	136.25	136.95	0.70	6E34D011150
2/24/1995	136.21	137.35	1.14	6E34D011151
4/12/1995	136.17	137.17	1.00	6E34D011152
6/21/1995	136.07	137.26	1.19	6E34D011153
10/2/1995	135.84	137.35	1.51	6E34D011154
12/28/1995	135.66	137.41	1.76	6E34D011155
4/11/1996	135.47	138.08	2.61	6E34D011156
8/9/1996	135.18	137.05	1.86	6E34D011157

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
10/23/1996	134.97	137.08	2.11	6E34D011158
1/3/1997	134.80	137.14	2.34	6E34D011159
5/9/1997	134.55	136.92	2.38	6E34D011160
9/3/1997	134.27	136.80	2.54	6E34D011161
12/3/1997	134.10	136.83	2.74	6E34D011162
5/13/1998	133.92	135.46	1.54	6E34D011163
11/12/1998	133.54	135.31	1.77	6E34D011164
3/12/1999	133.33	135.67	2.35	6E34D011165
11/22/1999	132.73	134.76	2.03	6E34D011166
3/24/2000	132.49	134.94	2.45	6E34D011167
6/29/2000	132.27	134.70	2.43	6E34D011168
9/15/2000	132.03	134.58	2.55	6E34D011169
5/17/2001	131.50	135.00	3.50	6E34D011170
10/17/2001	131.07	134.88	3.82	6E34D011171
11/14/2001	130.99	134.85	3.86	6E34D011172
2/12/2002	130.79	134.76	3.97	6E34D011173
8/30/2002	130.28	134.61	4.33	6E34D011174
12/13/2002	129.98	133.21	3.23	6E34D011175
3/17/2003	129.79	133.02	3.23	6E34D011176
6/30/2003	129.53	132.63	3.09	6E34D011177
10/6/2003	129.22	132.81	3.59	6E34D011178
12/29/2003	129.00	132.96	3.96	6E34D011179
4/8/2004	128.80	132.66	3.86	6E34D011180
10/7/2004	128.30	132.47	4.17	6E34D011181
2/10/2005	128.16	131.80	3.64	6E34D011182
1/5/2006	127.48	131.68	4.21	6E34D011183
6/14/2006	127.12	131.04	3.92	6E34D011184
8/17/2006	126.88	130.92	4.04	6E34D011185
1/10/2007	126.49	131.10	4.61	6E34D011186
6/4/2007	126.16	130.92	4.76	6E34D011187
8/12/2007	125.89	130.10	4.21	6E34D011188
9/21/2007	125.74	130.58	4.85	6E34D011189
1/8/2008	125.48	130.89	5.41	6E34D011190
5/8/2008	125.26	130.52	5.26	6E34D011191
12/1/2008	124.57	130.42	5.85	6E34D011192
12/4/2008	124.57	130.83	6.26	6E34D011193
6/26/1952	147.43	153.83	6.39	6E34K011194
2/24/1954	146.48	152.52	6.04	6E34K011195
11/9/1954	145.99	151.82	5.83	6E34K011196
7/29/1965	139.19	145.49	6.30	6E34K011197
8/27/1980	139.39	141.37	1.98	6E34K011198
12/1/2008	125.17	130.07	4.90	6E34K011199
12/4/2008	125.16	130.57	5.40	6E34K011200
7/19/1984	139.14	139.02	-0.11	6E34M011202
2/16/1985	139.05	139.30	0.25	6E34M011203
5/26/1985	138.98	137.71	-1.27	6E34M011204

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
1/20/1986	138.75	139.08	0.33	6E34M011205
4/22/1986	138.73	137.92	-0.81	6E34M011206
9/11/1986	138.53	137.89	-0.63	6E34M011207
12/8/1986	138.44	138.53	0.09	6E34M011208
4/27/1987	138.36	138.23	-0.13	6E34M011209
7/27/1987	138.21	138.29	0.08	6E34M011210
11/19/1987	138.06	138.75	0.69	6E34M011211
1/20/1988	138.06	138.87	0.81	6E34M011212
4/1/1988	138.03	137.53	-0.50	6E34M011213
6/8/1988	137.93	137.59	-0.34	6E34M011214
10/25/1988	137.68	138.14	0.46	6E34M011215
2/3/1989	137.56	138.35	0.79	6E34M011216
8/8/1989	137.22	137.71	0.49	6E34M011217
10/26/1989	137.06	138.14	1.08	6E34M011218
2/6/1990	136.95	137.92	0.97	6E34M011219
9/1/1990	136.62	136.49	-0.13	6E34M011220
1/14/1991	136.52	139.11	2.59	6E34M011221
2/19/1991	136.52	138.96	2.44	6E34M011222
3/5/1991	136.52	139.19	2.66	6E34M011223
3/19/1991	136.52	138.78	2.25	6E34M011224
4/11/1991	136.52	138.88	2.37	6E34M011225
5/9/1991	136.49	138.75	2.26	6E34M011226
5/30/1991	136.46	138.14	1.68	6E34M011227
7/23/1991	136.37	138.08	1.71	6E34M011228
10/31/1991	136.21	138.08	1.86	6E34M011229
1/7/1992	136.16	138.08	1.91	6E34M011230
3/12/1992	136.14	138.29	2.15	6E34M011231
5/12/1992	136.10	137.83	1.74	6E34M011232
7/7/1992	136.12	137.50	1.38	6E34M011233
9/2/1992	136.18	137.65	1.47	6E34M011234
9/13/1992	136.19	137.62	1.42	6E34M011235
12/8/1992	136.29	137.83	1.54	6E34M011236
1/21/1993	136.38	138.11	1.73	6E34M011237
2/3/1993	136.41	138.05	1.63	6E34M011238
2/12/1993	136.44	138.08	1.64	6E34M011239
2/24/1993	136.46	138.05	1.58	6E34M011240
3/11/1993	136.49	137.86	1.37	6E34M011241
3/27/1993	136.52	137.77	1.25	6E34M011242
4/16/1993	136.54	137.47	0.93	6E34M011243
5/11/1993	136.55	137.59	1.04	6E34M011244
7/2/1993	136.53	137.56	1.03	6E34M011245
8/19/1993	136.48	137.53	1.04	6E34M011246
10/20/1993	136.43	137.68	1.25	6E34M011247
12/24/1993	136.41	137.74	1.33	6E34M011248
2/11/1994	136.42	137.83	1.42	6E34M011249
3/25/1994	136.41	137.80	1.39	6E34M011250
5/25/1994	136.38	137.56	1.18	6E34M011251
8/24/1994	136.29	137.50	1.21	6E34M011252

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
10/6/1994	136.23	137.50	1.27	6E34M011253
12/21/1994	136.17	137.50	1.33	6E34M011254
2/24/1995	136.15	137.53	1.38	6E34M011255
4/12/1995	136.11	137.41	1.29	6E34M011256
6/21/1995	136.00	137.25	1.25	6E34M011257
10/2/1995	135.76	137.28	1.52	6E34M011258
12/26/1995	135.61	137.28	1.68	6E34M011259
4/11/1996	135.44	137.10	1.66	6E34M011260
8/9/1996	135.11	136.95	1.83	6E34M011261
10/23/1996	134.89	136.92	2.03	6E34M011262
1/3/1997	134.74	136.95	2.21	6E34M011263
5/9/1997	134.51	136.73	2.22	6E34M011264
9/3/1997	134.23	136.58	2.36	6E34M011265
12/3/1997	134.08	136.73	2.66	6E34M011266
5/13/1998	133.93	136.58	2.65	6E34M011267
11/12/1998	133.48	136.34	2.86	6E34M011268
3/12/1999	133.28	136.25	2.96	6E34M011269
11/22/1999	132.62	135.73	3.10	6E34M011270
2/17/2000	132.47	135.73	3.26	6E34M011271
3/24/2000	132.41	135.67	3.25	6E34M011272
6/29/2000	132.15	135.30	3.15	6E34M011273
9/15/2000	131.87	135.24	3.37	6E34M011274
12/18/2000	131.62	135.27	3.66	6E34M011275
5/17/2001	131.37	135.18	3.81	6E34M011276
10/17/2001	130.87	135.03	4.16	6E34M011277
11/17/2001	130.79	135.00	4.21	6E34M011278
2/12/2002	130.62	134.88	4.26	6E34M011279
8/30/2002	130.06	134.69	4.63	6E34M011280
12/13/2002	129.76	134.57	4.81	6E34M011281
3/17/2003	129.61	134.48	4.87	6E34M011282
6/30/2003	129.34	133.96	4.62	6E34M011283
10/6/2003	128.99	134.14	5.15	6E34M011284
12/29/2003	128.78	133.96	5.18	6E34M011285
2/12/2004	128.71	133.93	5.22	6E34M011286
4/8/2004	128.62	133.75	5.13	6E34M011287
7/23/2004	128.33	133.29	4.96	6E34M011288
11/16/2004	128.01	133.44	5.43	6E34M011289
2/10/2005	128.03	133.35	5.32	6E34M011290
8/23/2005	127.60	132.99	5.38	6E34M011291
10/20/2005	127.41	130.04	2.63	6E34M011292
1/5/2006	127.29	131.71	4.41	6E34M011293
6/12/2006	126.95	132.32	5.37	6E34M011294
6/14/2006	126.95	131.95	5.00	6E34M011295
8/17/2006	126.67	132.22	5.55	6E34M011296
1/10/2007	126.27	132.10	5.83	6E34M011297
9/21/2007	125.51	128.44	2.94	6E34M011298
12/1/2008	124.35	128.31	3.96	6E34M011299
12/4/2008	124.35	128.77	4.42	6E34M011300

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
12/21/1954	145.09	149.48	4.39	6E35N011301
3/7/1955	145.03	149.26	4.23	6E35N011302
11/28/1955	144.63	148.44	3.81	6E35N011303
3/18/1956	144.51	147.19	2.68	6E35N011304
11/16/1956	144.04	148.05	4.00	6E35N011305
3/15/1957	143.90	145.78	1.88	6E35N011306
11/26/1957	143.42	144.30	0.89	6E35N011307
3/15/1958	143.29	145.59	2.30	6E35N011308
4/21/1958	143.25	145.30	2.06	6E35N011309
5/5/1958	143.22	146.31	3.09	6E35N011310
6/23/1958	143.13	141.31	-1.82	6E35N011311
7/22/1958	143.08	142.01	-1.06	6E35N011312
8/14/1958	143.03	141.34	-1.69	6E35N011313
9/23/1958	142.95	141.49	-1.45	6E35N011314
10/20/1958	142.90	142.65	-0.25	6E35N011315
11/12/1958	142.86	144.21	1.34	6E35N011316
1/5/1959	142.79	146.22	3.43	6E35N011317
1/26/1959	142.76	146.64	3.88	6E35N011318
2/18/1959	142.74	146.71	3.97	6E35N011319
3/12/1959	142.71	144.33	1.62	6E35N011320
3/19/1959	142.70	144.42	1.72	6E35N011321
5/12/1959	142.60	142.07	-0.53	6E35N011322
6/11/1959	142.54	142.86	0.32	6E35N011323
11/24/1959	142.23	144.95	2.72	6E35N011324
2/27/1960	142.15	143.41	1.26	6E35N011325
11/22/1960	141.69	144.74	3.05	6E35N011326
3/8/1961	141.56	143.07	1.51	6E35N011327
10/26/1961	141.14	133.97	-7.17	6E35N011328
3/15/1962	140.97	145.39	4.42	6E35N011329
11/2/1962	140.55	144.31	3.76	6E35N011330
1/23/1963	140.45	145.55	5.10	6E35N011331
2/12/1963	140.42	145.39	4.97	6E35N011332
3/15/1963	140.38	128.78	-11.61	6E35N011333
4/10/1963	140.35	142.41	2.07	6E35N011334
8/8/1963	140.13	144.84	4.71	6E35N011335
9/4/1963	140.08	144.15	4.07	6E35N011336
10/31/1963	140.05	144.59	4.54	6E35N011337
11/12/1963	140.05	144.69	4.64	6E35N011338
12/5/1963	140.04	144.56	4.52	6E35N011339
1/6/1964	140.02	145.03	5.01	6E35N011340
2/5/1964	139.99	137.65	-2.34	6E35N011341
3/9/1964	139.96	133.80	-6.17	6E35N011342
3/20/1964	139.95	144.40	4.45	6E35N011343
4/3/1964	139.94	135.41	-4.53	6E35N011344
7/7/1964	139.80	143.70	3.90	6E35N011345
7/17/1964	139.78	143.69	3.91	6E35N011346
8/5/1964	139.75	139.61	-0.14	6E35N011347

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/2/1964	139.61	144.51	4.91	6E35N011348
12/1/1964	139.58	144.62	5.04	6E35N011349
1/6/1965	139.54	141.76	2.22	6E35N011350
2/1/1965	139.51	134.25	-5.27	6E35N011351
4/5/1965	139.44	144.48	5.04	6E35N011352
5/24/1965	139.37	144.37	5.00	6E35N011353
6/24/1965	139.33	144.50	5.18	6E35N011354
6/29/1965	139.32	144.50	5.18	6E35N011355
7/30/1965	139.27	144.22	4.95	6E35N011356
8/3/1965	139.27	141.61	2.35	6E35N011357
10/4/1965	139.18	144.41	5.23	6E35N011358
10/26/1965	139.15	129.70	-9.45	6E35N011359
12/10/1965	139.14	144.39	5.25	6E35N011360
1/10/1966	139.13	142.50	3.37	6E35N011361
2/1/1966	139.12	144.39	5.27	6E35N011362
3/4/1966	139.10	143.97	4.87	6E35N011363
3/10/1966	139.09	131.43	-7.66	6E35N011364
7/6/1966	138.94	144.19	5.25	6E35N011365
8/1/1966	138.91	144.58	5.67	6E35N011366
10/26/1966	138.82	138.56	-0.25	6E35N011367
1/13/1967	138.80	144.14	5.35	6E35N011368
3/23/1967	138.77	140.83	2.06	6E35N011369
10/24/1967	138.58	128.96	-9.62	6E35N011370
11/8/1968	138.39	138.14	-0.25	6E35N011371
3/27/1969	138.49	140.41	1.92	6E35N011372
10/28/1969	138.43	137.50	-0.93	6E35N011373
3/23/1970	138.48	142.99	4.51	6E35N011374
11/12/1970	138.39	136.33	-2.06	6E35N011375
3/30/1971	138.40	142.97	4.58	6E35N011376
12/26/1978	137.92	140.68	2.76	6E35N011377
8/8/1980	139.04	140.27	1.23	6E35N011378
2/12/2004	129.96	131.40	1.44	6E35N011379
2/10/2005	129.33	131.10	1.77	6E35N011380
5/5/2005	129.25	130.58	1.33	6E35N011381
10/12/2005	128.91	130.26	1.35	6E35N011382
6/12/2006	128.45	129.90	1.44	6E35N011383
6/9/2009	125.91	128.68	2.76	6E35N011384
11/19/2015	120.48	125.21	4.73	6E35N011385
4/12/2016	120.25	124.91	4.66	6E35N011386
12/11/2008	127.10	130.08	2.98	6E35Q011385
12/1/2009	126.31	129.45	3.14	6E35Q011386
5/4/2010	125.96	129.11	3.15	6E35Q011387
11/18/2010	125.47	129.06	3.59	6E35Q011388
11/18/2011	124.66	129.04	4.38	6E35Q011389
4/11/2012	124.38	128.47	4.09	6E35Q011390
11/14/2012	123.91	128.23	4.31	6E35Q011391
4/9/2013	123.60	128.04	4.44	6E35Q011392

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/13/2013	123.11	127.75	4.64	6E35Q011393
4/10/2014	122.79	127.60	4.80	6E35Q011394
12/9/2014	122.23	127.24	5.01	6E35Q011395
3/30/2015	121.99	127.14	5.15	6E35Q011396
4/15/2015	121.96	127.09	5.13	6E35Q011397
11/19/2015	121.50	126.82	5.32	6E35Q011398
4/12/2016	121.22	126.60	5.38	6E35Q011399
4/4/1951	145.55	148.10	2.55	6E36Q011387
11/19/1953	144.72	146.68	1.96	6E36Q011388
2/24/1954	144.62	146.54	1.93	6E36Q011389
11/9/1954	144.30	144.34	0.04	6E36Q011390
3/7/1955	144.21	145.57	1.37	6E36Q011391
11/28/1955	143.89	144.20	0.31	6E36Q011392
3/18/1956	143.78	143.42	-0.36	6E36Q011393
7/2/1956	143.61	143.85	0.23	6E36Q011394
11/16/1956	143.38	143.69	0.30	6E36Q011395
3/15/1957	143.24	143.32	0.08	6E36Q011396
11/26/1957	142.84	142.63	-0.21	6E36Q011397
3/15/1958	142.72	143.27	0.55	6E36Q011398
4/21/1958	142.67	142.43	-0.24	6E36Q011399
5/5/1958	142.65	141.39	-1.26	6E36Q011400
6/23/1958	142.59	140.81	-1.77	6E36Q011401
7/22/1958	142.54	142.00	-0.54	6E36Q011402
8/14/1958	142.51	140.42	-2.09	6E36Q011403
9/23/1958	142.45	140.51	-1.94	6E36Q011404
10/20/1958	142.41	140.39	-2.02	6E36Q011405
11/5/1958	142.39	141.02	-1.36	6E36Q011406
11/12/1958	142.38	140.94	-1.44	6E36Q011407
1/5/1959	142.31	142.67	0.37	6E36Q011408
1/26/1959	142.28	143.19	0.91	6E36Q011409
3/12/1959	142.22	143.34	1.12	6E36Q011410
3/19/1959	142.22	142.67	0.46	6E36Q011411
5/12/1959	142.14	141.51	-0.62	6E36Q011412
6/11/1959	142.09	140.87	-1.21	6E36Q011413
11/24/1959	141.82	141.74	-0.07	6E36Q011414
2/27/1960	141.72	141.71	-0.01	6E36Q011415
11/22/1960	141.34	141.47	0.13	6E36Q011416
3/8/1961	141.21	142.43	1.22	6E36Q011417
10/26/1961	140.85	141.86	1.01	6E36Q011418
3/15/1962	140.67	142.43	1.77	6E36Q011419
11/2/1962	140.32	141.90	1.58	6E36Q011420
1/10/1963	140.23	142.79	2.57	6E36Q011421
2/12/1963	140.19	142.62	2.43	6E36Q011422
3/11/1963	140.15	142.22	2.06	6E36Q011423
3/15/1963	140.15	142.32	2.18	6E36Q011424
4/10/1963	140.11	141.79	1.68	6E36Q011425
5/7/1963	140.08	141.62	1.54	6E36Q011426

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/18/1963	140.01	140.88	0.87	6E36Q011427
7/9/1963	139.98	141.03	1.04	6E36Q011428
8/8/1963	139.94	140.93	0.99	6E36Q011429
9/4/1963	139.89	140.92	1.03	6E36Q011430
10/8/1963	139.86	141.15	1.28	6E36Q011431
10/31/1963	139.87	142.18	2.30	6E36Q011432
11/12/1963	139.88	141.89	2.01	6E36Q011433
12/5/1963	139.87	142.03	2.16	6E36Q011434
1/6/1964	139.84	142.89	3.05	6E36Q011435
2/5/1964	139.81	142.30	2.49	6E36Q011436
3/9/1964	139.78	141.80	2.02	6E36Q011437
3/20/1964	139.77	142.39	2.62	6E36Q011438
4/3/1964	139.76	141.60	1.84	6E36Q011439
5/8/1964	139.72	141.04	1.32	6E36Q011440
6/3/1964	139.69	140.31	0.62	6E36Q011441
7/7/1964	139.65	139.91	0.26	6E36Q011442
8/5/1964	139.61	139.89	0.28	6E36Q011443
9/11/1964	139.56	140.24	0.67	6E36Q011444
9/30/1964	139.54	140.42	0.89	6E36Q011445
11/2/1964	139.49	141.28	1.79	6E36Q011446
12/1/1964	139.46	141.78	2.33	6E36Q011447
1/6/1965	139.41	141.98	2.56	6E36Q011448
2/1/1965	139.38	142.04	2.66	6E36Q011449
3/3/1965	139.35	141.93	2.58	6E36Q011450
4/5/1965	139.31	141.29	1.98	6E36Q011451
5/5/1965	139.28	141.03	1.76	6E36Q011452
5/24/1965	139.25	140.78	1.53	6E36Q011453
6/29/1965	139.21	140.88	1.68	6E36Q011454
7/23/1965	139.18	140.73	1.55	6E36Q011455
8/3/1965	139.16	140.56	1.40	6E36Q011456
9/7/1965	139.12	140.28	1.16	6E36Q011457
10/4/1965	139.09	140.49	1.40	6E36Q011458
10/26/1965	139.06	141.02	1.96	6E36Q011459
11/5/1965	139.05	141.29	2.24	6E36Q011460
12/10/1965	139.03	141.42	2.40	6E36Q011461
1/10/1966	139.01	141.86	2.85	6E36Q011462
2/1/1966	139.00	141.85	2.85	6E36Q011463
3/4/1966	138.98	141.63	2.65	6E36Q011464
3/10/1966	138.97	141.39	2.42	6E36Q011465
4/5/1966	138.95	141.39	2.44	6E36Q011466
5/3/1966	138.93	141.11	2.18	6E36Q011467
6/2/1966	138.90	140.97	2.07	6E36Q011468
7/6/1966	138.86	140.56	1.69	6E36Q011469
8/1/1966	138.84	140.48	1.64	6E36Q011470
10/26/1966	138.75	141.36	2.61	6E36Q011471
1/13/1967	138.68	141.73	3.04	6E36Q011472
3/23/1967	138.64	141.82	3.18	6E36Q011473
10/24/1967	138.47	141.60	3.13	6E36Q011474

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
3/13/1968	138.39	141.83	3.44	6E36Q011475
11/8/1968	138.27	141.64	3.37	6E36Q011476
3/27/1969	138.26	141.74	3.48	6E36Q011477
10/28/1969	138.23	141.42	3.19	6E36Q011478
3/23/1970	138.21	141.62	3.42	6E36Q011479
11/12/1970	138.15	141.29	3.14	6E36Q011480
3/30/1971	138.12	141.05	2.93	6E36Q011481
8/8/1980	138.87	138.41	-0.46	6E36Q011482
2/12/2004	130.99	128.26	-2.73	6E36Q011483
10/12/2005	130.02	127.98	-2.04	6E36Q011484
3/10/2009	127.55	124.84	-2.70	6E36Q011485
1/7/1953	145.14	150.70	5.56	6E01C011522
11/19/1953	144.79	149.85	5.06	6E01C011523
1/1/1980	138.86	140.64	1.78	6E01C011524
5/5/2005	130.17	132.16	1.98	6E01C011525
10/12/2005	129.90	131.92	2.01	6E01C011526
1/5/2006	129.79	112.29	-17.50	6E01C011527
2/22/2006	129.70	131.74	2.03	6E01C011528
6/12/2006	129.51	131.59	2.08	6E01C011529
9/26/2007	128.54	130.89	2.35	6E01C011530
2/13/2008	128.23	130.76	2.52	6E01C011531
12/2/2008	127.60	130.27	2.67	6E01C011532
3/24/2009	127.37	130.14	2.77	6E01C011533
12/8/1992	136.77	134.64	-2.13	6E02C031534
1/12/1993	136.78	134.85	-1.93	6E02C031535
2/3/1993	136.82	134.88	-1.93	6E02C031536
2/12/1993	136.82	134.88	-1.94	6E02C031537
2/24/1993	136.83	134.88	-1.95	6E02C031538
3/11/1993	136.84	134.82	-2.01	6E02C031539
3/27/1993	136.84	134.61	-2.23	6E02C031540
4/16/1993	136.83	134.43	-2.40	6E02C031541
5/11/1993	136.82	134.34	-2.48	6E02C031542
7/2/1993	136.78	134.18	-2.59	6E02C031543
8/19/1993	136.73	134.09	-2.64	6E02C031544
10/20/1993	136.67	134.00	-2.67	6E02C031545
12/24/1993	136.63	134.00	-2.62	6E02C031546
2/11/1994	136.59	134.15	-2.44	6E02C031547
3/25/1994	136.57	134.15	-2.41	6E02C031548
5/25/1994	136.53	133.91	-2.62	6E02C031549
8/24/1994	136.45	133.67	-2.79	6E02C031550
10/6/1994	136.40	133.54	-2.86	6E02C031551
12/21/1994	136.33	133.48	-2.84	6E02C031552
2/24/1995	136.27	133.70	-2.58	6E02C031553
4/12/1995	136.23	133.48	-2.75	6E02C031554
6/21/1995	136.15	133.24	-2.91	6E02C031555
10/2/1995	136.01	132.99	-3.01	6E02C031556

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
12/28/1995	135.89	132.93	-2.95	6E02C031557
4/11/1996	135.73	132.78	-2.95	6E02C031558
8/9/1996	135.50	132.42	-3.09	6E02C031559
10/23/1996	135.34	132.32	-3.02	6E02C031560
1/3/1997	135.21	132.29	-2.92	6E02C031561
5/9/1997	134.99	131.96	-3.03	6E02C031562
9/3/1997	134.77	131.53	-3.24	6E02C031563
12/3/1997	134.64	131.59	-3.05	6E02C031564
5/13/1998	134.45	131.38	-3.07	6E02C031565
11/12/1998	134.11	130.74	-3.37	6E02C031566
3/12/1999	133.91	130.71	-3.20	6E02C031567
5/17/1999	133.80	130.47	-3.33	6E02C031568
11/22/1999	133.39	129.95	-3.44	6E02C031569
3/24/2000	133.17	129.98	-3.19	6E02C031570
9/15/2000	132.74	129.43	-3.31	6E02C031571
12/18/2000	132.52	129.12	-3.40	6E02C031572
5/17/2001	132.25	129.18	-3.06	6E02C031573
10/17/2001	131.87	128.85	-3.02	6E02C031574
11/14/2001	131.80	128.58	-3.22	6E02C031575
2/22/2002	131.60	128.58	-3.03	6E02C031576
8/30/2002	131.16	127.78	-3.37	6E02C031577
12/13/2002	130.90	127.69	-3.21	6E02C031578
3/17/2003	130.72	127.90	-2.82	6E02C031579
11/18/2004	129.38	125.95	-3.43	6E02C031580
2/10/2005	129.34	126.26	-3.08	6E02C031581
2/22/2006	128.70	128.06	-0.65	6E02C031582
1/10/2007	127.94	123.97	-3.97	6E02C031583
2/12/2004	125.20	130.09	4.89	6E04F011584
2/10/2005	126.42	129.94	3.52	6E04F011585
4/6/2006	123.01	128.83	5.82	6E04F011586
2/22/2007	122.00	128.43	6.43	6E04F011587
2/26/2008	121.32	128.11	6.79	6E04F011588
12/2/2008	119.61	127.62	8.02	6E04F011589
3/26/2009	119.76	127.16	7.39	6E04F011590
3/25/2010	118.58	126.98	8.40	6E04F011591
2/18/1953	150.07	148.40	-1.67	6E05P011590
11/19/1953	149.59	147.33	-2.26	6E05P011591
2/3/1954	149.45	147.15	-2.30	6E05P011592
2/24/1954	149.42	147.11	-2.30	6E05P011593
11/9/1954	148.98	146.30	-2.68	6E05P011594
3/7/1955	148.78	146.13	-2.65	6E05P011595
11/29/1955	148.33	145.43	-2.90	6E05P011596
3/18/1956	148.15	145.32	-2.82	6E05P011597
11/16/1956	147.72	144.79	-2.93	6E05P011598
3/15/1957	147.50	144.71	-2.79	6E05P011599
11/26/1957	147.04	144.08	-2.96	6E05P011600

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
3/15/1958	146.85	144.02	-2.83	6E05P011601
11/5/1958	146.40	143.42	-2.98	6E05P011602
3/12/1959	146.14	143.35	-2.80	6E05P011603
11/24/1959	145.63	142.98	-2.65	6E05P011604
2/28/1960	145.45	142.64	-2.82	6E05P011605
11/22/1960	144.96	142.37	-2.59	6E05P011606
3/8/1961	144.75	142.40	-2.36	6E05P011607
10/26/1961	144.31	142.22	-2.09	6E05P011608
3/15/1962	144.03	142.26	-1.77	6E05P011609
11/2/1962	143.60	142.08	-1.53	6E05P011610
3/15/1963	143.35	142.15	-1.20	6E05P011611
10/31/1963	143.44	141.99	-1.44	6E05P011612
3/20/1964	143.30	142.03	-1.27	6E05P011613
11/12/1964	142.73	141.74	-1.00	6E05P011614
3/19/1965	142.45	141.79	-0.66	6E05P011615
8/11/1965	142.19	141.53	-0.66	6E05P011616
10/26/1965	142.06	141.33	-0.73	6E05P011617
3/3/1966	142.15	141.33	-0.82	6E05P011618
10/26/1966	141.75	140.43	-1.31	6E05P011619
3/23/1967	141.54	141.07	-0.47	6E05P011620
10/24/1967	141.23	140.79	-0.44	6E05P011621
3/13/1968	141.06	140.76	-0.29	6E05P011622
11/8/1968	140.89	140.74	-0.15	6E05P011623
3/27/1969	140.78	140.52	-0.26	6E05P011624
10/28/1969	140.61	140.26	-0.35	6E05P011625
3/23/1970	140.47	140.19	-0.29	6E05P011626
11/10/1970	140.27	139.95	-0.32	6E05P011627
3/30/1971	140.14	139.86	-0.28	6E05P011628
8/7/1980	139.86	137.61	-2.25	6E05P011629
6/30/1980	137.76	133.68	-4.08	6E07K031630
6/30/1987	136.14	135.20	-0.93	6E07K031631
6/30/1991	134.99	133.99	-1.00	6E07K031632
6/30/1993	134.28	131.91	-2.37	6E07K031633
6/30/1995	132.24	131.55	-0.69	6E07K031634
6/30/1997	130.80	128.29	-2.51	6E07K031635
6/2/1998	131.14	127.83	-3.31	6E07K031636
6/29/1999	130.01	127.25	-2.76	6E07K031637
6/8/2001	128.07	125.48	-2.58	6E07K031638
7/29/2002	127.17	124.51	-2.67	6E07K031639
7/31/2003	126.47	123.87	-2.61	6E07K031640
5/13/2005	126.14	121.88	-4.25	6E07K031641
3/3/2006	126.00	121.61	-4.39	6E07K031642
5/21/2006	125.92	121.70	-4.22	6E07K031643
3/8/2007	125.58	121.52	-4.06	6E07K031644
12/1/2008	124.57	120.25	-4.32	6E07K031645
12/3/2008	124.57	120.90	-3.67	6E07K031646
3/25/2010	124.10	121.60	-2.50	6E07K031647

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/18/2010	125.77	125.61	-0.16	6E07K031648
4/17/2012	126.43	121.57	-4.86	6E07K031649
11/14/2012	126.52	122.07	-4.45	6E07K031650
4/9/2013	126.52	121.38	-5.14	6E07K031651
11/13/2013	126.44	121.30	-5.14	6E07K031652
11/25/2013	126.44	121.29	-5.15	6E07K031653
2/5/2014	126.41	121.22	-5.19	6E07K031654
4/9/2014	126.38	121.16	-5.22	6E07K031655
6/3/2014	126.36	121.38	-4.98	6E07K031656
3/30/2015	126.18	120.87	-5.31	6E07K031657
4/15/2015	126.17	120.91	-5.26	6E07K031658
11/19/2015	126.08	120.99	-5.09	6E07K031659
4/13/2016	126.05	120.82	-5.23	6E07K031660
2/12/2004	126.14	124.77	-1.37	6E09E011647
4/13/2007	123.32	122.43	-0.89	6E09E011648
2/22/2008	122.75	122.02	-0.74	6E09E011649
10/12/2010	119.56	120.41	0.85	6E09E011650
4/9/2013	118.33	120.11	1.78	6E09E011651
10/18/2013	118.48	120.11	1.63	6E09E011652
11/13/2013	118.47	119.57	1.10	6E09E011653
3/28/2014	118.66	121.14	2.48	6E09E011654
4/9/2014	118.60	119.85	1.25	6E09E011655
3/10/2015	118.21	120.72	2.51	6E09E011656
4/15/2015	118.10	119.35	1.25	6E09E011657
11/19/2015	117.41	119.15	1.74	6E09E011658
3/23/2016	117.50	120.80	3.30	6E09E011659
2/18/1953	146.19	146.46	0.28	6E10N011650
12/8/1953	145.79	144.64	-1.16	6E10N011651
2/28/1960	143.00	140.49	-2.51	6E10N011652
11/22/1960	142.53	140.49	-2.04	6E10N011653
3/8/1961	142.42	141.22	-1.20	6E10N011654
10/26/1961	141.98	140.99	-0.99	6E10N011655
3/15/1962	141.89	141.56	-0.33	6E10N011656
11/2/1962	141.45	141.25	-0.20	6E10N011657
3/15/1963	141.35	141.62	0.27	6E10N011658
10/31/1963	141.10	141.49	0.39	6E10N011659
3/20/1964	141.00	141.64	0.64	6E10N011660
11/12/1964	140.61	140.53	-0.08	6E10N011661
3/19/1965	140.47	140.94	0.47	6E10N011662
8/4/1965	140.18	140.12	-0.06	6E10N011663
10/25/1965	140.08	140.17	0.09	6E10N011664
3/3/1966	140.12	140.52	0.40	6E10N011665
10/26/1966	139.75	140.17	0.43	6E10N011666
3/23/1967	139.65	140.76	1.11	6E10N011667
10/24/1967	139.33	140.11	0.77	6E10N011668
3/12/1968	139.29	140.45	1.16	6E10N011669

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/8/1968	139.01	140.20	1.19	6E10N011670
3/27/1969	139.03	140.44	1.42	6E10N011671
10/28/1969	138.74	140.12	1.37	6E10N011672
3/23/1970	138.87	140.29	1.42	6E10N011673
11/12/1970	138.74	139.95	1.22	6E10N011674
3/30/1971	138.72	139.92	1.19	6E10N011675
8/13/1980	137.99	138.41	0.43	6E10N011676
3/11/2009	122.65	123.25	0.61	6E10N011677
3/11/2009	122.69	121.67	-1.03	6E10N041678
11/16/1953	144.68	146.46	1.78	6E11D021679
2/24/1954	144.60	145.86	1.27	6E11D021680
5/14/1954	144.38	130.69	-13.69	6E11D021681
11/8/1954	144.27	138.94	-5.33	6E11D021682
3/7/1955	144.25	145.79	1.54	6E11D021683
11/29/1955	143.93	138.03	-5.90	6E11D021684
3/18/1956	143.75	144.46	0.71	6E11D021685
7/2/1956	143.49	137.25	-6.24	6E11D021686
11/16/1956	143.41	144.07	0.65	6E11D021687
3/14/1957	143.31	134.17	-9.14	6E11D021688
11/27/1957	142.93	134.28	-8.65	6E11D021689
3/15/1958	142.87	136.10	-6.77	6E11D021690
4/21/1958	142.75	134.34	-8.41	6E11D021691
5/1/1958	142.73	132.08	-10.65	6E11D021692
6/23/1958	142.57	131.90	-10.67	6E11D021693
7/22/1958	142.53	132.29	-10.23	6E11D021694
8/14/1958	142.45	131.81	-10.64	6E11D021695
9/23/1958	142.43	139.46	-2.97	6E11D021696
10/20/1958	142.42	135.68	-6.74	6E11D021697
11/5/1958	142.41	140.25	-2.17	6E11D021698
11/12/1958	142.42	140.01	-2.42	6E11D021699
1/5/1959	142.42	136.56	-5.86	6E11D021700
1/26/1959	142.40	143.85	1.45	6E11D021701
2/18/1959	142.39	143.66	1.27	6E11D021702
3/12/1959	142.32	134.46	-7.86	6E11D021703
3/19/1959	142.28	133.97	-8.31	6E11D021704
5/12/1959	142.12	134.24	-7.87	6E11D021705
6/11/1959	142.05	132.08	-9.97	6E11D021706
11/24/1959	141.93	142.17	0.25	6E11D021707
2/28/1960	141.92	132.68	-9.24	6E11D021708
11/22/1960	141.46	141.45	-0.01	6E11D021709
3/8/1961	141.33	142.03	0.70	6E11D021710
10/26/1961	140.91	141.55	0.65	6E11D021711
3/15/1962	140.82	140.67	-0.15	6E11D021712
11/2/1962	140.39	141.62	1.23	6E11D021713
3/15/1963	140.31	142.30	1.99	6E11D021714
10/31/1963	140.19	142.02	1.83	6E11D021715

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
1/6/1964	140.09	142.52	2.43	6E11D021716
2/5/1964	140.06	135.08	-4.98	6E11D021717
3/9/1964	140.01	141.39	1.38	6E11D021718
3/20/1964	139.98	142.23	2.25	6E11D021719
4/3/1964	139.95	135.13	-4.82	6E11D021720
5/8/1964	139.83	138.22	-1.61	6E11D021721
7/7/1964	139.70	139.48	-0.22	6E11D021722
9/11/1964	139.57	136.57	-3.00	6E11D021723
9/30/1964	139.58	134.02	-5.56	6E11D021724
11/2/1964	139.55	141.65	2.10	6E11D021725
12/1/1964	139.63	142.11	2.48	6E11D021726
1/6/1965	139.57	141.90	2.34	6E11D021727
2/1/1965	139.54	142.28	2.74	6E11D021728
3/3/1965	139.49	141.36	1.86	6E11D021729
4/2/1965	139.43	133.49	-5.94	6E11D021730
4/5/1965	139.43	133.49	-5.93	6E11D021731
5/24/1965	139.30	133.84	-5.45	6E11D021732
6/29/1965	139.24	134.53	-4.72	6E11D021733
7/1/1965	139.24	142.28	3.05	6E11D021734
7/30/1965	139.19	133.51	-5.68	6E11D021735
8/3/1965	139.18	135.19	-3.99	6E11D021736
9/7/1965	139.10	133.52	-5.58	6E11D021737
10/4/1965	139.11	140.51	1.39	6E11D021738
10/25/1965	139.09	136.71	-2.38	6E11D021739
11/5/1965	139.12	141.44	2.32	6E11D021740
12/10/1965	139.28	141.73	2.45	6E11D021741
2/1/1966	139.22	135.98	-3.23	6E11D021742
3/4/1966	139.18	134.06	-5.12	6E11D021743
3/10/1966	139.16	135.33	-3.83	6E11D021744
4/5/1966	139.11	136.24	-2.87	6E11D021745
5/3/1966	139.03	134.15	-4.88	6E11D021746
6/2/1966	138.95	133.67	-5.28	6E11D021747
7/6/1966	138.90	133.10	-5.79	6E11D021748
10/27/1966	138.80	141.47	2.68	6E11D021749
1/13/1967	138.83	141.78	2.95	6E11D021750
3/23/1967	138.73	141.82	3.09	6E11D021751
6/22/1967	138.56	141.46	2.90	6E11D021752
9/26/1967	138.49	141.52	3.03	6E11D021753
9/27/1967	138.49	141.52	3.03	6E11D021754
10/24/1967	138.46	141.45	2.99	6E11D021755
3/13/1968	138.46	141.86	3.39	6E11D021756
11/8/1968	138.25	141.51	3.26	6E11D021757
3/27/1969	138.30	142.06	3.76	6E11D021758
10/28/1969	138.11	141.30	3.19	6E11D021759
3/13/1970	138.20	138.55	0.35	6E11D021760
3/23/1970	138.20	138.55	0.35	6E11D021761
11/12/1970	138.06	141.20	3.14	6E11D021762
3/30/1971	138.07	141.30	3.23	6E11D021763

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
12/26/1978	137.50	139.52	2.02	6E11D021764
12/27/1978	137.50	139.52	2.02	6E11D021765
7/22/1980	138.22	138.57	0.35	6E11D021766
8/13/1980	138.18	132.14	-6.03	6E11D021767
2/12/1981	138.30	139.20	0.90	6E11D021768
2/4/1982	138.23	139.00	0.77	6E11D021769
10/1/1982	138.08	137.87	-0.21	6E11D021770
9/27/1983	138.29	138.49	0.20	6E11D021771
9/17/1984	137.98	138.28	0.30	6E11D021772
2/26/1985	138.06	138.55	0.49	6E11D021773
9/13/1985	137.79	137.59	-0.20	6E11D021774
5/7/1986	137.71	136.76	-0.95	6E11D021775
2/18/1987	137.55	137.87	0.32	6E11D021776
9/17/1987	137.23	137.09	-0.14	6E11D021777
3/10/1988	137.29	136.97	-0.31	6E11D021778
9/27/1988	136.94	136.71	-0.23	6E11D021779
3/31/1989	136.92	136.74	-0.18	6E11D021780
9/27/1989	136.67	136.19	-0.48	6E11D021781
3/13/1990	136.51	136.33	-0.18	6E11D021782
9/29/1990	136.30	135.33	-0.98	6E11D021783
3/11/1991	136.12	136.21	0.09	6E11D021784
9/23/1991	135.85	135.56	-0.29	6E11D021785
3/16/1992	135.72	135.93	0.21	6E11D021786
9/24/1992	136.18	135.24	-0.94	6E11D021787
4/12/1993	136.34	134.86	-1.48	6E11D021788
9/17/1993	136.17	134.67	-1.50	6E11D021789
4/28/1994	136.09	134.66	-1.43	6E11D021790
2/10/2005	128.91	129.03	0.12	6E11D021791
3/3/2006	128.21	128.12	-0.09	6E11D021792
3/10/2009	125.76	126.36	0.60	6E11D021793
3/18/2009	125.75	126.26	0.51	6E11D021794
2/18/1953	144.44	146.60	2.16	6E11M011795
12/8/1953	144.03	146.25	2.22	6E11M011796
2/3/1954	143.98	146.27	2.29	6E11M011797
2/24/1954	143.85	145.42	1.57	6E11M011798
11/8/1954	143.62	144.97	1.35	6E11M011799
3/7/1955	143.60	145.46	1.87	6E11M011800
11/29/1955	143.39	144.02	0.63	6E11M011801
3/18/1956	143.13	144.12	0.99	6E11M011802
11/16/1956	142.91	143.71	0.79	6E11M011803
3/14/1957	142.81	142.19	-0.62	6E11M011804
11/27/1957	142.54	141.74	-0.80	6E11M011805
3/15/1958	142.44	142.71	0.27	6E11M011806
11/4/1958	142.08	140.85	-1.23	6E11M011807
3/12/1959	141.99	141.94	-0.04	6E11M011808
11/24/1959	141.67	142.25	0.59	6E11M011809
2/28/1960	141.69	140.64	-1.05	6E11M011810

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/22/1960	141.26	141.52	0.27	6E11M011811
3/8/1961	141.15	141.89	0.74	6E11M011812
10/26/1961	140.77	141.24	0.47	6E11M011813
3/15/1962	140.70	141.77	1.07	6E11M011814
11/2/1962	140.32	141.10	0.78	6E11M011815
3/15/1963	140.24	141.67	1.43	6E11M011816
10/31/1963	140.23	141.38	1.15	6E11M011817
3/20/1964	140.02	141.59	1.57	6E11M011818
11/13/1964	139.63	141.02	1.40	6E11M011819
3/19/1965	139.51	140.94	1.43	6E11M011820
7/30/1965	139.27	139.41	0.14	6E11M011821
10/25/1965	139.17	140.06	0.89	6E11M011822
3/4/1966	139.28	140.60	1.32	6E11M011823
10/27/1966	138.91	140.29	1.38	6E11M011824
3/23/1967	138.84	140.69	1.84	6E11M011825
10/24/1967	138.58	139.77	1.19	6E11M011826
3/13/1968	138.56	140.32	1.77	6E11M011827
3/27/1969	138.35	140.23	1.88	6E11M011828
10/28/1969	138.14	139.26	1.11	6E11M011829
3/23/1970	138.19	136.85	-1.34	6E11M011830
3/30/1970	138.19	139.59	1.41	6E11M011831
11/12/1970	138.06	139.19	1.13	6E11M011832
8/13/1980	137.99	135.90	-2.09	6E11M011833
7/31/1965	138.64	137.27	-1.36	6E12G011834
3/13/1968	137.96	136.22	-1.74	6E12G011835
3/27/1969	137.76	135.80	-1.96	6E12G011836
10/28/1969	137.65	135.32	-2.33	6E12G011837
3/23/1970	137.62	135.40	-2.22	6E12G011838
11/12/1970	137.53	134.93	-2.60	6E12G011839
3/30/1971	137.51	135.01	-2.50	6E12G011840
3/10/2009	128.76	127.13	-1.63	6E12G011841
3/26/2009	128.74	127.26	-1.47	6E12G011842
12/9/1953	145.55	144.88	-0.68	6E15E021843
9/17/1954	145.21	143.37	-1.83	6E15E021844
3/26/1956	144.75	142.15	-2.59	6E15E021845
3/29/1957	144.31	142.76	-1.54	6E15E021846
6/1/1961	142.36	141.51	-0.84	6E15E021847
6/25/1961	142.31	141.64	-0.68	6E15E021848
10/17/1963	141.30	140.22	-1.08	6E15E021849
8/4/1965	140.55	140.33	-0.22	6E15E021850
12/8/1986	136.35	135.81	-0.54	6E15E021851
4/27/1987	136.54	135.91	-0.64	6E15E021852
7/27/1987	135.92	135.78	-0.13	6E15E021853
11/19/1987	136.07	135.75	-0.32	6E15E021854
1/20/1988	136.22	135.72	-0.50	6E15E021855
4/1/1988	135.87	135.66	-0.21	6E15E021856

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/8/1988	135.30	135.51	0.21	6E15E021857
10/25/1988	134.85	135.39	0.54	6E15E021858
2/3/1989	135.29	135.36	0.07	6E15E021859
8/8/1989	134.61	134.99	0.38	6E15E021860
10/26/1989	134.39	134.81	0.42	6E15E021861
2/6/1990	134.63	134.78	0.15	6E15E021862
9/1/1990	134.03	134.50	0.47	6E15E021863
1/14/1991	133.86	135.08	1.22	6E15E021864
2/19/1991	133.98	134.81	0.83	6E15E021865
3/5/1991	133.98	134.84	0.86	6E15E021866
3/19/1991	133.98	134.75	0.76	6E15E021867
4/11/1991	133.94	134.69	0.75	6E15E021868
5/9/1991	133.83	134.47	0.65	6E15E021869
7/23/1991	133.49	133.64	0.14	6E15E021870
10/31/1991	133.33	133.56	0.23	6E15E021871
1/7/1992	133.31	133.83	0.52	6E15E021872
3/12/1992	133.88	134.02	0.14	6E15E021873
5/12/1992	133.95	133.62	-0.33	6E15E021874
7/7/1992	134.00	133.41	-0.59	6E15E021875
9/2/1992	133.94	133.32	-0.62	6E15E021876
10/13/1992	133.74	133.25	-0.49	6E15E021877
12/8/1992	133.83	133.35	-0.48	6E15E021878
1/21/1993	134.20	133.50	-0.70	6E15E021879
2/3/1993	134.42	133.53	-0.89	6E15E021880
2/12/1993	134.49	133.53	-0.96	6E15E021881
2/24/1993	134.56	133.56	-1.00	6E15E021882
3/11/1993	134.58	133.50	-1.08	6E15E021883
3/27/1993	134.59	133.44	-1.15	6E15E021884
4/16/1993	134.57	133.38	-1.19	6E15E021885
5/11/1993	134.54	133.28	-1.26	6E15E021886
7/2/1993	134.38	133.13	-1.25	6E15E021887
8/19/1993	134.23	133.01	-1.22	6E15E021888
10/20/1993	134.13	132.83	-1.30	6E15E021889
12/24/1993	134.15	132.89	-1.27	6E15E021890
2/11/1994	134.30	132.92	-1.38	6E15E021891
3/25/1994	134.40	132.95	-1.45	6E15E021892
5/25/1994	134.31	132.77	-1.54	6E15E021893
8/24/1994	134.21	132.28	-1.93	6E15E021894
10/6/1994	134.18	132.13	-2.06	6E15E021895
12/2/1994	133.92	131.91	-2.00	6E15E021896
2/24/1995	134.26	132.22	-2.04	6E15E021897
4/12/1995	134.25	131.94	-2.31	6E15E021898
6/21/1995	134.07	131.61	-2.46	6E15E021899
10/2/1995	133.72	131.12	-2.59	6E15E021900
12/28/1995	133.67	130.85	-2.83	6E15E021901
4/11/1996	133.65	130.66	-2.98	6E15E021902
8/9/1996	133.30	130.39	-2.91	6E15E021903
10/23/1996	133.21	130.24	-2.98	6E15E021904

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
1/3/1997	133.02	130.15	-2.87	6E15E021905
5/9/1997	133.07	130.08	-2.98	6E15E021906
9/3/1997	132.71	129.57	-3.14	6E15E021907
12/3/1997	132.61	129.47	-3.13	6E15E021908
5/13/1998	132.47	129.23	-3.24	6E15E021909
11/12/1998	131.96	128.56	-3.40	6E15E021910
3/12/1999	132.02	128.56	-3.46	6E15E021911
5/17/1999	131.72	128.59	-3.13	6E15E021912
11/12/1999	131.11	127.86	-3.25	6E15E021913
3/24/2000	131.08	127.89	-3.19	6E15E021914
6/30/2000	130.67	127.52	-3.15	6E15E021915
9/15/2000	130.33	127.22	-3.11	6E15E021916
12/18/2000	130.03	127.10	-2.93	6E15E021917
5/17/2001	129.85	127.16	-2.69	6E15E021918
10/17/2001	129.33	126.67	-2.66	6E15E021919
11/14/2001	129.23	126.64	-2.59	6E15E021920
2/22/2002	128.94	126.52	-2.42	6E15E021921
8/30/2002	127.75	126.00	-1.75	6E15E021922
12/13/2002	127.49	125.76	-1.74	6E15E021923
3/17/2003	127.48	125.79	-1.70	6E15E021924
6/30/2003	126.76	125.48	-1.28	6E15E021925
10/6/2003	126.17	124.87	-1.30	6E15E021926
12/29/2003	126.46	124.63	-1.83	6E15E021927
2/12/2004	126.48	124.60	-1.88	6E15E021928
4/8/2004	126.39	124.54	-1.85	6E15E021929
7/23/2004	125.86	124.17	-1.69	6E15E021930
11/18/2004	126.03	123.74	-2.28	6E15E021931
1/2/1950	146.84	147.41	0.57	6E15F011932
2/19/1953	145.84	146.26	0.42	6E15F011933
12/8/1953	145.50	144.76	-0.74	6E15F011934
3/7/1955	145.11	144.04	-1.07	6E15F011935
11/29/1955	144.79	143.50	-1.30	6E15F011936
3/18/1956	144.73	144.06	-0.67	6E15F011937
11/16/1956	144.38	141.62	-2.76	6E15F011938
3/15/1957	144.31	143.16	-1.15	6E15F011939
11/27/1957	143.95	142.55	-1.40	6E15F011940
3/5/1958	143.89	142.90	-0.99	6E15F011941
11/4/1958	143.57	140.62	-2.95	6E15F011942
8/5/1965	140.73	140.30	-0.43	6E15F011943
3/11/2009	125.52	124.83	-0.70	6E15G011944
6/30/1987	136.29	134.92	-1.37	6E16A021945
6/30/1991	133.42	138.58	5.16	6E16A021946
6/30/1993	133.70	136.38	2.68	6E16A021947
6/30/1995	133.15	131.05	-2.10	6E16A021948
6/30/1997	131.72	129.74	-1.98	6E16A021949

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/2/1998	131.44	128.70	-2.74	6E16A021950
6/29/1999	130.15	127.55	-2.61	6E16A021951
6/5/2000	129.51	127.00	-2.52	6E16A021952
7/29/2002	126.39	125.11	-1.29	6E16A021953
7/31/2003	124.60	124.56	-0.05	6E16A021954
5/13/2005	125.20	123.86	-1.34	6E16A021955
5/21/2006	124.33	123.16	-1.18	6E16A021956
3/8/2007	123.51	122.00	-1.51	6E16A021957
3/10/2008	122.91	121.51	-1.40	6E16A021958
12/1/2008	121.35	121.08	-0.27	6E16A021959
10/12/2010	120.35	119.74	-0.61	6E16A021960
4/9/2013	121.01	119.52	-1.49	6E16A021961
10/18/2013	120.07	118.58	-1.49	6E16A021962
3/28/2014	120.72	119.74	-0.98	6E16A021963
3/10/2015	119.80	119.77	-0.03	6E16A021964
10/12/2015	119.64	119.06	-0.58	6E16A021965
3/23/2016	120.05	120.01	-0.04	6E16A021966
6/30/1991	136.82	135.23	-1.59	6E16N011960
6/30/1993	128.06	134.62	6.56	6E16N011961
6/30/1995	126.67	129.81	3.14	6E16N011962
6/30/1997	125.57	128.40	2.84	6E16N011963
6/2/1998	126.83	127.25	0.42	6E16N011964
6/29/1999	126.05	126.79	0.74	6E16N011965
6/5/2000	123.73	124.84	1.11	6E16N011966
6/8/2001	126.41	125.23	-1.17	6E16N011967
7/29/2002	122.56	124.32	1.76	6E16N011968
7/31/2003	122.24	124.02	1.77	6E16N011969
2/10/2005	124.40	123.69	-0.71	6E16N011970
5/13/2005	123.44	122.83	-0.61	6E16N011971
5/21/2006	124.02	123.25	-0.77	6E16N011972
3/8/2007	123.11	121.27	-1.84	6E16N011973
3/20/2008	121.49	120.75	-0.74	6E16N011974
12/1/2008	119.37	119.41	0.04	6E16N011975
12/2/2008	119.42	119.93	0.51	6E16N011976
3/25/2010	120.76	121.86	1.10	6E16N011977
10/12/2010	119.85	118.78	-1.07	6E16N011978
10/18/2013	123.42	119.60	-3.82	6E16N011979
3/10/2015	121.85	119.15	-2.70	6E16N011980
10/12/2015	122.15	118.97	-3.18	6E16N011981
3/23/2016	122.74	120.06	-2.68	6E16N011982
6/30/1991	139.24	138.27	-0.97	6E18L011976
6/30/1993	137.51	136.14	-1.37	6E18L011977
6/30/1995	134.29	135.53	1.24	6E18L011978
6/30/1997	133.09	133.33	0.24	6E18L011979
6/2/1998	131.80	126.35	-5.45	6E18L011980
6/29/1999	130.02	126.23	-3.79	6E18L011981

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/5/2000	129.39	125.56	-3.83	6E18L011982
6/8/2001	128.04	125.29	-2.76	6E18L011983
7/29/2002	126.79	124.83	-1.96	6E18L011984
7/31/2003	125.66	124.16	-1.51	6E18L011985
5/13/2005	127.96	123.00	-4.96	6E18L011986
3/3/2006	127.62	121.08	-6.54	6E18L011987
5/21/2006	127.42	122.88	-4.54	6E18L011988
3/8/2007	126.81	122.39	-4.42	6E18L011989
12/1/2008	125.91	94.67	-31.24	6E18L011990
12/3/2008	125.91	95.33	-30.57	6E18L011991
3/25/2010	125.53	121.64	-3.89	6E18L011992
10/12/2010	124.85	119.23	-5.62	6E18L011993
4/9/2013	123.62	115.52	-8.10	6E18L011994
10/18/2013	123.38	115.88	-7.50	6E18L011995
3/28/2014	123.21	115.52	-7.69	6E18L011996
3/10/2015	122.82	115.36	-7.46	6E18L011997
4/20/2016	124.12	121.25	-2.87	6E18L011998
6/5/2000	125.44	127.90	2.46	6E20A011992
6/8/2001	127.88	125.89	-1.99	6E20A011993
7/29/2002	124.57	127.35	2.78	6E20A011994
7/31/2003	124.29	126.56	2.27	6E20A011995
2/12/2004	125.02	126.37	1.35	6E20A011996
2/10/2005	126.48	125.49	-0.99	6E20A011997
5/5/2005	125.78	124.91	-0.87	6E20A011998
5/13/2005	125.88	127.11	1.22	6E20A011999
2/17/2006	127.04	124.67	-2.37	6E20A012000
5/21/2006	126.45	126.86	0.41	6E20A012001
3/20/2008	123.99	122.66	-1.33	6E20A012002
3/12/2009	123.39	120.92	-2.47	6E20A012003
3/25/2010	122.95	121.66	-1.29	6E20A012004
10/12/2010	122.38	121.38	-1.00	6E20A012005
4/9/2013	125.49	120.89	-4.60	6E20A012006
10/18/2013	125.61	121.11	-4.50	6E20A012007
11/13/2013	125.63	120.64	-4.99	6E20A012008
3/28/2014	125.69	121.66	-4.03	6E20A012009
4/9/2014	125.70	120.95	-4.75	6E20A012010
4/15/2015	124.37	120.04	-4.33	6E20A012011
11/19/2015	124.58	120.08	-4.50	6E20A012012
4/13/2016	124.58	118.24	-6.34	6E20A012013
4/22/2016	125.00	118.40	-6.60	6E20A012014
1/1/1948	146.33	144.52	-1.81	6E22A012004
2/19/1953	145.30	146.72	1.42	6E22A012005
11/30/1953	145.00	146.78	1.77	6E22A012006
2/24/1954	144.97	145.55	0.58	6E22A012007
11/10/1954	144.67	145.75	1.08	6E22A012008
3/7/1955	144.65	145.93	1.28	6E22A012009

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/29/1955	144.38	144.76	0.38	6E22A012010
3/18/1956	144.33	145.78	1.44	6E22A012011
11/16/1956	144.03	145.58	1.55	6E22A012012
3/14/1957	144.00	145.78	1.78	6E22A012013
11/27/1957	143.69	145.60	1.92	6E22A012014
3/15/1958	143.65	145.65	2.00	6E22A012015
11/4/1958	143.38	144.90	1.53	6E22A012016
1/5/1959	143.36	144.98	1.62	6E22A012017
1/26/1959	143.35	144.98	1.63	6E22A012018
2/18/1959	143.33	145.01	1.68	6E22A012019
3/12/1959	143.32	145.16	1.84	6E22A012020
3/19/1959	143.31	145.04	1.73	6E22A012021
5/12/1959	143.24	144.98	1.74	6E22A012022
6/11/1959	143.19	144.98	1.79	6E22A012023
11/24/1959	142.98	144.86	1.88	6E22A012024
2/27/1960	142.98	144.97	1.99	6E22A012025
11/22/1960	142.64	144.66	2.02	6E22A012026
3/8/1961	142.59	144.74	2.15	6E22A012027
10/26/1961	142.27	144.28	2.01	6E22A012028
3/15/1962	142.19	144.31	2.12	6E22A012029
11/2/1962	141.88	143.88	2.01	6E22A012030
3/14/1963	141.81	143.85	2.04	6E22A012031
10/31/1963	141.73	143.81	2.08	6E22A012032
1/6/1964	141.72	143.57	1.85	6E22A012033
2/5/1964	141.72	143.44	1.72	6E22A012034
3/9/1964	141.71	143.50	1.79	6E22A012035
3/20/1964	141.70	143.85	2.14	6E22A012036
4/3/1964	141.69	143.42	1.73	6E22A012037
5/8/1964	141.65	143.31	1.66	6E22A012038
6/3/1964	141.61	143.14	1.52	6E22A012039
7/7/1964	141.56	143.15	1.59	6E22A012040
8/5/1964	141.51	143.04	1.53	6E22A012041
9/11/1964	141.46	142.87	1.41	6E22A012042
9/30/1964	141.44	142.85	1.41	6E22A012043
11/2/1964	141.40	142.90	1.50	6E22A012044
12/1/1964	141.38	142.99	1.61	6E22A012045
1/6/1965	141.37	143.07	1.70	6E22A012046
2/1/1965	141.36	143.08	1.72	6E22A012047
3/3/1965	141.34	143.09	1.75	6E22A012048
4/5/1965	141.32	143.09	1.77	6E22A012049
5/5/1965	141.28	142.94	1.66	6E22A012050
5/24/1965	141.25	142.91	1.66	6E22A012051
6/29/1965	141.19	142.67	1.48	6E22A012052
8/2/1965	141.14	142.76	1.63	6E22A012053
8/3/1965	141.14	142.71	1.58	6E22A012054
9/7/1965	141.09	142.71	1.62	6E22A012055
10/4/1965	141.05	142.69	1.63	6E22A012056
10/25/1965	141.03	142.71	1.69	6E22A012057

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/5/1965	141.02	142.69	1.67	6E22A012058
12/10/1965	141.05	142.83	1.78	6E22A012059
1/10/1966	141.07	142.94	1.88	6E22A012060
2/1/1966	141.07	142.85	1.78	6E22A012061
3/3/1966	141.06	143.04	1.98	6E22A012062
3/10/1966	141.06	142.81	1.75	6E22A012063
4/5/1966	141.05	142.77	1.72	6E22A012064
5/3/1966	141.01	142.66	1.64	6E22A012065
6/2/1966	140.97	142.61	1.63	6E22A012066
7/6/1966	140.92	142.73	1.81	6E22A012067
8/1/1966	140.88	142.68	1.80	6E22A012068
10/26/1966	140.77	142.64	1.87	6E22A012069
1/13/1967	140.74	142.69	1.95	6E22A012070
3/23/1967	140.71	142.71	2.00	6E22A012071
6/22/1967	140.58	142.53	1.95	6E22A012072
9/26/1967	140.44	142.09	1.65	6E22A012073
10/24/1967	140.41	142.11	1.70	6E22A012074
3/12/1968	140.36	142.34	1.98	6E22A012075
11/8/1968	140.06	142.08	2.02	6E22A012076
3/27/1969	140.03	140.34	0.31	6E22A012077
10/28/1969	139.75	142.00	2.25	6E22A012078
3/23/1970	139.69	141.64	1.95	6E22A012079
11/10/1970	139.42	141.23	1.82	6E22A012080
3/30/1971	139.39	141.33	1.93	6E22A012081
3/24/2009	130.06	136.05	5.99	6E22A012082
6/30/1980	136.98	111.39	-25.59	6E22A022083
6/30/1987	135.75	116.58	-19.18	6E22A022084
6/30/1991	134.97	125.72	-9.25	6E22A022085
6/30/1993	135.29	128.65	-6.65	6E22A022086
6/2/1998	135.18	135.53	0.36	6E22A022087
6/29/1999	134.83	136.54	1.71	6E22A022088
6/5/2000	134.46	136.84	2.38	6E22A022089
6/8/2001	133.99	136.66	2.67	6E22A022090
7/29/2002	133.37	135.38	2.02	6E22A022091
7/31/2003	132.81	135.50	2.69	6E22A022092
3/11/2009	130.30	139.12	8.82	6E22A022093
3/24/2009	130.28	137.29	7.01	6E22A022094
6/30/1987	136.89	121.76	-15.13	6E22B012095
6/30/1991	135.92	59.88	-76.04	6E22B012096
6/2/1998	135.61	134.87	-0.75	6E22B012097
2/12/2004	132.18	137.15	4.97	6E22B012098
2/10/2005	132.44	137.52	5.07	6E22B012099
2/17/2006	131.98	137.70	5.72	6E22B012100
2/22/2007	131.45	138.17	6.72	6E22B012101
2/21/2008	130.51	137.92	7.41	6E22B012102
12/1/2008	129.76	138.39	8.63	6E22B012103

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
3/25/2010	129.16	138.31	9.15	6E22B012104
11/18/2011	129.09	138.27	9.18	6E22B012105
4/17/2012	129.17	138.60	9.43	6E22B012106
12/21/2012	129.08	138.74	9.66	6E22B012107
4/9/2013	129.12	138.84	9.72	6E22B012108
5/3/2013	129.11	138.79	9.69	6E22B012109
11/25/2013	129.01	138.84	9.82	6E22B012110
2/5/2014	128.99	138.92	9.93	6E22B012111
4/9/2014	128.97	138.94	9.97	6E22B012112
6/3/2014	128.92	138.90	9.98	6E22B012113
12/9/2014	128.67	138.86	10.18	6E22B012114
3/30/2015	128.62	138.95	10.33	6E22B012115
4/15/2015	128.61	138.97	10.36	6E22B012116
11/18/2015	128.53	138.86	10.33	6E22B012117
4/13/2016	128.47	138.87	10.40	6E22B012118
6/30/1980	136.30	141.76	5.47	6E22D012103
6/30/1987	133.09	124.39	-8.70	6E22D012104
6/30/1991	132.60	114.94	-17.66	6E22D012105
6/30/1993	135.21	145.54	10.33	6E22D012106
6/30/1995	134.68	127.56	-7.12	6E22D012107
6/30/1997	132.90	126.46	-6.44	6E22D012108
6/2/1998	133.60	127.53	-6.07	6E22D012109
6/29/1999	132.36	126.77	-5.60	6E22D012110
6/5/2000	131.73	126.89	-4.84	6E22D012111
6/8/2001	129.18	126.86	-2.32	6E22D012112
2/12/2004	127.76	126.49	-1.27	6E22D012113
5/5/2005	125.99	110.00	-15.99	6E22D012114
5/13/2005	126.01	112.66	-13.36	6E22D012115
2/17/2006	126.45	114.64	-11.82	6E22D012116
5/21/2006	126.94	112.47	-14.47	6E22D012117
3/8/2007	126.03	114.88	-11.15	6E22D012118
12/1/2008	122.71	104.76	-17.95	6E22D012119
12/2/2008	122.72	105.11	-17.61	6E22D012120
3/25/2010	123.31	106.11	-17.20	6E22D012121
10/12/2010	123.51	108.49	-15.02	6E22D012122
4/9/2013	125.42	110.69	-14.73	6E22D012123
10/18/2013	125.49	109.65	-15.84	6E22D012124
3/28/2014	125.56	108.58	-16.98	6E22D012125
3/10/2015	125.11	108.67	-16.44	6E22D012126
10/12/2015	125.02	111.49	-13.53	6E22D012127
3/23/2016	124.98	112.92	-12.06	6E22D012128
6/30/1980	139.23	142.90	3.67	6E23E012121
6/30/1987	137.69	120.34	-17.35	6E23E012122
6/30/1991	136.83	126.13	-10.69	6E23E012123
6/30/1993	137.45	128.39	-9.06	6E23E012124
6/2/1998	137.54	136.16	-1.37	6E23E012125

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/29/1999	137.12	136.86	-0.26	6E23E012126
6/5/2000	136.76	137.14	0.38	6E23E012127
6/8/2001	136.41	137.99	1.58	6E23E012128
7/29/2002	135.81	137.23	1.42	6E23E012129
7/31/2003	135.42	138.66	3.24	6E23E012130
5/13/2005	135.53	139.24	3.71	6E23E012131
3/20/2008	134.01	139.36	5.36	6E23E012132
1/9/2009	133.80	139.23	5.43	6E23E012133
3/12/2009	133.67	139.75	6.07	6E23E012134
11/14/2012	133.13	123.23	-9.90	6E23E012135
6/30/1980	139.82	145.71	5.89	6E23J012135
6/30/1987	136.98	128.33	-8.65	6E23J012136
6/30/1991	136.21	112.79	-23.42	6E23J012137
6/30/1993	138.31	131.50	-6.81	6E23J012138
6/30/1995	138.95	133.91	-5.04	6E23J012139
6/30/1997	138.49	136.96	-1.54	6E23J012140
6/2/1998	139.33	138.30	-1.03	6E23J012141
6/29/1999	139.04	137.57	-1.47	6E23J012142
6/5/2000	138.83	139.88	1.05	6E23J012143
6/8/2001	138.67	139.82	1.15	6E23J012144
7/29/2002	138.19	140.55	2.36	6E23J012145
7/31/2003	138.15	140.83	2.68	6E23J012146
2/10/2004	138.26	139.58	1.32	6E23J012147
2/12/2005	138.93	142.11	3.17	6E23J012148
5/13/2005	138.56	142.41	3.85	6E23J012149
5/21/2006	138.20	140.43	2.23	6E23J012150
3/8/2007	137.32	138.39	1.07	6E23J012151
3/10/2008	136.72	137.51	0.78	6E23J012152
12/1/2008	136.30	139.40	3.10	6E23J012153
3/25/2010	136.75	141.39	4.64	6E23J012154
10/12/2010	136.52	140.39	3.87	6E23J012155
4/9/2013	136.14	140.60	4.46	6E23J012156
10/18/2013	136.38	142.85	6.47	6E23J012157
3/10/2015	135.63	143.46	7.83	6E23J012158
10/12/2015	135.38	142.92	7.54	6E23J012159
3/23/2016	135.43	143.31	7.88	6E23J012160
5/19/2004	137.73	140.41	2.68	6E23J022154
2/10/2005	138.33	143.27	4.94	6E23J022155
2/17/2006	137.83	141.44	3.61	6E23J022156
6/12/2006	137.59	141.26	3.66	6E23J022157
9/26/2008	135.72	139.79	4.07	6E23J022158
2/26/2009	136.19	140.44	4.25	6E23J022159
12/1/2009	136.01	141.35	5.34	6E23J022160
5/4/2010	136.17	141.53	5.36	6E23J022161
11/18/2010	135.70	141.26	5.56	6E23J022162
11/18/2011	136.46	142.54	6.08	6E23J022163

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
4/17/2012	136.20	143.85	7.65	6E23J022164
12/21/2012	133.58	144.05	10.46	6E23J022165
4/9/2013	135.55	143.65	8.10	6E23J022166
11/13/2013	135.80	143.01	7.21	6E23J022167
11/25/2013	135.79	144.26	8.46	6E23J022168
2/5/2014	135.77	143.07	7.30	6E23J022169
4/9/2014	135.69	144.48	8.79	6E23J022170
12/9/2014	135.16	144.53	9.37	6E23J022171
3/30/2015	135.07	143.18	8.11	6E23J022172
4/15/2015	135.04	143.12	8.08	6E23J022173
11/19/2015	134.91	141.75	6.84	6E23J022174
12/23/2015	135.01	141.90	6.89	6E23J022175
4/13/2016	134.74	140.04	5.30	6E23J022176
6/30/1980	141.97	138.48	-3.49	6E25A012158
6/30/1987	141.10	140.61	-0.49	6E25A012159
6/30/1991	139.81	136.04	-3.77	6E25A012160
6/30/1993	130.48	140.31	9.83	6E25A012161
6/30/1995	140.48	144.27	3.79	6E25A012162
6/30/1997	134.17	141.92	7.75	6E25A012163
6/2/1998	140.90	142.35	1.45	6E25A012164
6/29/1999	140.69	142.72	2.03	6E25A012165
6/5/2000	139.49	142.17	2.68	6E25A012166
6/8/2001	140.44	142.01	1.57	6E25A012167
7/29/2002	134.52	141.50	6.98	6E25A012168
7/31/2003	139.31	141.13	1.82	6E25A012169
2/12/2004	140.13	143.75	3.62	6E25A012170
5/21/2006	140.55	144.54	3.99	6E25A012171
6/12/2006	140.38	144.21	3.83	6E25A012172
2/22/2007	140.17	147.43	7.26	6E25A012173
3/8/2007	140.18	144.06	3.88	6E25A012174
1/20/2008	139.36	143.87	4.51	6E25A012175
9/26/2008	137.41	146.87	9.46	6E25A012176
12/1/2008	133.93	143.56	9.63	6E25A012177
2/26/2009	139.63	146.95	7.32	6E25A012178
11/18/2010	136.72	146.95	10.23	6E25A012179
4/17/2012	139.42	144.69	5.27	6E25A012180
11/14/2012	139.36	144.76	5.40	6E25A012181
4/9/2013	139.19	145.01	5.81	6E25A012182
11/25/2013	139.15	144.87	5.72	6E25A012183
2/5/2014	139.08	147.69	8.61	6E25A012184
4/9/2014	135.65	144.57	8.91	6E25A012185
11/20/2014	127.65	143.72	16.07	6E25A012186
6/30/1980	142.34	144.36	2.02	6E25C012176
6/30/1987	140.96	126.99	-13.97	6E25C012177
6/30/1991	139.83	127.60	-12.23	6E25C012178
6/30/1993	139.45	129.12	-10.33	6E25C012179

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
6/30/1995	140.73	138.21	-2.52	6E25C012180
6/30/1997	139.87	140.22	0.34	6E25C012181
6/2/1998	141.22	141.96	0.73	6E25C012182
6/29/1999	141.06	142.84	1.78	6E25C012183
6/5/2000	140.85	141.26	0.41	6E25C012184
6/8/2001	140.84	141.53	0.69	6E25C012185
7/29/2002	139.92	140.83	0.91	6E25C012186
7/31/2003	140.30	140.92	0.62	6E25C012187
2/12/2004	140.58	141.68	1.10	6E25C012188
2/17/2006	141.24	141.80	0.56	6E25C012189
6/12/2006	141.07	143.10	2.02	6E25C012190
2/22/2007	140.60	137.79	-2.81	6E25C012191
3/8/2007	140.58	142.05	1.46	6E25C012192
3/10/2008	140.15	142.44	2.29	6E25C012193
9/26/2008	139.35	135.00	-4.35	6E25C012194
12/1/2008	138.94	125.44	-13.50	6E25C012195
2/26/2009	140.01	136.55	-3.46	6E25C012196
3/25/2010	139.88	142.01	2.13	6E25C012197
11/18/2011	141.05	144.13	3.08	6E25C012198
4/17/2012	139.98	144.72	4.74	6E25C012199
11/14/2012	139.92	145.08	5.16	6E25C012200
4/9/2013	139.75	145.32	5.57	6E25C012201
11/13/2013	139.76	145.48	5.72	6E25C012202
11/25/2013	139.73	144.87	5.14	6E25C012203
2/5/2014	139.66	145.42	5.76	6E25C012204
4/9/2014	139.22	144.57	5.35	6E25C012205
11/20/2014	137.54	143.72	6.18	6E25C012206
2/5/2015	138.77	144.03	5.26	6E25C012207
11/9/2015	137.73	142.54	4.81	6E25C012208
4/28/2016	138.73	143.61	4.88	6E25C012209
1/1/1980	146.65	146.81	0.15	6E34A012194
5/5/2005	150.60	150.03	-0.57	6E34A012195
8/23/2005	150.47	150.34	-0.13	6E34A012196
10/12/2005	150.47	150.27	-0.19	6E34A012197
1/5/2006	150.71	150.47	-0.24	6E34A012198
2/22/2006	150.66	150.26	-0.40	6E34A012199
6/12/2006	150.48	150.35	-0.13	6E34A012200
2/22/2007	150.01	150.59	0.58	6E34A012201
2/13/2008	149.32	150.90	1.58	6E34A012202
12/1/2008	148.75	151.19	2.44	6E34A012203
3/25/2009	149.09	151.21	2.12	6E34A012204
11/13/2013	147.23	151.90	4.67	6E34A012205
11/20/1953	141.61	138.29	-3.32	7E07N012205
2/24/1954	141.57	138.44	-3.13	7E07N012206
11/8/1954	141.52	138.04	-3.48	7E07N012207
3/7/1955	141.52	138.21	-3.31	7E07N012208

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
11/29/1955	141.39	137.85	-3.54	7E07N012209
3/18/1956	141.12	137.96	-3.16	7E07N012210
11/16/1956	140.97	137.65	-3.32	7E07N012211
3/14/1957	140.87	137.47	-3.40	7E07N012212
11/27/1957	140.71	137.38	-3.32	7E07N012213
3/15/1958	140.57	137.52	-3.05	7E07N012214
11/4/1958	140.40	137.06	-3.34	7E07N012215
3/12/1959	140.22	137.27	-2.95	7E07N012216
11/24/1959	140.01	136.85	-3.16	7E07N012217
2/28/1960	140.01	136.98	-3.03	7E07N012218
11/22/1960	139.70	136.86	-2.84	7E07N012219
3/8/1961	139.53	136.95	-2.57	7E07N012220
10/26/1961	139.25	136.66	-2.60	7E07N012221
3/15/1962	139.14	136.75	-2.38	7E07N012222
11/2/1962	138.88	136.48	-2.41	7E07N012223
3/15/1963	138.74	136.56	-2.18	7E07N012224
3/20/1964	138.58	136.48	-2.10	7E07N012225
11/13/1964	138.36	135.38	-2.99	7E07N012226
3/19/1965	138.21	135.31	-2.91	7E07N012227
10/25/1965	138.00	136.09	-1.91	7E07N012228
10/3/2008	129.88	126.68	-3.20	7E07R012229
12/1/2008	129.81	127.17	-2.63	7E07R012230
12/4/2008	129.80	127.07	-2.73	7E07R012231
11/18/2010	128.69	126.26	-2.43	7E07R012232
11/14/2012	127.58	125.85	-1.73	7E07R012233
4/9/2013	127.34	125.84	-1.50	7E07R012234
11/13/2013	127.01	125.66	-1.35	7E07R012235
4/9/2014	126.76	125.62	-1.14	7E07R012236
4/15/2015	126.15	125.44	-0.71	7E07R012237
11/19/2015	125.81	125.25	-0.56	7E07R012238
3/23/2016	125.60	125.24	-0.36	7E07R012239
10/3/2008	129.88	126.68	-3.20	7E07R022231
12/1/2008	129.80	127.16	-2.65	7E07R022232
12/4/2008	129.80	127.06	-2.74	7E07R022233
1/12/2010	129.19	126.45	-2.74	7E07R022234
11/18/2010	128.69	126.26	-2.43	7E07R022235
11/14/2012	127.58	125.85	-1.73	7E07R022236
4/9/2013	127.34	125.84	-1.50	7E07R022237
11/13/2013	127.00	125.66	-1.34	7E07R022238
4/9/2014	126.76	125.62	-1.14	7E07R022239
4/15/2015	126.15	125.44	-0.71	7E07R022240
11/19/2015	125.81	125.26	-0.55	7E07R022241
3/23/2016	125.60	125.24	-0.36	7E07R022242
2/18/1953	147.06	151.91	4.85	7E20P012233
12/9/1953	146.91	149.80	2.90	7E20P012234

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
2/23/1954	146.84	151.61	4.77	7E20P012235
2/24/1954	146.84	151.68	4.84	7E20P012236
11/8/1954	146.75	148.99	2.24	7E20P012237
3/7/1955	146.66	149.58	2.92	7E20P012238
11/29/1955	146.55	148.69	2.14	7E20P012239
3/18/1956	146.44	151.08	4.63	7E20P012240
11/16/1956	146.35	151.39	5.04	7E20P012241
3/15/1957	146.26	151.72	5.46	7E20P012242
11/27/1957	146.17	152.00	5.83	7E20P012243
11/4/1958	146.00	152.00	6.00	7E20P012244
3/12/1959	145.88	152.13	6.25	7E20P012245
11/24/1959	145.79	152.26	6.47	7E20P012246
2/28/1960	145.73	152.31	6.58	7E20P012247
11/23/1960	145.61	152.34	6.73	7E20P012248
3/8/1961	145.51	152.37	6.87	7E20P012249
10/26/1961	145.42	152.42	7.00	7E20P012250
3/15/1962	145.31	152.44	7.13	7E20P012251
11/1/1962	145.22	152.43	7.21	7E20P012252
3/14/1963	145.11	152.46	7.35	7E20P012253
10/31/1963	145.08	152.47	7.39	7E20P012254
3/20/1964	144.95	152.54	7.59	7E20P012255
11/13/1964	144.90	152.35	7.45	7E20P012256
3/19/1965	144.79	152.25	7.46	7E20P012257
7/28/1965	144.76	152.33	7.58	7E20P012258
10/25/1965	144.73	152.32	7.59	7E20P012259
3/4/1966	144.67	152.04	7.36	7E20P012260
10/26/1966	144.61	152.23	7.62	7E20P012261
3/23/1967	144.50	152.20	7.70	7E20P012262
10/24/1967	144.45	152.13	7.68	7E20P012263
3/12/1968	144.35	152.13	7.78	7E20P012264
11/8/1968	144.28	152.11	7.83	7E20P012265
3/27/1969	144.18	152.04	7.86	7E20P012266
10/28/1969	144.11	151.97	7.86	7E20P012267
3/23/1970	144.01	149.94	5.93	7E20P012268
11/10/1970	143.93	151.88	7.95	7E20P012269
3/30/1971	143.82	151.85	8.03	7E20P012270
12/1/2008	139.98	151.95	11.97	7E20P012271
12/5/2008	139.99	152.09	12.10	7E20P012272
3/13/2009	139.99	151.95	11.96	7E20P012273
12/1/2008	141.32	147.40	6.08	7E30G042274
12/4/2008	141.33	147.73	6.40	7E30G042275
11/2/1952	152.60	152.37	-0.23	7E32Q012276
12/10/1953	152.48	154.51	2.03	7E32Q012277
11/10/1954	152.26	154.47	2.22	7E32Q012278
7/29/1965	150.46	153.22	2.76	7E32Q012279
2/20/1980	148.98	151.81	2.83	7E32Q012280

Appendix C. Residuals

Date	SIMULATED EQUIVALENT (feet)	OBSERVED VALUE (feet)	Residual (Observed - Simulated)	OBSERVATION NAME
12/5/2008	149.28	153.28	4.00	7E32Q012281
3/12/2009	148.32	147.87	-0.46	7E03M022282
6/4/2007	127.99	199.11	71.13	6E31E030001
1/8/2008	126.78	197.63	70.85	6E31E030002
5/8/2008	126.91	196.69	69.78	6E31E030003
8/11/2008	126.83	197.64	70.82	6E31E030004
8/12/2008	126.82	196.66	69.84	6E31E030005
12/5/2008	126.06	197.64	71.59	6E31E030006
5/13/2009	125.35	197.01	71.66	6E31E030007

APPENDIX D2

BWD Water Quality Review and Assessment

WATER QUALITY REVIEW AND ASSESSMENT:
BORREGO WATER DISTRICT (BWD) WATER SUPPLY WELLS

OVERVIEW

The purpose of this Report is to review water quality data for active Borrego Water District (BWD) water supply production wells to

1) Provide an overview of water quality conditions among the wells and assess spatial variations;
2) Examine how water quality has changed over time due to overdraft;
3) Evaluate the potential relationships among multiple water quality parameters as a means to support trend analyses for the five primary chemicals of concern (COCs) that include arsenic, total dissolved solids (TDS), nitrate, sulfate, and fluoride (As, TDS, NO_3, SO_4, and F);
4) Determine how well water quality trends may (or may not) be able to be identified among BWD water supply wells; and,

The Borrego Springs Subbasin (Subbasin) of the Borrego Valley Groundwater Basin is in a state of critical overdraft and subject to the Sustainable Groundwater Management Act (SGMA). As defined under SGMA[1] "A basin is subject to critical overdraft when continuation of present water management practices would probably result in significant adverse overdraft-related environmental, social, or economic impacts."

Pursuant to SGMA a Groundwater Sustainability Plan (GSP) is currently under development for the Subbasin. This work updates and extends beyond prior work done by Dudek to assess water quality trends for BWD wells as described in the Draft Borrego Springs Subbasin Groundwater Quality Risk Assessment presented to the BWD Board on 6/28/2017.[2]

The analyses included herein will be used in subsequent ENSI reports to examine potential BWD water supply impacts and costs associated with current and future water quality conditions.

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[1] See: https://water.ca.gov/Programs/Groundwater-Management/Bulletin-118/Critically-Overdrafted-Basins

[2] The data used in the Report were located and compiled by Dudek staff as part of the GSP preparation process. The analyses presented in this Report would not have been possible without their support.

Preparation of the GSP is underway and it is understood that the draft GSP will be available for public review by January 2019[3]. The GSP will include a range of potential options for Projects and Managements Actions (PMAs), including PMAs to address water quality and water quality optimization. Among the direct impacts of degraded groundwater quality to BWD include:

- Need for Water Treatment to achieve drinking water standards (on a per well basis)
- Impact of water quality on the choice and design of replacement wells at existing well locations
- Potential need for Intra-Subbasin Transfer of Potable water from new or existing wells due to degraded water quality due to natural or anthropogenic sources

Groundwater quality data also have a role in the assessment of potential water management options that include but are not limited to:

- Options for Enhanced Natural Recharge (understood to be limited)[4]
- Artificial Recharge using Treated Wastewater

Of primary concern to BWD is the ability of historical data combined with ongoing water quality monitoring program to assess water quality trends. The data are needed to support management of their water system, for example to assess the probability of MCL (maximum contaminant level) exceedances and to plan for water treatment, if needed.

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[3] The GSP is being developed by the Groundwater Sustainability Agency (GSA) that consists of the County of San Diego and the Borrego Water District. See overview at: https://www.sandiegocounty.gov/pds/SGMA.html

[4] It is understood that that recharge basins within the floodplains where much of Borrego Springs' residential population is located are likely not permittable due to County Flood Control Management concerns. Similarly managed artificial recharge areas located along mountain fronts within or nearby to the Anza Borrego State Park are also not likely permittable given their potential impact on the State Park.

This report includes the following sections:

1.0 HYDROLOGIC CONDITIONS

A brief summary of the hydrologic conditions of the Subbasin is provided here to support review of the water chemistry data. Included is a description of groundwater recharge, pre- and post-development groundwater levels, and aquifer conditions. Many of the figures and much of the discussion included in this section was derived from the USGS Model Report prepared in 2015 entitled *Hydrogeology, hydrologic effects of development, and simulation of groundwater flow in the Borrego Valley, San Diego County, California*: U.S. Geological Survey Scientific Investigations Report 2015–5150[5]. For reference the *simulation of groundwater flow* refers to the use of a numerical model (in this case the USGS Modflow Model as described in the 2015 report) to examine the groundwater levels, recharge, and overall hydrologic conditions for the period of 1945 to 2010. The GSP contains additional detailed hydrologic information, and updates the USGS modeling work.

1.1 Basin Location and Setting: Contributory Watersheds

The Borrego Springs Subbasin (Subbasin) of the Borrego Valley Groundwater Basin is located at the western-most extent of the Sonoran Desert. The primary source of water to the Subbasin is surface water (storm water and ephemeral stream flow) that flows into the valley from adjacent mountain watersheds and infiltrates within the valley. The contributory watersheds are approximately 400 square miles (mi^2) and much larger in area than the approximately 98mi^2 Subbasin as illustrated in **Figure 1**.

Direct recharge by rainfall within the valley is very low compared to surface water inflows as the annual rainfall averages 5.8 inches per year (in/yr.) [USGS Model Report, page 43]. Stream and flood flows from the adjacent watersheds provide the bulk of the water that enters the Subbasin.

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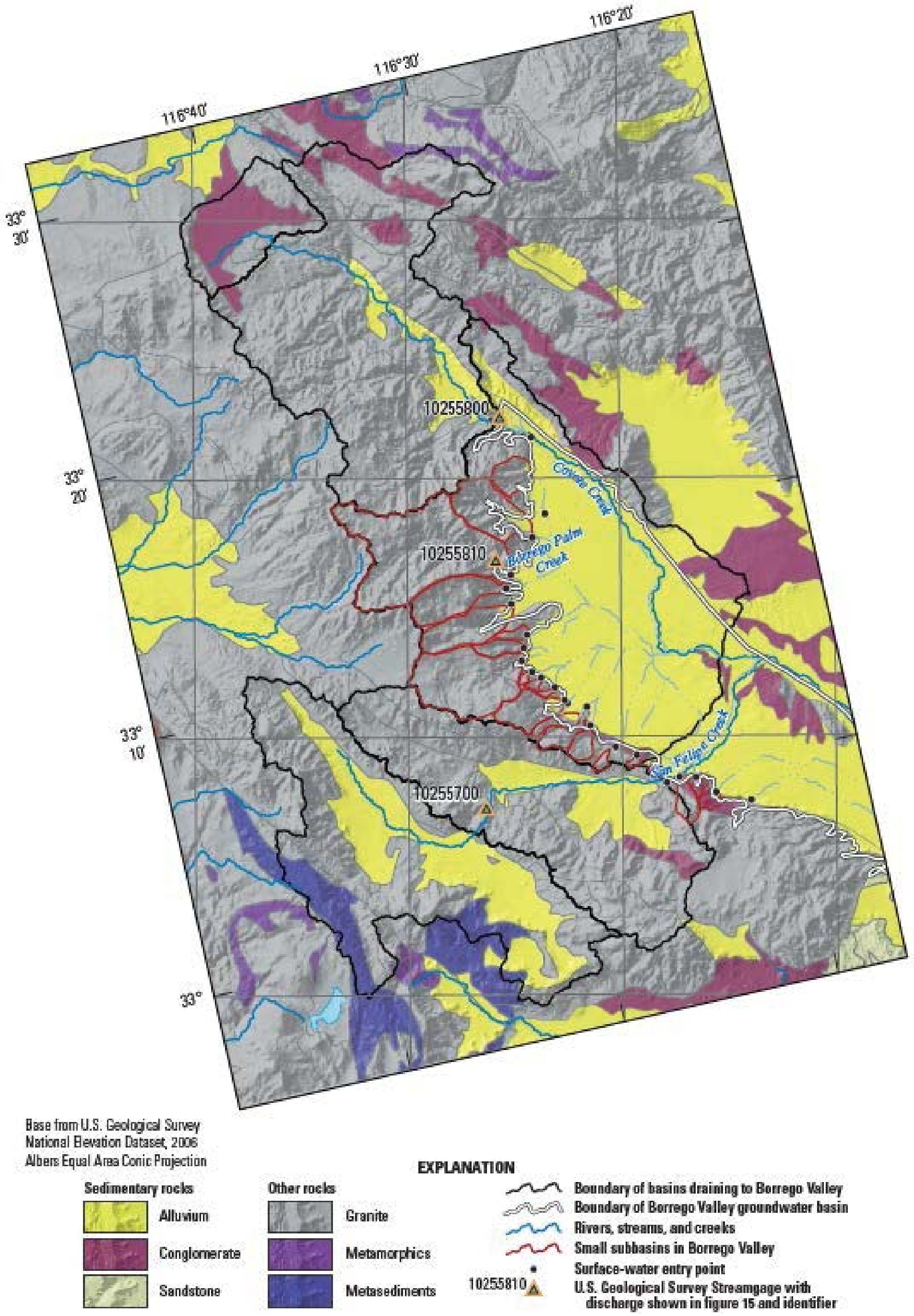
[5] Referenced herein as the "USGS Model Report": Faunt, C.C., Stamos, C.L., Flint, L.E., Wright, M.T., Burgess, M.K., Sneed, Michelle, Brandt, Justin, Martin, Peter, and Coes, A.L., 2015, Hydrogeology, hydrologic effects of development, and simulation of groundwater flow in the Borrego Valley, San Diego County, California: U.S. Geological Survey Scientific Investigations Report 2015–5150, 135 p.
See: http://dx.doi.org/10.3133/sir20155150

FIGURE 1 (from USGS Model Report)



Base from U.S. Geological Survey
National Elevation Dataset, 2006
Albers Equal Area Conic Projection

Figure 16. Drainage basin boundaries and geology used in the Basin Characterization Model to estimate climate-driven natural recharge in the Borrego Valley, California.

Note: The Subbasin lies within the area defined by alluvium. The tributary watersheds (e.g. that support Coyote Creek, Borrego Palm Creek, and San Felipe Creek) are outside of the Subbasin.

1.2 Historical Groundwater Conditions

The Subbasin receives recharge waters from the adjacent watersheds that include Coyote Creek, watersheds along the northwestern edge of the valley such as Borrego Palm Canyon, and San Felipe Creek that enters the south side of the valley (**Figure 1**).

Two water level maps from the USGS Model Report are included in **Figures 2A** and **2B** that depict pre- and post- development water levels (1945 and 2010). In both cases the Subbasin can be generally described as “closed” where surface water flows typically do not discharge from the valley but instead, if sufficient flows occur, terminate at the Borrego Sink.

Prior to development (**Figure 2A**) groundwater flow within the northern and central portions of the valley can generally be described as moving from northwest to southeast towards the Borrego Sink. Flow in the southern portion of the Subbasin is directed northeast towards the Borrego Sink. Pumping since 1945 has lowered groundwater levels and led the development of significant depressions of the water table associated with ‘pumping centers’ (see **Figure 2B**). From a groundwater perspective the overall flow patterns in the northern and central areas of the valley have changed from a roughly uniform flow (generally towards the Borrego Sink) to a condition where groundwater flow is reversed in some areas and now flows toward the pumping centers. The rate of pumping has greatly exceeded groundwater recharge rates and water levels have dropped well over 100 feet in some areas. Because the current rate of groundwater use continues to cause significant water level decline and loss of water from subsurface storage the Subbasin is now classified as being in critical overdraft.

Further description of historical and current groundwater conditions is included in the GSP.

FIGURE 2A (from USGS Model Report)

44 Hydrogeology, Hydrologic Effects of Development, and Simulation of Groundwater Flow in the Borrego Valley

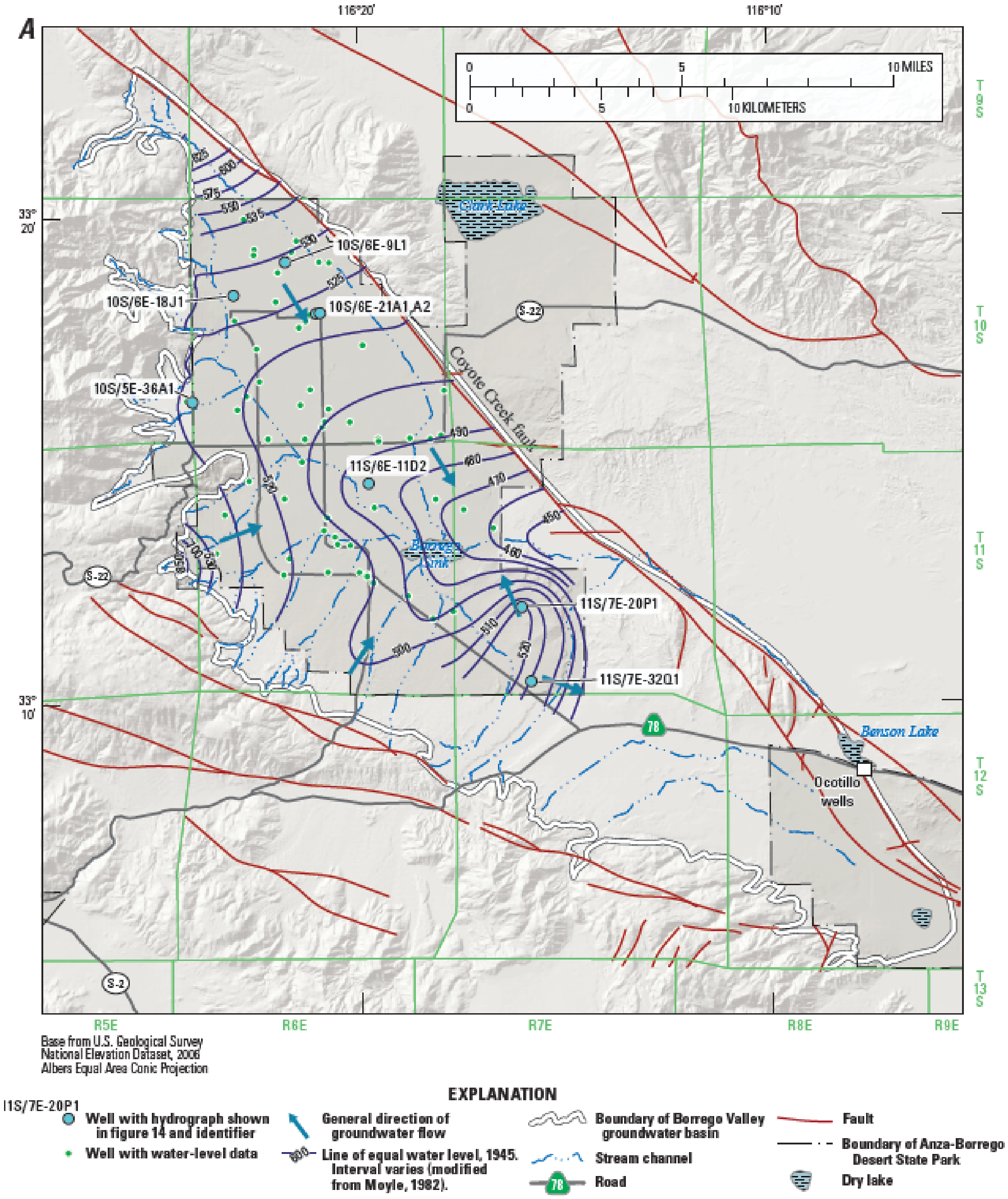
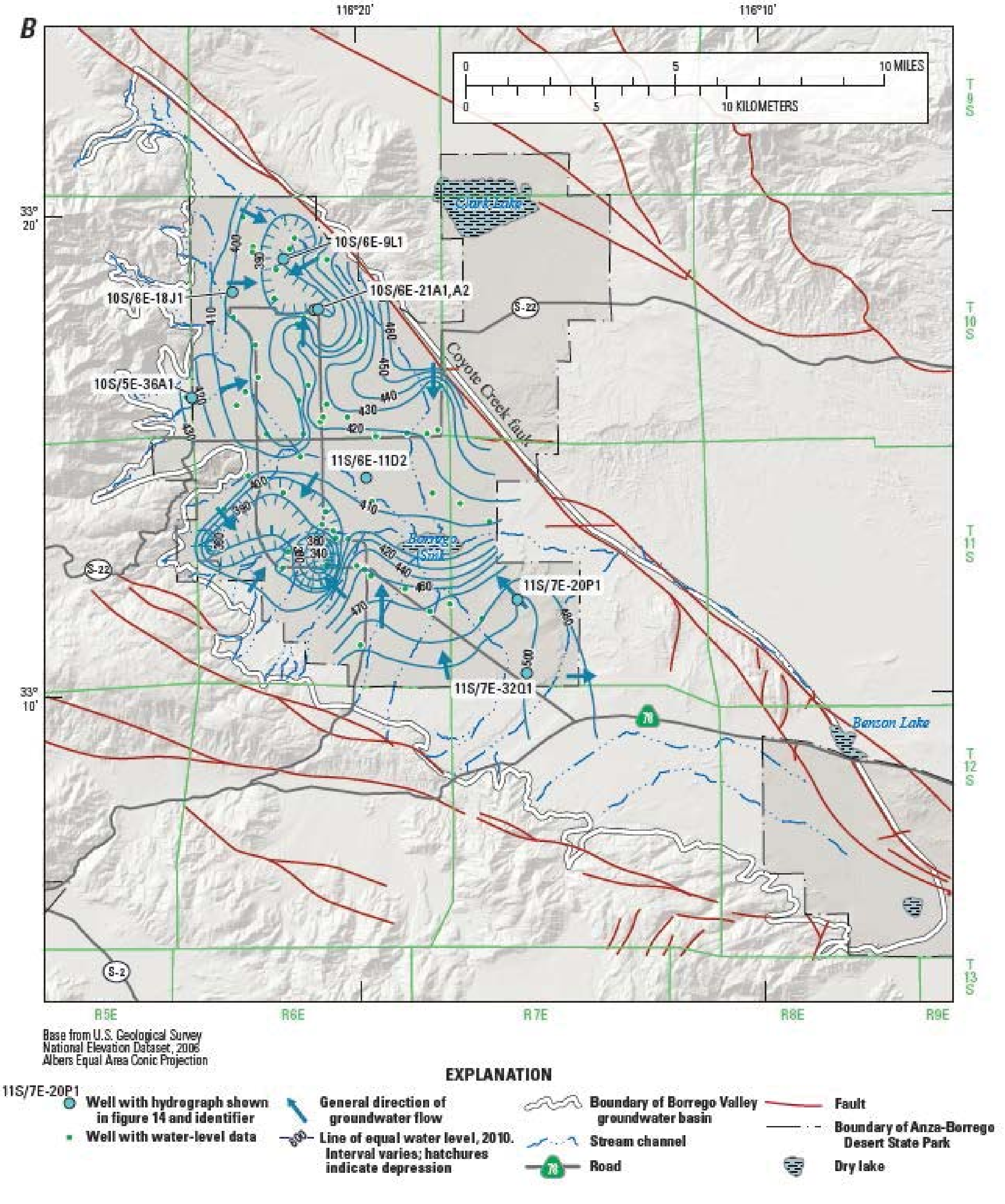


Figure 13. Water-level elevations and direction of groundwater flow in Borrego Valley, California, for *A*, 1945, approximately predevelopment, and *B*, 2010. (2010 data are modified from http://www.dpla.water.ca.gov/sd/groundwater/basin_assessment/basin_assment.html).

Note: The arrows indicating groundwater flow are roughly coincident with intermittent surface water channels (dashed blue lines) that enter from adjacent watersheds and flow towards the Borrego Sink.

FIGURE 2B (from USGS Model Report)



Base from U.S. Geological Survey
National Elevation Dataset, 2006
Albers Equal Area Conic Projection

Figure 13. —Continued

NOTE: Hachured areas show the two major pumping centers in the Subbasin. The influence of northern pumping center has caused groundwater to reverse flow direction (see arrow at well 10S/6E-21A1). The central pumping center captures groundwater that was previously flowing south and southeastward towards the Borrego Sink.

1.3 Stratigraphy and Aquifer Conceptual Model

The current conceptual model for the aquifer system as incorporated in the USGS Model is that it consists of three unconfined aquifers named the upper, middle and lower aquifers. The upper and middle aquifers are the primary sources of water currently and are typically comprised of unconsolidated sediments. However, with time, the upper aquifer has become or is expected to become dewatered and the lower aquifer will become a more important source of water as overdraft continues.

The lower aquifer sediments become consolidated with depth and have been subject to folding and faulting. The lower aquifer provides water supply for some pumpers, especially in the southern area of the Subbasin. **Figure 3** (Figure 7 of the USGS Model Report) depicts the Borrego Valley Groundwater Basin as described by Moyle, 1982.[6] Additional work has been done by Mitten et al (1989),[7] and by Netto (2001).[8] Of these, Netto (2001) provides the most detailed analysis of basin stratigraphy based on well log review and interpretation. Review of their work supports that locally confined aquifer conditions are expected to occur.

In brief there are a number of geologic features relevant to groundwater conditions and water quality:

- The Subbasin, as exemplified by the flow of water and sediment toward the current-day Borrego Sink, has historically been the locus of sediment deposition. Sedimentation initially occurred in a marine environment (with sediment sources located to the east) and transitioned to terrestrial environments as seen today.[9]
- The Borrego Sink, similar to dry lake beds that occur in the desert, is a location where water evaporates and minerals will accumulate and can form evaporite deposits. Historically similar conditions occurred as sediments were deposited. Thus, the middle and upper aquifers have the potential to include evaporite deposits that can re-dissolve and lead to elevated concentrations of sulfates and carbonates that result in corresponding increase in TDS.

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[6] Moyle, W. R., 1982, Water resources of Borrego Valley and vicinity, California; Phase 1, Definition of geologic and hydrologic characteristics of basin: U.S. Geological Survey Open-File Report 82–855, 39 p.

[7] Mitten, H.T., Lines, G.C., Berenbrock, Charles., and Durbin, T.J., 1988, Water resources of Borrego Valley and vicinity, California, San Diego County, California; Phase 2, Development of a groundwater flow model: U.S. Geological Survey Water-Resources Investigation Report 87–4199, 27 p.

[8] Netto, S.P., 2001, Water Resources of Borrego Valley San Diego County, California: Master's Thesis, San Diego State University, 143 p.

[9] See GSP. For general reference see: Dorsey, R.J., 2005. Stratigraphy, Tectonics, and Basin Evolution in the Anza-Borrego Desert Region. In "Fossil Treasures of the Anza-Borrego Desert", George T. Jefferson and Lowell Lindsay, editors, Sunbelt Publications, San Diego California, 2006 https://pages.uoregon.edu/rdorsey/Downloads/DorseyChaperNov05.pdf

- Structural features such as the Coyote Creek Fault, the Desert Lodge anticline, and the effect of basement uplift and exposure of lower aquifer sediments along the southeastern portion of the Subbasin (cross-section A-A' in **Figure 3**) limit groundwater flow within and out of the basin. The Coyote Creek Fault is assumed to be a 'no flow' boundary condition in the USGS Groundwater Model and as such serves to contain groundwater within the basin and direct flow to the southeast towards the Borrego Sink. The current-day topography combined with the geologic structure creates a 'closed' groundwater condition where ongoing evaporation of water will lead to the long-term accumulation of minerals (often referred to as 'salts') in soil and groundwater.
- While the lower aquifer is quite deep and contains a significant volume of groundwater, the sediments have less storage capacity than the upper and middle aquifers as quantified in the USGS Model by lower specific storage and specific yield. The lower aquifer is also expected to have poor water quality with depth.
- Waters that flow into the Subbasin from the adjacent watersheds will have varying chemistry depending on the geologic and hydrologic conditions encountered in the watersheds. For example, water that flows in Borrego Palm Creek from nearby crystalline rock of the San Ysidro Mountains (see **Figure 1**) will be different than the waters of San Felipe Creek that drain from an alluvial desert valley and more likely to accumulate dissolved minerals.

Please refer to the GSP for additional details.

FIGURE 3

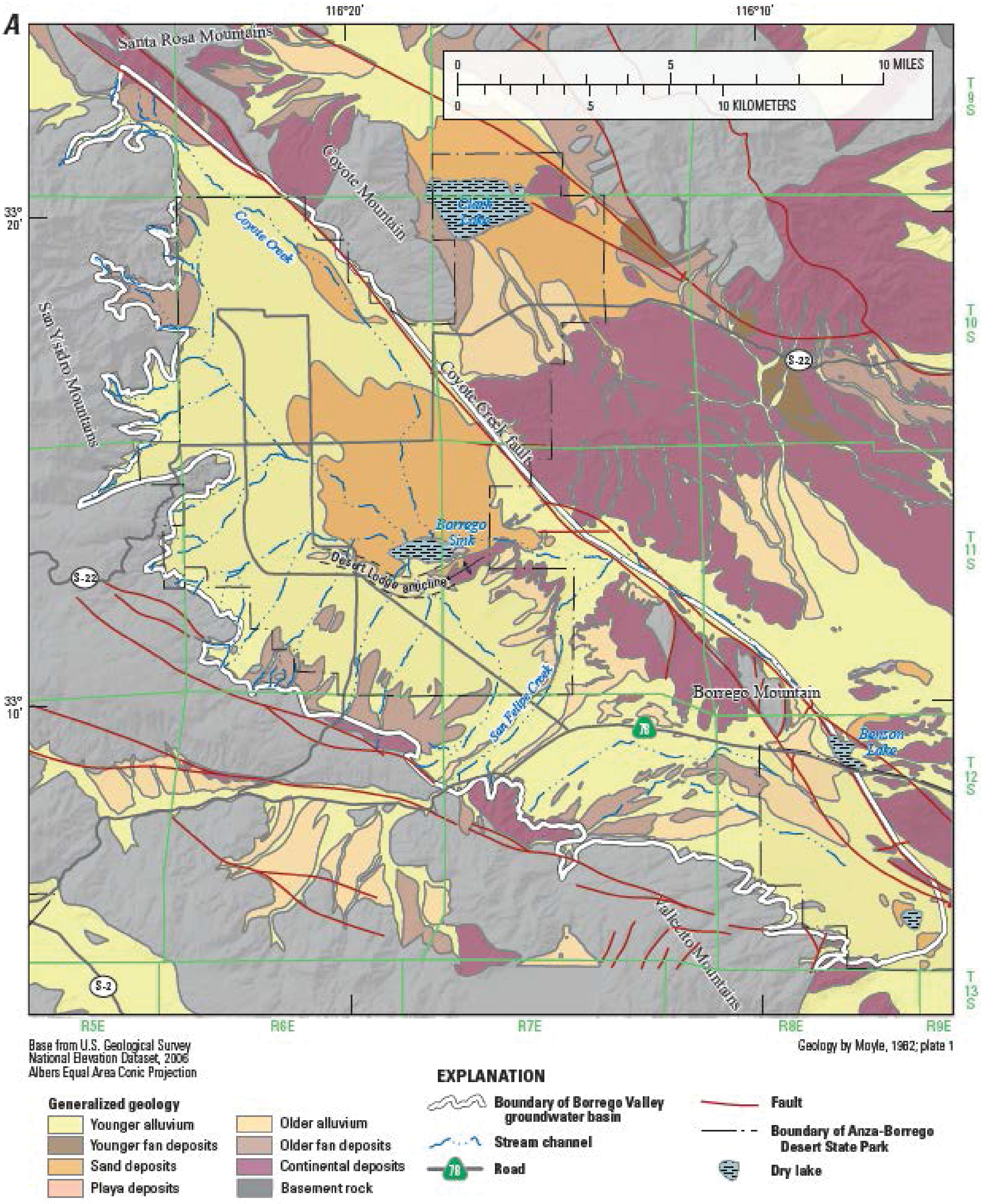


Figure 7. Maps showing Borrego Valley, California, showing *A*, geology; *B*, hydrogeology; and *C*, generalized hydrogeologic cross sections A-A' and B-B'. (Lines of section are shown in figure 7B.)

FIGURE 3, continued

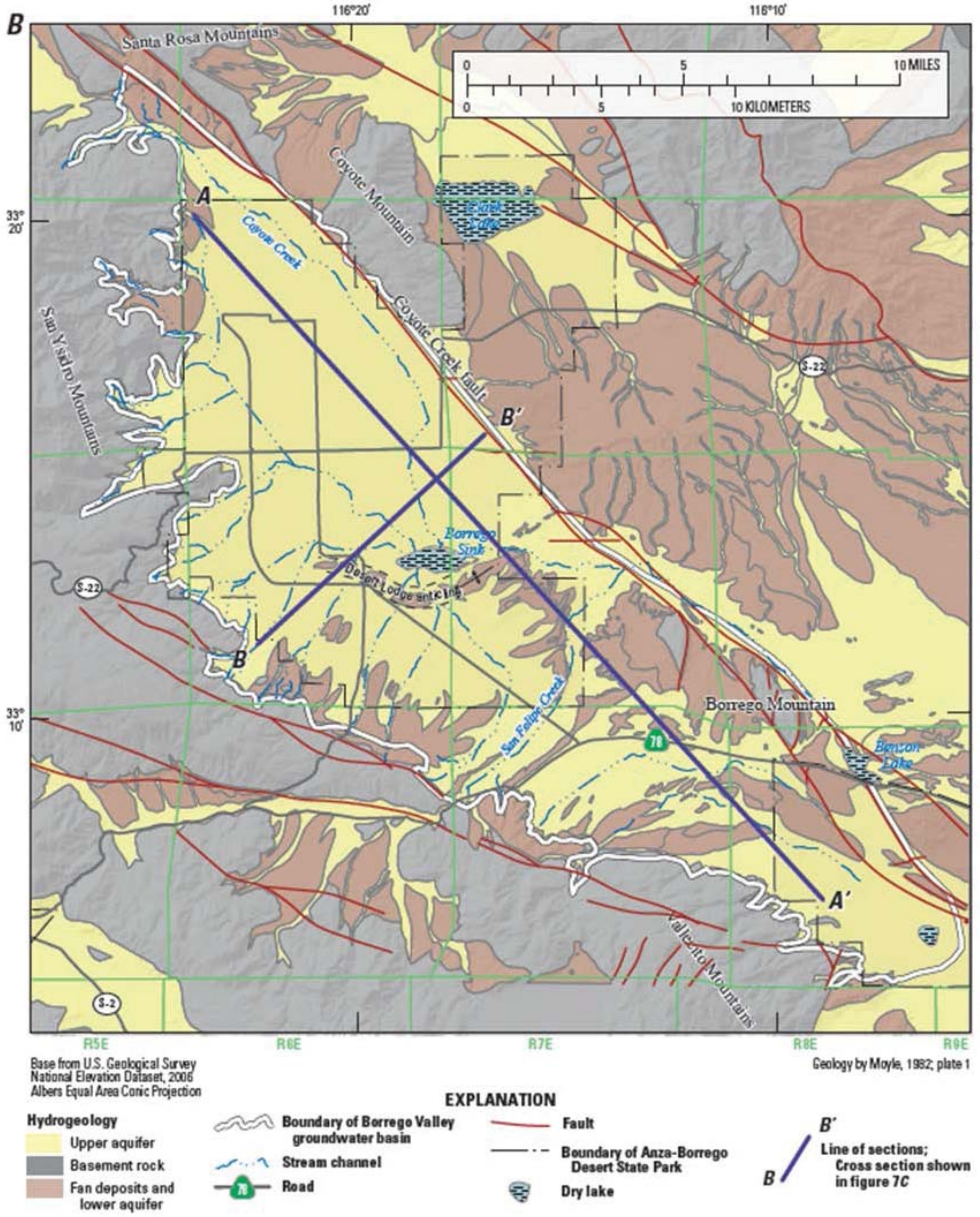
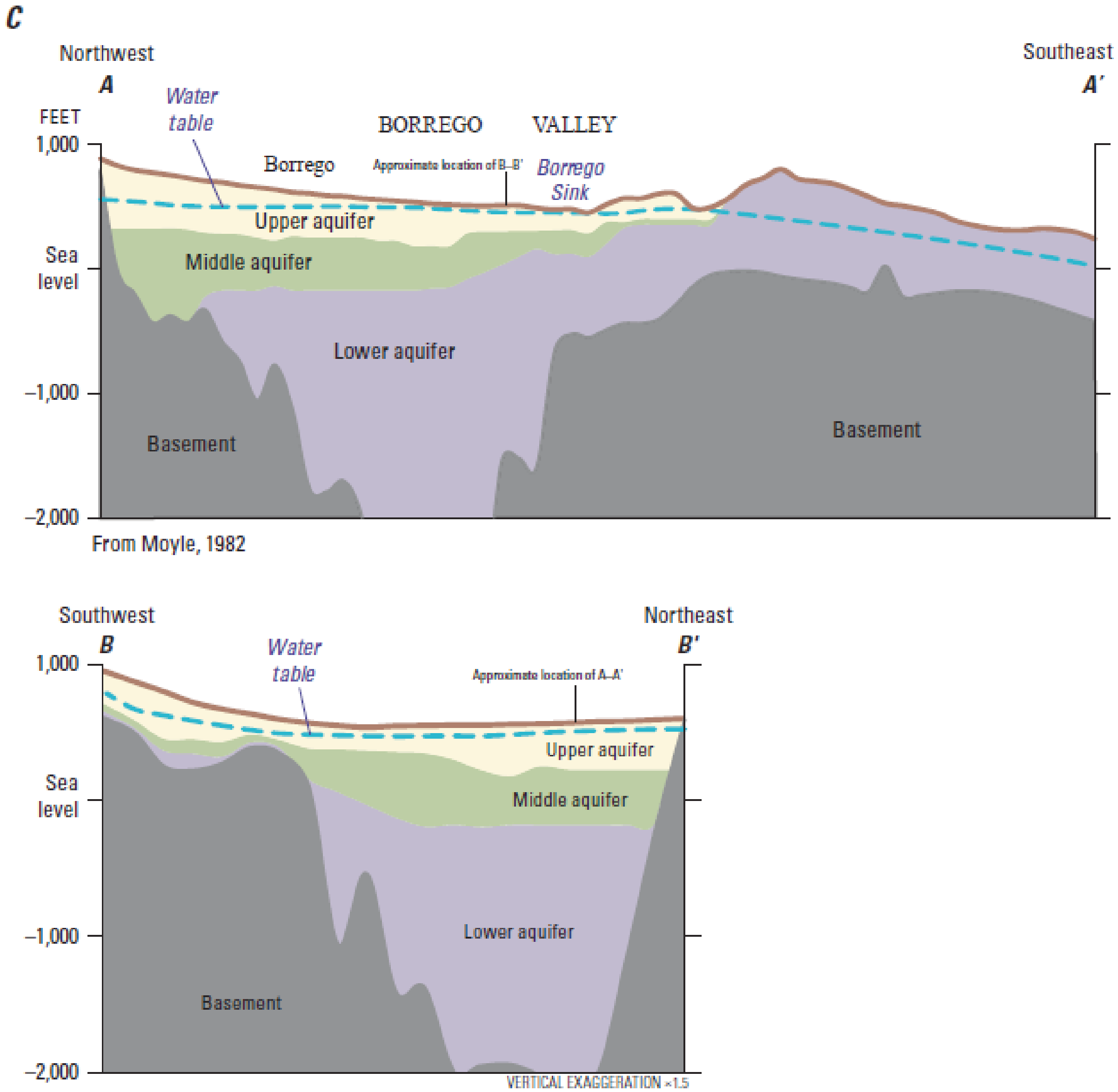


Figure 7. —Continued

FIGURE 3, continued



From Moyle, 1982

2.0 WELLS AND DATA USED IN THIS ANALYSIS

A total of 23 wells were included in this water quality analysis. Of these eight are active BWD supply wells and a ninth is used for emergency supply. The data for the wells were compiled and tabulated by Dudek staff as part of the GSP preparation process.

It is important to note that the wells were typically completed with long screened sections and can be open to flow from the upper, middle, and/or lower aquifers depending on the well construction, current groundwater levels, and well hydraulics. As a result, the data were not segregated by aquifer or depth.

Table 1A lists the active BWD wells and indicates the time periods when general minerals data were obtained. The wells have been segregated into three management areas (North, Central, and South) as established in prior work by Dudek.

TABLE 1A: BWD Water Supply Wells

Plot ID	Area	Well Name	GSA GWM Well	Year Inst.	gpm	Static Water Level (ft)	Draw Down (ft)	gpm/ft ***	Plant Eff.****	Well Depth (ft)	Sampling Period	
											start	end
4	North	**ID4-4***	Yes	1979**	365	205.4	63.5	6	71	802	1954**	2017
5		**ID4-11**	Yes	1995	620	223.2	5.8	107	73	770	1995	2017
2		**ID4-18***	Yes	1982	130	311.2	7.6	17	50	570	1984	2017
14	Central	**ID1-10***	Yes	1972	317	213.9	11.5	28	54	392	1972	2017
9		**ID1-12**	No	1984	890	145.5	10.4	86	72	580	1988	2018
12		**ID1-16**	Yes	1989	848	230.9	24.3	35	71	550	1993	2016
8		**ID5-5**	Yes	2000	542	182.1	16.1	34	62	700	2004	2016
13		**Wilcox**	Yes	1981	205	305.2	5.8	35	NA	502	2000	2017
15	South	**ID1-8**	Yes	1972	448	71.2	47.7	9	51	830	1972	2018

Notes: Data from 2018 Pump Check Results (in Dudek New Wellsite Feasibility Report, in process)
*, wells being considered for replacement (3)
**, ID4-4 was redrilled in 1979.
***, gpm/ft calculated from Pump Check data
****, Plant Efficiency from Pump Check, in percent. Values less than 60% are viewed to be of concern.

The ‘plot ID’ listed in **Tables 1A and 1B** supports the map-based location of the wells and roughly proceeds from north to south.

TABLE 1B

			Water Quality: 2Q 2018 (MCL as indicated)											
Plot ID (Figure 7)	Management Area	in GWM program?	TDS (500/1000 mg/L)	F (2 mg/L)	NO3 (as N, 10 mg/L)	SO4 (250/500 mg/L)	As (10 ug/L)	Well Name		gpm	TD (msl)	Year Inst.	notes	anion/cation trend over time (see Piper Diagram)
3	**North**	.					<2	ID4-3	IA	no data			last tested 2007	Percent Sulfate Increased, may be stable; Calcium has been variable
4		yes	330	0.16	0.5	110	2.2	ID4-4	**A***	365	-204	1979	(redrilled 1979)	Fairly stable (new well),
1		.					0	ID4-7/ Anza#4	IA	no data			last tested 1983	Percent Sulfate Increased (1973 to 1983)
5		yes	380	0.23	0.56	90	1.2J	ID4-11	**A**	620	-156	1995		Fairly stable
2		yes	**630**	0.87	0.54	**270**	<1.2	ID4-18	**A***	130	-121	1982		Percent Sulfate Increasing
14	**Central**	yes	340	0.48	1.3	67	2.8	ID1-10	**A***	317	-203	1972		Variable over time, no clear trend
9		yes	300	0.35	0.34	95	2.5	ID1-12	**A**	890	-48	1984		Fairly stable
12		yes	300	0.44	1	58	2.0	ID1-16	**A**	848	40	1989		Fairly stable
7A		.					<3	ID4-1	IA	no data			last tested 1980	Becoming more Calcium dominant (last gen min data 1980)
10		.					2.3	ID4-2	IA	no data			last tested 2010	Large change in 2010 (dec Sodium), no recent data to assess trend
7		.					2	ID4-5	IA	no data			last tested 1994	Limited data to assess trend
11		.					<2	ID4-10	IA	69?	200	1989	last tested 2012	Fairly stable
8		yes	330	0.8	0.39	100	2.1	ID5-5	**A**	542	-124	2000		Percent Sulfate Increased (2001 to 2013), may now be stable
6		.					6.4	Cocopah	**A**	1166	-393	2005	last tested 2013	Limited data to assess trend
13		yes	230	0.64	1.00	19	3.8	Wilcox	**(A)**	205	198	1981		Increasing bicarbonate, decreasing Calcium
20	**South**	yes	**1600**	0.18	0.76	**700**	<1.2	ID1-1	IA	200	-75	1972		Major changes 1972 to 2017: Increasing sulfate and Calcium; dec bicarbonate
21		yes	320	0.49	2.9	36	5.5	ID1-2	IA	200	-157	1972		Major changes 1972 to 2017: Increasing bicarbonate
15		yes	490	0.62	1.6	86	4	ID1-8	**A**	448	-335	1972		Increasing Sulfate and Chloride, Increasing Calcium
22		yes	**830**	0.56	0.5	**350**	**15**	Jack Crosby	(A)	10	194	2004		Limited data to assess trend
-		yes	640	0.37	**20**	100	2.5	WWTP	mw	mw	404	2009		Gen min data failed QA/ not assessed
16		yes	nm	nm	nm	nm	**15**	RH-3 (2017 data)	A	230	-323	2014		Limited data to assess trend
17		yes	400	1	0.49	110	6.3	RH-4	A	260	-147	2014		Limited data to assess trend
18		yes	480	1.3	3.6	100	**15**	RH-5	A	350	-169	2015		Increasing Bicarbonate
19		yes	330	1.2	3.3	31	**13**	RH-6	A	350	-312	2015		Limited data to assess trend
-		yes	450	0.51	1.2	76	2.8	MW-3	mw	mw	197	2005		Limited data to assess trend

xx	exceeds the MCL	**A***	active BWD Production Well, * indicates wells cuurently slate for replacement due to condition
note: Secondary MCLs apply to TDS and Sulfate		**A**	active non-BWD Production Well
Reccomended and maximum values		IA	Inactive BWD Well
are listed for TDS and Sulfate		mw	Monitoring Well

Figure 4 shows the well locations and names used in this Report. Review of **Figure 4** shows that the well locations are spatially biased along the western portion of the valley and the Subbasin. This is because the BWD wells are located in populated areas within their historical service areas (or Improvement Districts [ID] as indicated by the well names).

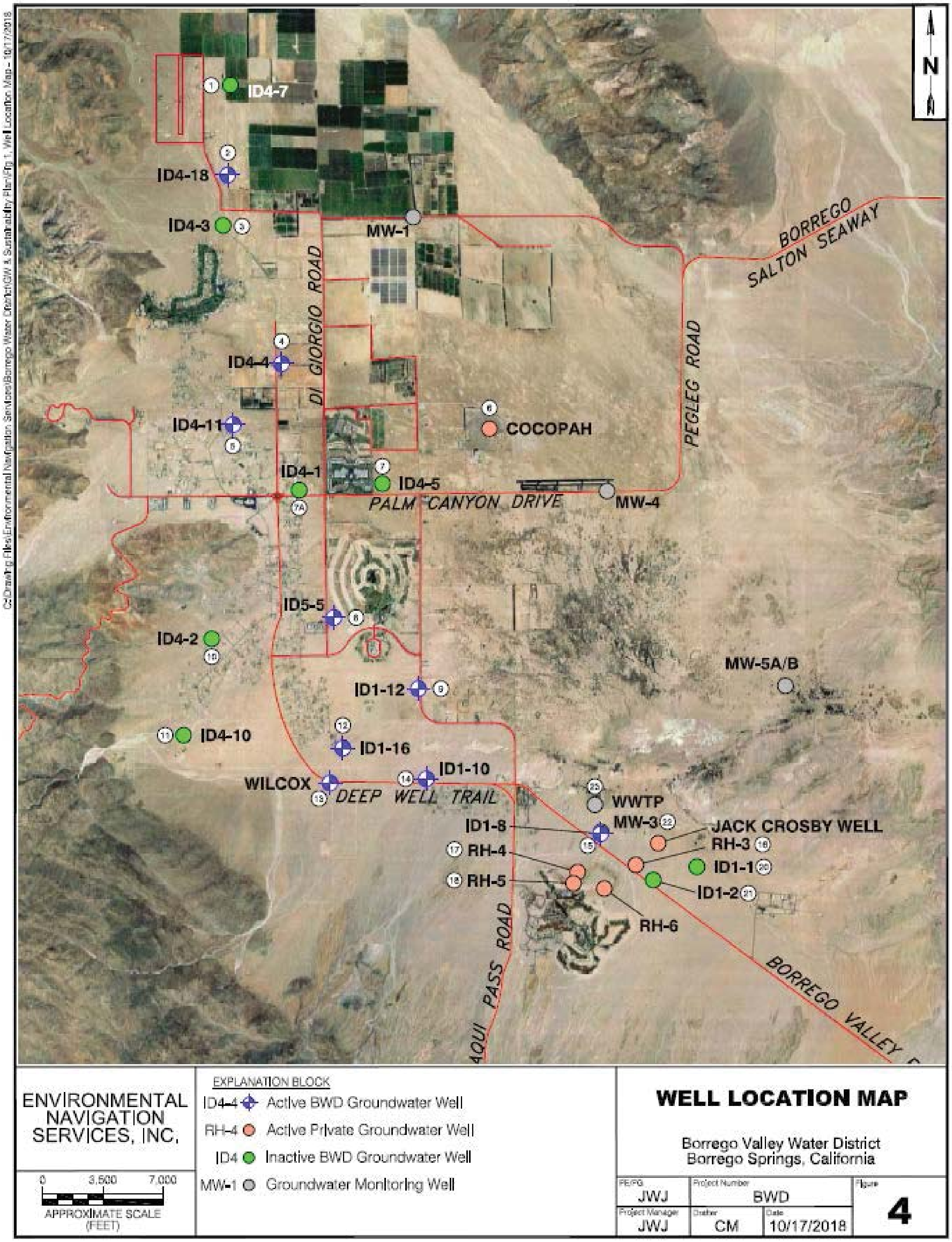
The analytical data used in the Report were located and compiled by Dudek staff from multiple sources as part of the GSP preparation process. The data base used here is from July 2018- the GSP data base is updated and revised on an ongoing basis. This Report focuses on:

- Chemicals of Concern (COCs) that include arsenic, TDS, nitrate, sulfate, and fluoride (As, TDS, NO_3, SO_4, and F).
- General Minerals: comprised of four cations- calcium (Ca^{+2}), sodium (Na^{+}), magnesium (Mg^{+2}), and potassium (K^{+}); and four anions- sulfate (SO_4^{-2} [also a COC]), chloride (Cl^{-}), carbonate (CO_3^{-2}) and bicarbonate (HCO_3^{-}).
- Hardness and pH.

The overall intent of this Report is to assess the use of multiple water quality parameters to examine how the primary COCs at BWD wells vary over time and to examine the likelihood that drinking water quality criteria will be exceeded. Of primary concern are arsenic and nitrate. Sulfate is also of concern.

Other COCs not examined in this Report include pesticides, herbicides, naturally-occurring radionuclides, and unregulated contaminants for which monitoring is required. Per State Law the Borrego Water District tests their water supply wells in accordance with California Code of Regulations Title 22 for a wide variety of potential contaminants because they operate a publicly-regulated water system. For additional information refer to their Consumer Confidence Report (CCR, available at http://www.bvgsp.org/sgma-blank.html).

FIGURE 4


C:\Drawing Files\Environmental Navigation Services\Borrego Water District\GW & Sustainability Plan\Fig 1, Well Location Map - 10/17/2018
N
① ID4-7
② ID4-18
ID4-3 ③
MW-1
DI GIORGIO ROAD
BORREGO SALTON SEAWAY
PEGLEG ROAD
④ ID4-4
⑥ COCOPAH
ID4-11 ⑤
ID4-1 ⑦A
⑦ ID4-5
PALM CANYON DRIVE
MW-4
ID5-5 ⑧
ID4-2 ⑩
MW-5A/B
ID1-12 ⑨
⑪ ID4-10
⑫ ID1-16
WILCOX ⑬
⑭ ID1-10
DEEP WELL TRAIL
㉒ WWTP
MW-3 ㉓
ID1-8 ⑮
JACK CROSBY WELL
RH-3 ⑯
⑰ RH-4
ID1-1 ⑳
⑱ RH-5
ID1-2 ㉑
RH-6
YAQUI PASS ROAD
BORREGO VALLEY R
ENVIRONMENTAL NAVIGATION SERVICES, INC.
0 3,500 7,000
APPROXIMATE SCALE (FEET)
EXPLANATION BLOCK
ID4-4 Active BWD Groundwater Well
RH-4 Active Private Groundwater Well
ID4 Inactive BWD Groundwater Well
MW-1 Groundwater Monitoring Well
WELL LOCATION MAP
Borrego Valley Water District
Borrego Springs, California
PE/PG JWJ
Project Number BWD
Figure 4
Project Manager JWJ
Drafter CM
Date 10/17/2018

3.0 SUBBASIN-WIDE WATER QUALITY: GENERAL MINERALS, ARSENIC, AND NITRATE

The term “general minerals” is a descriptor that includes the eight anions and cations that typically comprise most of the minerals, by mass, dissolved in groundwater. Anions are negatively charged and cations are positively charged. The eight dominant ions include four cations- calcium (Ca^{+2}), sodium (Na^{+}), magnesium (Mg^{+2}), and potassium (K^{+}); and four anions- sulfate ($SO4^{-2}$), chloride (Cl^{-}), carbonate ($CO3^{-2}$) and bicarbonate ($HCO3^{-}$). Of these, sulfate is a COC. TDS is also a COC and represents the sum all of the anions and cations in solution.

Table 2. Common Cations and Anions Analyzed in the Subbasin

Common Cations	Common Anions
calcium (Ca^{+2})	sulfate (SO_4^{-2})
sodium (Na^{+})	chloride (Cl^{-})
magnesium (Mg^{+2})	carbonate (CO_3^{-2})
potassium (K^{+})	bicarbonate (HCO_3^{-})

The dominant anions and cations can be used to examine how the chemistry of groundwater varies in time at a well, or spatially among wells. Because they occur as a result of rock and mineral dissolution, they can also be diagnostic of minerals such as sulfates and carbonates that occur in the subsurface, or that occur in water being recharged to the aquifer system.

Graphical methods used to depict multiple anions and cations include Stiff Diagrams and Trilinear or Piper Diagrams.[10] Both are used in this Report and will be explained in more detail in Sections 3.1 and 3.2, respectively.

3.1 Spatial Overview (DWR, 2014; Stiff Diagrams)

Stiff diagrams graphically depict the relative concentrations of three dominant anions (Cl, HCO3, and SO4) together with three dominant cations (Na, Ca, and Mg) determined from water samples.[11] A 2014 groundwater quality study was conducted by the California Department of Water Resources (DWR)[12] based on the compilation of DWR, BWD, and USGS water quality data generally obtained between 1950 and 2014. A map depicting Stiff Diagrams of water quality is depicted in **Figure 5**.

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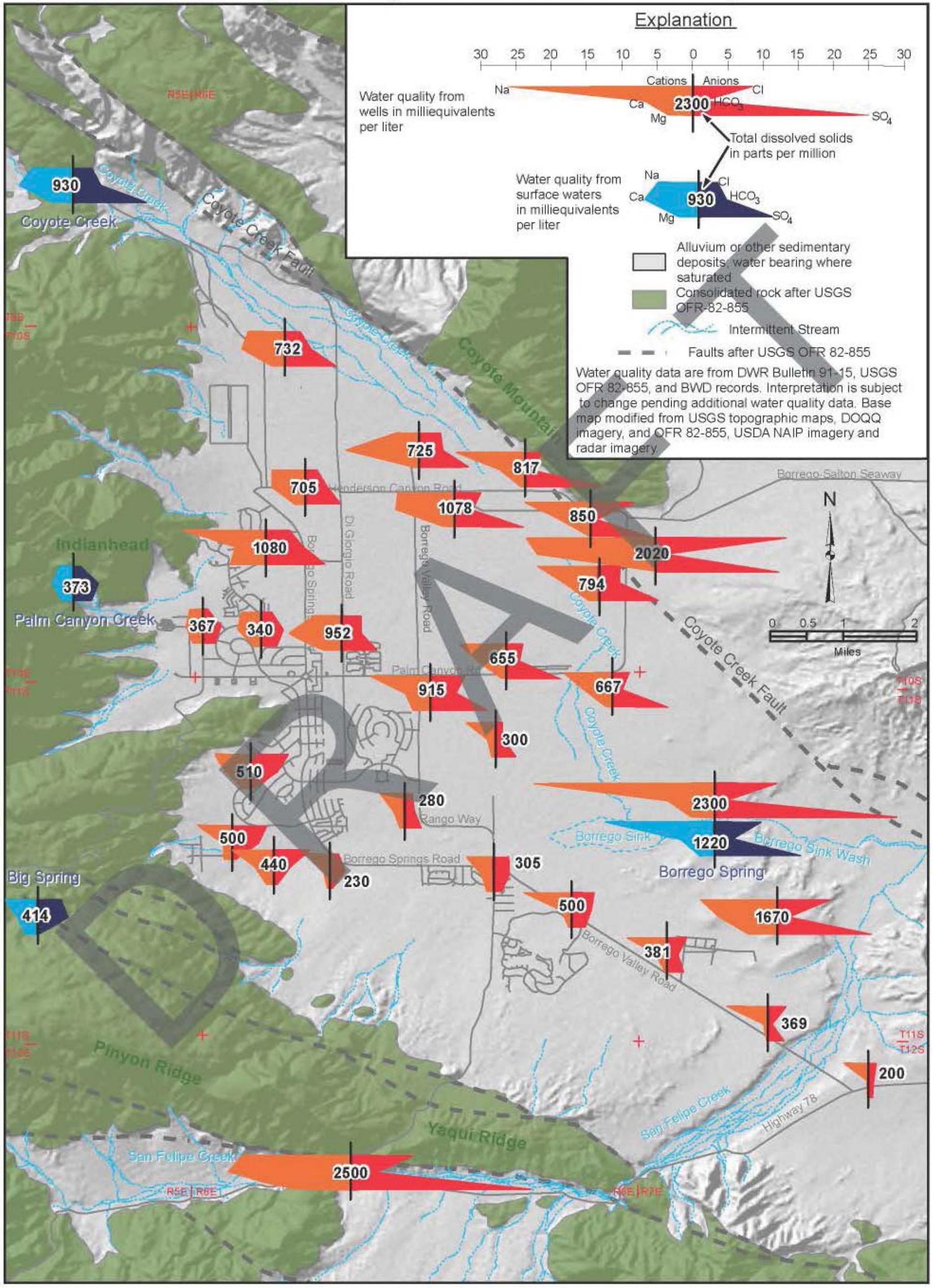
[10] An overview summary is provided by: Hem, J.D., 1989, Study and interpretation of the chemical characteristics of natural water: U.S.
Geological Survey Water-Supply Paper 2254, 3rd edition, Washington D.C., 263 p.

[11] Stiff, H.A., Jr., 1951, The interpretation of chemical water analysis by means of patterns: Journal of Petroleum Technology, v. 3, no. 10, p. 15-17.

[12] DWR, 2014. Powerpoint presentation by Dr. Tim Ross dated May 2014. A copy is included for reference in **Appendix A**.

FIGURE 5

Borrego Valley Groundwater Quality



Water quality data are from DWR Bulletin 91-15, USGS OFR 82-855, and BWD records. Interpretation is subject to change pending additional water quality data. Base map modified from USGS topographic maps, DOQQ imagery, and OFR 82-855, USDA NAIP imagery and radar imagery.

An explanation of how the analytes are depicted using Stiff Diagrams is also included in **Figure 5**. The 'legs' and overall size of the diagrams increase as the analytes increase in concentration and allow visual comparison of each of the sample results. Also included in the diagrams is the TDS in milligrams per liter. For reference the TDS of drinking water should be no more than 1,000 mg/L and ideally less than 500 mg/L (the recommended and maximum secondary MCLs, respectively).

DWR noted based on comparison of surface water and groundwater chemistry that "*The high proportion of Sulfate in the surface water of Coyote Creek appears to dominate the character of groundwater in the northern and eastern parts of the basin. The more Bicarbonate waters of Borrego Palm Canyon and Big Spring influence the groundwater along the western and southern parts of the basin.*" For reference, the surface water watersheds are shown in **Figure 1**.

Additional observations that can be made from the Stiff Diagrams include:

- Surface water inflows that enter the along the edges of the valley are the primary source of recharge. The highest quality groundwater (TDS < 500 mg/L) generally occurs near recharge areas.
- Groundwater quality tends to increase in TDS towards the Borrego Sink with distance from the recharge areas. Ongoing evaporation and accumulation of minerals is occurring within the Subbasin. The Subbasin is effectively a closed basin and has been a closed basin during much of the time that alluvial sediments have been deposited from current watersheds. (Please refer to the GSP for a detailed description of the Subbasin geology and sedimentology.)
- Elevated concentrations of sulfate in surface waters are of concern from a water quality standpoint. Groundwater within the San Felipe Creek watershed that potentially recharges the South Management Area contains relatively high concentrations of sulfate, calcium and sodium.
- The Stiff Diagrams highlight the dominance of sulfate in groundwater (lower right portion of the diagrams). Sodium and chloride (upper right and upper left 'legs') also occur at significant concentrations in many samples.

The DWR presentation also reviewed TDS trends with time and depth at selected wells. No consistent trends were identified. The data were not evaluated in terms of the upper, middle, or lower aquifer.

DWR also assessed nitrate. Review of their results is included in **Section 3.5**.

3.2 General Minerals: Spatial Variability Based on Piper Diagrams

The eight dominant anions and cations can also be analyzed using Piper trilinear diagrams (Piper, 1944).[13] In brief, the Piper plot is a visualization technique for groundwater chemistry data. It is based on a combination of ternary diagrams for the major anions and cations that are then projected onto a central diamond. The concentration data on (milligrams/liter) are converted to milliequivalent (meq/L), a measure of the number of electrochemically active ions in the solution.[14] The analytes are plotted as relative proportions in order to examine the relative percentages of each of the dissolved minerals, primarily to show clustering or patterns of samples. The diagrams also support interpretation of trends and potential mixing of waters that have different chemistry.

Figure 6A provides a brief explanation of the Piper diagram. The methodology is explained in more detail in **Appendix B**, together with the Piper trilinear diagrams for all of the wells as noted in **Table 1B**. Ternary diagrams present a combination of three values that add up to 100 percent. The three values are 'picked off of' the sides of triangle by projection along a triangular grid. Please refer to **Appendix B** as needed for additional explanation.

Recent general minerals data, dating from 2004 to present, were used to represent the water chemistry at each of the wells. Review of the data supported the use of two data subsets. The North and Central Management Area wells have been combined and the South Management Area wells are presented as a second set. **Figure 6** depicts the data. Each of the wells are numbered per **Figure 4** and **Table 1** to simplify the data presentation. The numbering generally follows from north to south along the axis of the valley.

3.2.1 Data Quality Review: General Minerals

The data presented in the Piper diagrams underwent a data quality review based on the ion chemistry. Groundwater under natural conditions should be at or near electrochemical equilibrium. Here the sum of the negatively charged anions (in meq/L) was checked versus the sum of the positively charged cations. The sums should be similar (within ~5%) for a solution that is in equilibrium. Not all of the data were used because in some cases not all of the eight general minerals data were analyzed and in other cases the anion/cation balance test failed. As explained above, the anion/cation balance test may fail as a result of less common anions or cations being present within the water quality sample that were not analyzed. Charge imbalance may also indicate laboratory error.

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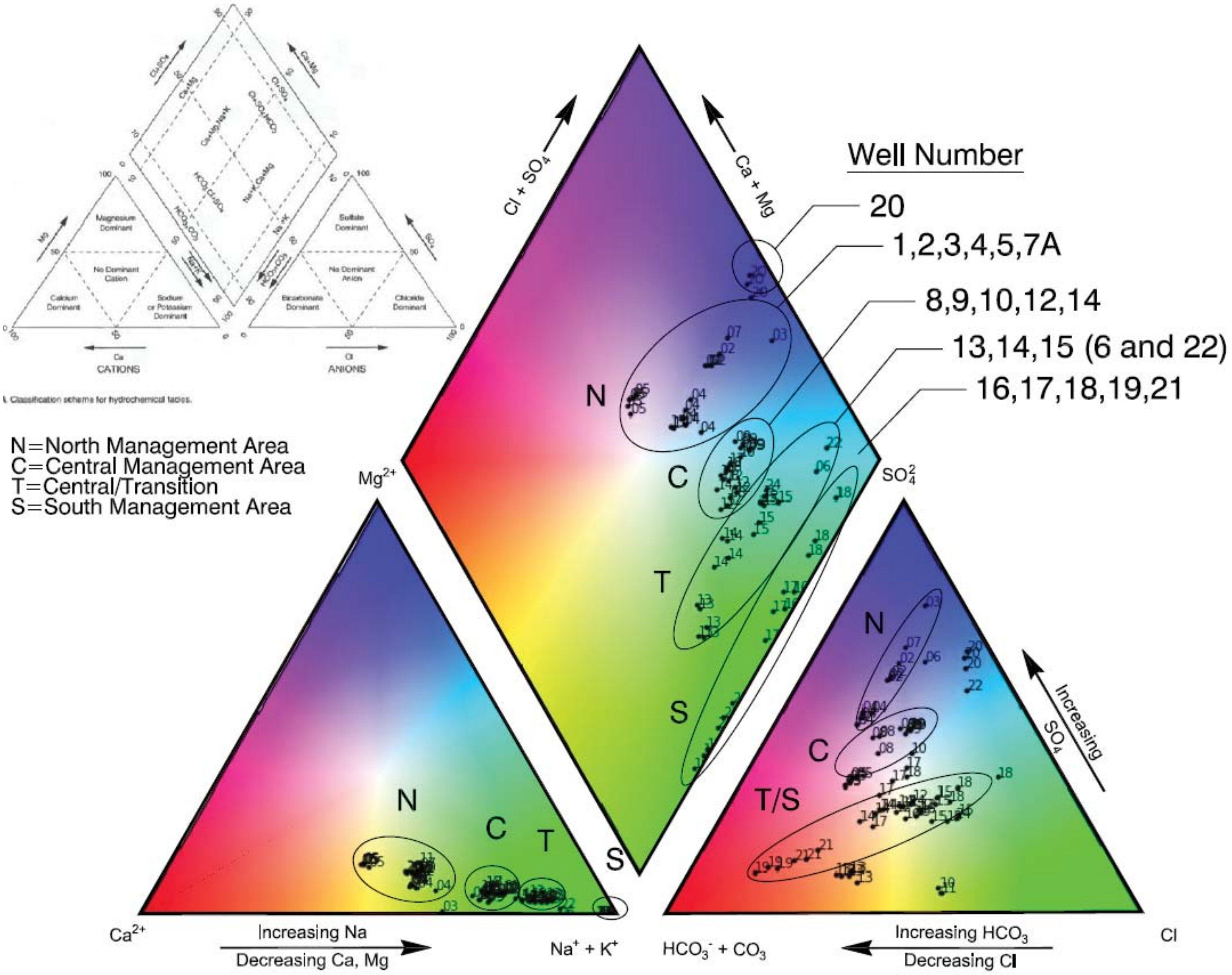
[13] Piper, A.M. 1944. A graphic procedure in the geochemical interpretation of water-analyses. Transactions-American Geophysical Union 25, no. 6: 914–923

[14] The number of ions in a solution is expressed in terms of moles, a unit widely used in chemistry as a convenient way to express amounts of reactants and products of chemical reactions. An equivalent is the number of moles of an ion in a solution, multiplied by the valence of that ion. For example, if 1 mole of NaCl and 1 mole of $CaCl_2$ are dissolved in a solution, there is 1 equivalent of Na, 2 equivalents of Ca, and 3 equivalents of Cl in that solution. The calculation is based on: mEq/L = (mg/L × valence) ÷ molecular weight.

The eight anions and cations generally comprise the bulk of the minerals that comprise TDS. Sodium and calcium are the dominant cations; bicarbonate, sulfate, and chloride are the dominant anions. The long-term average concentrations, in mg/L, for the nine BWD wells were TDS (378), calcium (39), sodium (82), magnesium (5.4), and potassium (5), sulfate (112), chloride (56), carbonate (0.6) and bicarbonate (124). Nitrate averaged 1.8 mg/L.

A calculation of TDS was made by summing the concentrations of the eight anions and cations and comparing it to the TDS for all samples that met a 5% or less charge imbalance criteria. On average the sum was less than the TDS by 40 mg/L, where the mass of cations exceeded the mass of anions. Other anionic COCs not included in the calculation include fluoride and nitrate, but when these were added into the calculations the mass of anions remained lower than the mass of cations. While the mass balances remained within tolerance, the results suggest that additional anions occur in groundwater that have not been tested. Phosphates are one type of anion that may occur but have not been included in the analytical program.

FIGURE 6: Piper Diagram, recent data for all wells (2004 to 2018)



Notes:

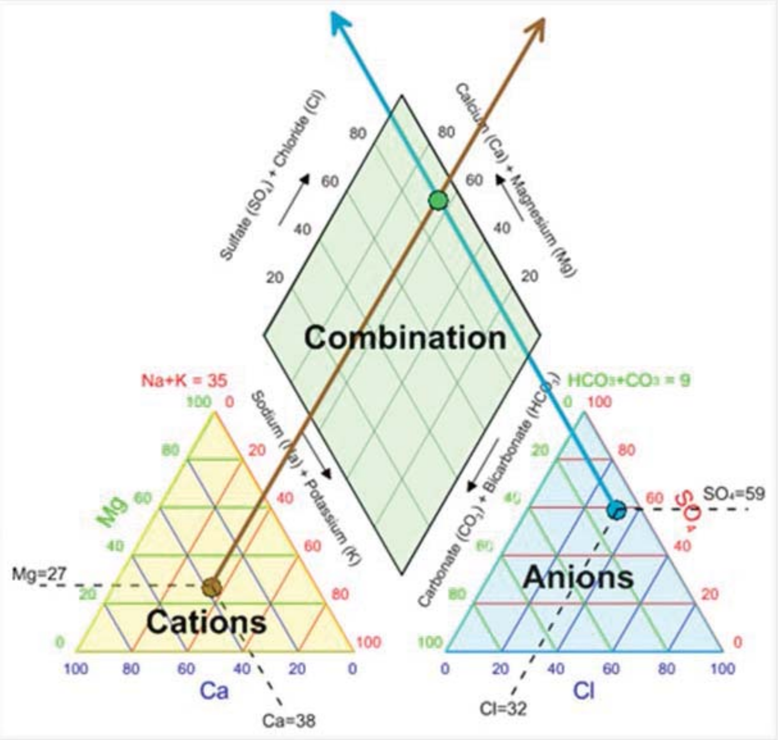
1. Numbers correspond to IDs shown in Figure 4. These generally increase from north to south.

2. The wells by management area include:

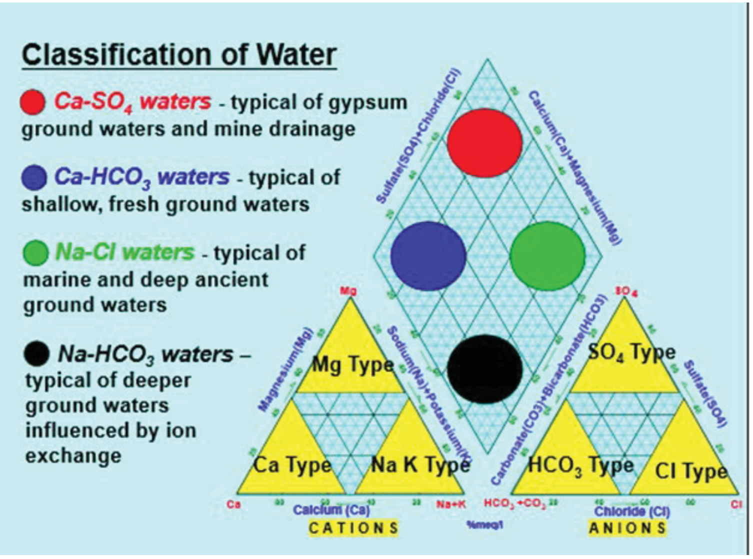
North Management Area: Wells # 1 to 5, #7, and #11
Central Management Area: Wells #8, #9, #10, and 12
“Transitional”: Wells #6, #13, #15, #16, #22
South Management Area: Wells #17 to 21, #23

FIGURE 6A

The Piper diagram is used to plot the 8 general minerals based on two ternary diagrams (triangles, at the base) that are projected onto a central diamond area. From (www.goldensoftware.com)



Where the subregions generally depict the chemical characteristics of the water (from http://inside.mines.edu/~epoeter/_GW/18WaterChem2/WaterChem2pdf.pdf)



Classification of Water

● ***Ca-SO_4 waters*** - typical of gypsum ground waters and mine drainage

● ***Ca-HCO_3 waters*** - typical of shallow, fresh ground waters

● ***Na-Cl waters*** - typical of marine and deep ancient ground waters

● ***Na-HCO_3 waters*** – typical of deeper ground waters influenced by ion exchange

Here colors are used to show subareas following a methodology presented by Peeters, 2014. (A Background Color Scheme for Piper Plots to Spatially Visualize Hydrochemical Patterns by Luk Peeters, Vol. 52, No. 1–Groundwater–January-February 2014). Also see **Appendix B**.

No distinction was made regarding well completion by aquifer because of a lack of water quality data as a function of depth. However, while the wells include a range of ell completions, the data do not indicate that any differentiation can be made among wells based on recent data (2004 to present). Review of the Piper Diagrams indicates that a systematic variation of water quality can be observed from north to south, and that the water quality in the South Management Area is sufficiently different to support segregation of the data into two data sets. Inorganic water quality depicted in the central Piper diagrams (**Figure 7**) indicates the data generally group by management area (MA): North MA (Wells # 1 to 7, and 11), Central MA (Wells #8, #9, #10, and 12), “Transitional” between the Central and South MAs (#13, #15, #16, #22), and South MA (#17 to 21, #23). Data from sets of wells align on the Piper diagram (**Figure 6**) indicative of waters that are mixing. Some general observations follow:

North and Central Management Areas

- A subset of the wells in the northern part of the basin (#1, #2, #3, and #4) occur along a line of anion data where high sulfate occurs.
- The North and Central Management Areas subdivide into two groups within the Piper diagram. With distance towards the south a general trend occurs where chloride decreases, bicarbonate increases, and sulfate decreases. Two mixing lines may occur where the waters go from sulfate dominant to a mixed condition (no dominant anion).

South Management Area

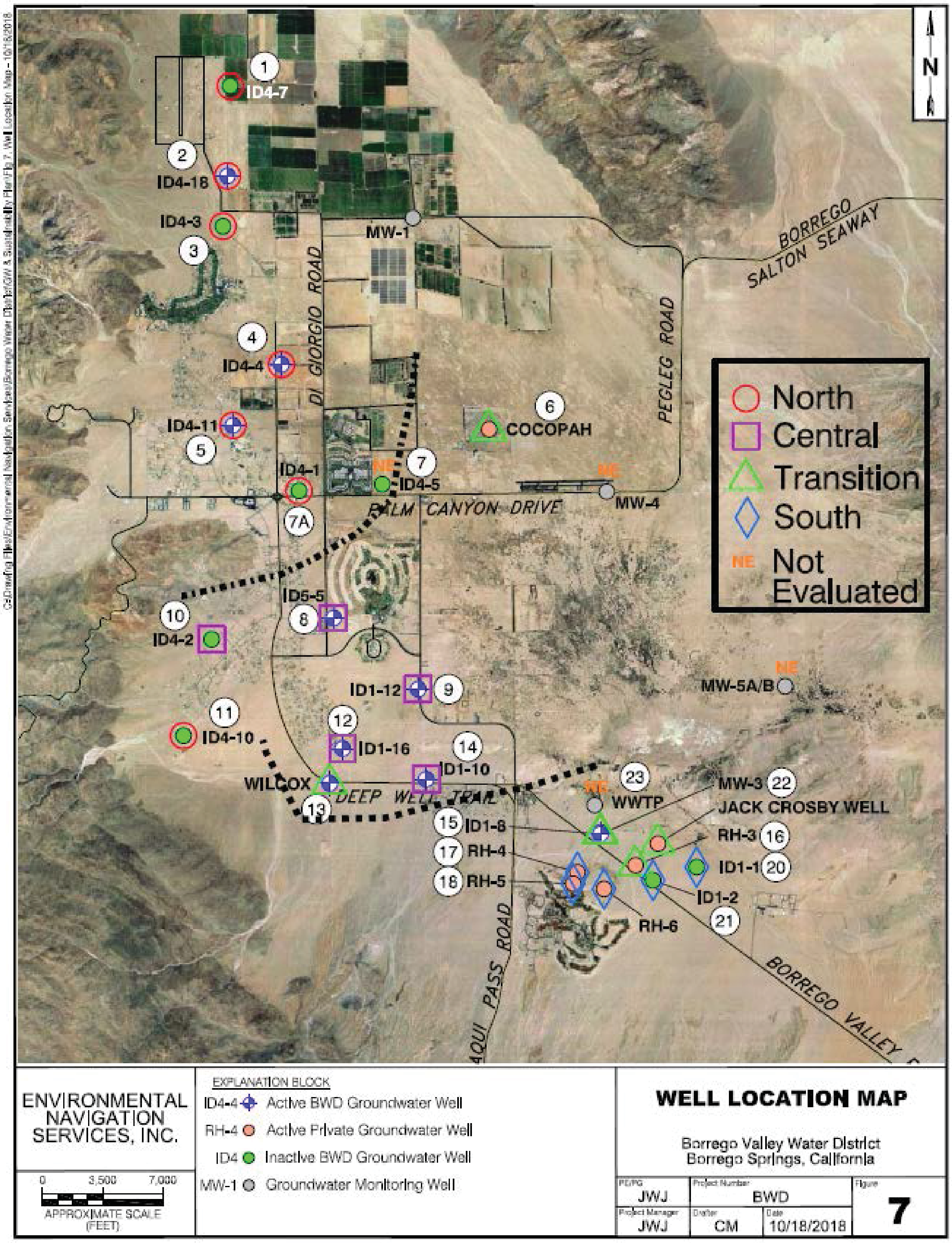
- A transitional zone occurs roughly coincident with the location of the Desert Lodge anticline (as depicted in **Figure 3**). The anticline is regarded as a structure that influences groundwater flow (refer to the GSP for further details).
- Mixing lines are observed for both cations and anions. For anions: as chloride decreases, bicarbonate increases, and sulfate decreases. For cations: as calcium decreases, sodium and magnesium increase.
- As also noted by the Stiff diagrams, the North Management Area has high sulfate as indicated by points that occur in the upper part of the cation ternary diagram. In contrast the South Management Area wells either have no dominant anion or become bicarbonate dominant (the lower left portion of the ternary diagram for anions).

Overall the Piper diagrams support that the inorganic water chemistry systematically varies across the Subbasin. The primary observations are summarized in **Figure 7**:

- Water quality gradually changes from north to south within the North and Central Management Areas, consistent with pre-development groundwater flow patterns.
- For both areas the cation relationships (calcium, magnesium, and sodium) are similar and are generally sodium dominant. In both cases the water quality is characterized by decreasing calcium and increasing percentages of sodium and magnesium.
- The South Management Area anionic water chemistry is different than the North and Central Management Areas, likely due to the difference in the San Felipe Creek recharge water and potential differences in aquifer mineralogy.

FIGURE 7

Shows water chemistry classified into the three Management Areas North, Central, and South. Also notes Transition (between central and south)



3.3 General Minerals: Variations Over Time at Wells, Piper Trilinear Diagrams

Of central concern to BWD and all other users of groundwater within the Subbasin is water quality degradation over time due to ongoing overdraft, irrigation and septic-related return flows, and loss of higher quality water due to dewatering of the upper aquifer. Piper trilinear diagrams were constructed for each of the wells using available historical data (compiled in **Appendix B**). Two examples are included as **Figures 8** and **9** where one well has had significant changes in water quality over time versus another that has been relatively stable.

The Piper diagrams depict relative ratios of the anions and cations, not the total concentrations. Also included in the figures are graphs of the anions and cations that present the measured concentrations (in mg/L).

ID1-8 (South Management Area, Well#15 on **Figure 7**)

Water chemistry has significantly changed over time at ID1-8. This well is in the South Management Area as depicted as Well #15 on **Figure 7**. It has been sampled since 1972. **Figure 8** includes a Piper Diagram and charts depicting TDS, cations, and anion concentrations over time.

Observed is historically decreasing bicarbonate, increasing chloride, and increasing calcium. Recent data indicates that water quality may be stabilizing.

In terms of overall chemistry (see **Figure 6A**) the water in this well in now described as sodium chloride dominant, typical of marine and deep ancient groundwater.

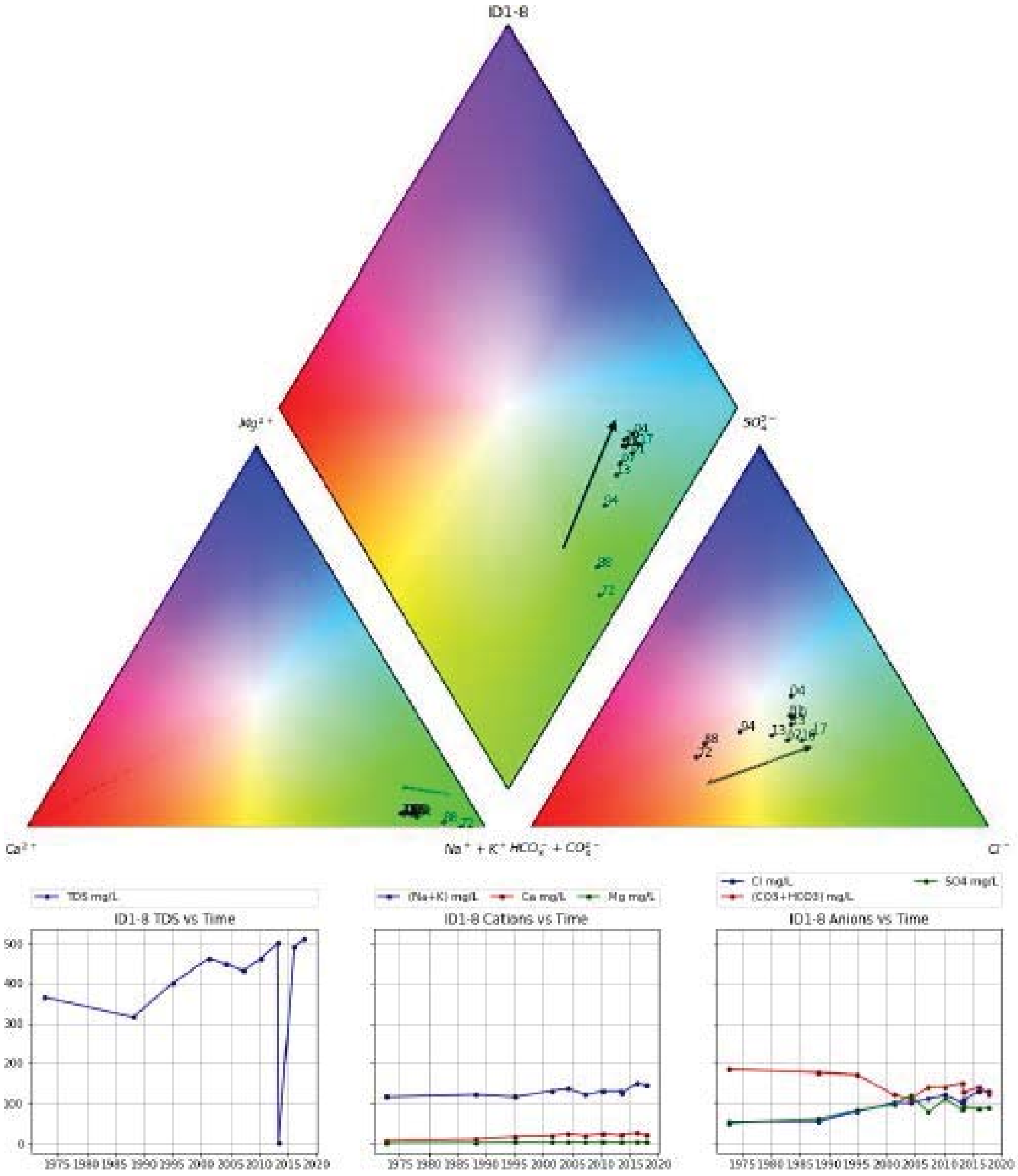
ID4-18 (North Management Area, Well #2 on **Figure 7**)

This well is in the North Management Area as depicted as Well #2 on **Figure 7**. It also has been sampled since 1972. **Figure 9** includes a Piper Diagram and charts depicting TDS, cations, and anion concentrations over time.

There is much less overall change with time compared to ID1-8, but the sampling data do show sulfate is increasing. The change is subtle change but significant since concentrations are above the recommended secondary MCL of 250 mg/L, but do remain below the upper MCL of 500 mg/L. Sulfate is increasing as bicarbonate decreases over time. The points in the anion portion of the diagram (lower right triangle) occur along a line indicative of increasing sulfate.

In terms of anion chemistry (see Figure 6A) the water in this well in now described as sulfate dominant. Sulfate is a COC.

FIGURE 8: ID1-8 (see Figure 8A for explanation of the diagram and axes)

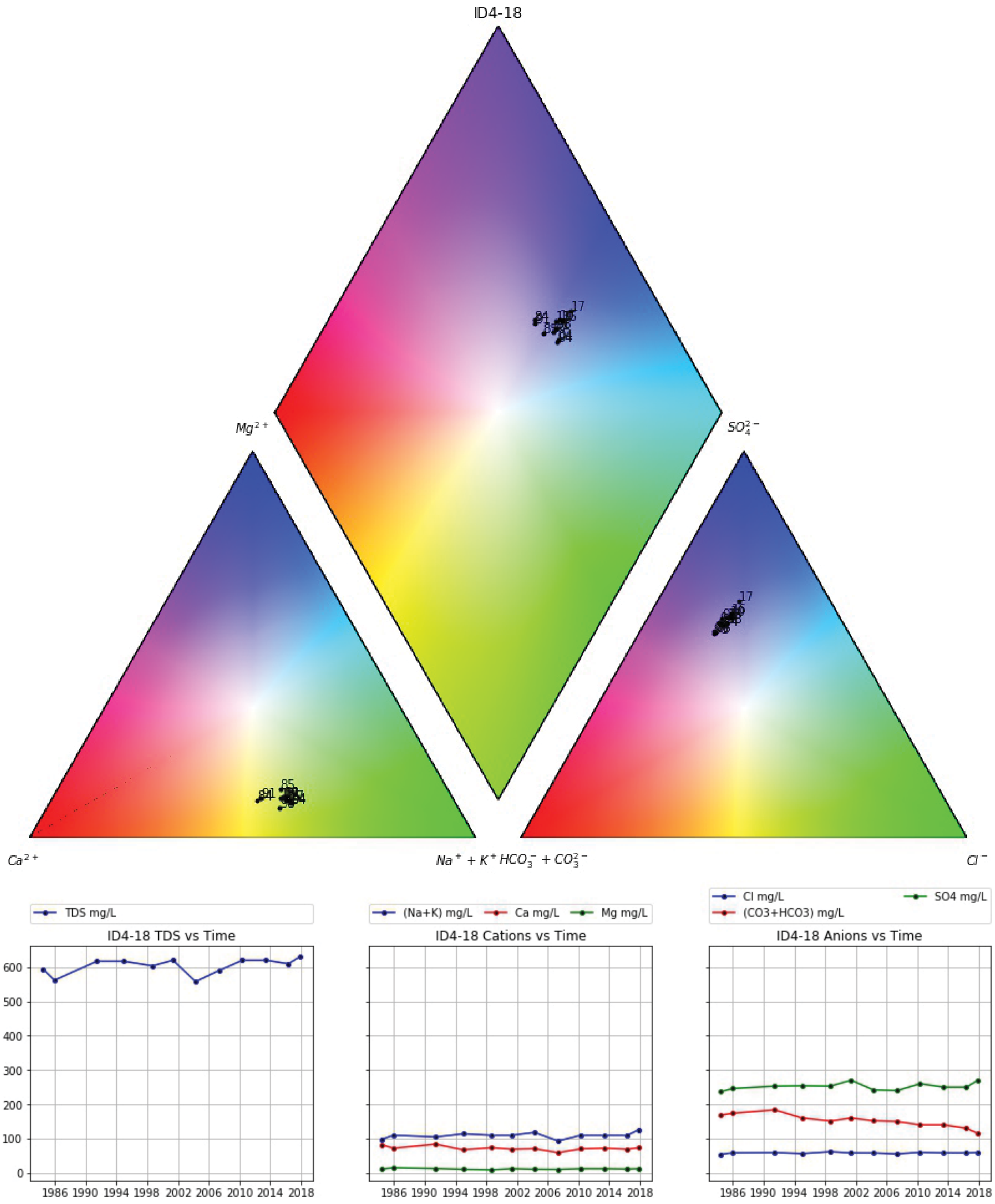


Notes:

1. The last two digits of the year the samples were taken are shown in the Piper diagram.

2. Chemistry has changed due to increases in sulfate, chloride, and sodium; and decreased bicarbonate. The change from 1970s to the 2000s is evident. TDS is also increasing.

FIGURE 9: ID4-18



Note:

1. The last two digits of the year the samples were taken are shown in the Piper diagram.

2. Water chemistry is fairly stable with a slow increase in sulfate and decrease in bicarbonate.

3.4 TDS with Depth

Well profiles based on TDS and temperature were presented by the DWR in a 2014 presentation (as referenced in footnote #11, a copy is included in **Appendix A**). **Figure 10** presents the profile data obtained from eleven wells that ranged in depth from 280 to 900 feet. For reference BWD water supply wells currently range in depth from 392 to 830 feet (Table 1).

Review of **Figure 10** supports the following:

- TDS varied by well, with linear increase with depth at each well. The exception is well ID4-3 where a step-wise increase in TDS was observed at a depth of approximately 350 feet.
- Groundwater temperature was relatively warm, ranging from approximately 80 to 90 ^{o}F. All wells exhibited increasing temperature with depth.

Geologic conditions and lithologies do change with depth, and it is generally expected that water quality change will decrease with depth. While quite important towards understanding the effect of overdraft on water quality, relatively few depth-specific groundwater chemistry data have been obtained in the Subbasin. The data presented in **Figure 10** are obtained by lowering measurement probes into the wells and are relatively inexpensive to collect provided there are no obstructions in the well. Additional discussion of well profiling methods is included in the report recommendations.

FIGURE 10

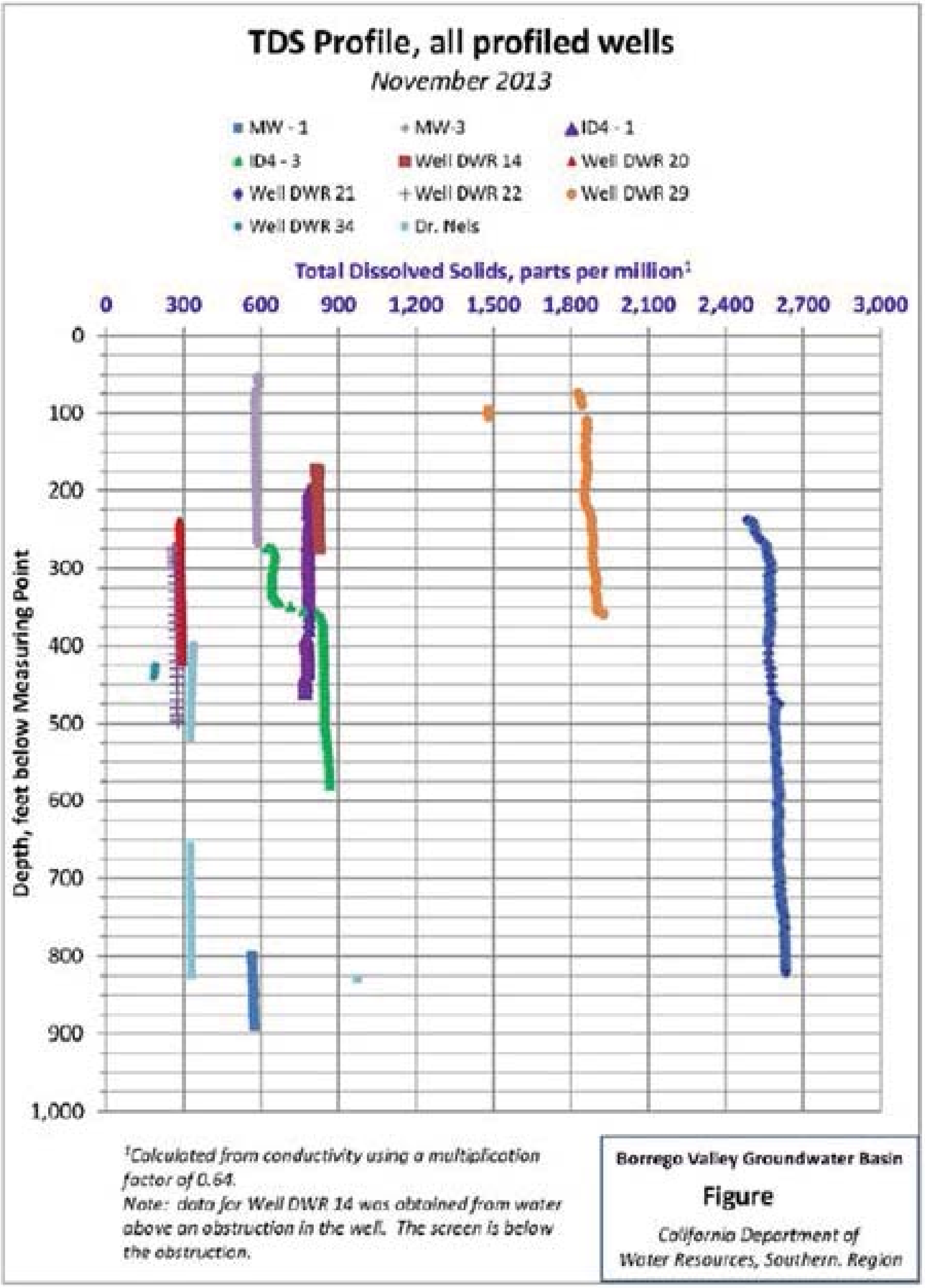
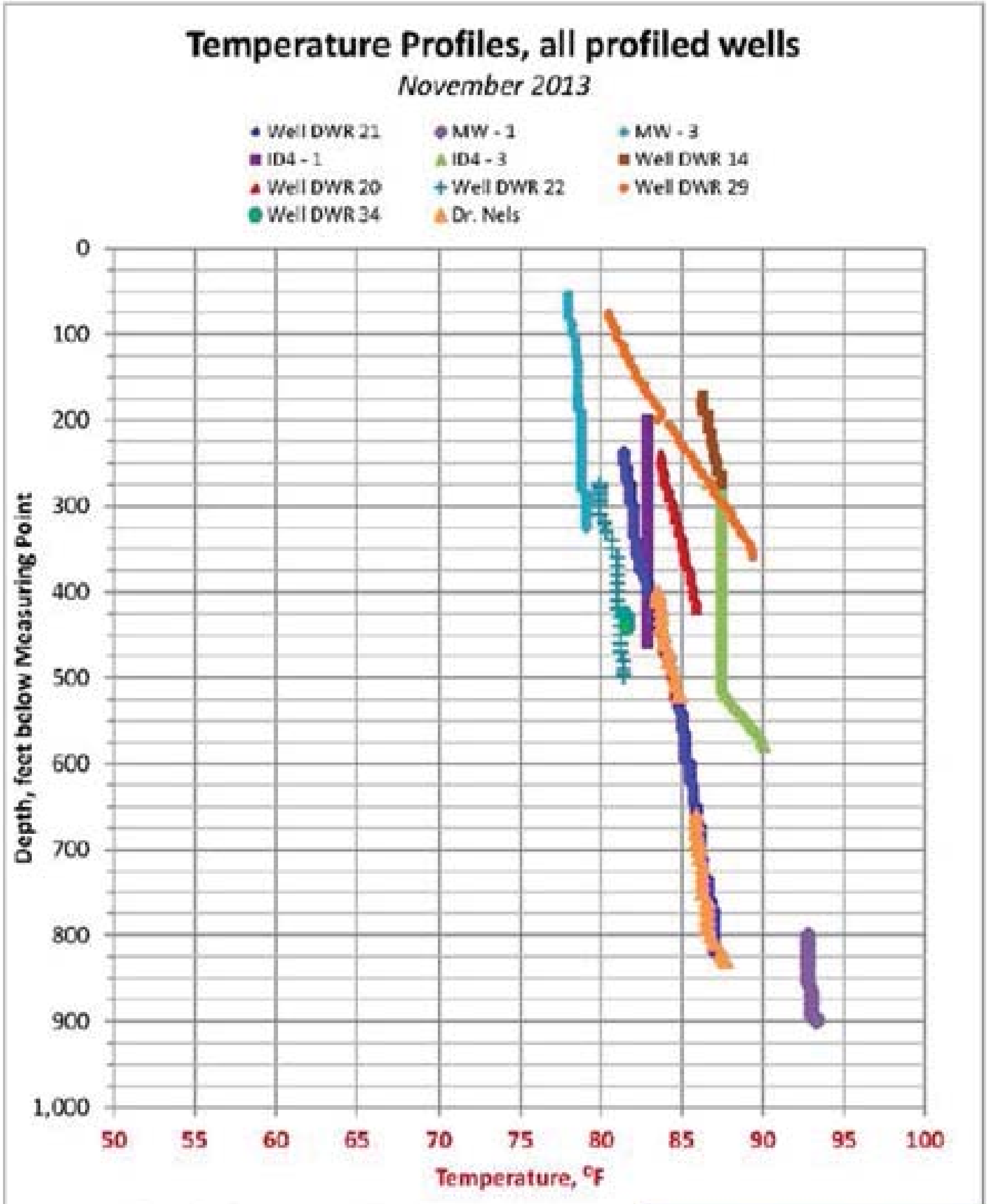

TDS Profile, all profiled wells
November 2013
MW - 1
MW-3
ID4 - 1
ID4 - 3
Well DWR 14
Well DWR 20
Well DWR 21
Well DWR 22
Well DWR 29
Well DWR 34
Dr. Nels
Total Dissolved Solids, parts per million¹
0
300
600
900
1,200
1,500
1,800
2,100
2,400
2,700
3,000
Depth, feet below Measuring Point
0
100
200
300
400
500
600
700
800
900
1,000
¹Calculated from conductivity using a multiplication factor of 0.64.
Note: data for Well DWR 14 was obtained from water above an obstruction in the well. The screen is below the obstruction.
Borrego Valley Groundwater Basin
Figure
California Department of Water Resources, Southern. Region

FIGURE 10, continued



[1]Calculated from conductivity using a multiplication factor of 0.64.

Note: data for Well DWR 14 was obtained from water above an obstruction in the well. The screen is below the obstruction.

Borrego Valley Groundwater Basin

Figure

California Department of Water Resources, Southern. Region

3.5 Nitrate

Nitrate (NO_3) is a groundwater contaminant that is commonly detected in drinking water supplies obtained from alluvial basins throughout the southwestern US (see, for example, USGS NAWQA[15], CA SWRCB GAMA[16], and others). Nitrate in groundwater has many natural sources, but nitrate concentrations in groundwater underlying agricultural and urban areas are commonly higher than in other areas. The primary sources of nitrate in the Subbasin include fertilizers associated with agriculture and turf grasses (golf courses), and septic systems.

The relationship between groundwater quality and overlying land uses was examined by DWR (DWR, 2014; in **Appendix A**). **Figure 11** shows "*the distribution of nitrate analyses for the Borrego Basin. Maximum content is shown per section and sections are colored according to the number of analyses in the section. Sections where the maximum contaminant level (MCL) are exceeded are shown in hatched patterns.*" The DWR analysis shows that nitrates occur above MCLs in multiple wells.

The USGS reviewed nitrate data and stated that "*TDS and nitrate concentrations were generally highest in the upper aquifer and in the northern part of the Borrego Valley where agricultural activities are primarily concentrated." (USGS Model Report, p.2) … "Water-quality samples from wells distributed throughout the valley show that NO_3-N concentrations ranged from less than 1 mg/L to almost 67 mg/L. NO_3-N concentrations were highest in the shallow aquifer and exceeded the CA-MCL of 10 mg/L in some samples from the shallow and middle aquifers in the northwestern part of the basin (fig. 26). NO_3-N concentrations in samples from the lower aquifer did not exceed 6.7 mg/L.*" (USGS Model Report p.64)

Further spatial analysis of the occurrence of nitrate relative to land use is not included in this report. Additional review of nitrate data is included in **Section 3.7**, and in the GSP.

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[15] Thiros, S.A., Paul, A.P., Bexfield, L.M., and Anning, D.W., 2014, The quality of our Nation's waters—Water quality in basin-fill aquifers of the southwestern United States: Arizona, California, Colorado, Nevada, New Mexico, and Utah, 1993–2009: U.S. Geological Survey Circular 1358, 113 p., http://dx.doi.org/10.3133/cir1358. National Ambient Water Quality Assessment (NAWQA)

[16] Groundwater Ambient Monitoring and Assessment Program (GAMA
See:)https://www.waterboards.ca.gov/gama/

3.5.1 Supporting Information Regarding Nitrate

Historical groundwater quality impairment for nitrates is noted in the GSP to predominantly occur in the upper aquifer of the North Management Area underlying the agricultural areas, and near areas with a high density of septic point sources. The primary source of nitrates is likely associated with either fertilizer applications.

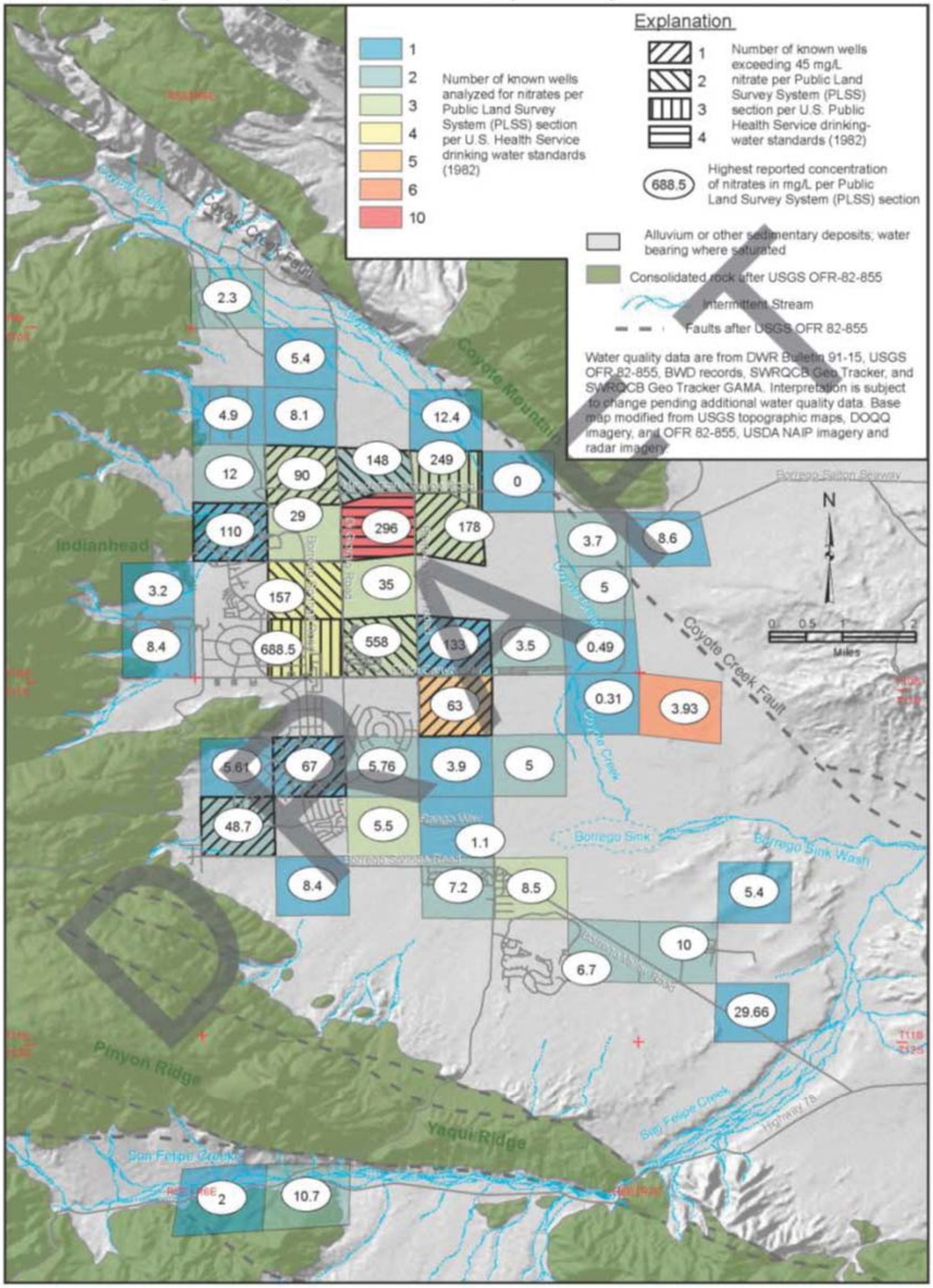
Information provided by Dudek in the GSP supports that nitrates have historically impacted multiple wells as follows. It is understood that the BWD Improvement District 4 (ID4) well 1 and 4, Borrego Springs Water Company Well No. 1 (located at the BWD office), the Roadrunner Mobile Home Park, and Santiago Estates wells were all taken out of potable service due to elevated nitrate. The latter two developments were connected to municipal wells operated by the BWD as an alternative source of supply. Well ID4-4 was re-drilled and screened deeper at the same location and successfully accessed good water quality not impacted by nitrates. The DiGiorgio wells 11, 14 and 15 located north of Henderson Road have historical detections of nitrate and TDS above drinking water standards. The existing groundwater network indicates elevated nitrate currently occurs at the Fortiner well No.1 in the North Management Area and at the BWD's WWTP monitoring well (see map, **Figure 4**).

Nitrate contamination enters the unconfined aquifer system via irrigation return flows and septic system discharge. An unconfined aquifer is directly open to the downward percolation of water. Thus, the uppermost portion of the aquifer is the most susceptible to nitrate impacts. However, as noted in **Table 1B**, nitrate impacts have been observed at low concentrations in all of the active BWD water supply wells.

There are two factors that can facilitate the downward migration of nitrates within the aquifer system- both caused by wells. The first is that ongoing pumping from deeper portions of the aquifer can actively draw shallow groundwater deeper into the aquifer system. The second is that inactive wells can act as conduits for groundwater flow and facilitate the drainage of water from the upper aquifer into deeper aquifers because of downward hydraulic gradients induced by ongoing pumping and overdraft (see Recommendations, Section 5.2, for additional discussion).

FIGURE 11

Borrego Valley Water Quality Analyses of Nitrates

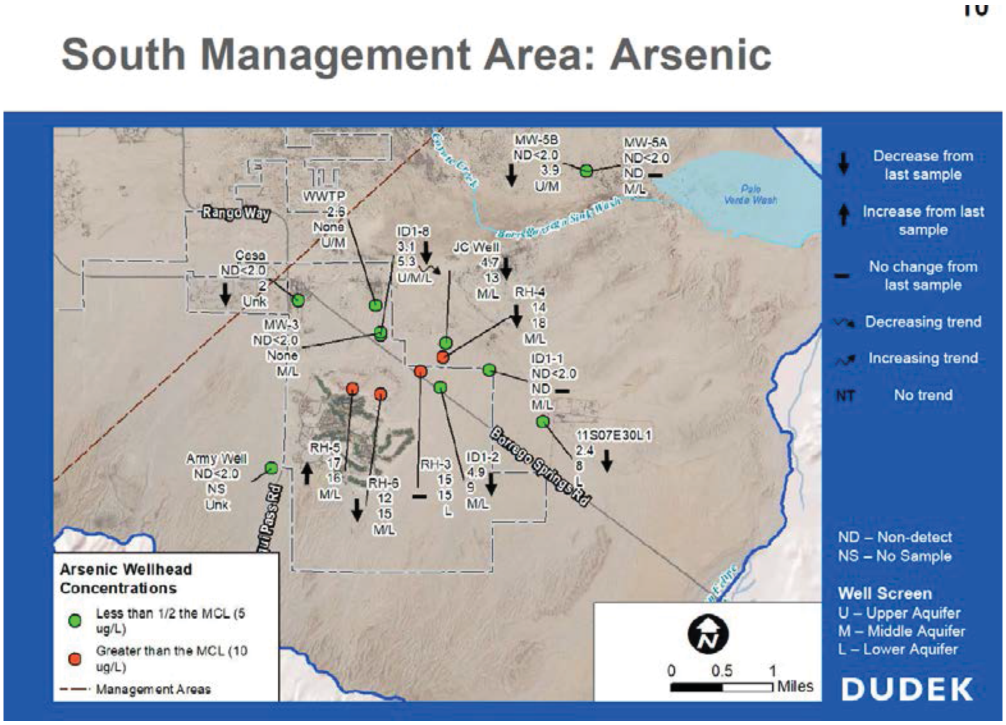


3.6 Arsenic

Arsenic is the primary drinking water COC identified throughout alluvial basins across the desert southwest (see, for example, previously cited USGS NWQA Report, 2014). The fate and transport of arsenic highly depends on the hadrochemical environment. Chemical conditions control the chemical state (valence) of the ion in solution- here arsenic can occur as either arsenate (As^{+3}) or arsenate (As^{+5}). The chemical behavior of arsenic in groundwater depends on multiple factors including the pH and the relative state of oxidation (i.e., chemically oxidizing or reducing, or 'redox' state). Arsenate (As^{+5}) for example, tends to become more soluble as pH increases. Microbial processes are also known to be involved in the oxidation and mobility of arsenic.[17]

Arsenic concentrations above MCLs currently occur in groundwater in the South Management Area, primarily in wells installed for the Ram's Hill Golf Course. **Figure 12**, from BWD Board presentation by Dudek dated 1/25/2018, shows prior sampling results. Sampling results for the remainder of the Subbasin indicate arsenic to occur at less than half the MCL (5 micrograms per liter [µg/L]). The sampling results for active BWD wells are summarized in **Section 4**.

FIGURE 12



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[17] Sun 2010. The Role of Denitrification on Arsenite Oxidation and Arsenic Mobility in An Anoxic Sediment Column Model with Activated Alumina. In Bioengineering and Biotechnology. https://onlinelibrary.wiley.com/doi/abs/10.1002/bit.22883 This work is cited because it supports that Nitrate, an alternative electron acceptor, can support oxidation of As^{+3} to As^{+5} (arsenate) by denitrifying bacteria in the absence of oxygen. Arsenate is generally considered to be mobile in groundwater at pH levels greater than 8.

3.6.1 Supporting Information Regarding Arsenic

To date all water quality testing has reported 'total arsenic'. While this is consistent with the reporting requirements for drinking water testing, the current monitoring program does not speciate arsenic by valence. The species that occur in groundwater can generally be inferred based on knowledge of water conditions- specifically the pH and Eh (or redox state).

A study of arsenic and nitrate in the Subbasin done in cooperation with the BWD was published by Rezaie-Boroon et al, in 2014.[18] The study was based on data from six BWD wells (ID4-18, ID4-11, ID1-12, ID4-10, ID1-10, and Wilcox) for the period of 2006 to 2014. Their trend analyses are not summarized here because four more years of data have since been collected and the trends have changed. Their work emphasized the following:

- The chemical environment as determined by pH and Eh is important. Both pH and Eh conditions control how dissolved arsenic occurs in aqueous environment (see reference).[19] Arsenic is more soluble in an alkaline (high pH) and anoxic environments. The relative mobility of arsenic depends on its valence, typically occurring as either arsenite (As^{+3}) or arsenate (As^{+5}). As^{+3} is typically more mobile than As^{+5} in anoxic groundwater.
- The presence of iron oxide coatings on soil and sediment particles supports arsenic adsorbtion and can cause the concentration of arsenic in solution to decrease. This will typically occur under oxidizing conditions where As^{+5} will generally occur versus As^{+3}, and where iron oxides will occur.
- *"The most common forms of arsenic in groundwater are their oxy-anions, arsenite (As+3) and arsenate (As^{+5}). Both cations are capable of adsorbing to various subsurface materials, such as iron oxides and clay particles. Iron oxides are particularly important to arsenate fate and transport"* because…*"arsenate [ed: As+5] strongly adsorbs to these surfaces in acidic to neutral waters."* Thus, increases in pH will support the desorption or release of arsenate into groundwater.

The interaction of arsenic with soil and aquifer material containing iron oxide is summarized in a 2015 report by the Water Research Foundation.[20] This study is potentially relevant to the use of arsenic-bearing irrigation water, because it shows that arsenic can be removed from water when passed through soil. The Water Research Foundation report concluded that "Results of this study provide an inexpensive arsenic treatment method for water utilities", while

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[18] Rezaie-Boroon et al, 2014. The Source of Arsenic and Nitrate in Borrego Valley Groundwater Aquifer. Journal of Water Resource and Protection, 5, p1589-1602. https://www.scirp.org/journal/PaperInformation.aspx?PaperID=51944

[19] Stein, C.L., Brandon, W.C. and McTigue, D.F. (2005) Arsenic Behavior under Sulfate-Reducing Conditions: Beware of the "Danger Zone". EPA Science Forum 2005: Collaborative Science for Environmental Solutions, 16-18 May 2005, Washington DC.

[20] Water Research Foundation, 2015. In-situ Arsenic Removal During Groundwater Recharge Through Unsaturated Alluvium. Web Report #4299.

recognizing that the work was a pilot study and that a good understanding of site conditions is necessary to achieve similar results.

Arsenic may also be released from the dewatering or release of water in from clays. A recent study published in 2018 for the San Joaquin Valley of California examined the potential release of arsenic from the Corcoran Clay, a regionally extensive clay deposit that is being compressed as a result of land subsidence due to groundwater overdraft.[21] Their results "support the premise that arsenic can reside within pore water of clay strata within aquifers and is released due to overpumping".

Four factors were seen to contribute to the occurrence of arsenic in groundwater that included clay thickness, dissolved manganese (Mn) concentrations, elevation (depth), and recent subsidence. As stated in their report "We highlighted four of the most important variables describing arsenic concentration within the Tulare Basin in the recent model, shown in Fig. 2a-d [of their report]. Of these, the thickness of the Corcoran Clay (a confining unit that overlies a lower aquifer) shows a positive correlation with arsenic concentrations due to increased clay content. Elevation has a negative correlation, as lower areas are more likely to have been water-saturated and thus anaerobic. A positive correlation was found between $\log_{10}$(Mn) and arsenic concentrations, as the presence of manganese indicates an anoxic environment, in which arsenic tends to be more soluble. Significantly, recent subsidence from InSAR[22] [ed: land surface elevation data] showed a positive correlation, as over-pumping leads to increased pore water drainage from clays. The first three variables are well-known from the literature and not related to human activity. The quantitative link between pumping-induced subsidence and arsenic concentrations has not been shown before, and is directly related to human activity."

Their analysis supports that geochemical data that include measurements of oxidation-reduction potential (redox) and oxygen content, and testing for minerals that are indicative of geochemical conditions (such as ferrous and ferric iron, and manganese) can support assessment of the potential for arsenic to become mobile in the aquifer system. A recent USGS publication provides further explanation of the role of iron oxides under varying pH and redox conditions (USGS Scientific Investigations Report 2012–5065[23]). A key point made by the USGS is that arsenic becomes mobile at a pH greater than 8 under oxidizing and neutral/transitional

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[21] Overpumping leads to California groundwater arsenic threat. By Ryan Smith, Rosemary Knight, and Scott Fendorf. June 2018. In Nature Communications (2018) 9:2089, DOI: 10.1038/s41467-018-04475, www.nature.com/naturecommunications. or at https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5988660/pdf/41467_2018_Article_4475.pdf

[22] "InSAR (Interferometric Synthetic Aperture Radar) is a technique for mapping ground deformation using radar images of the Earth's surface that are collected from orbiting satellites". see https://volcanoes.usgs.gov/vhp/insar.html

[23] Predicted Nitrate and Arsenic Concentrations in Basin-Fill Aquifers of the Southwestern United States, by David W. Anning, Angela P. Paul, Tim S. McKinney, Jena M. Huntington, Laura M. Bexfield, and Susan A. Thiros; https://pubs.usgs.gov/sir/2012/5065/pdf/sir20125065.pdf

redox conditions, and is potentially mobile under strongly reducing conditions where both arsenite and iron can be in solution.

The USGS Model Report evaluated land subsidence in the Subbasin for the period of the 1960s to 2010 (page 70 of their report) and concluded that "…land subsidence attributed to aquifer-system compaction is not currently a problem in the Borrego Valley and is unlikely to be a significant problem in the future". However, this does not preclude the potential release or extraction of arsenic from clay-rich portions of the aquifer system that may occur under current or future pumping absent subsidence, or as a result of changes in geochemical conditions that could mobilize arsenic from clay-rich sediments that may contain arsenic.

Overall the occurrence, nature, and extent of arsenic in the Subbasin is not well understood. It is more prevalent in South Management Area wells. While currently water quality conditions are good relative to arsenic, it was observed to be at or near drinking water MCLs in multiple BWD water supply wells during the last decade and could affect BWD's water supply in the future.

3.7 Correlations Among Water Quality Parameters (Combined Data Assessment)

One of the goals of this Report is to evaluate whether multiple chemical parameters can be used to better define and predict COC trends at BWD water supply wells. Piper diagrams presented in **Section 3.2** were used to examine spatial trends and also illustrate that there are definable relationships among the general minerals seen in the trilinear diagrams. In this section the water chemistry data are combined for all wells to examine general relationships and correlations. The data set also includes pH, hardness. Other potentially important geochemical parameters such as iron and manganese were not included because they were not uniformly obtained for the water quality samples historically collected.

3.7.1 Water Quality Data Correlations

Water quality data obtained since 2004 were used to examine potential correlations and relationships. The recent data were selected to represent current conditions as water quality has changed over time in many wells. Among the parameters that were tested include anions (HCO_3, Cl, SO_4), cations (Ca, Mg, and Na [potassium was not included as less data were collected]), pH, TDS, Ca+ Na, Cl+HCO_3, As, F, and NO_3. Also included in the correlation analysis were two parameters named Midst and Low Sat that represented the percentage of well screen open to flow per aquifer unit as described in each of the wells (for example if a well is completed with the same amount of screen length per aquifer then both values would be 50 percent).

Correlations greater than 0.5 or less than -0.5 are highlighted in **Table 3**. Values between 0.5 and 0.7 are underlined, and values greater than 0.7 are in bold. The South Management Area data have been separated from the North and Central Management Areas.

Selected data are shown in graphical form in this section. The data set used in the correlations was limited to those samples where the general minerals charge balance was within 10 percent. The graphs further restrict the data to only include higher quality data with a +/- 5 % charge balance. Hem (1985) considers data with 5% charge balance to be of good quality[24].

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[24] John Hem, 1985. Study and Interpretation of the Chemical Characteristics of Natural Water. USGS Water-Supply Paper 2254. From page 163: "Under optimum conditions, the analytical results for major constituents of water have an accuracy of +/-2 - +/- 10 percent. That is, the difference between the reported result and the actual concentration in the sample at the time of analysis should be between 2 and 10 percent of the actual value. Solutes present in concentrations above 100 mg/L generally can be determined with an accuracy of better than +/- 5 percent. Limits of precision (reproducibility) are similar."

Table 3

NORTH and CENTRAL

	Bicarbonate	Chloride	Sulfate	Fluoride	Calcium	Magnesium	Sodium			cation	anion	pct middle	pct lower	Arsenic	Nitrate
	HCO3	**Cl**	**SO4**	**F**	**Ca**	**Mg**	**Na**	**pH**	**TDS**	**Ca+Na**	**Cl+HCO3**	**MidSat**	**LowSat**	**As**	**NO3**
HCO3	1.00	**0.73**	-0.38	-0.30	0.46	**0.76**	-0.10	-0.69	0.27	0.18	**0.94**	-0.48	0.30	-0.28	0.49
Cl		1.00	-0.26	-0.09	0.28	0.54	0.31	-0.53	0.43	0.36	**0.92**	-0.40	0.15	-0.13	**0.72**
SO4			1.00	0.26	0.46	0.07	0.67	0.16	**0.70**	**0.70**	-0.35	0.01	0.09	0.23	-0.43
F				1.00	-0.30	-0.23	0.54	0.48	0.15	0.21	-0.21	-0.43	0.47	0.66	-0.14
Ca					1.00	**0.79**	0.34	-0.60	**0.72**	**0.77**	0.40	-0.31	0.25	-0.32	0.14
Mg						1.00	0.23	**-0.75**	0.57	0.58	**0.70**	-0.48	0.40	-0.33	0.37
Na							1.00	0.03	**0.83**	**0.86**	0.10	-0.39	0.38	0.31	0.22
pH								1.00	-0.31	-0.30	-0.65	0.24	-0.12	0.68	-0.46
TDS									1.00	**0.95**	0.37	-0.41	0.33	0.04	0.21
Ca+Na										1.00	0.28	-0.43	0.39	0.04	0.23
Cl+HCO3											1.00	-0.47	0.24	-0.23	0.65
MidSat												1.00	**-0.86**	-0.30	-0.43
LowSat													1.00	0.30	0.22
As														1.00	-0.18
NO3															1.00

SOUTH

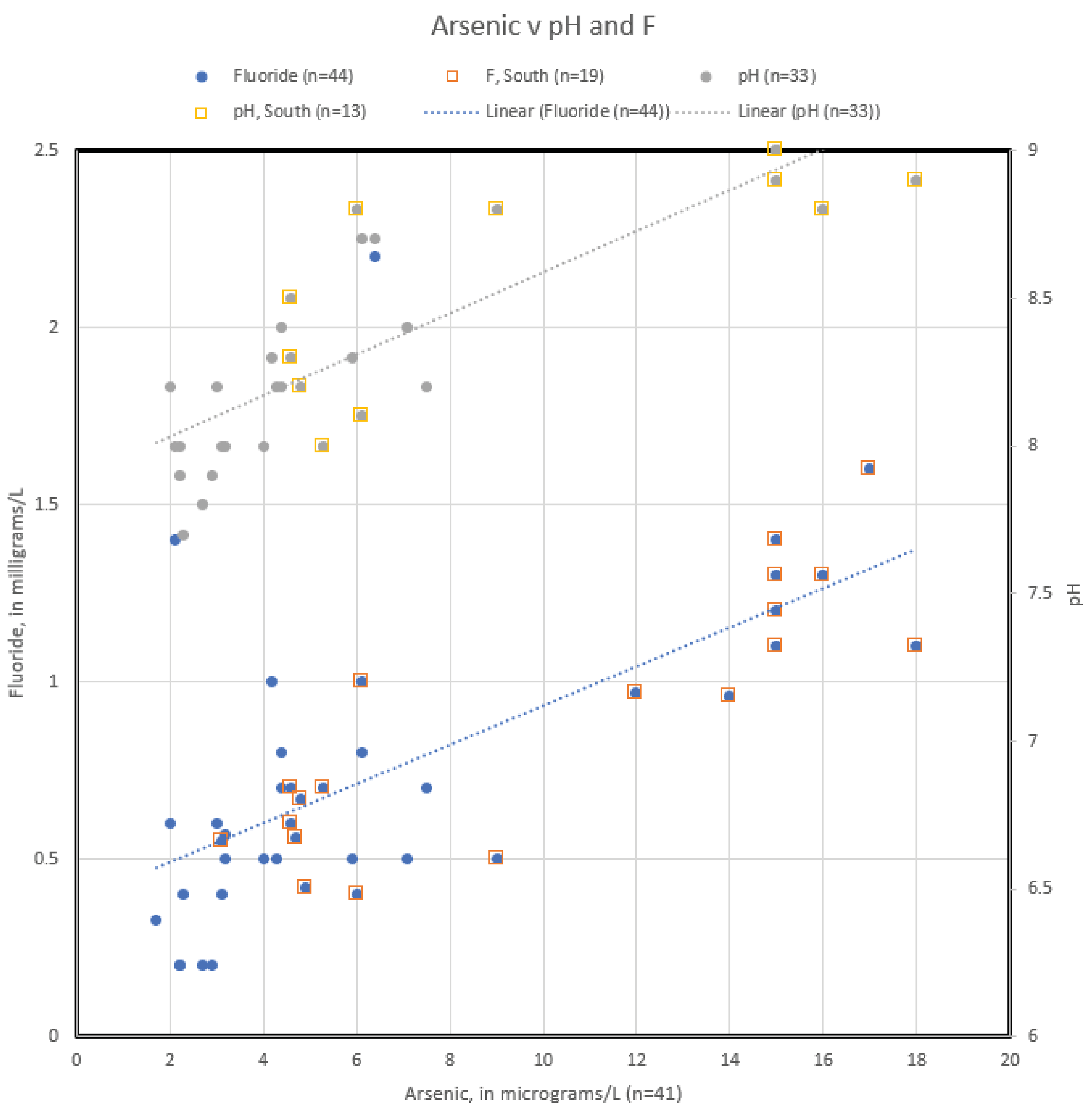
	Bicarbonate	Chloride	Sulfate	Fluoride	Calcium	Magnesium	Sodium					pct middle	pct lower	Arsenic	Nitrate
	HCO3	**Cl**	**SO4**	**F**	**Ca**	**Mg**	**Na**	**pH**	**TDS**	**Ca+Na**	**Cl+HCO3**	**MidSat**	**LowSat**	**As**	**NO3**
HCO3	1.00	-0.45	-0.44	0.14	-0.37	**-0.31**	-0.16	0.27	-0.33	-0.25	0.14	0.31	-0.33	0.10	0.19
Cl		1.00	**0.87**	-0.31	**0.80**	0.36	**0.83**	-0.34	**0.92**	**0.84**	0.47	0.17	-0.19	-0.08	0.11
SO4			1.00	-0.37	**0.95**	0.46	**0.73**	-0.31	**0.96**	**0.86**	0.37	-0.03	0.04	-0.01	0.01
F				1.00	-0.48	-0.16	-0.14	0.56	-0.40	-0.41	-0.33	-0.23	0.23	**0.73**	-0.22
Ca					1.00	0.42	0.60	-0.46	**0.92**	**0.78**	0.29	0.05	-0.05	-0.13	0.08
Mg						1.00	-0.03	**-0.13**	0.42	0.16	0.07	-0.11	0.11	0.06	-0.05
Na							1.00	-0.10	**0.81**	**0.86**	0.49	0.24	-0.24	0.09	0.19
pH								1.00	-0.35	-0.25	-0.13	-0.18	0.19	0.55	-0.30
TDS									1.00	**0.89**	0.44	0.14	-0.14	-0.03	0.18
Ca+Na										1.00	**0.70**	0.18	-0.19	-0.06	0.15
Cl+HCO3											1.00	0.27	-0.30	-0.14	0.05
MidSat												1.00	-1.00	-0.15	0.46
LowSat													1.00	0.17	-0.45
As														1.00	-0.06
NO3															1.00

COC	**North and Central**	**South**
Arsenic	pH (.68), F (.66)	F (.73), pH (.55)
Nitrate	Cl (.72)	-none-
Sulfate	TDS (.70), Na (.67)	TDS (.96), Ca (.95), Cl (.87), Na (.73)
Fluoride	As (.66), Na (.54)	As (.73), pH (.56)
TDS	Na (.83), Ca (.72), SO_4 (.70), Mg (.57)	SO_4(.96), Cl (.92), Ca (.92), Na (.81)

Arsenic and Fluoride

Arsenic and fluoride concentrations are correlated and both increase with pH. **Figure 13** depicts arsenic versus fluoride and pH. (pH versus As is in the upper portion of the graph and the y-axis label is to the right; fluoride versus As is in the lower portion and the y-axis is to the left). In both cases the correlations are influenced by the higher arsenic concentrations observed in the South Management Area (as noted by squares drawn around the data points). Every occurrence of arsenic above the MCL of 10 µg/L is associated with pH values greater than 8.5 (upper portion of the graph).

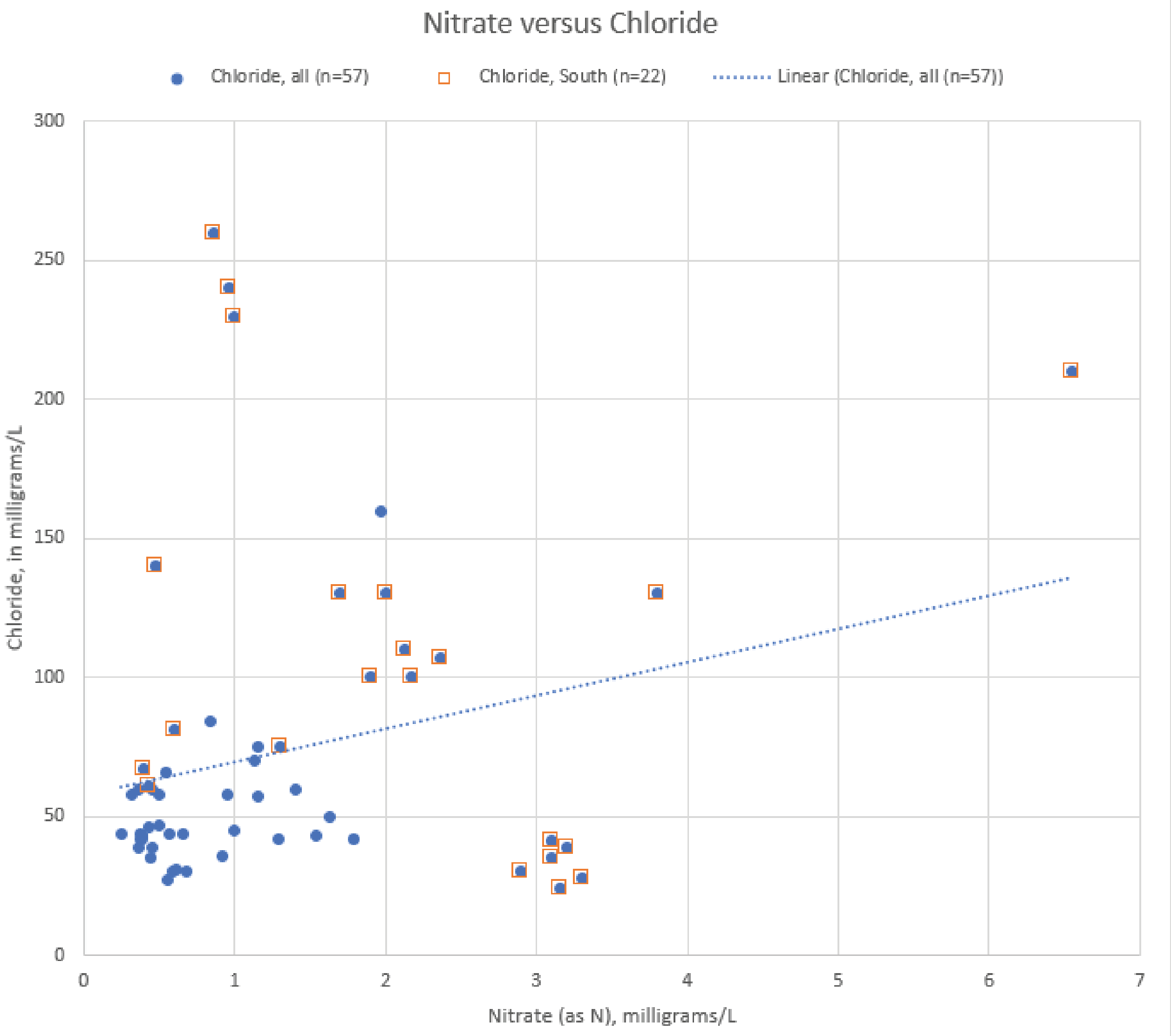
FIGURE 13



Nitrate

Nitrate had few water quality parameter correlations. Nitrate versus chloride is depicted in **Figure 14**. While there was a statistically-indicated correlation in **Table 3** for the North and Central Management Areas, chloride does not appear to be a globally useful predictor of nitrate.

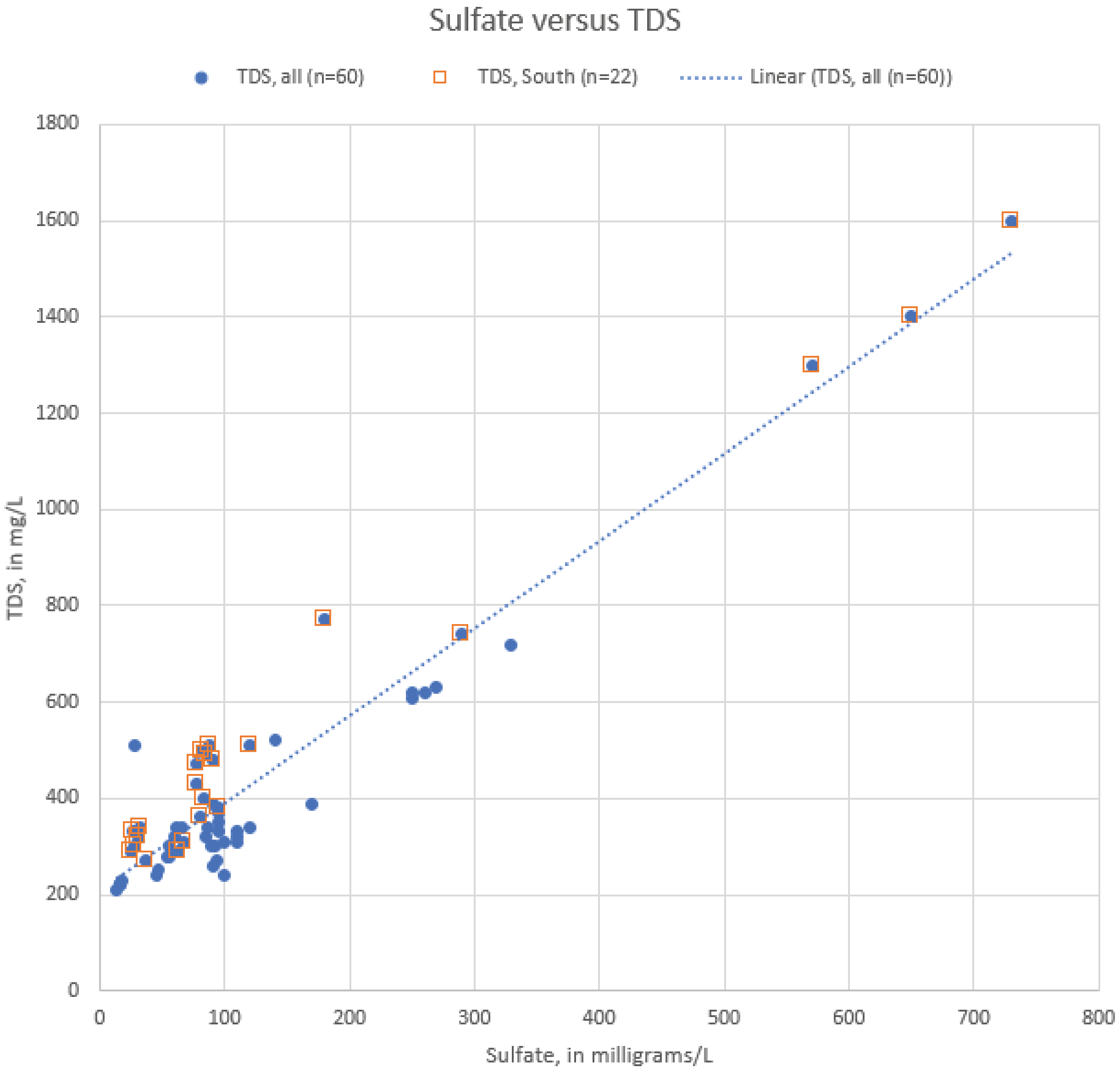
FIGURE 14



Sulfate

The correlation of sulfate with TDS is depicted in **Figure 15**. The three high sulfate values (> 500 mg/L) from the South Management Area strongly influence the correlation.

FIGURE 15

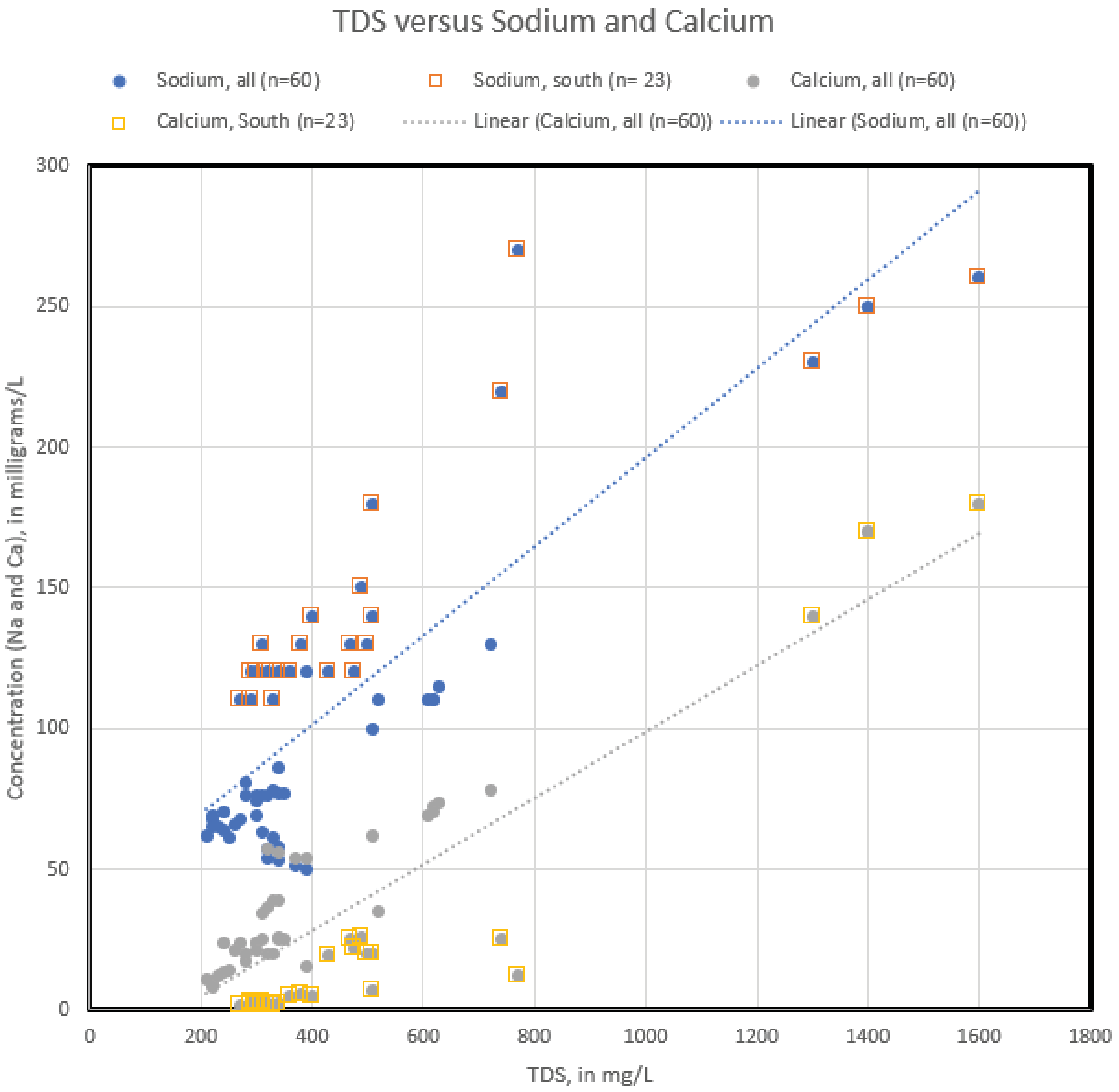


TDS

Multiple analytes correlated with TDS. Sulfate is shown in the previous figure. Sodium and calcium are shown versus TDS in **Figure 16**, and chloride versus TDS is shown in **Figure 17**. Both figures show that the South Management Area water chemistry is different than that observed to the north. The regression lines in **Figure 16** effectively split the two sets of data by management area.

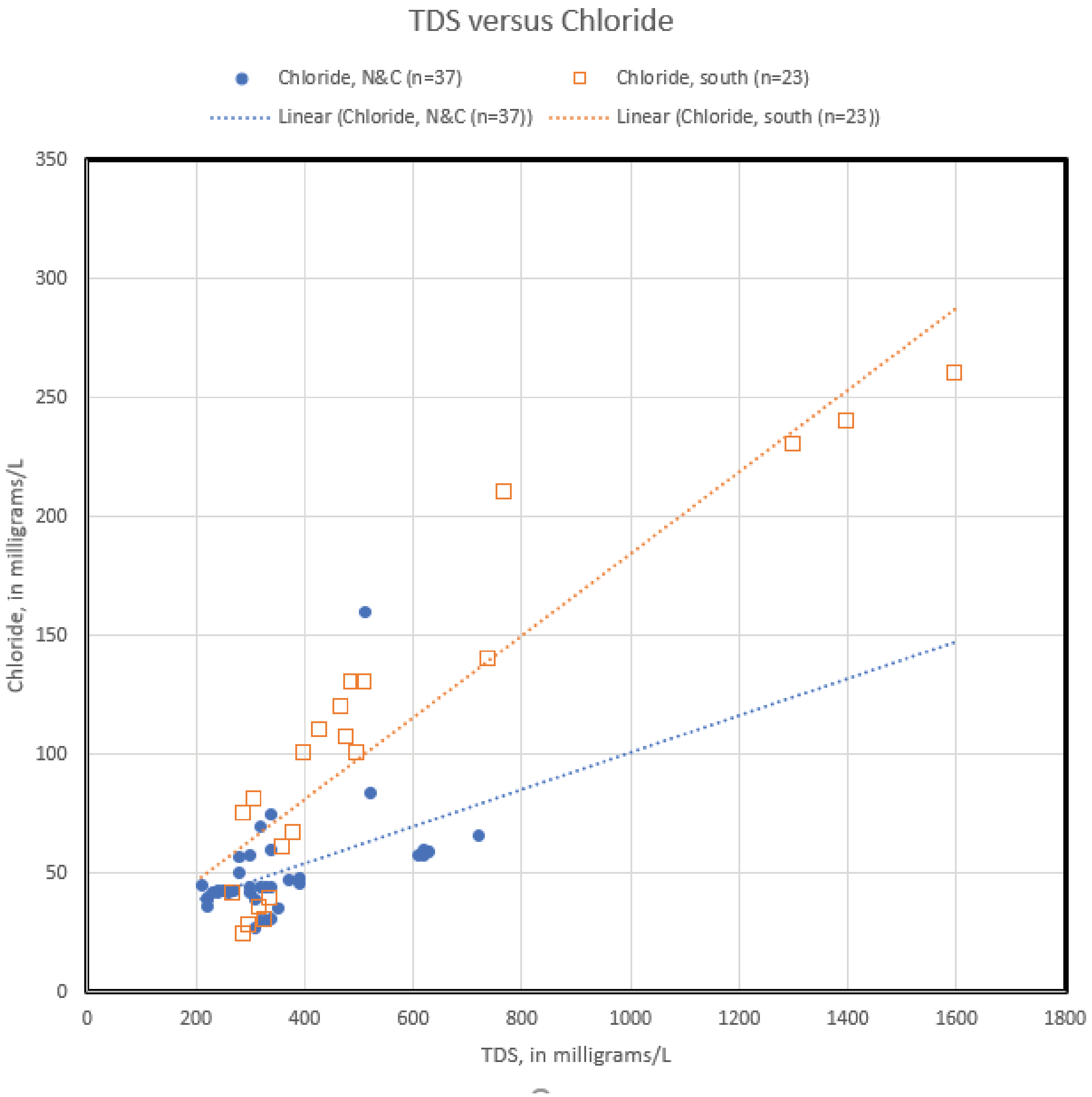
While correlations exist for all three analytes, sodium and chloride represents a higher percentage of TDS and calcium represents a smaller percentage of TDS in the South Management Area.

FIGURE 16



Chloride data segregated by management area are depicted in **Figure 17**. The highest chloride concentrations typically occur in the South Management Area.

FIGURE 17



3.8 General Minerals: Summary of Observations

A summary of the Piper diagram analyses for the 23 wells used in this Report is included in **Table 1B**.

- Water quality has clearly changed over time. Of the 23 wells, six had insufficient general minerals data to assess trends. Of the 17 wells with sufficient temporal data, approximately 70 percent showed a change in natural water chemistry over time.
- Sulfate is the general mineral most commonly observed to be increasing in groundwater (as a relative percentage per the Piper diagrams).
- Groundwater quality systematically varies with distance along the valley, with water in the South Management Area being noticeably different. Here the well data were not differentiated by aquifer or relative depth

Five COCs are included in this Report. Nitrate and arsenic are currently the chemical of highest concern specific to BWD drinking water quality. Fluoride, sulfate, and TDS are other three COCs. The data were collected over varying time periods and not all sampling events included a complete set of the eight general minerals. A review of the COCs for all of the active BWD wells is provided in **Section 4**.

Limited depth-specific hydraulic and contaminant data are available to assess the nature and extent of COCs in groundwater. As a result, the analyses among wells is limited to spatial comparisons. The lack of depth-specific data is a data gap that affects the assessment of all water quality parameters. The primary impact of this data gap is that the depth-dependent data will provide a good indication of how water quality will change over time as water levels decline. If specific zones are contributing poor water quality, then the data can be used to selectively complete future water wells to reduce the impact of the inflow of poor water quality.

4.0 CHEMICALS OF CONCERN (COCs) AT BWD WATER SUPPLY WELLS

The five chemicals of concern (COCs) include arsenic, total dissolved solids, nitrate, sulfate, and fluoride (As, TDS, NO_3, SO_4, and F). There are nine BWD water supply wells reviewed here. The COC and Piper diagram data for these wells is depicted in the following Figures that follow this subsection:

Figure 18 ID4-4 (Well #4, as depicted in Figure 4)
Figure 19 ID4-11 (Well #5, as depicted in Figure 4)
Figure 20 ID4-18 (Well #2, as depicted in Figure 4)
Figure 21 ID1-10 (Well #14, as depicted in Figure 4)
Figure 22 ID1-12 (Well #9, as depicted in Figure 4)
Figure 23 ID1-16 (Well #12, as depicted in Figure 4)
Figure 24 ID5-5 (Well #8, as depicted in Figure 4)
Figure 25 Wilcox (Well #13, as depicted in Figure 4)
Figure 26 ID1-8 (Well #15, as depicted in Figure 4)

Of these, three wells are being considered for replacement- ID4-4, ID4-18, and ID1-10. **Table 4** summarizes the review of **Figures 18 through 26**.

Water quality trends, if identified, are based on visual description of the various data. The GSP describes the use of Mann-Kendall statistical trend analyses, a non-parametric way to detect a monotonic trend (up or down), to assess individual water quality parameters. The work here is focused on identifying correlations among parameters.

NOTE: Well ID4-4 was redrilled in 1979. Water chemistry changed.

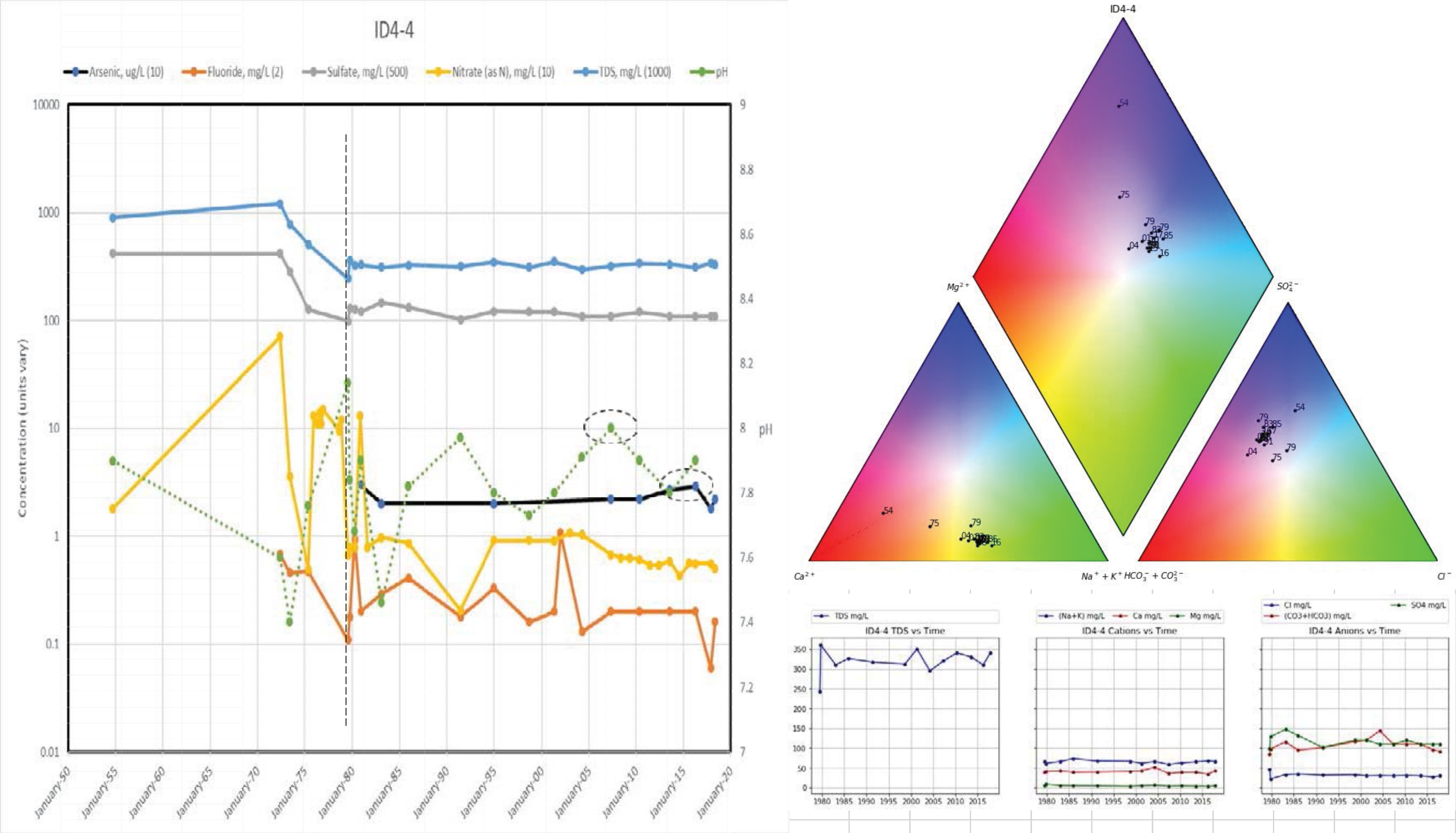


FIGURE 18. BWD Well ID4-4

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

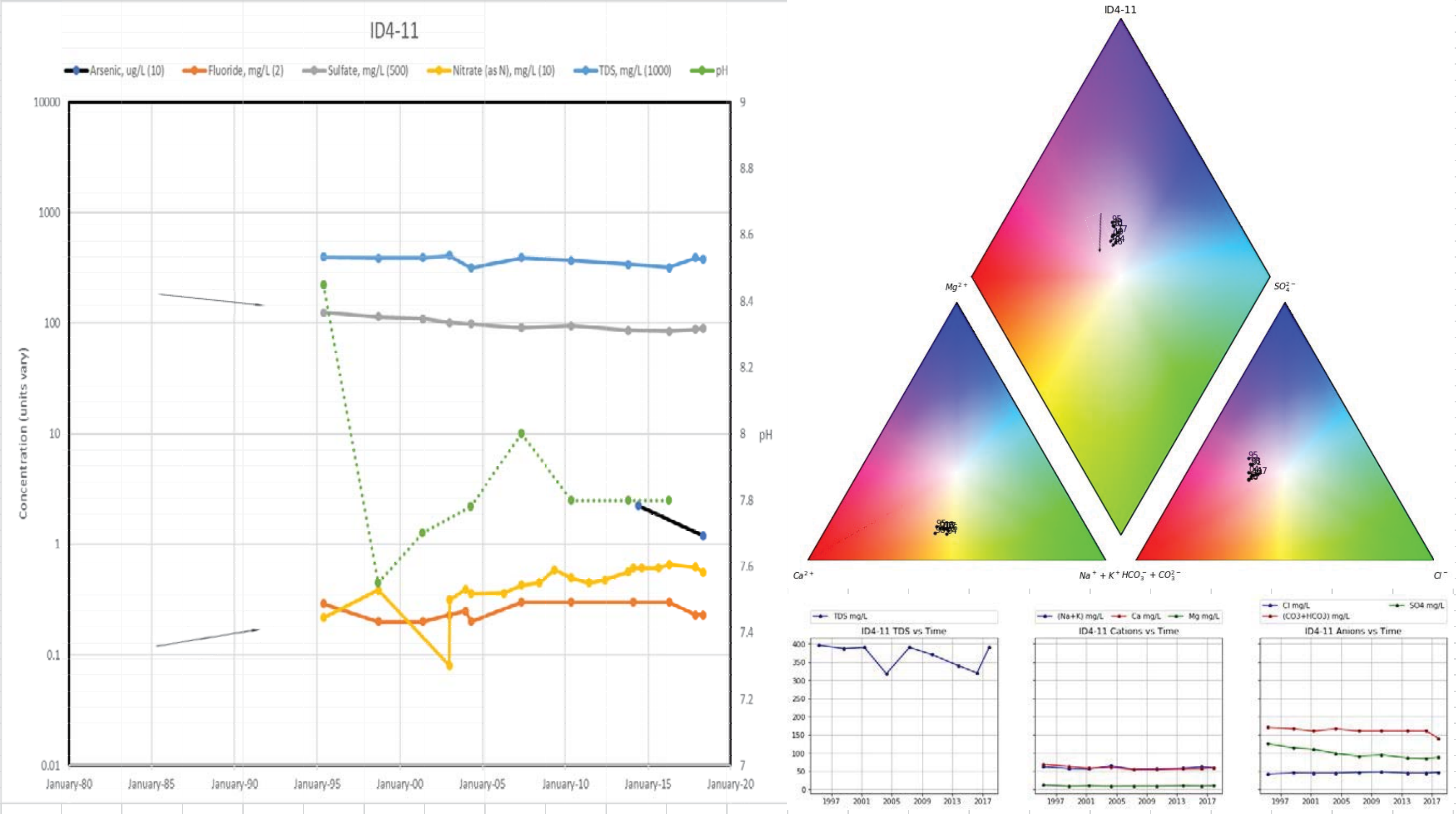


FIGURE 19. BWD Well ID4-11

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

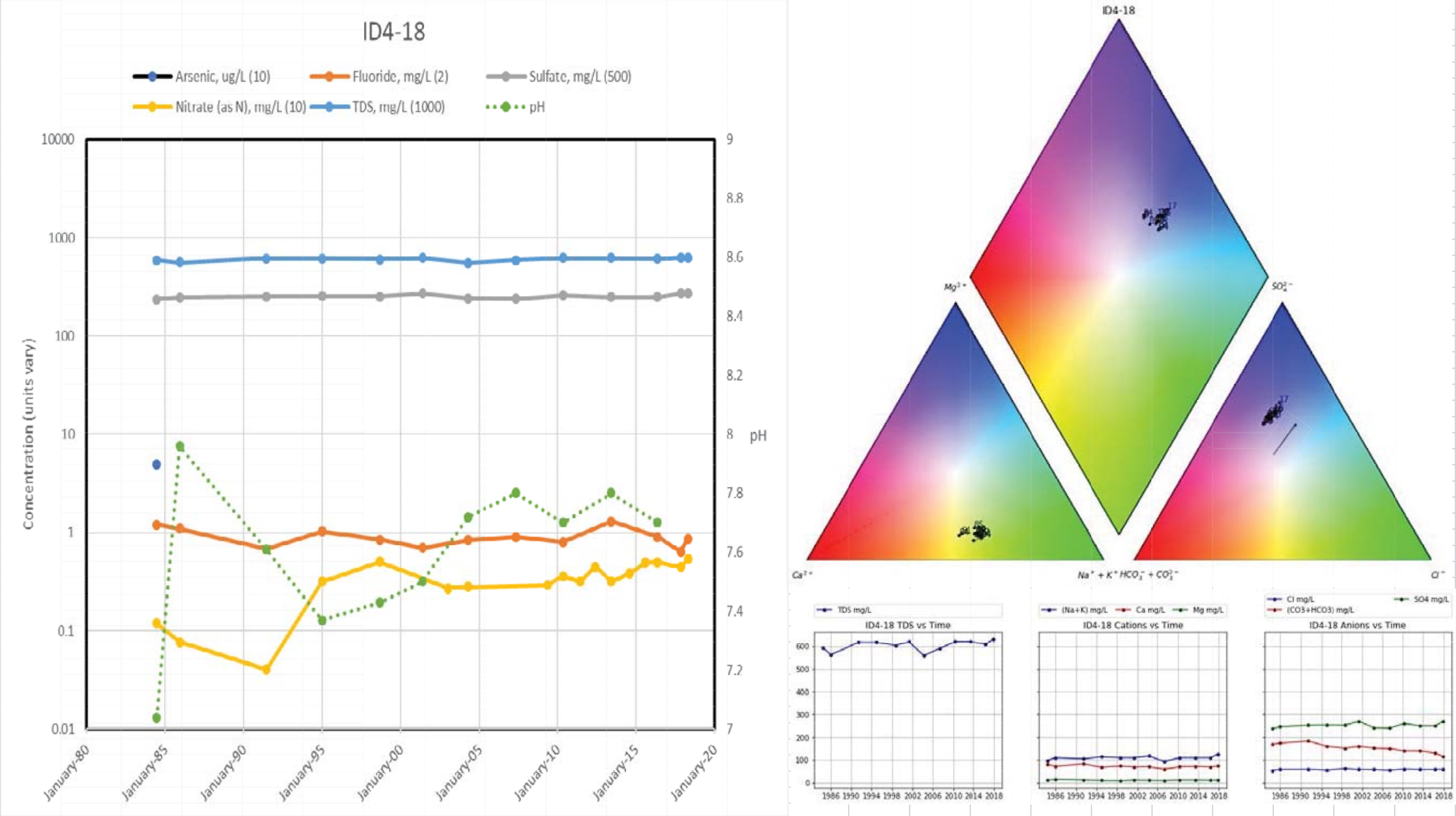


FIGURE 20. BWD Well ID4-18

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

FIGURE 21. BWD Well ID1-10

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

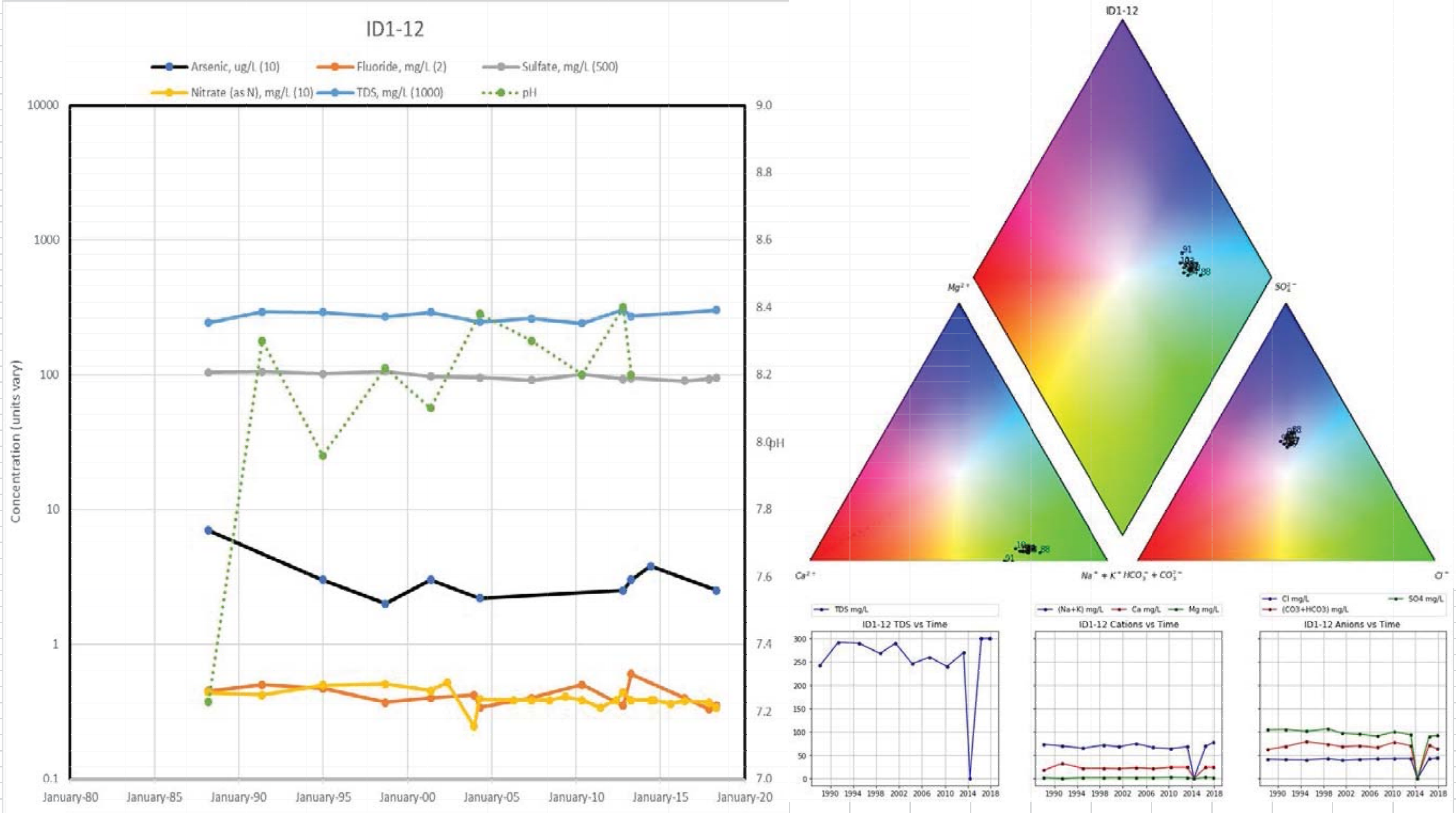


FIGURE 22. BWD Well ID1-12

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

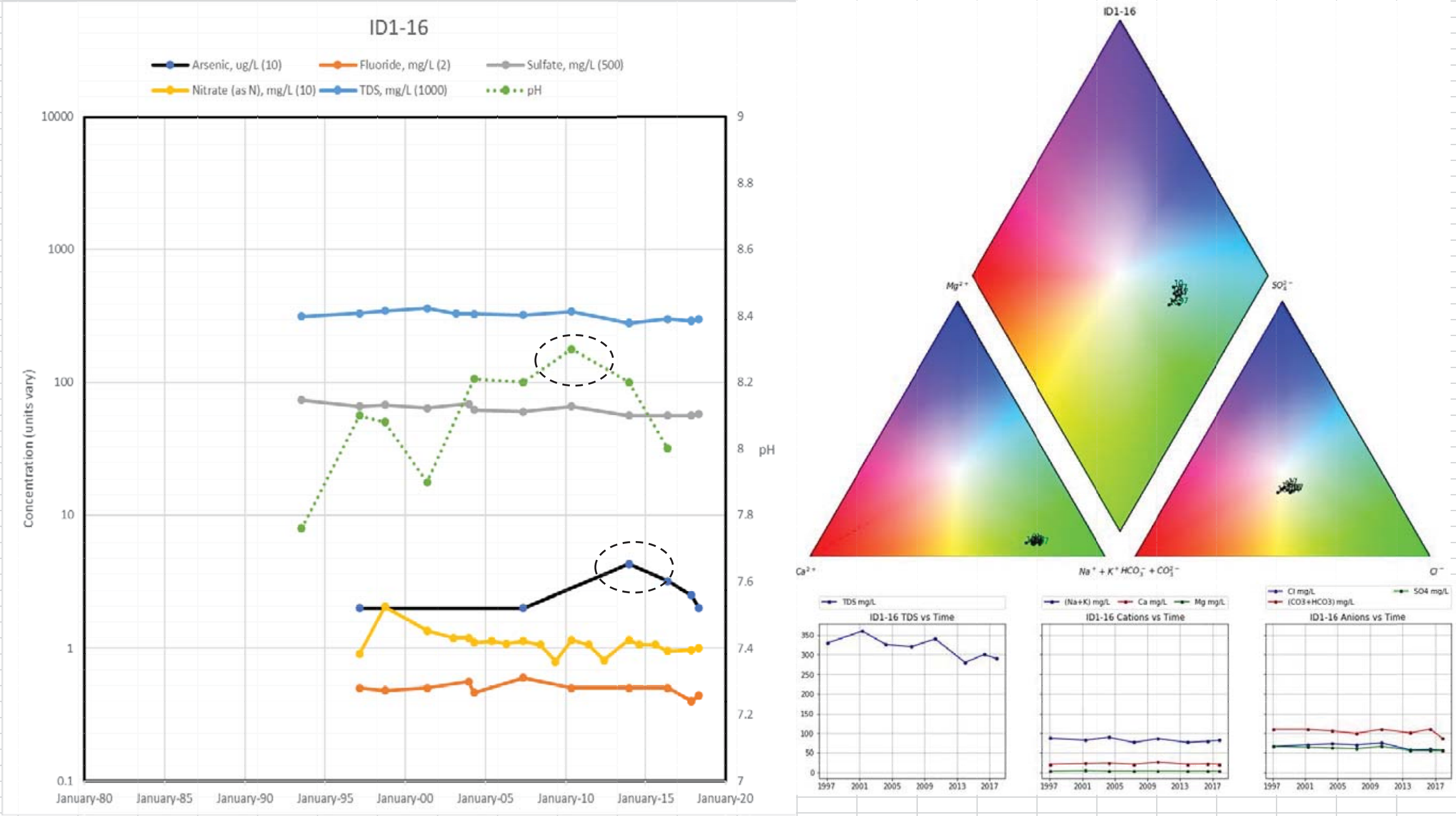


FIGURE 23. BWD Well ID1-16

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

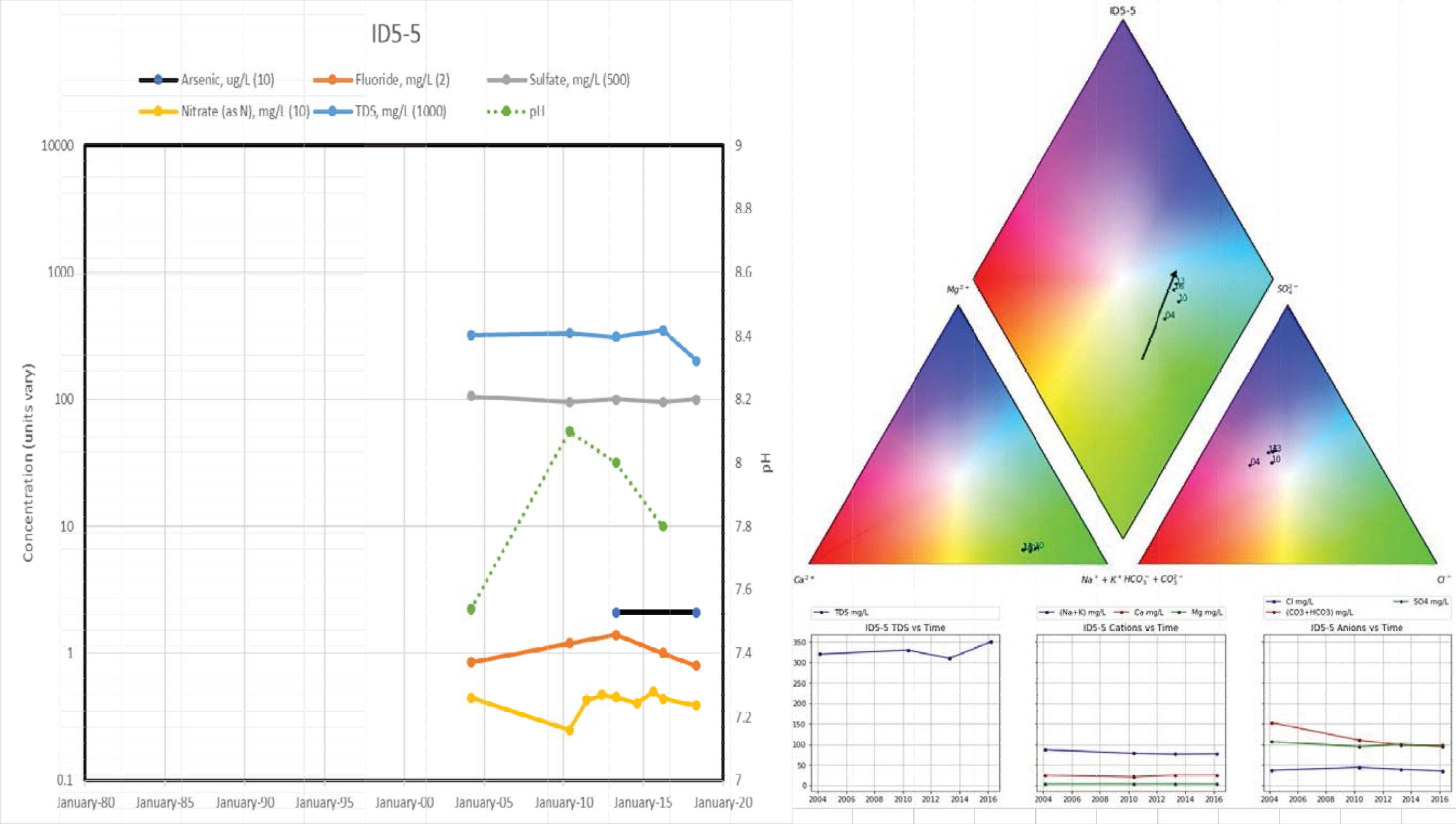


FIGURE 24. BWD Well ID5-5

Notes: pH and COC concentrations versus time shown left panel.
Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

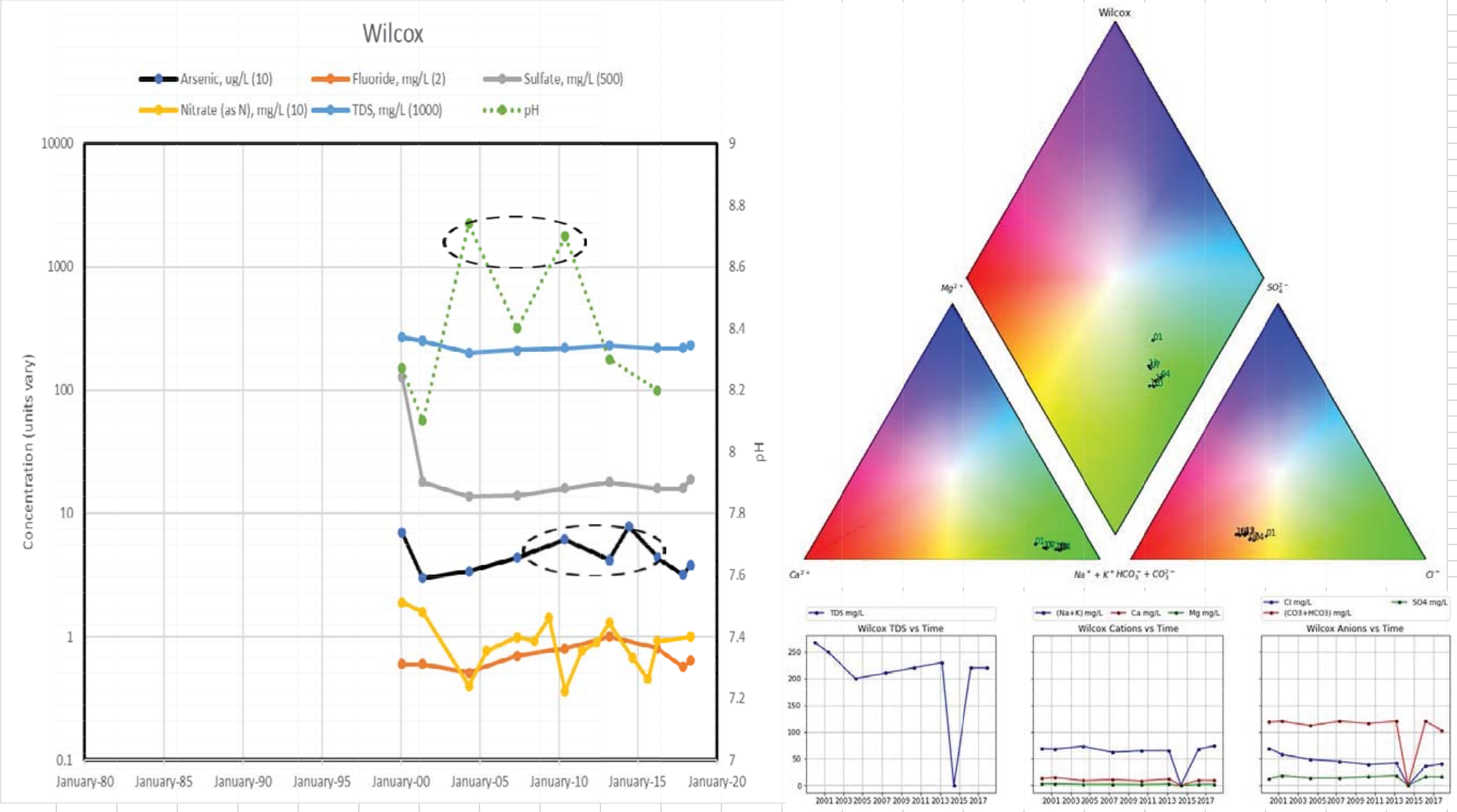


FIGURE 25. BWD Wilcox Well

Notes: pH and COC concentrations versus time shown left panel.

Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

FIGURE 26. BWD Well ID1-8

Notes: pH and COC concentrations versus time shown left panel.

Piper trilinear diagram depicts change over time- the labels indicate the last two digits of the year when sampled (e.g. 72 = 1972)

TABLE 4

WELL	TDS/ Gen Min (MCL: 500 recc/1000 max, mg/L)	Sulfate (MCL: 250 recc/500 max,mg/L)	Arsenic (MCL: 10 ug/L)	pH	Nitrate (MCL: 10 mg/L as N)	Fluoride (MCL: 2 mg/L)
ID4-4 (#4)**	Stable (330) TDS: 320 to 340 GenMins*: Vble, cation trend may develop	Stable (110) SO4: 110 to 120	In Range (2.2) As: 1.8 to 2.9	Stable Range pH*: 7.8 to 8	Decreasing (0.5) NO3: 1.0 to 0.43	In Range (0.16) 0.6 to 0.2
ID4-11 (#5)	Stable (380) TDS: 320 to 390 GenMins*: Vble, anion trend may develop	Stable SO4: 91 to 95 Was decreasing prior to 2005	Insuff. Data (2.1) As: 1.2 to 2.2 Two recent detects	Stable Range pH*: 7.8 to 8	Increasing (0.56) NO3: 0.36 to 0.66	In Range (0.23) 0.23 to 0.3
ID4-18 (#2)**	Possibly Increasing (630) TDS: 590 to 630 GenMins: inc SO4, dec HCO3	Increasing (**270**) SO4: 240 to 270 Slowly changing	Non-Detect	Stable Range pH*: 7.7 to 7.8	Increasing (0.54) NO3: 0.29 to 0.54	In Range (0.87) 0.54 to 1.3
ID1-10 (#14)**	Possibly Increasing (340) TDS: 250 to 340 GenMins: inc SO4, dec HCO3 (major changes since 1972)	Increasing (67) SO4: 45 to 67 Slowly changing	In Wide Range (2.8) As: 1.2 to **12.2** Maximum 6/2014	In Wide Range pH*: 8.0 to 8.4 Maximum 5/2010 (*~2 yr ahead of As*)	In Range (1.3) NO3: 1.27 to 2.02	In Range (0.48) 0.43 to 0.7
ID1-12 (#9)	Stable (300) TDS: 260 to 300 GenMins: Stable	Stable (95) SO4: 91 to 95	In Range (2.5) As: 2.5 to 3.79	In Range pH*: 8.2 to 8.4	In Range (0.34) NO3: 0.34 to 0.44	In Range (0.34) 0.38 to 0.6
ID1-16 (#12)	Possibly Decreasing (340) TDS: 280 to 340 GenMins: SO4 slowly decreasing	Decreasing (58) SO4: 56 to 66 Slowly changing	In Range (2.0) As: 2.0 to 4.3 Maximum 12/2013	In Range pH*: 8.0 to 8.3 Maximum 5/2010 (*~3 yr ahead of As*)	In Range (1.3) NO3: 1.27 to 2.02	In Range (0.48) 0.43 to 0.7
ID5-5 (#8)	Stable (350) TDS: 202 to 350 GenMins*: Vble, anion trend may develop (inc SO4)	Stable (100) SO4: 95 to 106	Insuff. Data (2.1) As: 2.1 (twice) Two recent detects	In Wide Range pH*: 7.54 to 8.1	In Range (0.39) NO3: 0.25 to 0.50	In Range (0.8) 0.85 to 1.4
Wilcox (#13)	Stable (230) TDS: 210 to 230 GenMins: SO4 slowly increasing	Increasing (19) SO4: 14 to 19 Slowly changing	In Range (3.8) As: 3.2 to 7.8 Maximum 6/2014	In Range pH*: 8.2 to 8.7 Maximum 5/2010 (*~4 yr ahead of As*)	In Range (1.0) NO3: 0.36 to 1.42	In Range (0.64) 0.57 to 0.87
ID1-8 (#15)	Possibly Increasing (460) TDS: 430 to 510 GenMins: long-term inc SO4 & Cl & Ca, dec HCO3 (major changes since 1972)	Stable (86) SO4: 82 to 110	In Range (4.0) As: 3.1 to 6.8 Maximum 5/2010	In Range pH*: 8.0 to 8.4 Maximum during 2004 to 2007 (*~3 to 6 yr ahead of As*)	In Range (1.6) NO3: 1.6 to 2.46 (long-term inc)	In Range (0.62) 0.55 to 1.0

Notes:
- * Most recent general minerals and pH analyses done in 2016
- ** Wells expected to be replaced or re-drilled in short-term

Explanation:
Trends noted as Stable, Increasing, Decreasing, Possibly Increasing/Decreasing, or In a Range
Number after descriptor – e.g. Stable (330), is the most recent sampling result from Spring 2018
Next line is the range of values observed since 2005
GenMins refers to the set of general minerals data- eight major anions and cations
xx, a value that is highlighted occurs at a concentration greater than 50% of the MCL
xx, a value that is highlighted and bold occurs at a concentration greater than the MCL

4.1 North Management Area (3 Wells: ID4-4, ID4-11, and ID4-18)

The North Management Area wells are generally located to the west and upgradient of the irrigated agricultural areas visible in **Figures 4 and 7**. COC-specific observations are included in **Table 4**.

ID4-4

ID4-4 was re-drilled in 1979 due to high nitrate concentrations related to the upper aquifer. Nitrate remains detectable but at low concentrations. Water quality is good and reasonably stable. The District is currently planning to re-drill this well at the same site as a result of poor well conditions that resulted in sanding and the installation if a well liner that limits the depth to which the pump can be installed in the well.

Additional information regarding the well replacement can be found in a 8/30/2018 Dudek presentation entitled "Water Vulnerability & New Extraction Well Site Feasibility Analysis" posted at the County SGMA website:
https://www.sandiegocounty.gov/content/dam/sdc/pds/SGMA/Prop-1-SDAC-Grant-Task-5-New-Extraction-Well-Site-Feasibility-Analysis.pdf

ID4-11

Water quality in ID4-11 is good and reasonably stable.

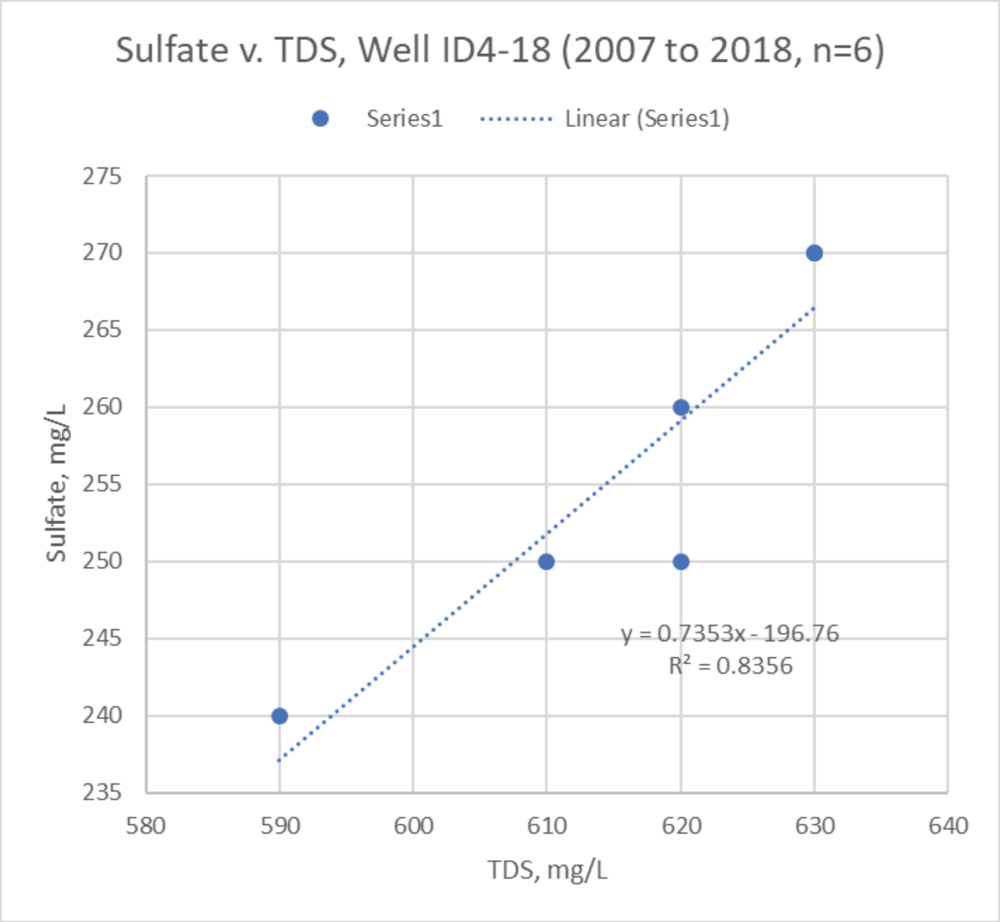
ID4-18

TDS is between the recommended and upper secondary MCL (currently at 630 mg/L). Sulfate is slowly increasing and is above the recommended secondary MCL of 250 mg/L. Arsenic has not been detected in this well (last reported as ND < 1.2 µg/L).

Figure 27 shows how TDS and sulfate are correlated and is presented as an example of how TDS measurements based on electrical conductivity testing may be able to be used to assess sulfate.

FIGURE 27

Date	TDS	Sulfate
5/8/2007	590	240
5/11/2010	620	260
6/10/2013	620	250
5/16/2016	610	250
11/17/2017	630	270
4/30/2018	630	270



4.2 Central Management Area (5: ID1-10, ID1-12, ID1-16, ID5-5, and Wilcox)

The Central Management Area is associated with both the “central” and “transitional” water quality type as indicated in **Figure 6** and COC-specific observations included in Table 4.

ID1-10
Water quality in ID1-10 is currently good and reasonably stable.

Elevated arsenic concentrations (a maximum of 12.2 µg/L that exceeded the MCL of 10 µg/L) were observed in 2014 that were preceded by elevated pHs of 8.2 to 8.4 (see **Figure 21**). Arsenic concentrations and elevated pH conditions have since declined.

ID1-12
Water quality in ID1-12 is currently good and reasonably stable.

ID1-16
Water quality in ID1-12 is currently good and reasonably stable.

Elevated arsenic concentrations (a maximum of 4.3 µg/L) were observed in 2014 that were preceded by and elevated pH of 8.3 (see **Figure 23**). Arsenic concentrations and elevated pH conditions have since declined.

ID5-5
Water quality in ID5-5 is currently good and reasonably stable.

Wilcox
Water quality in the Wilcox well is currently good and reasonably stable.

Elevated arsenic concentrations (a maximum of 7.8 µg/L) were observed in 2010 and 2014 that were preceded by elevated pH of greater than 8.6 (see **Figure 25**). Arsenic concentrations and elevated pH conditions have since declined.

4.3 South Management Area (1: ID1-8)

As previously discussed, the water chemistry observed in the South Management Area is distinctly different than that observed to the north. COC-specific observations are included in Table 4.

ID1-8

Water chemistry at ID1-8 has significantly changed over time, but now appears to be stabilizing. Water quality in ID1-8 is currently good.

Arsenic is of concern due to MCL exceedances consistently observed in nearby Ram's Hill wells.

Elevated arsenic concentrations (a maximum of 6.8 µg/L) were observed in 2010 that were preceded by an elevated pH of 8.3 (see **Figure 26**). Arsenic concentrations and elevated pH conditions have since declined.

5.0 SUMMARY

The multi-parameter assessment of water quality and COC trends provides additional insight compared to single parameter assessments.

Natural Water Chemistry (anions and cations)

- Natural water chemistry as determined by the eight dominant anions and cation systematically varies across the Subbasin (these include calcium [Ca], magnesium [Mg], sodium [Na], potassium [K], chloride [Cl], sulfate [SO_4], bicarbonate [HCO_3], and carbonate [CO_3]).

  The observed variations generally correlate with the previously established management areas that are further discussed in the GSP. Overall trends generally correlate with the well location relative to the pre-development groundwater flow paths and distance from where recharge waters enter the Subbasin,

- Water samples from BWD water supply wells show that the dominant cations and anions are sodium and calcium; and bicarbonate, sulfate, and chloride, respectively.

- The water type transitions from a calcium sulfate to a sodium chloride in the Northern Management Area wells.

- Sodium bicarbonate type water generally occurs in the South Management Area as tested. The groundwater analysis further supports that the South Management Area has distinctly different water quality than observed in the north and central groundwater management areas.

- The primary causes for the difference in water quality within the Subbasin include variations in the water being recharged (e.g. Coyote Creek versus San Felipe Creek), proximity of irrigated lands (e.g. nitrate impacts due to fertilizer application), aquifer lithology (local deposits of evaporites and potential arsenic-bearing clays), aquifer depth (related to increase in TDS), and location within the Subbasin with respect to the Borrego Sink where enhanced evaporation of ephemeral surface water occurs.

- Due to the location of the BWD wells this analysis does not fully represent the water quality distribution in the Subbasin. Refer to **Figures 4 and 7** for the well locations. As result the spatial trends identified among the wells are limited to examining variations along the western side of the Subbasin.

- Water quality as a function of depth has not been assessed in the BWD water supply wells, for example by the use of depth-specific water sampling. Well profiling data obtained by the DWR (**Figure 10**, for example) indicate that TDS linearly increases with depth. Given the high correlation with sulfate, the increase in TDS implies that sulfate will also increase with depth.

- Multiple aquifers are represented in the water chemistry data because of the construction of the 23 wells used in this report. As a result, water quality could not be differentiated in terms of the three-layer aquifer system (upper/middle/lower) used by the USGS and others (for example in the USGS Model Report).

- Temporal trends are more readily identified when multiple general mineral analyses are considered for each of the wells. Here Piper trilinear diagrams were used to assess the eight dominant anions and cations.

- 17 of the 23 wells had sufficient anion and cation data for temporal analysis and in some cases, well over 40 years data are available. Of these approximately 70 percent have experienced changes in water chemistry over time. The changes are generally attributed to long-term overdraft.

Chemicals of Concern (COCs)

- Five COCs were examined: arsenic, nitrate, TDS, sulfate, and fluoride. The overall analyses are improved when all five parameters are considered together and geochemical factors such as pH are included. The five COCs are depicted together with pH for each of the nine active BWD water supply wells in **Section 4**.

- Single parameter trend assessments, for example using Mann-Kendall trend analyses included in previous studies, are not repeated here.

- The COC analysis is based on a comparison of concentrations with current MCLs. Down-revision of the criteria, especially for arsenic, could have a large impact on BWD operations should water treatment be required. The State of California MCL for arsenic was last revised (from 50 to 10 ug/L) on 1/28/2008[25]. As of February 2017, there is no indication that the State Water Resources Control Board is planning to revise the arsenic MCL[26].

- Overall the water quality is currently good and water can be delivered without the need for advanced treatment. However, short-term water quality trends have been of concern, especially for arsenic. The following summarizes the analysis per COC.

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[25] See: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Arsenic.html

[26] Per a state review from 2017: "We are not aware of changes in treatment that would permit materially greater protection of public health, nor of new scientific evidence of a materially different public health risk than was previously determined. Thus, we do not plan on further review of the arsenic MCL." See: https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/reviewofmaximumcontaminantlevels-2017.pdf

Arsenic and Fluoride

Arsenic concentrations were increasing in multiple BWD water supply wells until 2014 and have since decreased. The potential for MCLS to be exceeded is of high concern to BWD due to the potential cost of water treatment and/or well replacement. The MCL was temporarily exceeded in one well, ID1-10. Review of the data shows that there is a relationship between pH and arsenic where elevated arsenic concentrations occur under alkaline conditions with pH levels of approximately 8 and greater. Especially noteworthy is that peak arsenic concentrations can be observed to occur after the peak pH was observed in multiple wells (ID1-10, ID1-16, Wilcox, and ID1-8). The lag time is approximately 2 to 4 years. While additional data and observations are required to further assess the connection between arsenic and pH, this relationship could prove important toward the monitoring and management of BWD's water supply.

Fluoride is discussed with arsenic because it has been observed to correlate with arsenic. While fluoride occurs at detectable concentrations in all of the active BWD wells, it has not been of concern as concentrations have typically been well less than 1.0 mg/L, less than half the MCL. Given the correlation it may prove useful towards future trend analyses for arsenic.

TDS and Sulfate

TDS represents the sum of all anions and cations that occur in the water. Here a number of these anions and cations have been observed to correlate with TDS. **Figures 15 through 17** show the correlation with TDS for sulfate, sodium, calcium, and chloride. A specific example is shown for well ID4-18 in **Figure 27** where TDS and sulfate are well correlated.

The USGS Model Report (p. 2) identified TDS and sulfate as "the only constituents that show increasing concentrations with simultaneous declines in groundwater levels".

Electrical conductivity measurements are commonly used to assess TDS. In this case they can be used as a field-based monitoring tool for TDS, and in turn support tracking of sulfate. The TDS profiles presented by DWR (**Figure 10**) are examples of electrical conductivity measurements used to evaluate TDS.

Nitrate

Historically there have been significant nitrate-related water quality problems encountered in BWD wells that led to well reconstruction, abandonment, and replacement. These wells were typically producing water from the uppermost portion of the aquifer system. As noted in **Table 4**, nitrate occurs in all of the active BWD wells at varying concentrations well below the MCL. Nitrate predominantly occurs as a result of fertilizers contained in irrigation return flow, and from septic systems. Historically, because the upper portion of the aquifer system is unconfined, nitrate has primarily affected wells that were completed (open to flow) at the water table.

The USGS Model Report (p.2) noted that "TDS and nitrate concentrations were generally highest in the upper aquifer and in the northern part of the Borrego Valley where agricultural activities are primarily concentrated".

Nitrate concentrations are primarily related to land-based activities and do not correlate with inorganic water quality data. Overall determination of historical impacts and ongoing susceptibility of the aquifer to nitrate contamination will require review of prior, current, and future land use placed in a spatial context. Work done by DWR (for example as illustrated in **Figure 11**) is an example of how land use information can be used. Among the land use parameters that would go into a nitrate source analysis would the location and types of septic and sewer systems, current and historical agricultural activities, and current and historical irrigated turf/golf courses.

5.1 Other Potential COCs

This report focused on the dominant anions and cations, and the five primary COCs. Other potential COCs include naturally-occurring uranium and radionuclides. Anthropogenic COCs include herbicides, pesticides, and similar chemicals used for agriculture and turf management. Microbial contamination, typically associated with animal wastes and sewage/septic, is also of potential concern.

Groundwater quality provided by BWD water supply wells is currently good and meets California drinking water maximum contaminant levels (MCLs). To date the current wells are producing water without the need for treatment. The BWD public water supply monitoring program is conducted in compliance with the State of California's requirements as administered by the State Water Resources Control Board Division of Drinking Water (DDW) and includes a wide range of analytes.

BWD provides all sampling data to the DDW, and is listed as public water supply CA3710036. A summary of BWD's sampling program for other COCs can be reviewed in the annual consumer confidence report, available online at http://nebula.wsimg.com/c30a61991a5160ddf5e577fe9f7b3c01?AccessKeyId=D2148395D6E5BC38D600&disposition=0&alloworigin=1. The BWD is also sampling all of its water supply well semi-annually as part of the GSA monitoring network rather than the minimum 3-year timeframe currently required by DDW.

5.2 Recommendations

- The COC analysis supports expansion of groundwater monitoring and testing program to include field-based water quality measurements of water being produced by BWD. Monthly wellhead measurements are recommended for electrical conductivity (EC), pH, and oxidation-reduction (redox) potential. These could be conducted at the same time BWD personnel collect monthly bacteria samples. EC can be used to calculate TDS, and by correlation estimate sulfate in some wells. Redox and pH are key geochemical parameters that can readily be measured at the wellhead by BWD personnel.

- Conduct vertical profiling and depth-specific sampling of water supply wells when the wells become accessible, for example during pump removal for maintenance. The primary goals of the testing are to identify potential zones where water quality may be poor and to examine the relative rate of flow of water into the well with depth. Both types of information will support assessment of well performance as overdraft continues.

  Long-term the vertical profiling will provide data to better understand the water quality trends and support BWD water management planning. For example, the data will support assessment of sulfate trends by understanding how concentrations may or may not be increasing with depth and support projections of how water quality will change as overdraft while pumping reductions occur over the 20-year GSP planning period.

- Use the groundwater model to assess pre- and post-SGMA groundwater flow conditions and potential changes in water chemistry. Current pumping conditions have changed groundwater flow patterns within the North and Central Management Area due to the establishment of two pumping centers. Future pumping reductions will likely alter groundwater flow patterns. The model can be used to support calculations of groundwater flow rates and directions using ‘particle tracking’, a methodology that looks at how water flows over time. The modeling software (USGS Modflow model) includes Modpath, a post-processing software that works with the model output.

- Use the groundwater model water balance to develop a ‘mixing cell’ calculation of salt balance to assess the potential rate of accumulation of dissolved minerals associated with water use. The Subbasin is effectively a closed system where dissolved minerals and other solutes have will continue to accumulate over time. The primary purpose of the calculations is to assess long-term TDS changes that result from irrigation and septic return flows as overdraft continues. The calculations will also support examination of areas where BWD water production may need to be established using new or existing water wells.

- Investigate the potential causes of the temporary increases in arsenic concentrations and pH observed in BWD wells as a means of predicting future arsenic concentrations. A lag time of 2 to 4 years is observed in multiple BWD wells where elevated pH preceded the increase in arsenic concentrations that could prove to be important towards BWD's water supply and risk management.

- Expand on the analysis of nitrate in groundwater relative to land use as described by the DWR (e.g. **Figure 11**). Additional discussion of the occurrence of nitrate in groundwater is included in the GSP that describes land uses within the Subbasin.

- Expand the water chemistry and water quality evaluation to areas within and downgradient of the agricultural areas in the North and Central Management Areas.

- Continue to collect the full suite of general minerals (8 anions and cations) together with pH and redox measurements. Water chemistry parameters should be collected using 'flow cells' where the chemistry of the water is tested before it is exposed to the atmosphere.[27]

- Conduct selective sampling for phosphate and review the overall electrochemical balance for all potential anions and cations to determine why the current data have excess cations relative anions (see **Section 3.2.1**).

- Further assess lithologic and geochemical conditions associated with the occurrence of arsenic. For example, work done in the San Joaquin valley (discussed in **Section 3.6.1**) linked the release of water from clay to increased arsenic concentrations in groundwater. Further review of Subbasin stratigraphy work done by Netto (2001) is warranted. Re-analysis of the geostatistical work done by the USGS to evaluate sediment lithologies may also prove useful towards understanding the nature and extent of sediments potentially associated with arsenic. Lithologic sampling and

---

[27] An example is shown below. Water flows directly from the well into a chamber where measurements are made. From: http://www.geotechenv.com/flowcell_sampling_systems.html. It is understood that Dudek staff are using flow cells during sampling of Rams Hill wells to measure pH, specific conductance, temperature, turbidity, dissolved oxygen, oxygen-reduction potential, and color. Their Sampling and Analysis Plan could be used for the remaining wells within the GSP monitoring program.

Geotech Flowblock
<40 mL cell volume for flow rates of
100 mL/min to 1 gpm (3.8 LPM)

geochemical testing for arsenic and related minerals is recommended during the installation of new wells.

- Investigate the potential interaction of microbially-mediated oxidation and reduction processes (e.g. denitrification and sulfate reduction) specific to arsenic mobility.

- Examine the potential application of recharge basins to facilitate arsenic removal as a result of geochemical processes in the vadose zone (see discussions in Section **3.6.1**).

- Develop an inventory of abandoned wells, including well completion information and potential condition. Abandoned wells have the potential to act as conduits for the downward flow of shallow groundwater contaminants such as surface applied fertilizers, agricultural chemicals, and turf management chemicals. Abandoned wells may need to be properly destroyed per California Well Standards (See information available from the County of San Diego https://www.sandiegocounty.gov/content/sdc/deh/lwqd/lu_water_wells.html)

- Continue to track changes in groundwater quality as a function of water level to assess trends relative to the potential for water quality degradation and the likelihood of the need for water treatment. Use the data to assess potential cost and water system reliability risks to BWD.

- Continue to track water treatment technologies and costs for arsenic as the potential for revision of the arsenic MCL is, in part, dependent on cost-benefit analyses for water treatment (see COC discussion in Section 5).

6.0 REFERENCES

All references are cited within the text using footnotes.

APPENDIX A

DWR, 2014

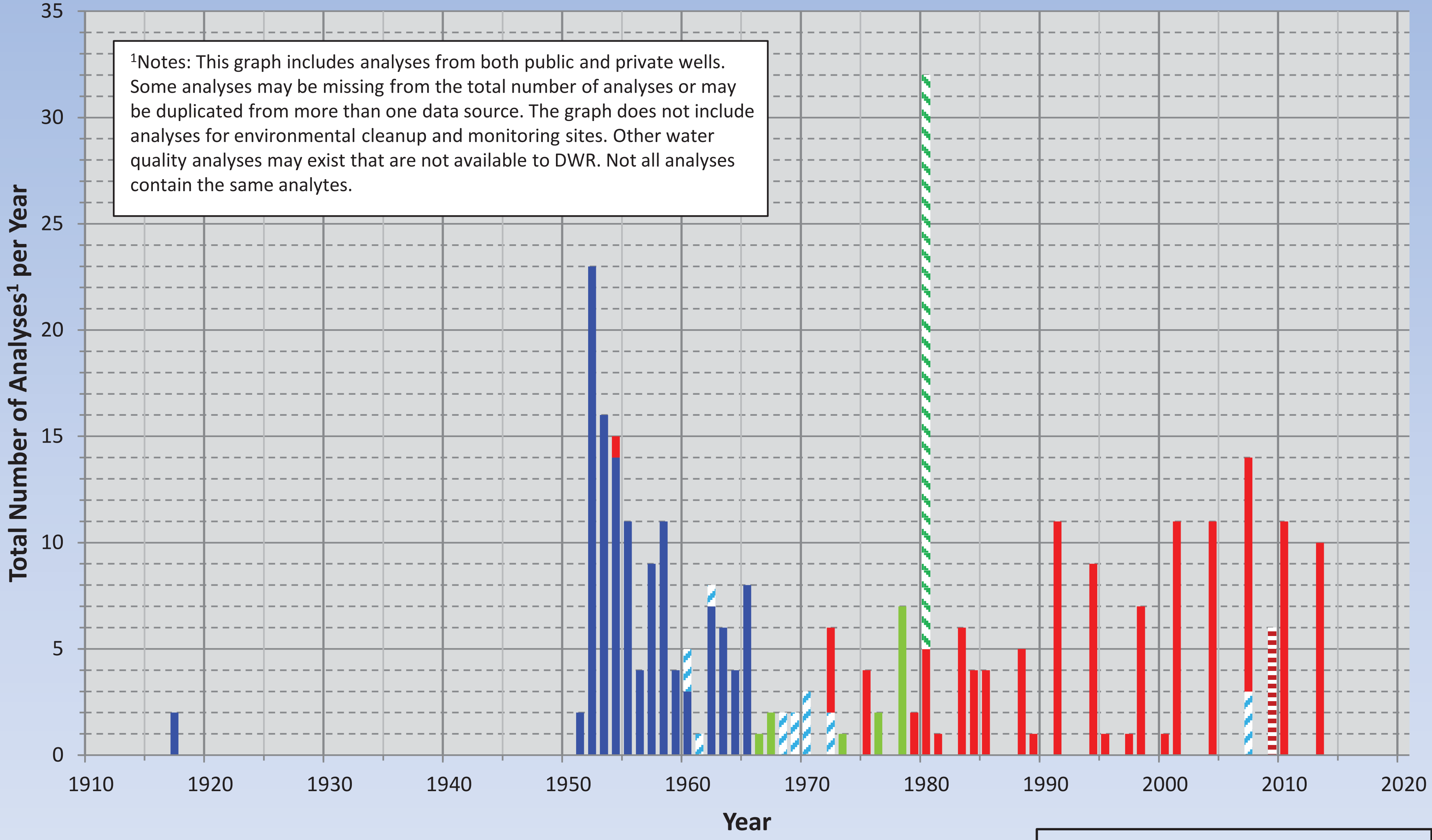
Groundwater Quality Information
for
Borrego Valley

DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

Groundwater Quality Information
for
Borrego Valley

Southern Region May 2014

Water Quality Analyses by Year and Source



[1]Notes: This graph includes analyses from both public and private wells. Some analyses may be missing from the total number of analyses or may be duplicated from more than one data source. The graph does not include analyses for environmental cleanup and monitoring sites. Other water quality analyses may exist that are not available to DWR. Not all analyses contain the same analytes.

🟦 DWR Bulletin 91-15	▨ DWR Water Quality Database
🟥 BWD Water Quality Database	▨ USGS 82-855
▤ USGS GAMA	🟩 USGS files

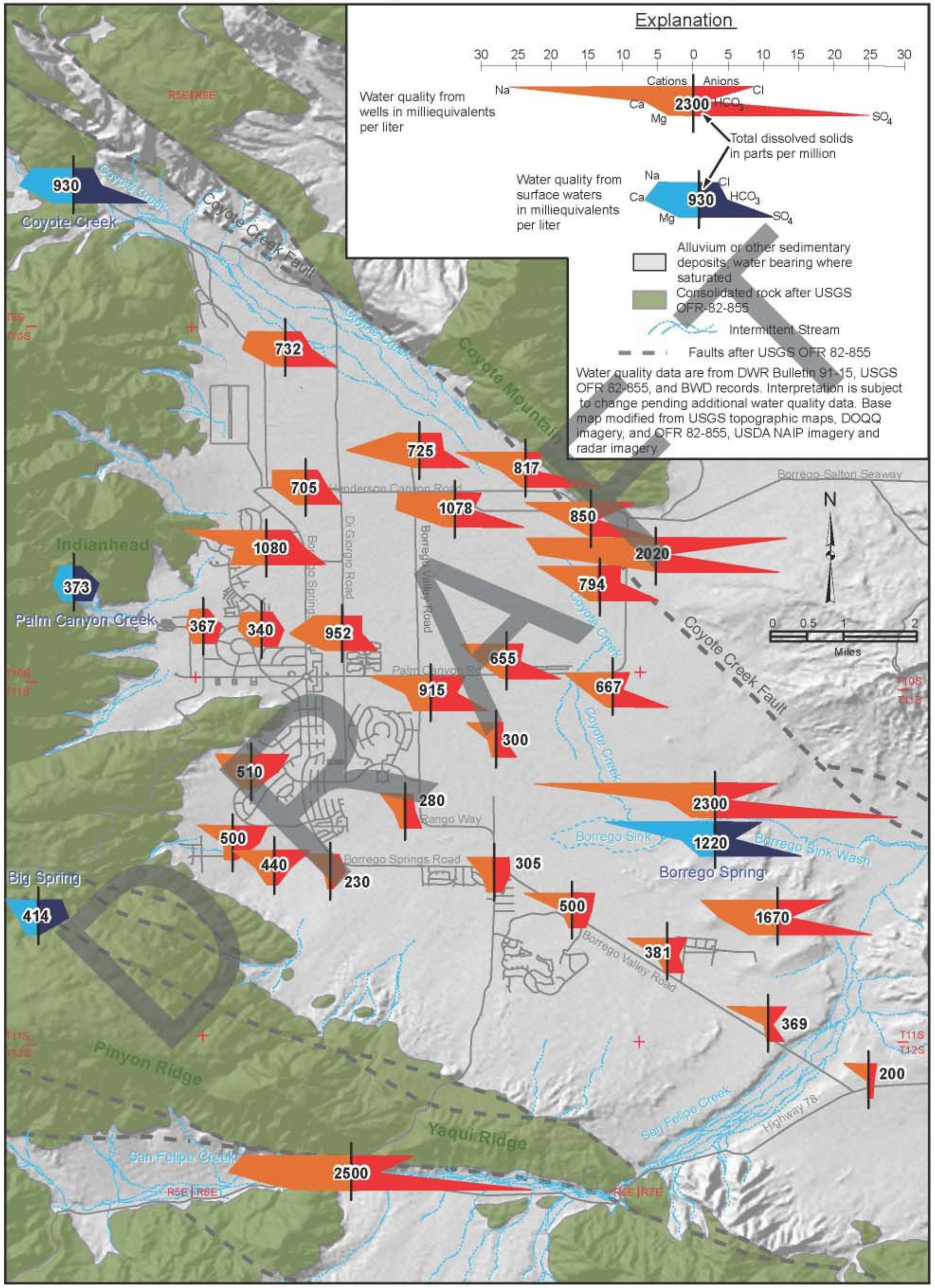
Borrego Valley Groundwater Basin

Figure

California Department of
Water Resources, Southern Region

More than 300 water quality analyses have been identified.

Borrego Valley Groundwater Quality



Water quality data are from DWR Bulletin 91-15, USGS OFR 82-855, and BWD records. Interpretation is subject to change pending additional water quality data. Base map modified from USGS topographic maps, DOQQ imagery, and OFR 82-855, USDA NAIP imagery and radar imagery.

Figure showing major water quality constituents in groundwater and surface water in Borrego Valley. The high proportion of Sulfate in the surface water of Coyote Creek appears to dominate the character of groundwater in the northern and eastern parts of the basin. The more Bicarbonate waters of Borrego Palm Canyon and Big Spring influence the groundwater along the western and southern parts of the basin.

Borrego Valley Water Quality Analyses of Nitrates

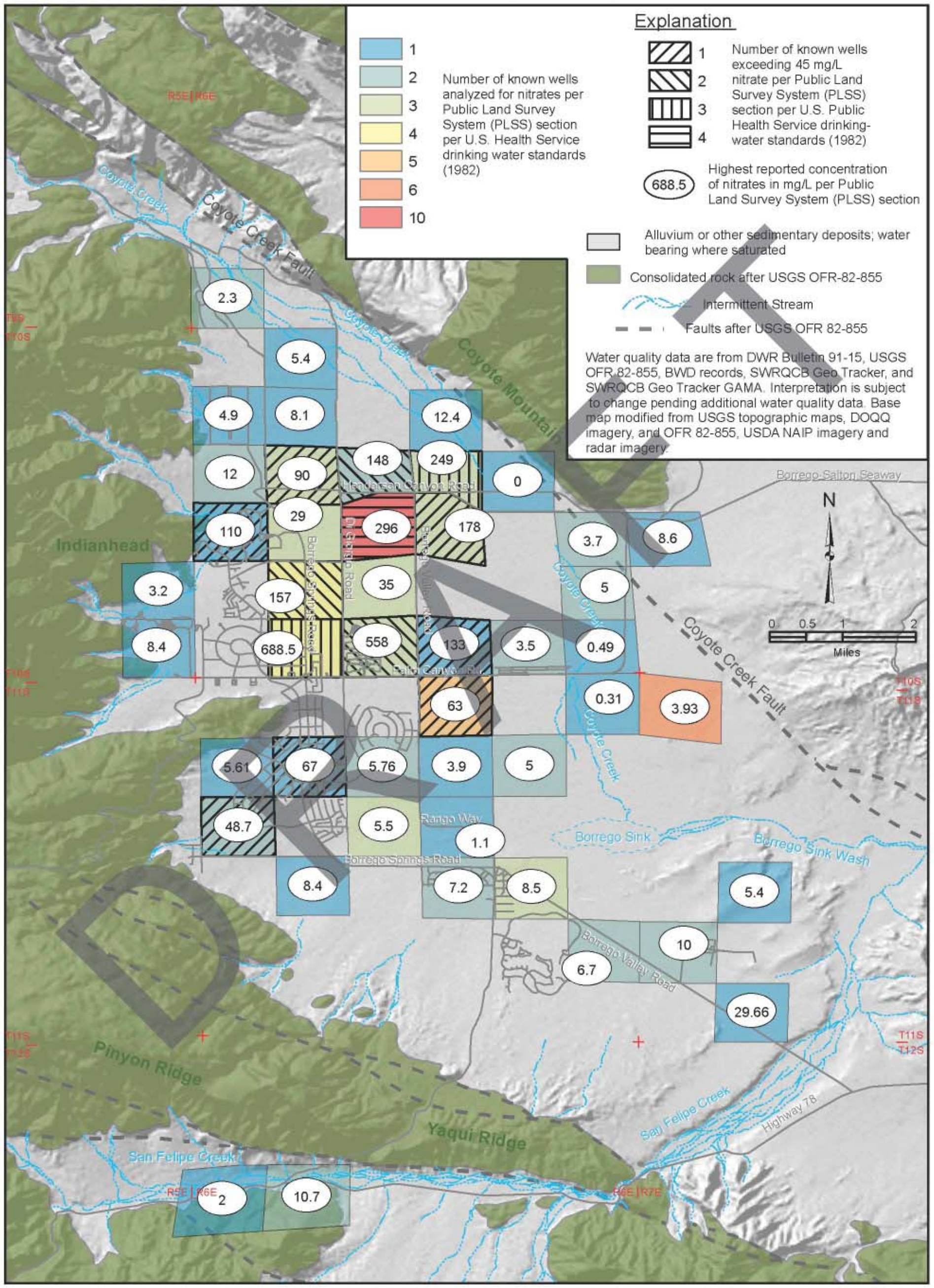
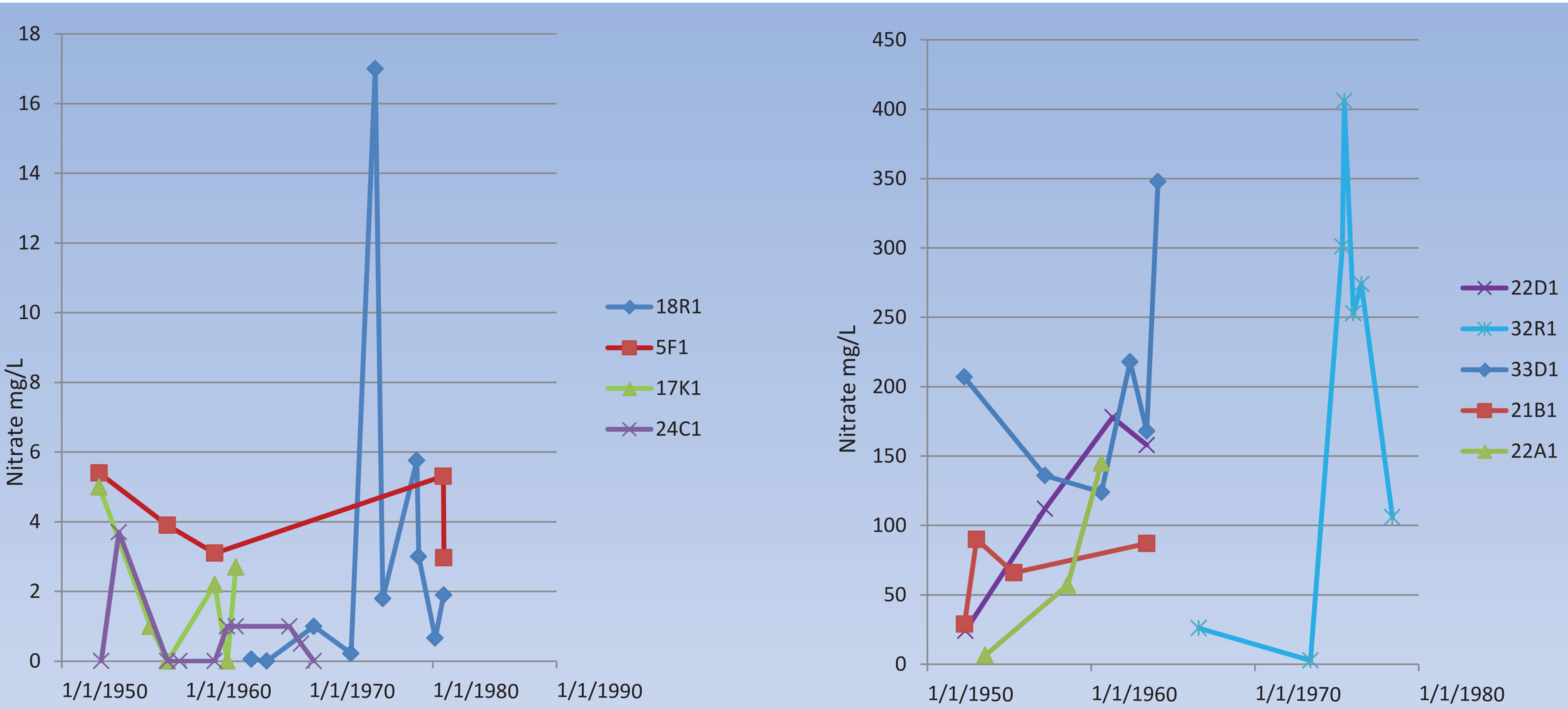
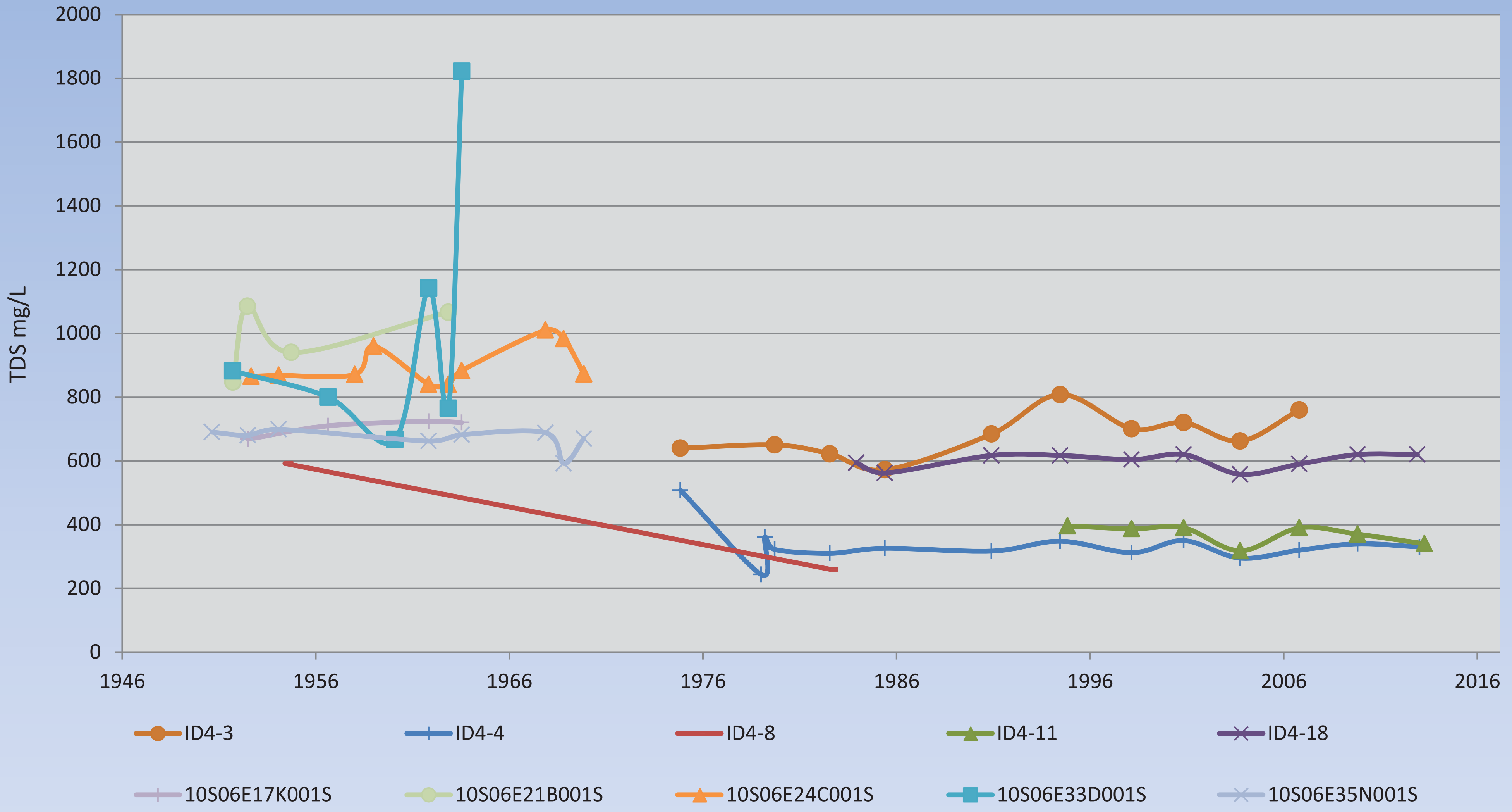


Figure showing the distribution of Nitrate analyses for the Borrego Basin. Maximum content is shown per section and sections are colored according to the number of analyses in the section. Sections where the maximum contaminant level (MCL) are exceeded are shown in hatched patterns.



Nitrate content is graphed through time for several wells in the Borrego Basin. No obvious trend is apparent. (MCL is 45 mg/L)

North Borrego Valley



DEPARTMENT OF WATER RESOURCES
STATE OF CALIFORNIA

Graph showing change in TDS content through time for several wells in the northern part of the basin. No clear increase in TDS is observed.

South Borrego Valley

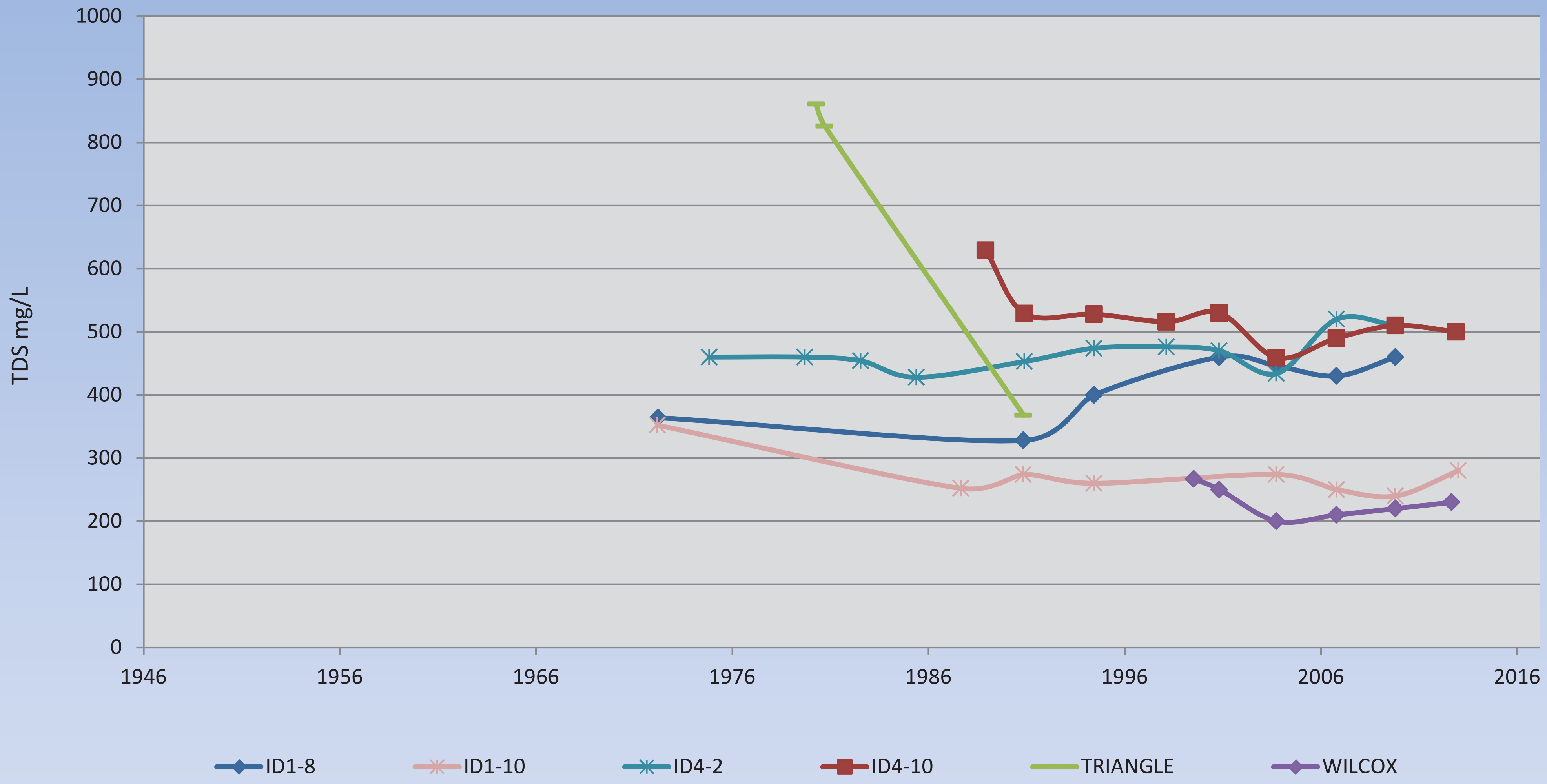
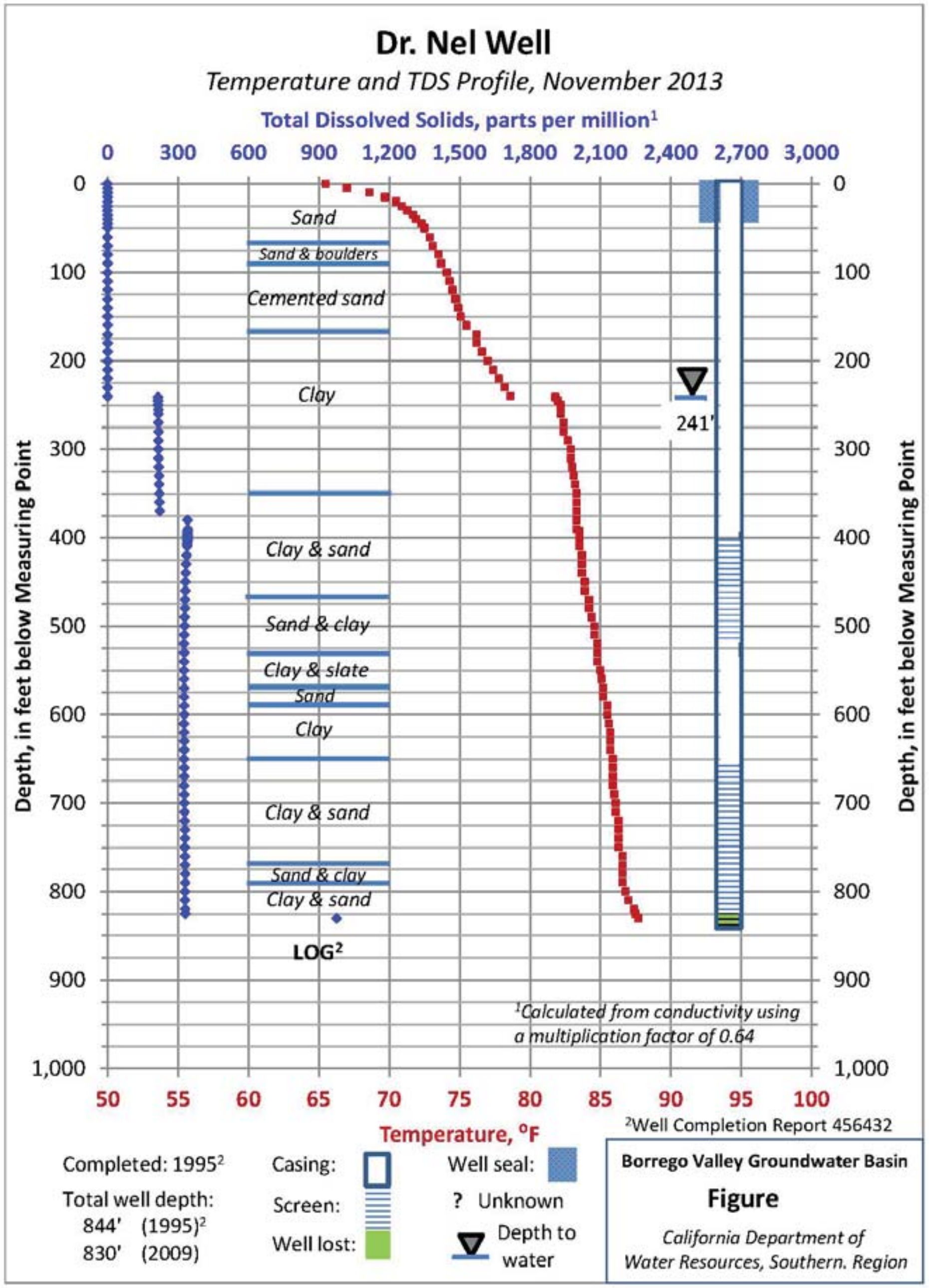
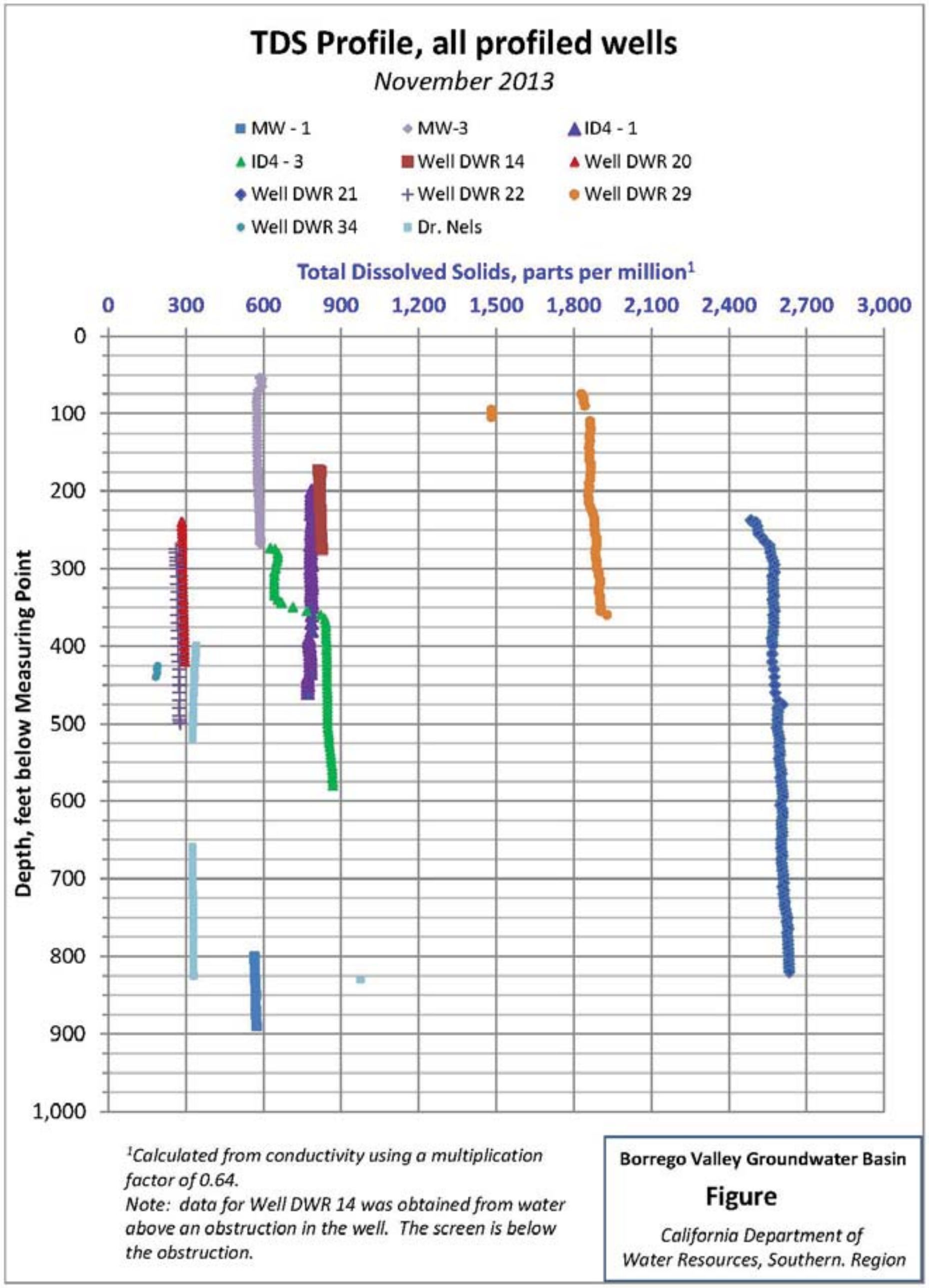


Figure showing TDS content through time for several wells in the southern portion of the basin. Most show decrease in TDS through time.



A profile of TDS content and temperature for Dr. Nel's Well. Changes in TDS appear to occur at the well screen. TDS does not change appreciably with depth through the screened interval. Temperature rises steadily with depth.



[1] *Calculated from conductivity using a multiplication factor of 0.64.*

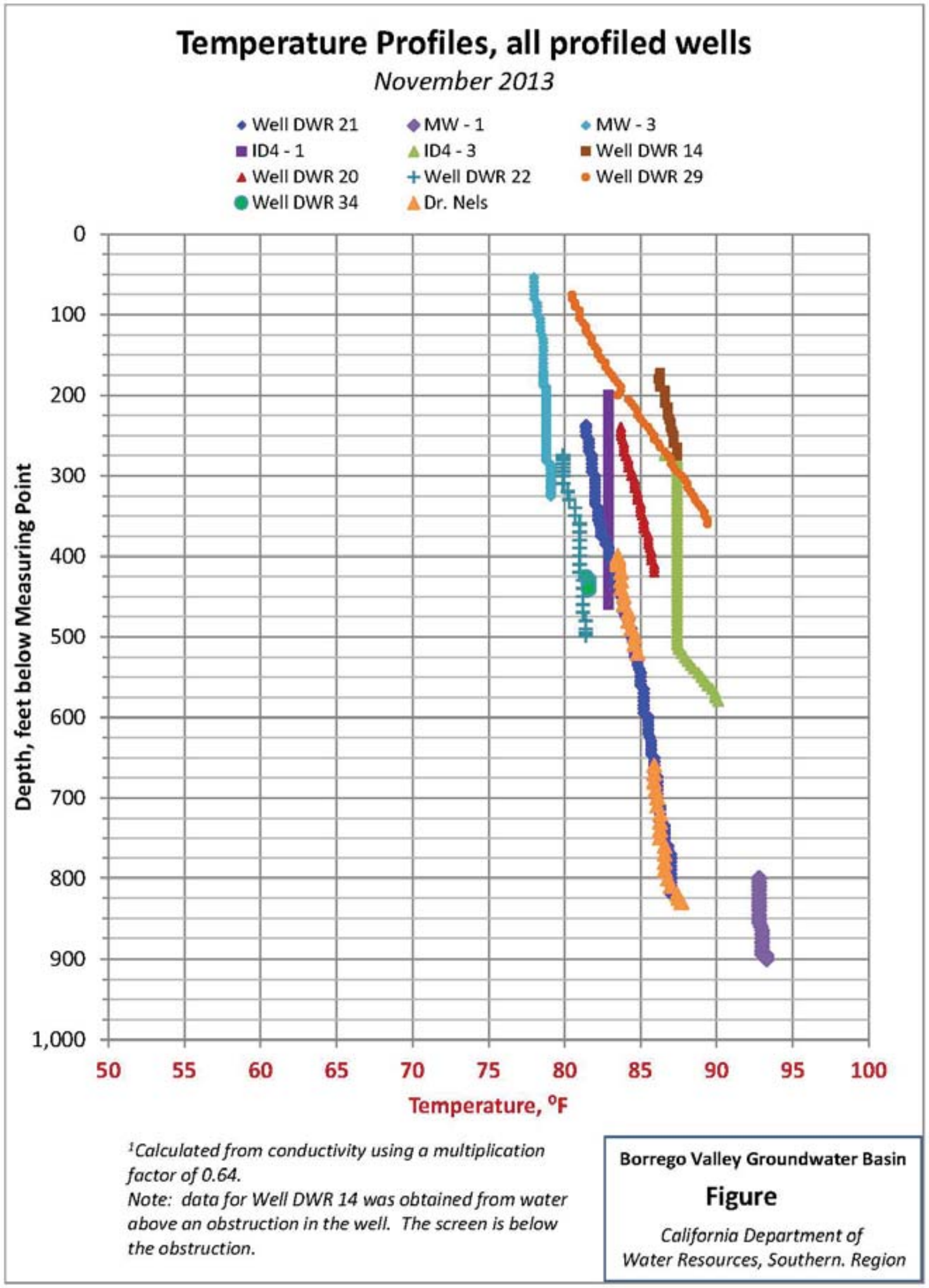
Note: data for Well DWR 14 was obtained from water above an obstruction in the well. The screen is below the obstruction.

Borrego Valley Groundwater Basin

Figure

California Department of Water Resources, Southern. Region

Profiles of TDS with respect to depth for wells in Borrego Valley. Most show slight increase in TDS with depth



Temperature Profiles, all profiled wells

November 2013

[1]Calculated from conductivity using a multiplication factor of 0.64.

Note: data for Well DWR 14 was obtained from water above an obstruction in the well. The screen is below the obstruction.

Borrego Valley Groundwater Basin

Figure

California Department of Water Resources, Southern. Region

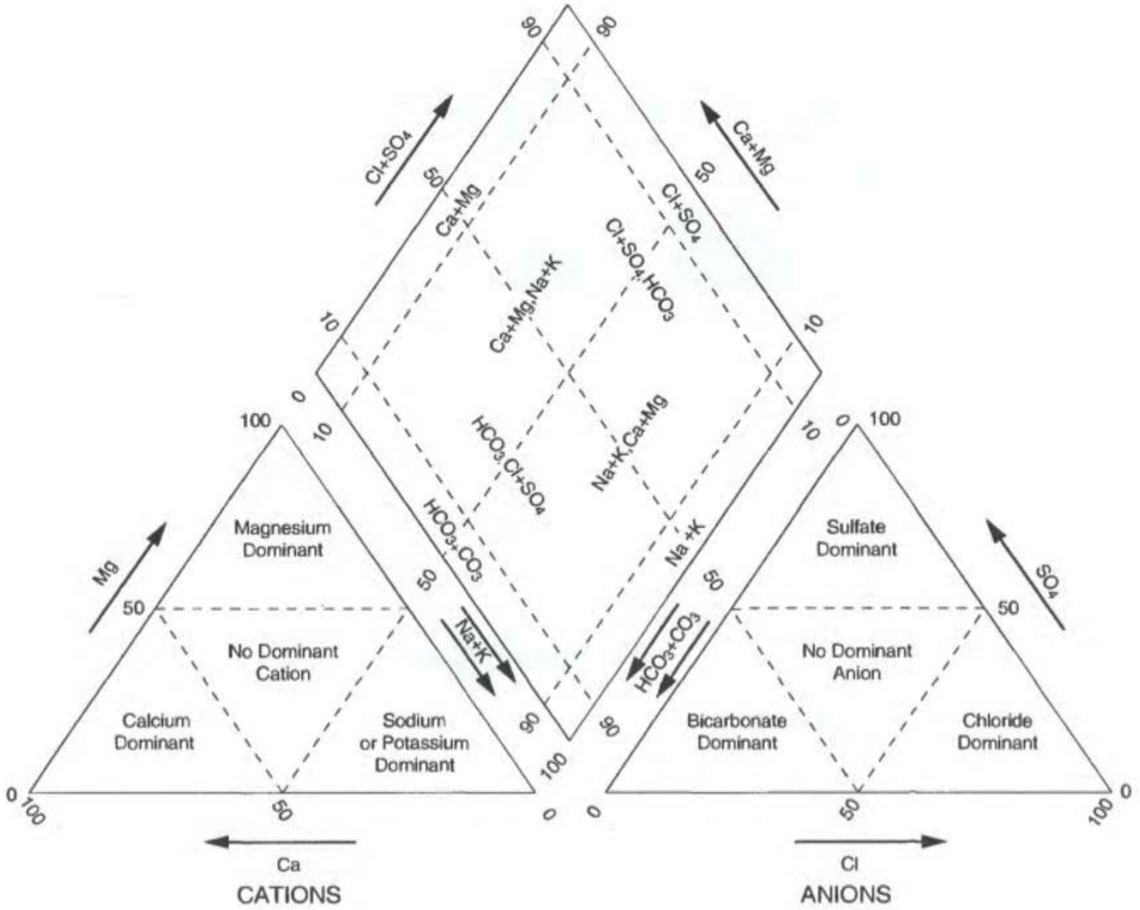
Profiles of Temperature with respect to depth. Most wells show increase in temperature with depth.

Summary

- More than 300 analyses identified
- Water character reflects recharge source
- More than 100 Nitrate analyses, widespread
- No apparent trend through time for Nitrate or TDS
- 11 Wells profiled for Temperature and TDS
- No consistent trend for TDS with depth in well.

APPENDIX B

PIPER DIAGRAMS, ALL WELLS

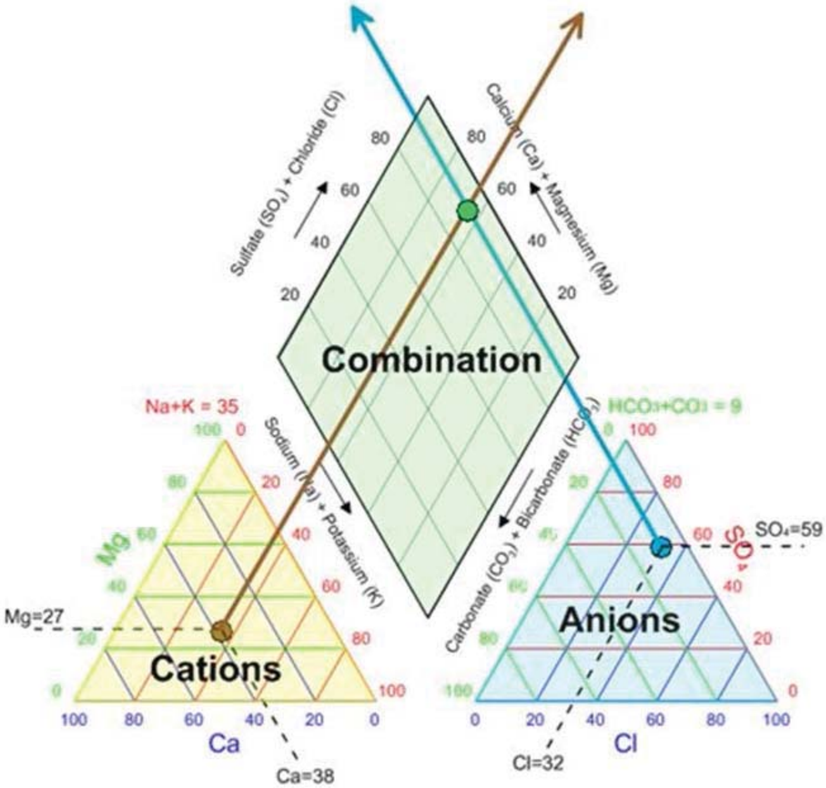


A. Classification scheme for hydrochemical facies.

APPENDIX B: PIPER DIAGRAMS

B.1 EXPLANATION OF PIPER DIAGRAMS

The eight dominant anions and cations that occur in groundwater can be used to describe of the type of water. A Piper trilinear diagram[1] combines sodium and potassium (cations), and carbonate and bicarbonate (anions) to reduce the total number of anions and cations from eight to six, with 3 values for each. This allows the anions and cations to be depicted using ternary diagrams. The values are then then projected onto a central diamond. An example of the projection follows:



From: https://support.goldensoftware.com/hc/en-us/articles/115003101648-What-is-a-piper-plot-trilinear-diagram-

The values used for the anions and cations are converted from mass/liter to milliequivalents/liter, a measure of the relative number of anions and cations in the solution. For example, if NaCl is dissolved into pure water there are an equal number of sodium cations (Na^+) and chloride anions (Cl^-). An analysis by weight will show that there is more chloride because chloride has a larger molecular weight (MW) - the MW of Na is 22.9 grams/mole versus Cl that has a MW of 35.45 grams/mole. ‘Equivalents’ are derived by dividing the reported mass by the MW so that the relative number of ions (in moles) is calculated.

---

[1] Piper, A.M. 1944. A graphic procedure in the geochemical interpretation of water-analyses. Transactions-American Geophysical Union 25, no. 6: 914–923

APPENDIX B: PIPER DIAGRAMS

The overall intent of the diagram is to support grouping and classification of water types, also termed hydrochemical facies. An example follows from https://www.hatarilabs.com/ih-en/what-is-a-piper-diagram-and-how-to-create-one

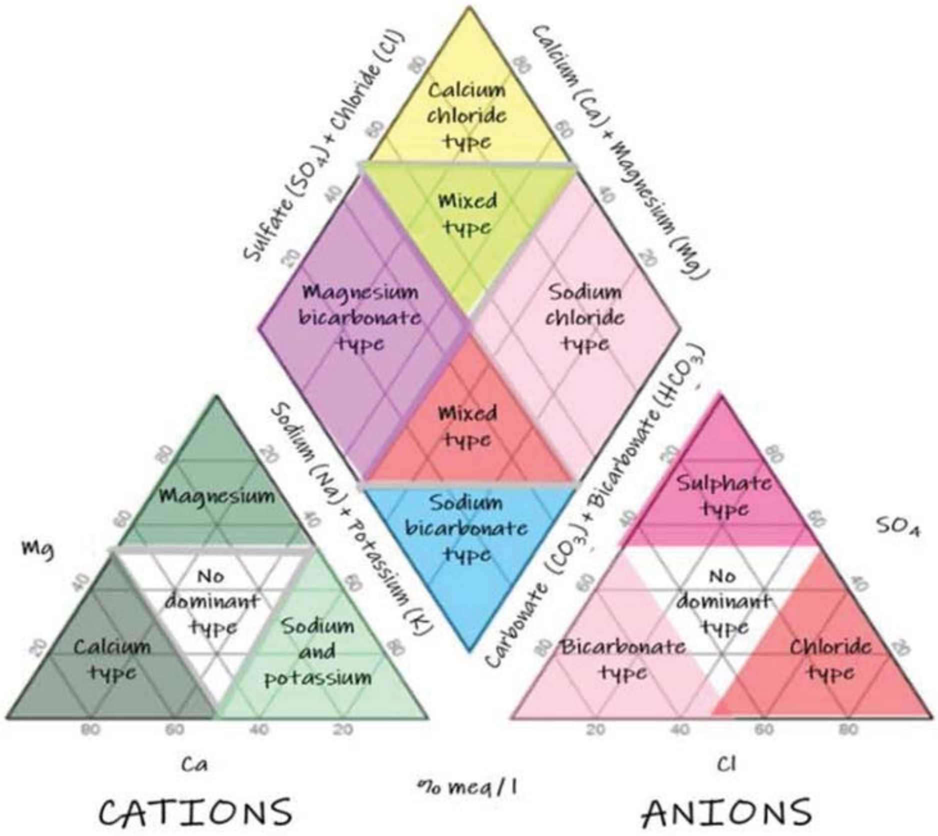


FIGURE 1A: HYDROCHEMICAL FACIES IN THE CATION AND ANION TRIANGLES AND IN THE DIAMOND.

The lower triangles are ternary diagrams that represent the relative proportion of anions or cations. The various types of water, or facies, are shown in the middle diamond.

Piper diagrams depicted in this report use a colored field scheme implemented in the Python programming language as published by Peeters, 2014[2]. Rather than drawing an underlying grid, the colored fields are used to help the visual interpretation of the data. The computations and graphics were developed using open source program code published by Peeters.

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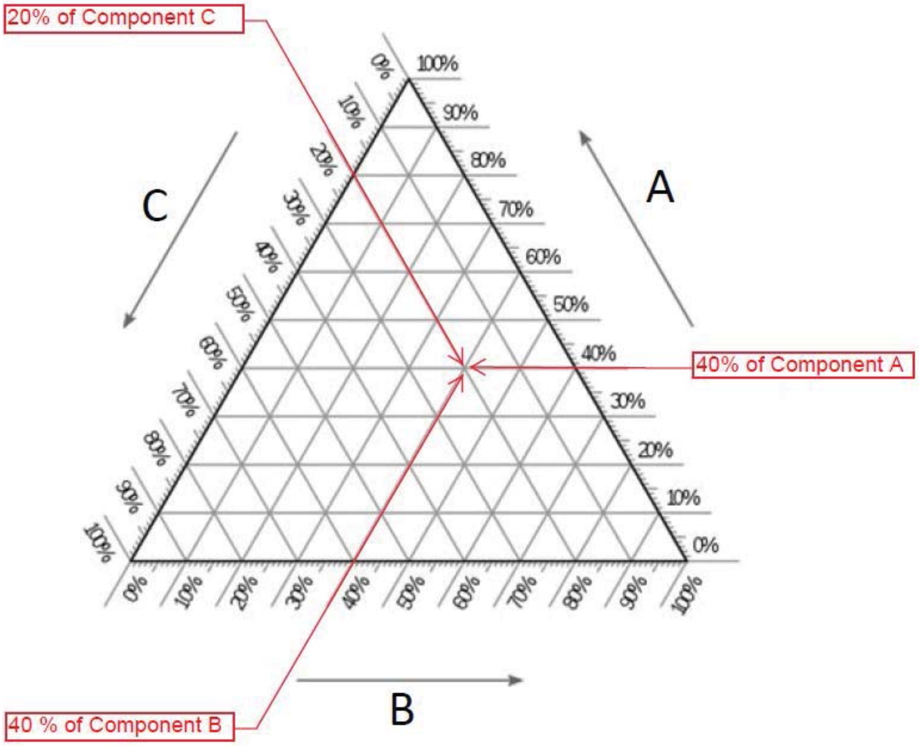
[2] Peeters, L., 2014. A Background Color Scheme for Piper Plots to Spatially Visualize Hydrochemical Patterns. Vol. 52, No. 1–Groundwater–January-February 2014

The following is an example of the ternary grid and how data are plotted:



All values equal 100% on the triangular grid. The highest percentage of each of the components occurs in the extreme corners of the triangle.

Values increase as indicated by the arrows.

Source:
https://upload.wikimedia.org/wikipedia/commons/thumb/a/ac/Blank_ternary_plot.svg/486px-Blank_ternary_plot.svg.png

APPENDIX B.2 PIPER DIAGRAMS USED IN THE REPORT

The following diagram are presented in the following order:

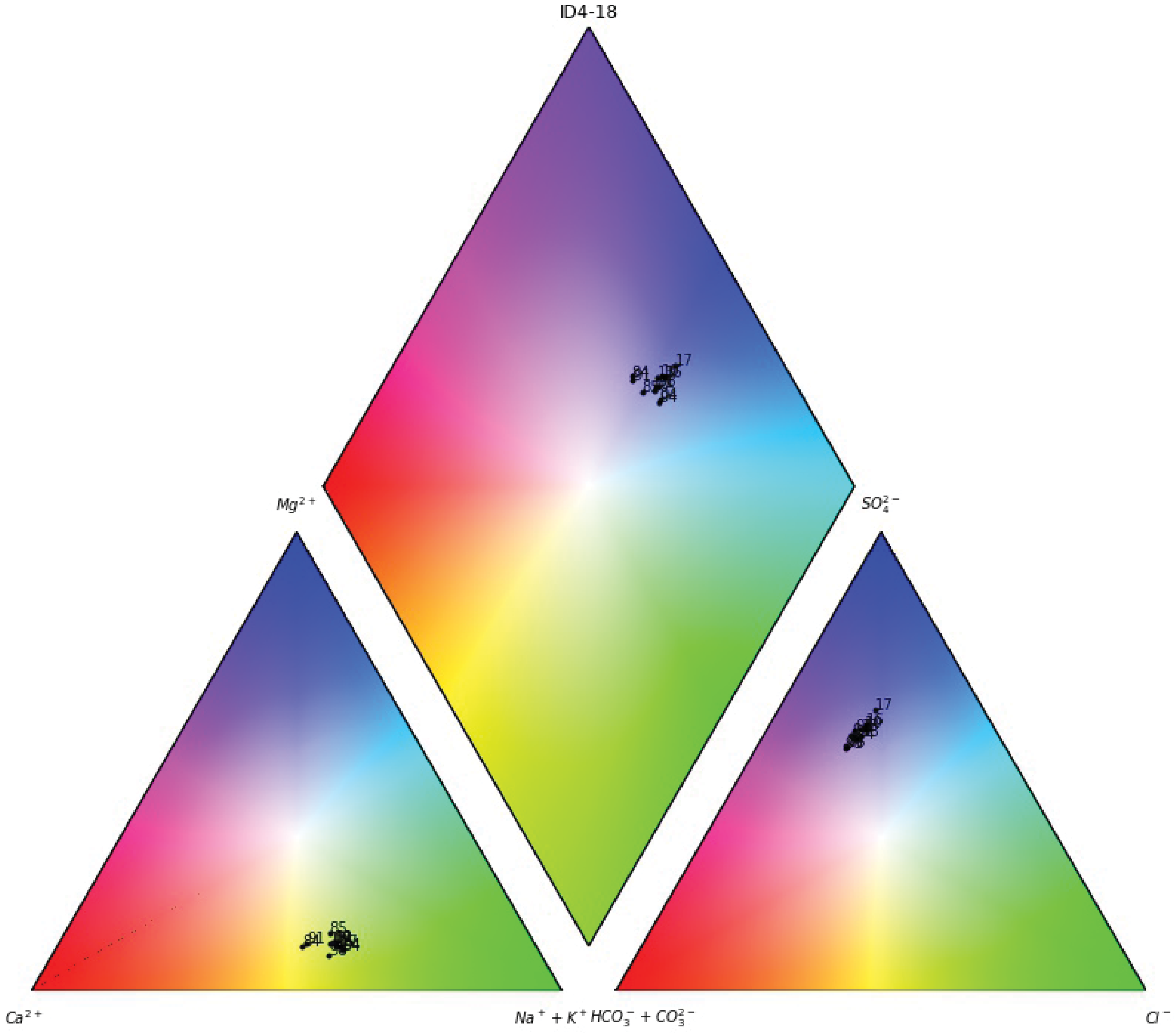
1: ID4-7 (not included due to insufficient data)
2: ID4-18
3: ID4-3
4: ID4-4
5: ID4-11
6: Cocopah
7: ID4-5
7A: ID4-1
8: ID5-5
9: ID1-12
10: ID4-2
11: ID4-10
12: ID1-16
13: Wilcox
14: ID1-10
15: ID1-8
16: RH-3
17: RH-4
18: RH-5
19: RH-6
20: ID1-1
21: ID1-2
22: Jack Crosby
23: WWTP (insufficient data)
24: MW-3 (insufficient data)

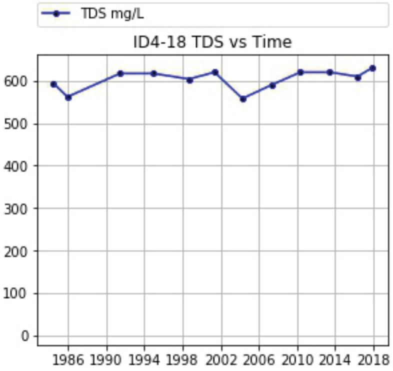
Recent Data: All (Piper only)
Recent Data: North and Central (Piper only)
Recent Data: South (Piper only)

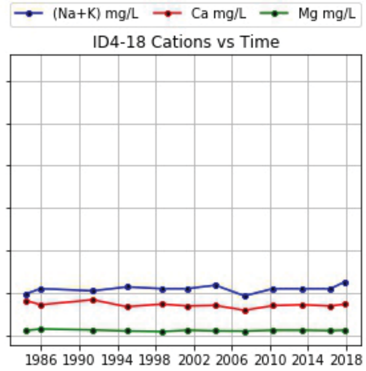
A copy of the map follows (**Figure 4**, from main body of report)

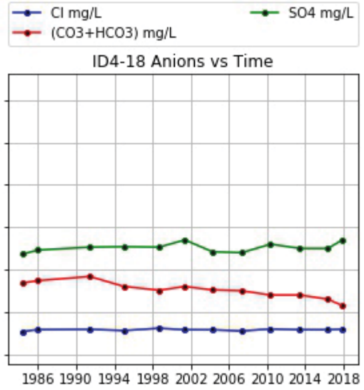

C:\Drawing Files\Environmental Navigation Services\Borrego Water District\GW & Sustainability Plan\Fig 1. Well Location Map - 10/17/2018
N
1 ID4-7
2 ID4-18
ID4-3 3
MW-1
BORREGO SALTON SEAWAY
DI GIORGIO ROAD
PEGLEG ROAD
4 ID4-4
ID4-11 5
6 COCOPAH
ID4-1 7A
7 ID4-5
PALM CANYON DRIVE
MW-4
ID5-5 8
ID4-2 10
MW-5A/B
ID1-12 9
11 ID4-10
12 ID1-16
WILCOX 13
14 ID1-10
DEEP WELL TRAIL
25 WWTP
ID1-8 15
MW-3 22
JACK CROSBY WELL
RH-3 19
17 RH-4
ID1-1 20
18 RH-5
ID1-2 21
RH-6
YAQUI PASS ROAD
BORREGO VALLEY ROAD
ENVIRONMENTAL NAVIGATION SERVICES, INC.
0 3,500 7,000
APPROXIMATE SCALE (FEET)
EXPLANATION BLOCK
ID4-4 Active BWD Groundwater Well
RH-4 Active Private Groundwater Well
ID4 Inactive BWD Groundwater Well
MW-1 Groundwater Monitoring Well
WELL LOCATION MAP
Borrego Valley Water District
Borrego Springs, California
PE/PG JWJ
Project Number BWD
Figure 4
Project Manager JWJ
Drafter CM
Date 10/17/2018

2: ID4-18

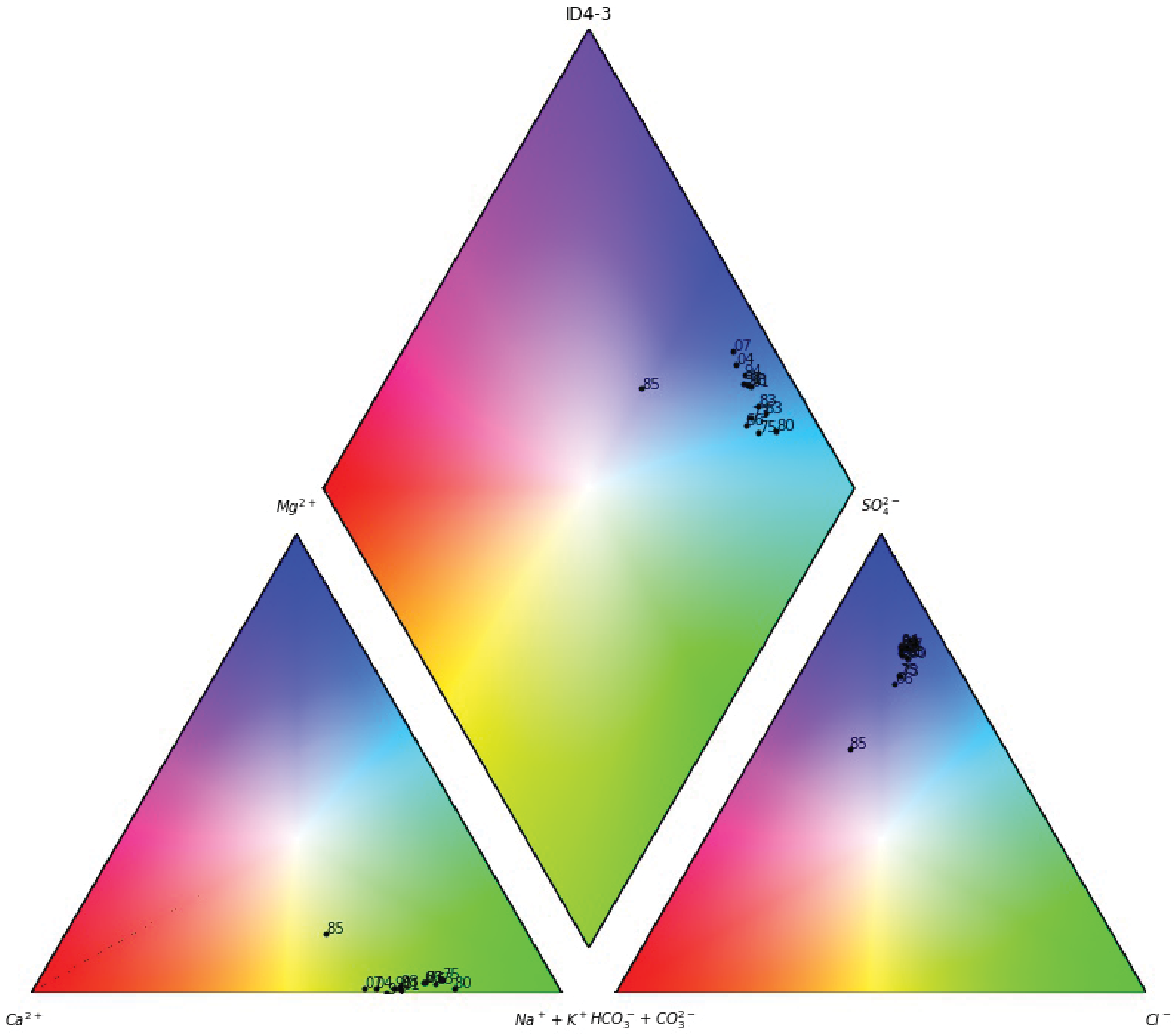

ID4-18
84
17
85
91
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-

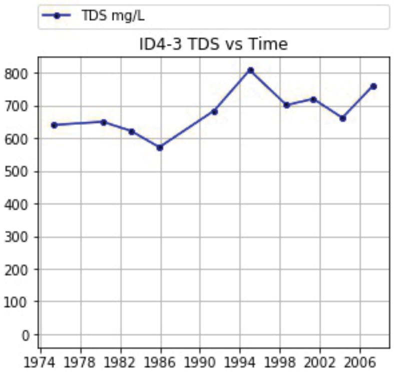

TDS mg/L
ID4-18 TDS vs Time
600
500
400
300
200
100
0
1986 1990 1994 1998 2002 2006 2010 2014 2018

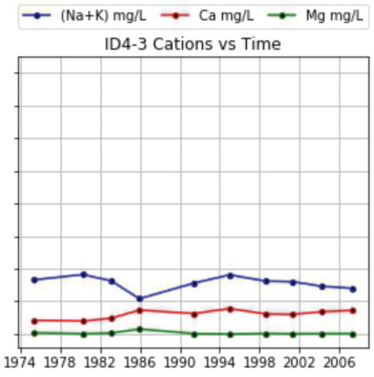

(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-18 Cations vs Time
1986 1990 1994 1998 2002 2006 2010 2014 2018

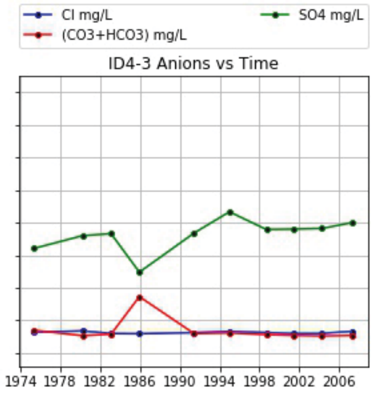

Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-18 Anions vs Time
1986 1990 1994 1998 2002 2006 2010 2014 2018

3: ID4-3

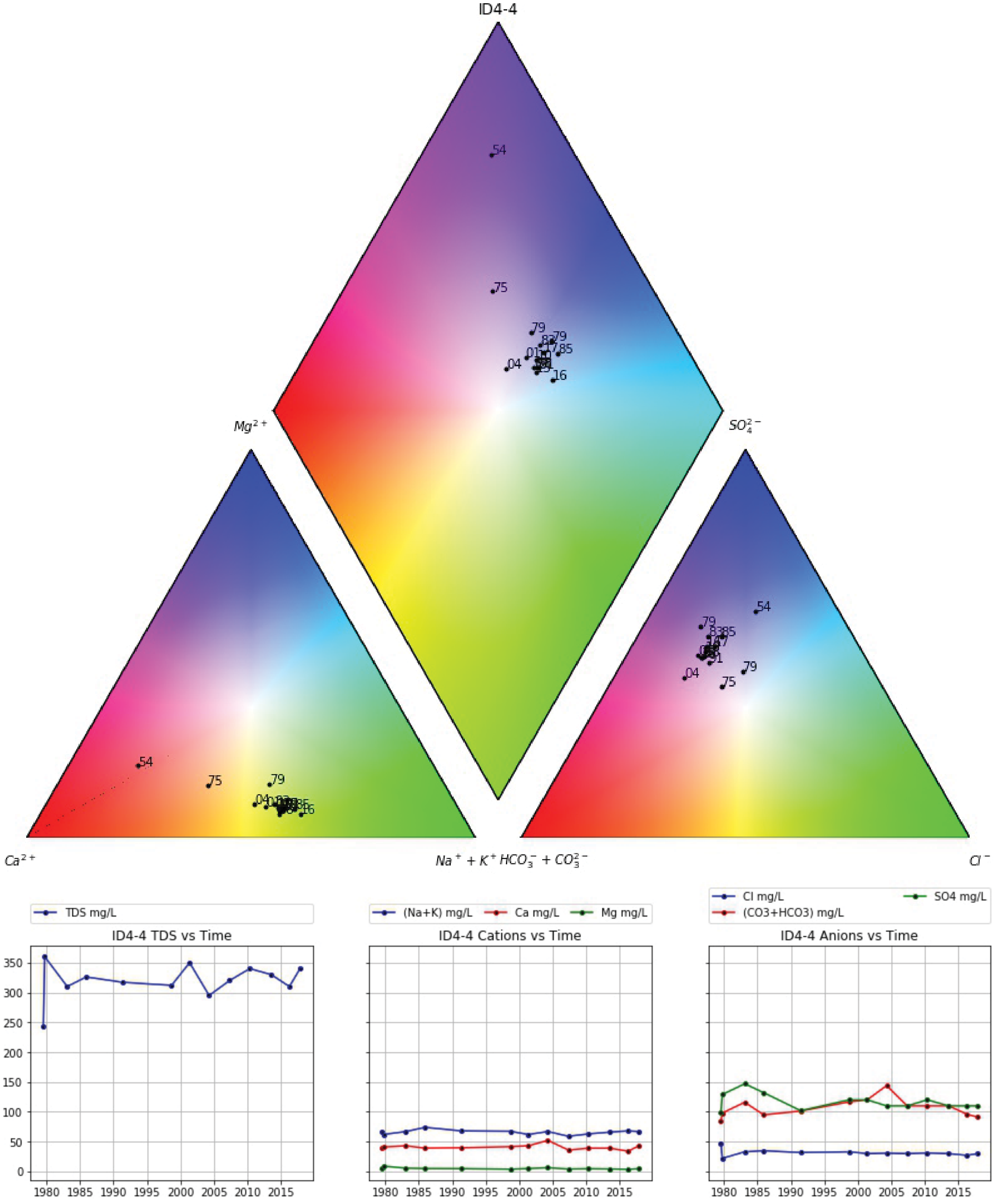

ID4-3
Mg²⁺
SO₄²⁻
Ca²⁺
Na⁺ + K⁺ HCO₃⁻ + CO₃²⁻
Cl⁻
07
04
85
83
75
80


TDS mg/L
ID4-3 TDS vs Time
800
700
600
500
400
300
200
100
0
1974
1978
1982
1986
1990
1994
1998
2002
2006

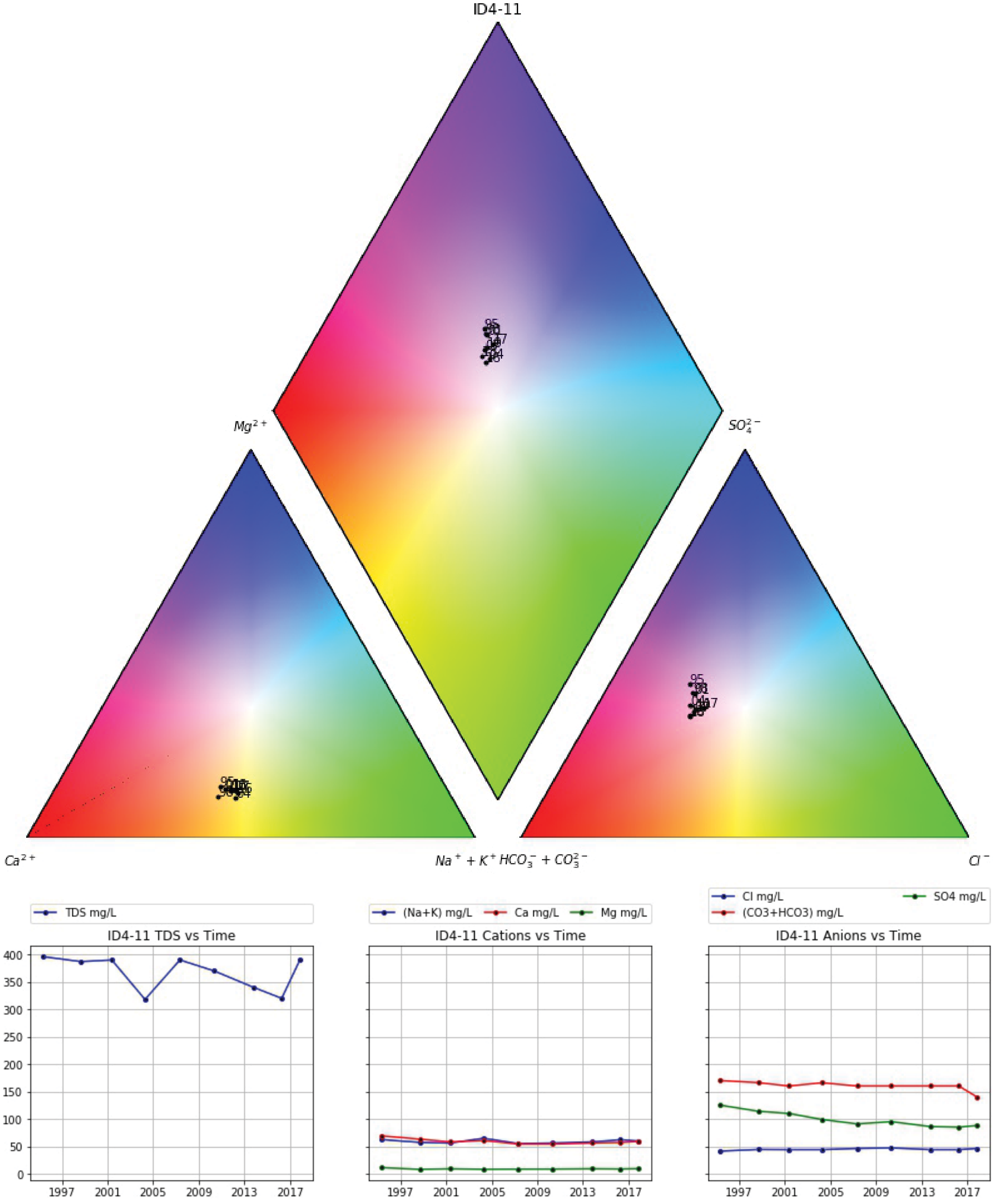

(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-3 Cations vs Time
1974
1978
1982
1986
1990
1994
1998
2002
2006


Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-3 Anions vs Time
1974
1978
1982
1986
1990
1994
1998
2002
2006

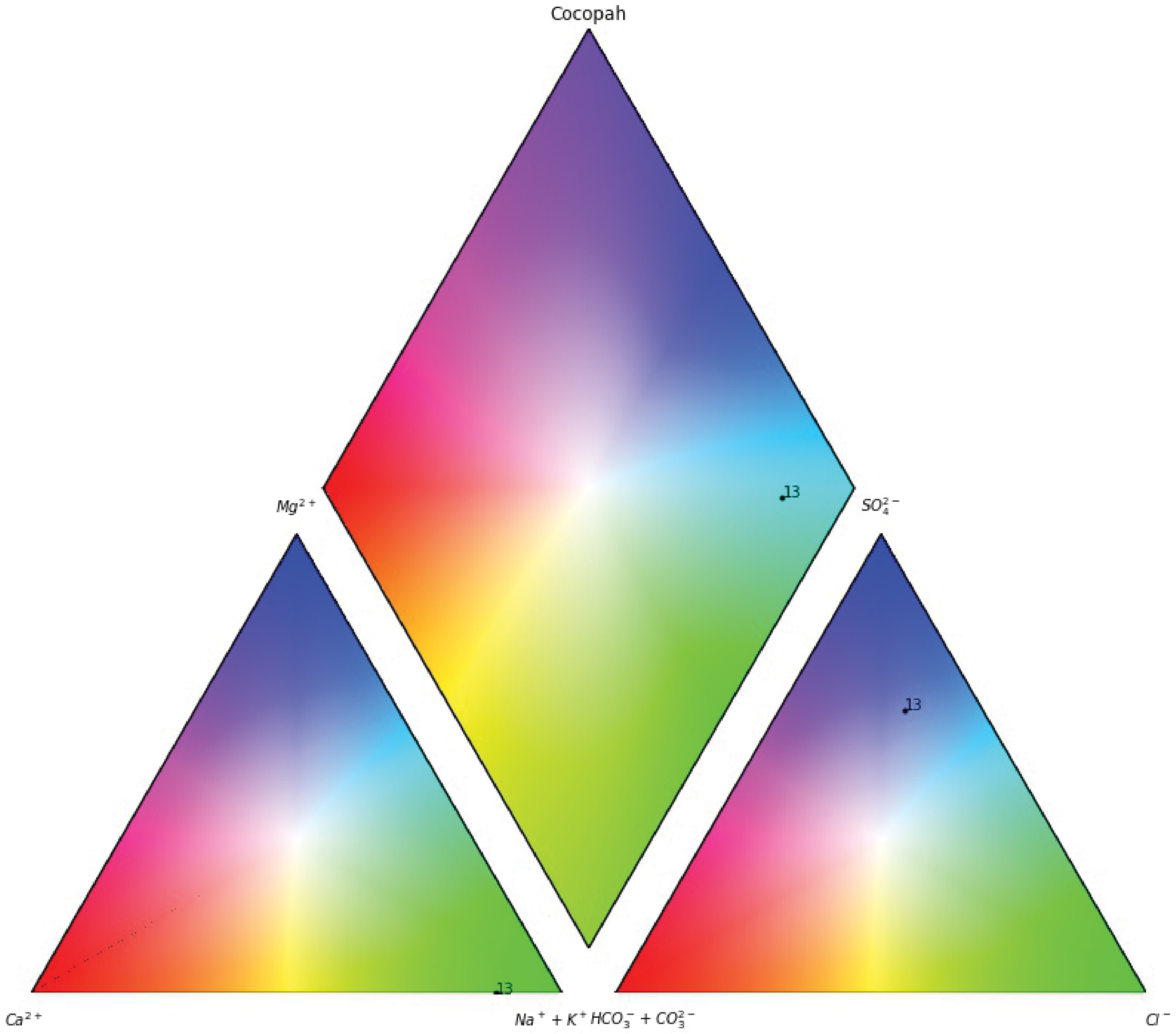
4: ID4-4

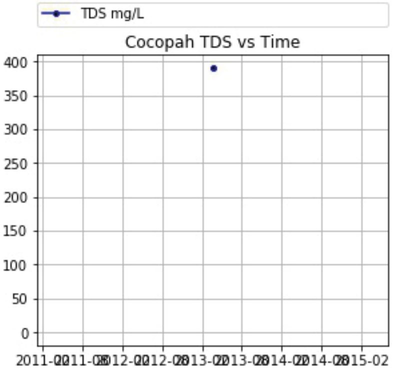

ID4-4
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
54
75
79
83
85
04
01
16
79
TDS mg/L
ID4-4 TDS vs Time
350
300
250
200
150
100
50
0
1980
1985
1990
1995
2000
2005
2010
2015
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-4 Cations vs Time
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID4-4 Anions vs Time

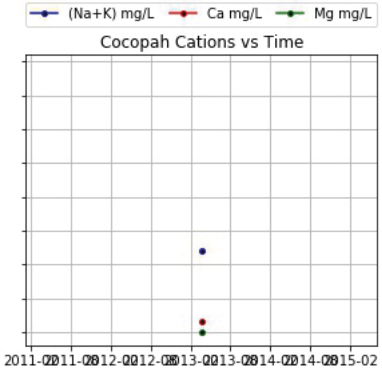
5: ID4-11

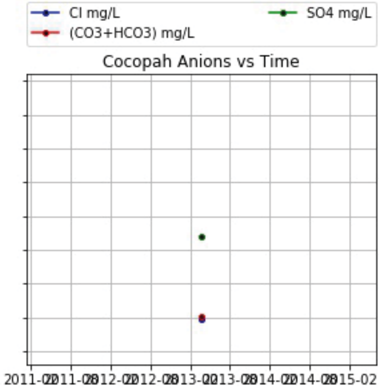

ID4-11
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
95
17
TDS mg/L
ID4-11 TDS vs Time
400
350
300
250
200
150
100
50
0
1997
2001
2005
2009
2013
2017
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-11 Cations vs Time
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID4-11 Anions vs Time

6: Cocopah

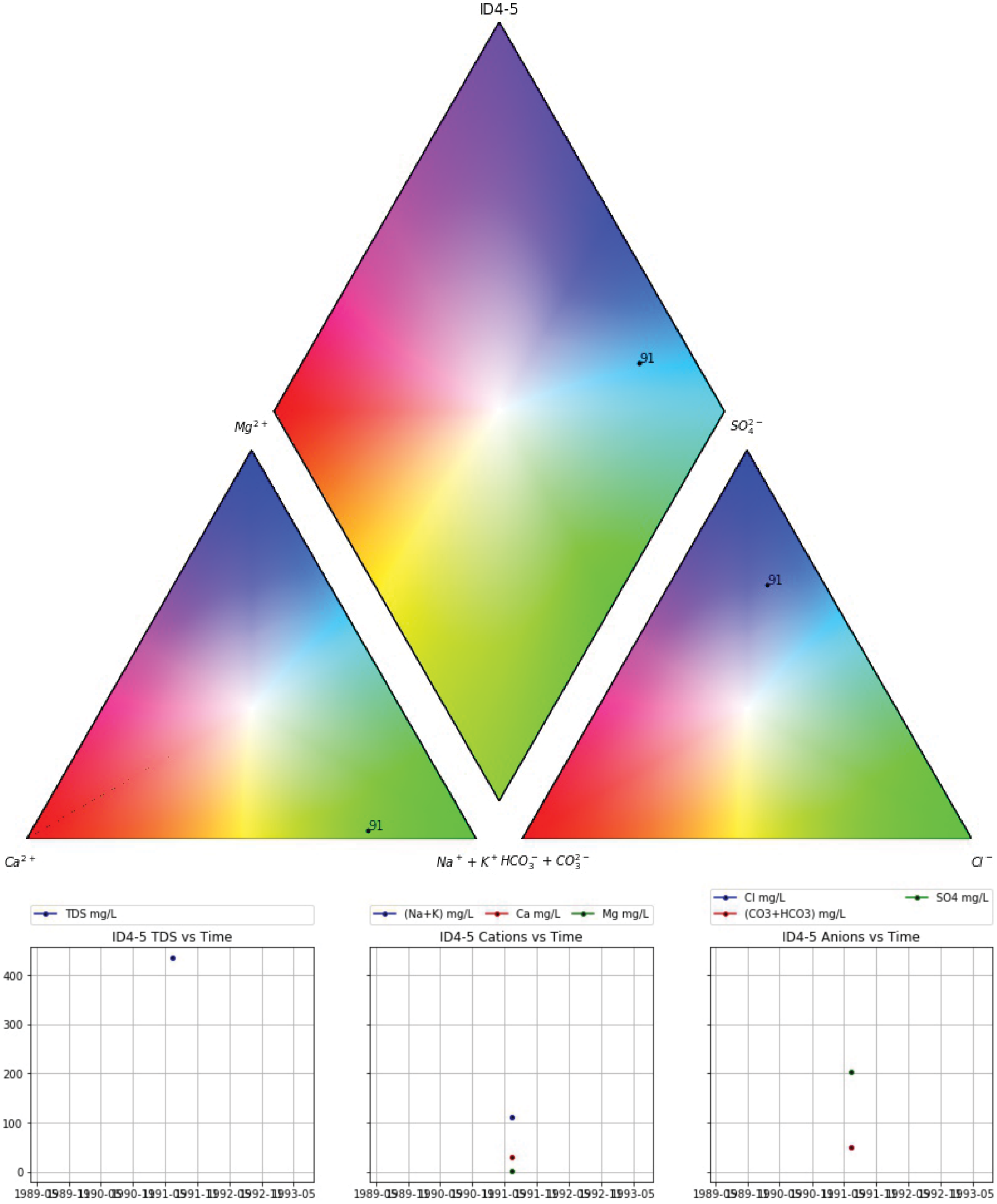

Cocopah
13
Mg^{2+}
SO_4^{2-}
13
13
Ca^{2+}
$Na^+ + K^+$
$HCO_3^- + CO_3^{2-}$
Cl^-


TDS mg/L
Cocopah TDS vs Time
400
350
300
250
200
150
100
50
0
2011-02
2011-08
2012-02
2012-08
2013-02
2013-08
2014-02
2014-08
2015-02

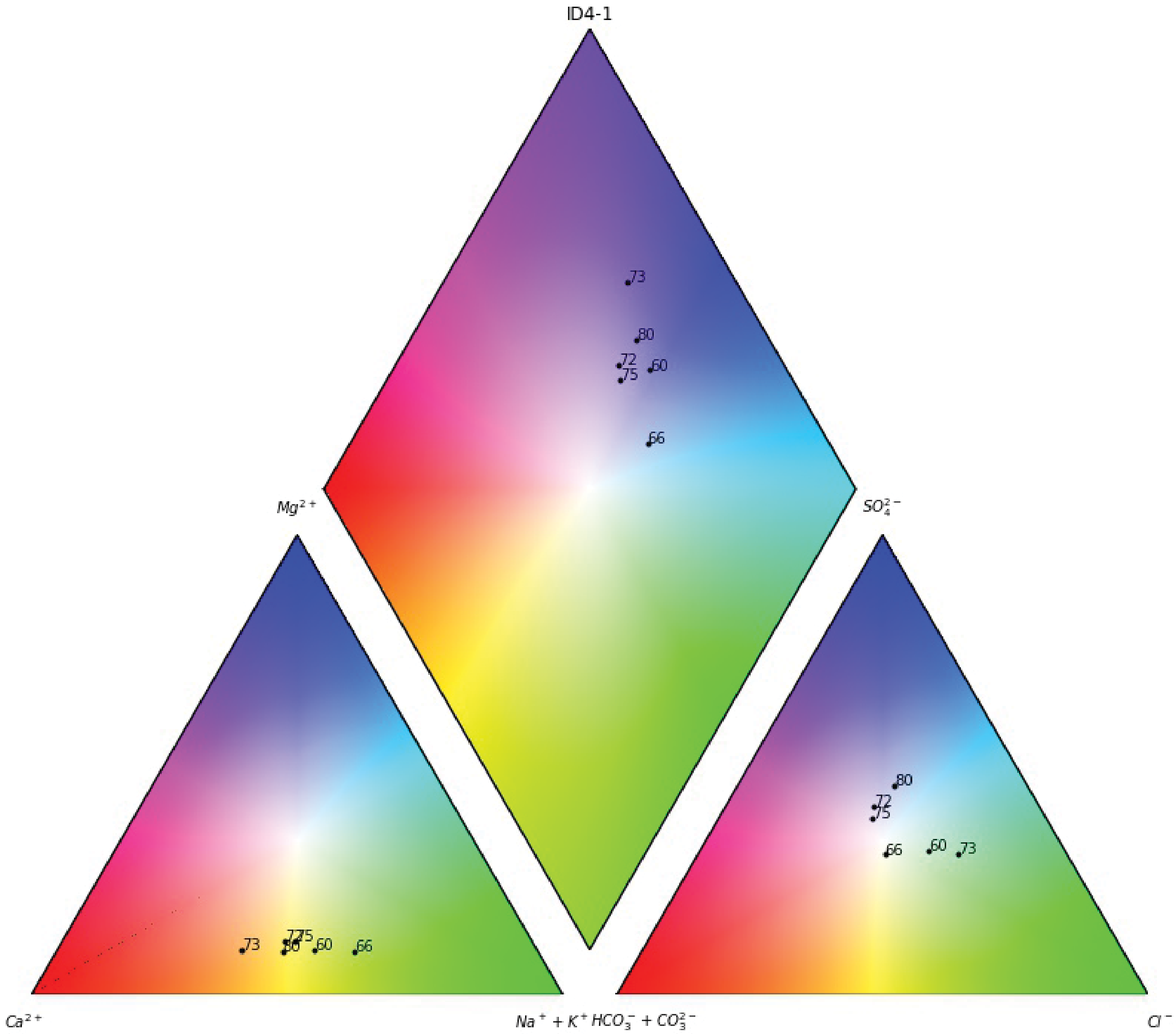

(Na+K) mg/L
Ca mg/L
Mg mg/L
Cocopah Cations vs Time
2011-02
2011-08
2012-02
2012-08
2013-02
2013-08
2014-02
2014-08
2015-02


Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
Cocopah Anions vs Time
2011-02
2011-08
2012-02
2012-08
2013-02
2013-08
2014-02
2014-08
2015-02

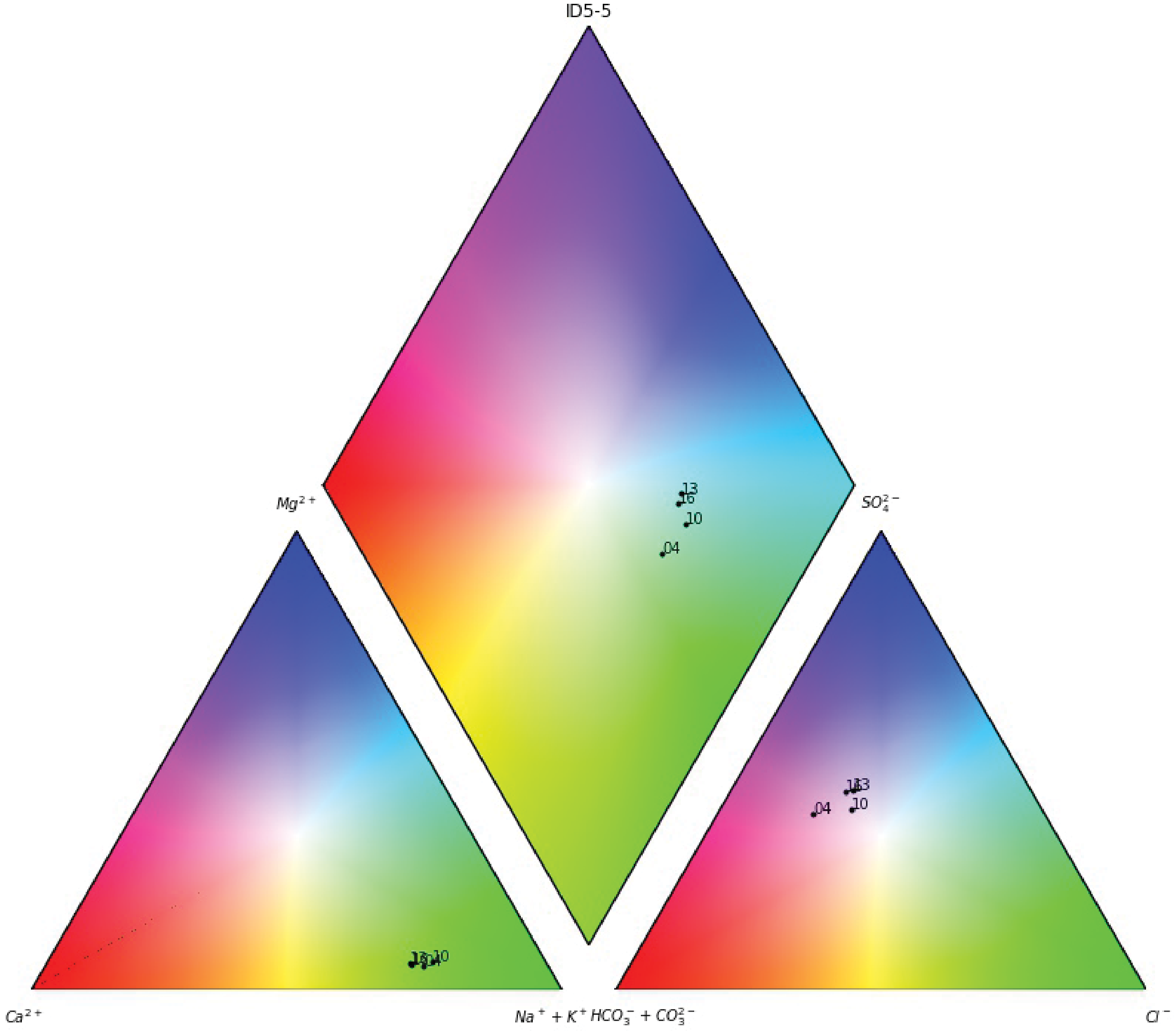
7: ID4-5

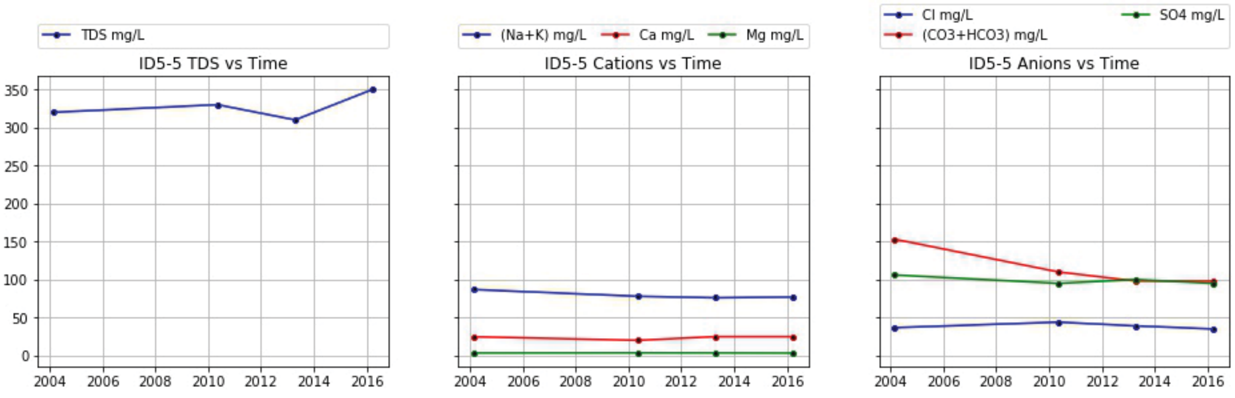

ID4-5
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
91
91
91
TDS mg/L
ID4-5 TDS vs Time
0
100
200
300
400
1989-05
1989-11
1990-05
1990-11
1991-05
1991-11
1992-05
1992-11
1993-05
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-5 Cations vs Time
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID4-5 Anions vs Time

7A: ID4-1

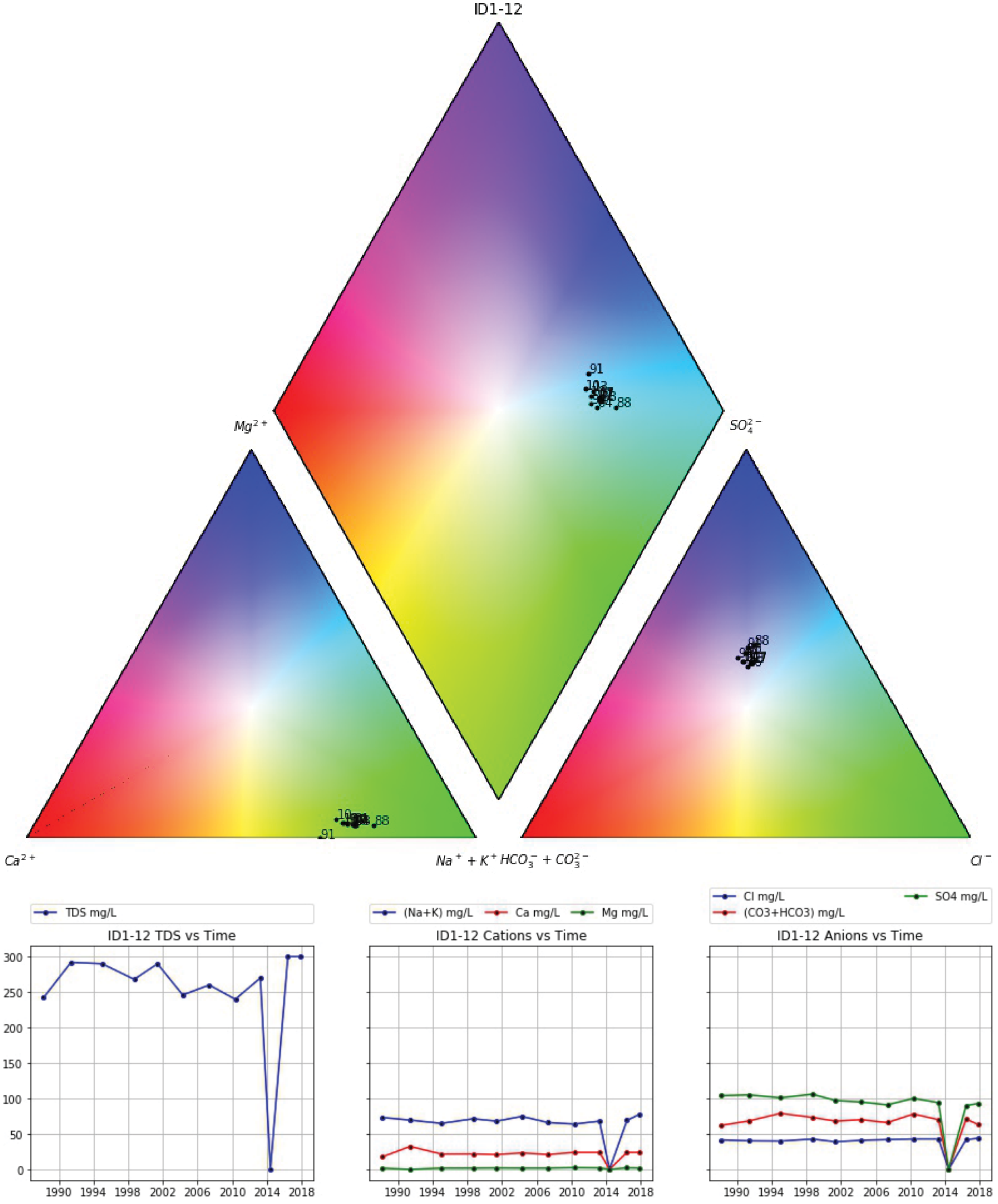

ID4-1
73
80
72
60
75
66
Mg^{2+}
SO_4^{2-}
73
72
75
80
60
66
80
72
75
66
60
73
Ca^{2+}
$Na^+ + K^+$
$HCO_3^- + CO_3^{2-}$
Cl^-

8: ID5-5

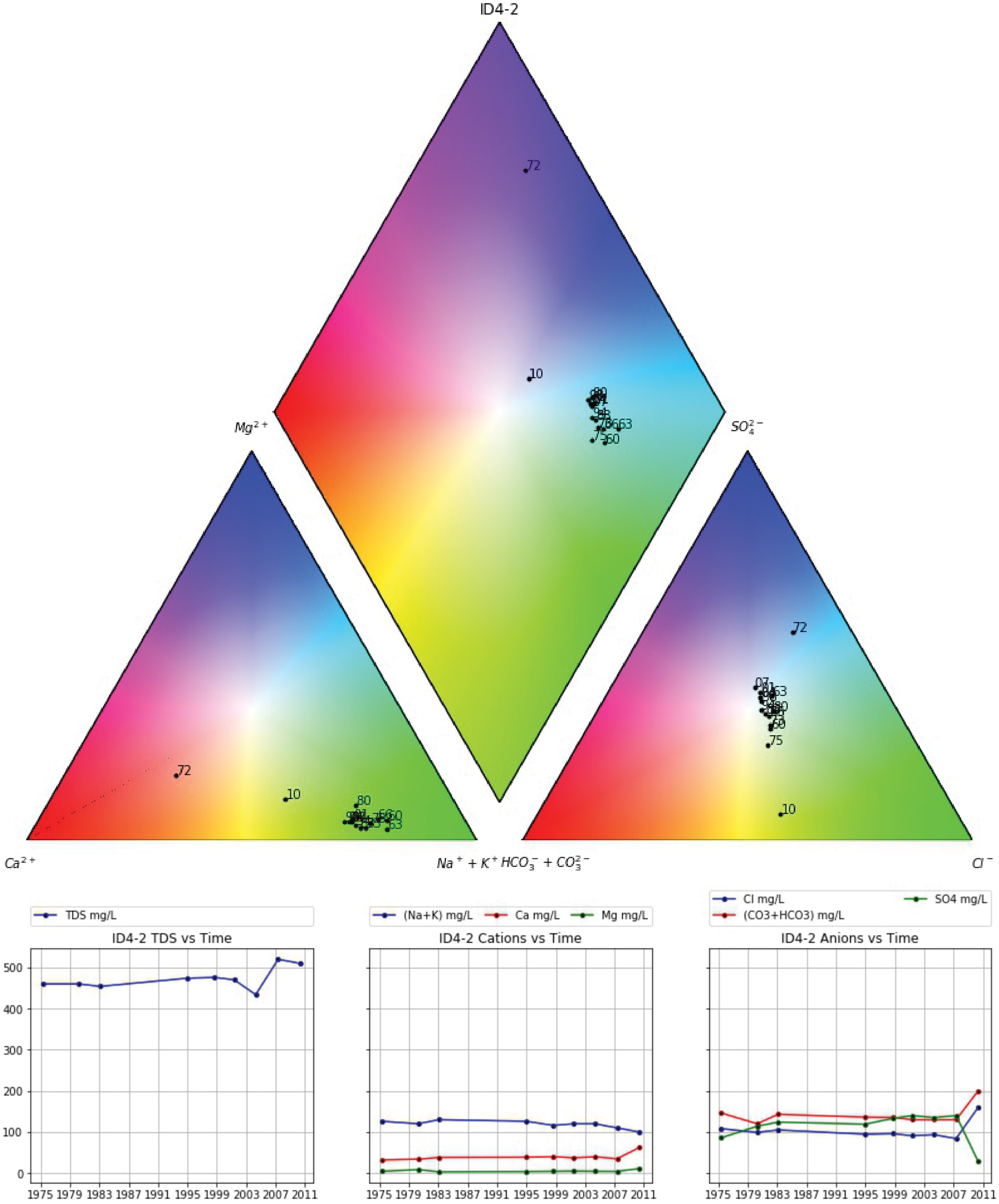

ID5-5
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
13
16
10
04
13
16
10
04
13
16
10
04


TDS mg/L
ID5-5 TDS vs Time
350
300
250
200
150
100
50
0
2004
2006
2008
2010
2012
2014
2016
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID5-5 Cations vs Time
2004
2006
2008
2010
2012
2014
2016
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID5-5 Anions vs Time
2004
2006
2008
2010
2012
2014
2016

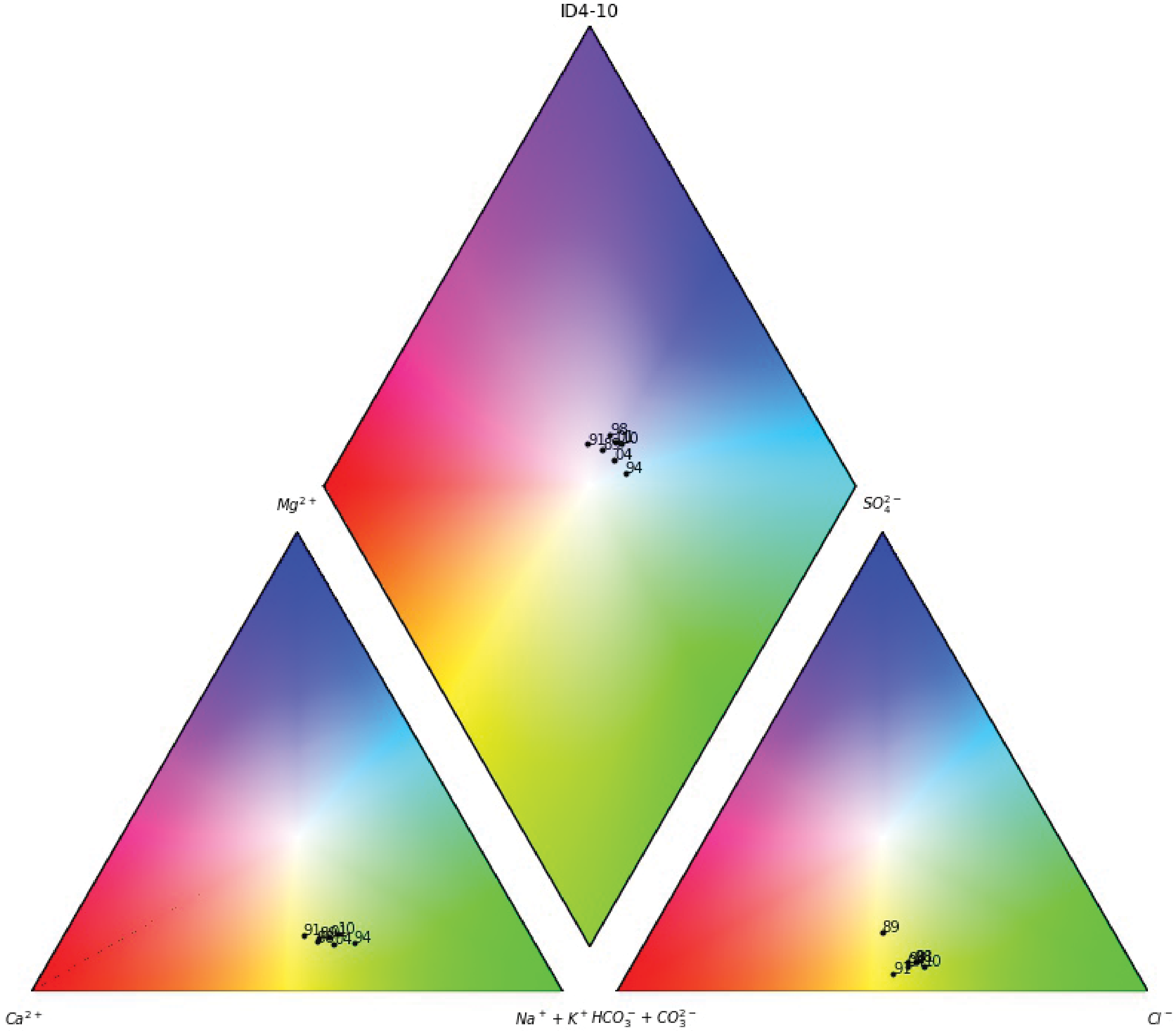
9: ID1-12

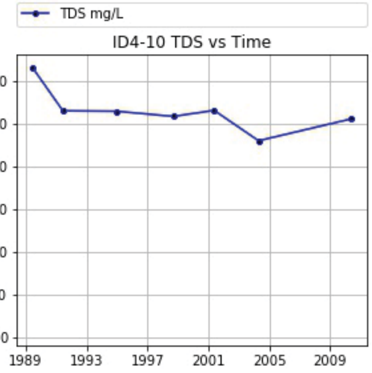

ID1-12
91
88
10
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
ID1-12 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-12 Cations vs Time
Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID1-12 Anions vs Time
0
50
100
150
200
250
300
1990
1994
1998
2002
2006
2010
2014
2018

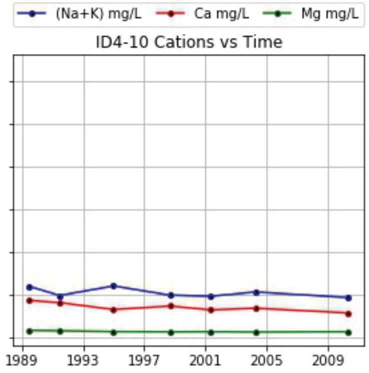
10: ID4-2

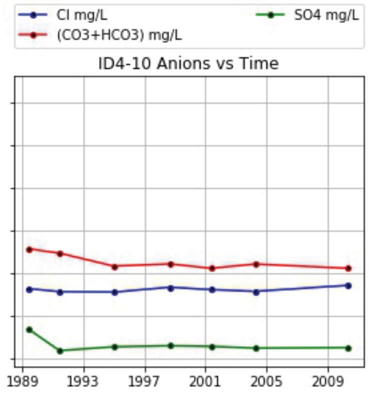

ID4-2
72
10
80
63
75
60
Mg²⁺
SO₄²⁻
Ca²⁺
Na⁺ + K⁺ HCO₃⁻ + CO₃²⁻
Cl⁻
07
TDS mg/L
ID4-2 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-2 Cations vs Time
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID4-2 Anions vs Time
0
100
200
300
400
500
1975 1979 1983 1987 1991 1995 1999 2003 2007 2011

11: ID4-10

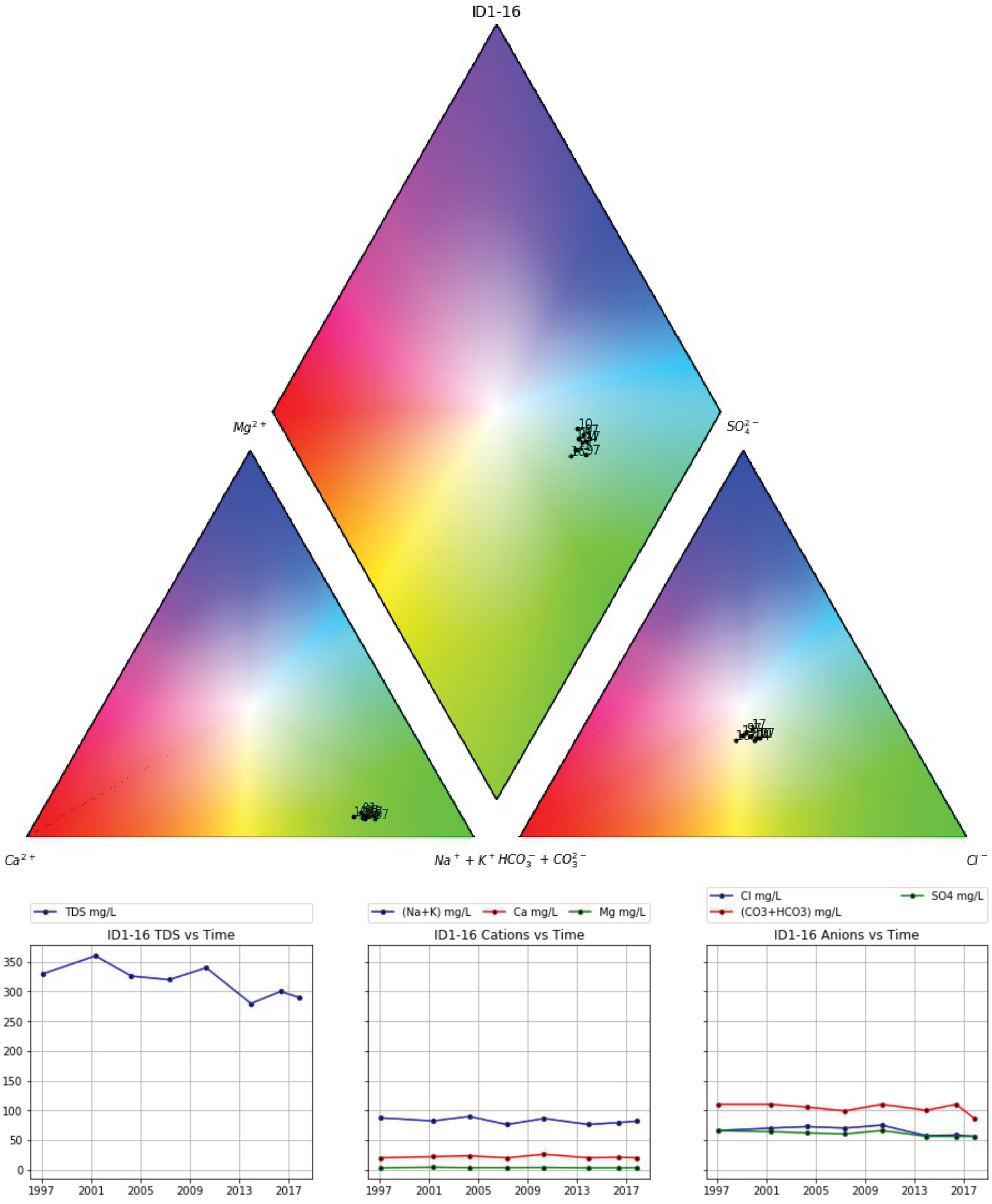

ID4-10
98
91
10
04
94
Mg^{2+}
SO_4^{2-}
91
10
04
94
89
91
10
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-


TDS mg/L
ID4-10 TDS vs Time
600
500
400
300
200
100
0
1989
1993
1997
2001
2005
2009

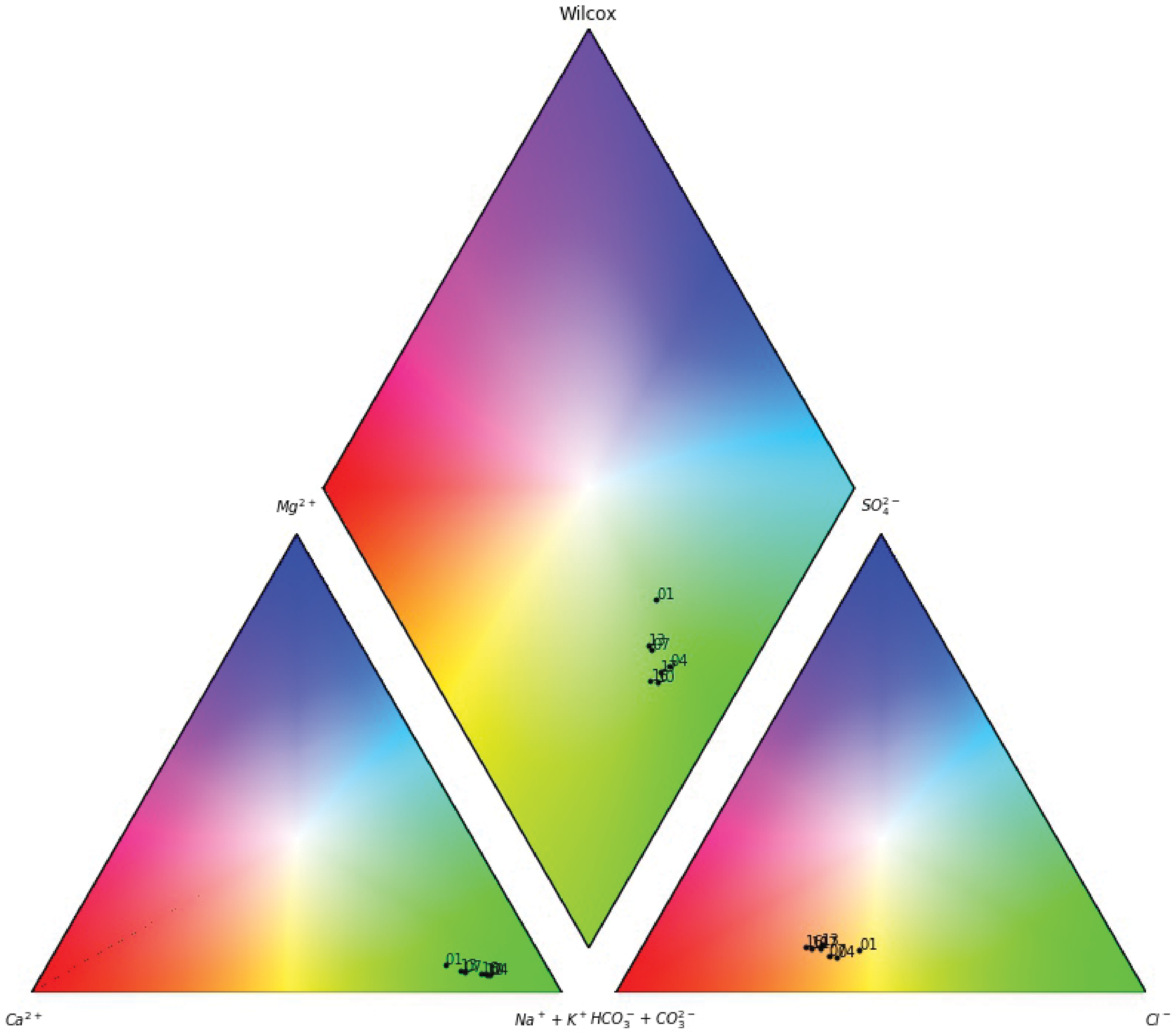

(Na+K) mg/L
Ca mg/L
Mg mg/L
ID4-10 Cations vs Time
1989
1993
1997
2001
2005
2009

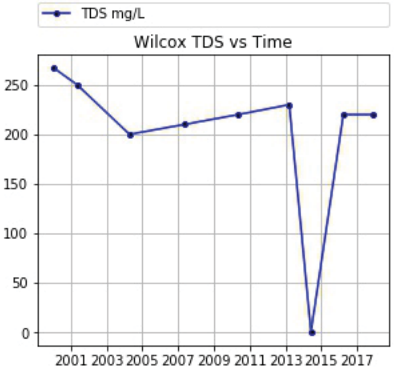

Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
ID4-10 Anions vs Time
1989
1993
1997
2001
2005
2009

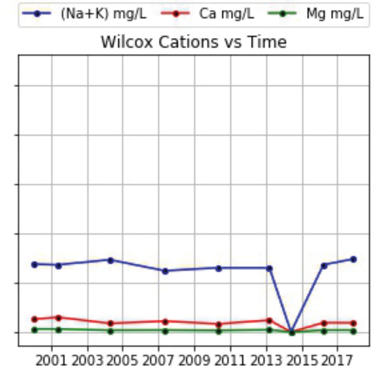
12: ID1-16

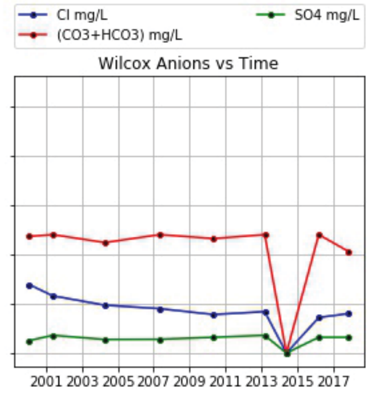

ID1-16
Mg2+
SO42−
Ca2+
Na+ + K+ HCO3− + CO32−
Cl−
TDS mg/L
ID1-16 TDS vs Time
350
300
250
200
150
100
50
0
1997
2001
2005
2009
2013
2017
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-16 Cations vs Time
1997
2001
2005
2009
2013
2017
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID1-16 Anions vs Time
1997
2001
2005
2009
2013
2017

13: Wilcox

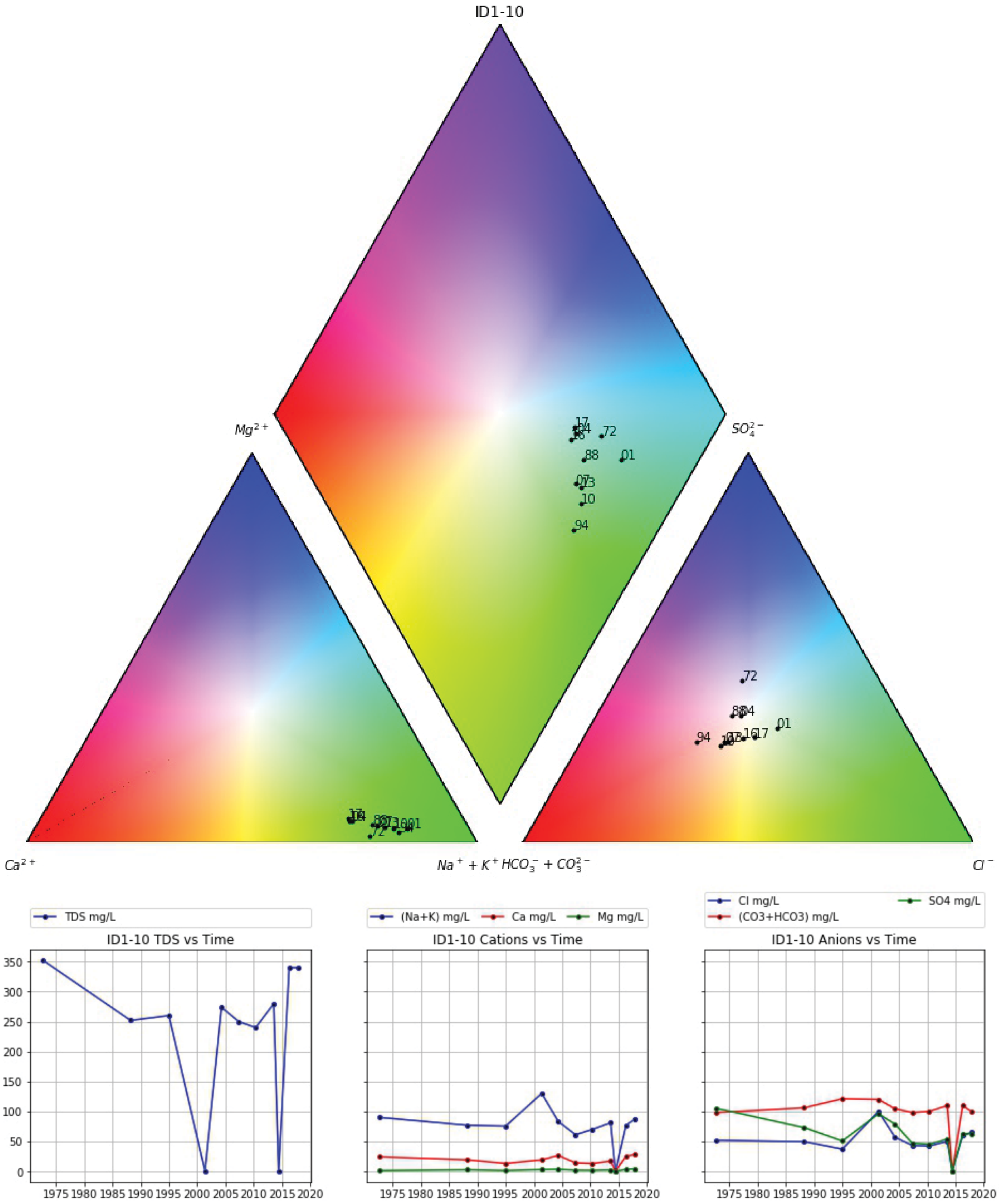

Wilcox
Mg^{2+}
SO_4^{2-}
01
13
07
04
10
16
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-


TDS mg/L
Wilcox TDS vs Time
250
200
150
100
50
0
2001 2003 2005 2007 2009 2011 2013 2015 2017

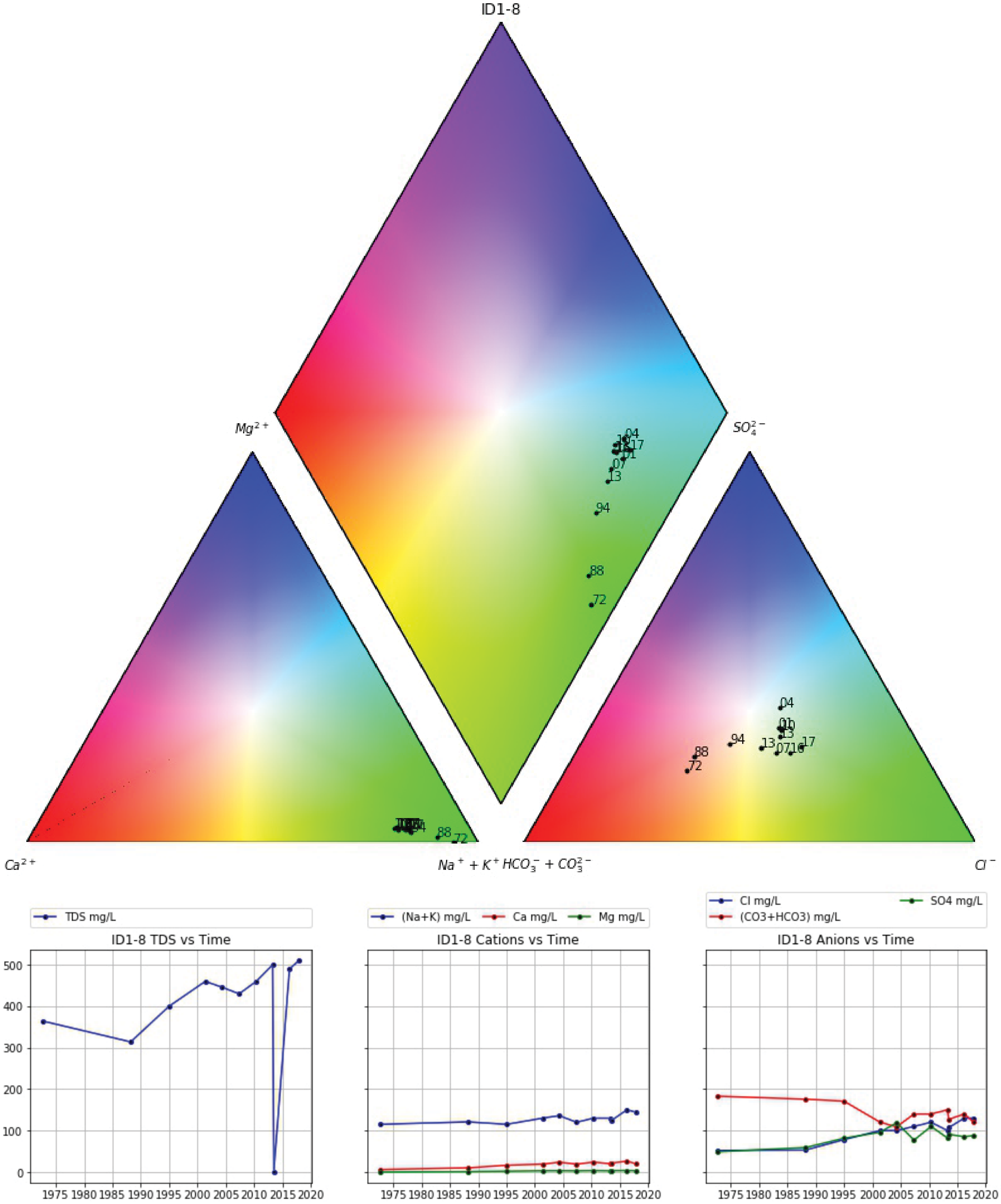

(Na+K) mg/L
Ca mg/L
Mg mg/L
Wilcox Cations vs Time
2001 2003 2005 2007 2009 2011 2013 2015 2017


Cl mg/L
SO4 mg/L
(CO3+HCO3) mg/L
Wilcox Anions vs Time
2001 2003 2005 2007 2009 2011 2013 2015 2017

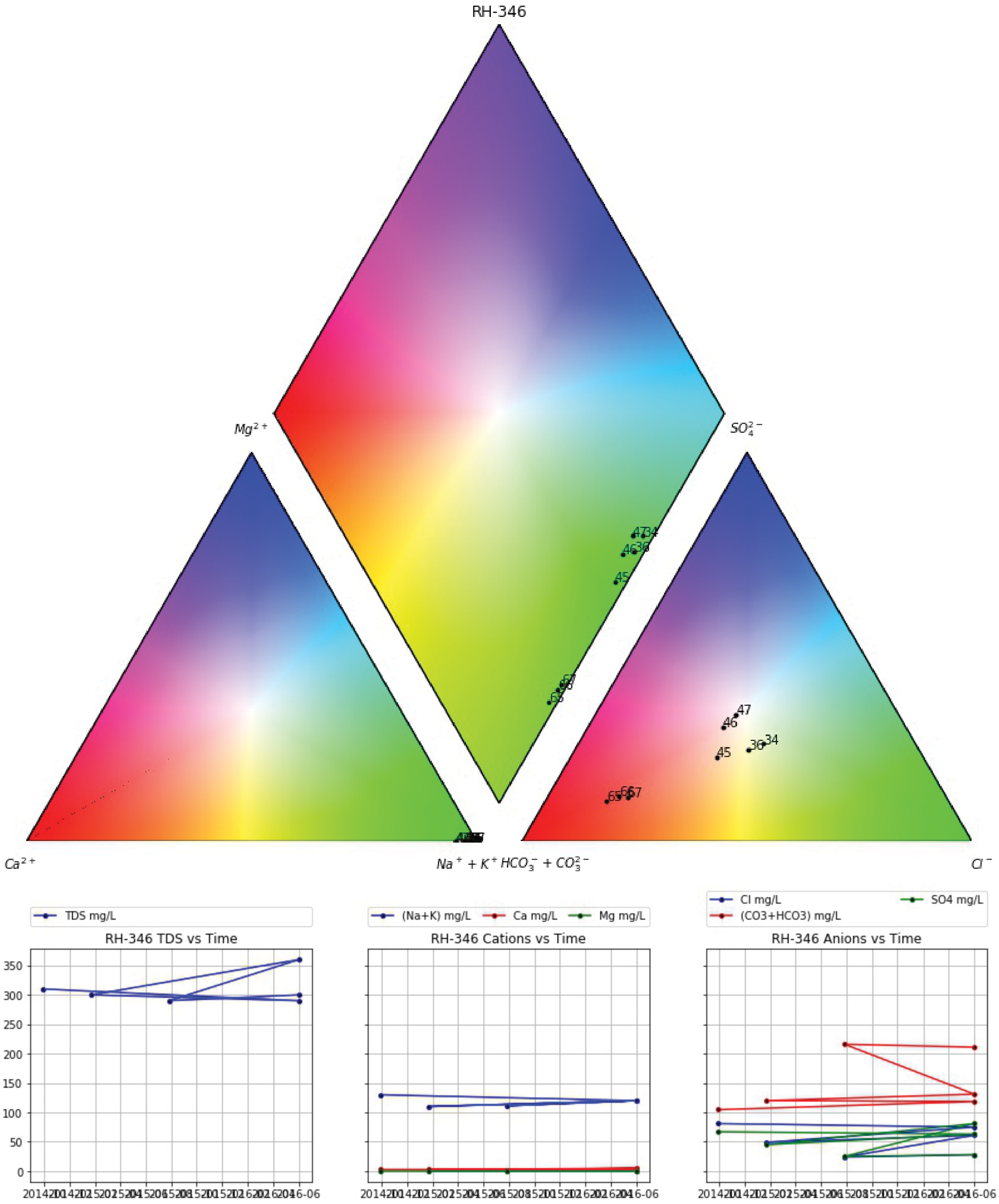
14: ID1-10


ID1-10
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
17
04
16
72
88
01
07
13
10
94
TDS mg/L
ID1-10 TDS vs Time
350
300
250
200
150
100
50
0
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-10 Cations vs Time
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID1-10 Anions vs Time

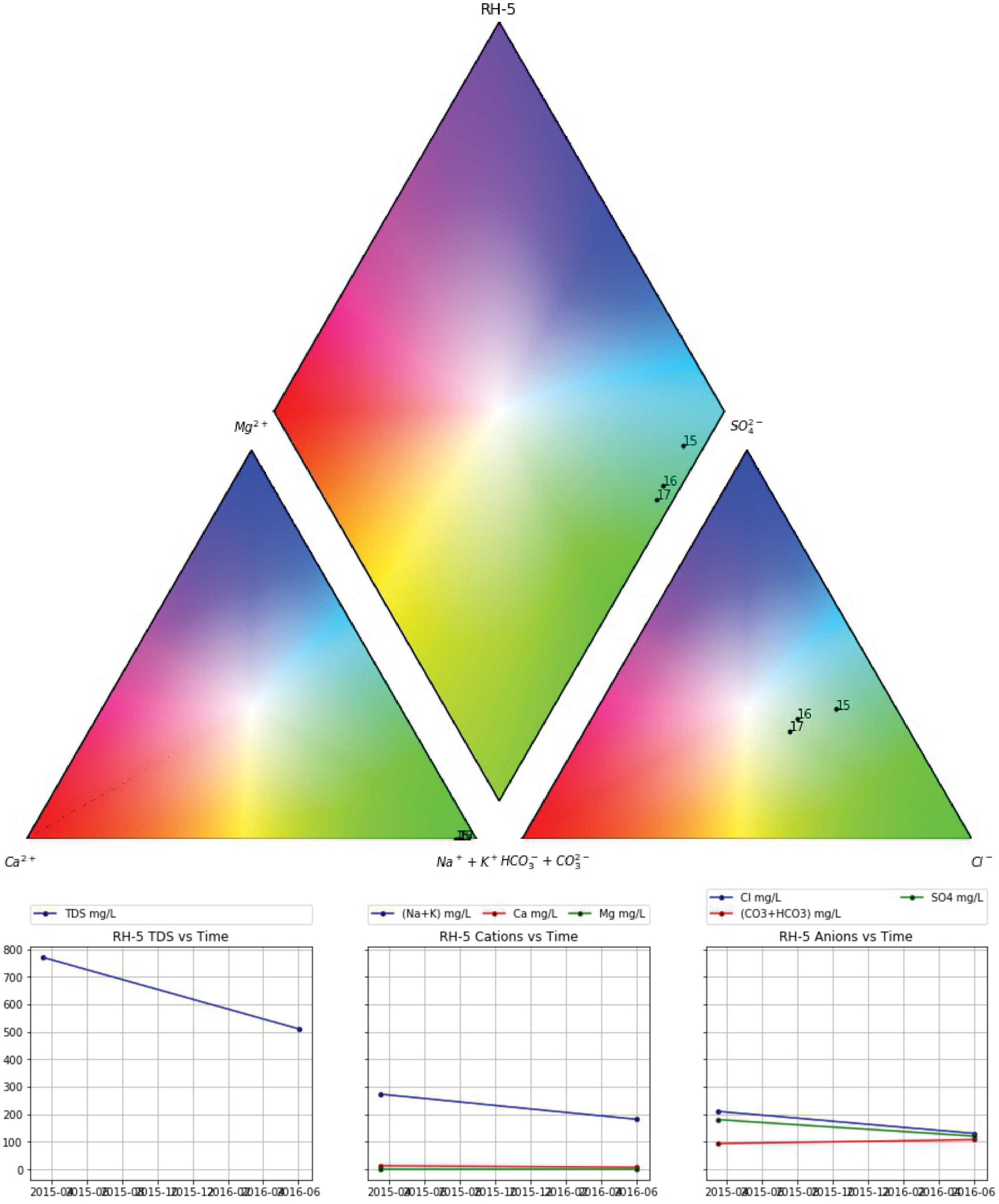
15: ID1-8


ID1-8
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
04
17
01
07
13
94
88
72
TDS mg/L
ID1-8 TDS vs Time
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-8 Cations vs Time
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID1-8 Anions vs Time
0
100
200
300
400
500
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020

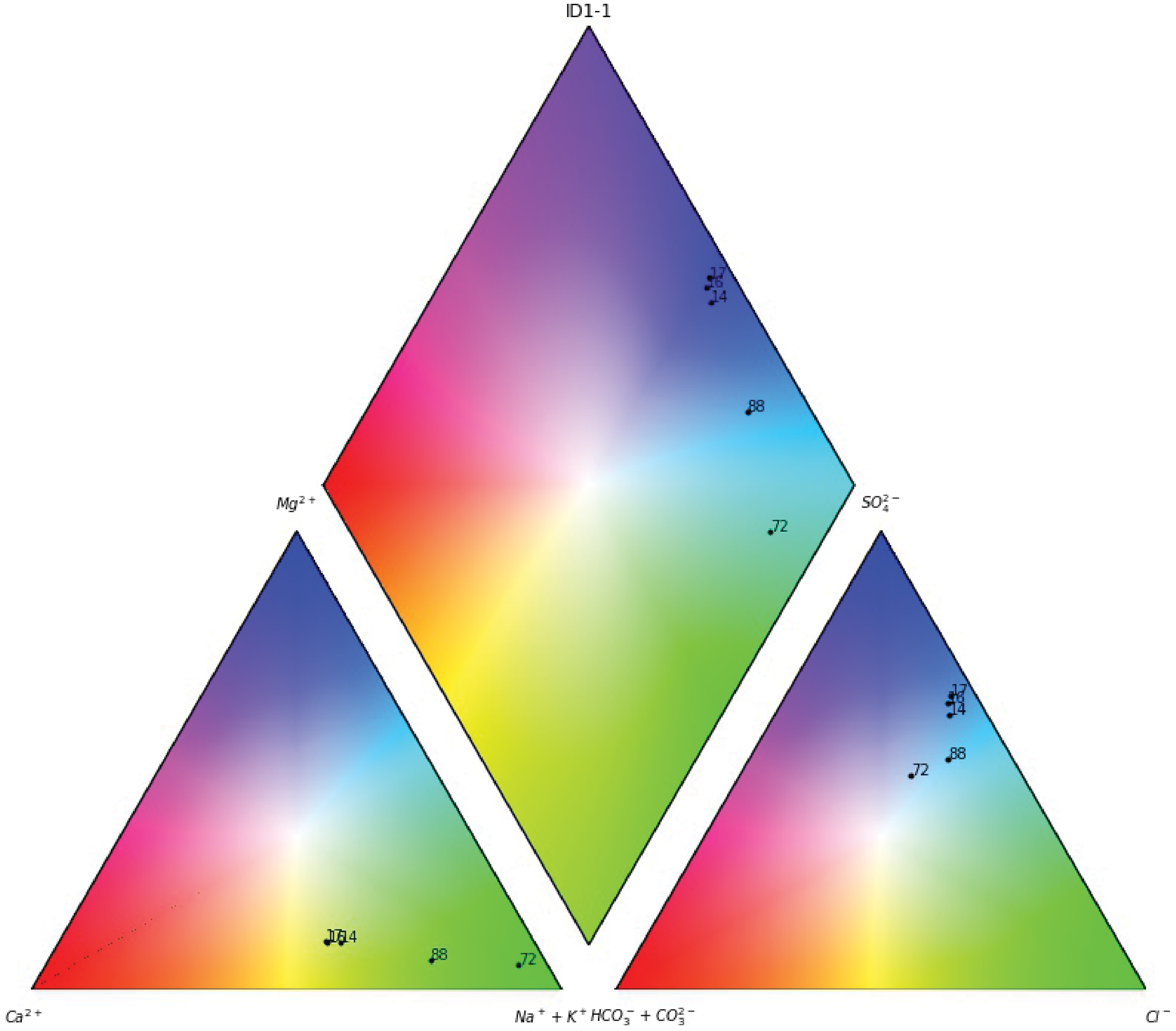
16: RH-3; 17: RH-4; 19: RH-6

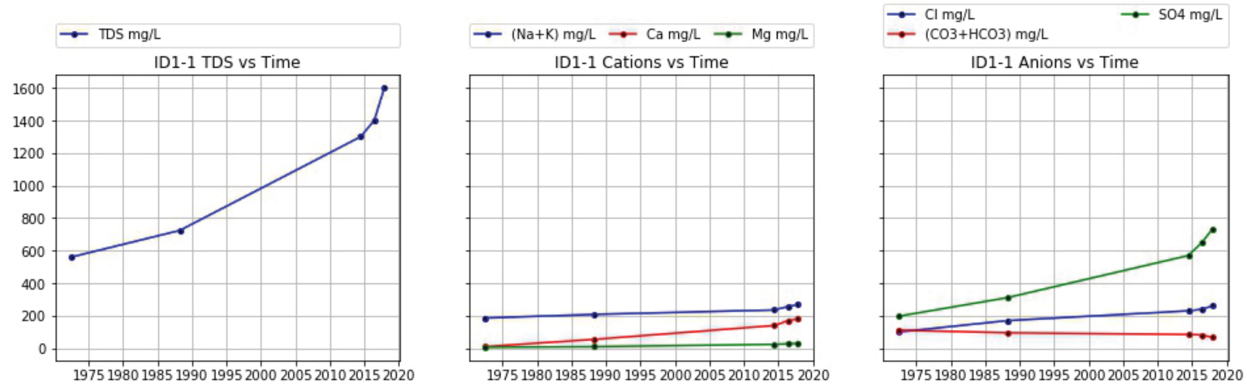


18: RH-5

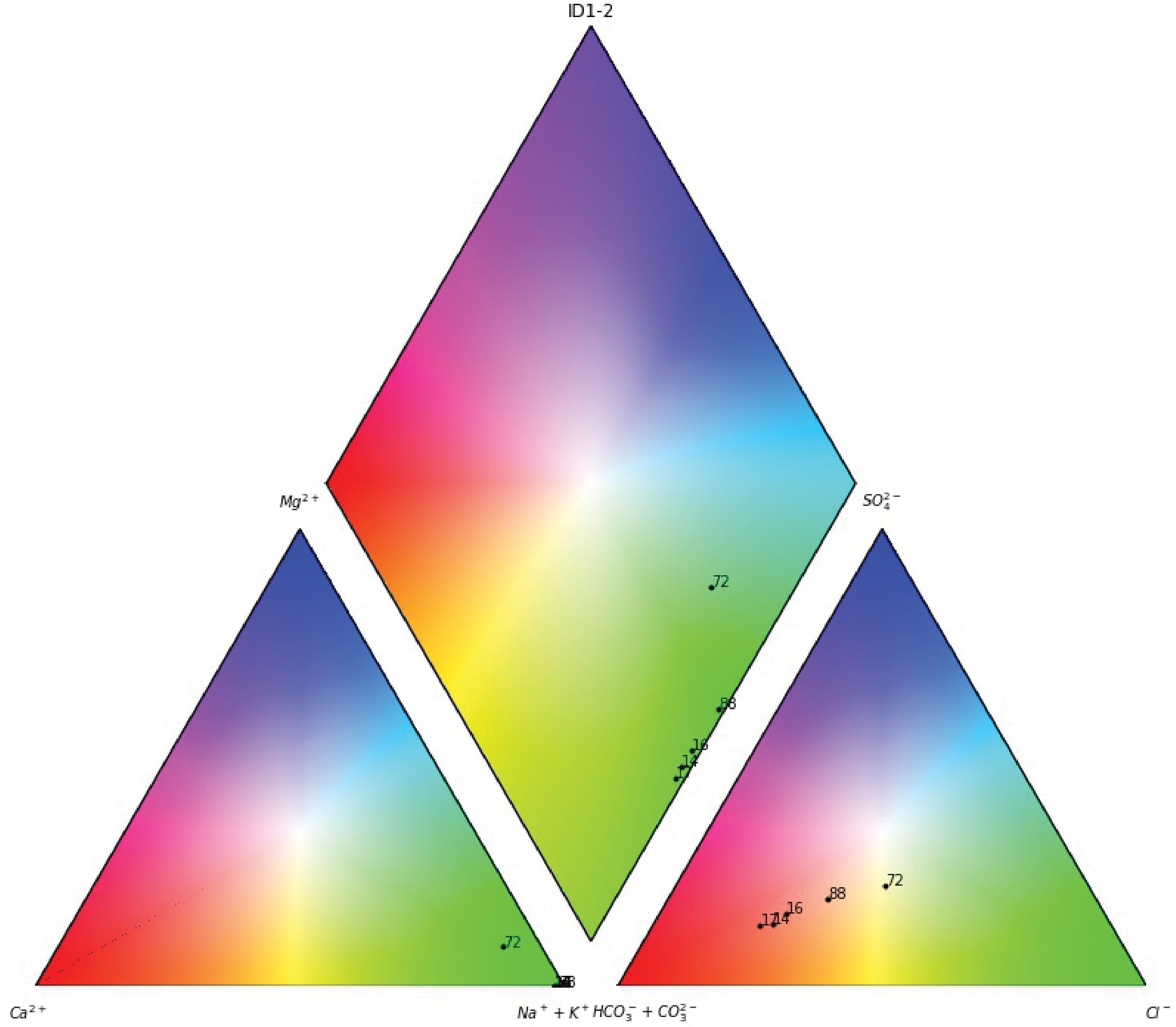

RH-5
Mg^{2+}
SO_4^{2-}
15
16
17
15
16
17
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
TDS mg/L
RH-5 TDS vs Time
800
700
600
500
400
300
200
100
0
2015-04
2015-06
2015-08
2015-10
2015-12
2016-02
2016-04
2016-06
(Na+K) mg/L
Ca mg/L
Mg mg/L
RH-5 Cations vs Time
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
RH-5 Anions vs Time

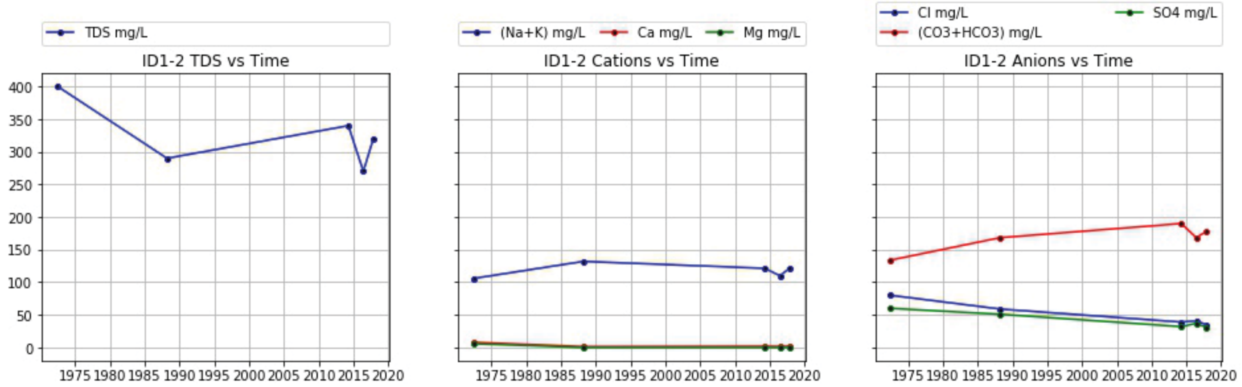
20: ID1-1


ID1-1
17
16
14
88
72
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-

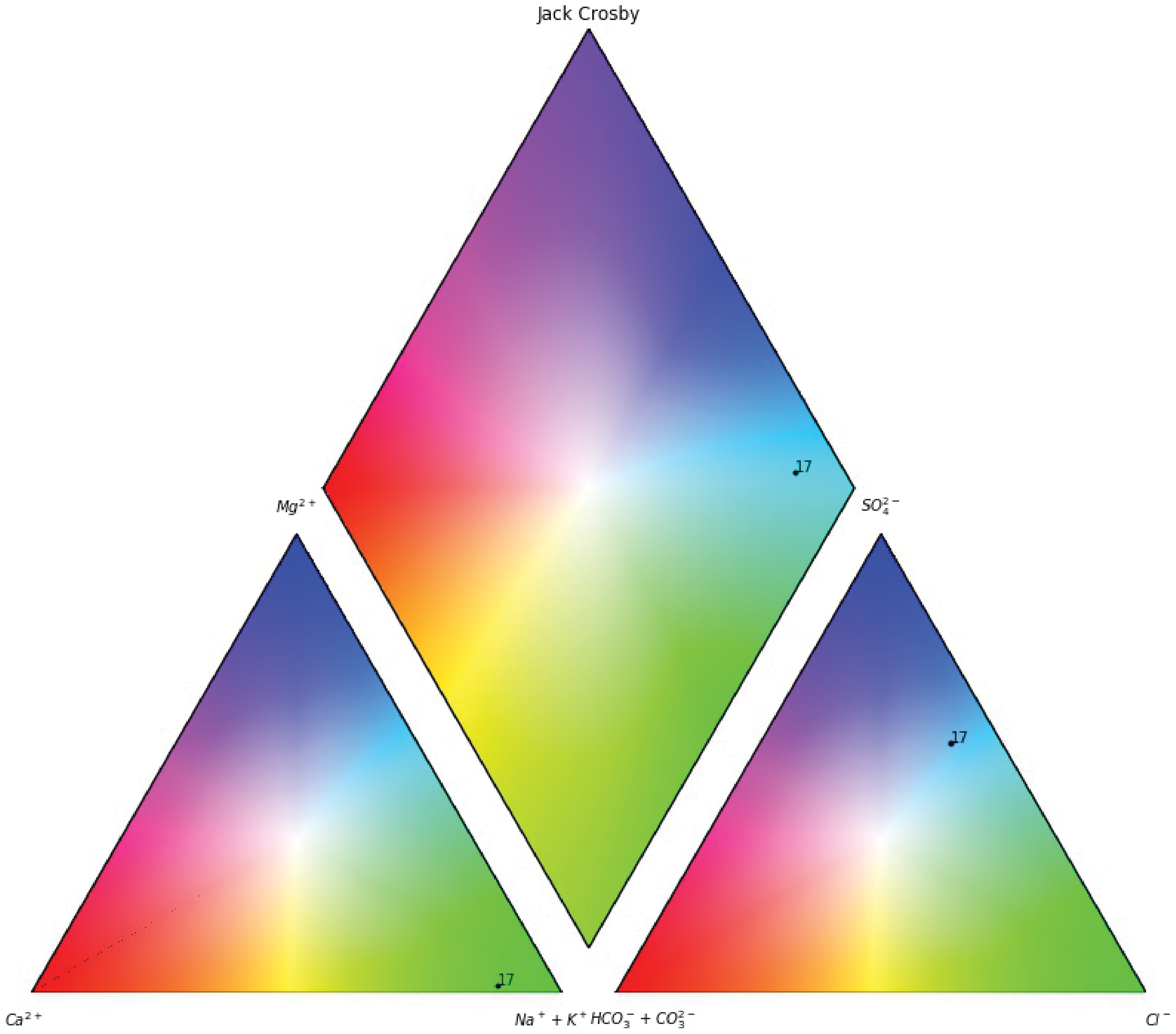

TDS mg/L
ID1-1 TDS vs Time
1600
1400
1200
1000
800
600
400
200
0
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-1 Cations vs Time
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID1-1 Anions vs Time
1975 1980 1985 1990 1995 2000 2005 2010 2015 2020

21: ID1-2


ID1-2
Mg^{2+}
SO_4^{2-}
Ca^{2+}
$Na^+ + K^+$ $HCO_3^- + CO_3^{2-}$
Cl^-
72
88
16
14
17
72
72
88
16
17
14

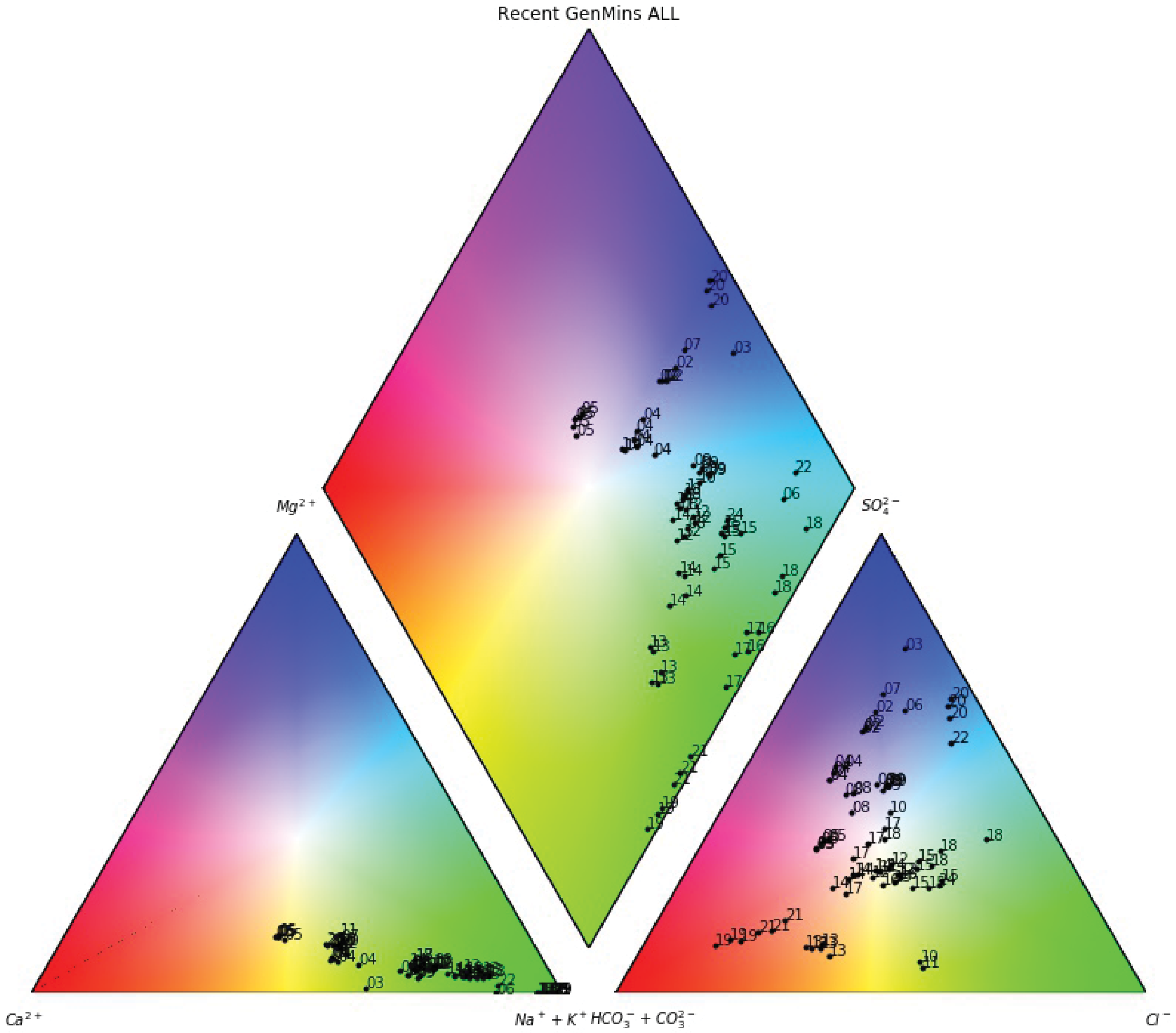

TDS mg/L
ID1-2 TDS vs Time
400
350
300
250
200
150
100
50
0
1975
1980
1985
1990
1995
2000
2005
2010
2015
2020
(Na+K) mg/L
Ca mg/L
Mg mg/L
ID1-2 Cations vs Time
Cl mg/L
(CO3+HCO3) mg/L
SO4 mg/L
ID1-2 Anions vs Time

22: Jack Crosby



One data point so no plots generated.

Recent Data: All (Piper only)

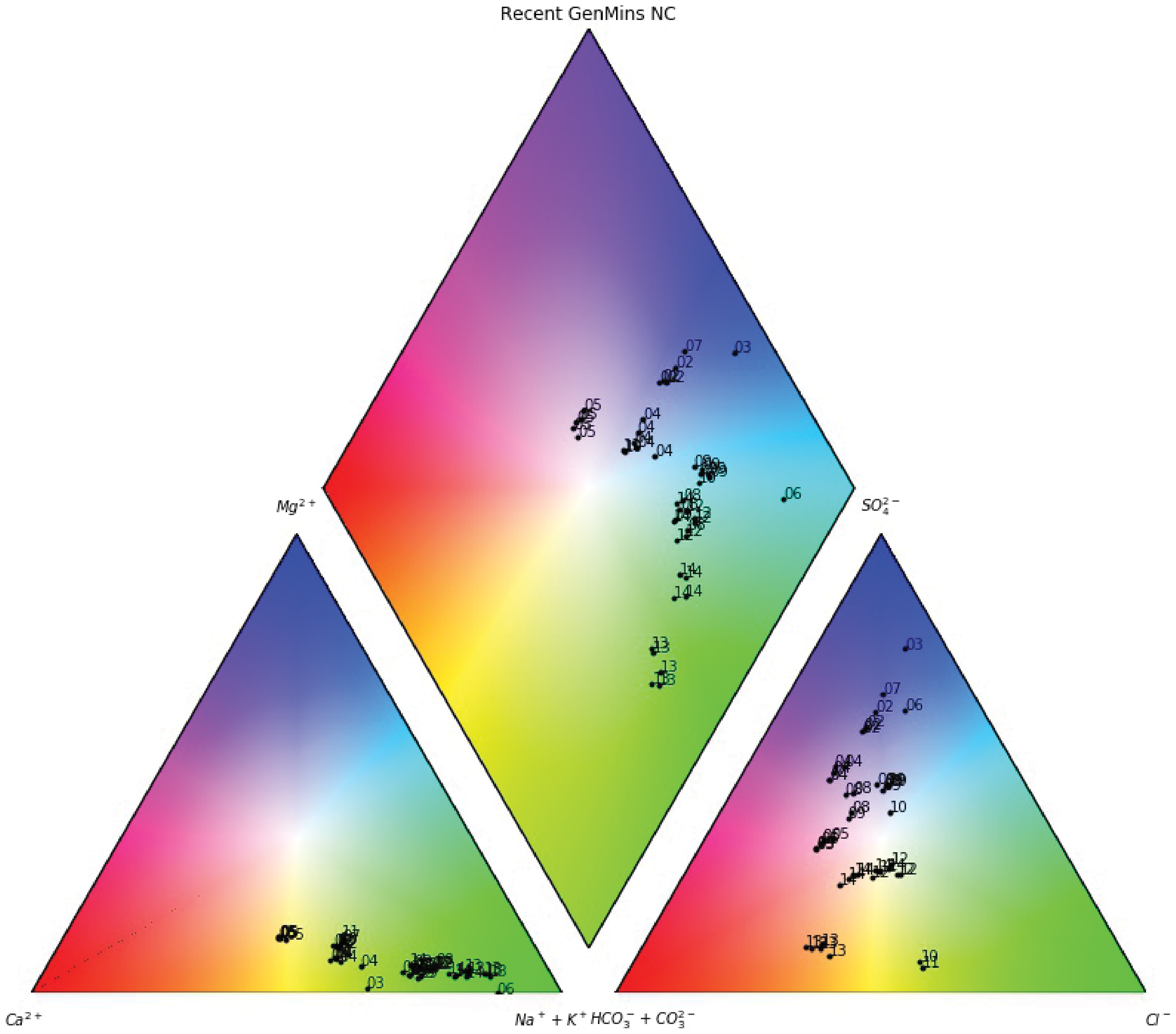


Notes:

The number on the diagrams correspond to sequential well numbers assigned to each of the wells as explained in the text. Data are for the period of 2005 to 2018.

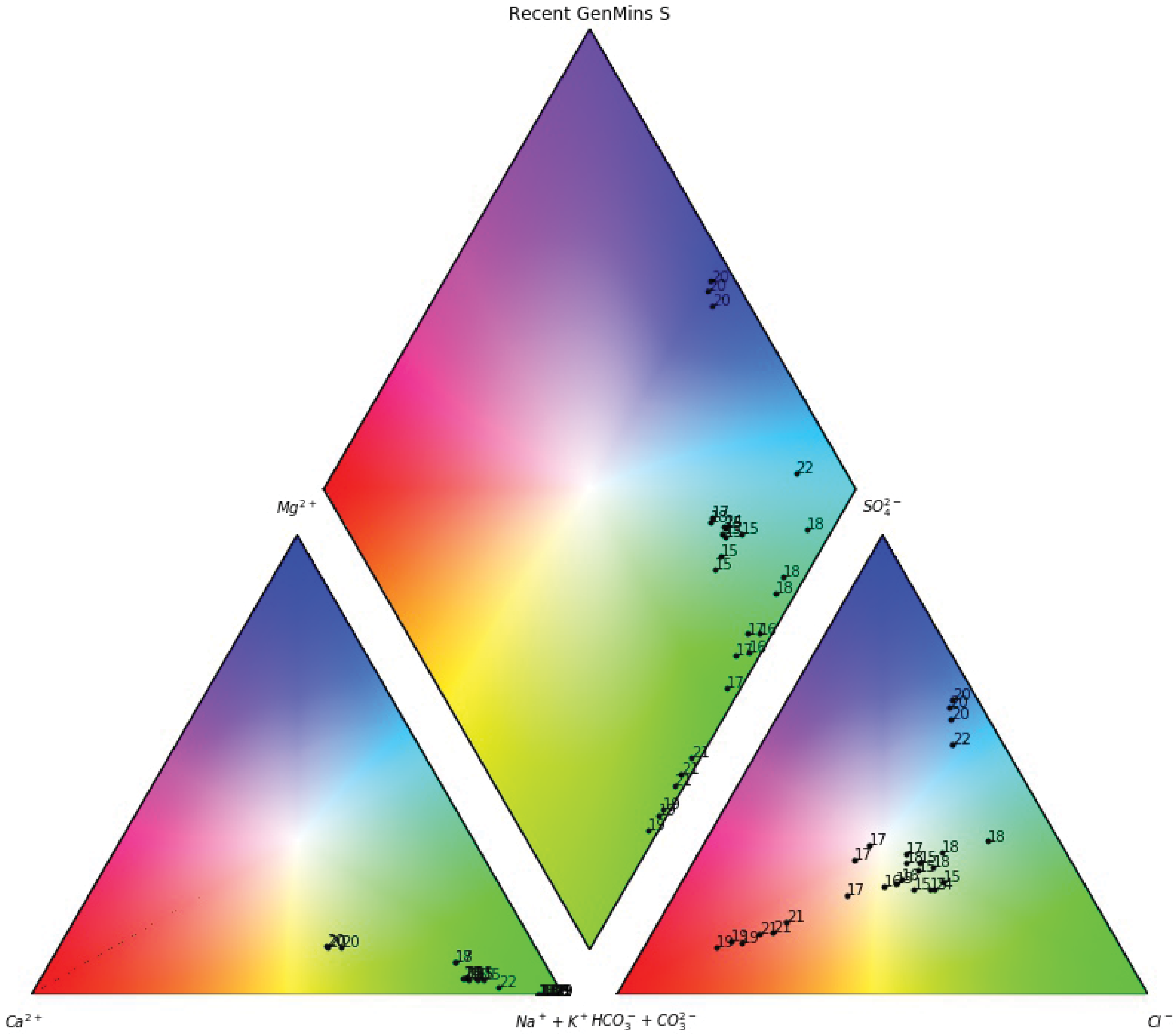
This Piper diagram is further explained in **Figure 6**.

Recent Data: North and Central (Piper only)



Note: The number on the diagrams correspond to sequential well numbers assigned to each of the wells as explained in the text. Data are for the period of 2005 to 2018.

Recent Data: South (Piper only)

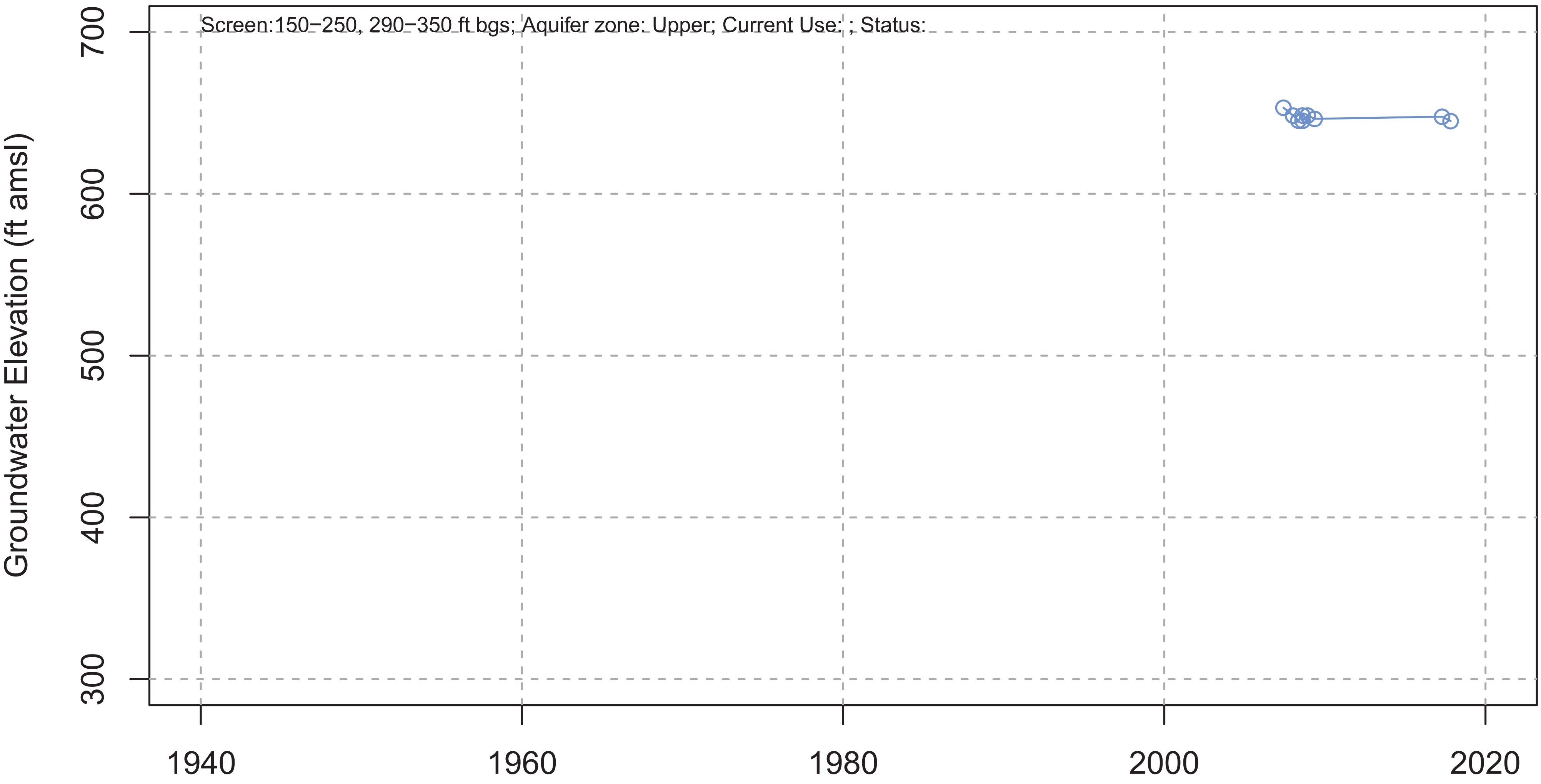


Note: The number on the diagrams correspond to sequential well numbers assigned to each of the wells as explained in the text. Data are for the period of 2005 to 2018.

APPENDIX D3

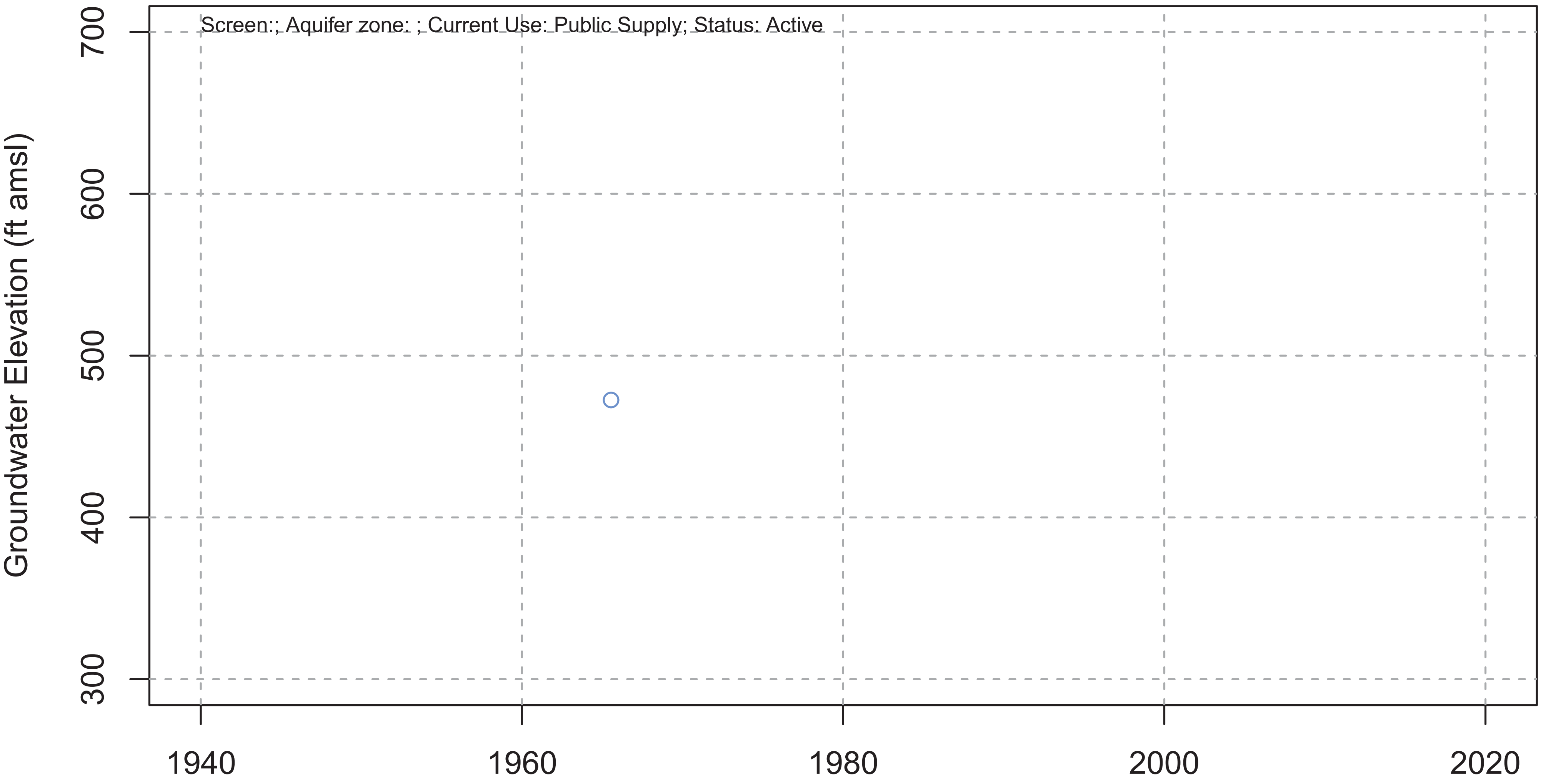
Groundwater Hydrographs

009S006E31E003S



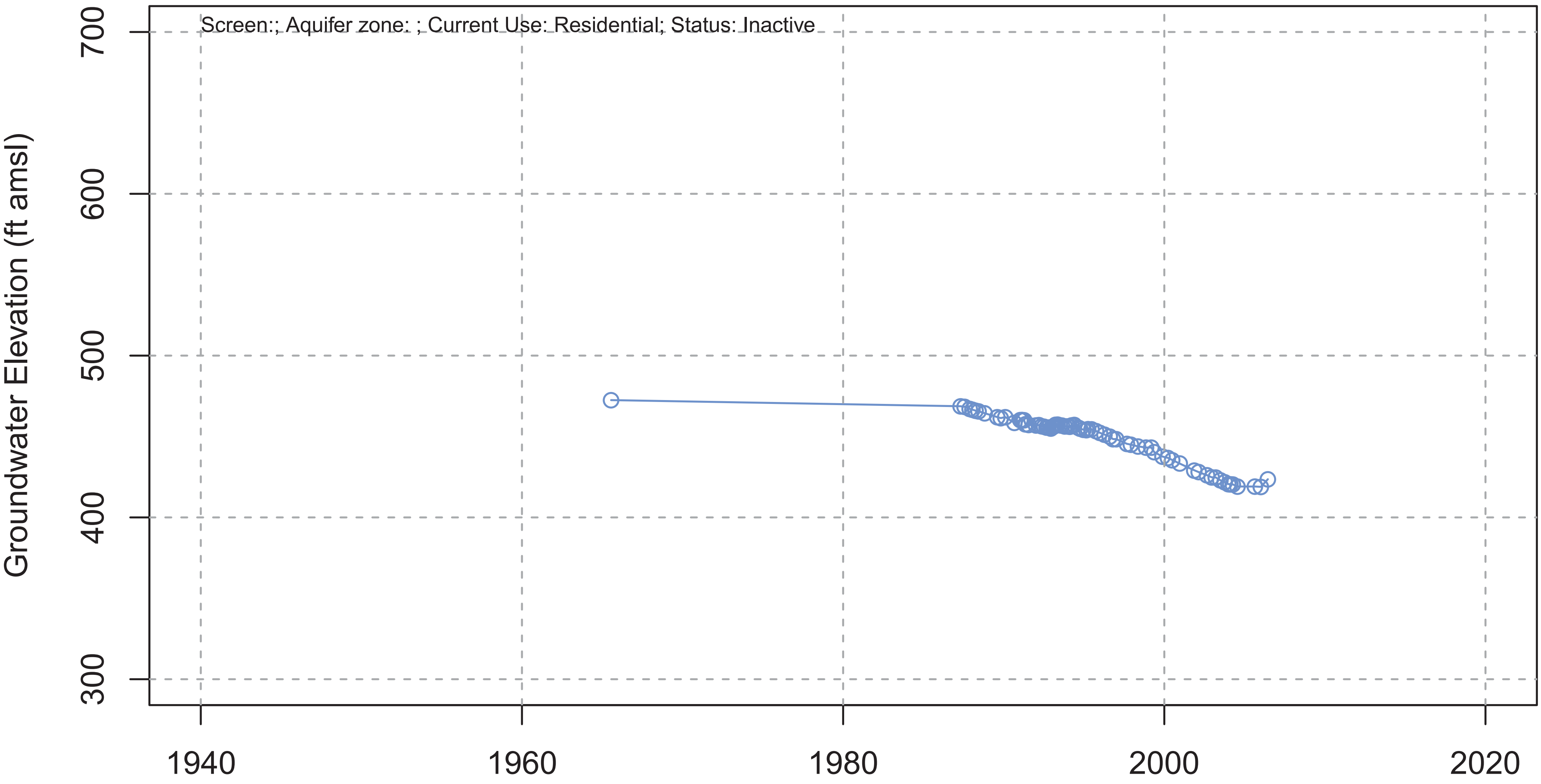
Local ID: Horse Camp ; Number of Measuring Agenc(y/ies): 4

010S005E25R001S



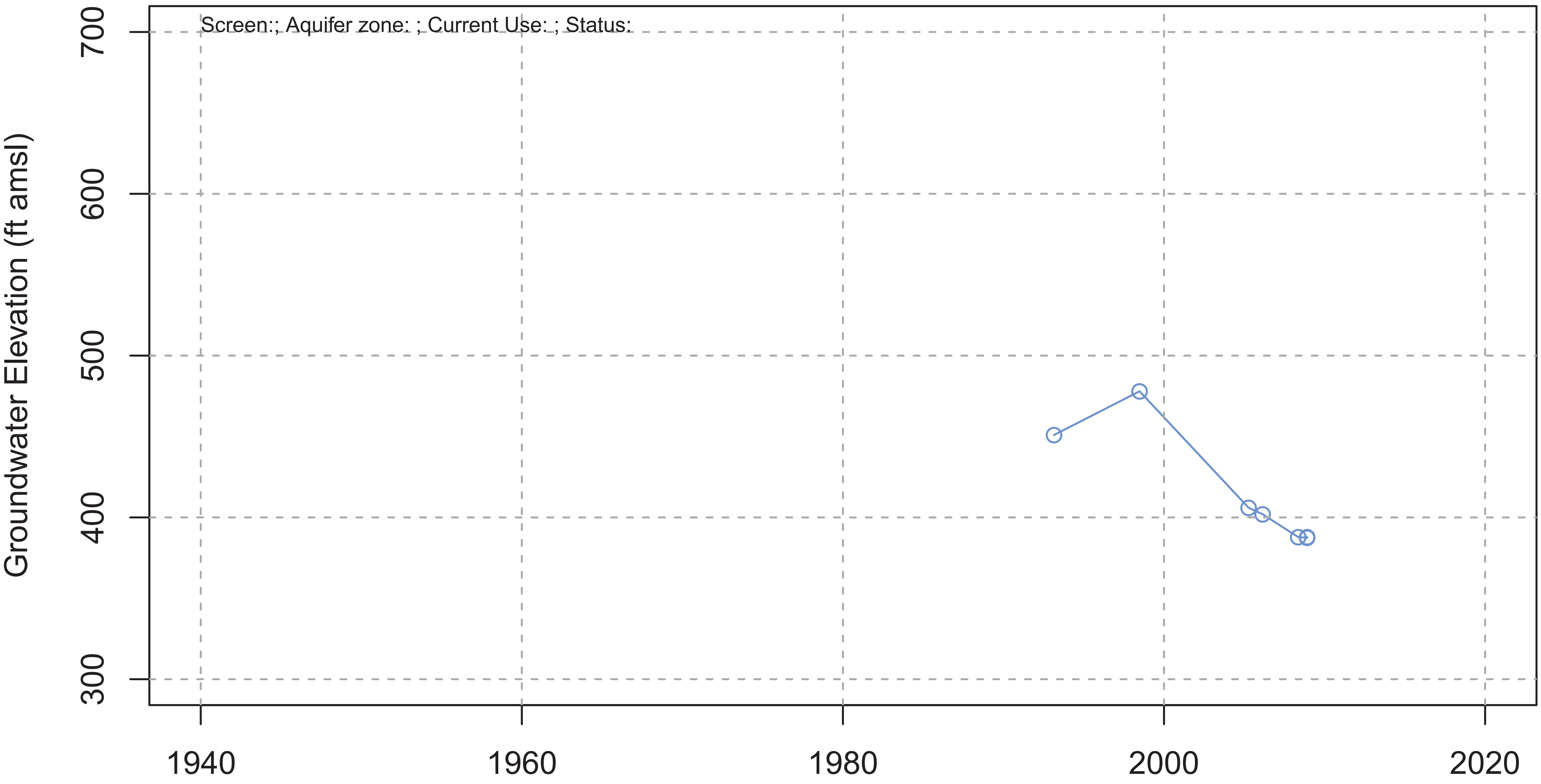
Local ID: State Park Well 1 ; Number of Measuring Agenc(y/ies): 1

010S005E36A001S

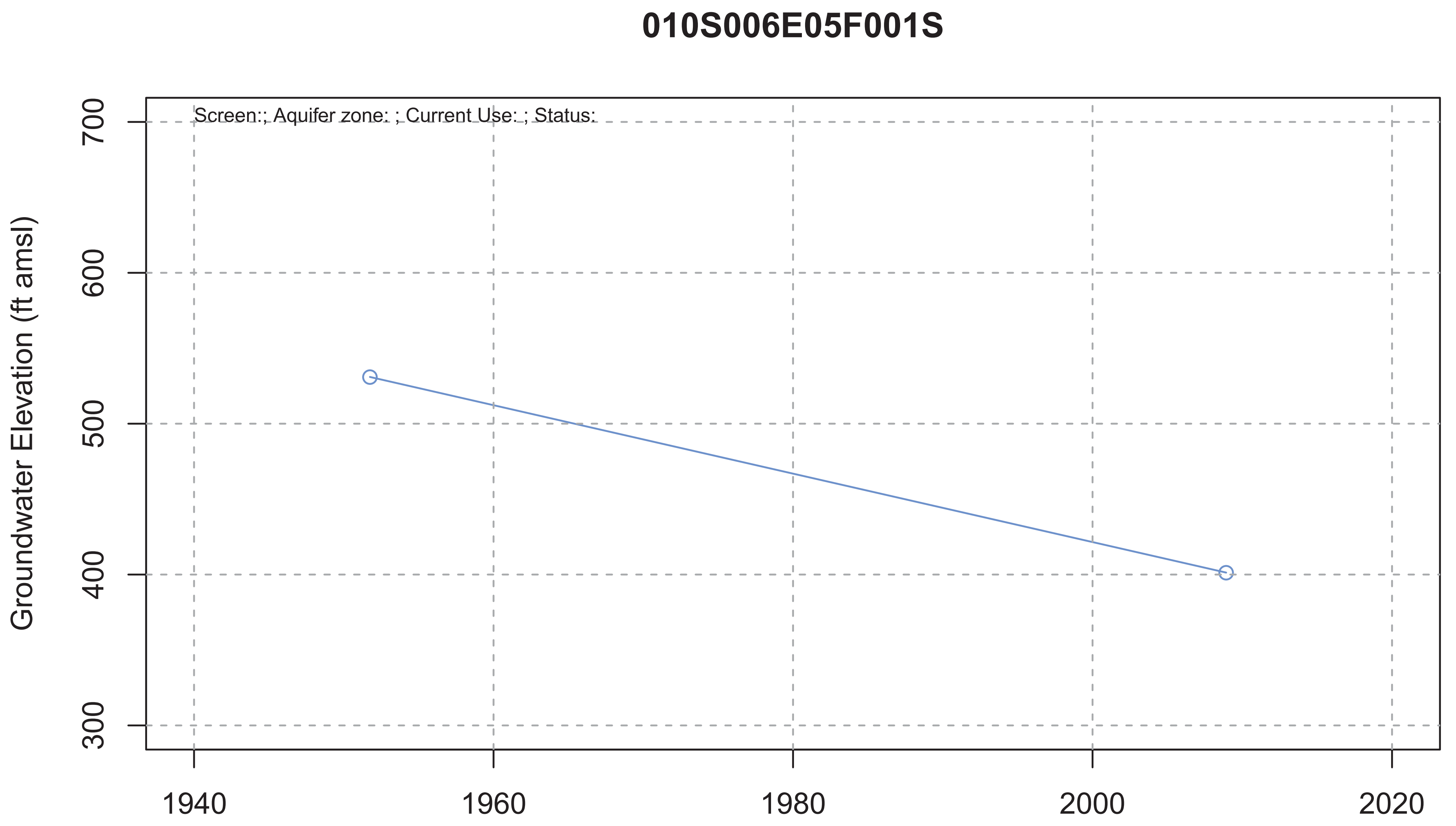


Local ID: State Park Well 2 ; Number of Measuring Agenc(y/ies): 2

010S006E04Q001S

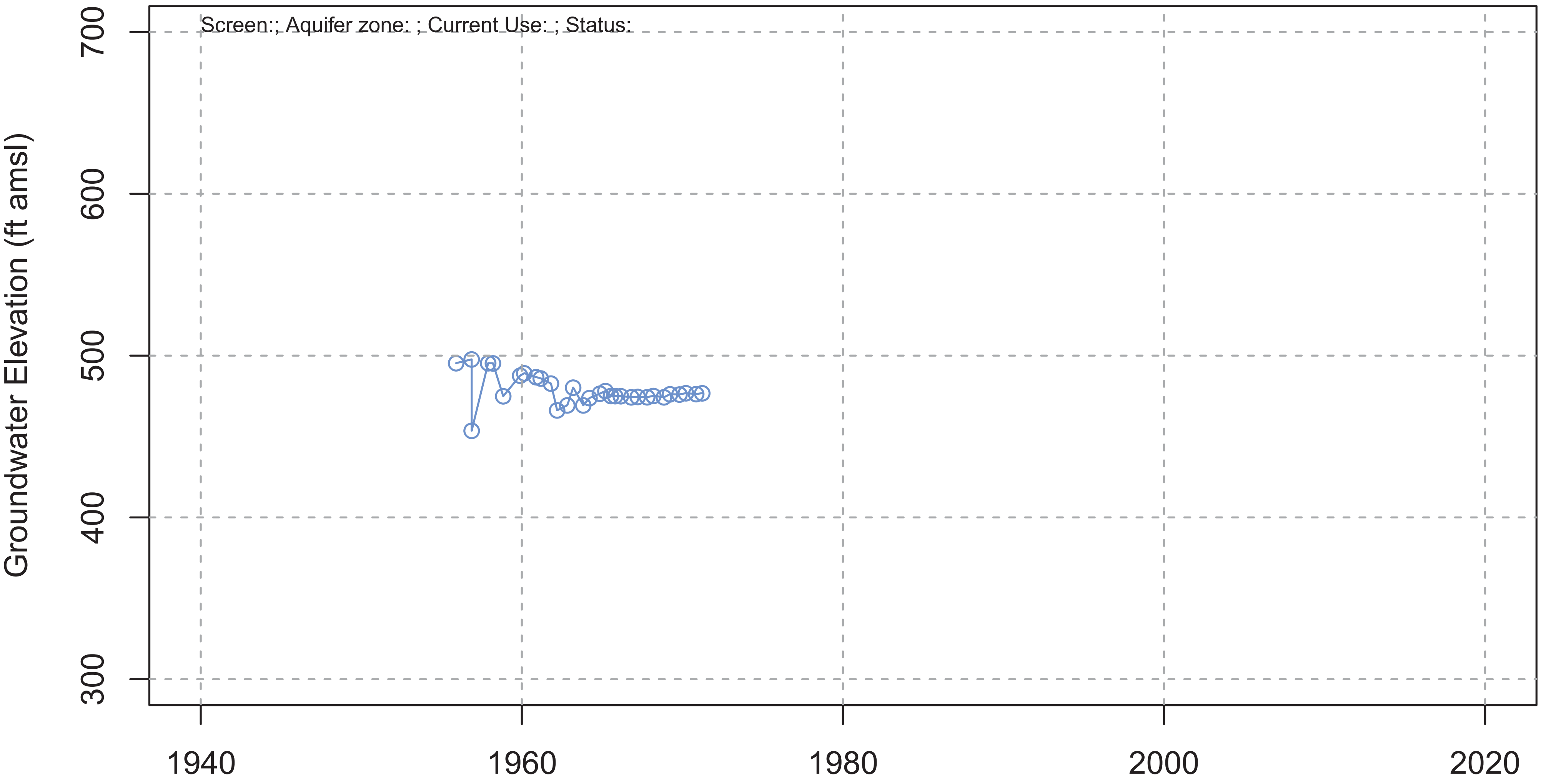


Local ID: Viking ; Number of Measuring Agenc(y/ies): 3



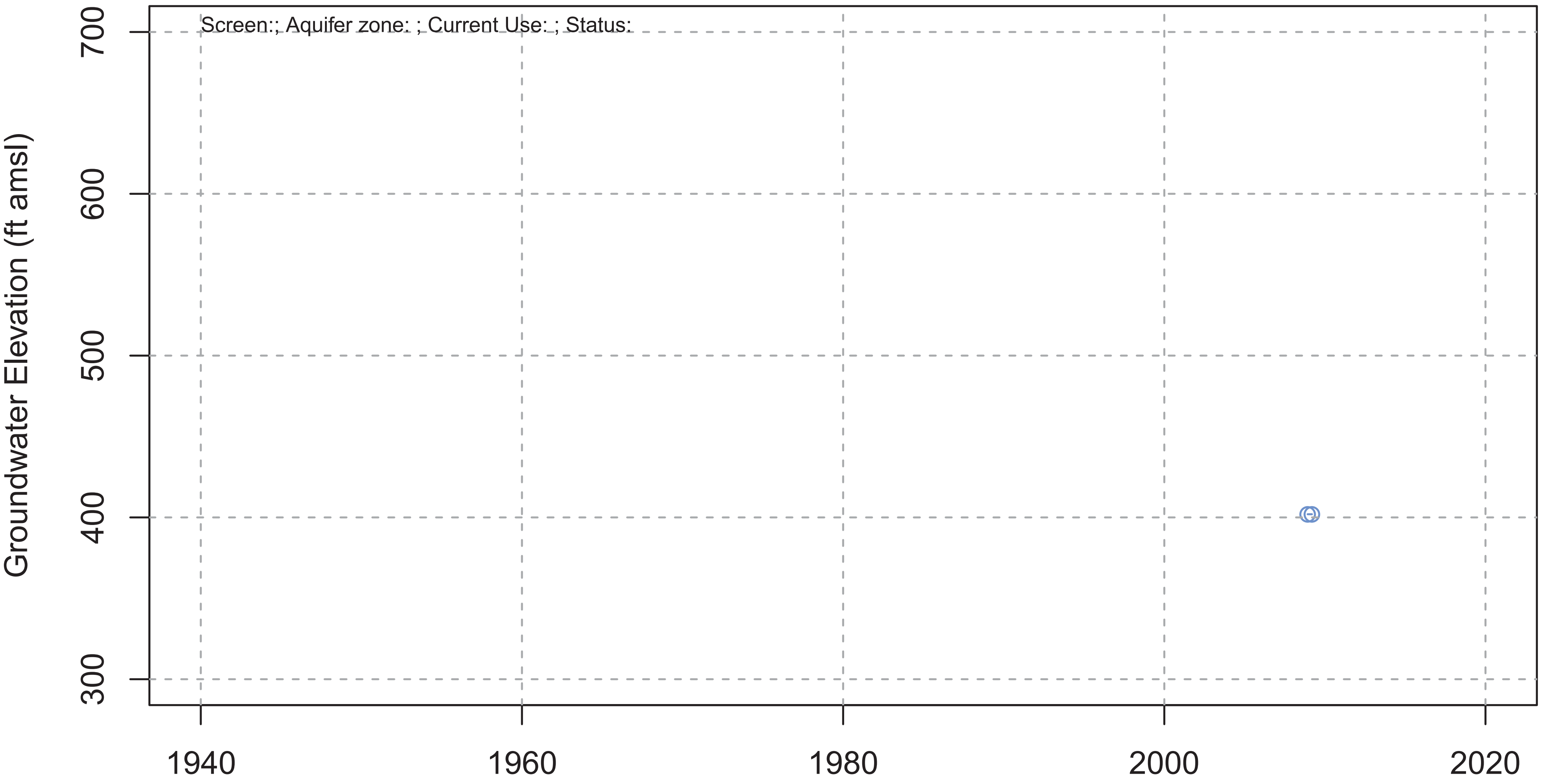
Local ID: 5F1 ; Number of Measuring Agenc(y/ies): 1

010S006E08B001S



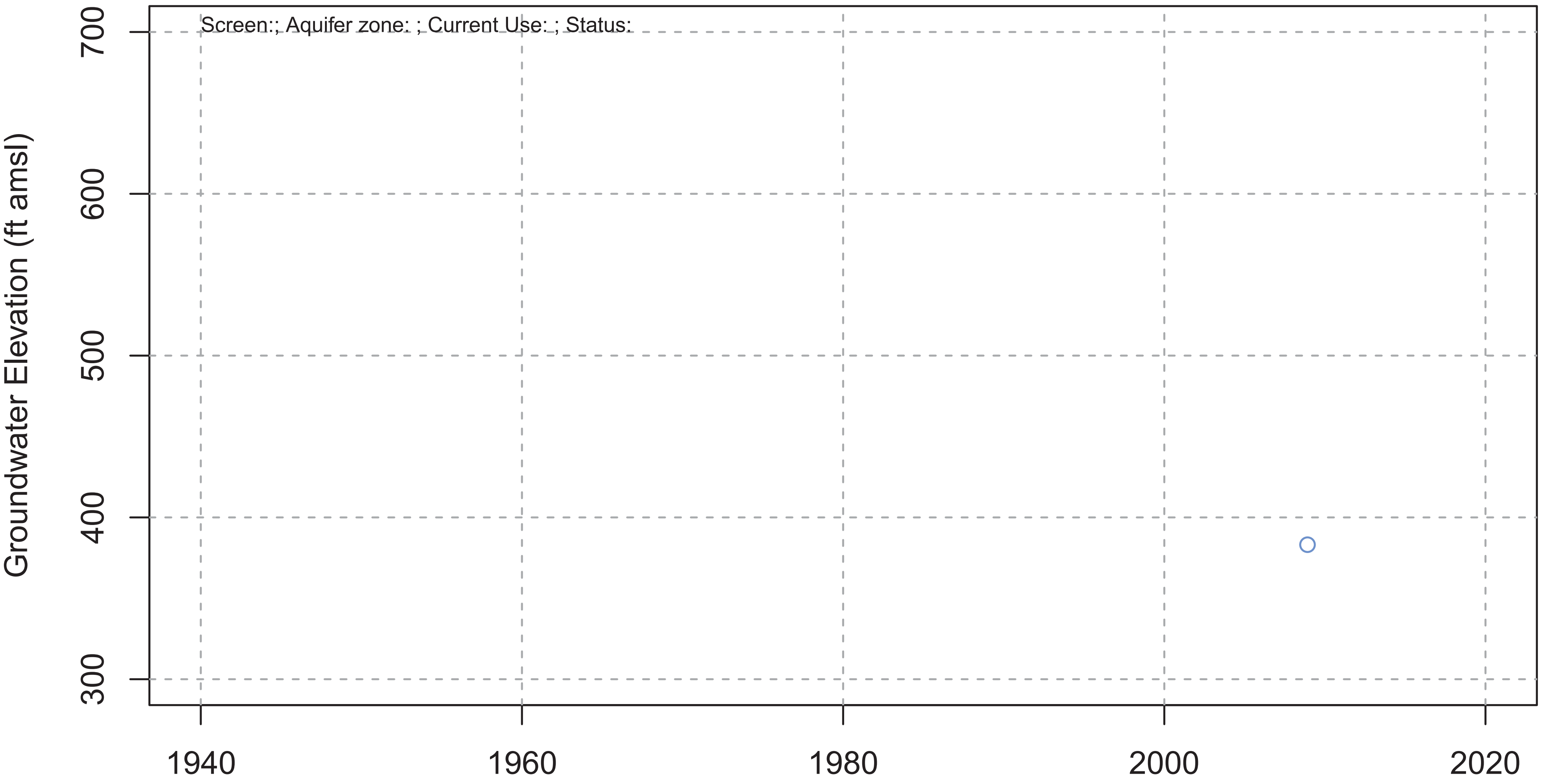
Local ID: N/A ; Number of Measuring Agenc(y/ies): 2

010S006E08F001S

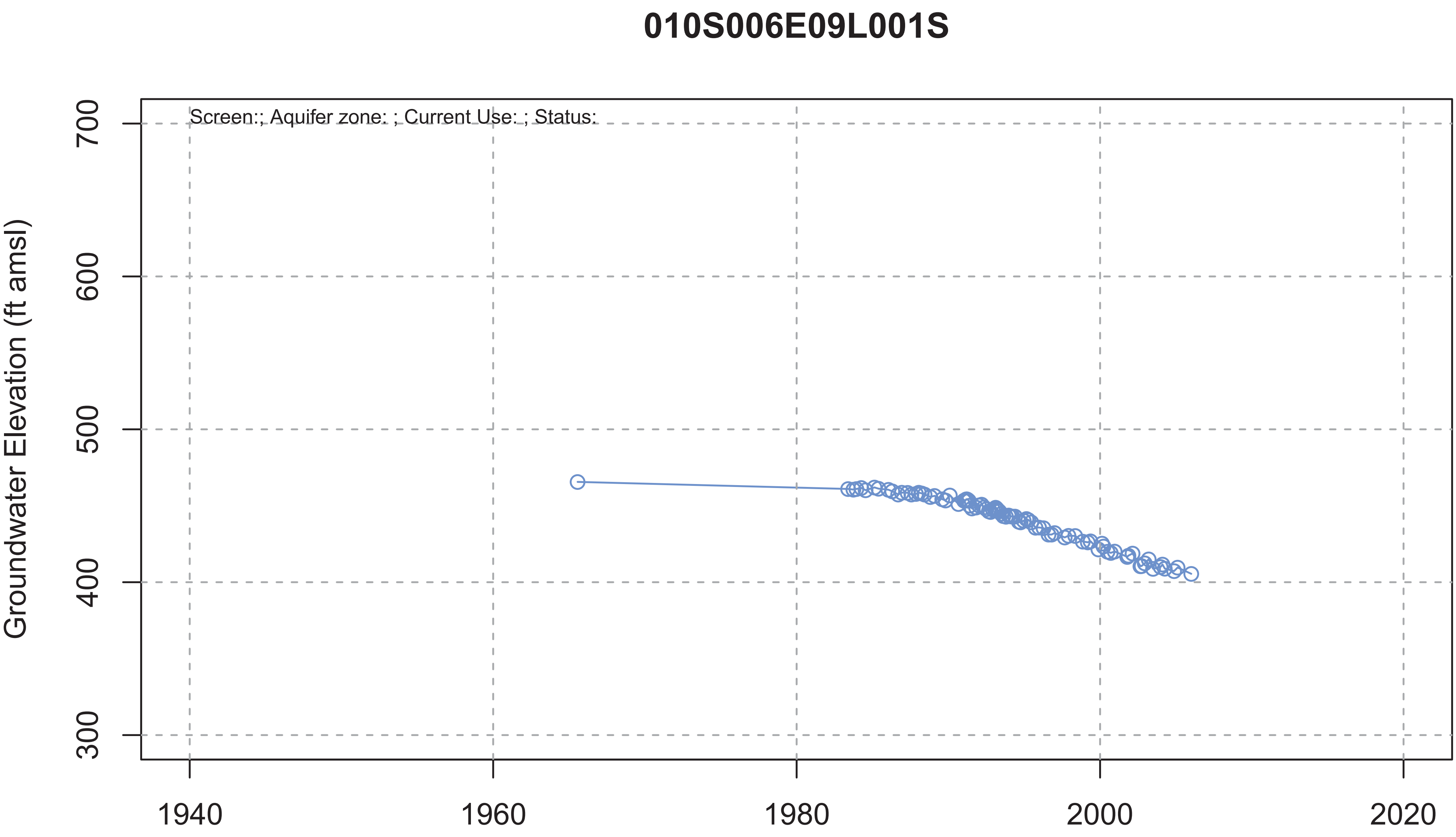


Local ID: Charmer 2 ; Number of Measuring Agenc(y/ies): 2

010S006E09C001S

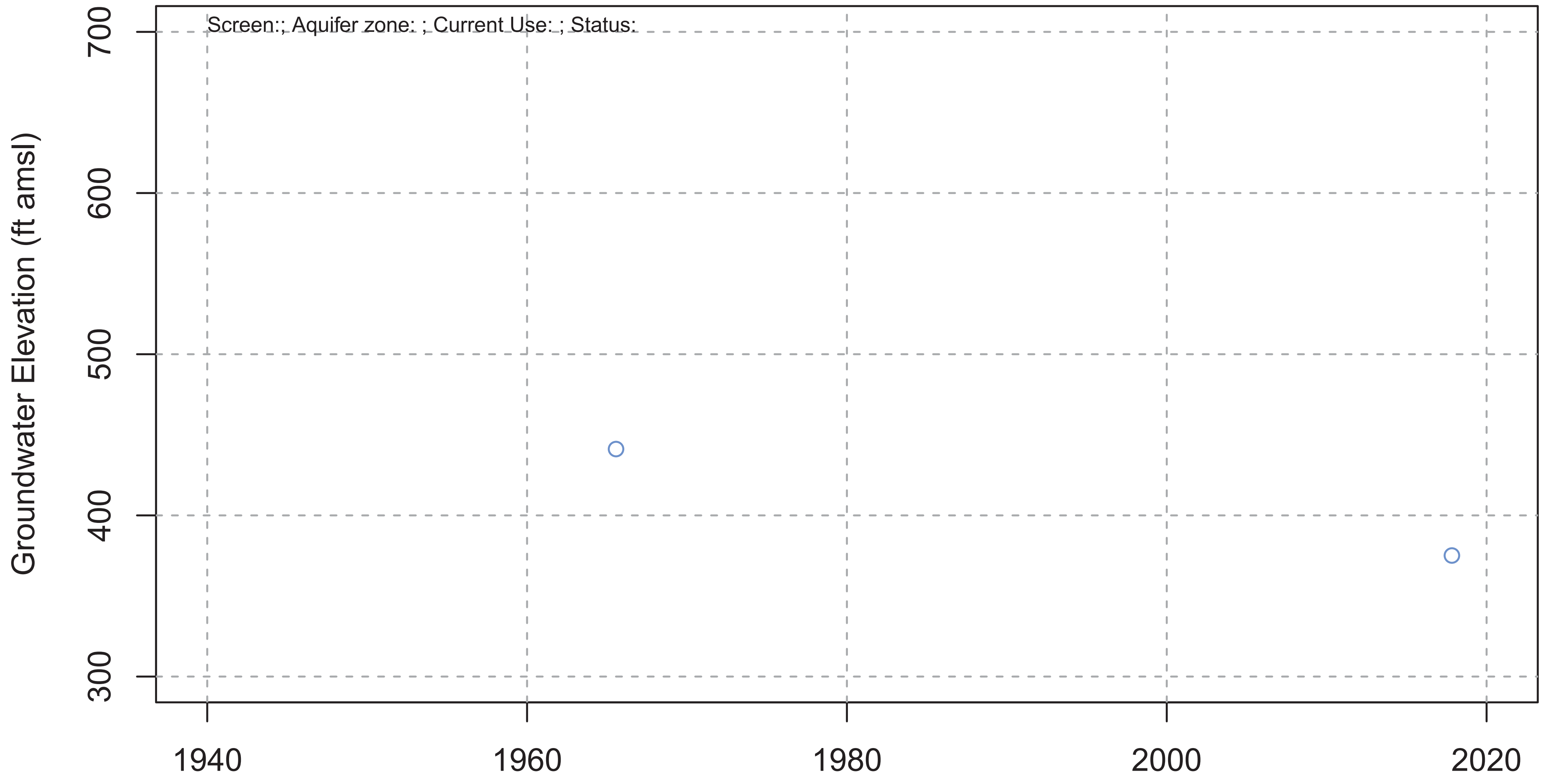


Local ID: N/A ; Number of Measuring Agenc(y/ies): 1



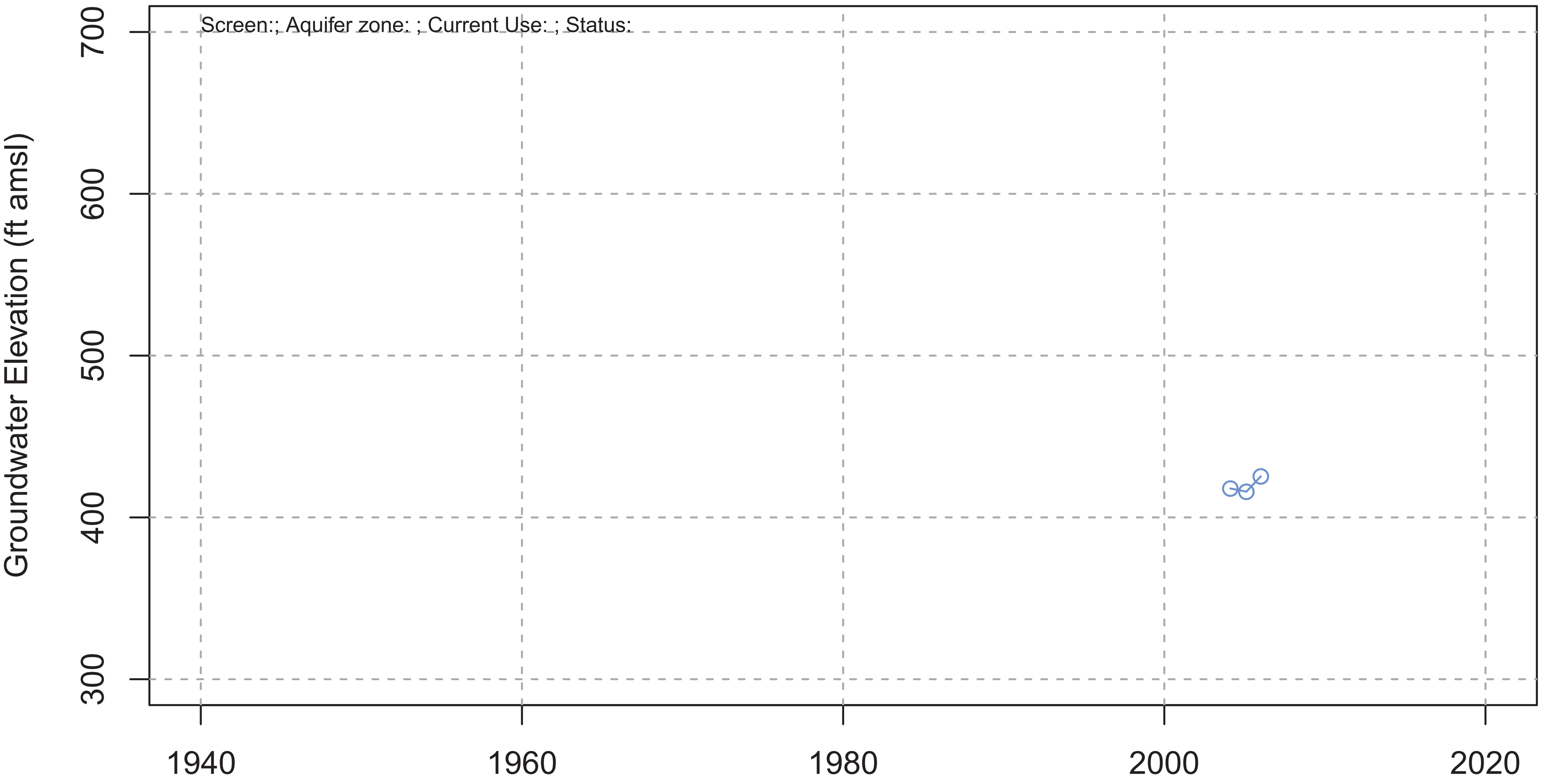
Local ID: N/A ; Number of Measuring Agenc(y/ies): 2

010S006E09N001S

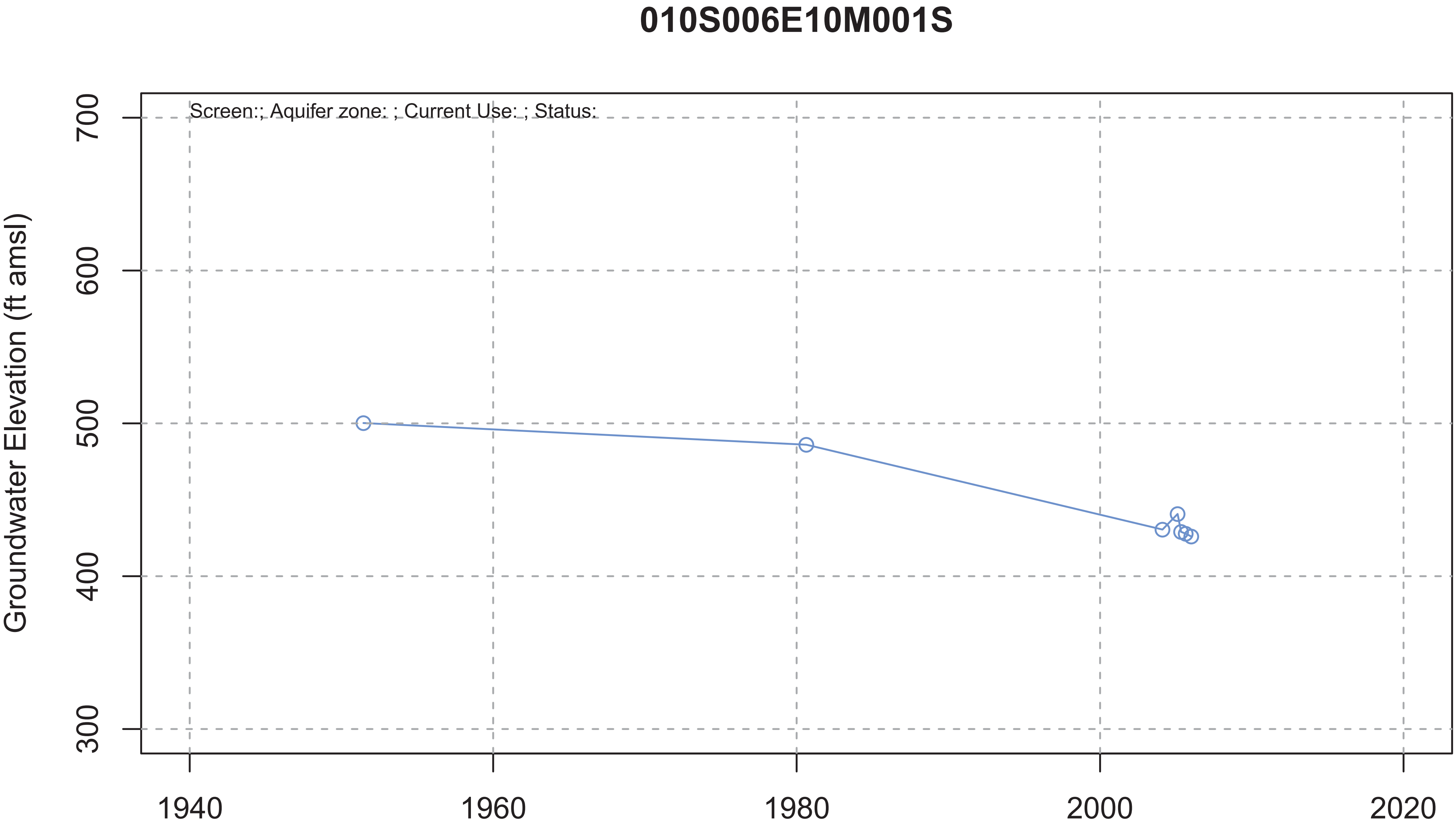


Local ID: Fortiner #1 (Allegre 1) ; Number of Measuring Agenc(y/ies): 3

010S006E10L001S



Local ID: N/A ; Number of Measuring Agenc(y/ies): 1

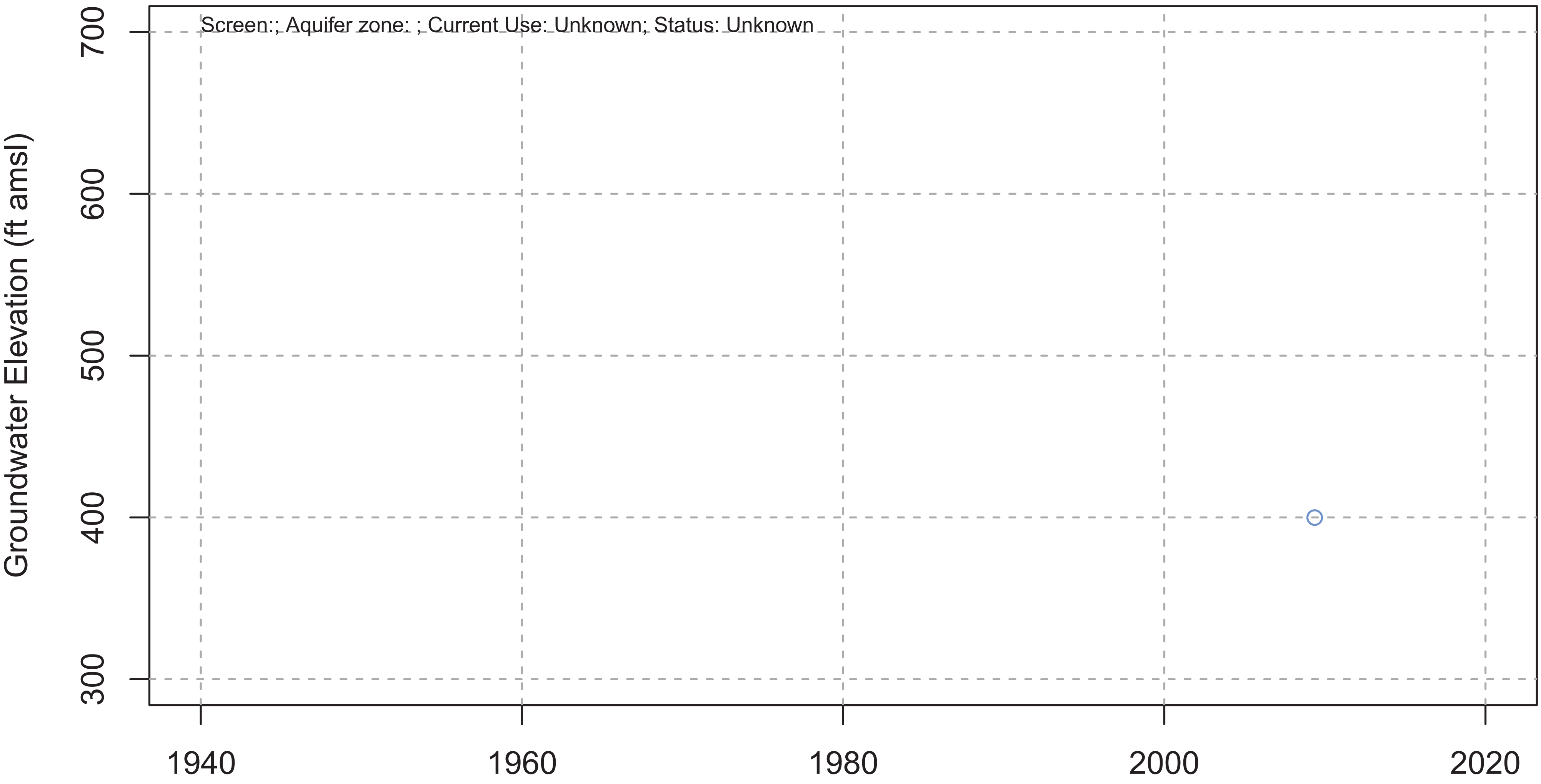


Local ID: N/A ; Number of Measuring Agenc(y/ies): 2

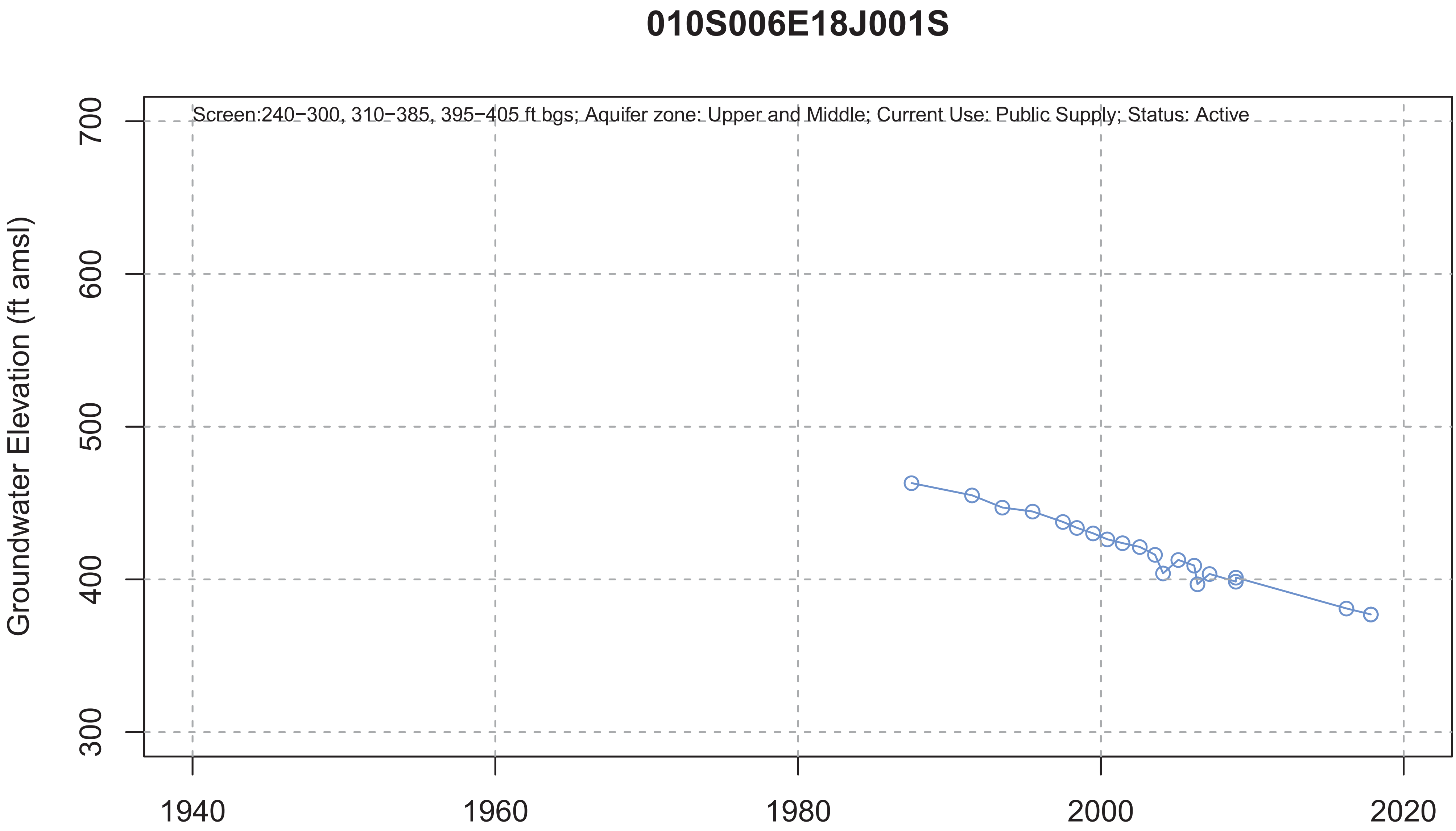
010S006E14G001S

Local ID: Hanna (Flowers) ; Number of Measuring Agenc(y/ies): 2

010S006E17J001S

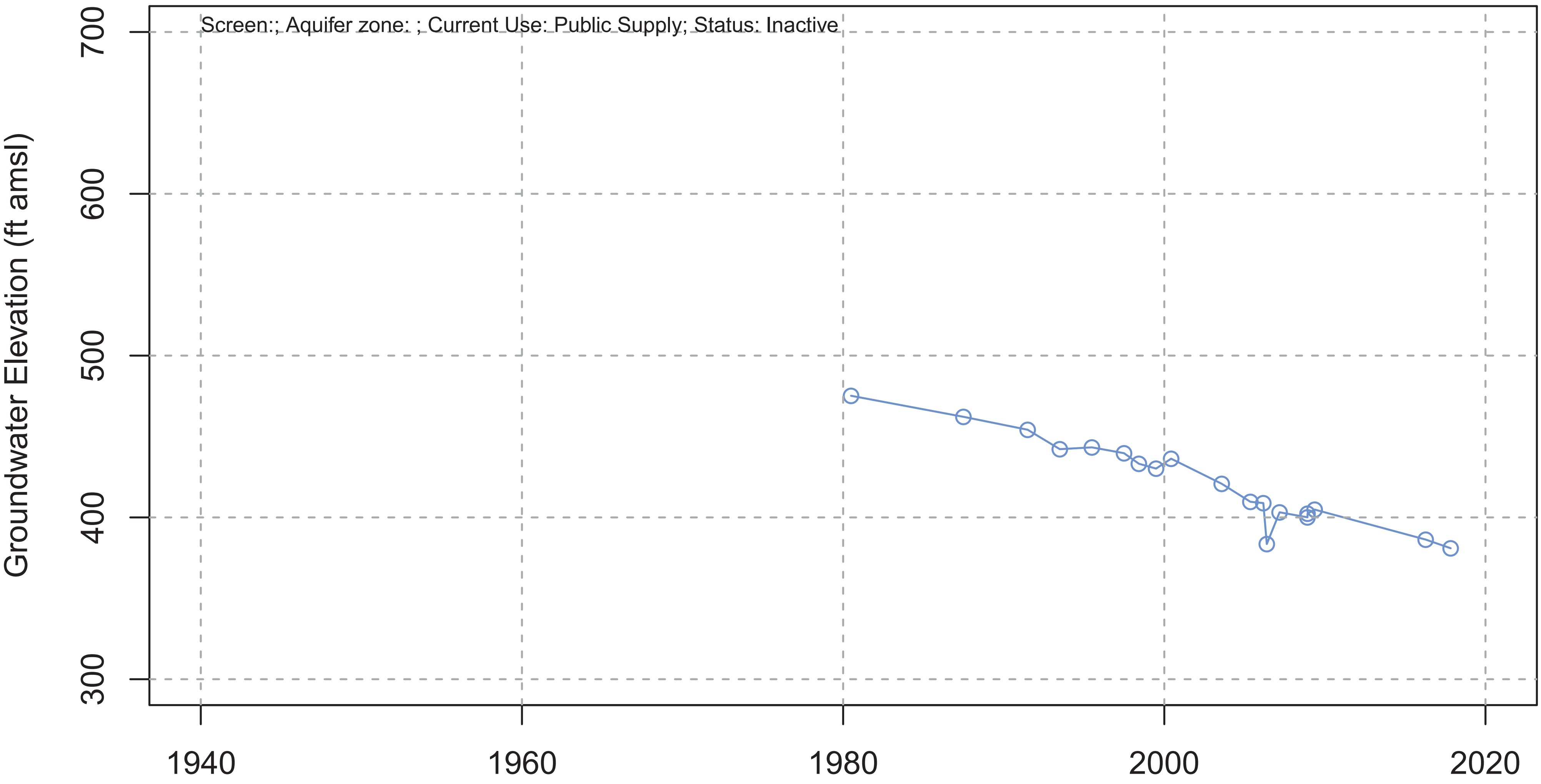


Local ID: N/A ; Number of Measuring Agenc(y/ies): 1

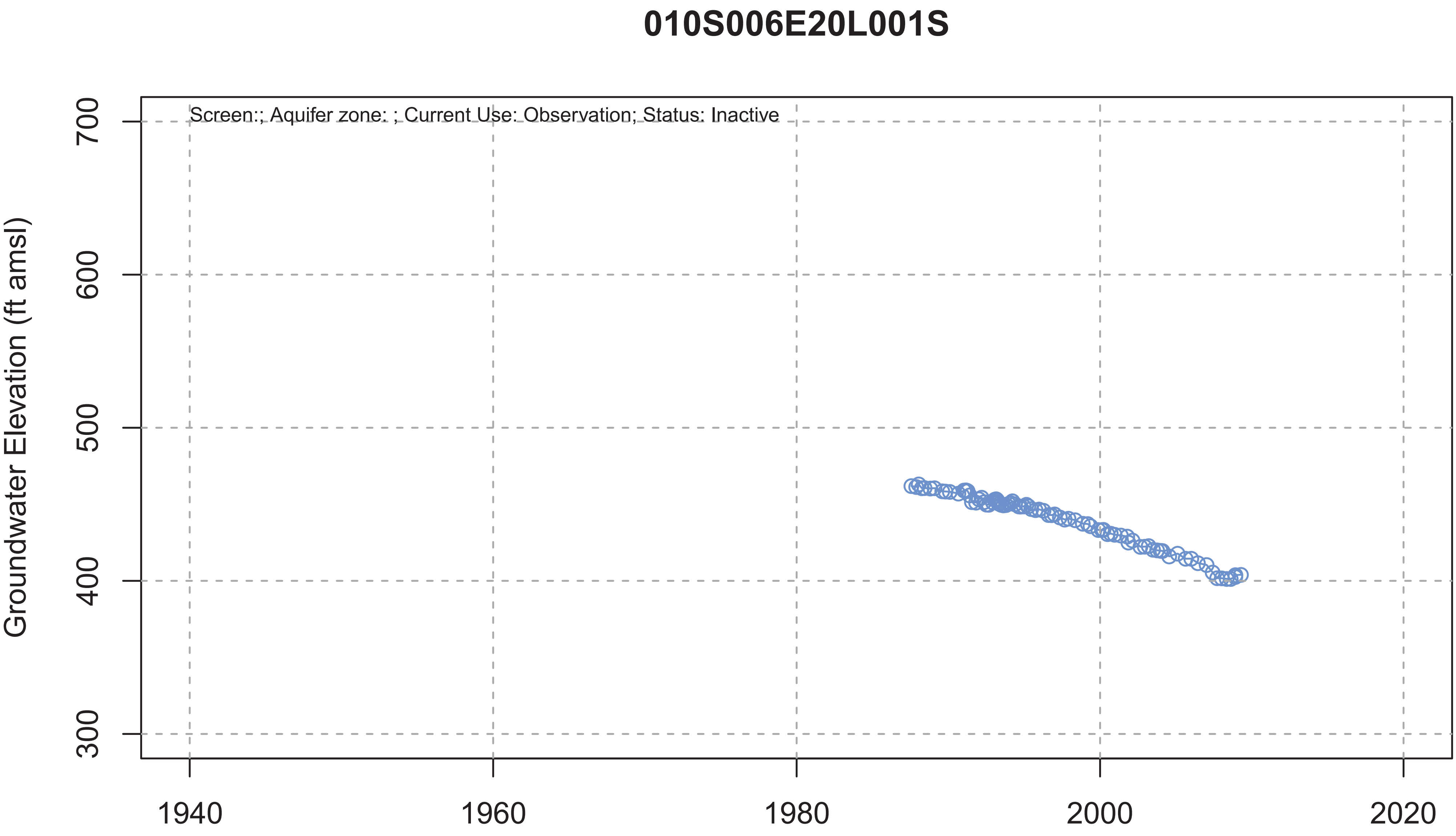


Local ID: ID4−18 ; Number of Measuring Agenc(y/ies): 4

010S006E18R001S

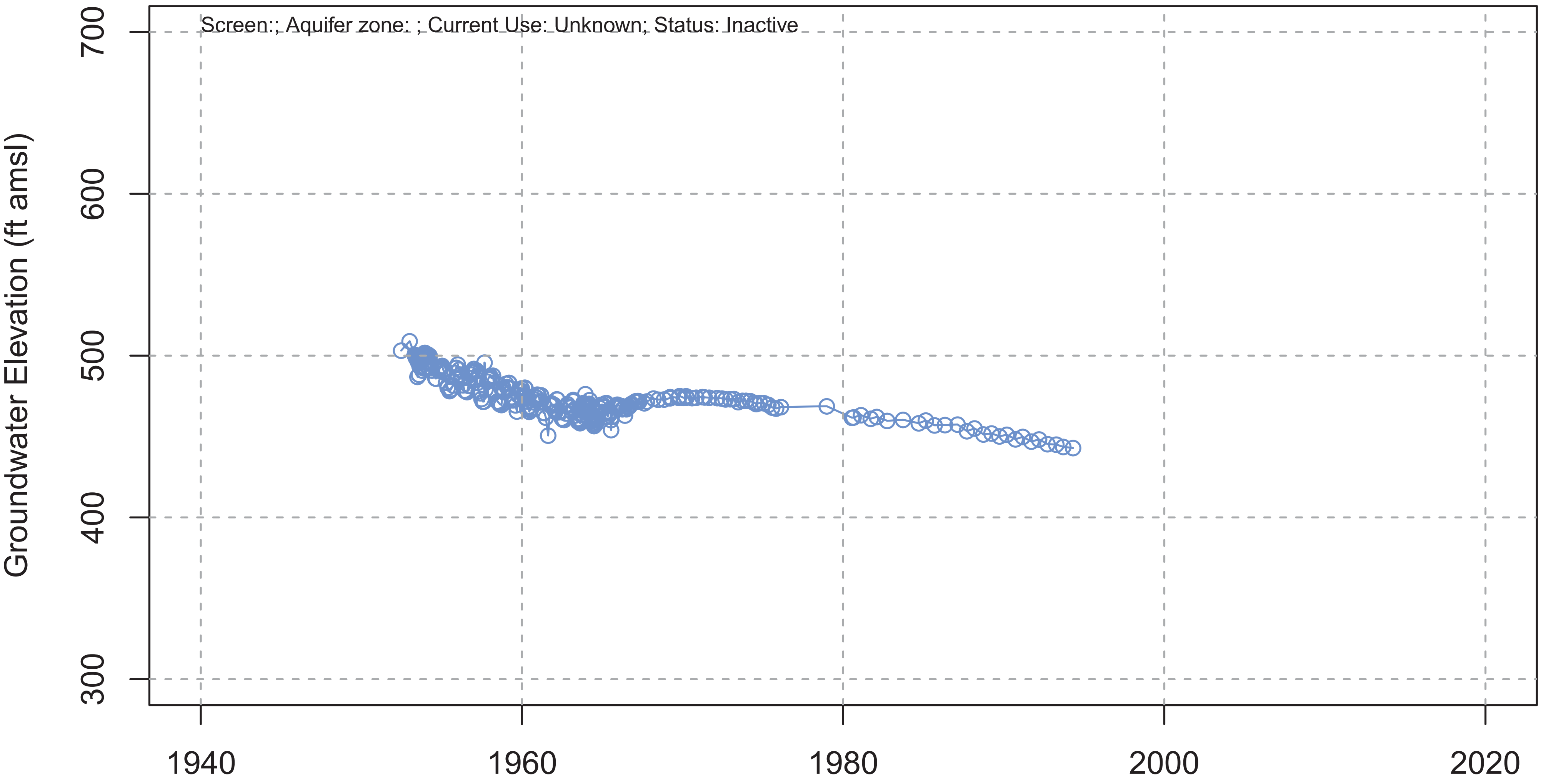


Local ID: ID4−3 ; Number of Measuring Agenc(y/ies): 5



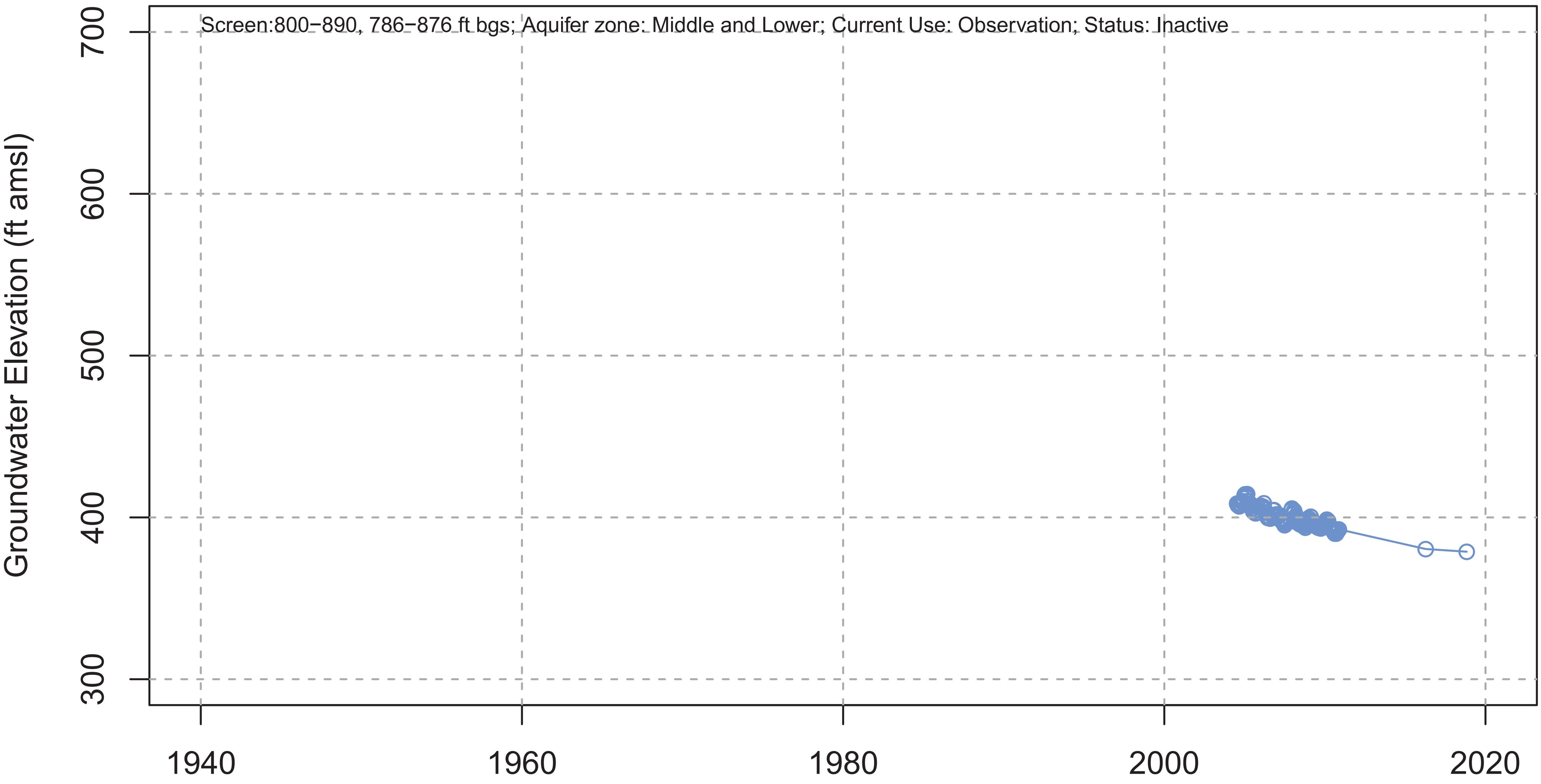
Local ID: Empty Irrigation ; Number of Measuring Agenc(y/ies): 3

010S006E21A001S



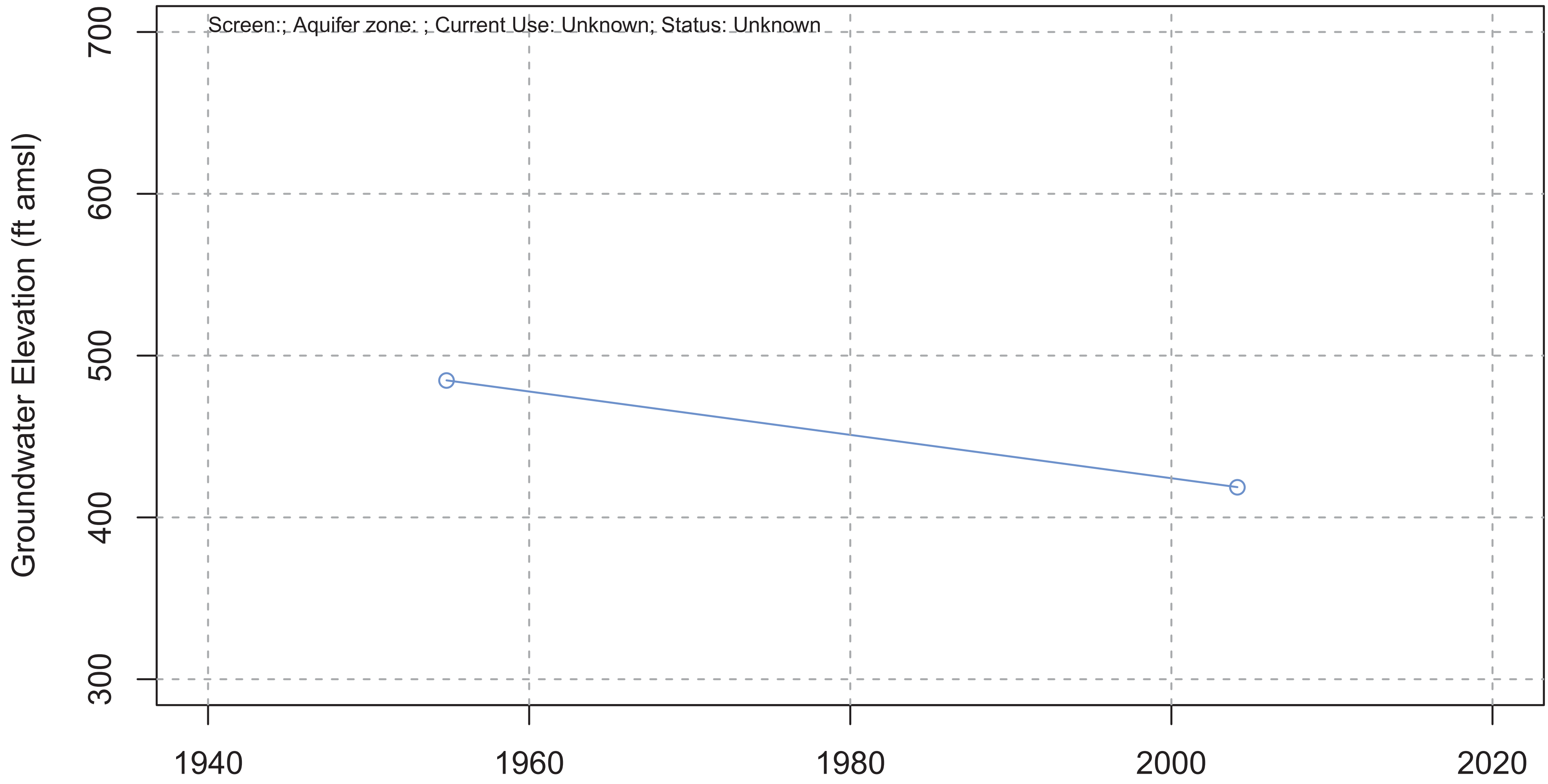
Local ID: 21A1 ; Number of Measuring Agenc(y/ies): 2

010S006E21A002S



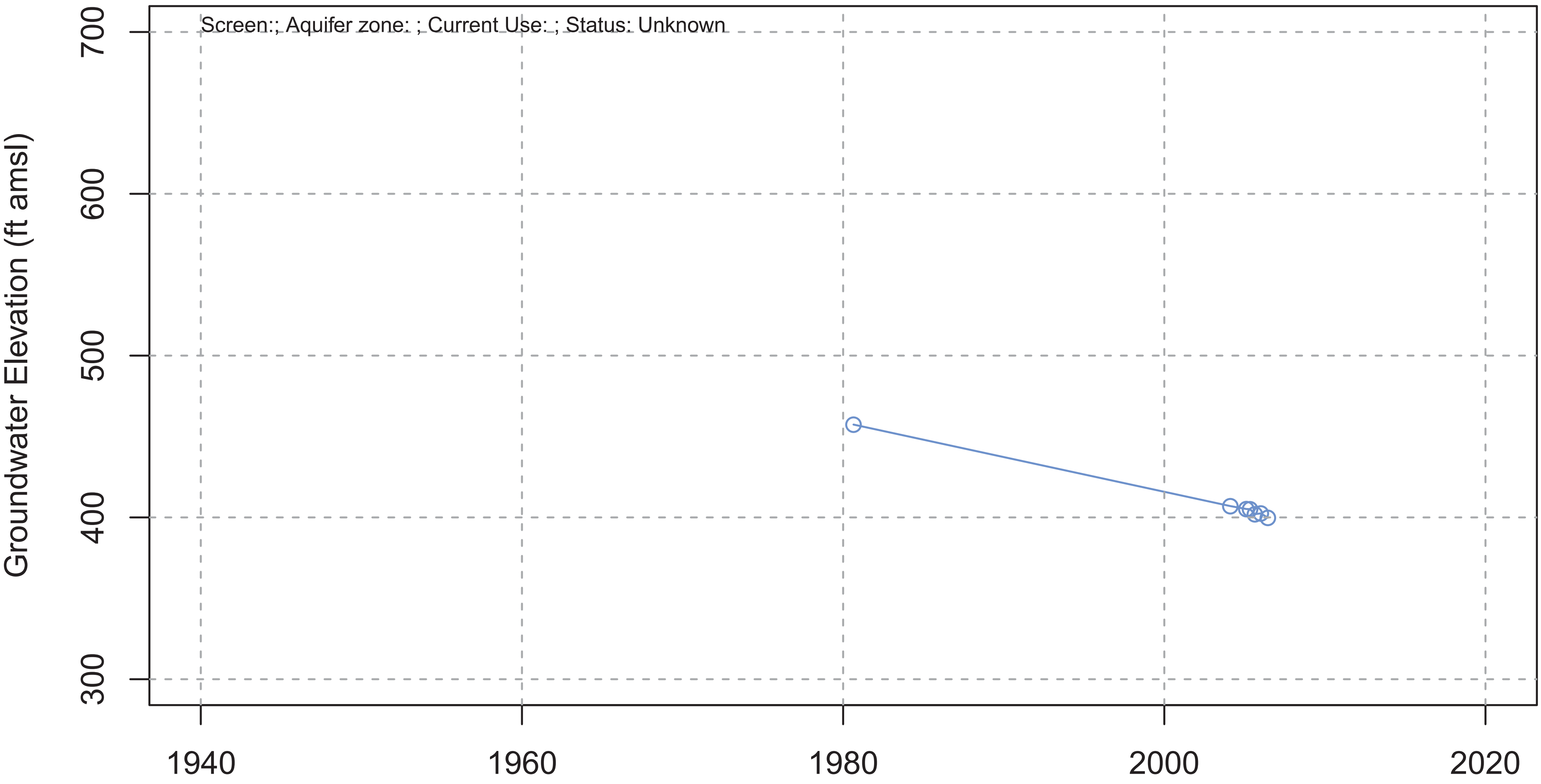
Local ID: MW−1 ; Number of Measuring Agenc(y/ies): 5

010S006E21B001S



Local ID: N/A ; Number of Measuring Agenc(y/ies): 2

010S006E21B002S



Local ID: N/A ; Number of Measuring Agenc(y/ies): 2

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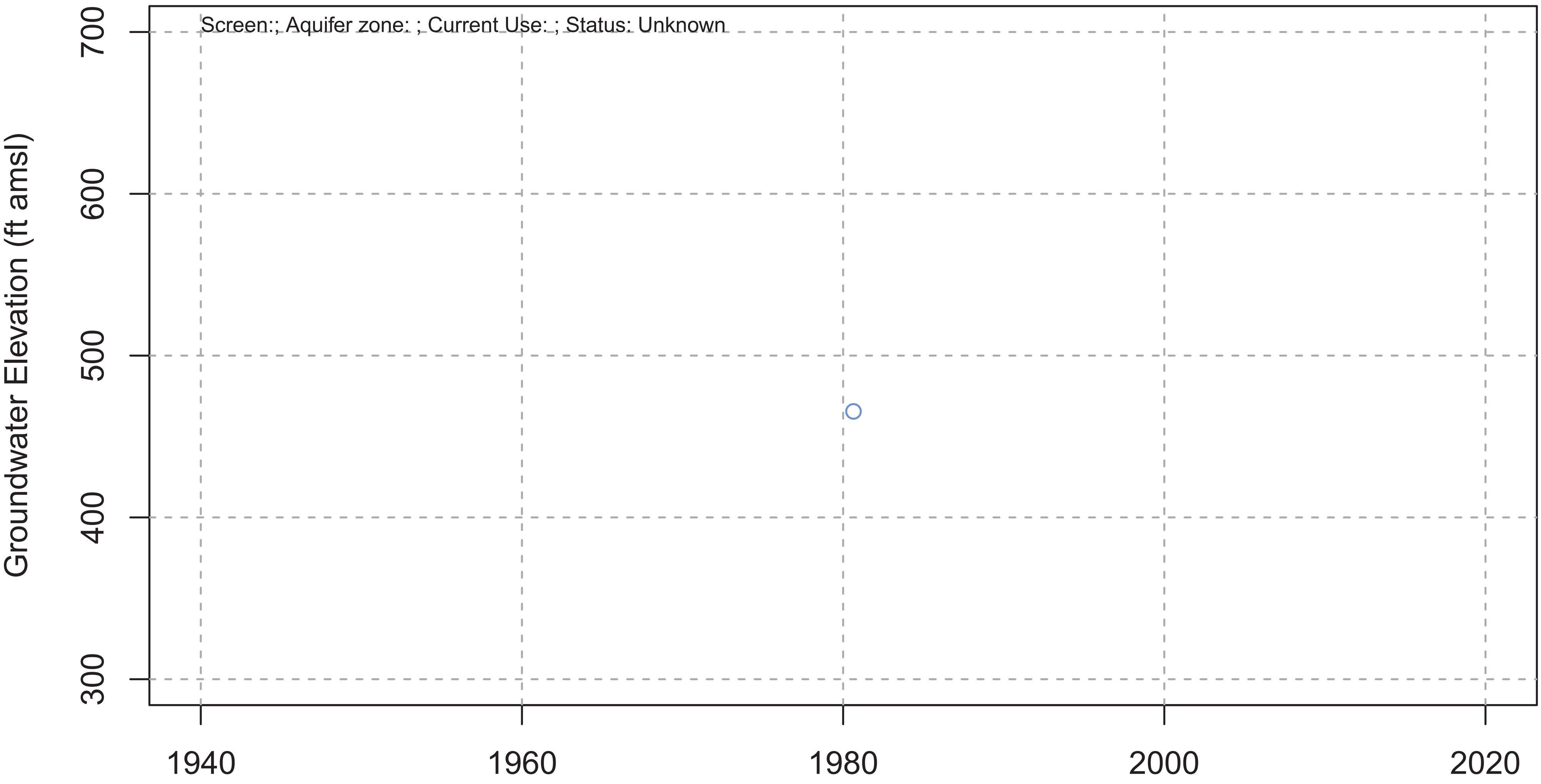
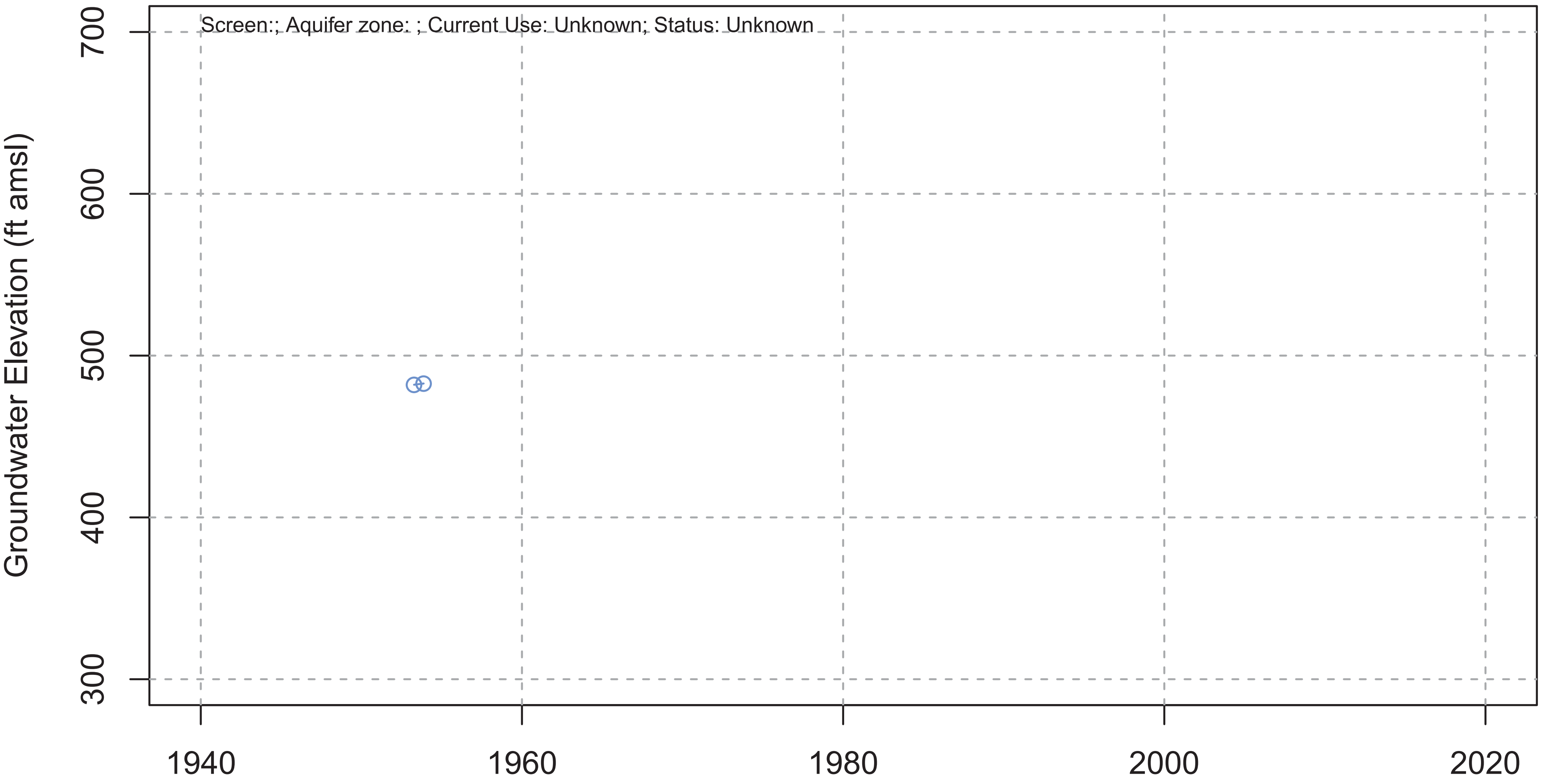
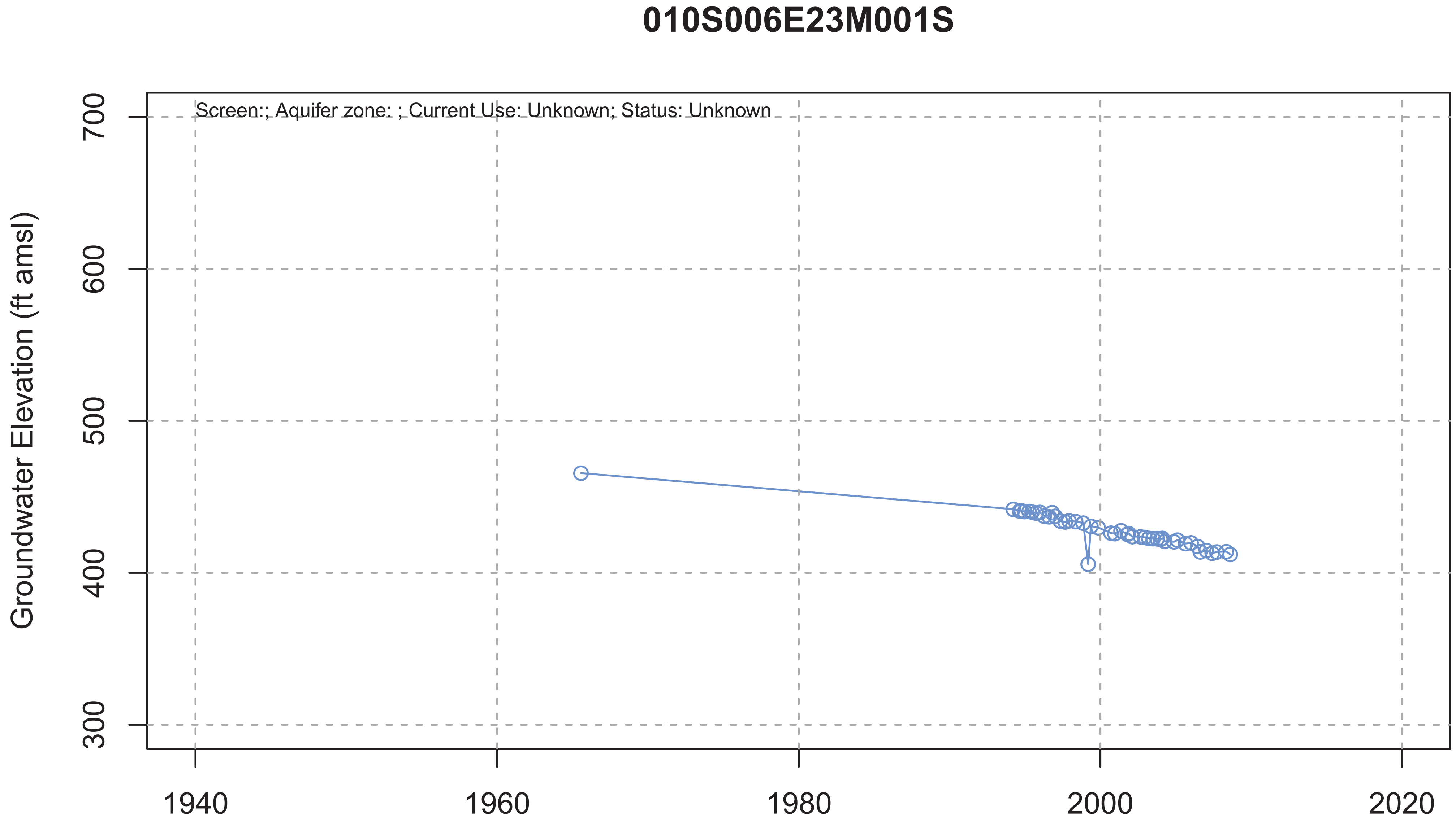


Local ID: N/A ; Number of Measuring Agenc(y/ies): 1

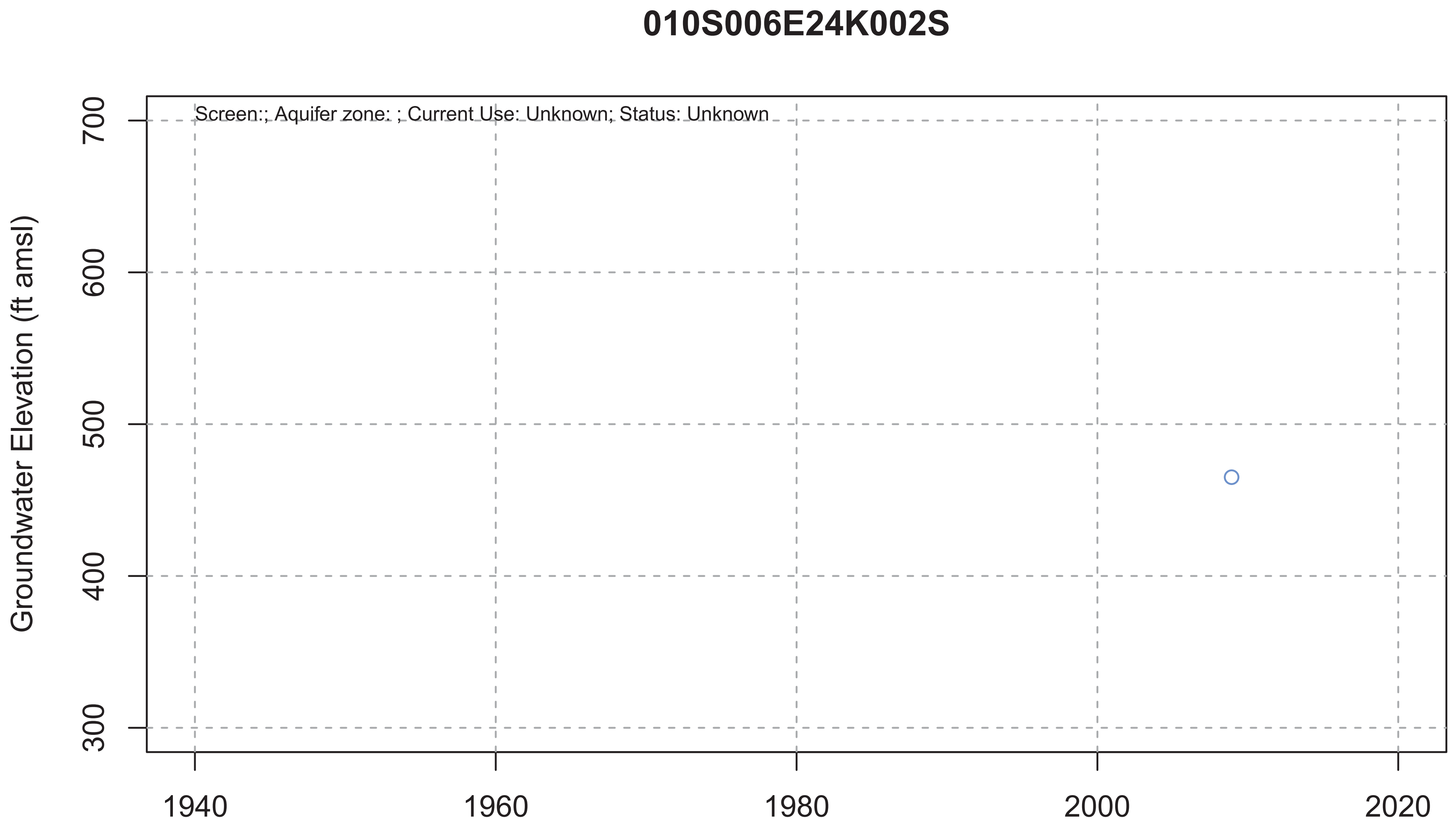
010S006E22A001S



Local ID: N/A ; Number of Measuring Agenc(y/ies): 1

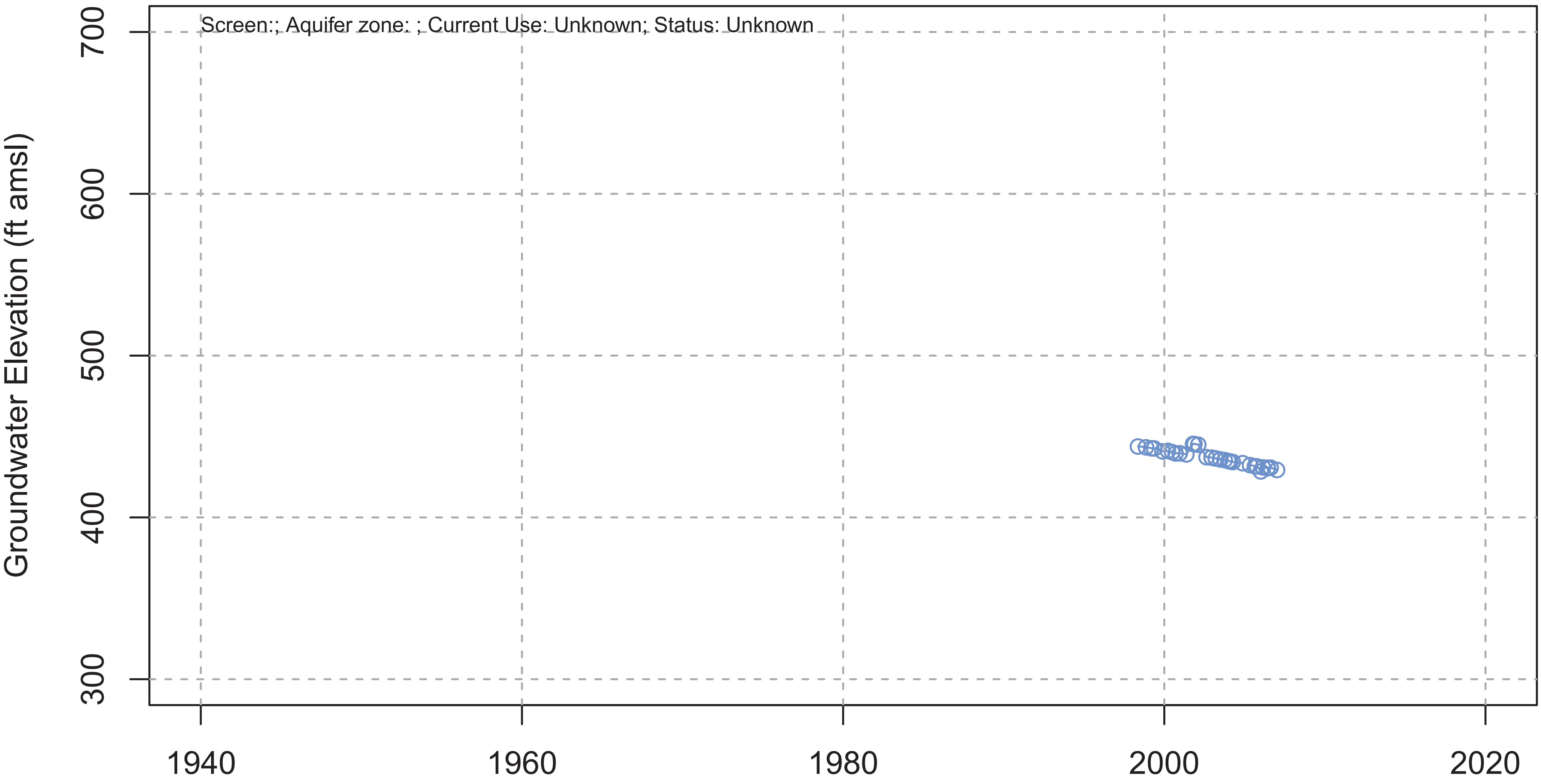


Local ID: Potato Field ; Number of Measuring Agenc(y/ies): 3



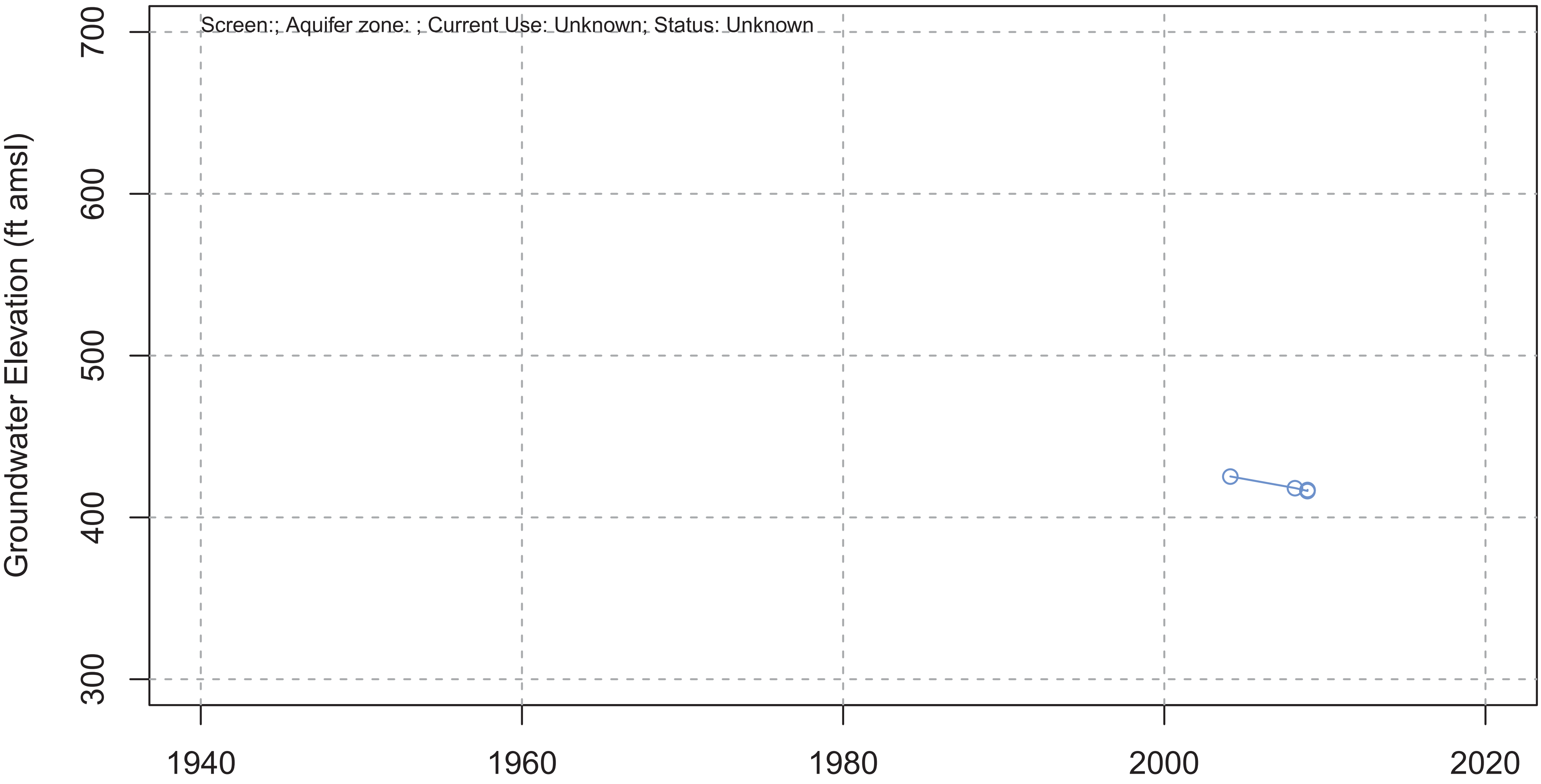
Local ID: Bad Donkey Ranch 2 ; Number of Measuring Agenc(y/ies): 1

010S006E25R001S



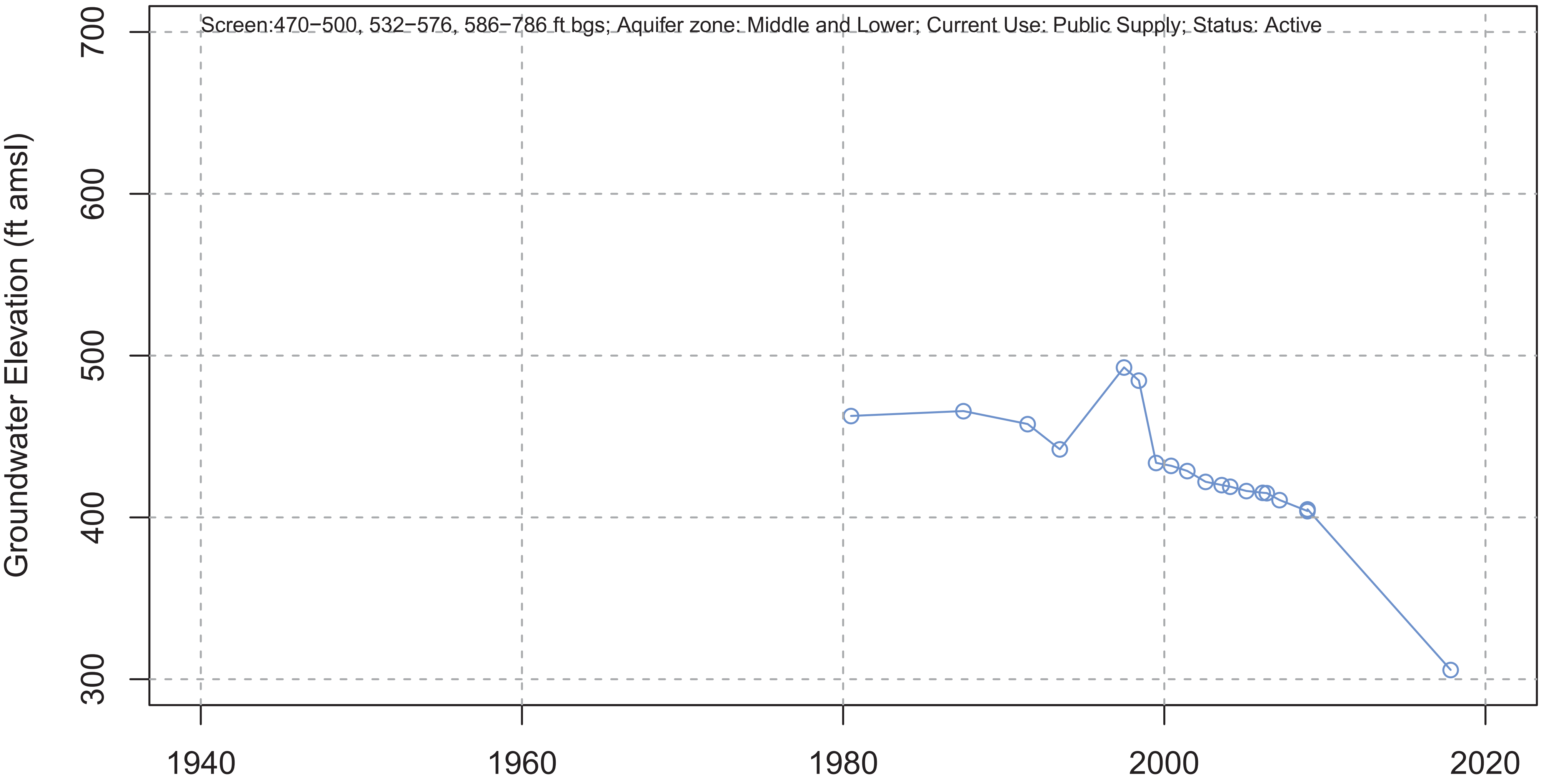
Local ID: Gray Irrigation ; Number of Measuring Agenc(y/ies): 3

010S006E28Q001S



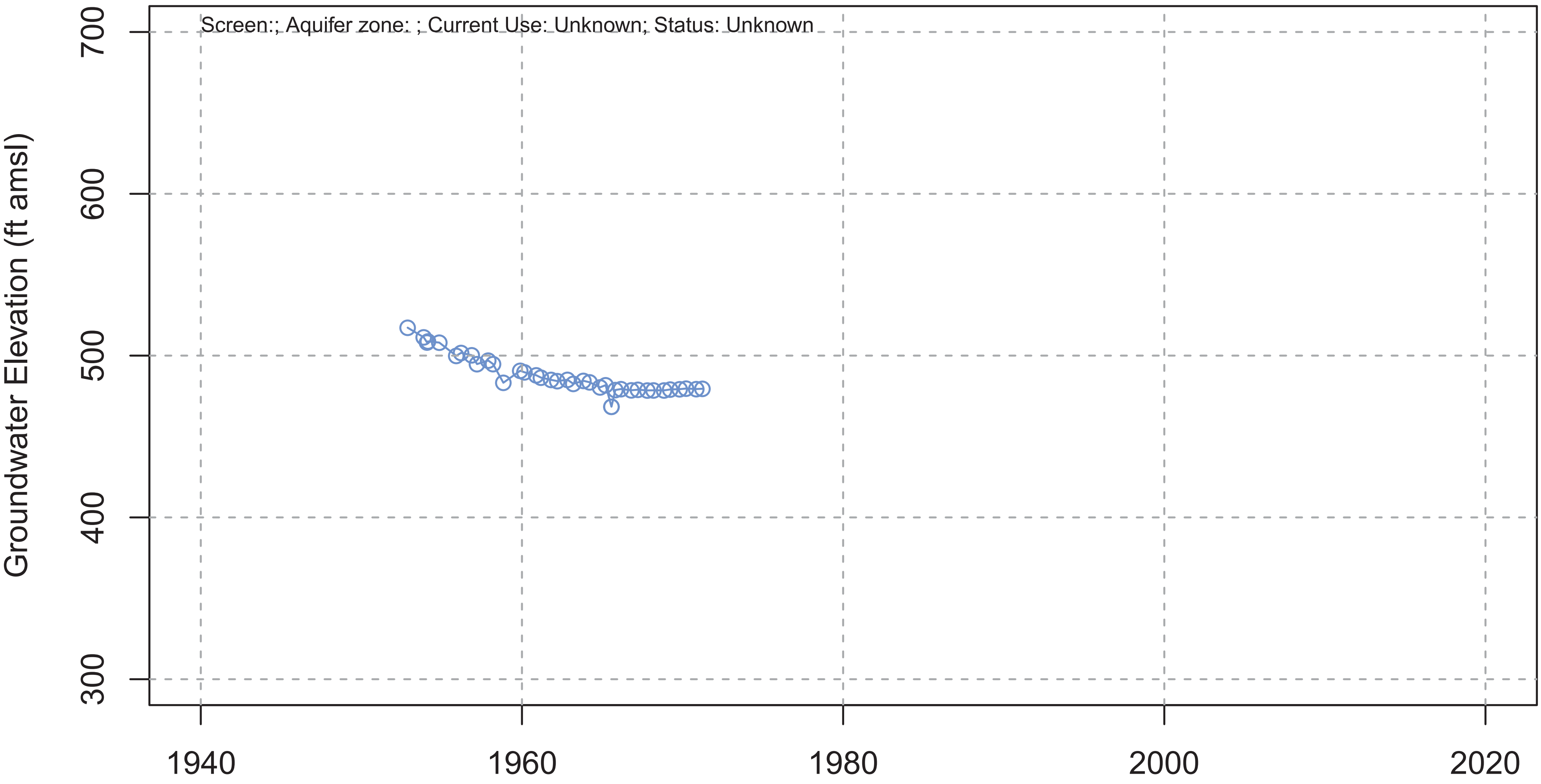
Local ID: Reiners ; Number of Measuring Agenc(y/ies): 2

010S006E29K002S



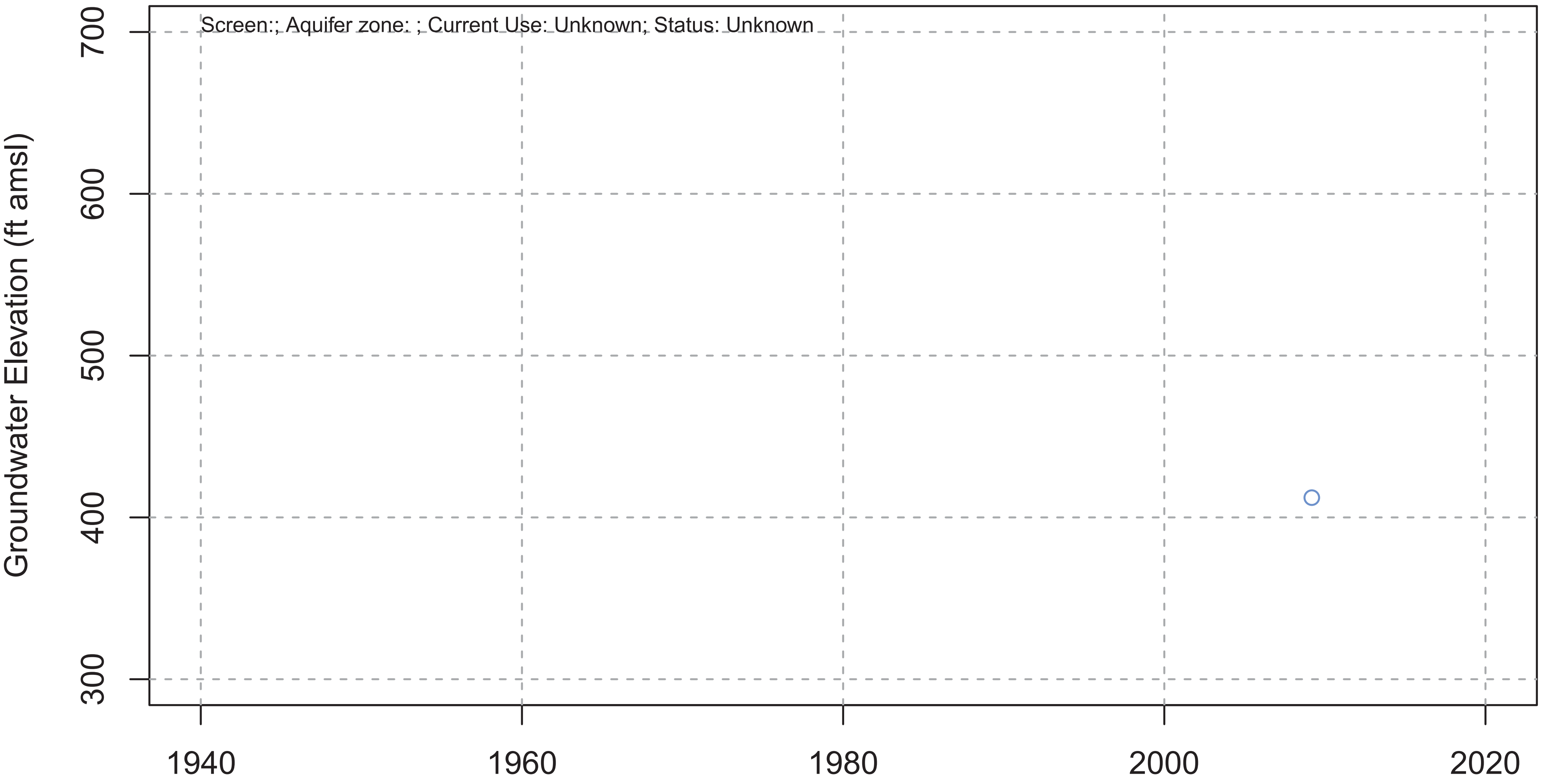
Local ID: ID4−4 ; Number of Measuring Agenc(y/ies): 3

010S006E29N001S



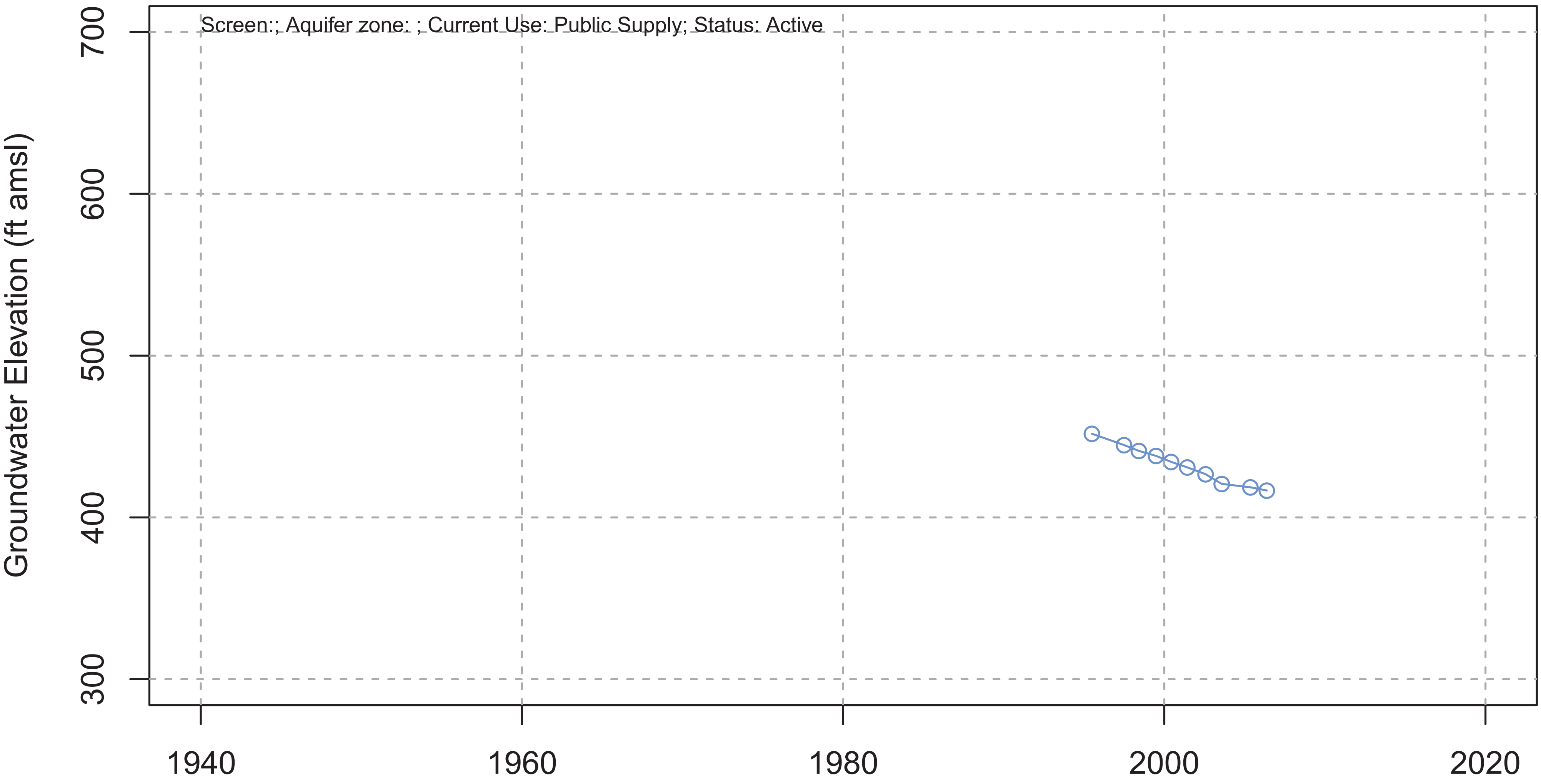
Local ID: N/A ; Number of Measuring Agenc(y/ies): 1

010S006E29N002S



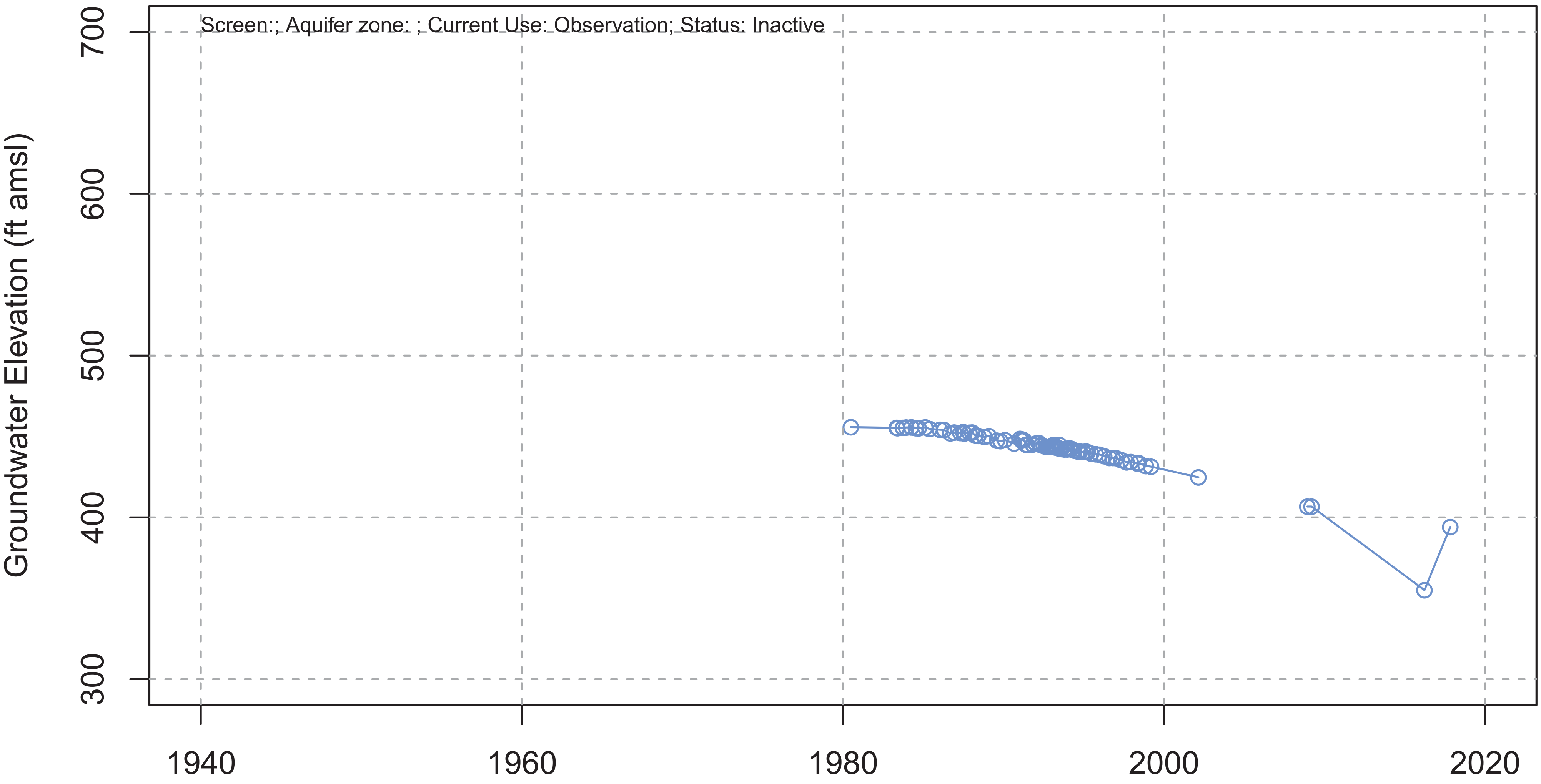
Local ID: Pecoff 2 ; Number of Measuring Agenc(y/ies): 1

010S006E32D001S

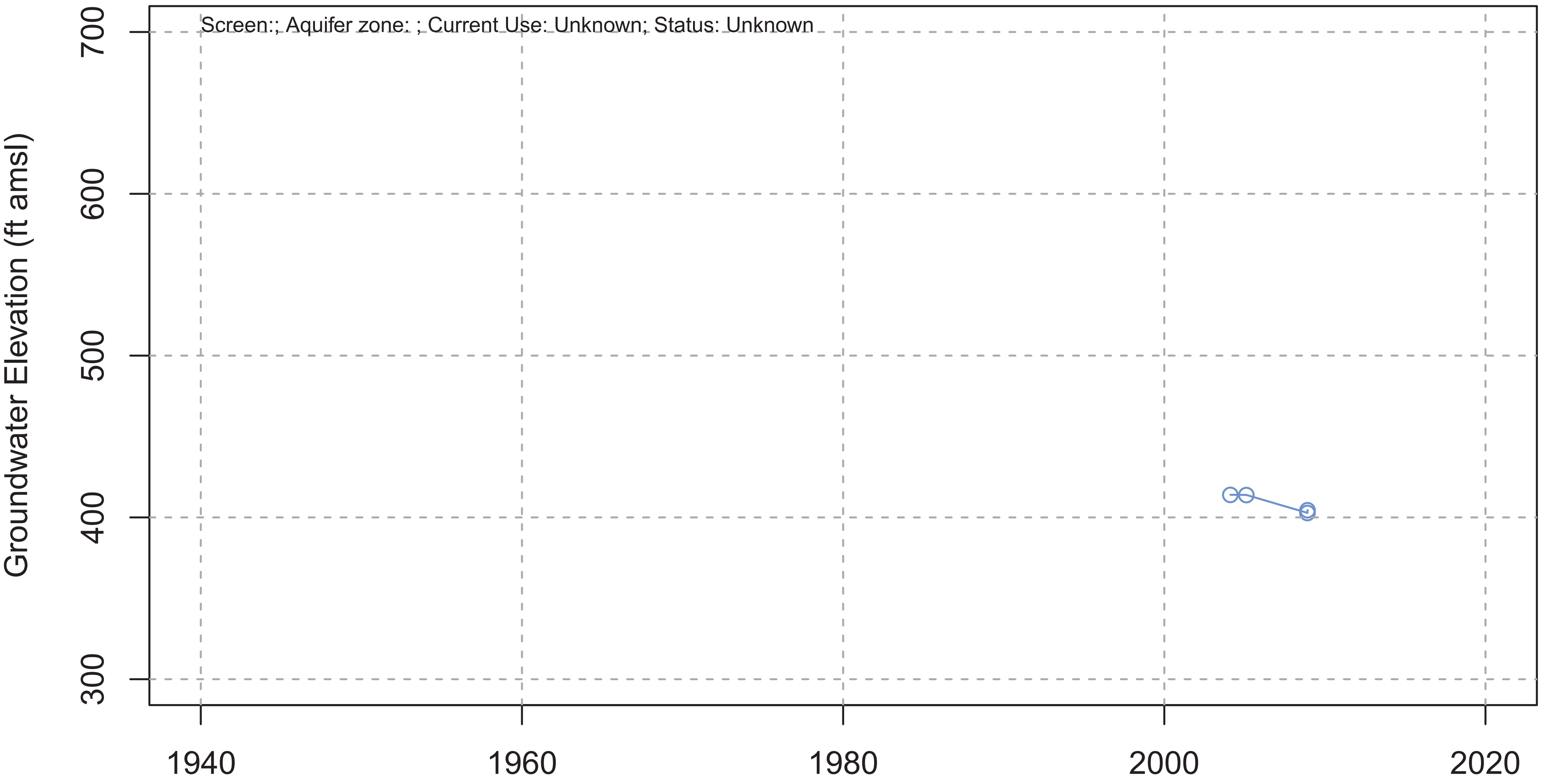


Local ID: ID4−11 ; Number of Measuring Agenc(y/ies): 2

010S006E32R001S



Local ID: ID4−1 ; Number of Measuring Agenc(y/ies): 5

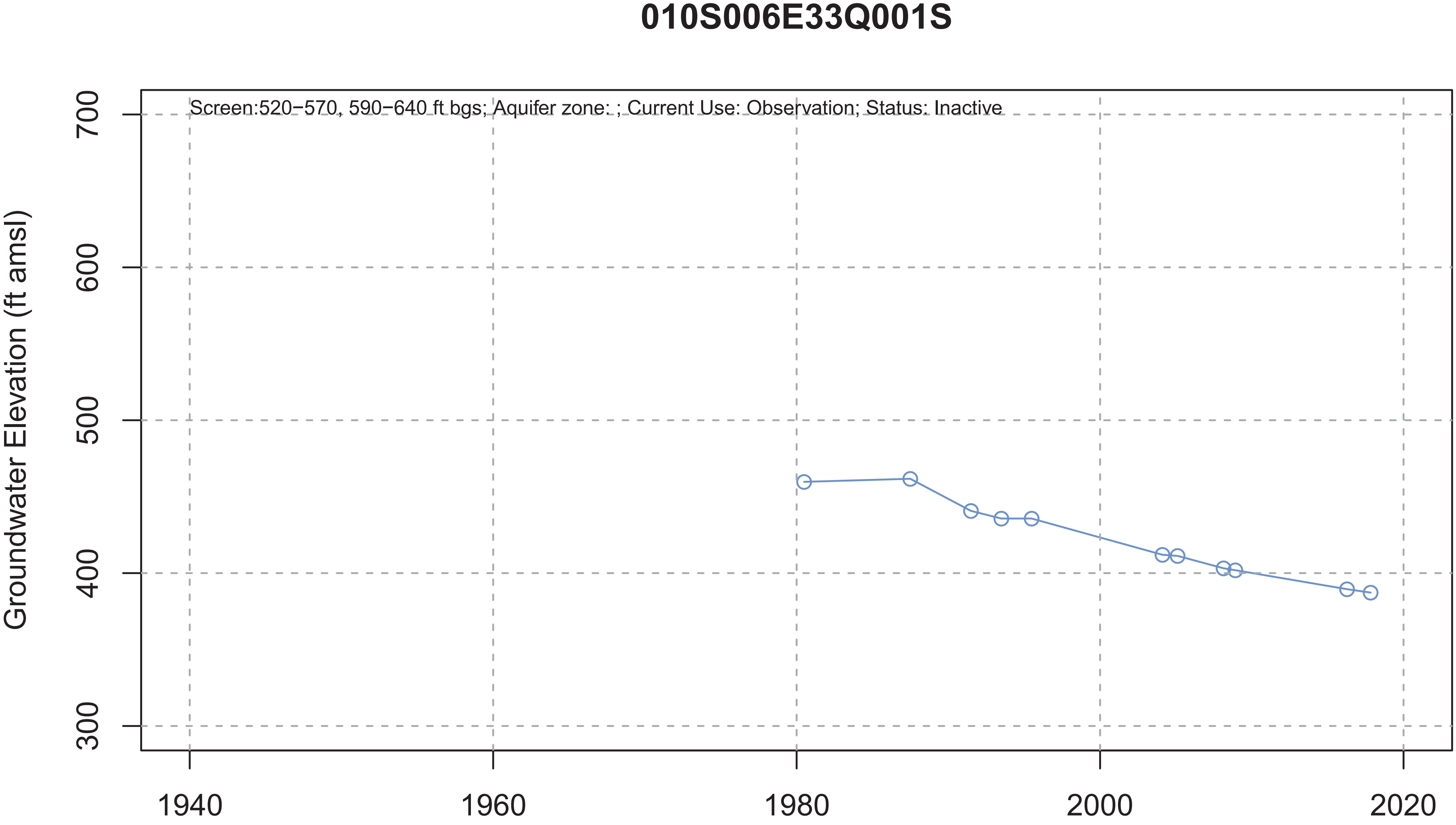


010S006E33C002S

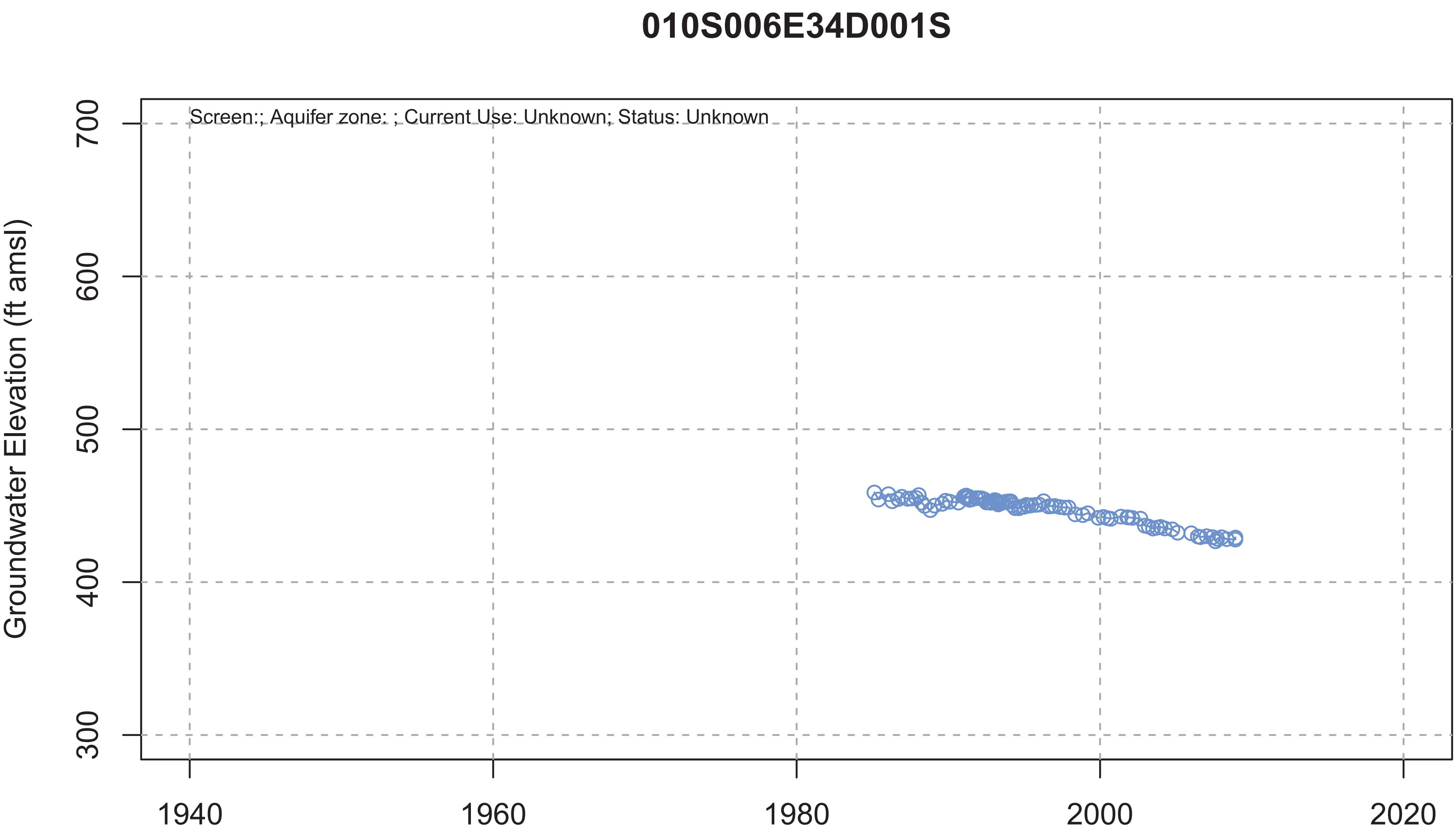
Local ID: Springs 2 ; Number of Measuring Agenc(y/ies): 2

010S006E33J001S

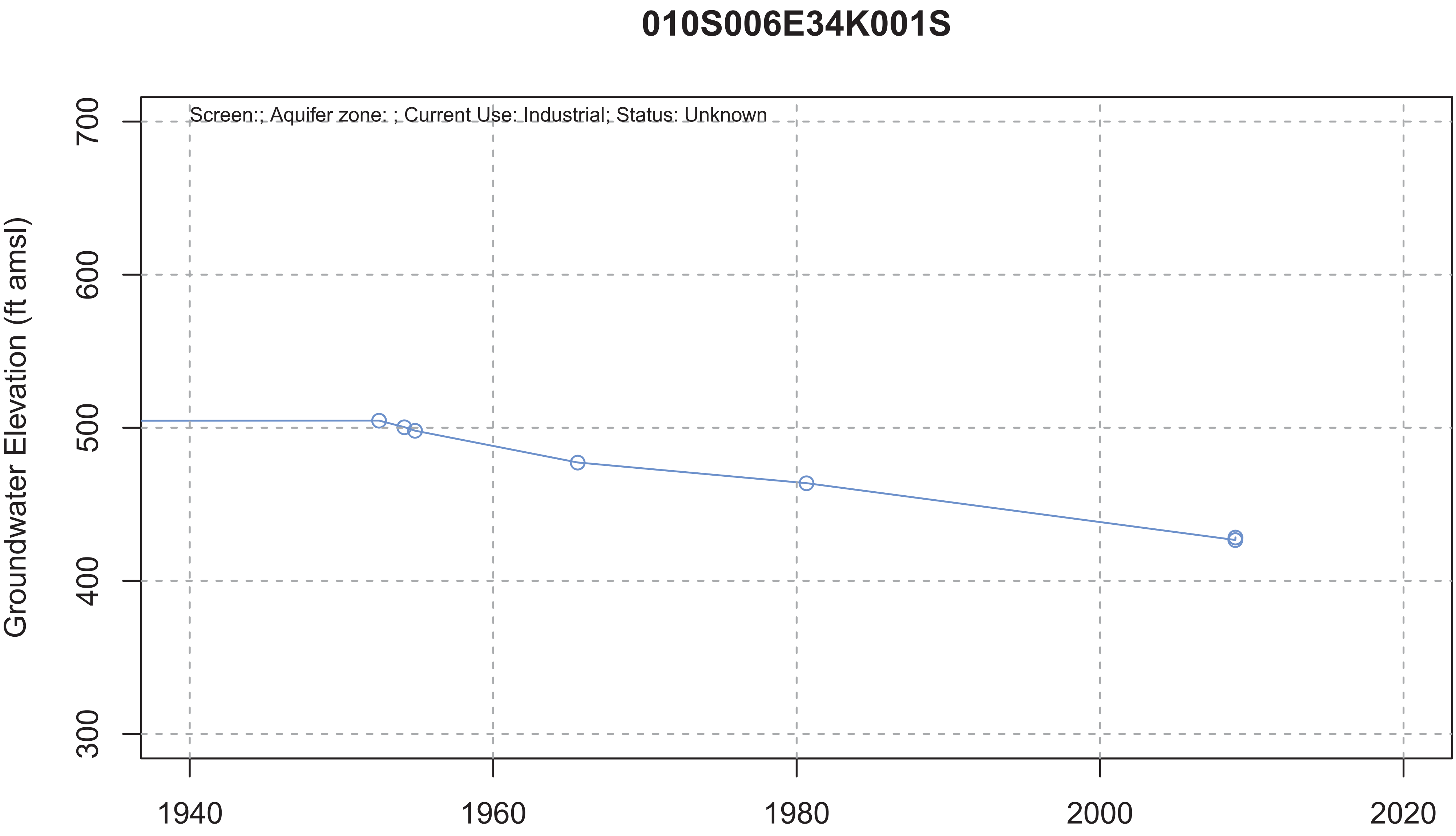
Local ID: Palleson ; Number of Measuring Agenc(y/ies): 3



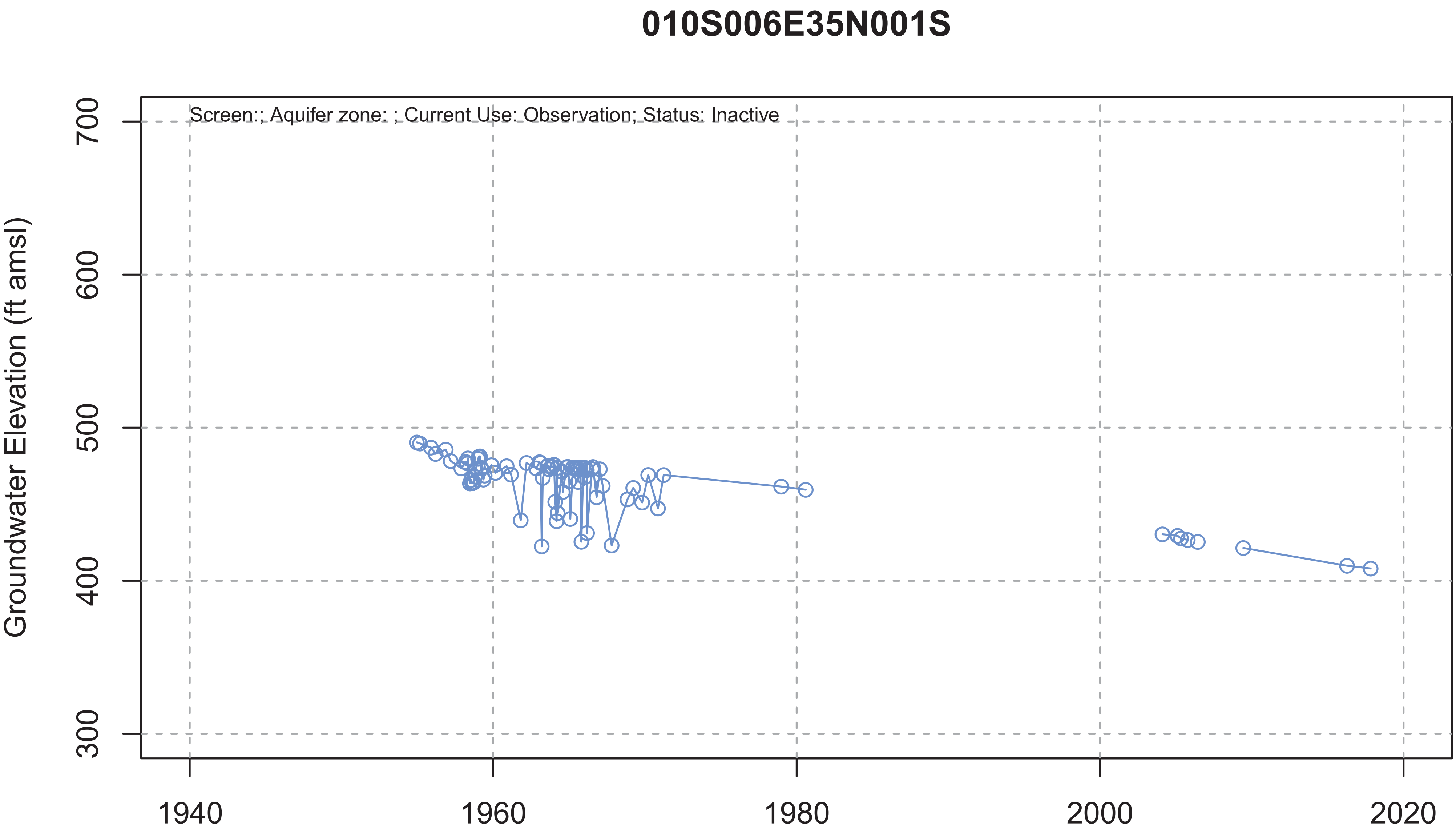
Local ID: ID4−5 ; Number of Measuring Agenc(y/ies): 4



Local ID: UEC North ; Number of Measuring Agenc(y/ies): 2

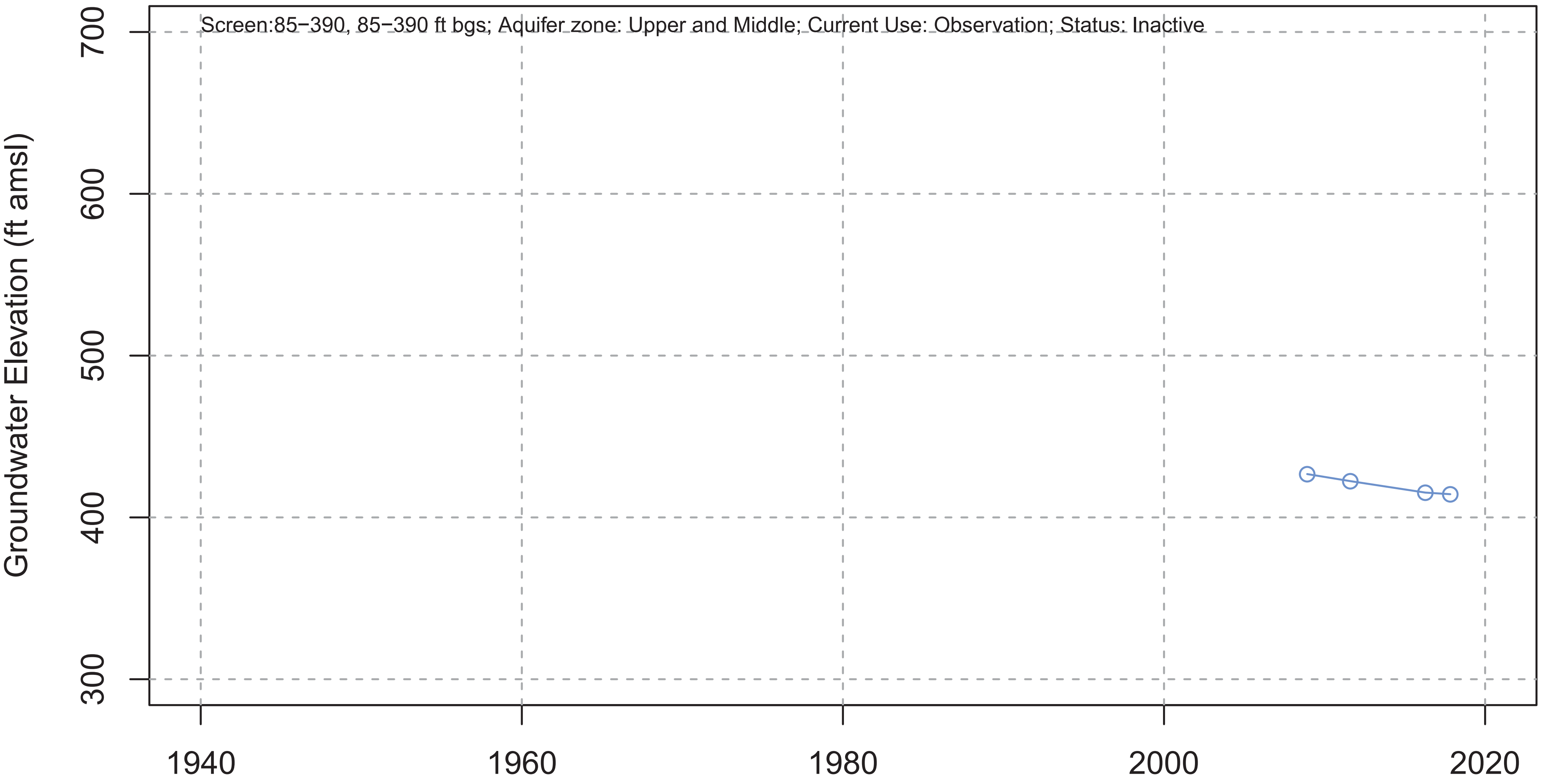


Local ID: Redimix Plant ; Number of Measuring Agenc(y/ies): 3

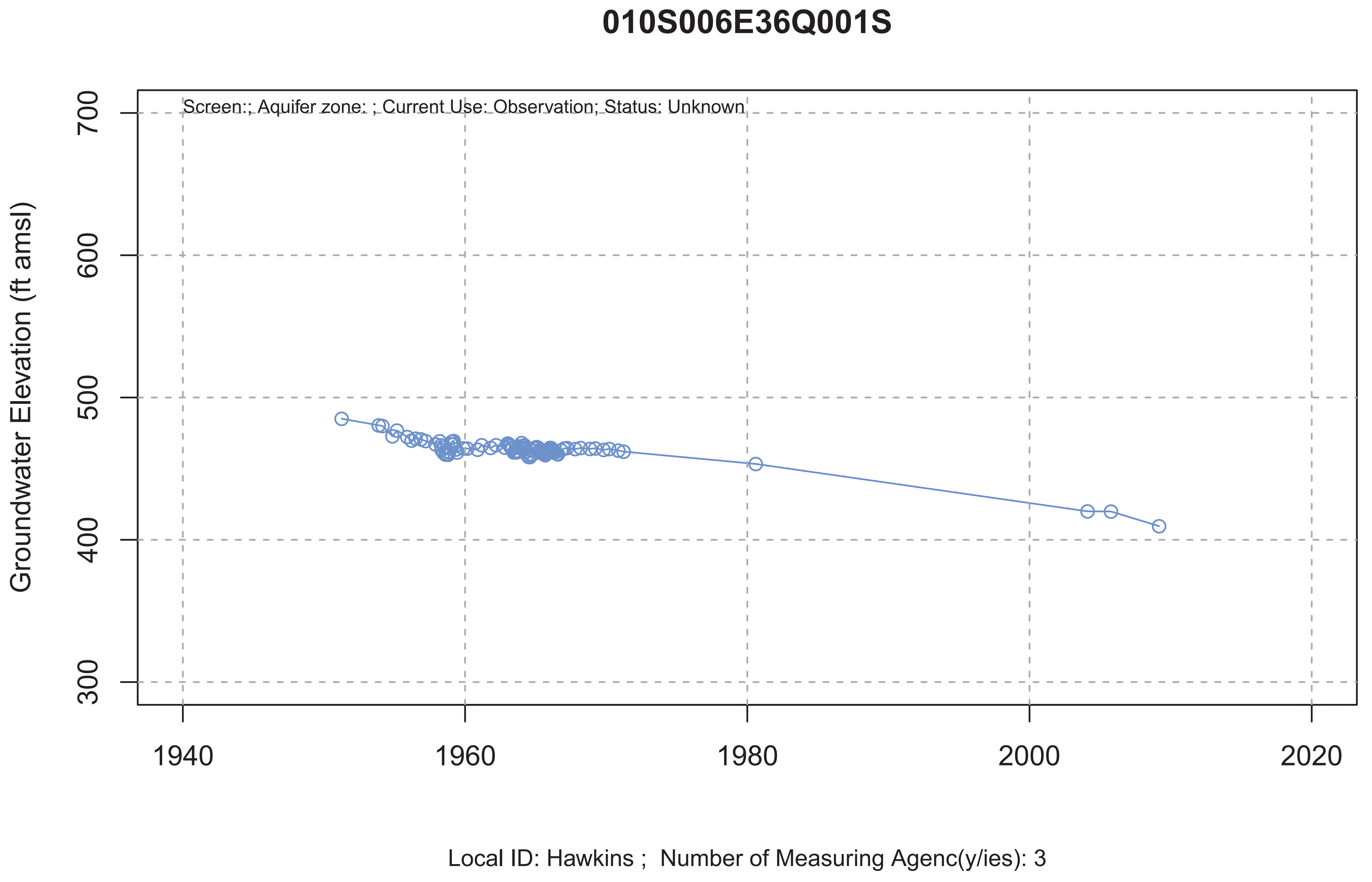


Local ID: Airport 2 ; Number of Measuring Agenc(y/ies): 6

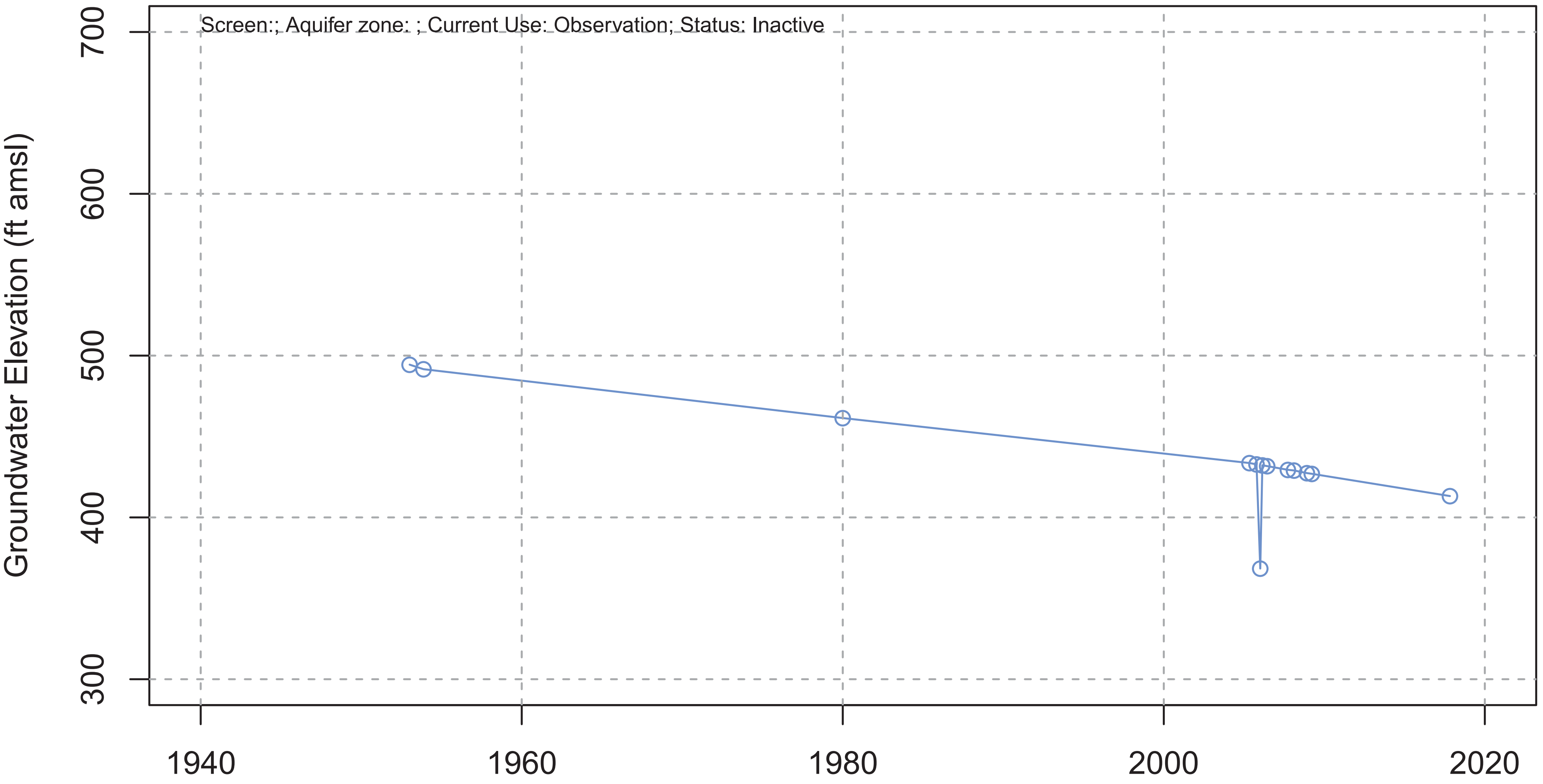
010S006E35Q001S



Local ID: MW−4 ; Number of Measuring Agenc(y/ies): 3

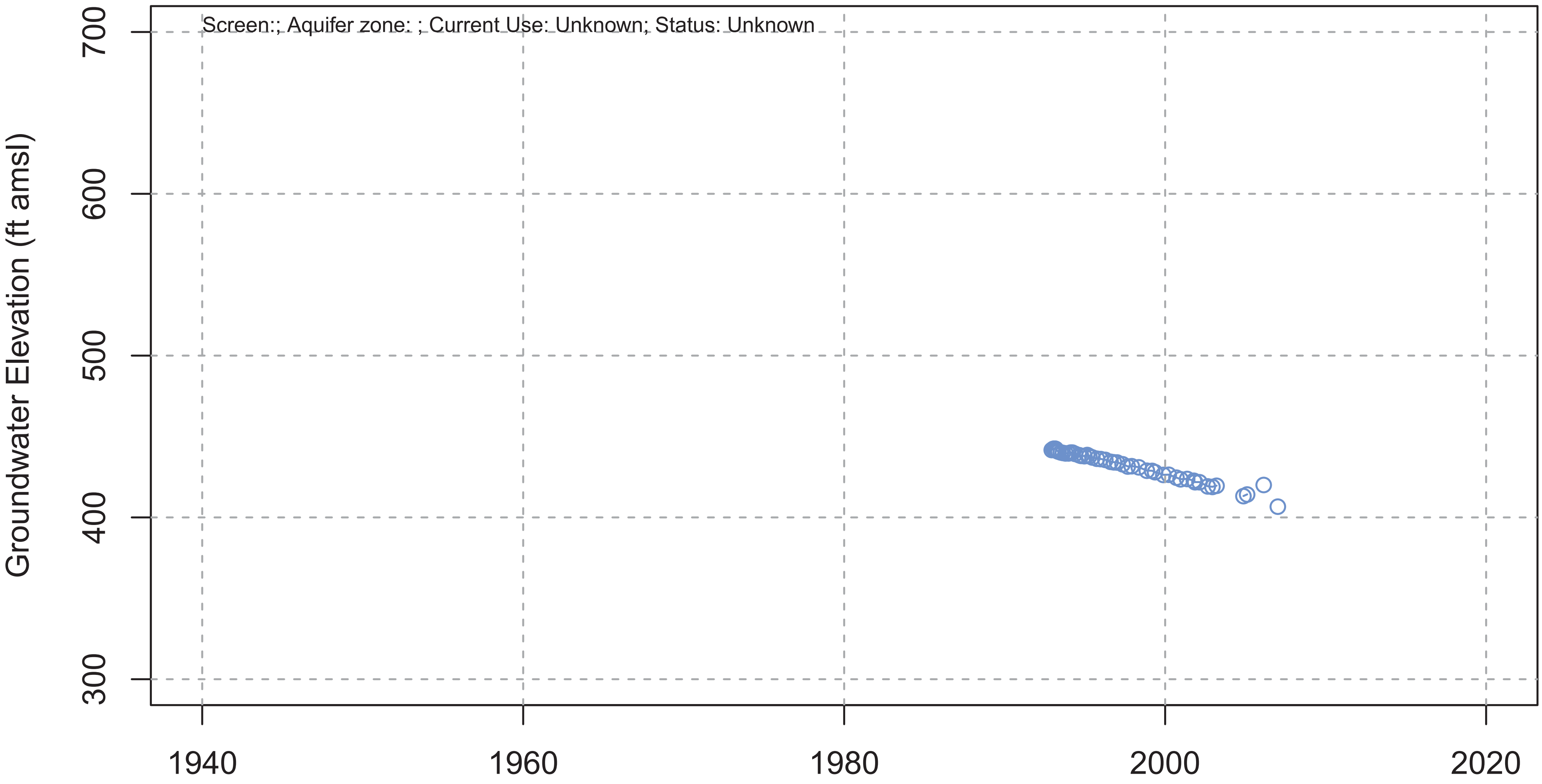
010S006E36Q001S
Screen:; Aquifer zone: ; Current Use: Observation; Status: Unknown
Groundwater Elevation (ft amsl)
700
600
500
400
300
1940
1960
1980
2000
2020
Local ID: Hawkins ; Number of Measuring Agenc(y/ies): 3

011S006E01C001S



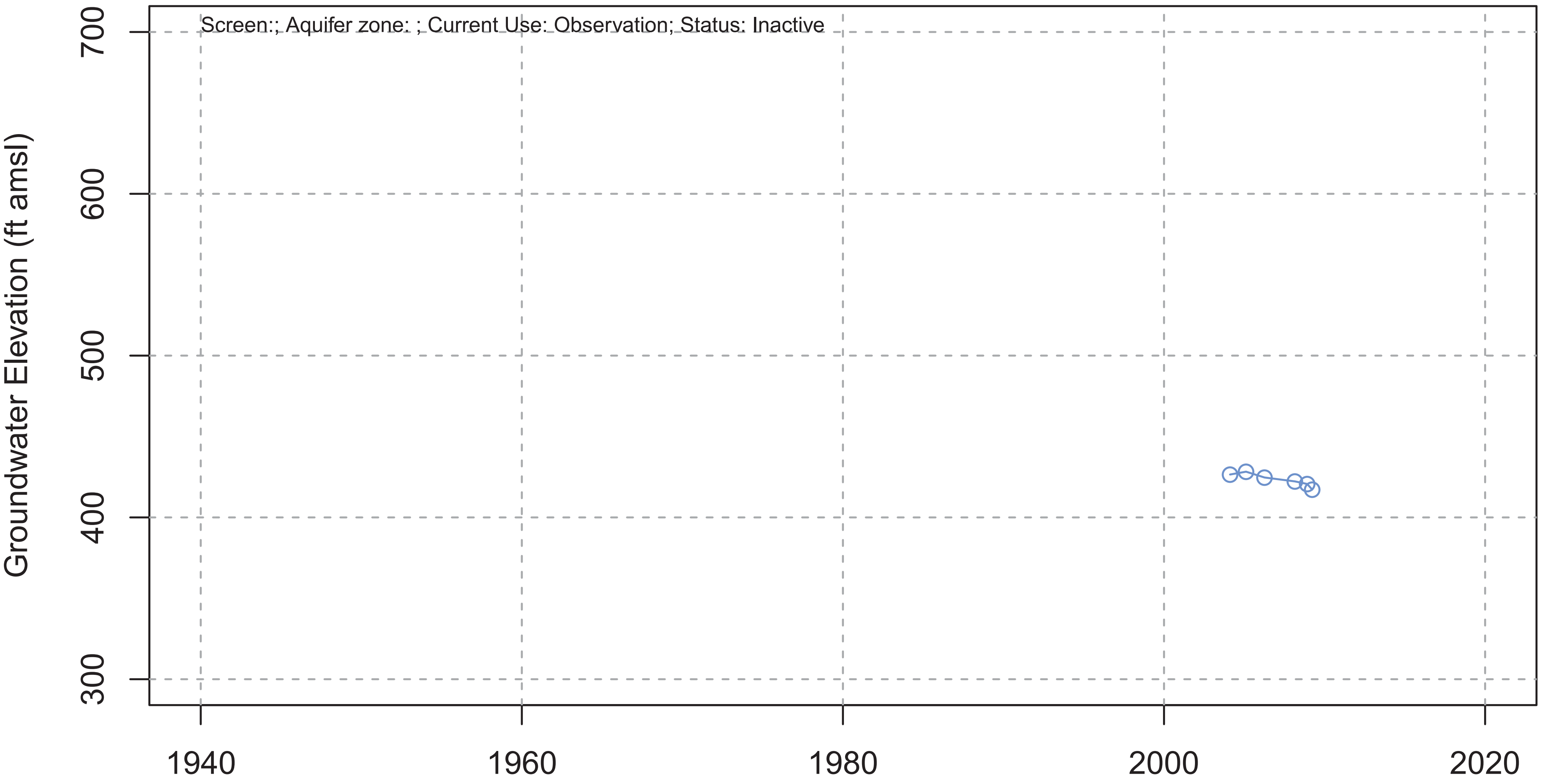
Local ID: Gabrych #2 ; Number of Measuring Agenc(y/ies): 4

011S006E02C003S



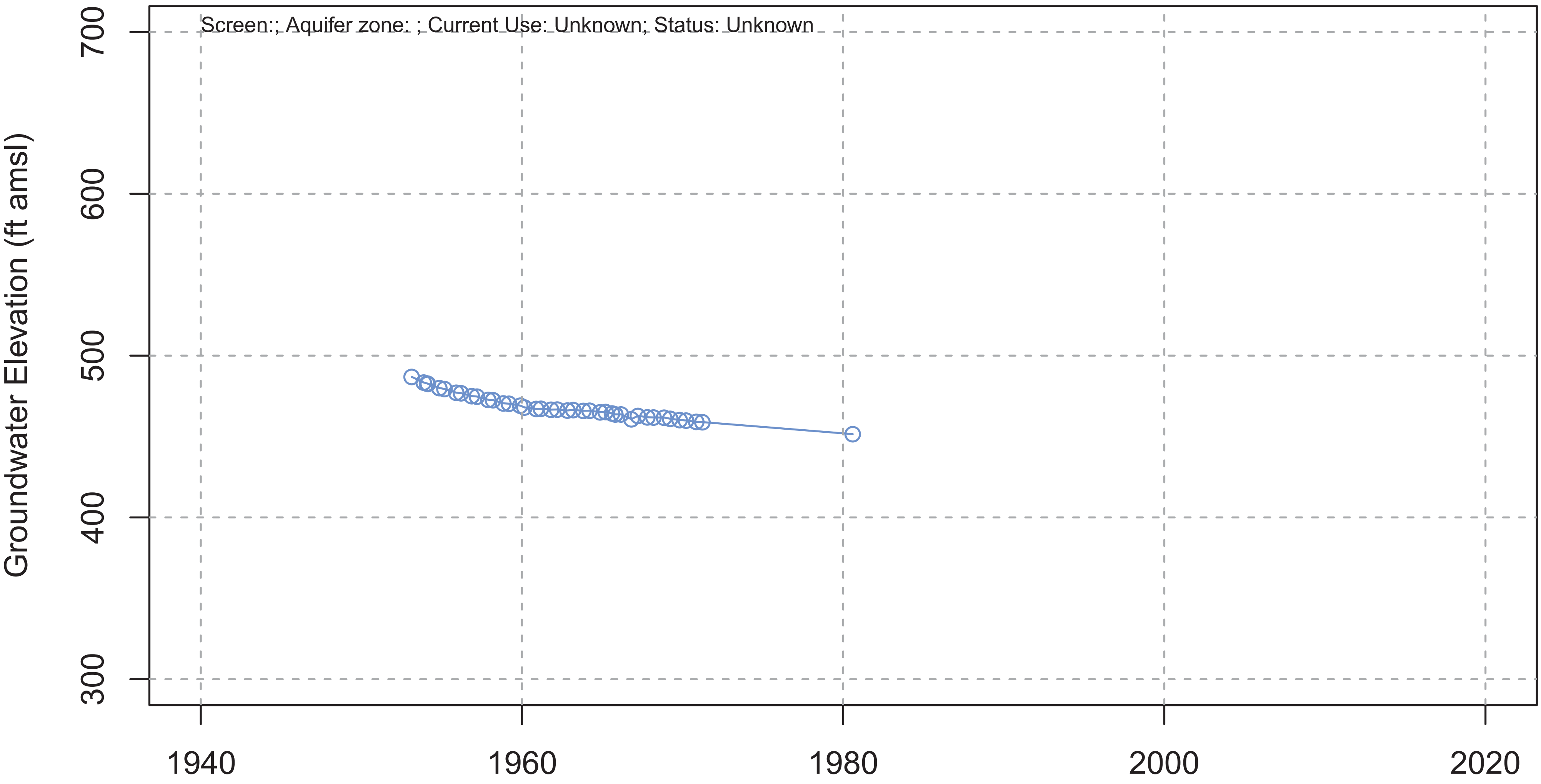
Local ID: N/A ; Number of Measuring Agenc(y/ies): 3

011S006E04F001S



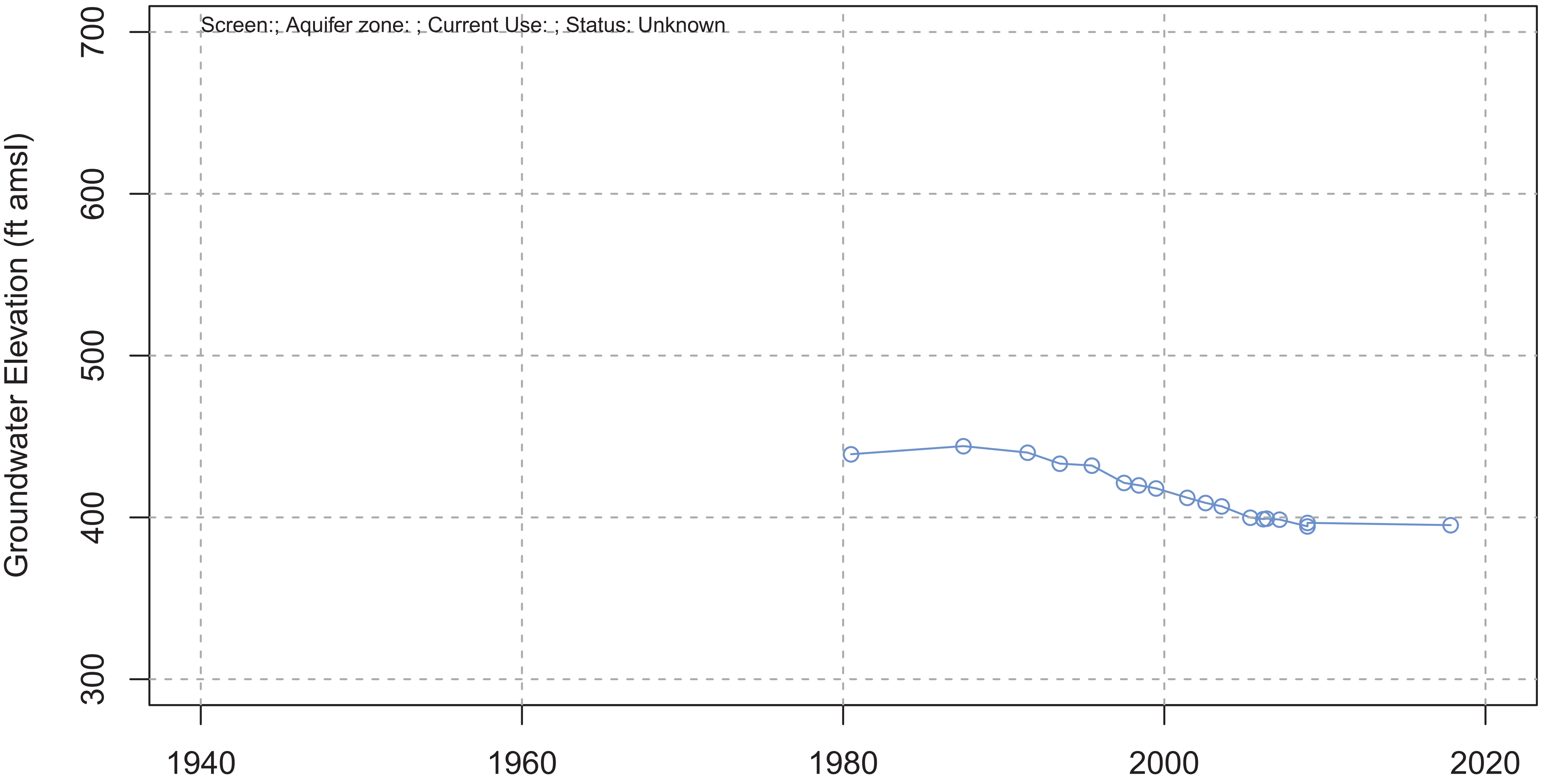
Local ID: Cameron 2 ; Number of Measuring Agenc(y/ies): 2

011S006E05P001S



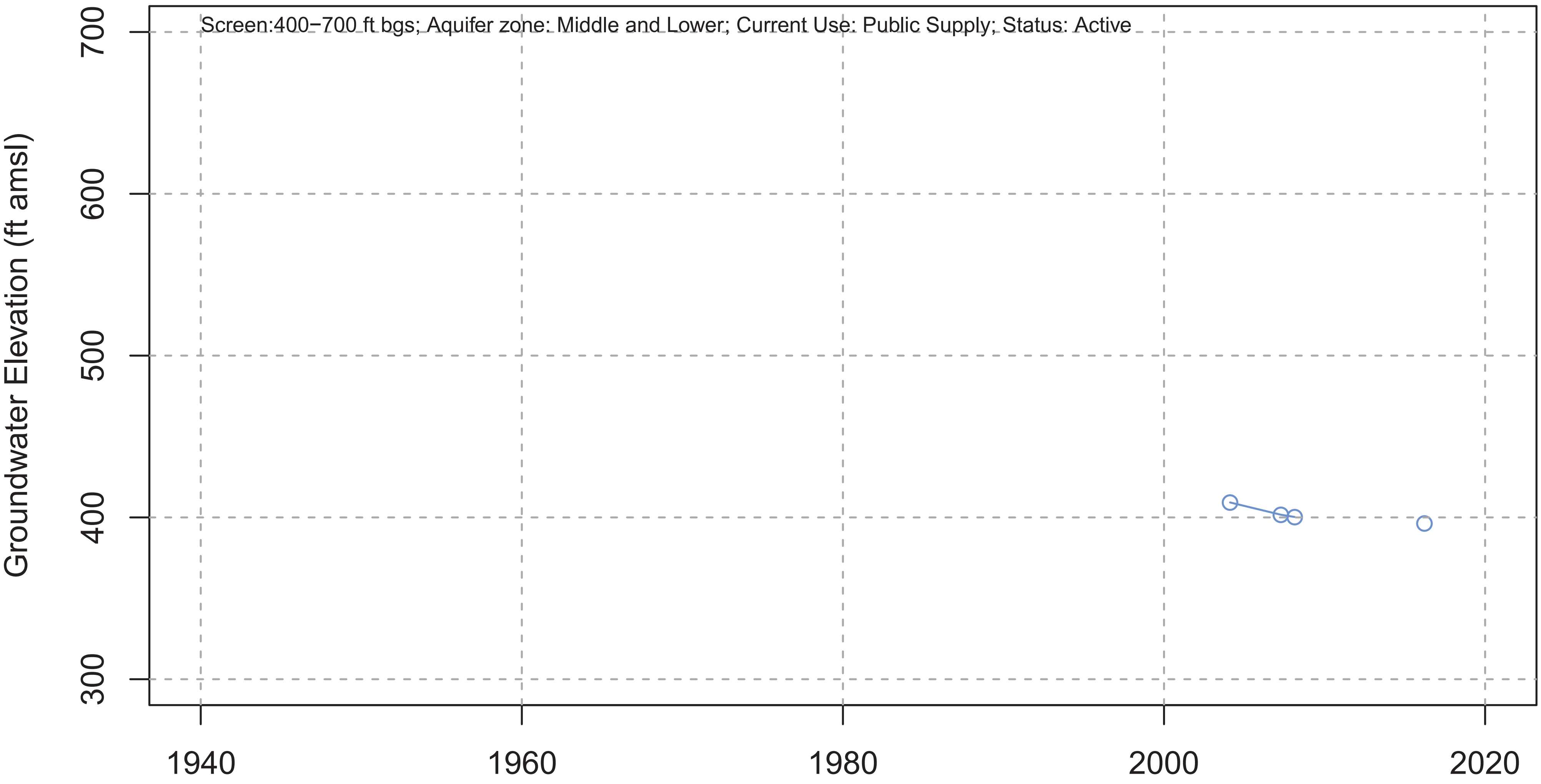
Local ID: Bending Elbow ; Number of Measuring Agenc(y/ies): 3

011S006E07K003S

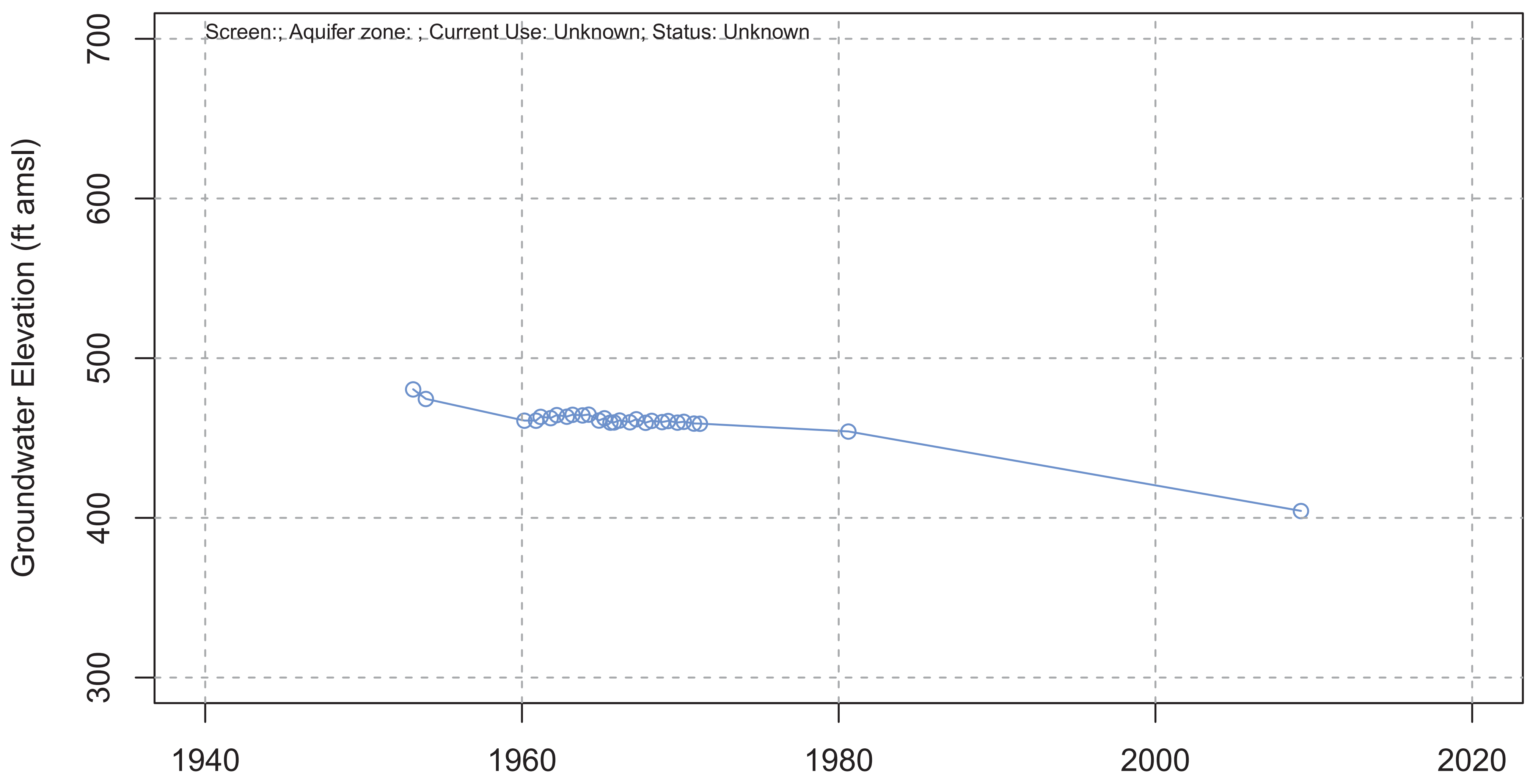


Local ID: N/A ; Number of Measuring Agenc(y/ies): 3

011S006E09E001S

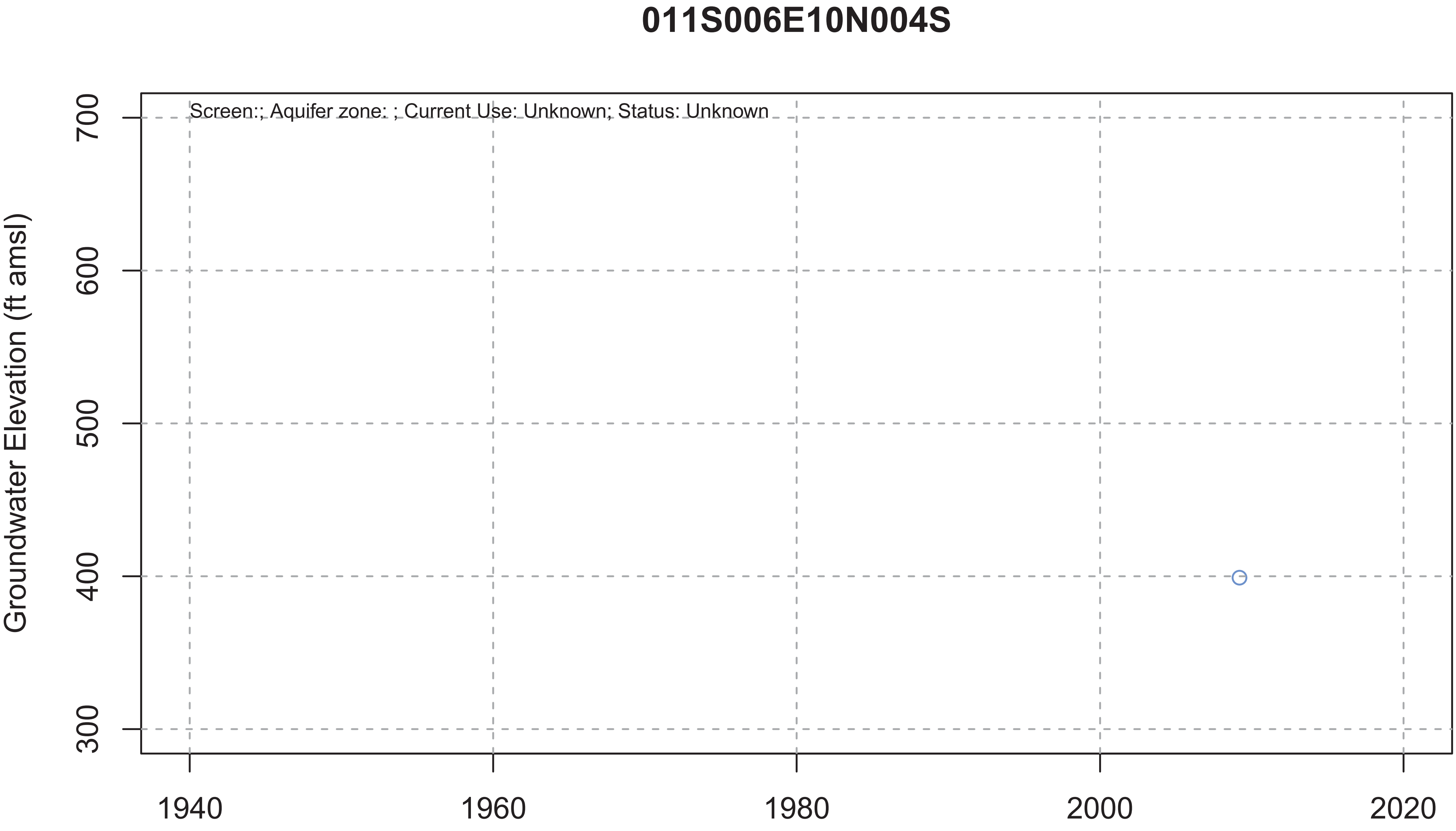


Local ID: ID5−5 ; Number of Measuring Agenc(y/ies): 3



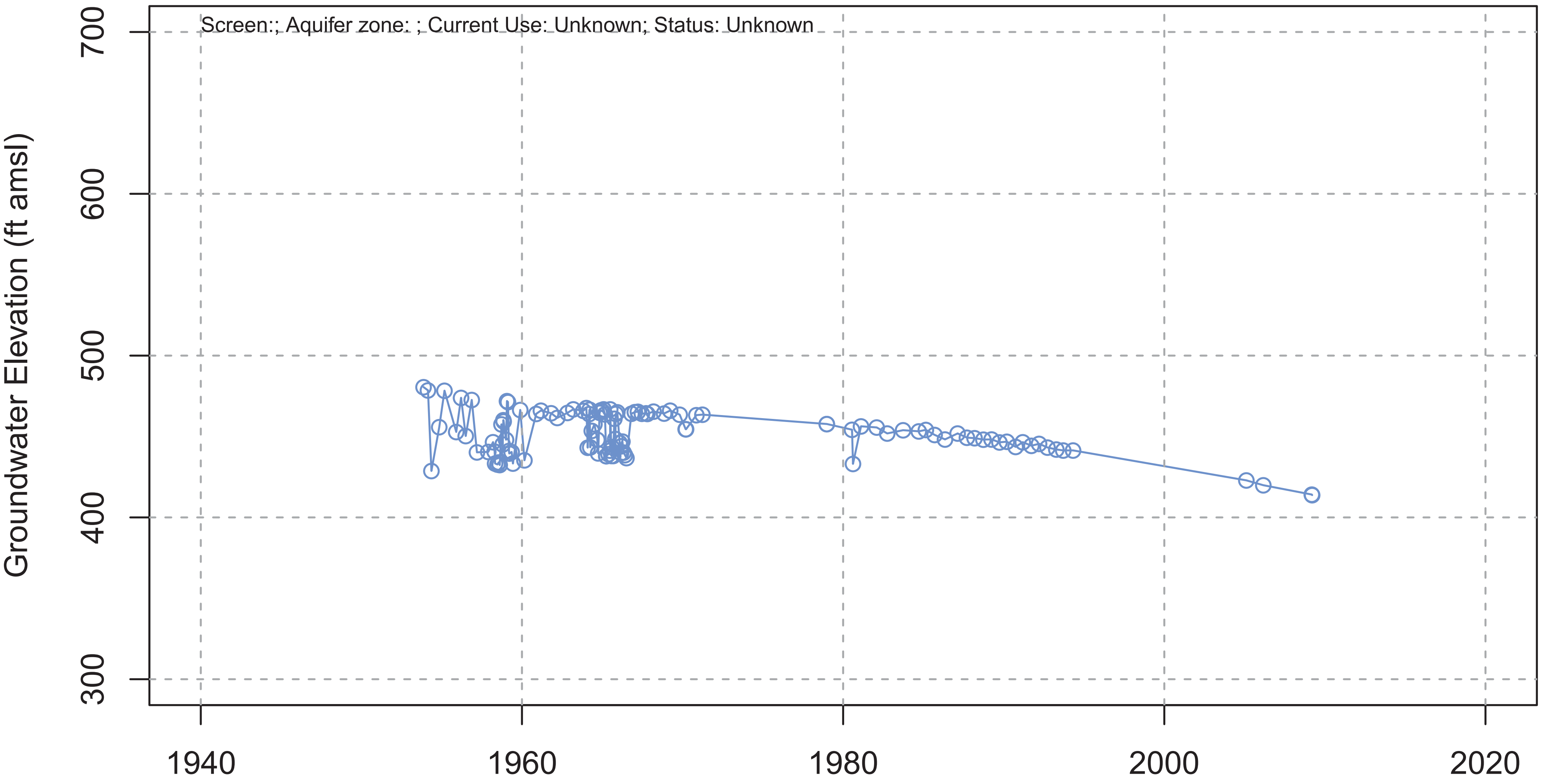
011S006E10N001S

Local ID: Abandoned Motel−1 ; Number of Measuring Agenc(y/ies): 2

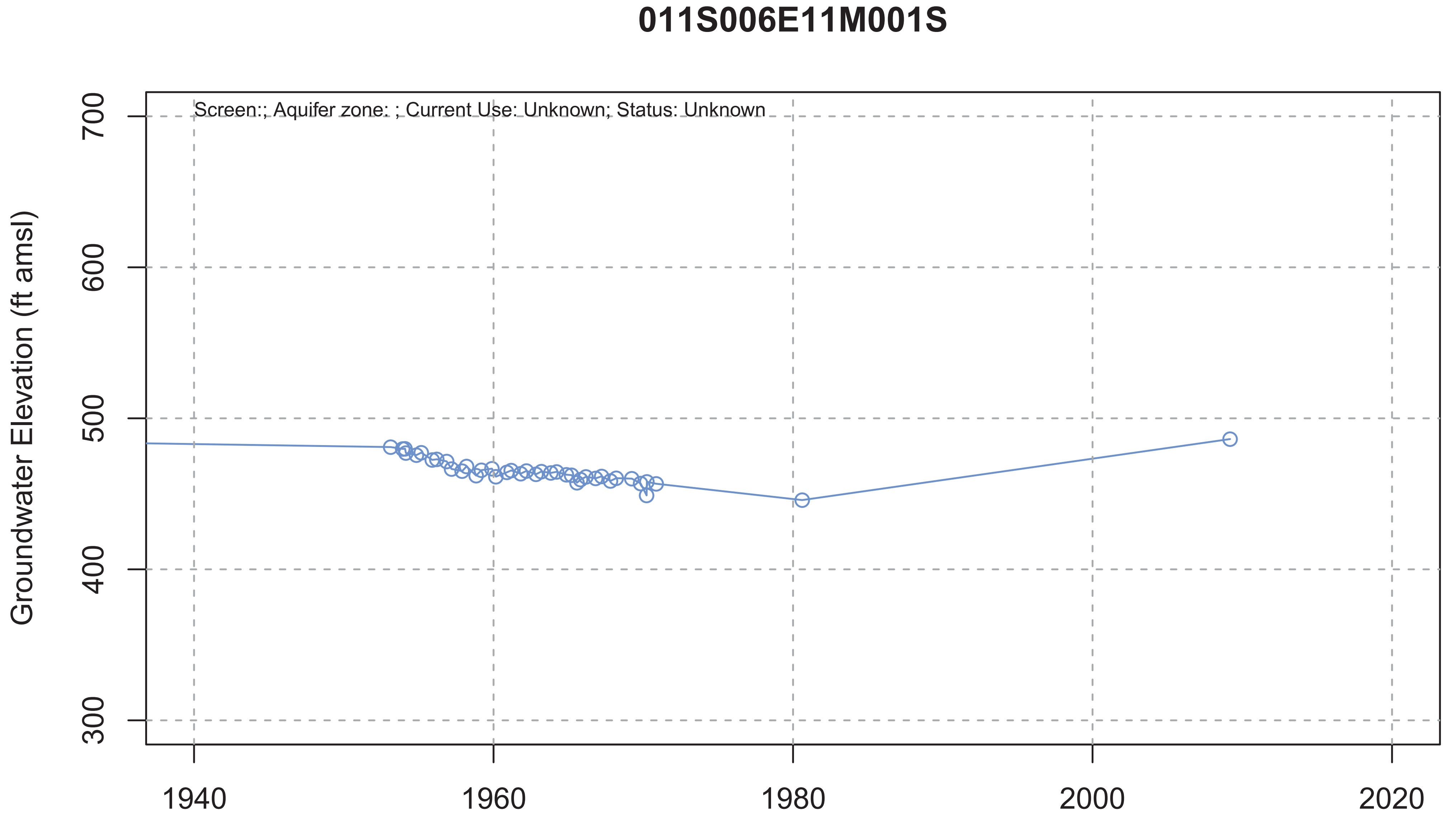


Local ID: Abandoned motel−2 ; Number of Measuring Agenc(y/ies): 1

011S006E11D002S

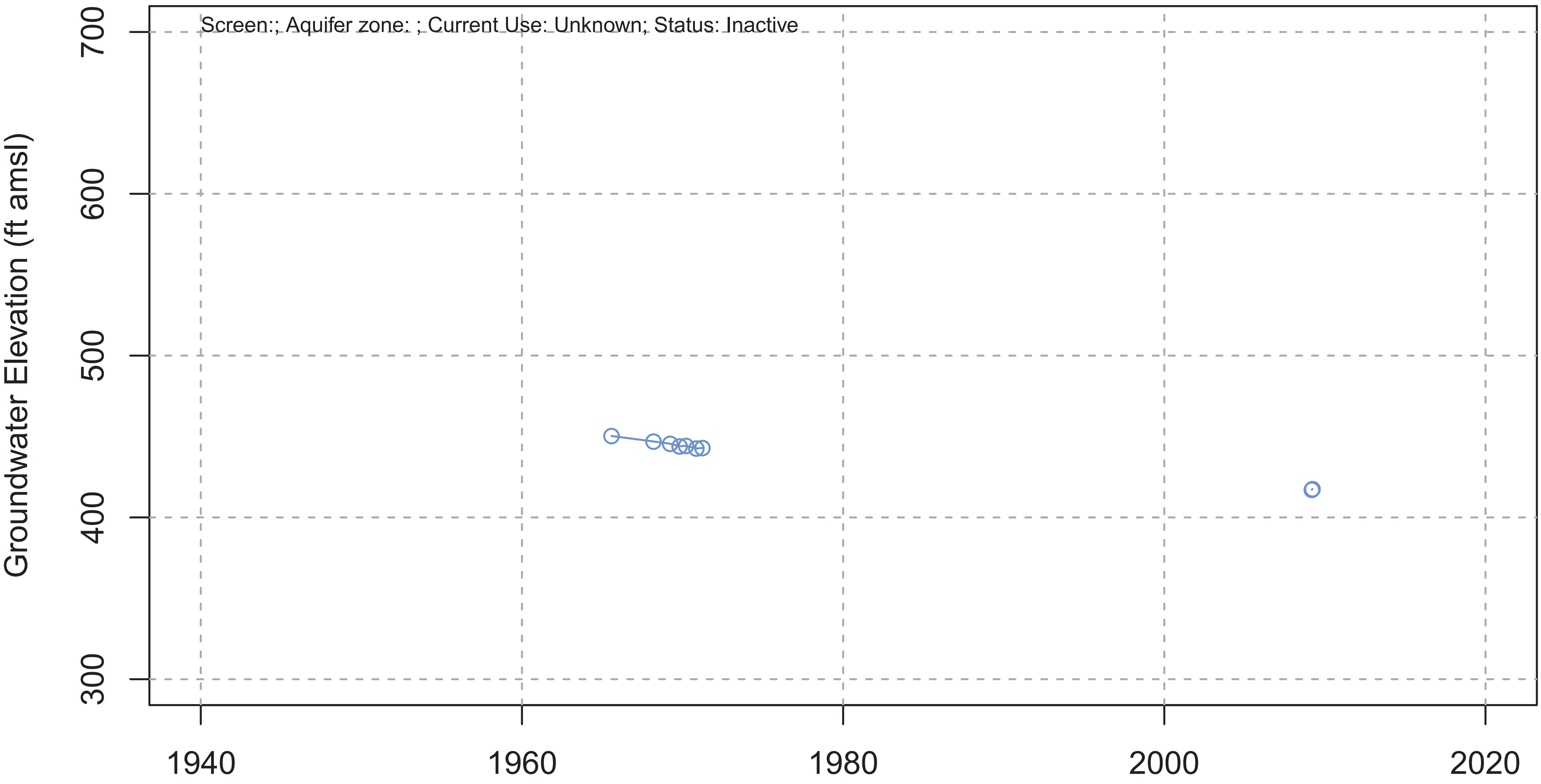


Local ID: Berkovitch ; Number of Measuring Agenc(y/ies): 2



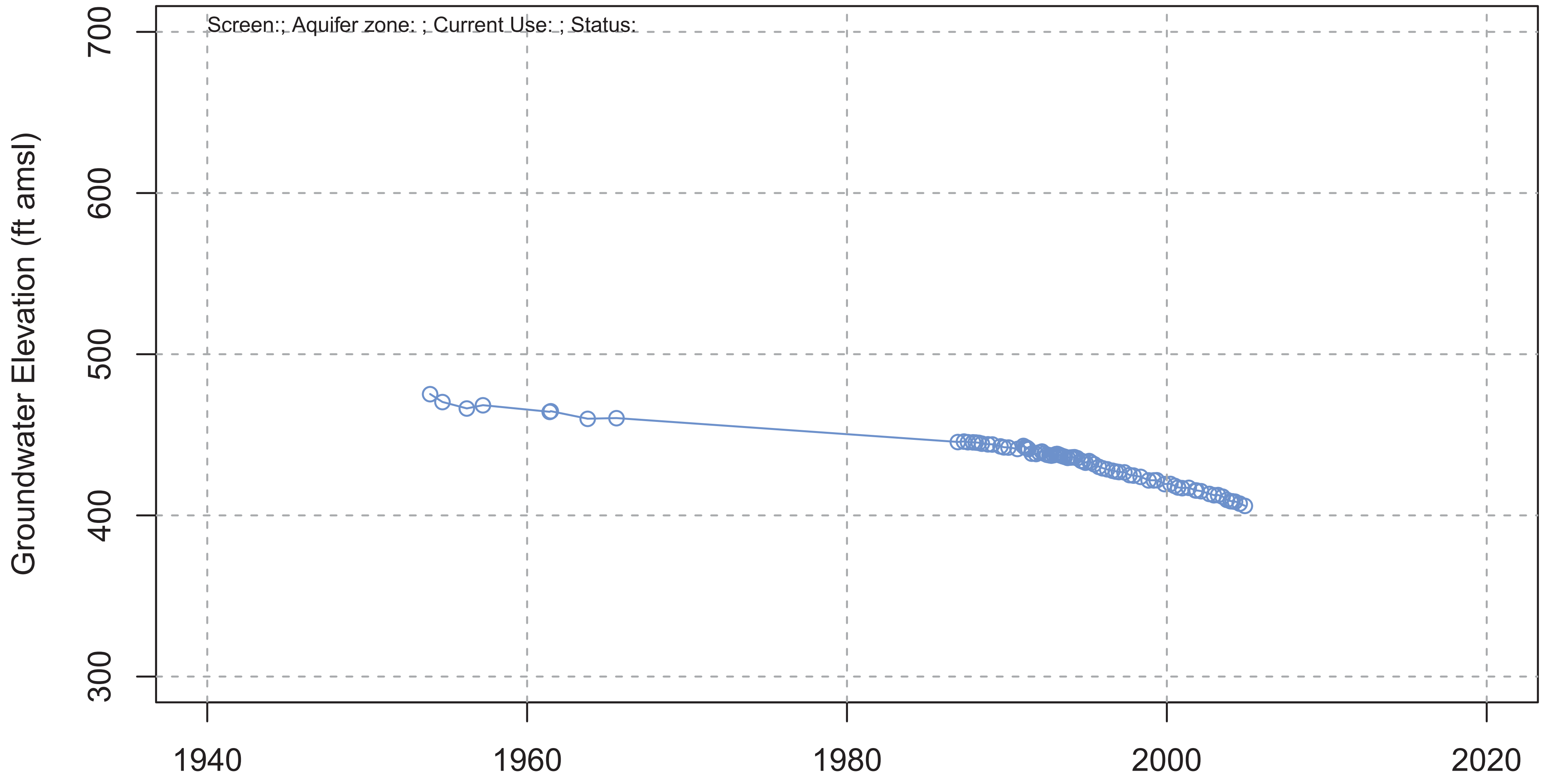
Local ID: Burned House 1 ; Number of Measuring Agenc(y/ies): 2

011S006E12G001S



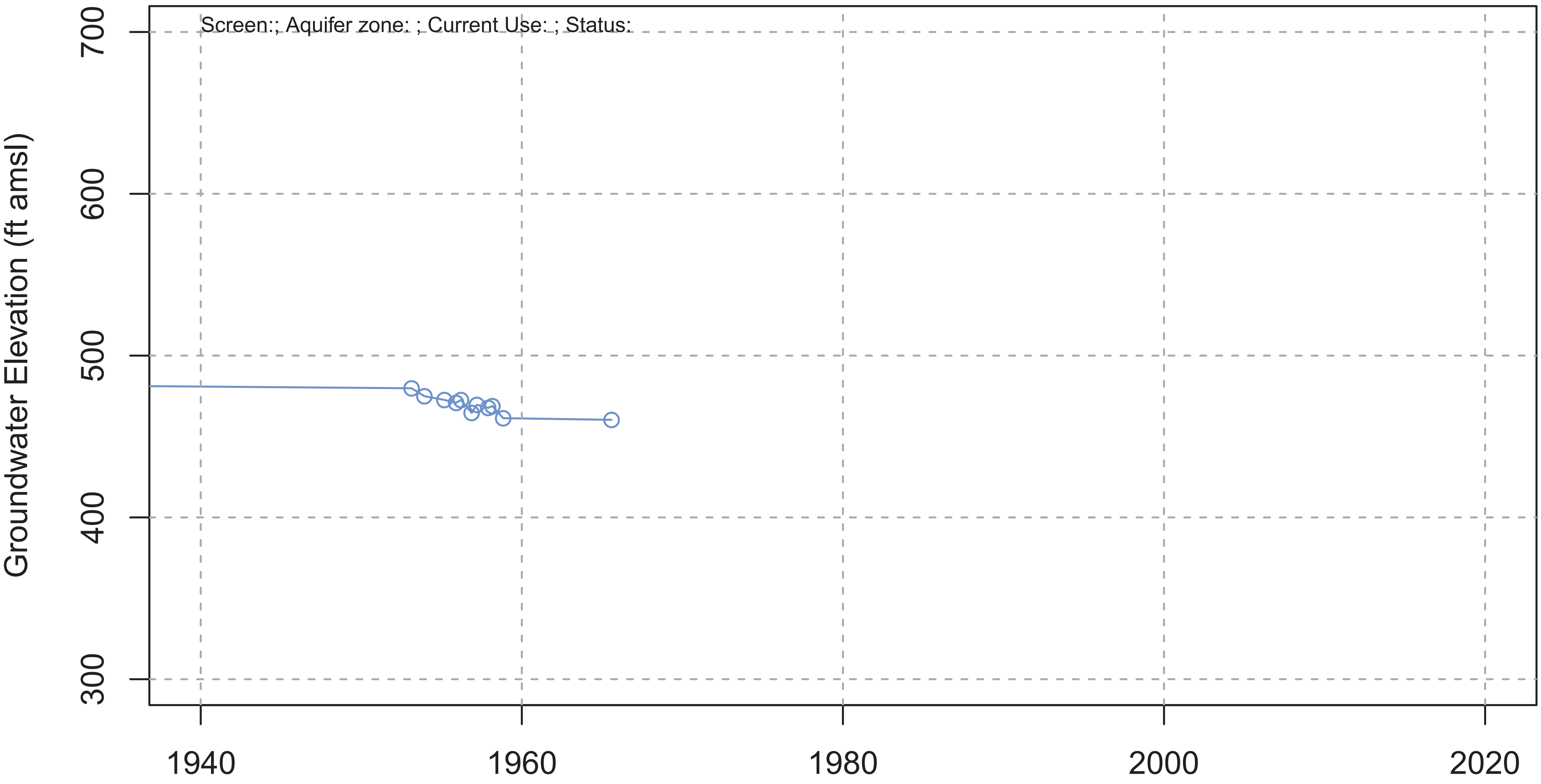
Local ID: Sink − 12G1 ; Number of Measuring Agenc(y/ies): 4

011S006E15E002S



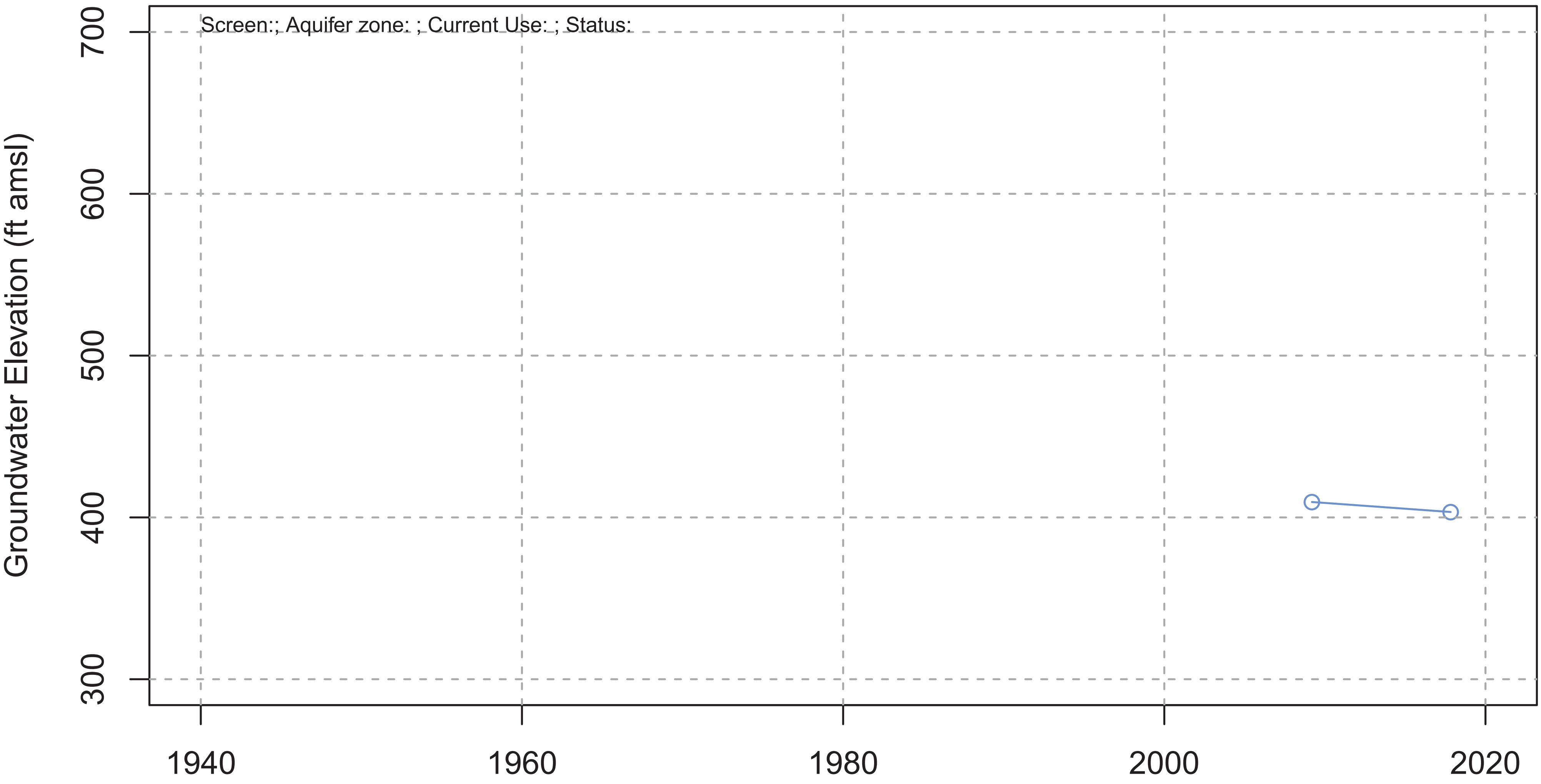
Local ID: Levie Well ; Number of Measuring Agenc(y/ies): 2

011S006E15F001S



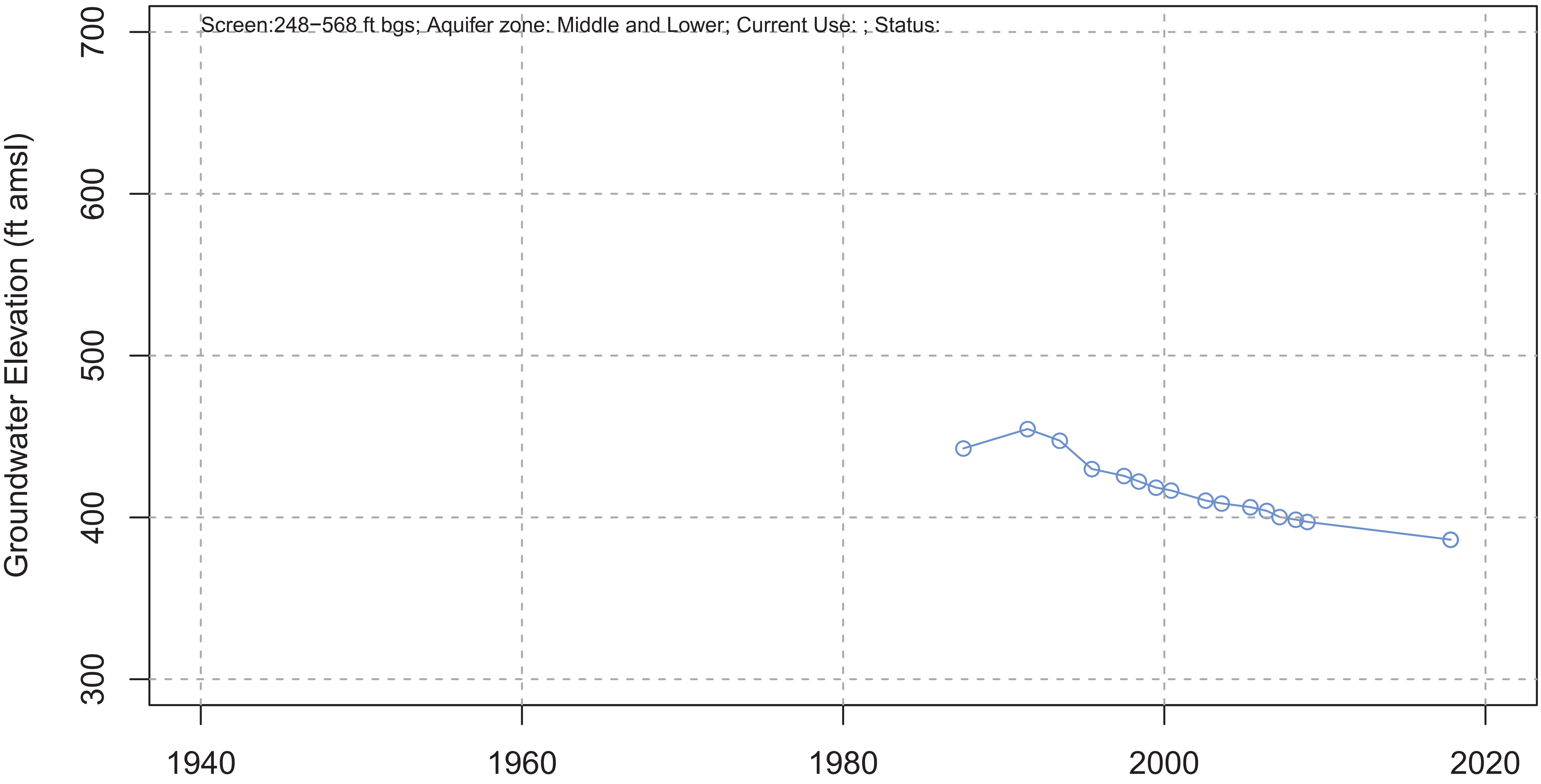
Local ID: N/A ; Number of Measuring Agenc(y/ies): 3

011S006E15G001S



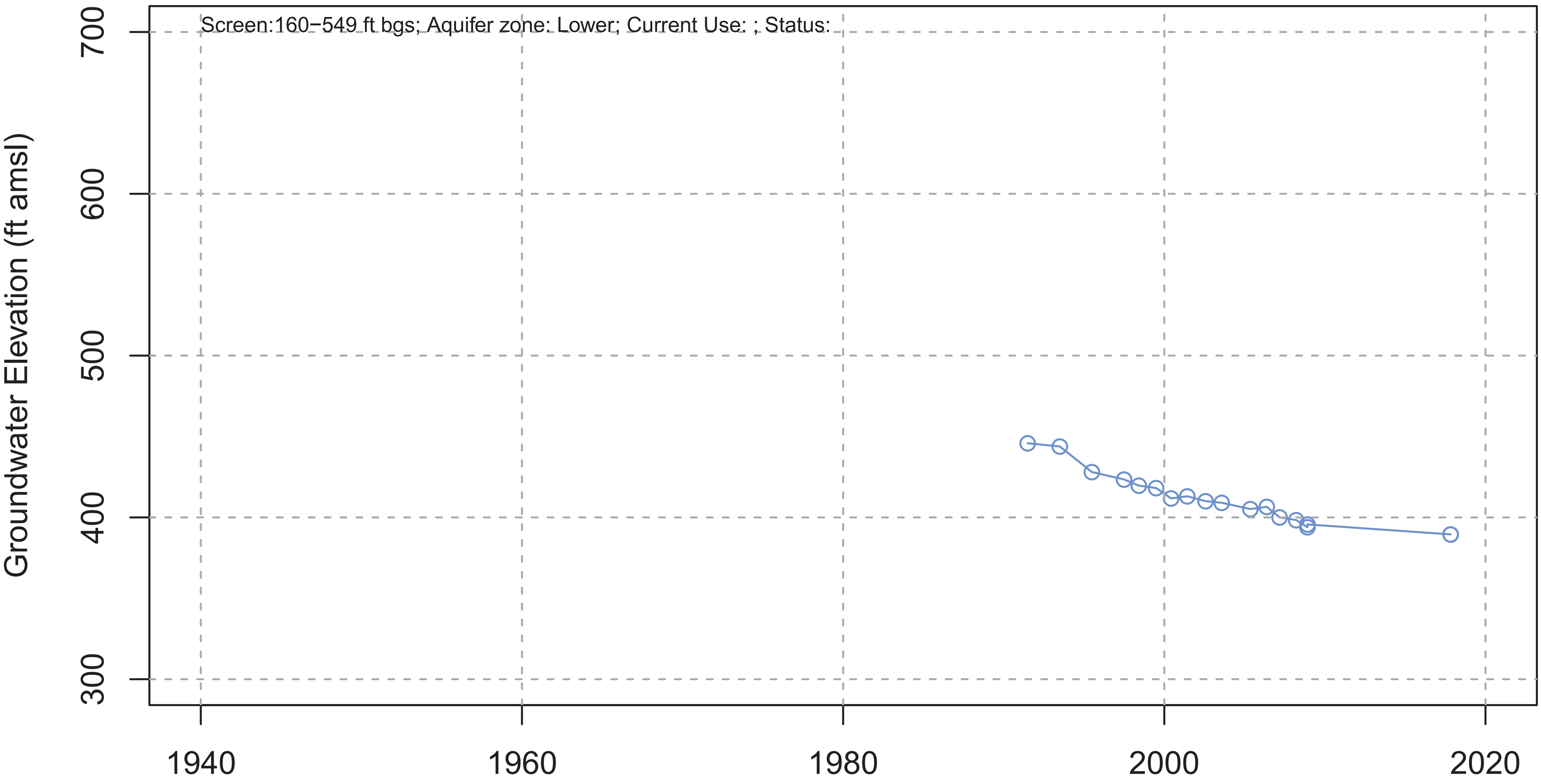
Local ID: County Yard (SD DOT) ; Number of Measuring Agenc(y/ies): 2

011S006E16A002S



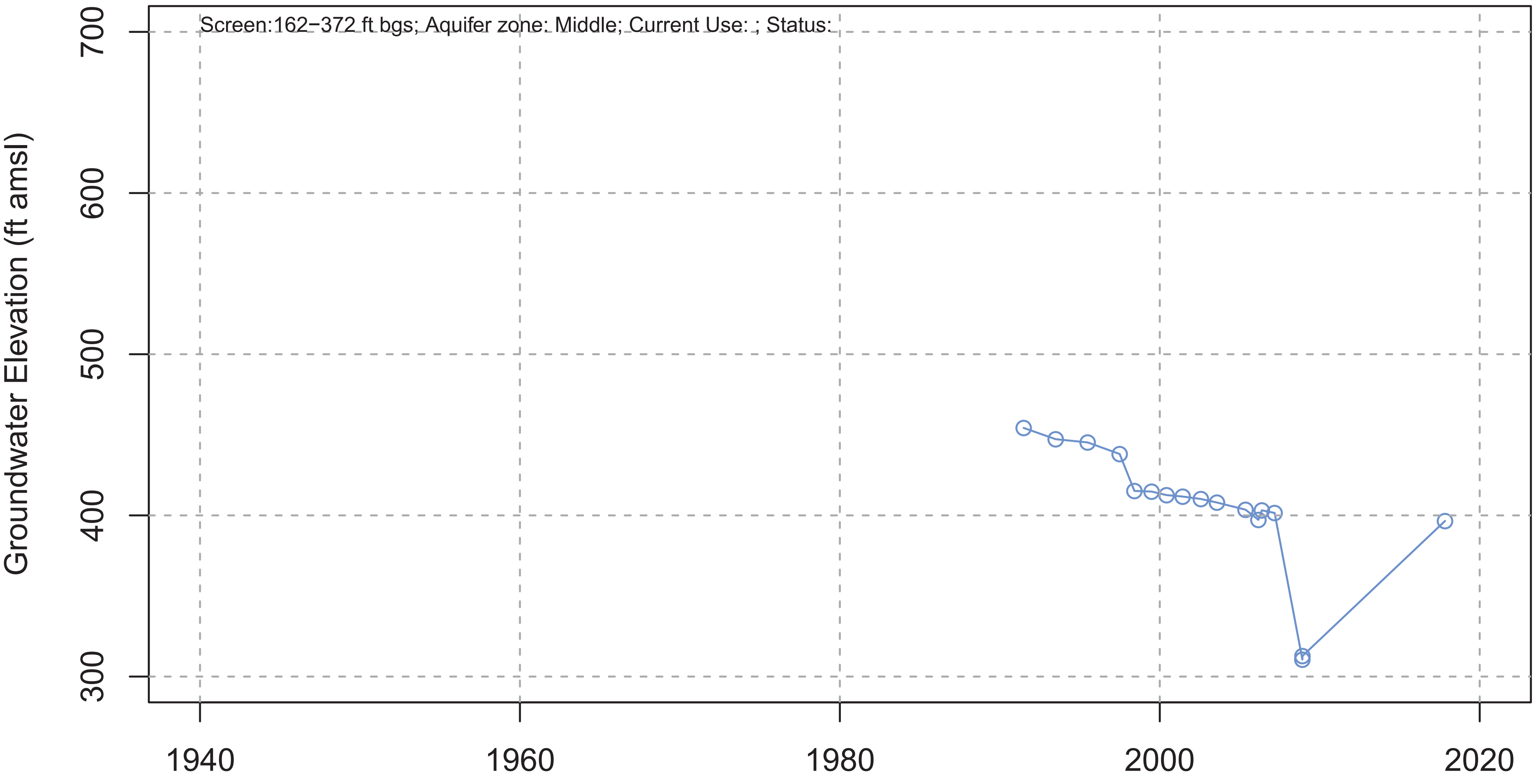
Local ID: ID1−12 ; Number of Measuring Agenc(y/ies): 4

011S006E16N001S



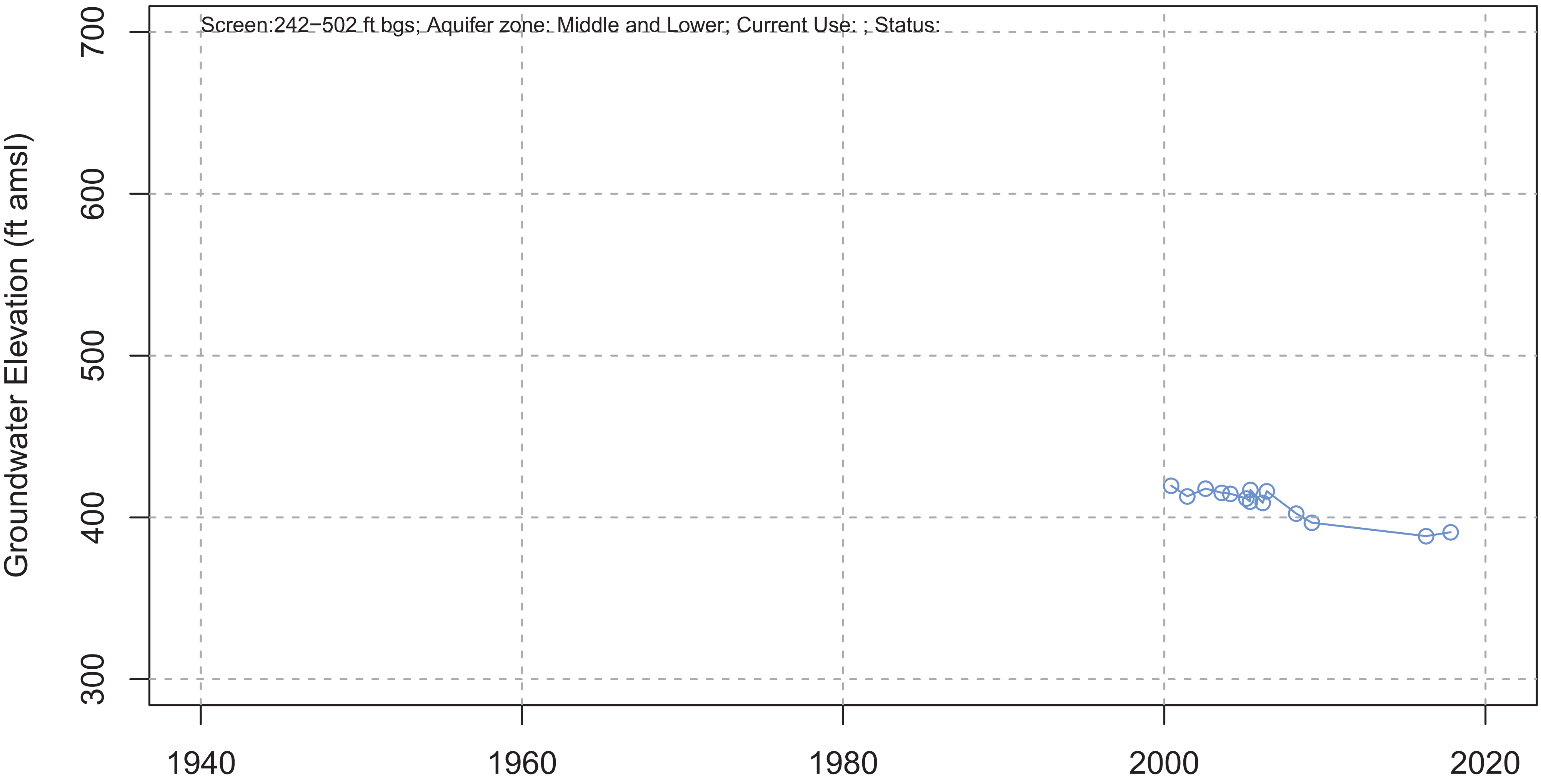
Local ID: ID1−16 ; Number of Measuring Agenc(y/ies): 4

011S006E18L001S



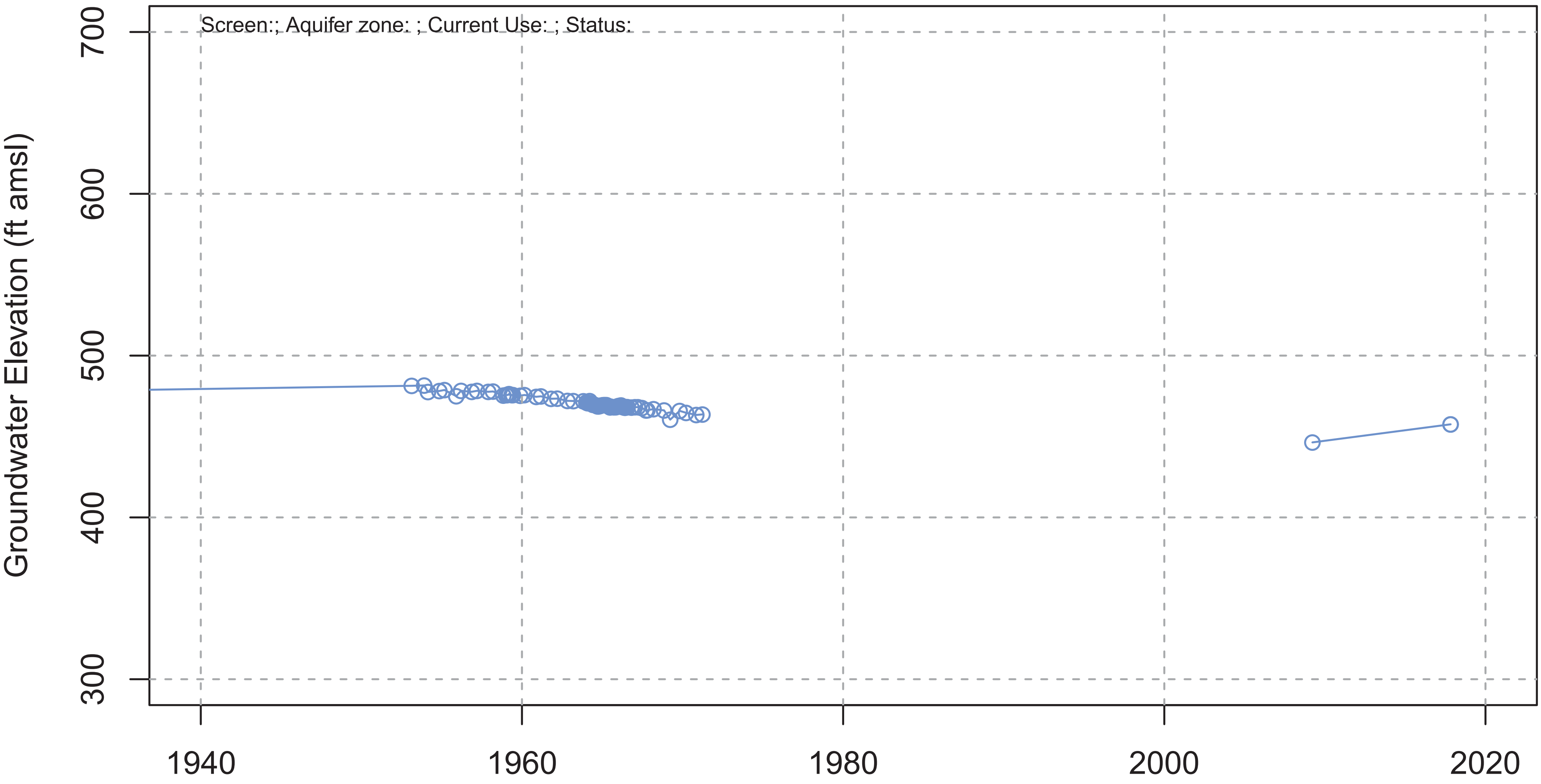
Local ID: ID4−10 ; Number of Measuring Agenc(y/ies): 3

011S006E20A001S



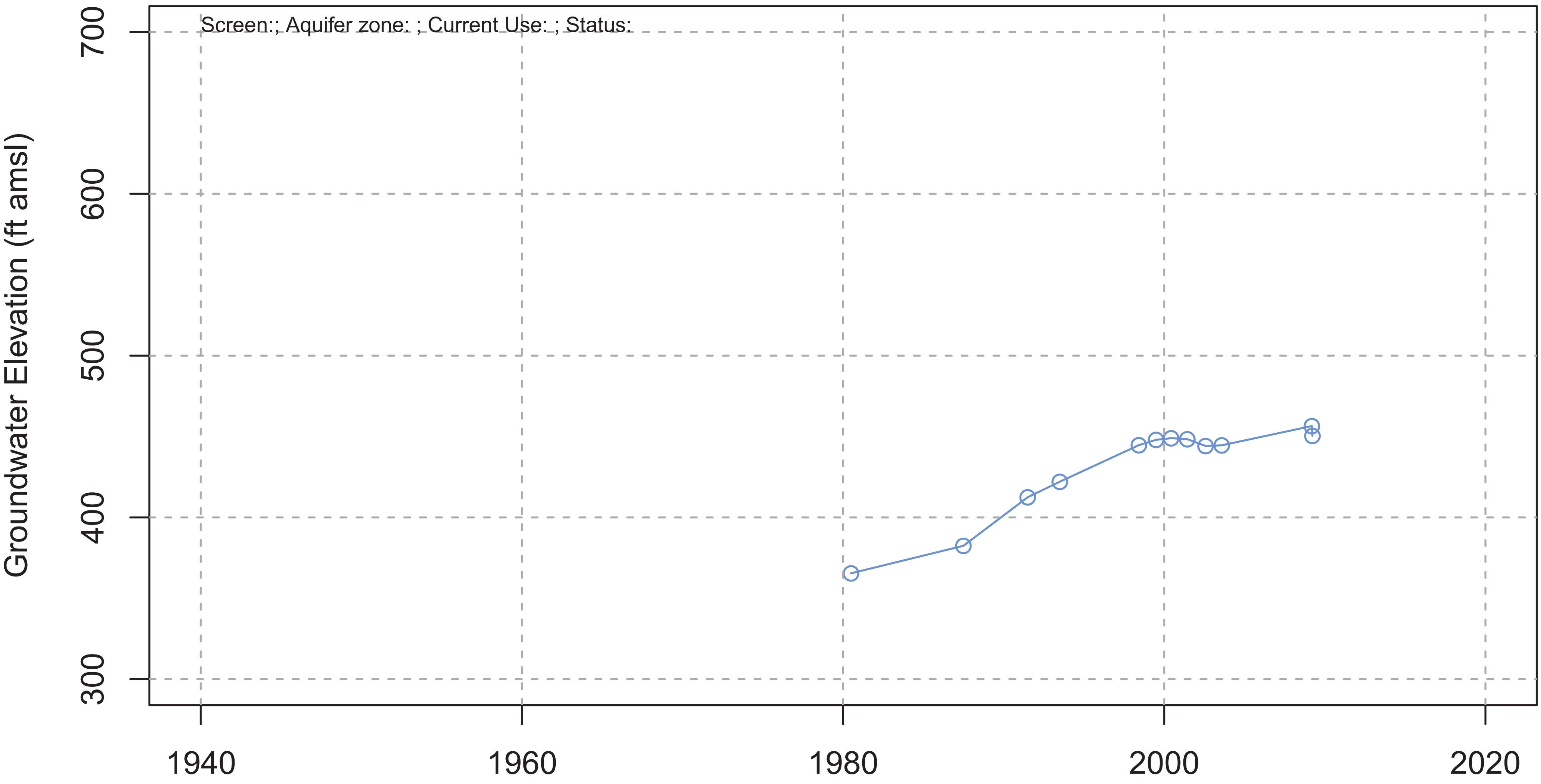
Local ID: Wilcox ; Number of Measuring Agenc(y/ies): 4

011S006E22A001S

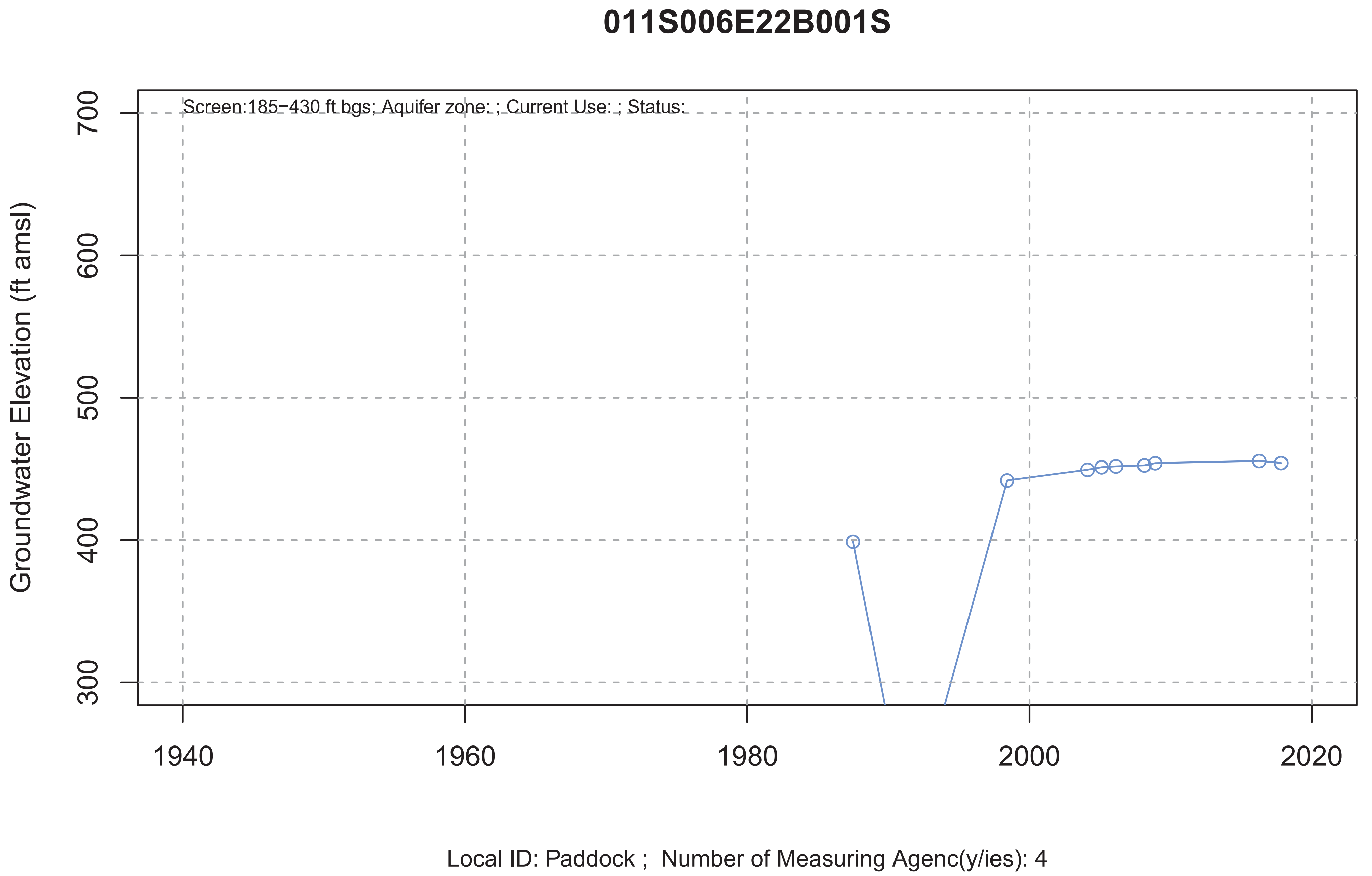


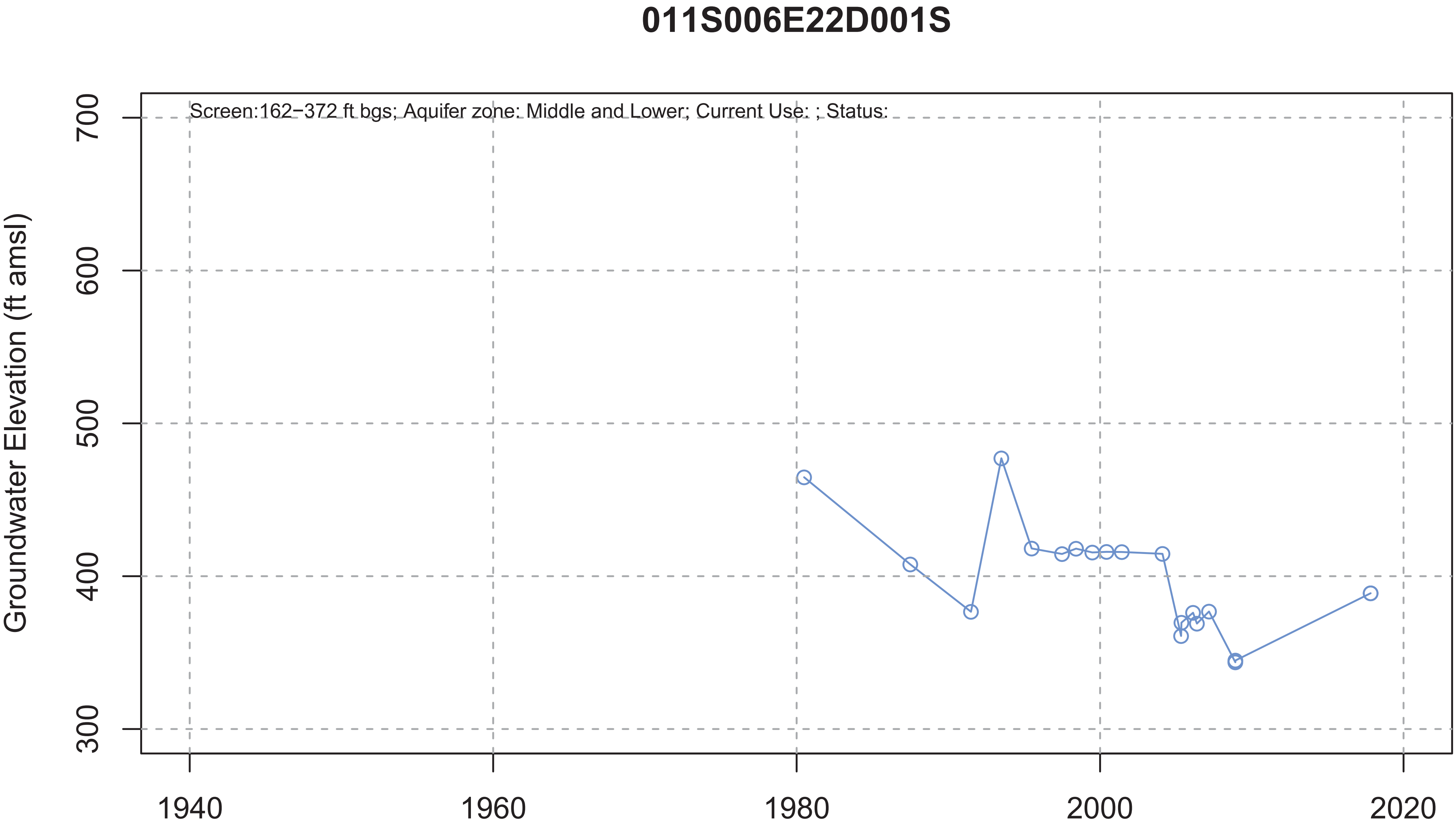
Local ID: Bakko ; Number of Measuring Agenc(y/ies): 4

011S006E22A002S



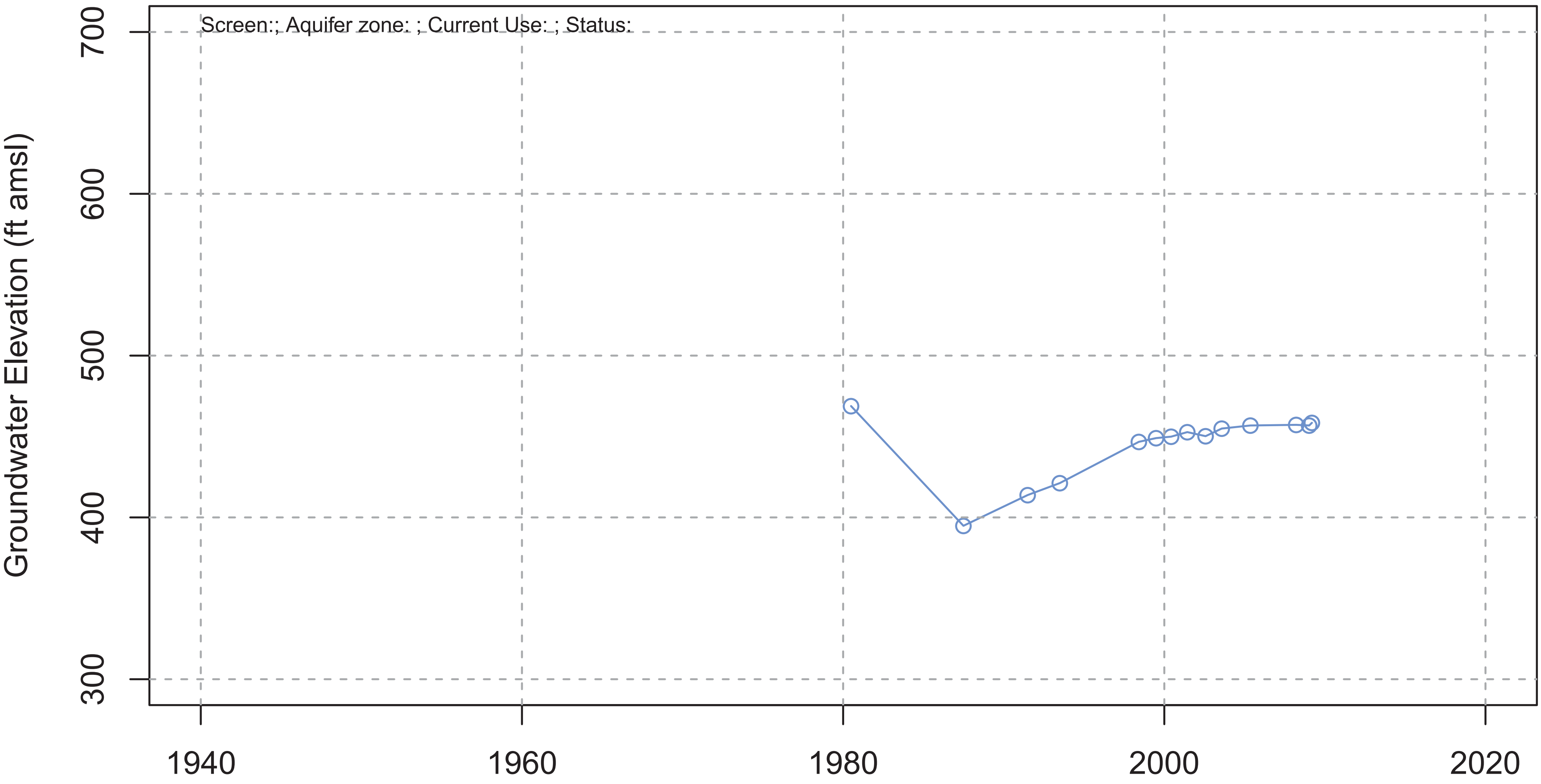
Local ID: Triangle ; Number of Measuring Agenc(y/ies): 2


011S006E22B001S
Screen:185−430 ft bgs; Aquifer zone: ; Current Use: ; Status:
Groundwater Elevation (ft amsl)
700
600
500
400
300
1940
1960
1980
2000
2020
Local ID: Paddock ; Number of Measuring Agenc(y/ies): 4



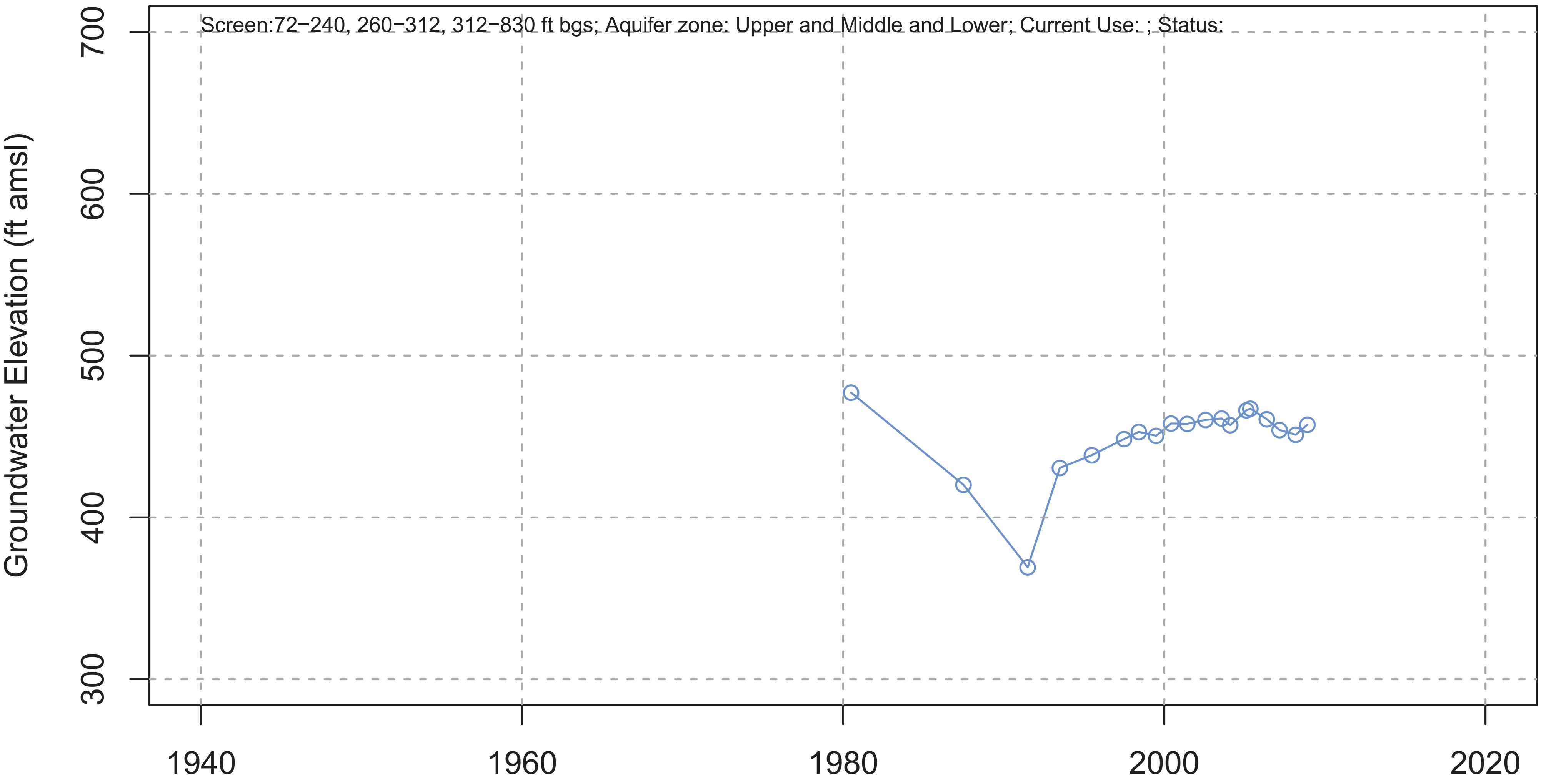
Local ID: ID1−10 ; Number of Measuring Agenc(y/ies): 4

011S006E23E001S



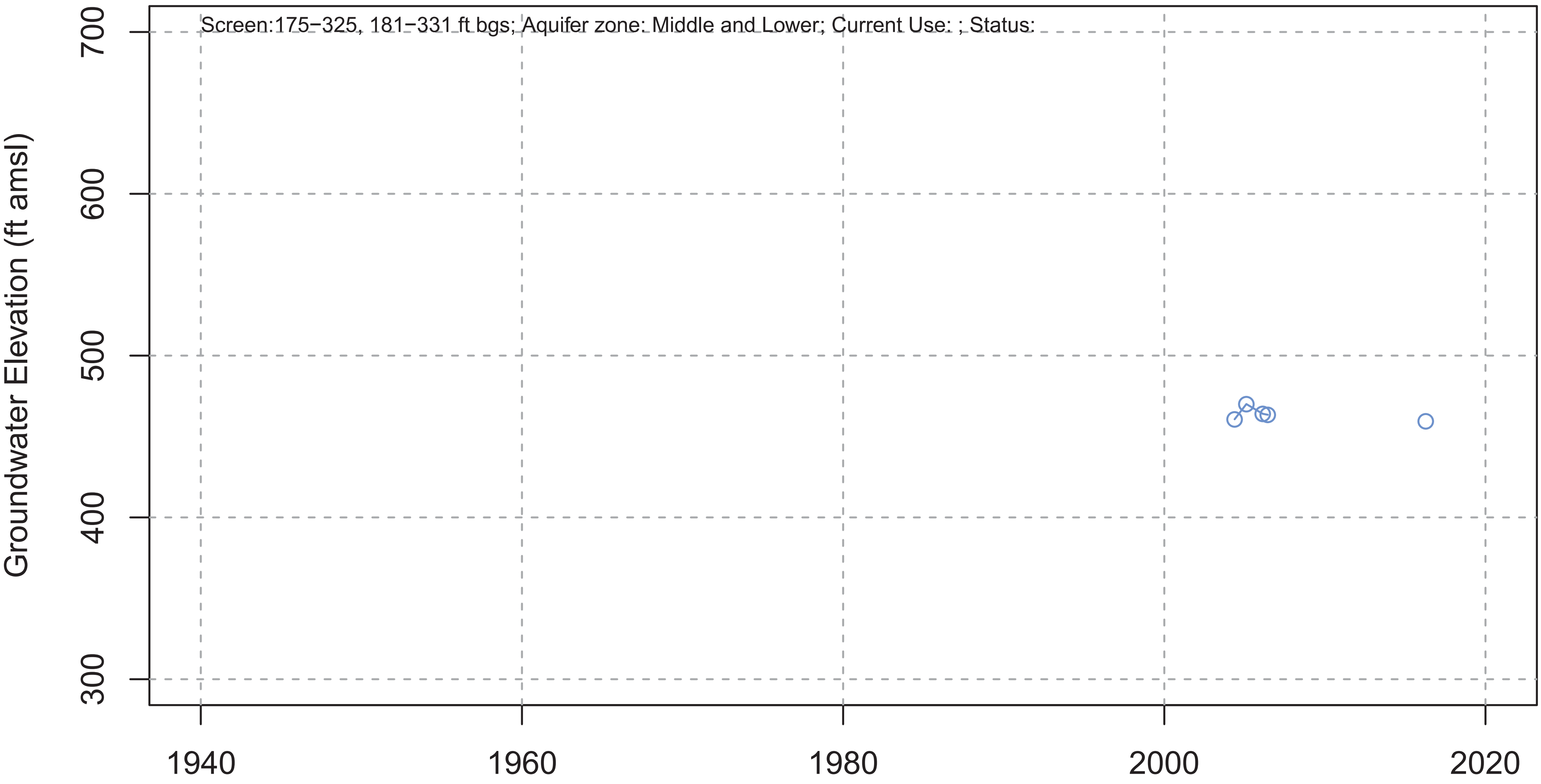
Local ID: La Casa ; Number of Measuring Agenc(y/ies): 2

011S006E23J001S



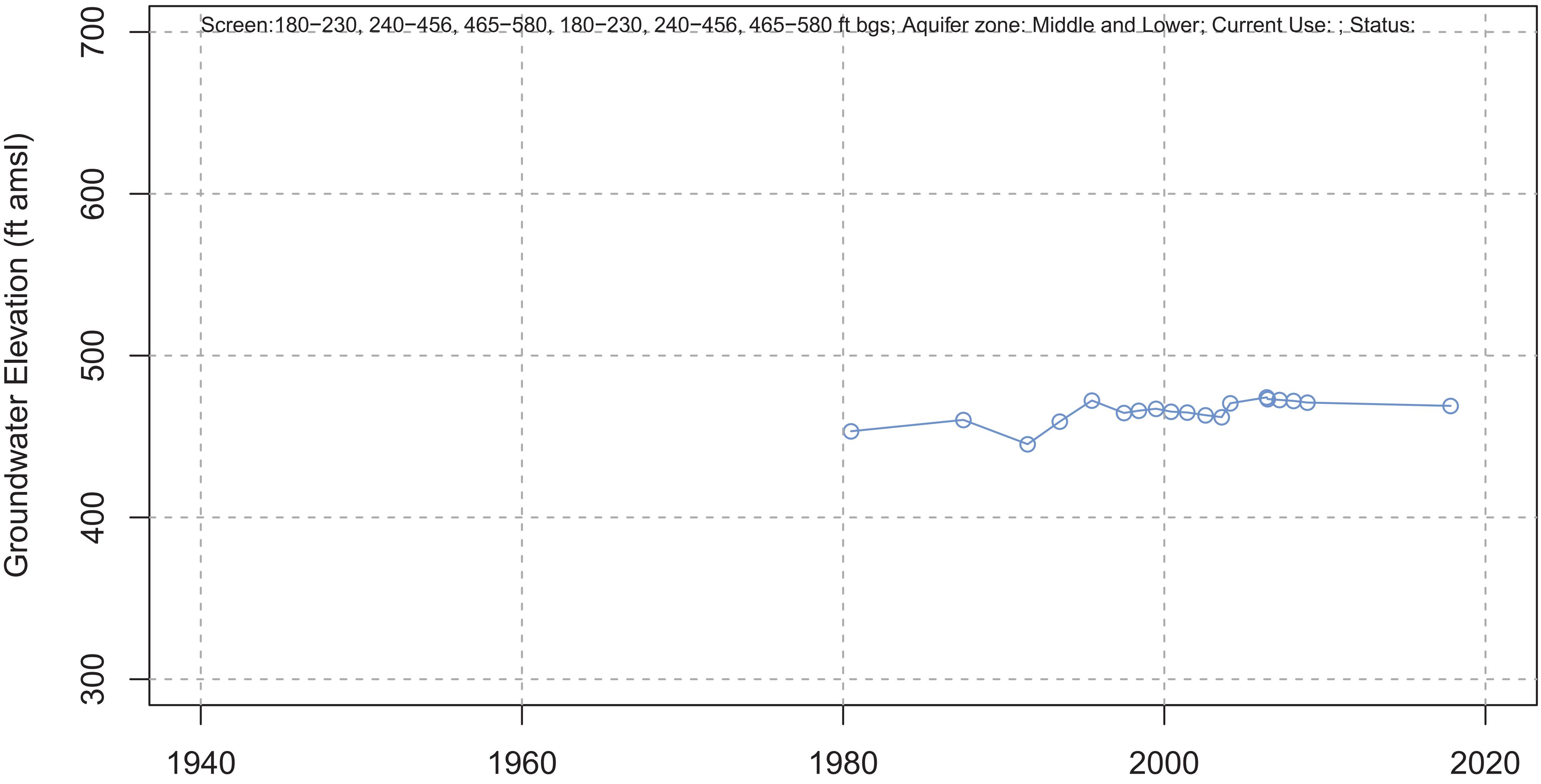
Local ID: ID1−8 ; Number of Measuring Agenc(y/ies): 2

011S006E23J002S



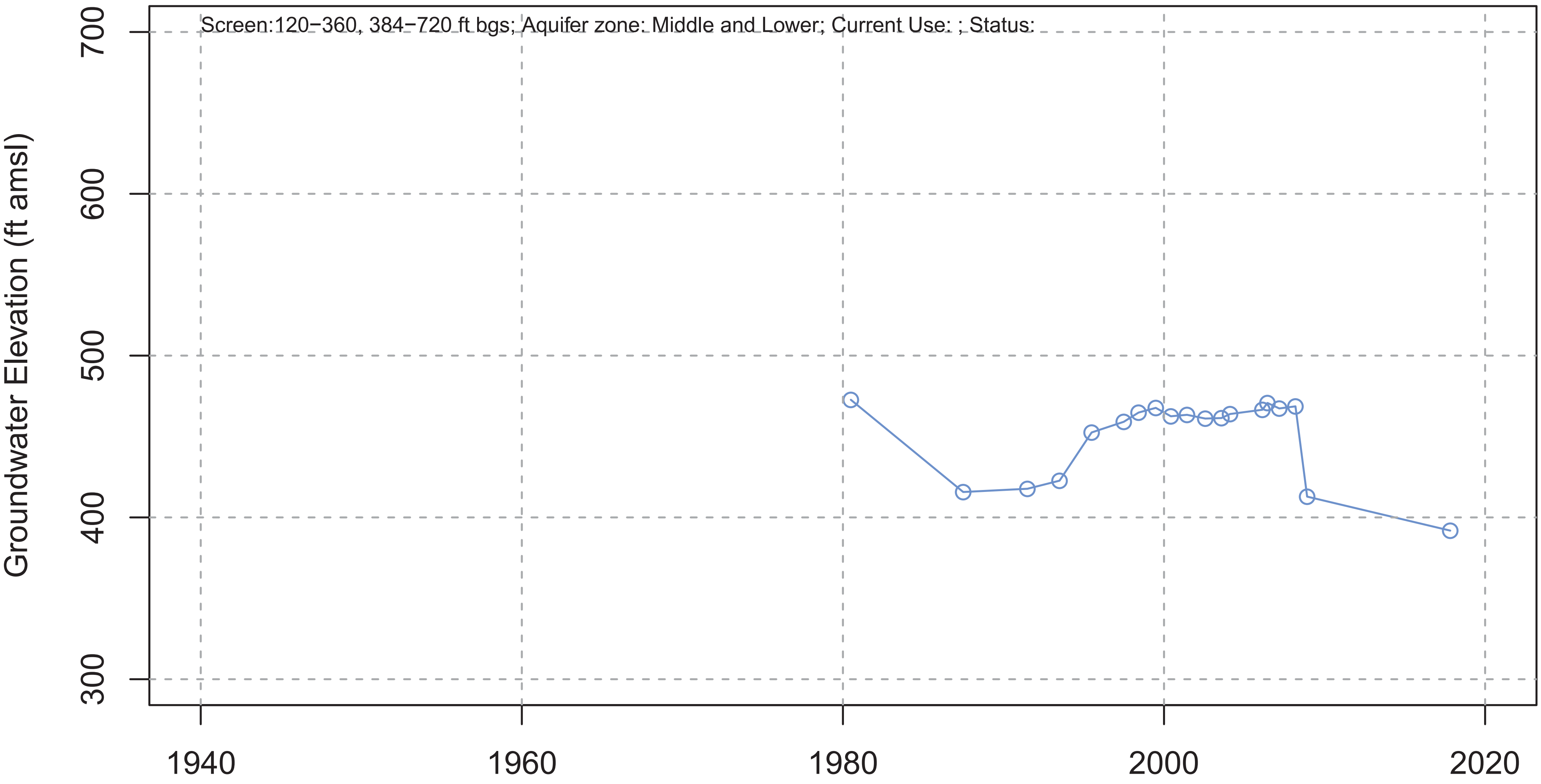
Local ID: MW−3 ; Number of Measuring Agenc(y/ies): 4

011S006E25A001S



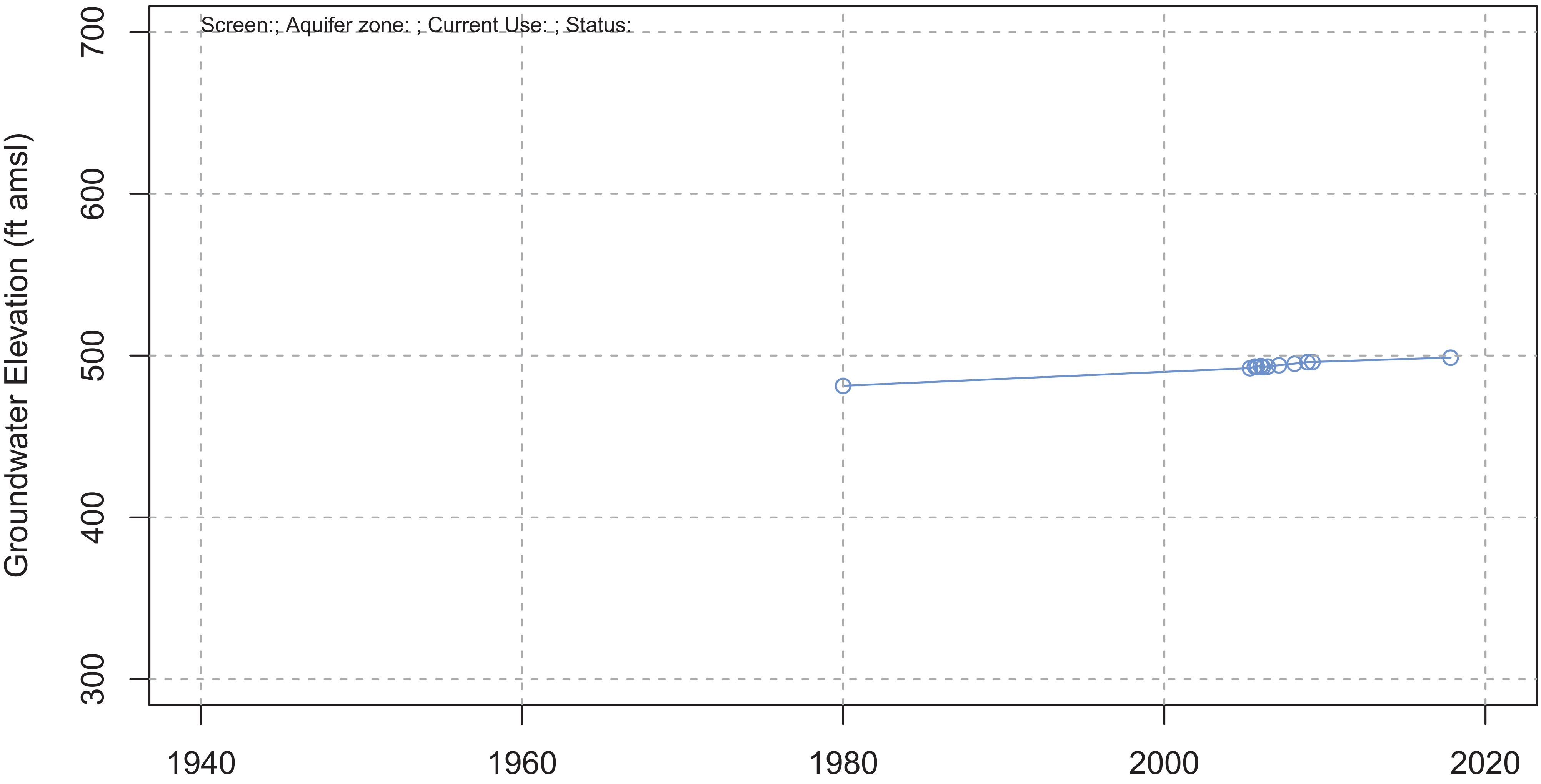
Local ID: ID1−1 ; Number of Measuring Agenc(y/ies): 3

011S006E25C001S



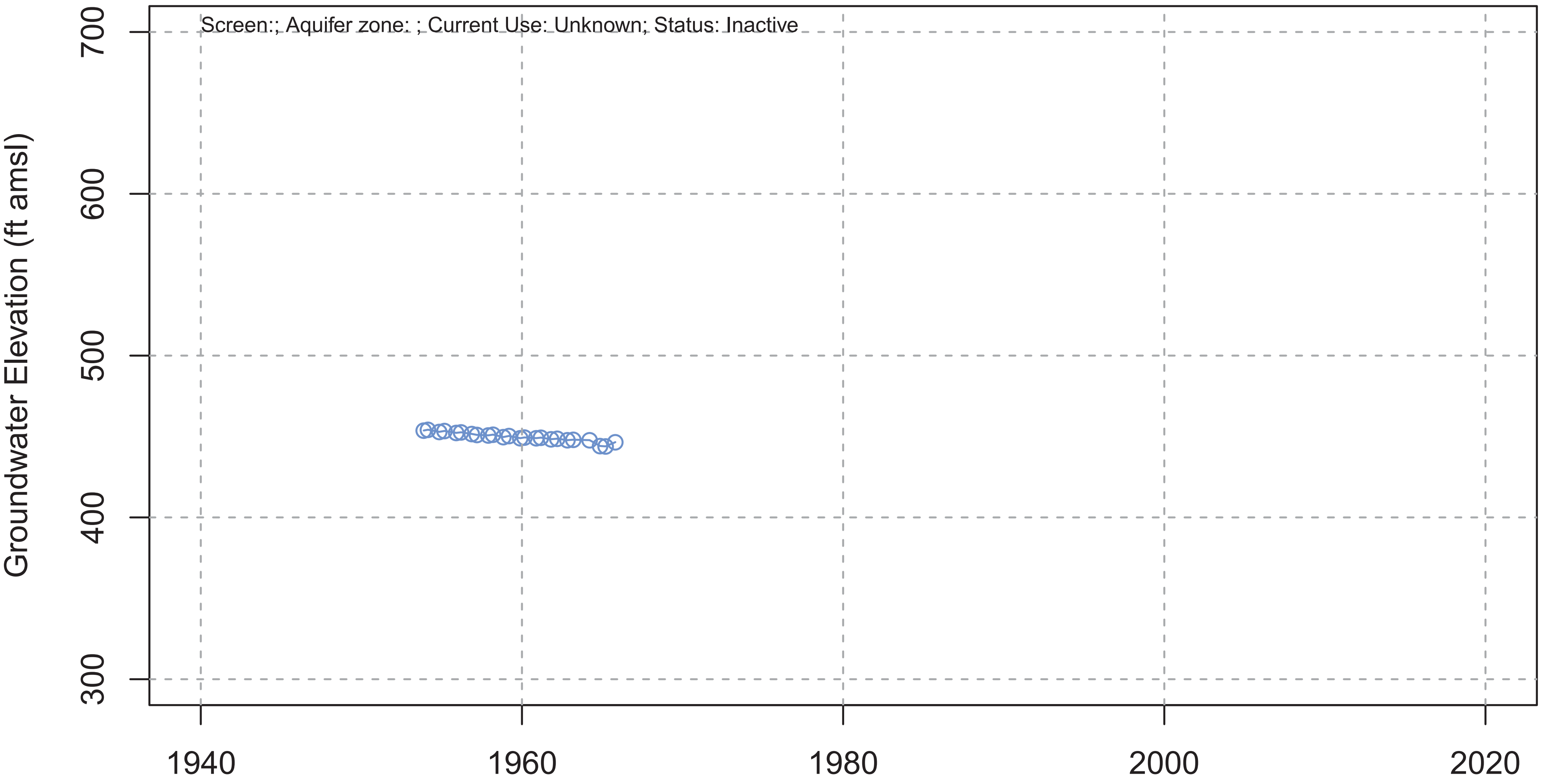
Local ID: ID1−2 ; Number of Measuring Agenc(y/ies): 3

011S006E34A001S



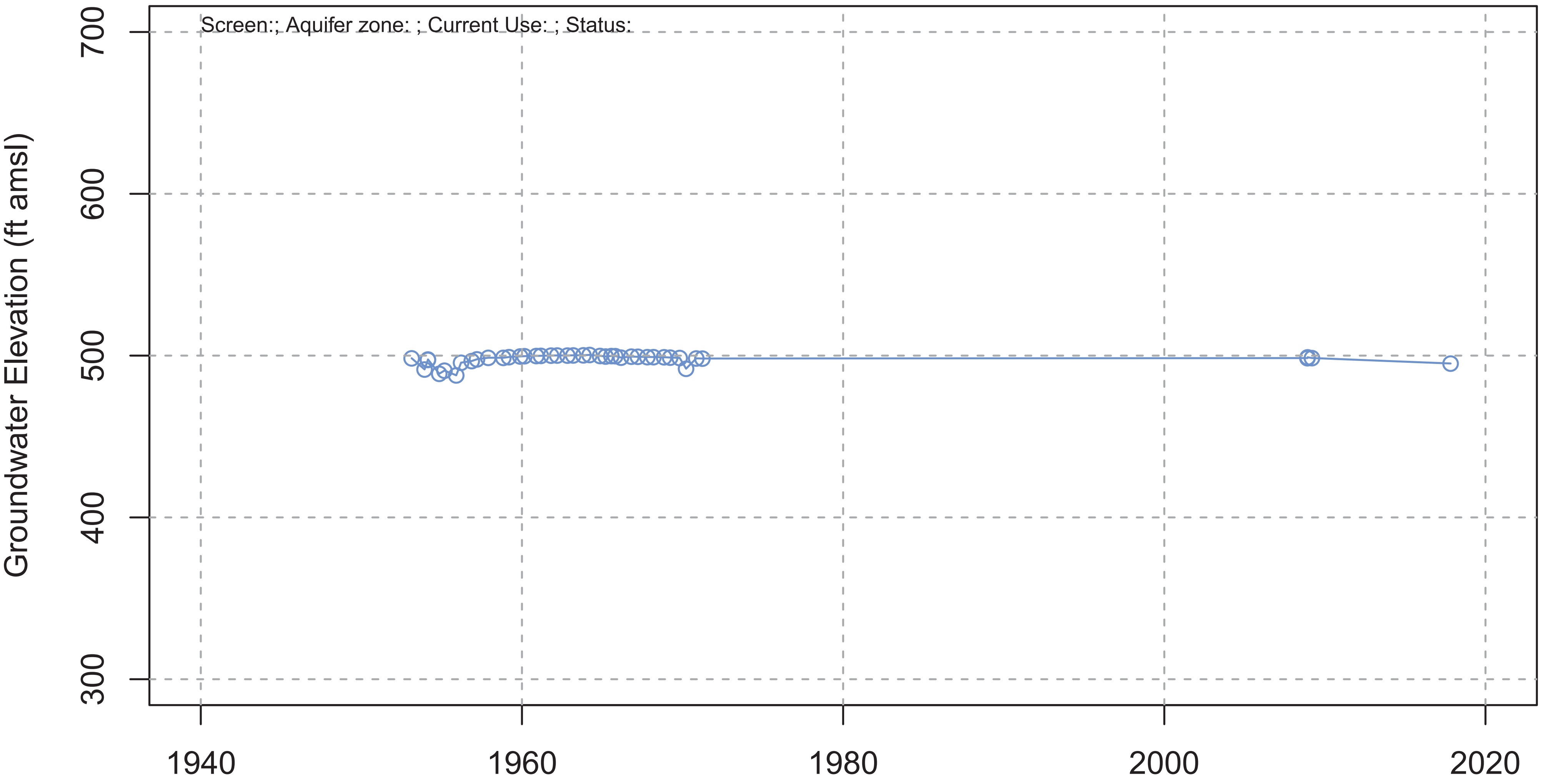
Local ID: Army Well ; Number of Measuring Agenc(y/ies): 4

011S007E07N001S



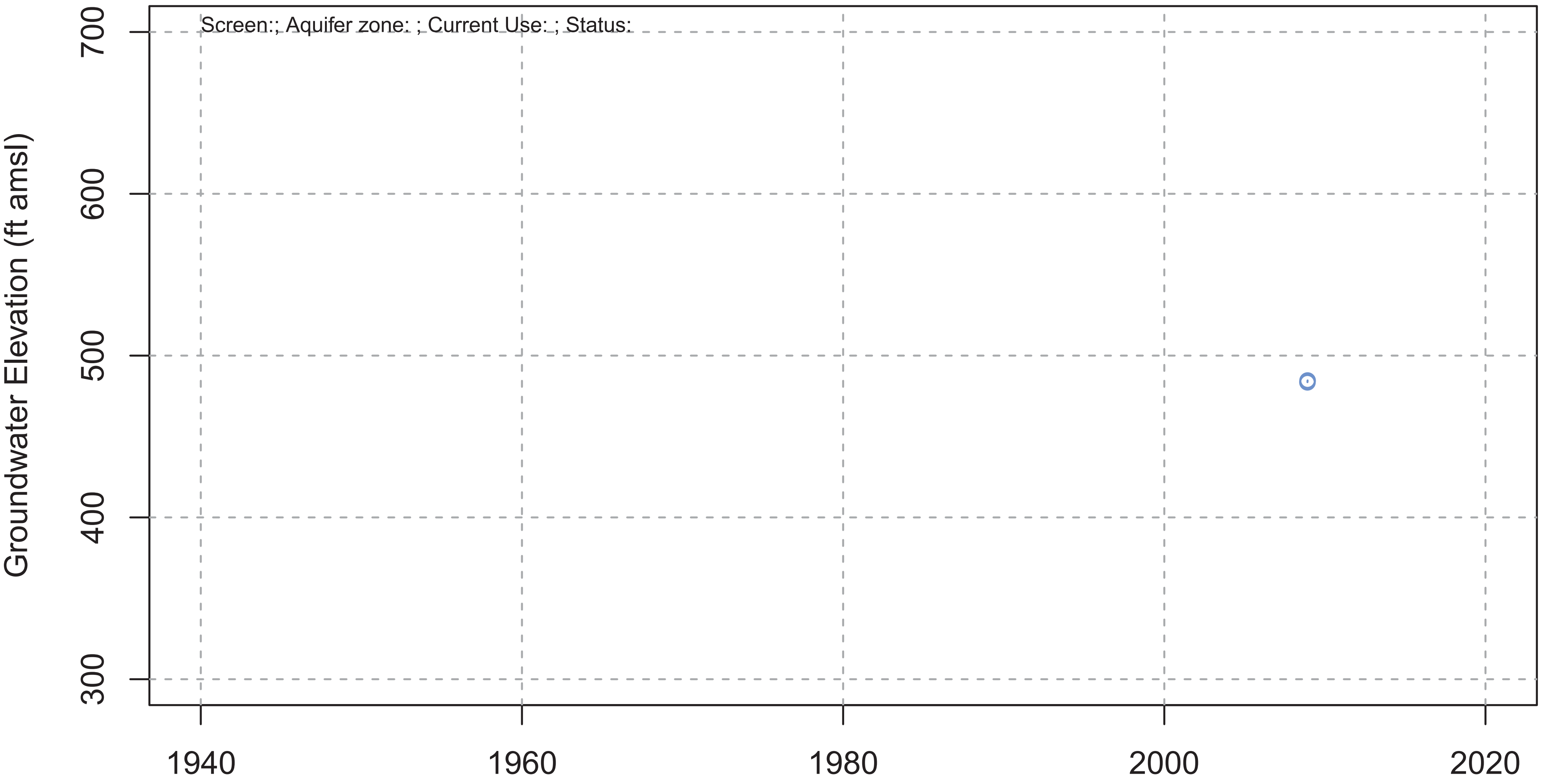
Local ID: Sink − 7N1 ; Number of Measuring Agenc(y/ies): 3

011S007E20P001S



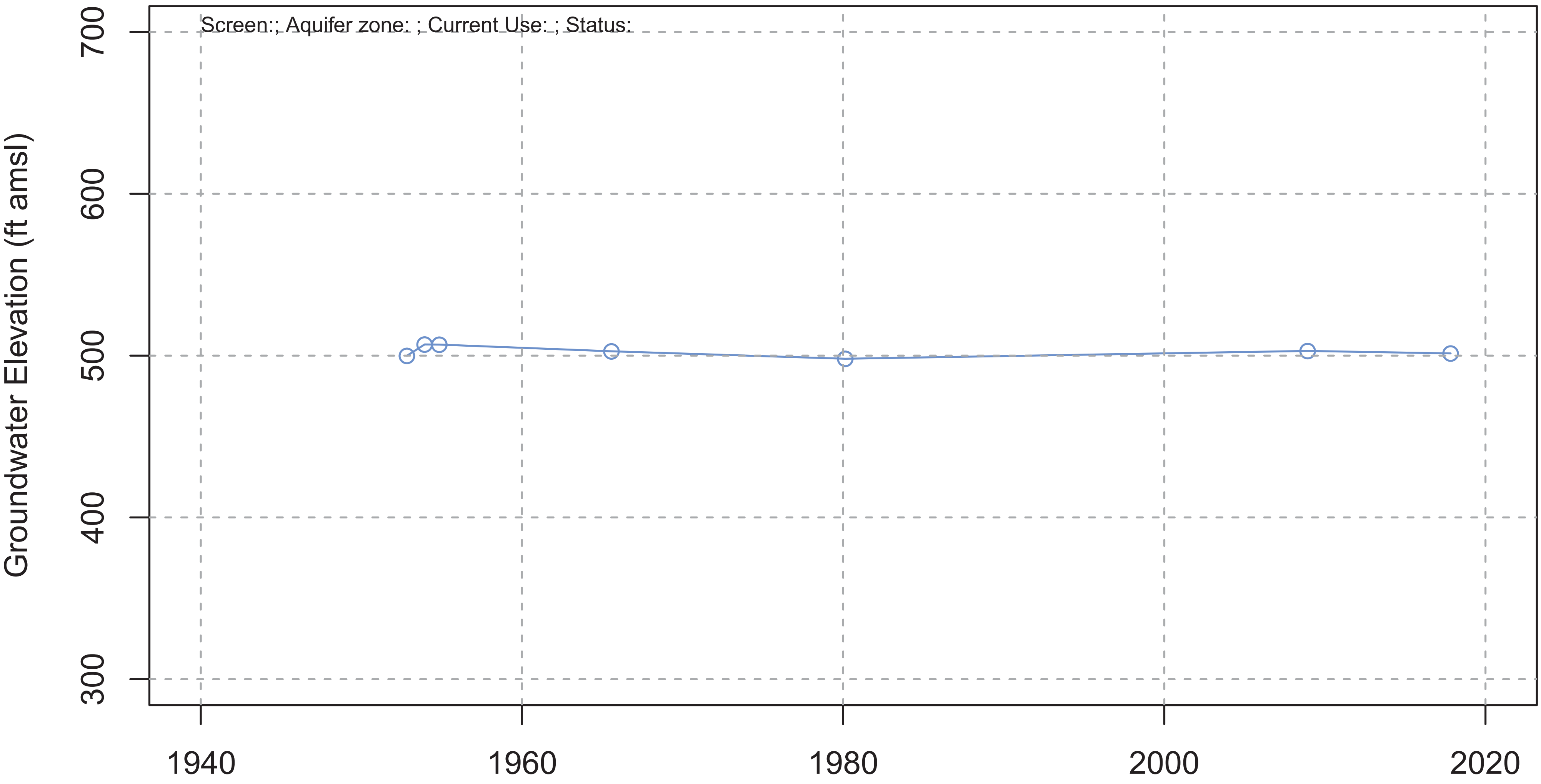
Local ID: Bing Crosby Well (Sky Ranch) ; Number of Measuring Agenc(y/ies): 5

011S007E30G004S

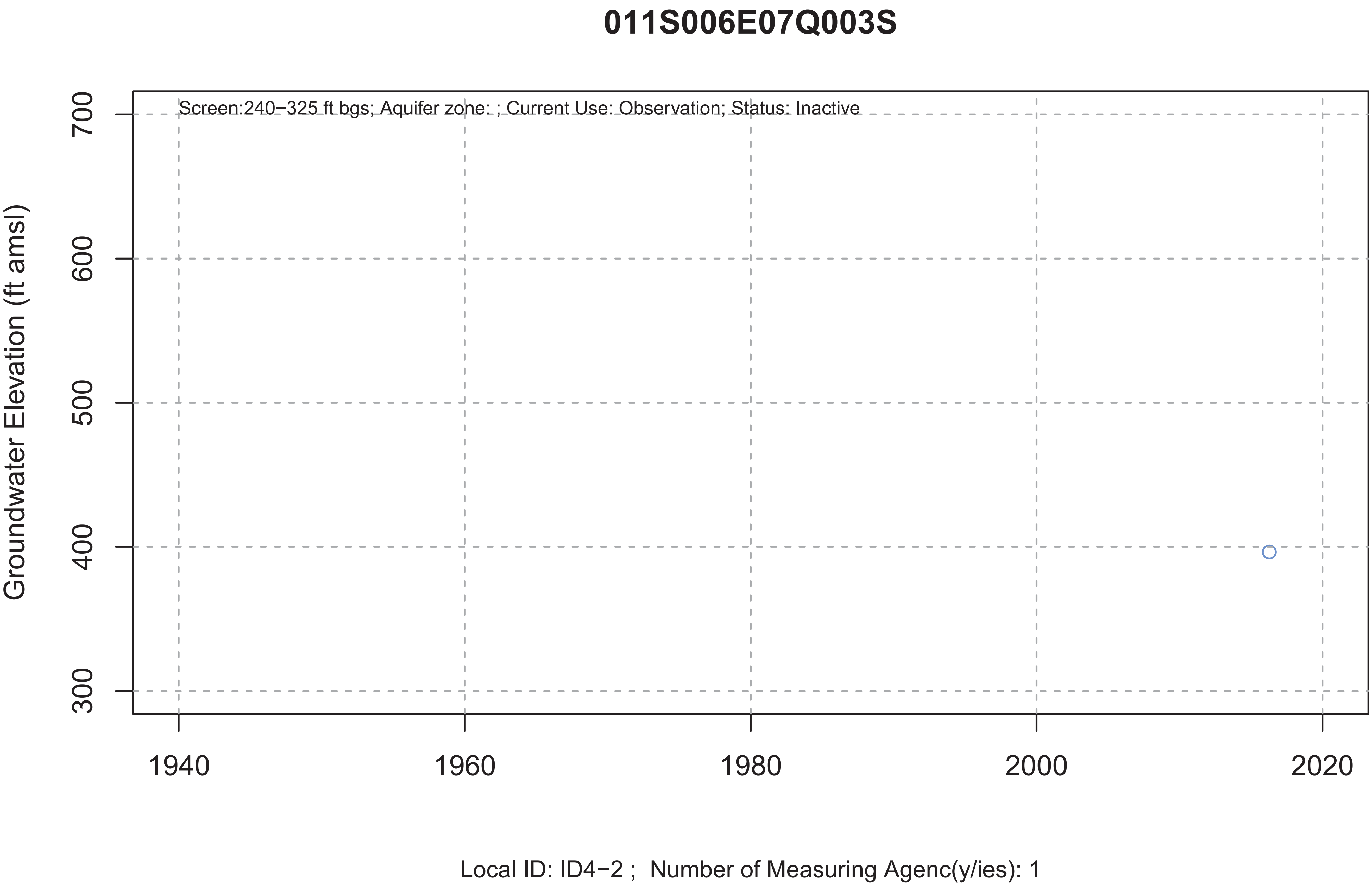


Local ID: Sky Ranch ; Number of Measuring Agenc(y/ies): 2

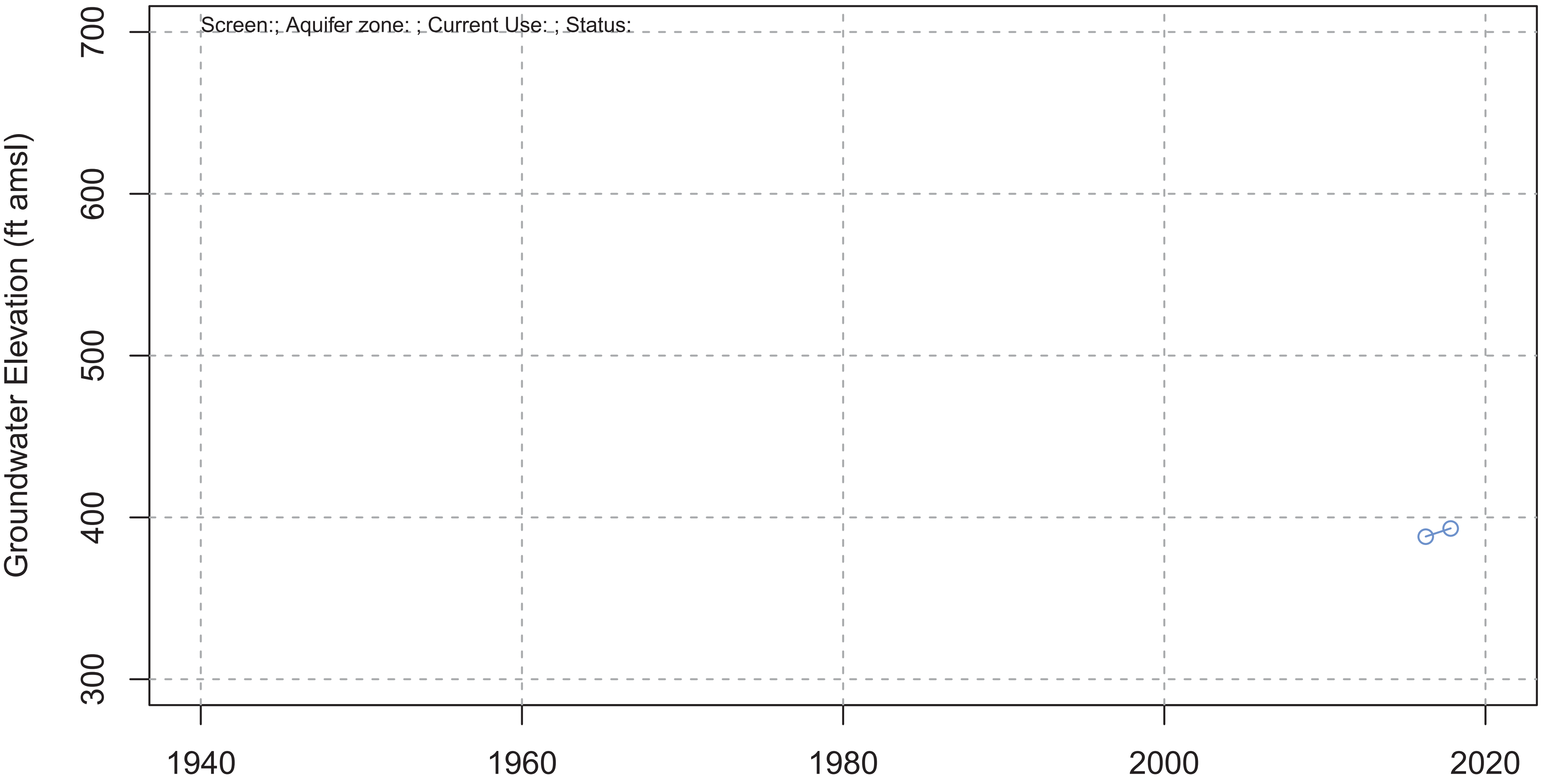
011S007E32Q001S



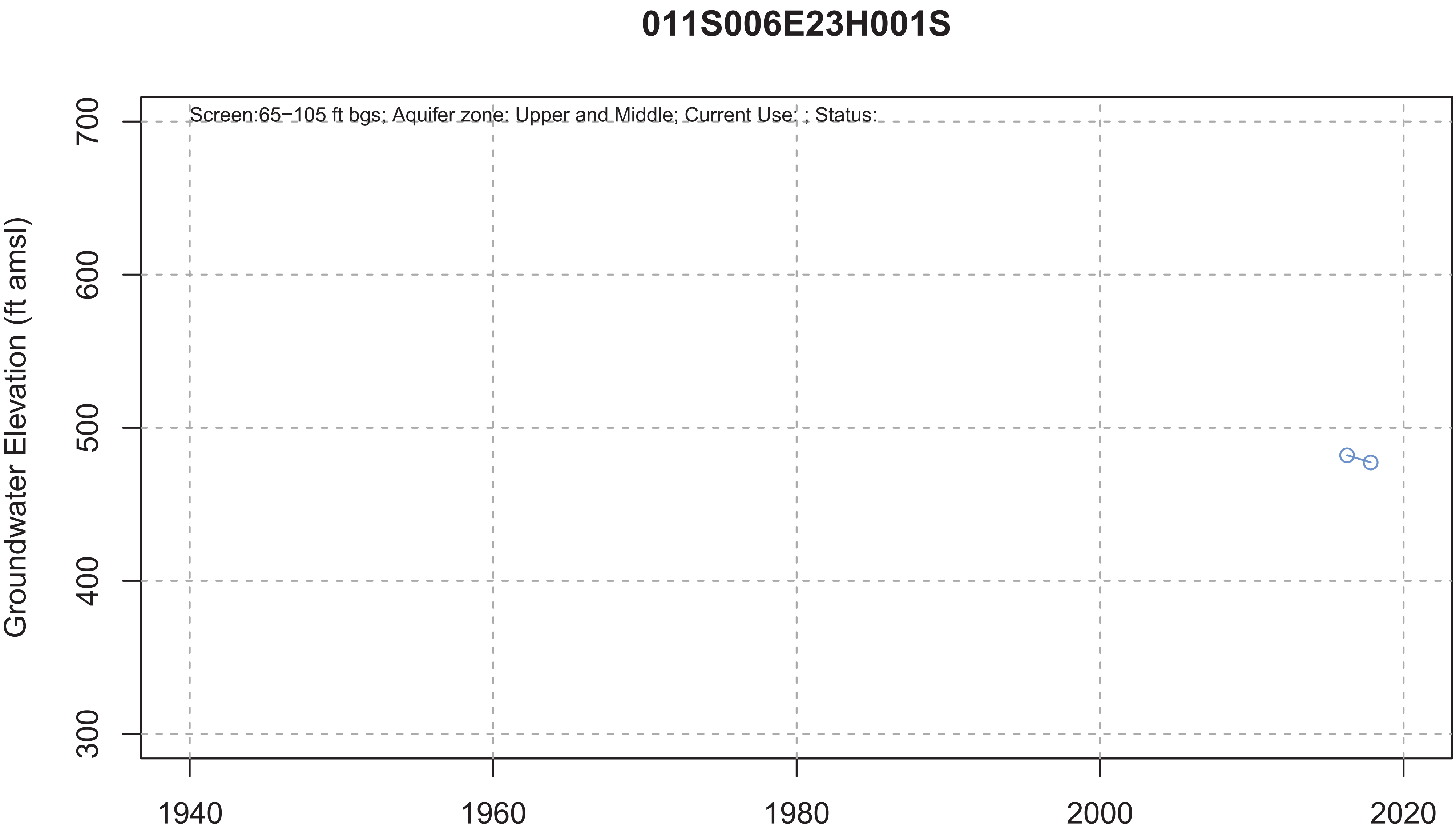
Local ID: Hayden (32Q1) ; Number of Measuring Agenc(y/ies): 3


011S006E07Q003S
Screen:240−325 ft bgs; Aquifer zone: ; Current Use: Observation; Status: Inactive
Groundwater Elevation (ft amsl)
700
600
500
400
300
1940
1960
1980
2000
2020
Local ID: ID4−2 ; Number of Measuring Agenc(y/ies): 1

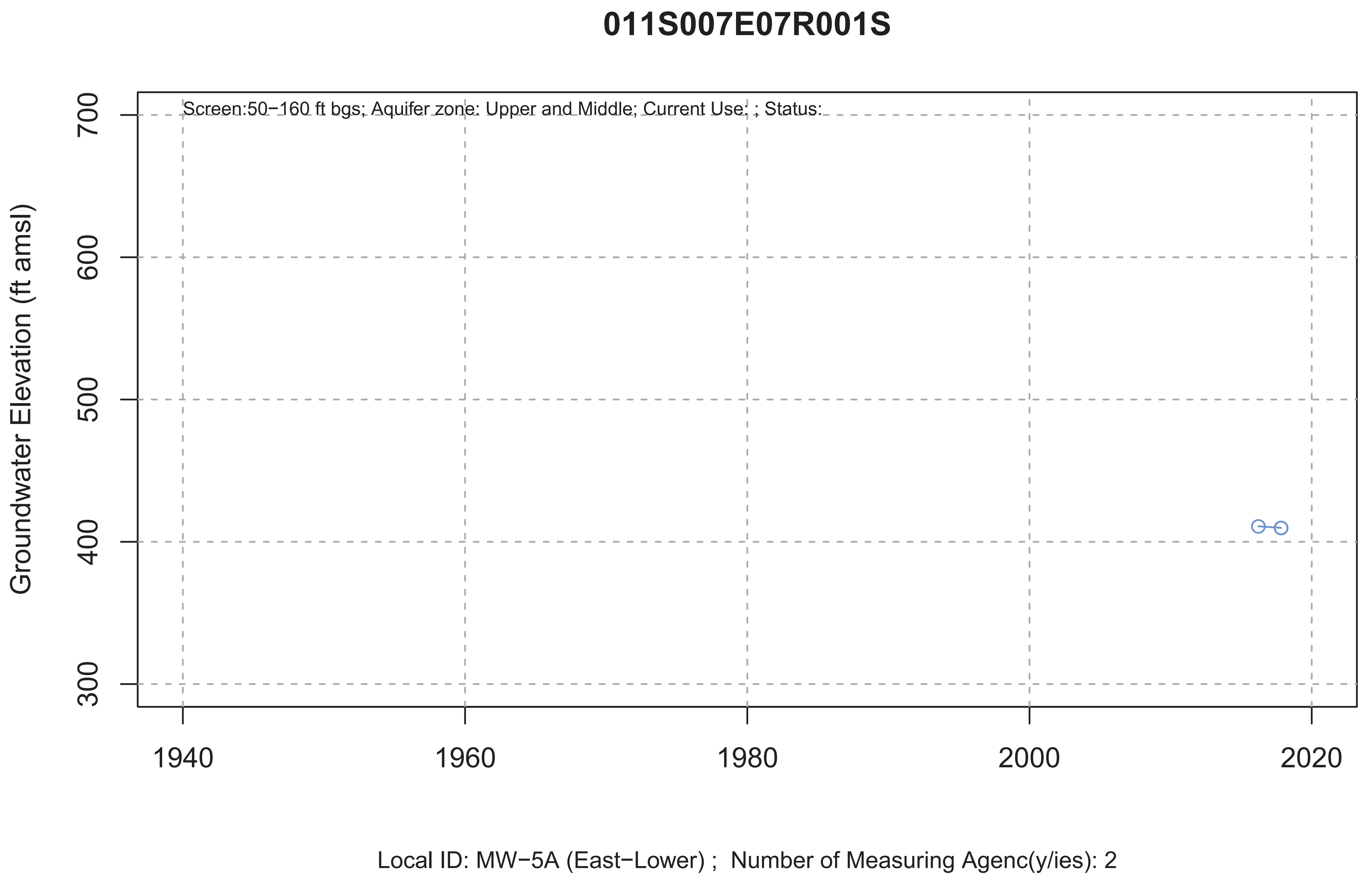
011S006E22E001S

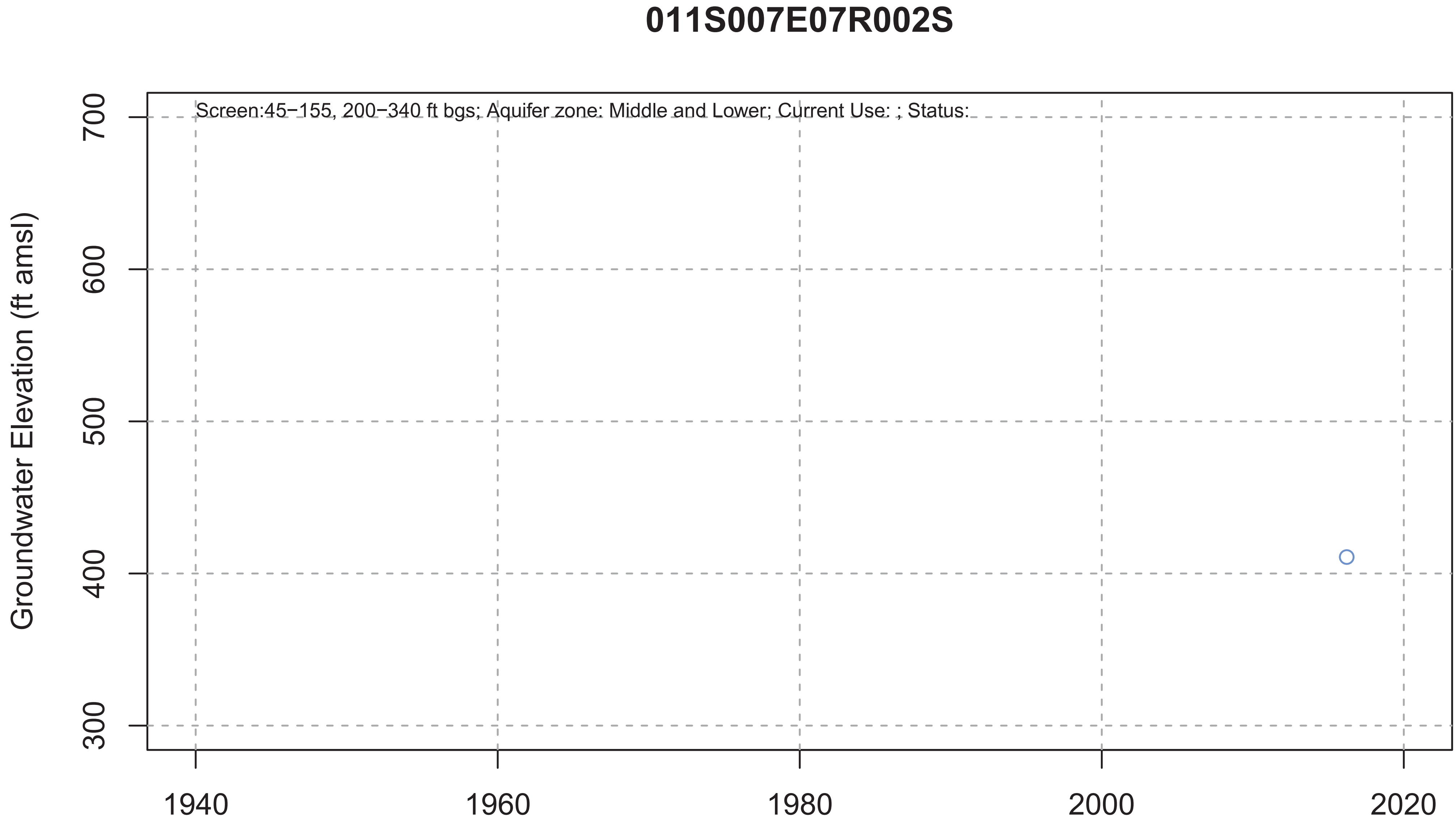


Local ID: Anzio/Yaqui Pass ; Number of Measuring Agenc(y/ies): 2



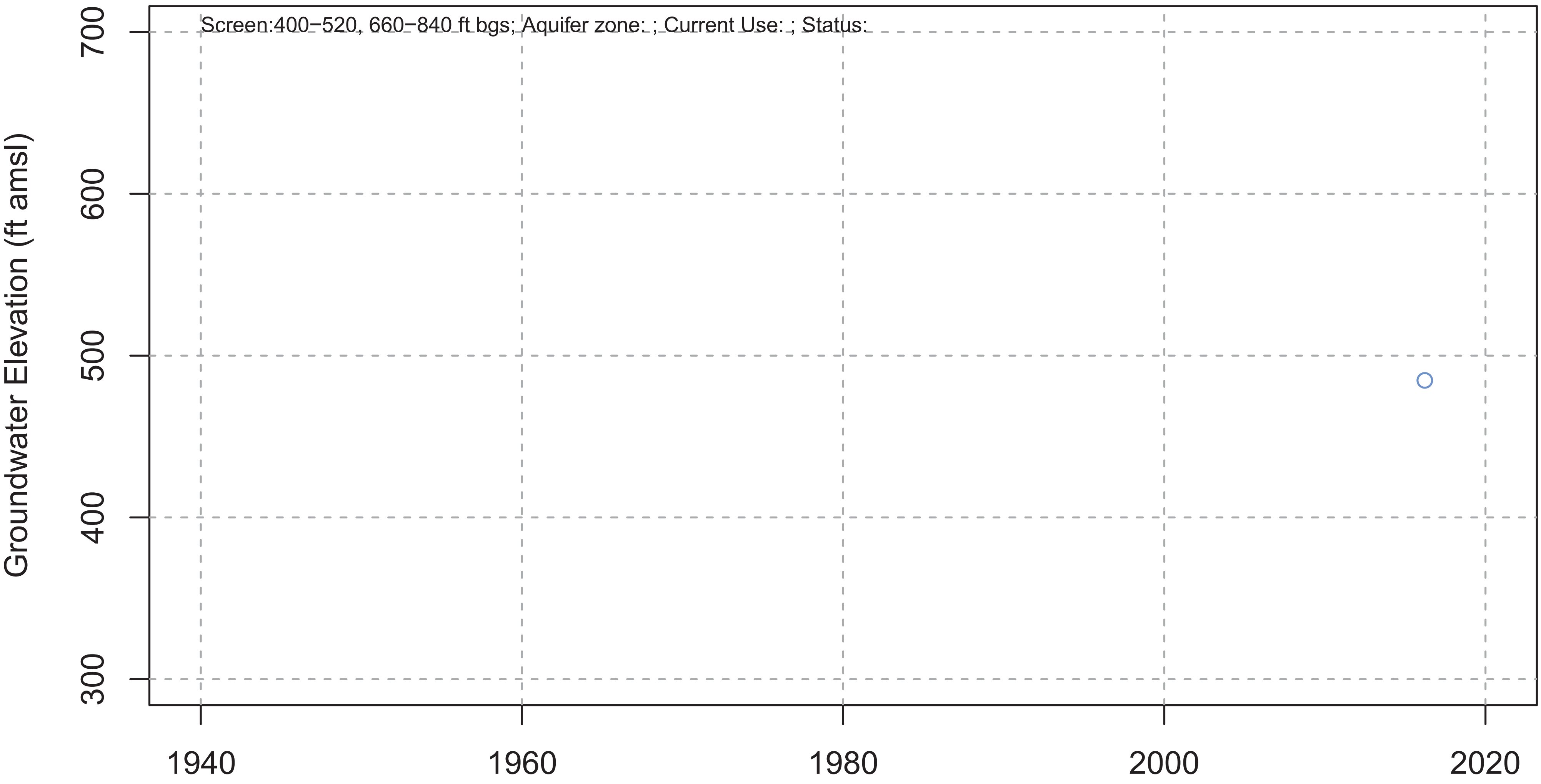
Local ID: WWTP−1 ; Number of Measuring Agenc(y/ies): 2


011S007E07R001S
Screen:50−160 ft bgs; Aquifer zone: Upper and Middle; Current Use: ; Status:
Groundwater Elevation (ft amsl)
700
600
500
400
300
1940
1960
1980
2000
2020
Local ID: MW−5A (East−Lower) ; Number of Measuring Agenc(y/ies): 2



Local ID: MW−5B (West−Upper) ; Number of Measuring Agenc(y/ies): 1

012S007E03L001S



Local ID: Nel Well (Dr Peter Nels) ; Number of Measuring Agenc(y/ies): 1

APPENDIX D4

Borrego Springs Subbasin Groundwater Dependent Ecosytems

605 THIRD STREET
ENCINITAS, CALIFORNIA 92024
T 760.942.5147 F 760.632.0164

DRAFT TECHNICAL MEMORANDUM

To:	Jim Bennett and Leanne Crow (County of San Diego)
From:	Trey Driscoll, PG, CHG
Subject:	Borrego Springs Groundwater Subbasin Potential Groundwater Dependent Ecosystems
Date:	February 28, 2019
cc:	Geoff Poole, Lyle Brecht, David Duncan (Borrego Water District)
Attachment(s):	Figures 1–22

The Sustainable Groundwater Management Act (SGMA) requires that all beneficial uses and users of groundwater, including environmental users of groundwater (Groundwater Dependent Ecosystems (GDEs)), be considered in Groundwater Sustainability Plans (GSPs) (California Water Code (CWC) Section 10723.2).[1] Each Plan shall provide a description of current and historical groundwater conditions in the basin, including data from January 1, 2015, to current conditions, based on the best available information that includes: Identification of groundwater dependent ecosystems within the basin, utilizing data available from the Department, as specified in Section 353.2, or the best available information (Title 23 California Code of Regulations (CCR) Section 354.16(g)).[2]

"A groundwater dependent ecosystem (GDE) is a plant and animal community that requires groundwater to meet some or all water needs" (TNC 2018). GDEs are defined under the SGMA as "ecological communities or species that depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface" (Title 23 CCR Section 351.(m)). GDEs encompass a wide range of natural communities, such as seeps and springs, wetlands and lakes, terrestrial vegetation and, rivers, streams and estuaries.

The Natural Communities Commonly Associated with Groundwater (NCCAG) dataset is provided by the Department of Water Resources (DWR) as a reference dataset and starting point for the identification of GDEs in groundwater basins (DWR 2018). Because the scale of the NCCAG dataset is statewide (i.e., coarse), and consists of a compilation of vegetation and surface hydrology feature (e.g., springs) mapping, it does not incorporate local, basin-specific groundwater conditions such as aquifer characteristics or current data on depth to groundwater. Therefore, the dataset is most appropriately used as an indicator of where GDEs, as defined by SGMA, are more likely to be present. A local, basin-specific analysis is required to verify the degree to which features mapped in the NCCAG dataset depend on groundwater emerging from aquifers or on groundwater occurring near the ground surface. Accordingly, features mapped as NCCAG dataset are referred to herein as "potential" GDEs.

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[1] SGMA is codified in California Water Code (CWC), Part 2.75 (Sustainable Groundwater Management), Section 10720–10737.8, et al.

[2] GSP Regulations refers to the emergency regulations adopted by DWR as California Code of Regulations (CCR), Title 23 (Waters), Division 2 (Department of Water Resources), Chapter 1.5 (Groundwater Management), Section 350 et seq. Title 23 CCR Section 353.2(B). States, "The Department [DWR] shall provide information, to the extent available, to assist Agencies in the preparation and implementation of Plans, which shall be posted on the Department's website.

The NCCAG dataset and its source data can be reviewed in context of local understanding of surface water hydrology, groundwater conditions, and geology. The NCCAG dataset is comprised of 48 publicly available state and federal agency mapping datasets.[3] After the vegetation, wetland, seeps, and springs data from these 48 datasets were compiled into the NCCAG dataset, data were screened to exclude vegetation and wetland types less likely to be associated with groundwater and retain types commonly associated with groundwater. This initial screening was conducted by DWR, California Department of Fish and Wildlife (CDFW) and the Nature Conservancy (TNC).

1 Identifying Potential Groundwater Dependent Ecosystems

Potential GDEs were identified by completing a review of the NCCAG dataset and other pertinent datasets discussed further below. Three primary potential GDEs areas are mapped within the Borrego Springs Groundwater Subbasin (7-024.01; Subbasin) by the NCCAG dataset, and include: 1) GDE Unit 1 – Coyote Creek, 2) GDE Unit 2 – Borrego Palm Creek, and 3) GDE Unit 3 – Mesquite Bosque (Borrego Sink) (Figure 1). Other potential GDEs areas are primarily located along the eastern flanks of the mountainous terrain that abuts the Subbasin to the west. These watersheds were delineated using the U.S. Geological Survey's (USGS) StreamStats application (USGS 2017) (Figure 2). The watersheds were delineated from the point of intersection of major drainages with the downstream edge of the Subbasin boundary. Ten watersheds were delineated to complete a detailed review of the NCCAG dataset, along with additional dataset comprised of County of San Diego vegetation communities associated with primarily riparian habitat; USGS's National Hydrography Dataset flow lines; perennial creeks, streams and springs mapped by the Anza-Borrego Desert State Park (ABDSP); springs identified on USGS quadrangle maps; land use data; and satellite color-infrared photography (Figure 3 through Figure 12).[4] Potential GDEs mapped within the contributing watersheds include, but are not limited to, Coyote Creek, Henderson Canyon, Borrego Palm Creek, Hellhole Palms Canyon, Culp Canyon, Tubb Canyon, San Felipe Creek and other minor or unnamed stream segments entering the Subbasin (Figures 3 through Figure 12).

As the GSP is focused on the Subbasin, the potential GDEs should either be located within the Subbasin boundary or be sufficiently approximate to the boundary that there is a reasonable potential for a substantial nexus to exist between the Subbasin's regional groundwater levels and the potential GDEs.

1.1 Primary Potential GDEs

The three primary potential GDEs areas are discussed in the following subsections. These GDE "Units" were identified based on the presence of NCCAG mapped within the Subbasin boundary and their overlap/proximity to perennial segments of major streams that enter the Subbasin, namely Coyote Creek and Borrego Palm Creek.

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[3] NCCAG dataset includes, but is not limited to, the following: VegCAMP – The Vegetation Classification and Mapping Program, California Department of Fish and Wildlife (CDFW); CALVEG – Classification and Assessment with Landsat Of Visible Ecological Groupings, USDA Forest Service; NWI V 2.0 – National Wetlands Inventory (Version 2.0), United States Fish and Wildlife Service; FVEG – California Department of Forestry and Fire Protection, Fire and Resources Assessment Program (CALFIRE FRAP); United States Geologic Survey (USGS) National Hydrography Dataset (NHD); and Mojave Desert Springs and Waterholes (Mojave Desert Spring Survey). NCCAG dataset viewer is available online at: https://gis.water.ca.gov/app/NCDatasetViewer/

[4] The mapped location of springs was developed from multiple datasets including the ABDSP (2017), Water Quality Control Plan for the Colorado River Basin (Basin Plan) and National Hydrography Dataset.

Other potential GDEs identified in Figure 3 through Figure 12 include Henderson Canyon, Hellhole Canyon, Culp Canyon, Tubb Canyon, and other minor or unnamed stream segments entering the Subbasin. These areas were not selected for detailed evaluation because the potential GDEs mapped in these areas are edge cases confined to the outer fringes of the Subbasin boundary; their geographic confinement to the mountain front at the end of large watersheds indicates that the vegetation communities are supported by surface water flows originating outside the Subbasin (which are storm fed and/or spring-fed). These contributing watershed and fringe areas are described in Section 1.2.

1.1.1 Coyote Creek Mapped GDEs (GDE Unit 1)

The NCCAG dataset has mapped both wetlands and vegetation within GDE Unit 1, Coyote Creek (Figures 1 and 3). These communities are narrowly focused within the riparian corridors associated with Coyote Creek. Potential GDE vegetation types mapped in association with Coyote Creek include: Desert Willow, Narrowleaf Willow, Honey Mesquite and Catclaw Acacia (drought deciduous [lacks leaves for most of the year]). The ecological conditions in Coyote Canyon have been evaluated by the ABDSP (Ostermann and Boyce 2002). The following information is excerpted from *Ecological Conditions in Coyote Canyon, Anza-Borrego Desert State Park® An Assessment of the Coyote Canyon Public Use Plan*:

> “Riparian vegetation covers approximately 120 acres at Lower Willows, 54 acres at Middle Willows, and 40 acres at Upper Willows” (Figure 3). “The biological importance of Coyote Canyon is largely a function of the perennial surface water and islands of tall-structured wetland vegetation in Lower, Middle and Upper Willows.” “Five sensitive habitat or vegetation types occur in Coyote Canyon, including: Desert Fan Palm Oasis Woodland, Mesquite Bosque, Mojave Riparian Forest, Sonoran Cottonwood Willow Riparian Forest, and Sonoran Riparian Woodland. Several of these riparian vegetation associations have been recognized for their rarity and sensitivity by the state of California. Lower and Middle Willows are identified as Significant Natural Areas (SNA) in the California Department of Fish and Game’s Natural Diversity Data Base because they contain sensitive Desert Fan Palm Oasis Woodland, Sonoran Riparian Forest, and nesting habitat for least Bell’s vireo. Upper Willows contains the same resources but was not designated as an SNA due simply to an oversight (California Department of Parks and Recreation 1995). All riparian habitat in Coyote Canyon is considered wetlands and is protected under the Keene-Nejedly California Wetlands Preservation Act of 1976. There are a variety of vegetation types both within riparian areas, and canyon wide. The tall-statured willow-dominated vegetation in Coyote Canyon is largely dominated by red willow (*Salix laevigata*), accompanied by arroyo willow (*Salix lasiolepis*), cottonwood (*Populus fremontii*), desert fan palm (*Washingtonia filifera*), and desert grape (*Vitis girdiana*). Perennial shrub species such as mulefat (*Baccharis salicifolia*), narrow-leaved willow (*Salix exigua*), and arrow weed (*Pluchea sericea*) are mixed with willow-dominated vegetation. Wetter portions of the wetlands are dominated by annual and perennial herbs such as cattail (*Typha latifolia*), tule (*Scirpus americanus*), and scratchgrass (*Muhlenbergia asperifolia*) (California Department of Parks and Recreation 2002). The boundary between wetland and upland habitats in Coyote Canyon is typically defined by stands of honey (*Prosopis glandulosa*) and screw-bean (*P. pubescens*) mesquite (California Department of Parks and Recreation 2002). These species have deep rooting systems and are able to better access subsurface moisture. Higher areas within the floodplain support sparse shrublands of low-statured drought-deciduous species such as alkali goldenbush (*Isocoma acradenia*), broom lotus (*Lotus rigidus*), and desert baccharis (*Baccharis*

> *sergiloides*) (California Department of Parks and Recreation 2002). It is the diversity and spatial arrangement of vegetation associations (i.e., wetland vegetation, mesquite bosque, dry wash vegetation, creosote bush scrub) in the Canyon, in combination with perennial surface water, that allow for a dense array of habitats and wildlife species. Vegetation is a key component of riparian habitat. It provides structure and cover for animals, shade which influences water temperature, and plays an important role in nutrient cycling and soil stabilization" (Ostermann and Boyce 2002).

1.1.2 Borrego Palm Canyon/Creek Mapped GDEs (GDE Unit 2)

The NCCAG dataset has mapped primarily vegetation within GDE Unit 2, Borrego Palm Canyon/Creek (Figures 1 and 6). These communities are narrowly focused within the riparian corridors associated with Palm Creek. Potential GDE vegetation types mapped in association with Palm Canyon include Desert Willow, California Fan Palm, and Catclaw Acacia.

1.1.3 Mesquite Bosque (Borrego Sink) GDEs (GDE Unit 3)

The NCCAG dataset has mapped primarily vegetation within GDE Unit 3, which consists of Mesquite Bosque narrowly focused along the Borrego Sink Wash east of the Borrego Sink (Figures 1 and 13). The potential GDE plant type primarily associated with the Borrego Sink is honey mesquite.

1.2 Contributing Watersheds Potential GDEs

Contributing watersheds along the eastern flanks of the mountainous terrain that abuts the Subbasin to the west were evaluated to identify potential GDEs. Watersheds were delineated from the point of intersection of major drainages with the downstream side of the Subbasin boundary. Ten watersheds including twenty-eight subwatersheds were delineated as listed in Table 1 and described in the following subsections.

1.2.1 Coyote Creek Watershed

The Coyote Creek watershed is comprised of two subwatersheds referred to as the Coyote Creek and Coyote Creek South subwatersheds. The area of the Coyote Creek watershed contributing to the Subbasin encompasses approximately 94,506 acres (Figures 1 and 3). The watershed is located almost entirely within the boundary of the ABDSP. Upper portions of the watershed are developed with rural residences in the Terwillinger Valley located in Riverside County. The maximum elevation of the watershed is 8,615 feet above mean sea level (amsl) on the flank of Toro Peak in the Santa Rosa Mountains that reaches a maximum 8,716 feet amsl at the peak. The minimum elevation of the watershed is approximately 1,200 feet at the Lower Willows. The Coyote Creek watershed is discussed further in Sections 2 and 5.

Table 1. Contributing Watersheds Area and Elevation

Contributing Watershed	Subwatershed	Area (Acres)	Total Area (Acres)[a]	Elevation (Feet, amsl)	
				Maximum	Minimum
Coyote Creek	Coyote Creek	92,722	94,506	8,615	1,200
	Coyote Creek South	1,784			
Horse Camp	North	556	1,931	3,700	940
	Middle North	569			
	Middle South	677			
	South	129			
Henderson Canyon	North 1	1,599	2,984	4,650	1,163
	North 2	123			
	North 3	209			
	South 1	45			
	South 2	582			
	South 3	426			
Borrego Palm Creek	NA	14,994	14,994	6,404	1,300
Hellhole Canyon	Panoramic Overlook Canyon	407	6,667	6,142	962
	North Fork	504			
	Middle Fork	1,535			
	South Fork	4,221			
Dry and Culp Canyons	Dry Canyon	1,009	6,140	4,491	956
	Culp Canyon	5,131			
Tubb Canyon	Tubb Canyon	2,396	3,095	4,520	920
	Road North	265			
	Road Middle	190			
	Road South	244			
Glorietta Canyon	Glorietta Canyon	1,852	2,595	4,589	1,250
	South Fork	743			
Yaqui Ridge	North 1	1,042	2,903	3,864	1,252
	North 2	47			
	North 3	979			
	Yaqui Pass	581			
	Yaqui Ridge	110			
	Cactus Valley	144			
San Felipe Creek	NA	117,339	117,339	5,719	992

Source: Watersheds delineated using StreamStats, USGS 2017.
Notes:
amsl = above mean sea level
NA = not applicable
[a] Total area of the contributing watersheds does not include areas within the Subbasin.

1.2.2 Horse Camp Watershed

The Horse Camp watershed is comprised of four subwatersheds referred to as the North, Middle North, Middle South and South subwatersheds (Figure 4). In total, the Horse Camp Watershed area is 1,931 acres. The Horse Camp subwatersheds are characterized by narrow canyons that drain the eastern foothill hills of the San Ysidro Mountains. The maximum elevation of the watershed is 3,700 feet amsl attained in the Middle South subwatershed and the minimum elevation is about 940 feet amsl in the South subwatershed. The NCCAG dataset indicates no mapped vegetation, wetlands or springs in the watershed. An isolated pocket of mapped vegetation is noted where the Horse Camp drainages converge in a wash on the edge of the valley. These potential GDEs are edge cases mapped in areas confined to the outer fringes of the Subbasin boundary; their geographic confinement to the mountain front indicates that the vegetation communities are supported by surface water flows originating outside the Subbasin and not sustained by the regional groundwater table.

1.2.3 Henderson Canyon Watershed

The Henderson Canyon watershed is comprised of six subwatersheds referred to as the North 1, North 2, North 3, South 1, South 2 and South 3 subwatersheds (Figure 5). The total Henderson Canyon watershed area is 2,984 acres. The maximum elevation of the watershed is 4,650 feet amsl attained in the North 1 subwatershed and the minimum elevation is about 1,163 feet amsl in the North Fork subwatershed. No springs are mapped in the watershed. Potential GDEs vegetation is mapped by the NCCAG dataset in the North 2 and South 2 subwatersheds. The mapped vegetation occurs along narrow corridors associated with ephemeral drainages. Mapped vegetation occurs in the Subbasin at the upper portion of the alluvial fans that originate from the watersheds. These potential GDEs are edge cases mapped in areas confined to the outer fringes of the Subbasin boundary; their geographic confinement to the mountain front indicates that the vegetation communities are supported by surface water flows originating outside the Subbasin and not sustained by the regional groundwater table.

1.2.4 Borrego Palm Creek Watershed

Borrego Palm Creek watershed encompasses approximately 14,994 (Figures 1 and 6). The watershed is located almost entirely located within the boundary of the ABDSP. The watershed rises to a maximum elevation of 6,404 feet amsl near Hot Springs Mountain, the highest peak in San Diego County at an elevation of 6,535 feet amsl. The minimum elevation of the watershed in 1,300 feet amsl at the First Palm Grove. The Borrego Palm Creek Watershed is discussed further in Sections 2 and 5.

1.2.5 Hellhole Canyon Watershed

The Hellhole Canyon watershed is comprised of four subwatersheds referred to as the Panoramic Overlook Canyon, North Fork, Middle Fork, and South Fork subwatersheds (Figure 7). The total Hellhole Canyon watershed area is 6,667 acres. The maximum elevation of the watershed is 6,142 feet amsl attained in the South Fork subwatershed and the minimum elevation is about 962 feet amsl in the North 3 subwatershed. The Hellhole Canyon subwatersheds discharge through narrow canyons to the Subbasin where the constricted canyons broaden onto an alluvial fan. Vegetation on the alluvial fan is sparse compared to the dense vegetation in the South Fork subwatershed. The County vegetation layer maps a narrow corridor of riparian habitat in the South Fork. Satellite-color infrared photography reveals vegetation along additional drainage segments of the South Fork and lesser vegetation in the Middle Fork. One spring is mapped in the Middle Fork subwatershed. Four springs are mapped in the South Fork. None of the springs or GDEs identified within the watershed occur within the Subbasin.

1.2.6 Dry Canyon and Culp Canyon Watersheds

The Dry Canyon and Culp Canyon watersheds are comprised of two watersheds (Figure 8). The total Dry Canyon and Culp Canyon watersheds area is 6,140 acres. Dry Canyon is intersected by Montezuma Valley Road in the middle to lower part of the watershed. Dry Canyon is sparsely vegetated with no mapped potential GDEs or springs. Culp Canyon extends to a much higher elevation reaching 4,591 feet amsl where it abuts the community of Ranchita. Much of the watershed is located above 3,000 feet amsl where 14 springs are mapped. No vegetation is mapped in the area of the springs; however, review of aerial photography reveals narrow corridors of vegetation associated with the spring complexes. Where Culp Canyon enters the valley it joins with several canyons, including Tubb Canyon, to form an alluvial fan. The NCCAG dataset maps vegetation on the alluvial fan. These potential GDEs are edge cases mapped in areas confined to the outer fringes of the Subbasin boundary; their geographic confinement to the mountain front indicates that the vegetation communities are supported by surface water flows originating outside the Subbasin and not sustained by the regional groundwater table.

1.2.7 Tubb Canyon Watershed

Tubb Canyon is comprised of four subwatersheds referred to as Tubb Canyon, and Tubb Canyon Road North, Middle and South subwatersheds. The total Tubb Canyon watershed area is 3,095 acres. The maximum elevation of the watershed is 4,520 feet amsl and the minimum elevation (i.e., outlet) is about 920 feet amsl. Tubb Canyon watershed discharges through a narrow canyon to the Subbasin where it broadens into an alluvial fan (Figure 9). Three springs are mapped in the watershed and include Big Spring, Middle Spring and Tubb Canyon Spring (ABDSP 2017). In the vicinity of Big Spring, seepwillow, catclaw and mesquite have been identified (San Diego Reader 2010). The satellite color-infrared photography indicates green, healthy vegetation as the color red (high reflection of near-infrared wavelengths). In a desert environment, the green healthy vegetation could represent a potential GDE. A narrow band of habitat appears in the Tubb Canyon Creek channel primarily associated with the mapped springs. A band of vegetation is mapped by the NCCAG dataset where Tubb Canyon opens into the Subbasin near Dry and Culp Canyons. As previously discussed for the Dry and Culp Canyon watersheds, this potential GDE is supported by surface water flows originating outside the Subbasin and not sustained by the regional groundwater table.

1.2.8 Glorietta Canyon Watershed

Glorietta Canyon watershed is comprised of two subwatersheds referred to as Glorietta Canyon and South Fork subwatersheds (Figure 10). The total Glorietta Canyon watershed area is approximately 2,595 acres. The maximum elevation of the watershed is 4,589 feet amsl and the minimum elevation (i.e., outlet) is about 1,250 feet amsl. The watershed discharges to the Yaqui Meadows area of the Subbasin. No springs are mapped in the Glorietta Canyon. The satellite color-infrared photography indicates limited vegetation associated with Glorietta Canyon, which agrees with the lack of mapped springs, vegetation and wetlands. No springs or potential GDEs are mapped in the Subbasin in the vicinity of Glorietta Canyon watershed.

1.2.9 Yaqui Ridge Watershed

The Yaqui Ridge watershed is comprised of six watersheds scattered along the ridgeline and referred to as the North1, North 2, North 3, Yaqui Pass, Yaqui Ridge and Cactus Valley subwatersheds (Figure 11). The total Yaqui Ridge Watersheds area is 2,903 acres. The maximum elevation of the watershed is 3,864 feet amsl and the minimum elevation (i.e., outlet) is about 1,252 feet amsl. Yaqui Pass Road crosses the South watershed. No vegetation or springs are mapped within the Yaqui Ridge Watershed. Sparse vegetation within the drainage channels is shown on aerial photography. No springs or potential GDEs are mapped in the Subbasin in the vicinity of Yaqui Ridge watershed.

1.2.10 San Felipe Creek Watershed

The San Felipe Creek watershed is comprised of one large watershed of approximately 117,339 acres (Figure 12). The watershed rises to a maximum elevation of 5,719 feet amsl in the Vulcan Mountains north of the town of Julian, and the minimum elevation (i.e., outlet) is about 992 feet amsl. San Felipe Creek enters the valley though a narrow canyon ("narrows") that cuts through Yaqui Ridge. A deeply incised broad wash extends from the narrows to the valley floor and beyond to the Palo-Verde Wash. Borrego Springs Road crosses the broad San Felipe Creek wash at what is known as the "Texas dip". This wash is often the location of periodic and dramatic flash floods. The San Felipe Creek wash forms the southern boundary of the Subbasin. The NCCAG dataset and County vegetation datasets map extensive vegetation in the upper portion of the watershed and in narrow corridors in the lower portions of the watershed. Limited vegetation is also mapped in the wash near where the San Felipe Creek enters the Subbasin. None of the potential GDE habitat identified occurs within the Subbasin.

2 Streamflow

2.1 Coyote Creek

Streamflow in the Coyote Creek watershed has been documented by USGS as the number one source of groundwater recharge to the Subbasin via stream flow leakage (i.e., infiltration of surface water runoff primarily during flood events). An estimated 65% of the surface water inflow to the Borrego Valley comes from Coyote Creek (USGS 1982).

Perennial stream flow in Coyote Creek occurs in the northern most section of the Subbasin. Groundwater daylights at lower elevations in the Collins Valley at the Oasis at Santa Catarina Spring and Lower Willows Spring where the stream is restricted by a narrow hard rock canyon. The restrictive canyon appears to act as a subsurface dam causing groundwater to daylight at the spring and flow into the Subbasin as surface water flow in Coyote Creek. This occurs approximately 1 mile upstream from the Subbasin boundary at an elevation of about 1,300 feet amsl. The spring was first documented in 1774 by members of the Anza Expedition near the site of a large Cahuilla Indian village.[5] "The creek contains three reaches where bedrock forces groundwater to the surface throughout the year, resulting in perennial surface or near-surface water. These areas, referred to as Lower, Middle, and Upper Willows, form three of the most verdant riparian wetlands of the California desert" (Ostermann and Boyce 2002). As the creek flows though the Subbasin, the alluvium becomes deeper and the surface flow either infiltrates into the Subbasin, is consumed by the riparian vegetation through transpiration and/or evaporates. During high rainfall events, flow extends Coyote creek further into the Subbasin for short periods of time.

Historical Stream Flow Measurements

There are two historical streamgages along Coyote Creek located at the northernmost boundary of the Subbasin, one of which stopped recording streamflow in 1983 and the other stopped recording flow in 1993. USGS Station Number 10255800 (Upper–Northern) recorded daily discharge data from 1950 – 1983; at this station, annual average stream flow was measured to be 1,831 acre-feet per year (USGS 2019). USGS Station Number 10255805

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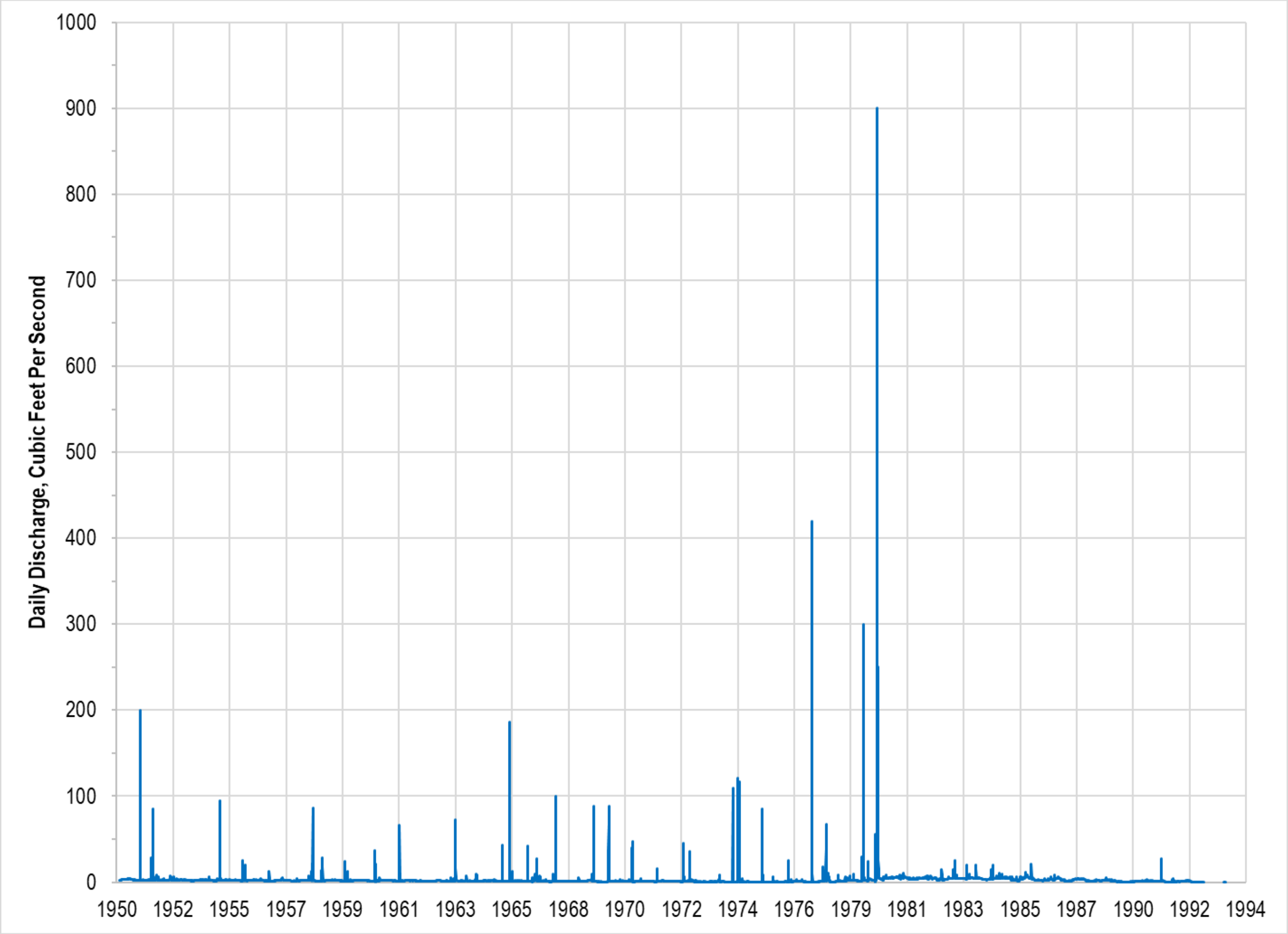
[5] Over 85 archeological sites have been recorded along the main creek in the Coyote Canyon, including major villages, food processing centers, rock art, and ceremonial and cremation sites (Ostermann and Boyce 2002).

(Lower–Southern) recorded daily discharge data from 1983 – 1993; at this station, annual average stream flow was measured to be 1,774 acre-feet per year (USGS 2019).

Exhibit 1. USGS 10255800 and 10255805 Coyote Creek Stream Flow 1950 to 1993



Source: USGS 2019
Notes: Discharge data from 1950 to 1983 was recorded at the upper-northern Coyote Creek USGS gage (10255800), while data from 1983 to 1993 was recorded at the lower-southern gage (10255805).

Annual variability over the period measured ranges from 326 acre-feet to 10,715 acre-feet. This large annual variability is a function of large annual variability of precipitation falling on the Coyote Creek watershed. Coyote Creek stream flow is generally correlated with precipitation and spring discharge form Clark Valley. Exhibit 1 shows the combined daily discharge from Coyote Creek USGS streamgages 10255800 and 10255805 for the period from 1950 to 1993.

Manual Stream Flow Measurements

To evaluate the potential GDEs associated with Coyote Creek, the GSA has investigated whether the perennial and ephemeral creek segments are gaining water or losing water to the underlying aquifer system. To complete this analysis, the GSA has commenced mapping the perennial extent of flow in to the Subbasin on a semi-annual basis (spring and fall). The upper historical streamgage is the GSA's manual monitoring point for Coyote Creek. At this location, the GSA manually measured an instantaneous stream flow of 0.46 cubic feet per second (CFS) in the spring 2018, which converts to 206.5 gallons per minute. At that time, the former lower historical USGS streamgage station was observed to be dry.

In the spring of 2018, the perennial extent of flow in Coyote Creek was documented to cease downstream of the third-crossing and upstream of the second crossing. No flow was observed in the spring of 2018 at the lower inactive USGS streamgage, which is one of the permanent locations for manual flow readings. In the fall of 2017, stream flow extended almost half-way from the second crossing to the first crossing. The crossings refer to where an unimproved trail crosses the creek bed, and are shown in Figure 1. In the fall of 2017, there was a precipitation event in the Coyote Creek watershed that produced runoff in Coyote Creek; however, no stream flow measurements are available for this event. Flow in the stream was observed to decrease incrementally from the upper inactive USGS streamgage to 2 locations measured downstream.

"From 1951 to 1992, average daily streamflow in the creek measured at Lower Willows [USGS gages 10255800 and 10255805] was relatively stable and ranged from 0.5 cubic feet per second (cfs) to 4.9 cfs, with the exception of 1980, when the average was 14.8 cfs" (Ostermann and Boyce 2002). The streamflow measurements taken by the GSA at approximately the same location are within the range of historical measurements. The evidence gathered thus far indicates that the reach of Coyote Creek that was mapped as potential GDE by DWR is a "losing" stream, and that this habitat, where it occurs, is supported by intermittent storm events and/or flows emanating from the upland watersheds and basins. The evidence points to a losing stream because despite having a watershed size of 94,506 acres, Coyote Creek loses flow with distance downstream (i.e., within 1 – 2 miles of its crossing into the Subbasin). Stream flow, or lack thereof, has a clear and immediate relationship with runoff events from precipitation. If groundwater emanating from the Borrego Springs Subbasin were contributing to base flow within Coyote Creek, there would be a less rapid and obvious response to precipitation, and rather than going dry upon entering the Subbasin, flow would be expected to be maintained (or even increase) with distance downstream. Additionally, the depth to the regional groundwater table in the Subbasin in the vicinity of Coyote Creek is hundreds of feet below ground surface (288 feet at State Well ID No. 009S006E31E003SI) and disconnected from surface flows.

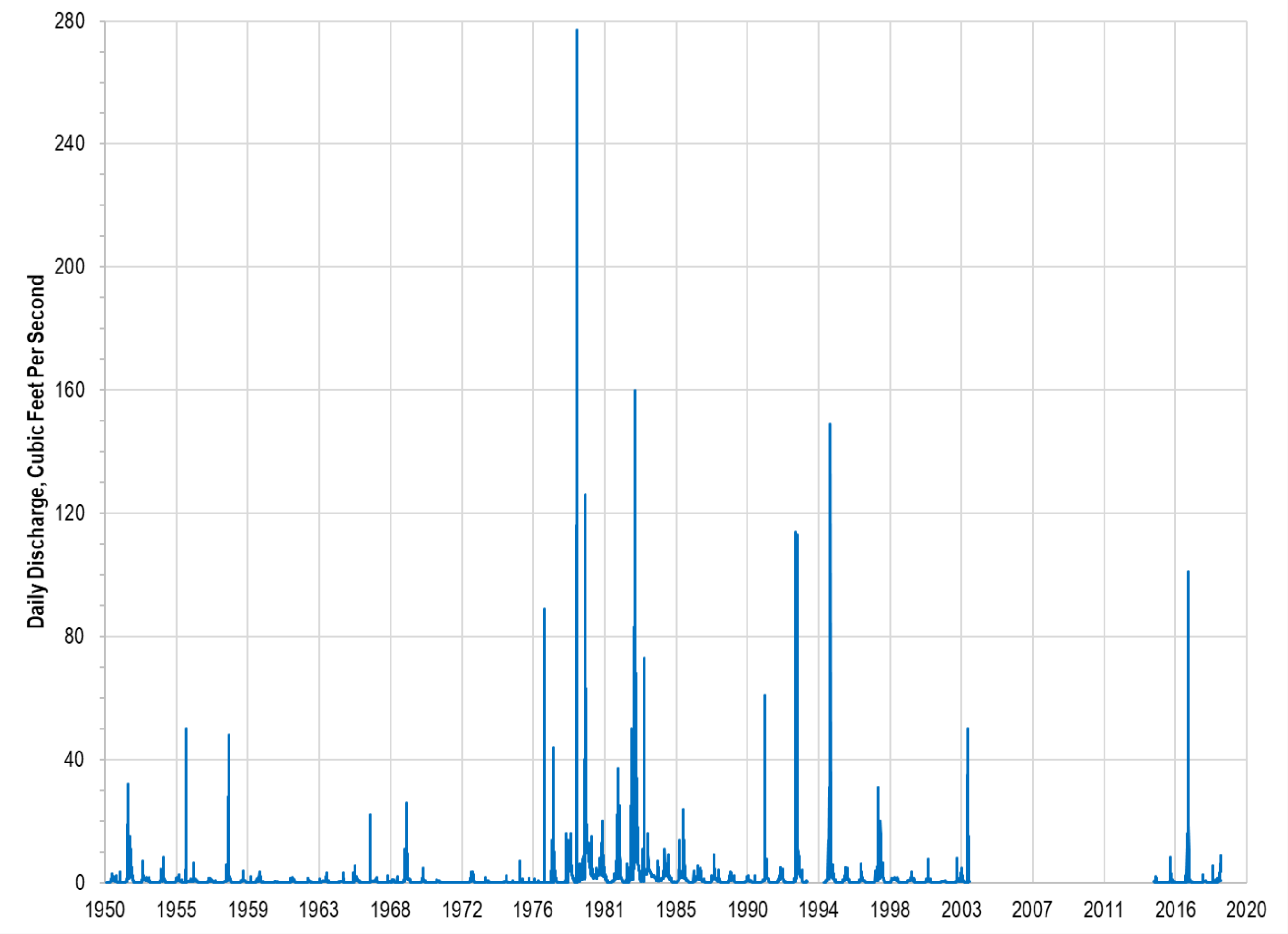
2.2 Borrego Palm Creek

Intermittent stream flow from the Borrego Palm Creek watershed is an important source of recharge to the Subbasin. Perennial flow occurs is observed to occur in Borrego Palm Creek upstream of the palm oasis but apart from wetter periods, the perennial flow infiltrates into the ground along the steep alluvial fan that emerges into the Subbasin.

Historical/Active Stream Flow Measurements

An active streamgage, USGS Station Number 10255810, is located on Borrego Palm Canyon downstream on the palm oasis. This streamgage has a 55-year period of record with sub-daily data (15 minute) from 2015 to 2019, and daily data from 1950 to 2003 (USGS 2019). The data indicate little to no flow over most of the period of record punctuated by higher flows associated with individual precipitation events. During wet years, prolonged stream flow after individual precipitation events is often recorded, but in most years little to no base flow is recorded in the summer months. Brief runoff events occur during occasional thunderstorms. Exhibit 2 shows the daily discharge from Borrego Palm Canyon USGS streamgage 10255810 for the period from 1950 to 2003, and 2015 to 2019.

Exhibit 2. USGS 10255810 Borrego Palm Canyon Stream Flow 1950 to 2019



Source: USGS 2019
Notes: Streamgage was inactive September 30, 2003 to January 6, 2015.

Manual Stream Flow Measurements

The USGS regularly performs manual streamflow monitoring of its active gages including the Borrego Palm Canyon streamgage. Nineteen manual measurements were taken by USGS staff in 2018 and 2019 with recorded stream flow of no flow to 7.26 cubic feet per second (449 gpm) (USGS 2019). The clear and consistent relationship between seasonal and episodic precipitation and the patterns of recorded stream flow indicates that the reach of Borrego Palm Creek that was mapped as potential GDE by DWR is a “losing” stream, and that this habitat, where it occurs, is supported by intermittent storm events and/or flows emanating from the upland watersheds and basins.

3 Borrego Sink (Mesquite Bosque)

According to the USGS (2015), the Borrego Sink, a topographic low where the water table prior to development was within 10 feet of land surface, was the site of about 450 acres of honey mesquite bosque and other native phreatophytes,[6] indicating that shallow groundwater and occasional accumulations of surface water was historically sufficient to support a groundwater dependent ecosystem. Prior to development, mesquite trees, salt grass, willow and rushes were reported to be abundant in the valley (Mendenhall 1909).

As stated in General Plan Update Groundwater Study completed by San Diego County (2010): "The mesquite bosque, a rare and sensitive groundwater-dependent habitat, is believed by many experts to be desiccating in portions of Borrego Valley, even though their taproots can reach down to 150 feet for water." The habitat covered an approximate four-square mile area. However, while mesquite bosque as a species have been recorded to have extremely deep taproots, the USGS (2015) notes that the maximum rooting depth for phreatophytes found locally in around the Borrego Sink and areas to the north was at 15.3 feet. Recent groundwater levels from wells adjacent to the main mapped habitat range from approximately 55 to 134 feet below the ground surface. Mitten (1988) and other estimated that prior to 1946, about 4,300 acre-feet of water was discharged from phreatophytes annually by evapotranspiration.

The honey mesquite bosque, shown as pink and green areas in Figure 1 north of the Borrego Sink, is considered a pre-2015 impact, because groundwater levels have declined to a level that no longer supports a viable habitat. Groundwater levels have long since declined below a level which can support the estimated rooting depth of the habitat, which is 15.3 feet (USGS 2015). Natural discharge determined from the Borrego Valley Hydrologic Model (BVHM) attributable to evapotranspiration was approximately 6,500 acre-feet per year prior to development, but has been virtually zero in the last several decades (1990–2010) (USGS 2015). The BVHM includes a component of evapotranspiration in the water budget, and estimates close to 400 acre-feet of percolating surface water throughout the Subbasin is lost to evapotranspiration under existing conditions. Based on the land uses and mapped vegetation incorporated into the BVHM, this is dominated by losses from farms, golf courses, non-native tamarisk, and other land uses. The green area in Figure 1 depicts the pre-pumping mapped historical extent of phreatophytes in the Subbasin by USGS (USGS 2015). The pink area depicts the mapped pre-January 1, 2015 extent of potential GDEs (SANGIS 2017); and the orange area depicts the extent of mapped GDEs by the NCCAG dataset (DWR 2018).

Pumping in the Subbasin has resulted in a groundwater level decline of about 44 feet over the last 65 years in the vicinity of the Borrego Sink. The average rate of decline over this 65 year period is approximately 0.67 feet per year. The 1955 groundwater level was about 11 feet below ground surface and the most recent groundwater level measured in the fall of 2018 was 55.2 feet below ground surface. Because of the long-term imbalance of pumping with available natural recharge, an irreversible impact has occurred to the honey mesquite bosque, which is mostly desiccated prior to January 1, 2015. The "Sink" wells shown in Figure 1 (i.e., 12G1 and 7N1) have become dry based on measurements recently performed by DWR. Groundwater level measurements collected in 2009 of Sink Well 12G1 and well MW-5B indicated similar groundwater level elevations, whichsuggeststhat well MW-5B is sufficiently representative of depth to the groundwater table in the area of the Borrego Sink.

Old Borrego Spring

In 1963, Lester Reed wrote in Old Time Cattlemen and Other Pioneers of the Anza-Borrego Area, "Since so much recent pumping of water in the Borrego Valley, the old spring no longer flows. This spring was one of the watering

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[6] Phreatophytes are long-rooted water loving plants that obtain water supply from groundwater or the capillary fringe just above the water table.

places upon which the Indians, and the old-timers could depend, although the water was of poor quality. The first time I visited Old Borrego Spring was just two or three days before Christmas 1913 when my brother Gilbert (Gib), and I were riding though on horseback from Imperial Valley to spend the holidays with our parents at the Mud Spring Ranch about fifteen miles southeast of Hemet. Since early boyhood, I heard old-timers talk about Borrego Springs water; so I thought I would try it. As I have said many times before, I found it to taste but very little better than the treated water we are expected to drink today (Reed 2004)."

The Old Borrego Spring was located in the vicinity of the Desert Lodge anticline, fold axes running perpendicular to the Veggie Line fault (notice uplifted sediments located south of the Old Borrego Spring and mapped NCCAG vegetation), Coyote Creek fault and Yaqui Ridge/San Felipe anticline associated with the San Jacinto fault zone (Steely 2009) (Figures 1 and 13). The faulting and folding effectively compartmentalize the deep sediments of the Subbasin from the adjacent Ocotillo Wells Groundwater Subbasin. When groundwater levels were closer to the surface in the Subbasin this resulted in 'daylighting' of groundwater at the Old Borrego Spring.

4 Potential GDEs Ecological Condition

To assess the ecological condition of potential GDEs, several additional datasets were reviewed.

4.1 Threatened and Endangered Species

The Environmental Conservation Online System (ECOS) contains spatial data of critical habitat for threatened and endangered species. Critical habitat for Peninsular bighorn sheep is identified in the Subbasin (Figure 14). Critical habitat for Least Bell's vireo is also identified in the vicinity of the Subbasin near where Coyote Creek enters the Subbasin. Potential effects to these critical habitats must be analyzed along with the endangered species themselves during the California Environmental Quality Act (CEQA) review of the GSP Projects and Management Actions. The U.S. Fish and Wildlife Information for Planning and Consultation (IPaC) lists the other endangered species in the larger contributing watershed to the Subbasin: 2 mammals, 24 migratory birds, 1 reptile, 2 amphibians, 2 fishes, 2 insects, and flowering plants (U.S Fish & Wildlife Service 2018). An official consultation based on the CEQA project description is required with the resource agencies in order to evaluate potential impacts, get an official species list, and make species determinations.

4.2 Areas of Conservation Emphasis

The Areas of Conservation Emphasis (ACE) is a California Department of Fish & Wildlife non-regulatory tool that brings together the best available map-based data in California to depict biodiversity, significant habitats, connectivity, climate change resilience, and other datasets for use in conservation planning. ACE project contains spatial data on native species richness, rarity, endemism, and sensitive habitats for six taxonomic groups: birds, fish, amphibians, plants, mammals, and reptiles. Information on the location of four sensitive habitat types (i.e., wetlands, riparian habitat, rare upland natural communities, and high-value salmonid habitat) are also summarized. The ACE dataset is available statewide based on watersheds using hydrological units at the 12-digit code level (HUC12) for aquatic habitat. The Borrego Valley HUC12 sub-watershed has a low Significant Aquatic Habitat Rank (Figure 15).

The ACE dataset is available statewide at a 2.5-square-mile hexagon grid for terrestrial habitat. The color ramp has been coded at the USDA Ecoregion level with each color approximate to the 20th percentile of land area in the Colorado Desert Ecoregion. The developed areas of Borrego Springs have a terrestrial habitat rank of 0 (Figure 16). Moving outward from the developed area of Borrego Springs the rank increases to higher terrestrial habitat values.

Species Biodiversity Summaries combine the three measures of biodiversity developed for ACE into a single metric. These three measures include: 1) native species richness; 2) rare species richness; and, 3) irreplaceability. Much of western flank of the Subbasin is ranked as high species biodiversity [grey hexagons] depicted in Figure 17. Interestingly, the Species Biodiversity Rank seems to conflict with the previous Significant Terrestrial Habitat Rank for the hexagons located in the central portion of the Subbasin.

The California National Diversity Database (CNDDB) or California Special Status Species contains text and spatial information on California's special status species (rare plants and animals). It is a positive detection database. Records in the database exist only where species were detected. This means there is a bias in the database towards locations that have more survey work. Also, the database is proprietary and shall be displayed at such a scale (no larger than a scale of 1:350,000), or in such a way that the viewers/users cannot determine exact location information of the elements mapped in the system. Several positive detections are noted in the CNDDB within the Subbasin (Figure 18).

The California Protected Areas Database (CPAD) contains GIS data about lands that are owned in fee and protected for open space purposes by over 1,000 public agencies or non-profit organizations. This dataset shows that the majority of lands surrounding Borrego Springs are protected areas managed by the Anza Borrego Desert State Park (Figure 19). Additional parcels are managed within the Subbasin by the Anza Borrego Foundation, Borrego Water District (BWD) and County.

5 Potential GDEs Hydrogeologic Conceptual Model

A Hydrogeologic conceptual model has been developed for the entire Subbasin to provide the framework for the development of water budgets, analytical and numerical models, and monitoring networks. A HCM differs from a mathematical (analytical or numerical) model in that it does not compute specific quantities of water flowing through or moving into or out of a basin, but rather provides a general understanding of the physical setting, characteristics, and processes that govern groundwater occurrence and movement within the basin. Figure 20 presents the parameters of the HCM developed for the Subbasin, which conceptually depicts basin boundaries, stratigraphy, water table, land use, and the components of inflow and outflow from the Subbasin. In order to better evaluate potential GDEs, it was necessary to refine the Subbasin-wide HCM to address specific areas of the Subbasin representative of the GDE Units. As such, large scale HCMs have been developed for the ephemeral and perennial creeks and drainages (Contributing Watersheds) and the Borrego Sink (Mesquite Bosque) to provide a better understanding of the physical setting, characteristics and processes that govern groundwater occurrence and movement in these unique settings within the larger HCM. The location-specific HCMs are described in the following subsections and shown where they occur in the context of the Subbasin-wide HCM in Figure 20.

5.1 Ephemeral and Perennial Creeks and Drainages (Contributing Watersheds)

A HCM was developed for the potential GDEs identified in the Subbasin and at the Subbasin margins. Figure 21 depicts a HCM applicable to GDE Unit 1 – Coyote Creek, GDE Unit 2 – Borrego Palm Creek and other similar canyons that drain mountainous terrain adjacent to the Subbasin. This HCM illustrates that the source of water for potential GDE Units 1 and 2, and other similar canyons is stream flow that originates from outside of the Subbasin. Ephemeral and perennial streams transition to disconnected streams as they flow across the numerous alluvial fans that descend on the Subbasin. Stream flow percolates into a thick unsaturated zone. The regional groundwater table is often hundreds of feet below the streams. At Coyote Creek, the nearest well, State Well ID No. 009S006E31E003SI, has a depth to groundwater of 288 feet below land surface. At Borrego Palm Canyon Creek, the nearest well, State Well ID No. 010S005E25R002S, has a depth to groundwater of 348 feet below land surface. Other wells located adjacent to the Subbasin margins all have depths to groundwater several hundred feet below land surface. Groundwater extraction from water wells in the Subbasin does not effect GDEs associated with ephemeral and perennial creeks and drainages because the groundwater accessed by the wells is not water that is accessible or available to the potential GDEs.

5.2 Borrego Sink (Mesquite Bosque)

A HCM was developed for the Borrego Sink (Mesquite Bosque) to evaluate potential GDEs. Figure 22 depicts a HCM for potential GDE Unit 3 - Borrego Sink (Mesquite Bosque). The Borrego Sink is a topographic low in the Subbasin. The sink in all but the most exceptional wet years acts as closed or terminal basin where flood waters pool and fine sediment settles. After flood events, most of the water that reaches the sink evaporates leaving a white crust of salt that is often visible on the surface of the sink. Some of the flood waters that reach the sink percolate into the fine sediment and may locally support perched groundwater zones. As previously discussed in Section 3, Old Borrego Spring no longer discharges to the Borrego Sink.

Driller's logs for wells located in the vicinity of the Borrego Sink were reviewed to characterize the subsurface lithology. In particular, the log for MW-5A and 5B and Rams Hill test borehole No. 12 were reviewed.

MW-5 is a multi-completion well constructed in 2006 drilled to a depth of 480 feet below ground surface (bgs) under the oversight of the BWD and DWR. MW-5 is located about 1.2 miles northeast of the Borrego Sink. "In general, the boring encountered variably thick interbedded materials (silt and clay). Based on the borehole cuttings and the geophysical logs, the geologic materials encountered can be separated into three main zones or sequences divided at prominent clay layers: an upper zone dominated by poorly consolidated coarse grained materials from the surface to about 165 feet below ground surface (bgs); a middle zone of moderately consolidated interbedded fine- and coarse-grained materials between 165 feet and 355 feet bgs; and a lower zone of consolidated or lithified beds for fine-grained and coarse-grained material between 355 to 480 feet bgs" (DWR 2007).

MW-5B is screened from 45 to 155 feet below ground surface and appears to sufficiently represent the depth of the groundwater table in the vicinity of the Borrego Sink though it is possible that it represents a semi-confined potentiometric surface rather than the unconfined water table. MW-5A is screened from 200 to 340 feet and has a similar groundwater level to the shallower MW-5B suggesting potentially unconfined conditions in this part of the Subbasin; however, it is uncertain whether a good well seal was obtained during installation of the multi-completion monitoring well.

Test borehole No. 12 was drilled in 2014 about 0.5 mile south of the Borrego Sink, immediately south of the Rams Hill Wastewater Treatment Facility. Interbedded sand, silt and clay was encountered to a total borehole depth of 764 below land surface. Coarser material was only encountered at the surface to a depth of about 30 feet, and in one zone from 490 to 610 feet below ground surface. Thick clay zones with thin interbedded silty sands were encountered from 30 to 490 feet and form 610 feet to 764 feet (Dudek 2014). The depositional environment indicated by log is often one of low energy as evidenced by thick fine grain deposits. The depositional environment of the upper portion of the log is consistent with that of a desert playa (current depositional environment) and lacustrine setting (lake setting that occurred in desert basins during the last ice age [Pleistocene Epoch]). Deeper sections of the borehole may have encountered the Palm Springs Formation. The Borrego Sink HCM illustrates the predominantly fine sediment characterized in the subsurface in the vicinity of the Borrego Sink with coarser sediment shown proximal to mountainous terrain from which the sediments are derived (Figure 22).

Groundwater levels in the vicinity of the Borrego Sink have been measured at “Sink” wells 7N1 and 12G1 since 1953 and 1965, respectively, and MW-5A and MW-5B since 2006. The “Sink” wells have since become dry based on measurements performed by DWR in 2009. It is not known exactly when the Sink wells went dry; however, the groundwater level in well 7N1 was last measured by the USGS in 1965 at a depth of 36.0 feet bgs and well 12G1 was measured by the DWR in 2009 at a depth of 64.0 feet bgs. The total well depth of of 7N1 is 30.0 feet and 12G1 is 65.2 feet as measured by DWR.[7] The overlap of a groundwater level measurement in 2009 of Sink Well 12G1 with MW-5B has a similar groundwater level elevation suggesting that well MW-5B is sufficiently representative of depth to the unconfined groundwater table in the area of the Borrego Sink. The depth to groundwater at MW-5B in the spring of 2018 was 55 feet bgs. The groundwater table in the vicinity of the Borrego Sink has declined approximately 44 feet over the period from 1953 to 2019. The decline in the groundwater table in the vicinity of the Borrego Sink has resulted in the drying of Old Borrego Spring and desiccation of the honey mesquite bosque as previously discussed in Section 3. Given that groundwater levels will not substantially recover under current climate conditions and pumping volumes, the impacts to the Borrego Sink are considered permanent and irreversible.

6 Evaluation of Nexus of GDEs with Subbasin Groundwater

The SGMA definition of GDEs was applied to evaluate reliance of ecological communities and species on Subbasin groundwater. The evaluation revealed that Subbasin creeks can be characterized as losing streams in that they primarily act as groundwater recharge areas rather than local discharge of groundwater from the Subbasin to the stream reach. Potential GDEs that exist within Subbasin creek drainages rely on both periodic surface flows and soil moisture, and not directly on the regional groundwater table, which based on groundwater levels recently measured adjacent to the creek drainages indicate groundwater levels are beyond the rooting depth zone of existing vegetation mapped as potential GDEs.

The impact of rapidly declining groundwater levels on GDE vegetation is most apparent in the Borrego Sink.. The honey mesquite bosque that previously flourished in the Borrego Sink has desiccated and its areal extent has decreased significantly as groundwater levels have dropped in response to increased groundwater extraction. Pumping in the Subbasin has resulted in a groundwater level decline of about 44 feet over the last 65 years in the vicinity of the Borrego Sink. Recent groundwater levels from wells adjacent to the main mapped habitat range from approximately 55 to 134 feet below the ground surface. Because of the long-term imbalance of pumping with

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[7] The total well depth of Sink well 7N1 measured by DWR at 30 feet is less than the last groundwater level measured by USGS in 1965 of 36.0 feet. Sink well 7N1 likely either collapsed at 30.0 or is filled with sediment in the bottom of the well.

available natural recharge, an irreversible impact has occurred to the honey mesquite bosque, which is mostly desiccated prior to January 1, 2015.

Vegetation that occurs in the Borrego Sink has access to soil moisture in the unsaturated zone and potentially perched groundwater where present. Perched groundwater consists of local pockets (or lenses) of low permeability sediment (e.g., clay and silt) that "pinch out", meaning they are not laterally extensive enough to be considered a regionally significant aquitard. These zones are considered "perched" because they occur above the regional groundwater table, and thus are disconnected from changes experienced within regional aquifer (including outflows such as pumping). With these types of subsurface conditions, surface water may be slower to percolate into the underlying regional groundwater table, possibly providing conditions necessary to sustain remnant stands of Mesquite Bosque and/or support ongoing recruitment in combination with periodic storm flow events. The percolating groundwater used by this vegetation removes water that would otherwise constitute recharge. In other words, rather than the regional aquifer being a water source for the vegetation, the vegetation subtracts from the water available for deep infiltration.

7 Conclusion and Recommendations

A review of available pertinent spatial datasets, historical data including stream flow and groundwater levels, and geology was completed to develop a robust HCM to evaluate nexus of GDEs with Subbasin regional groundwater levels. The comprehensive assessment revealed potential GDEs identified within the Subbasin no longer have direct reliance on groundwater emerging from aquifers or on groundwater occurring near the ground surface, and instead are sustained by periodic stormwater flows, soil moisture, and potentially perched groundwater where present. These findings indicate that based on best available data there is no need for the GSP to address minimum groundwater level thresholds with respect to potential GDEs.

Detailed mapping of vegetation is lacking for the area in the vicinity of the Borrego Sink. Groundwater level monitoring of wells located in the vicinity of the Borrego Sink should continue.

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9 Advisory Committee Meeting GDEs Presentations

GDE presentations by DUDEK at SGMA Borrego Valley GSP Advisory Committee meetings in chronological are as follows:

ACM 2017.11.27	Coyote Creek
ACM 2018.05.31	Groundwater Dependent Ecosystems
ACM 2018.07.26	Groundwater Dependent Ecosystems
ACM 2019.01.31	Groundwater Dependent Ecosystems (GDEs) Approach in GSP

Presentations are available from the County of San Diego's Borrego Valley Groundwater Basin website: https://www.sandiegocounty.gov/content/sdc/pds/SGMA/borrego-valley.html

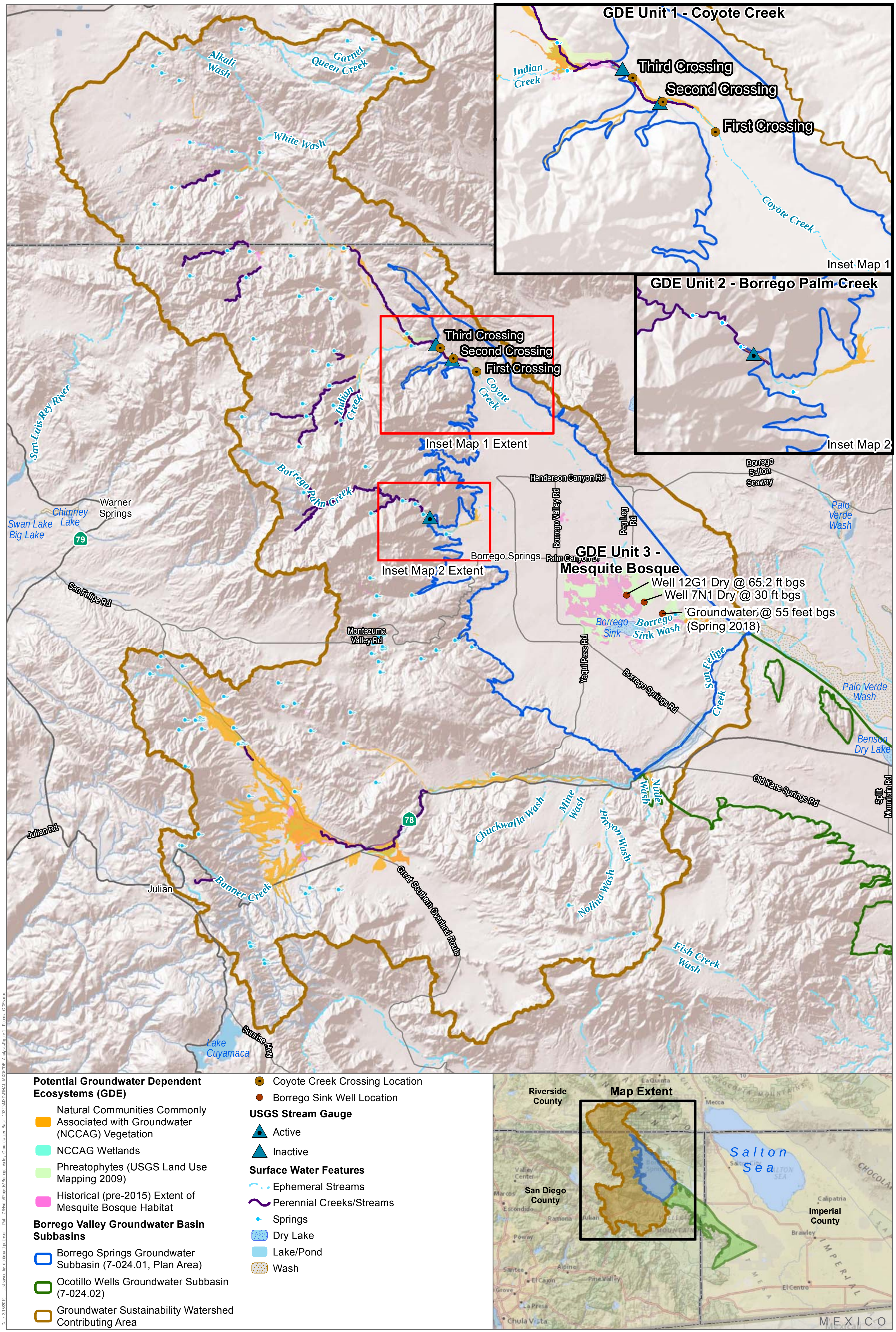
Tables and Figures

Table List

Exhibit List (exhibits are located within body of text)

Figure List

Figures 1-22



Date: 3/15/2019 - Last saved by: dpritchard-peterson - Path: Z:\Hydro\Projects\Borrego Valley Groundwater Basin 10329\MXD\FINAL MXD\GDE Analysis\Figure 1 - Potenial GDEs.mxd

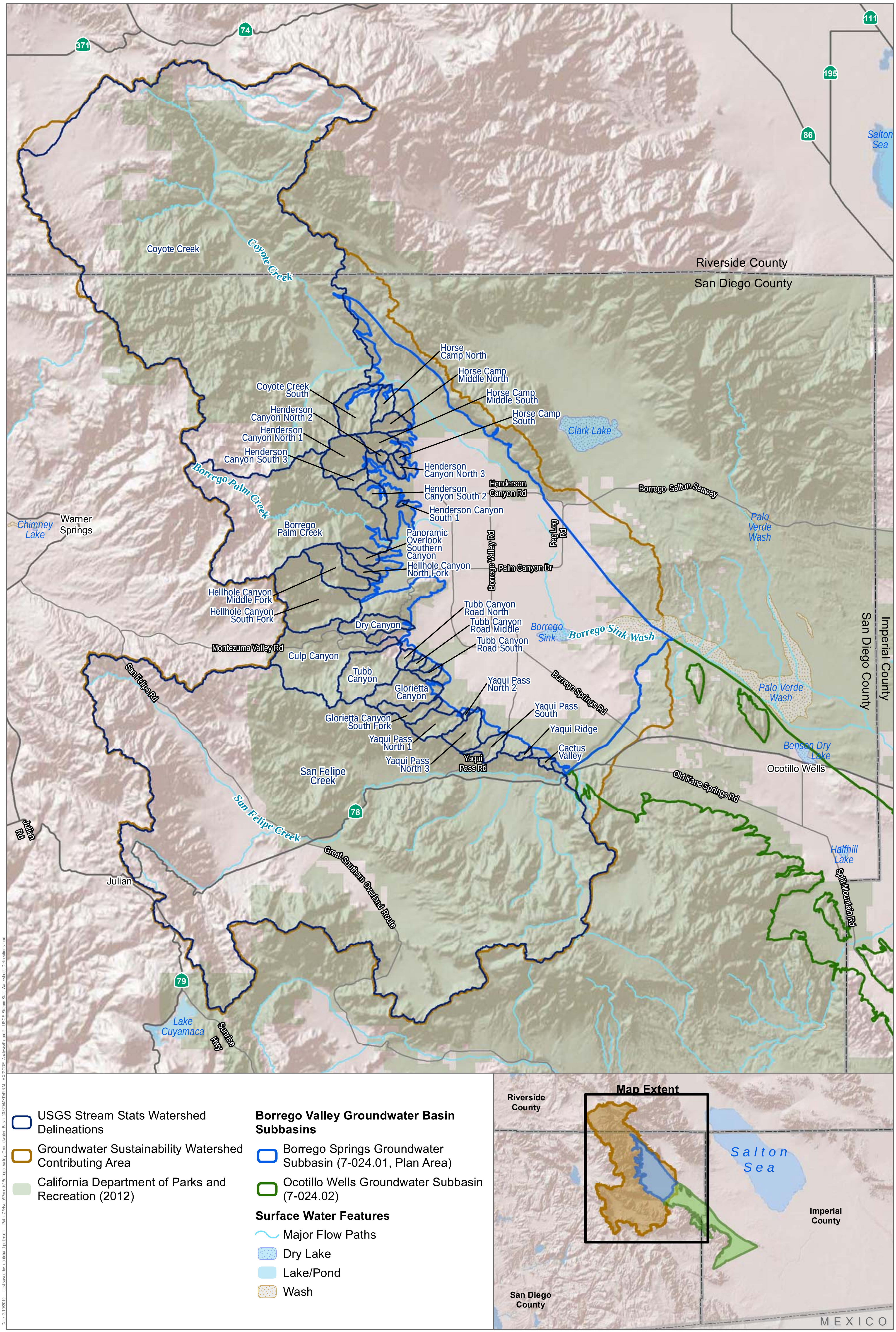
DRAFT March 2019

DATUM: NAD 1983. DATA SOURCE: DWR 2018; USGS NHD 2017; State Parks 2017; SanGIS 2017

DUDEK

Figure 1
Borrego Springs Subbasin and Potential Groundwater Dependent Ecosystems

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: USGS Stream Stats 2018

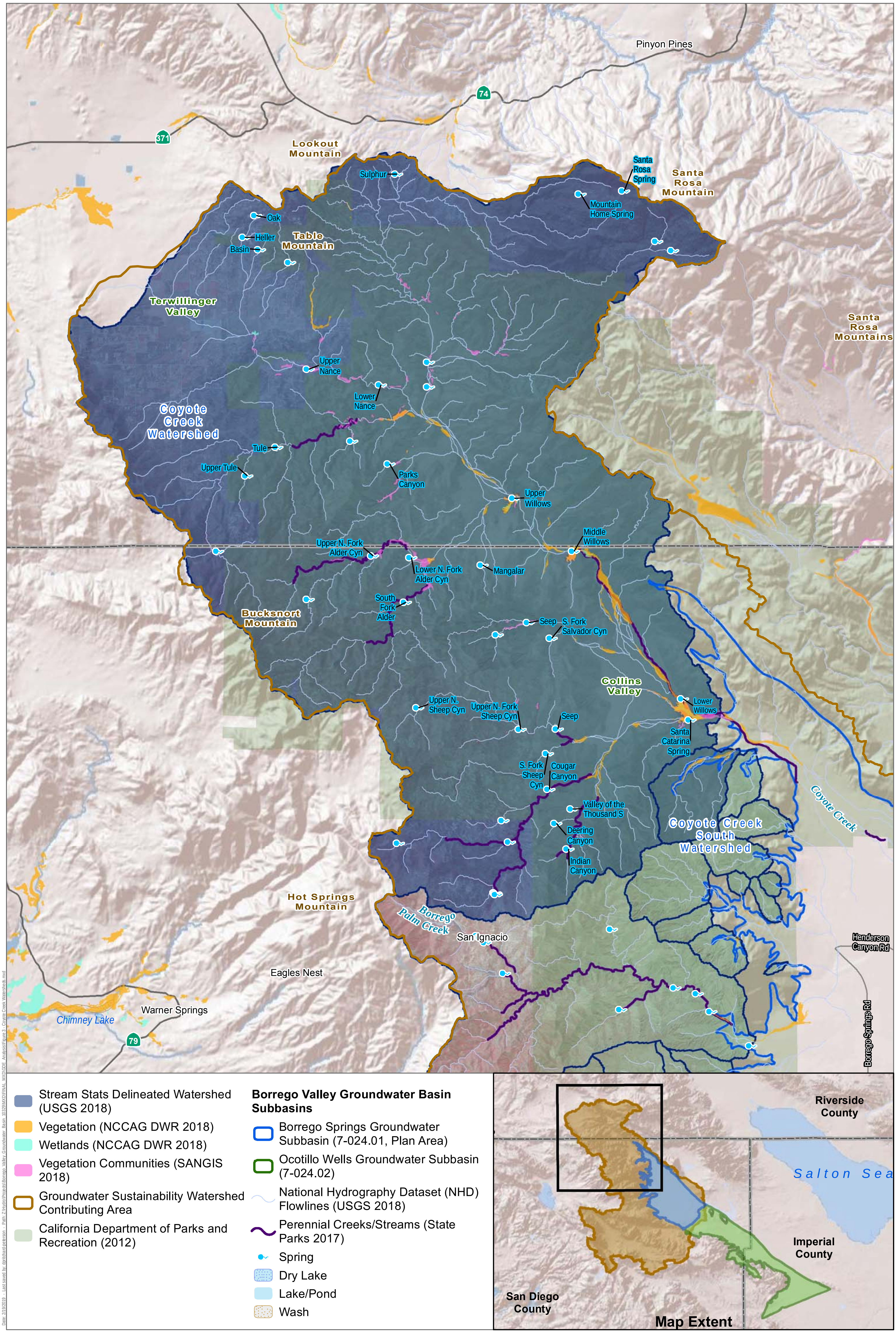
DUDEK

0 2 4 Miles

Figure 2

USGS Stream Stats Watershed Delineations

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

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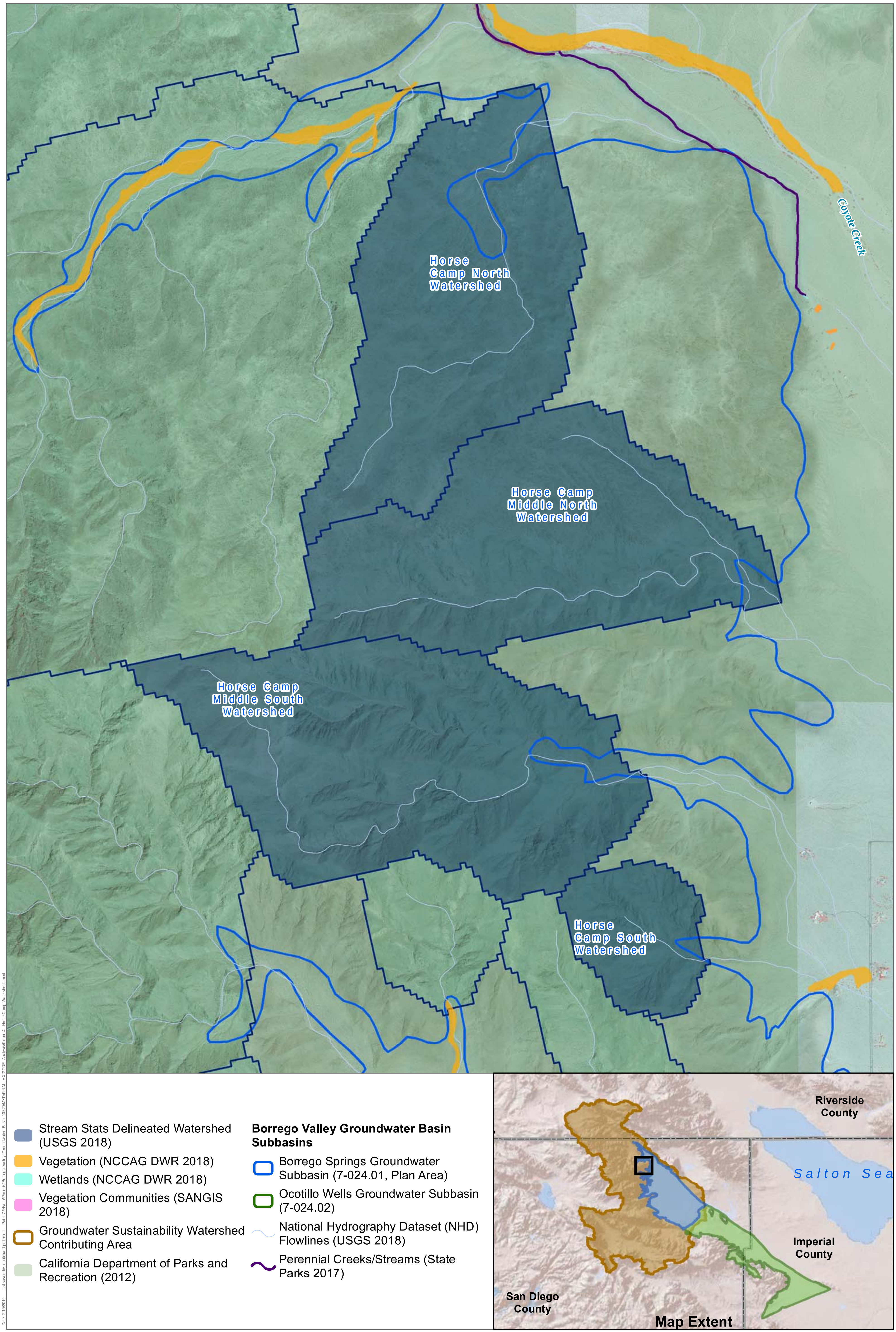
DUDEK

0 2 4 Miles

Figure 3
Coyote Creek Watersheds

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



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DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: USGS NHD 2018; USGS Stream Stats 2018; California State Parks 2017; USDA 2016; DWR 2018

DUDEK

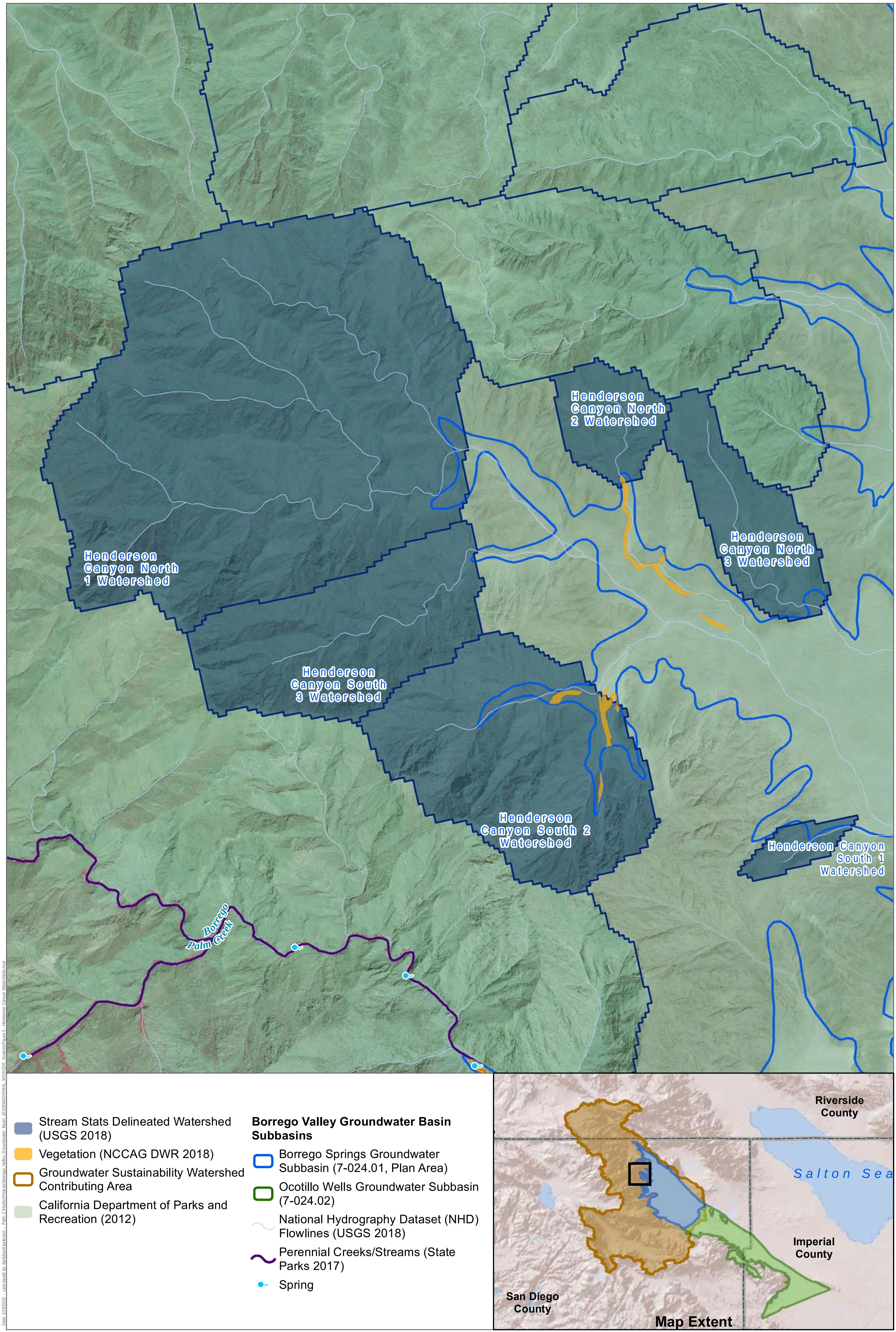
N

0 0.25 0.5 Miles

Figure 4

Horse Camp Watersheds

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



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DRAFT February 2019

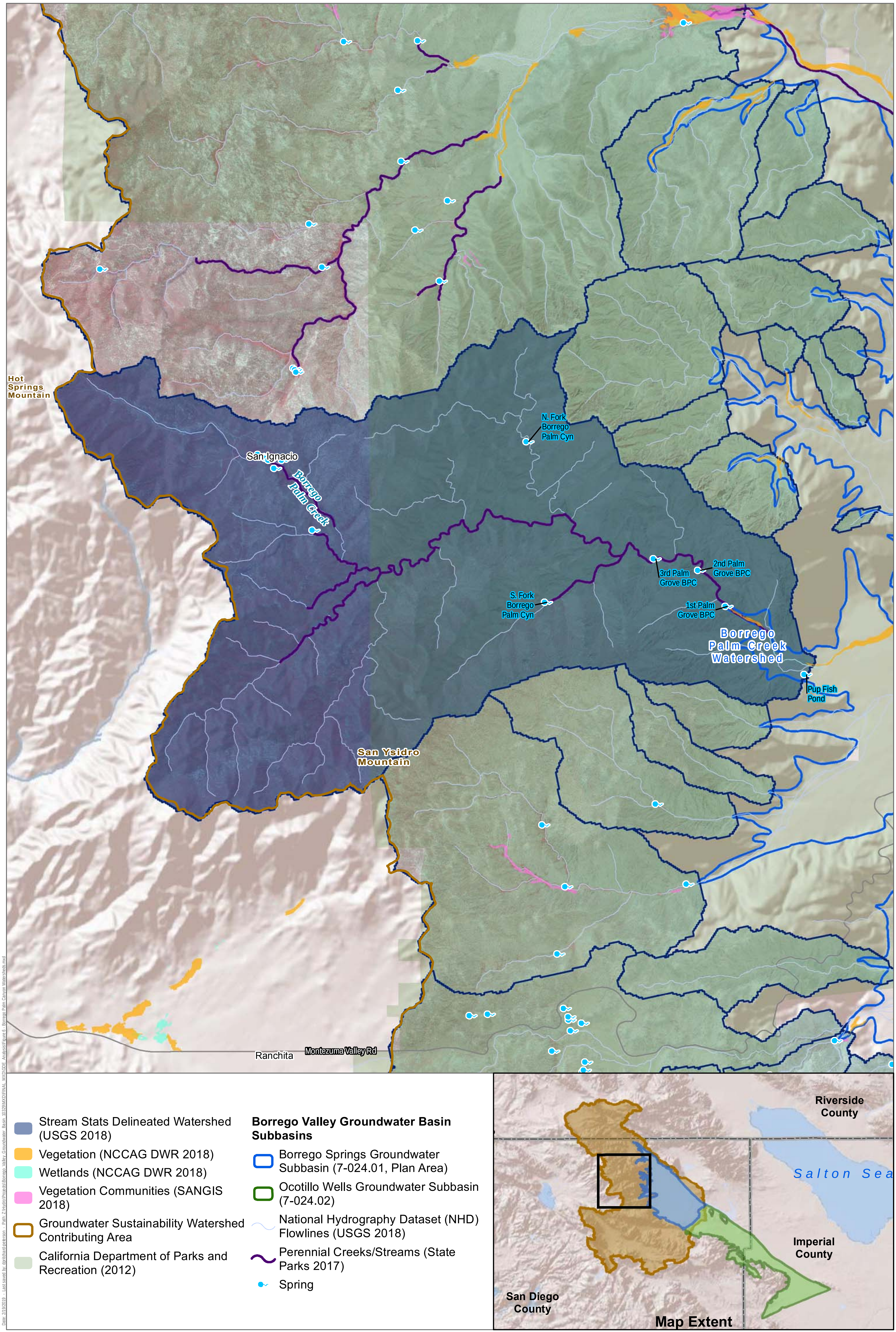
DATUM: NAD 1983. DATA SOURCE: USGS NHD 2018; USGS Stream Stats 2018; California State Parks 2017; USDA 2016; DWR 2018

DUDEK

0 0.5 1 Miles

Figure 5
Henderson Canyon Watersheds

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

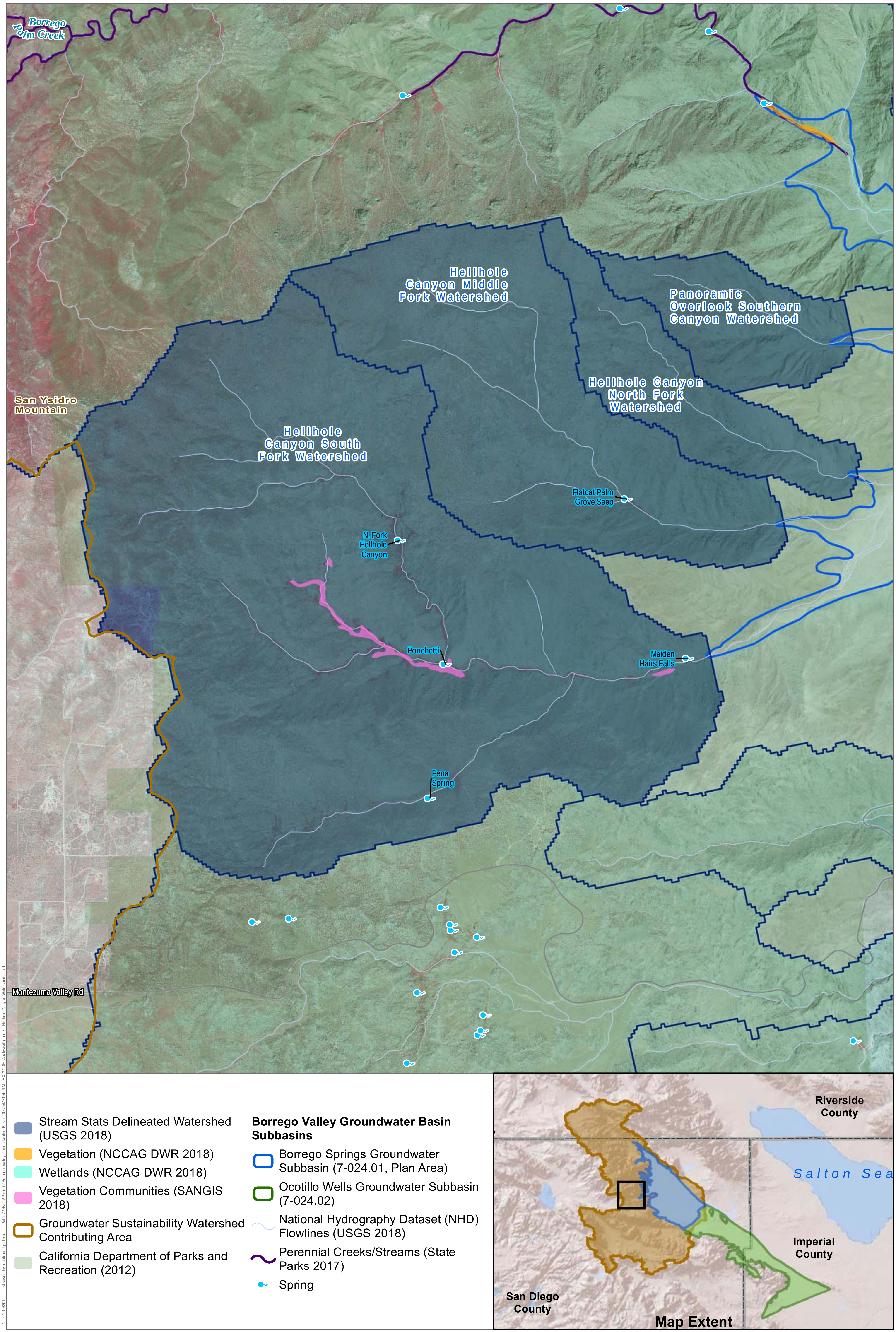
DATUM: NAD 1983. DATA SOURCE: USGS NHD 2018; USGS Stream Stats 2018; California State Parks 2017; USDA 2016; DWR 2018

DUDEK

Figure 6

Borrego Palm Canyon Watersheds

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



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DRAFT February 2019

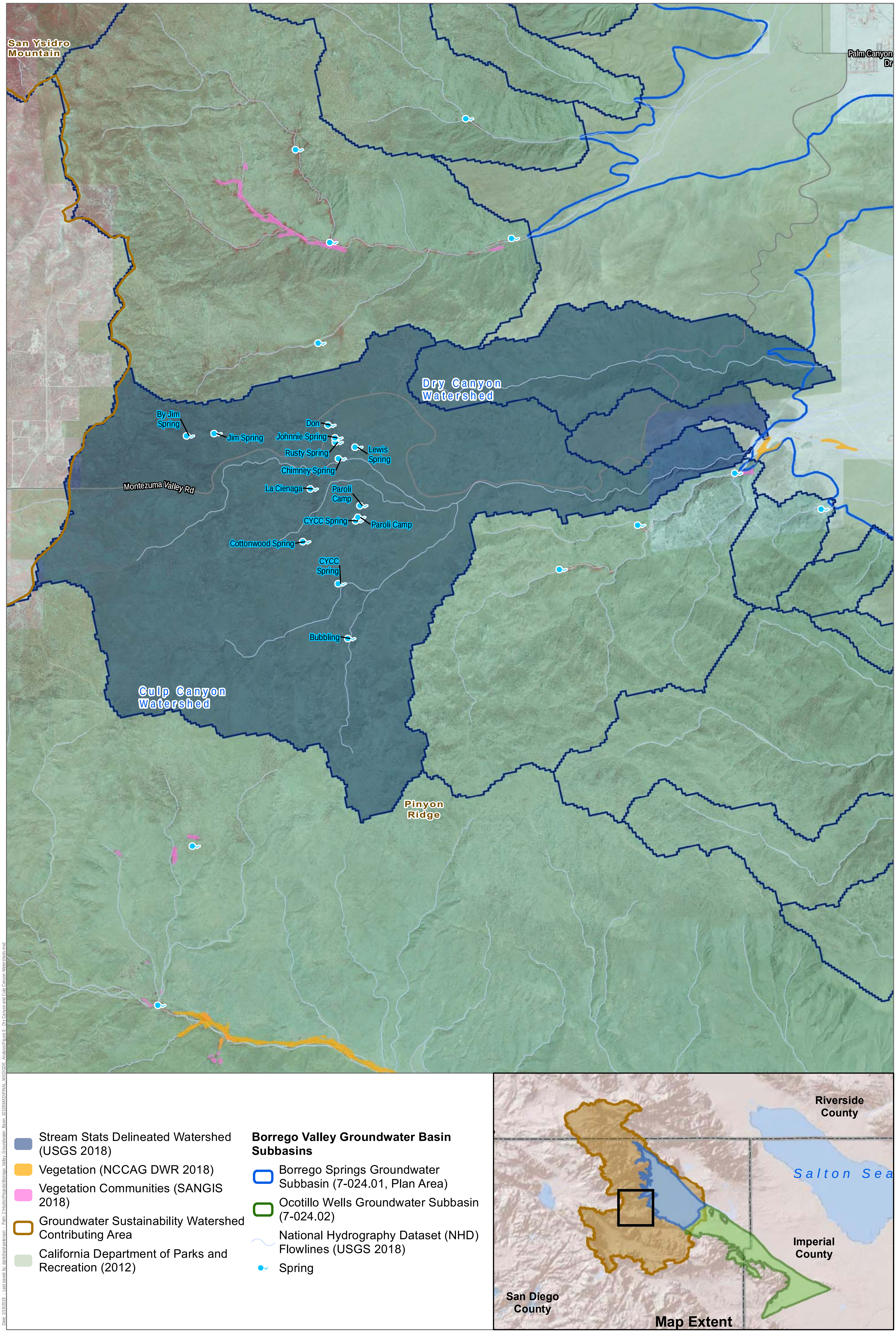
DATUM: NAD 1983. DATA SOURCE: USGS NHD 2018; USGS Stream Stats 2018; California State Parks 2017; USDA 2016; DWR 2018

DUDEK

0 0.5 1 Miles

Figure 7
Hellhole Canyon Watersheds

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

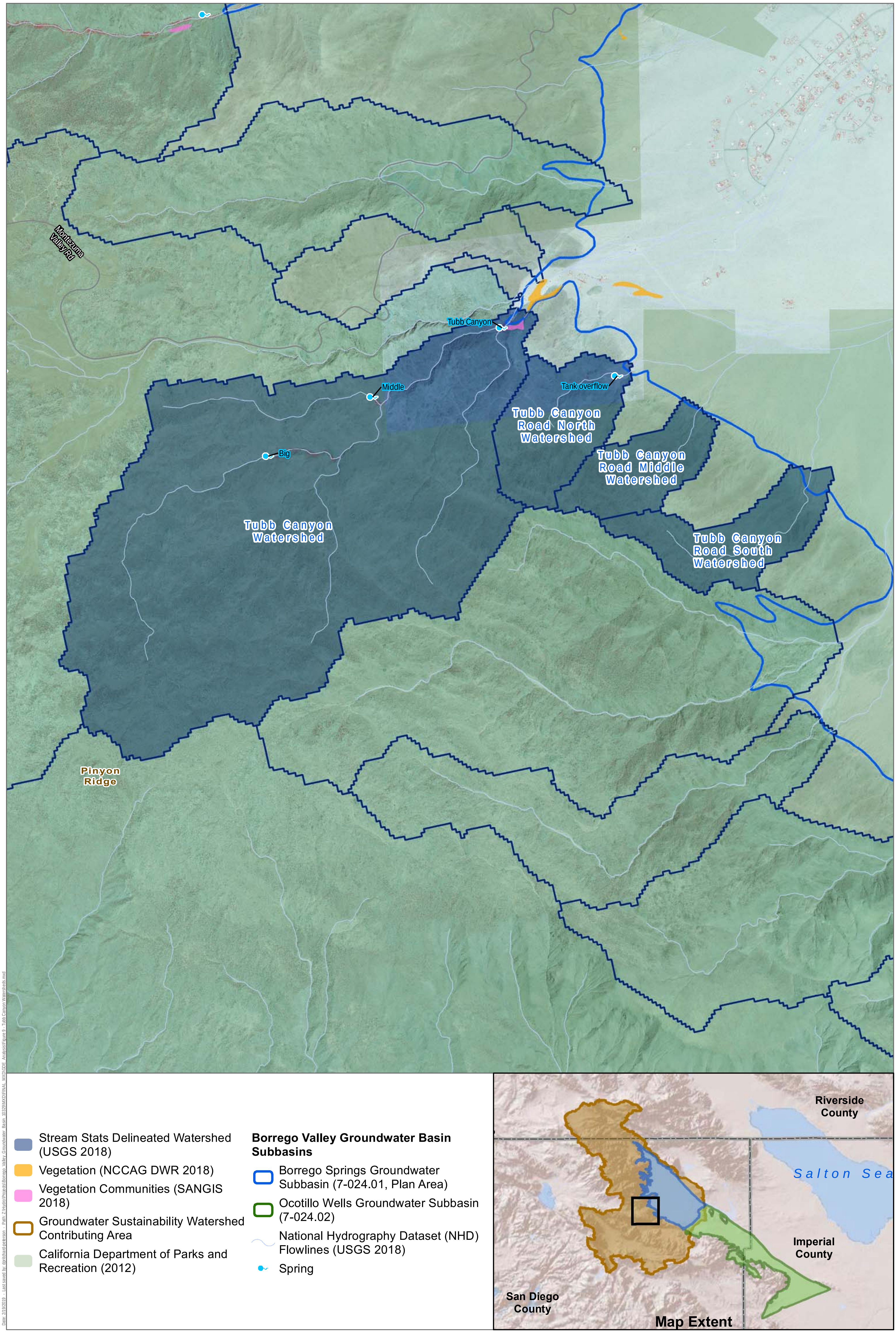
DATUM: NAD 1983. DATA SOURCE: USGS NHD 2018; USGS Stream Stats 2018; California State Parks 2017; USDA 2016; DWR 2018

DUDEK

0 0.5 1
Miles

Figure 8
Dry Canyon and Culp Canyon Watersheds

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



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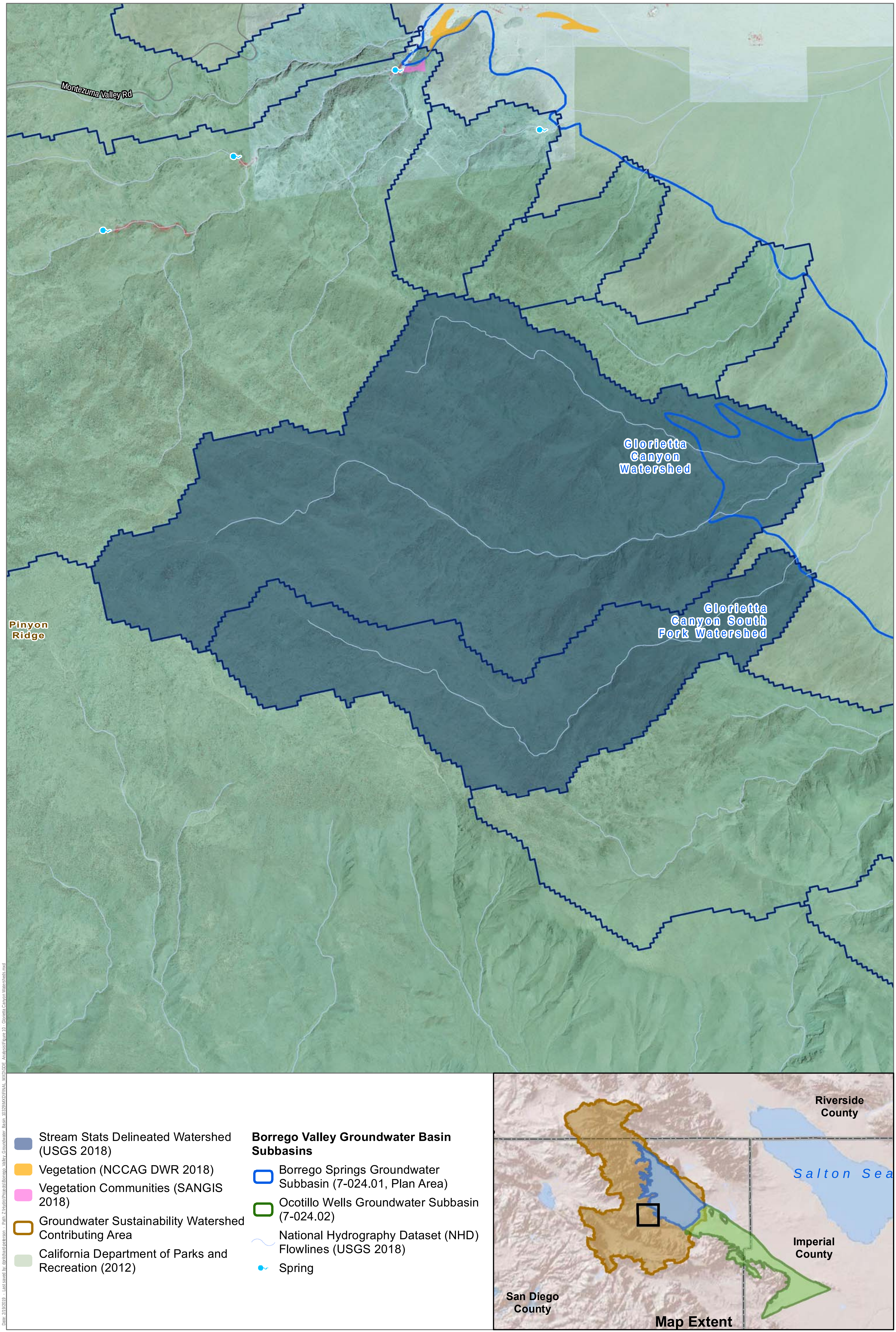
DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: USGS NHD 2018; USGS Stream Stats 2018; California State Parks 2017; USDA 2016; DWR 2018

DUDEK

0 0.5 1 Miles

Figure 9
Tubb Canyon Watersheds



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DRAFT February 2019

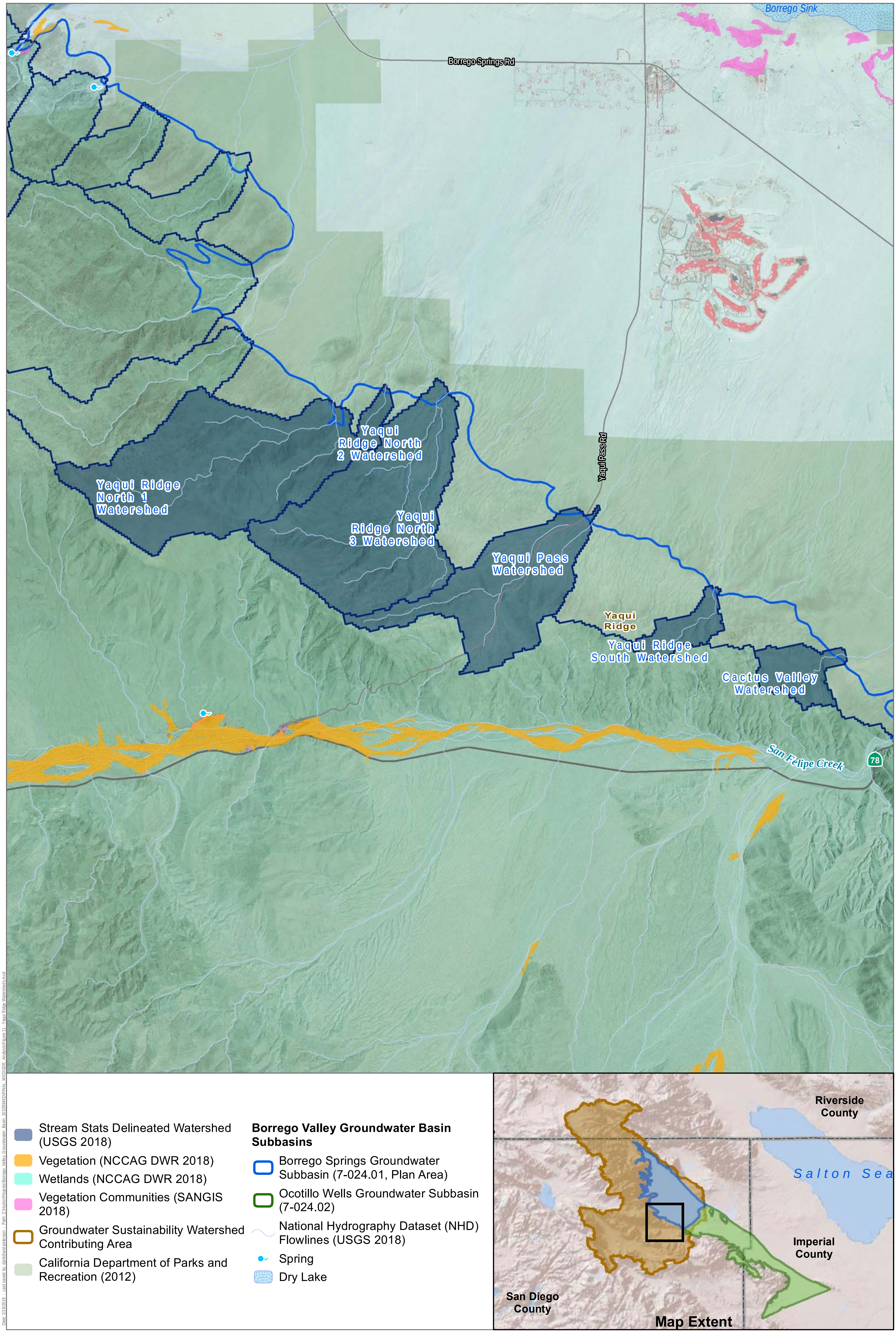
DATUM: NAD 1983. DATA SOURCE: USGS NHD 2018; USGS Stream Stats 2018; California State Parks 2017; USDA 2016; DWR 2018

DUDEK

0 0.5 1 Miles

Figure 10
Glorietta Canyon Watersheds

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



Date: 2/19/2019 - Last saved by: dpritchard-peterson - Path: Z:\Hydro\Projects\Borrego_Valley_Groundwater_Basin_10329\MXD\FINAL_MXD\GDE_Analysis\Figure 11 - Yaqui Ridge Watersheds.mxd

DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: USGS NHD 2018; USGS Stream Stats 2018; California State Parks 2017; USDA 2016; DWR 2018

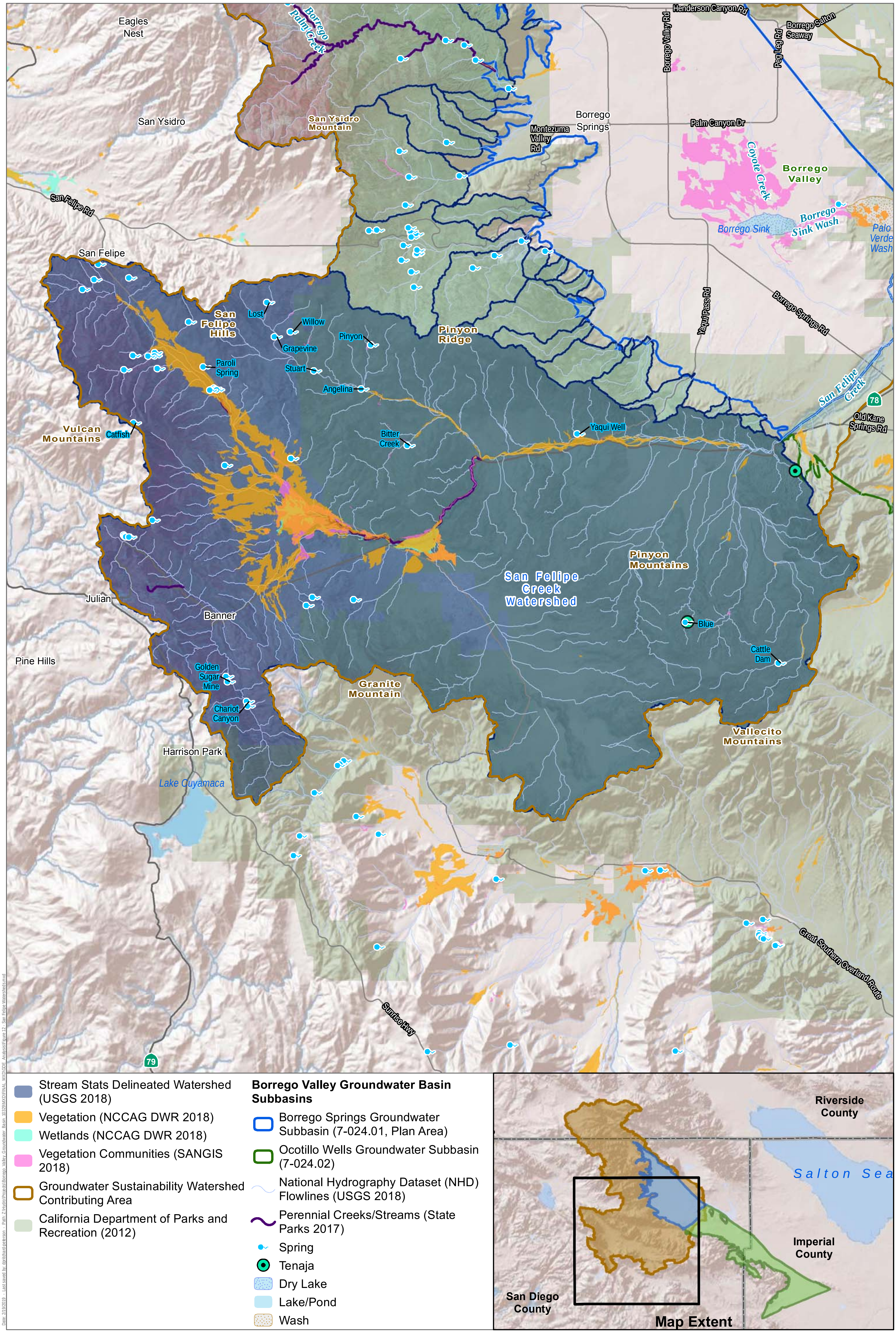
DUDEK

0 0.5 1 Miles

Figure 11

Yaqui Ridge Watersheds

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

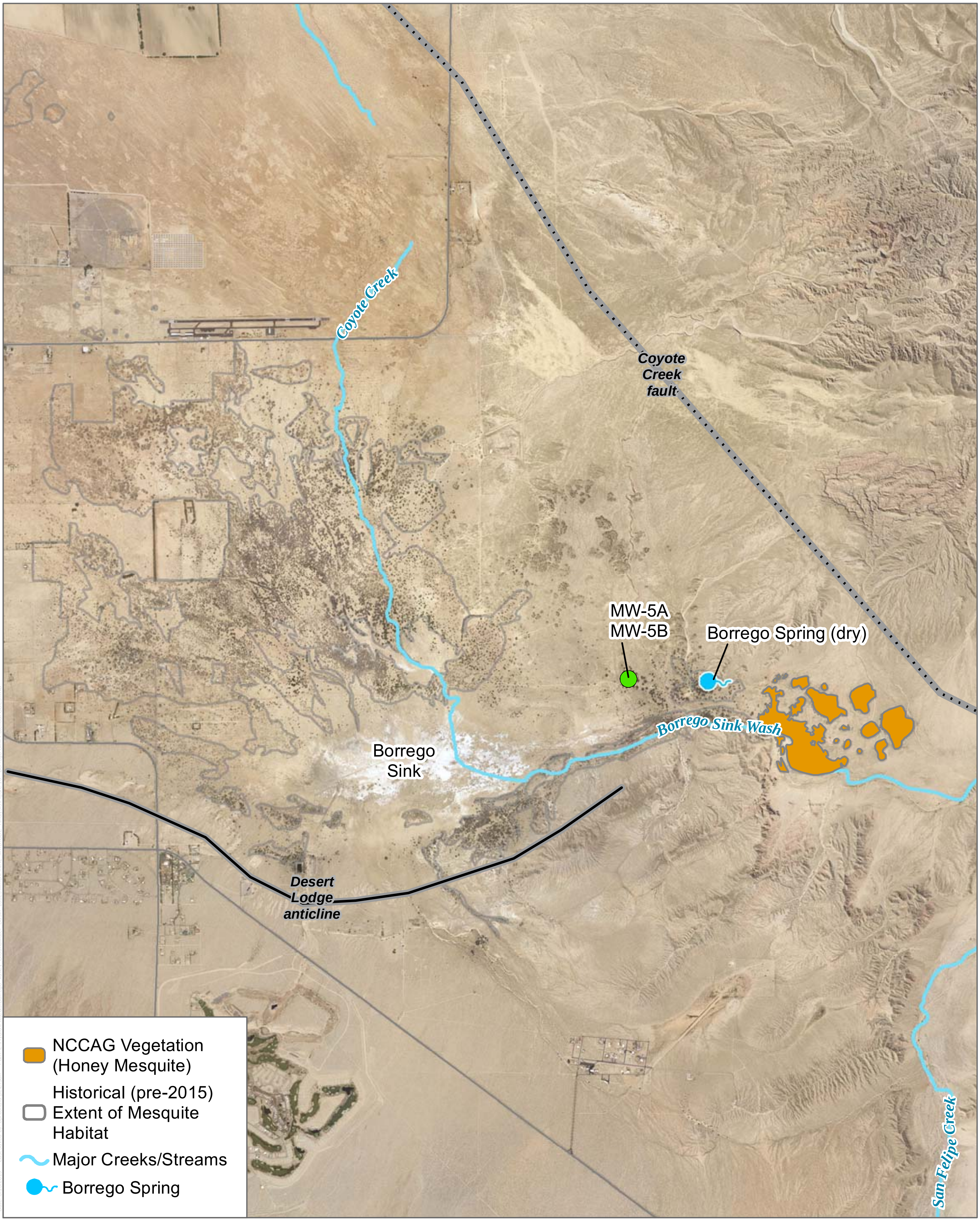
DATUM: NAD 1983. DATA SOURCE: USGS NHD 2018; USGS Stream Stats 2018; California State Parks 2017; USDA 2016; DWR 2018

DUDEK

0 2 4 Miles

Figure 12
San Felipe Watersheds

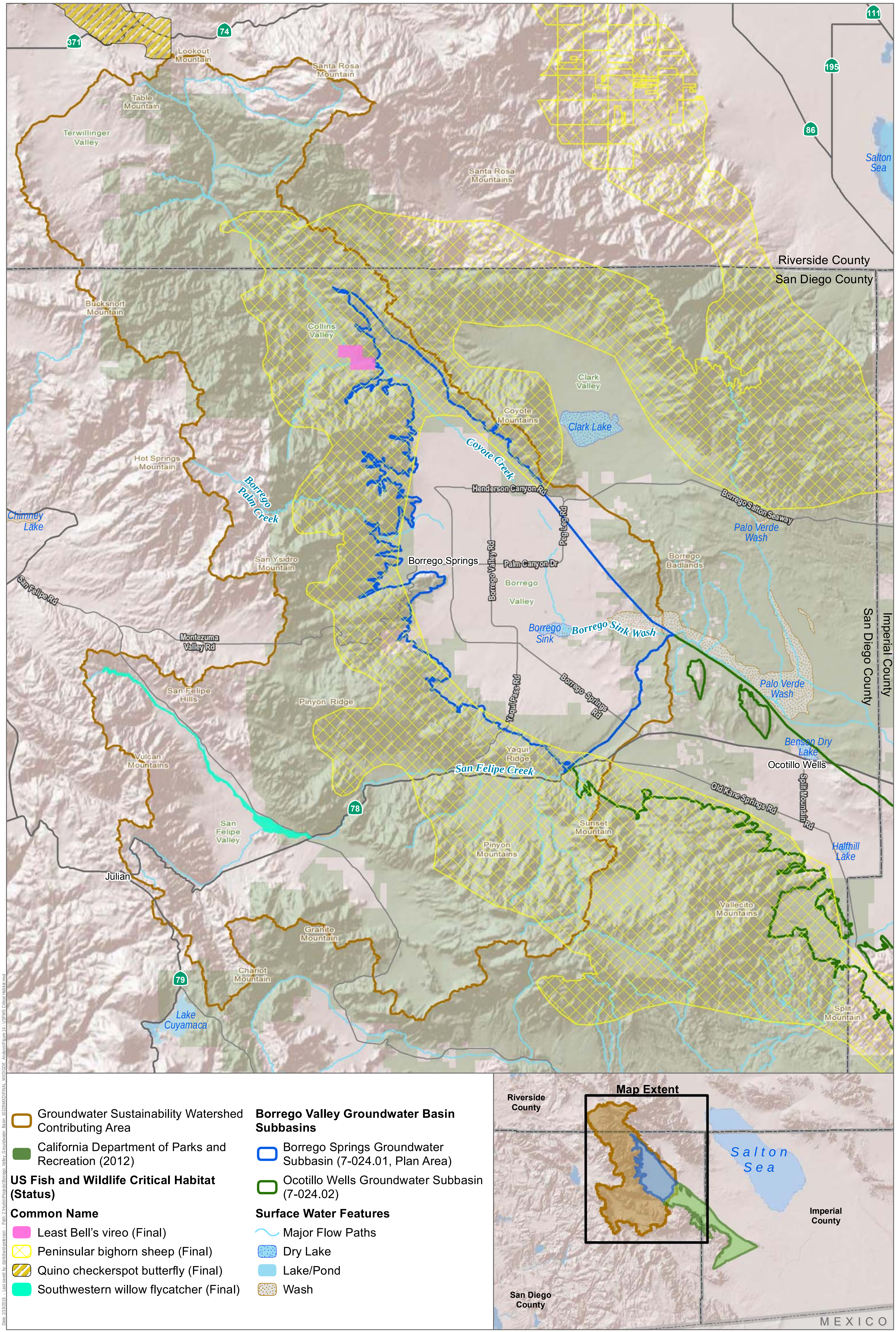
Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



SOURCE: DWR; USGS NHD; SanGIS

DUDEK

Figure 13
Borrego Sink Potential GDEs



DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: USFWS 2018

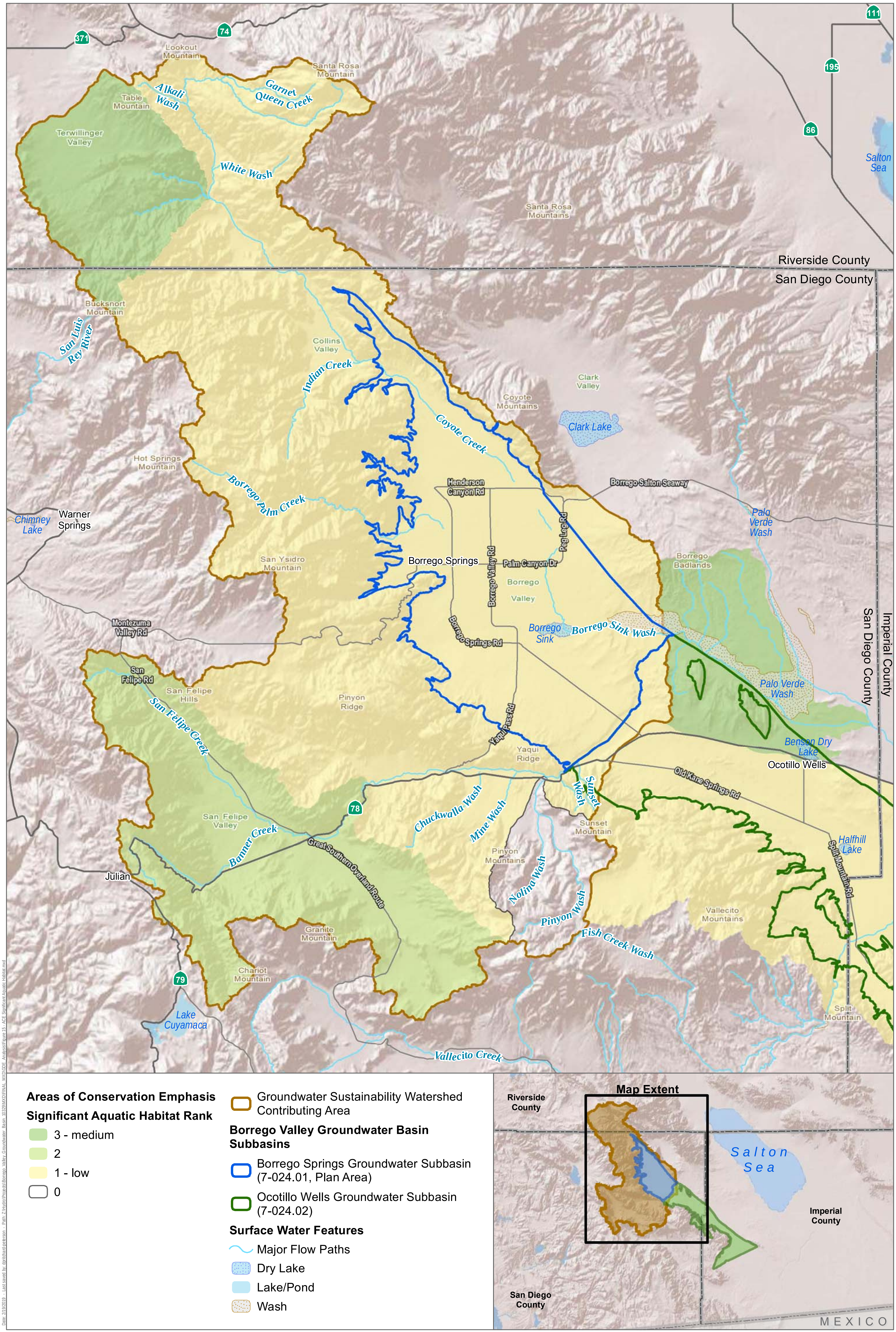
DUDEK

0 2 4 Miles

Figure 14

US Fish and Wildlife Critical Habitat

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: CDFW 2018

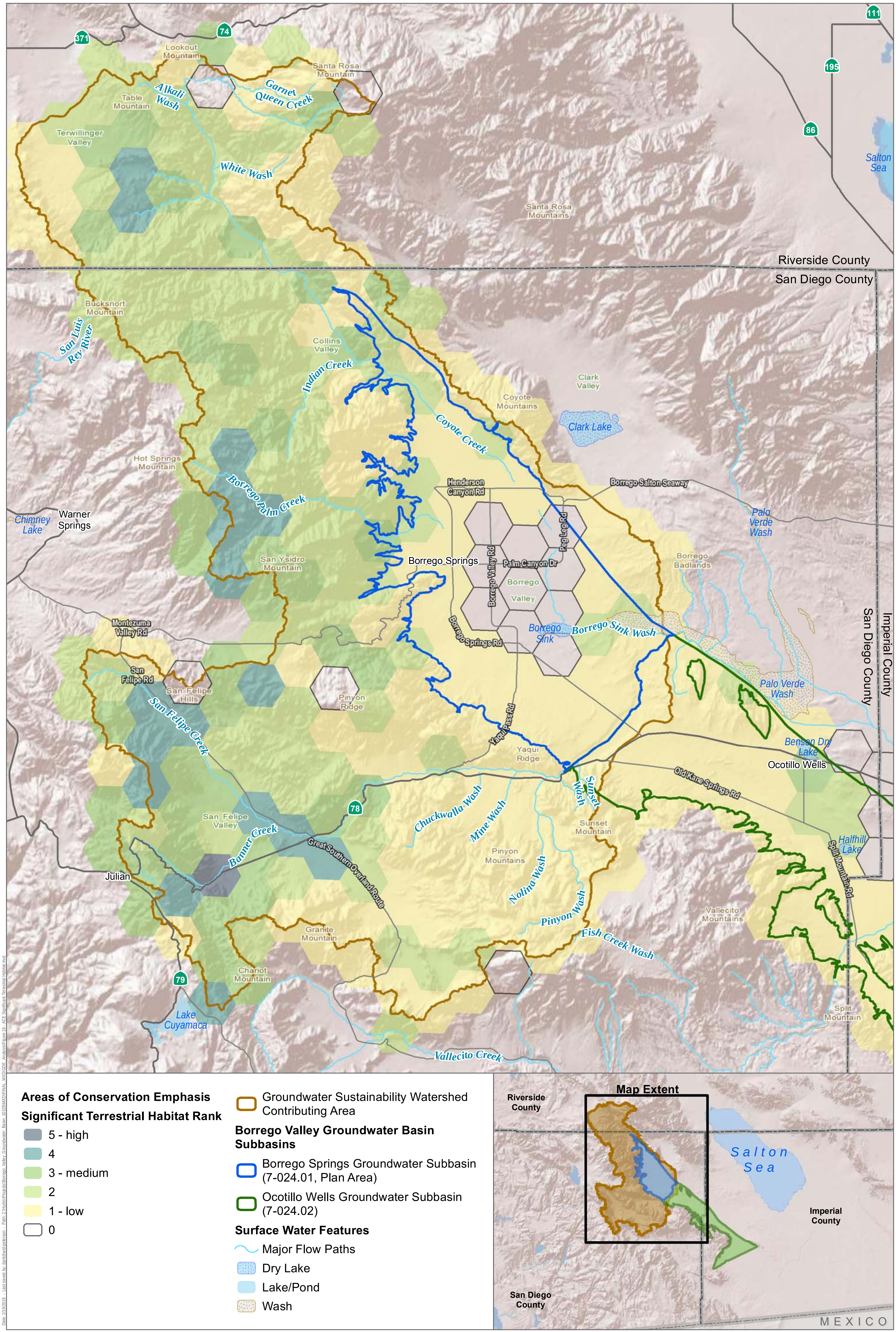
DUDEK

0 1.5 3 Miles

Figure 15

Areas of Conservation Emphasis (ACE) - Significant Aquatic Habitat

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

DATUM: NAD 1983. DATA SOURCE: CDFW 2018

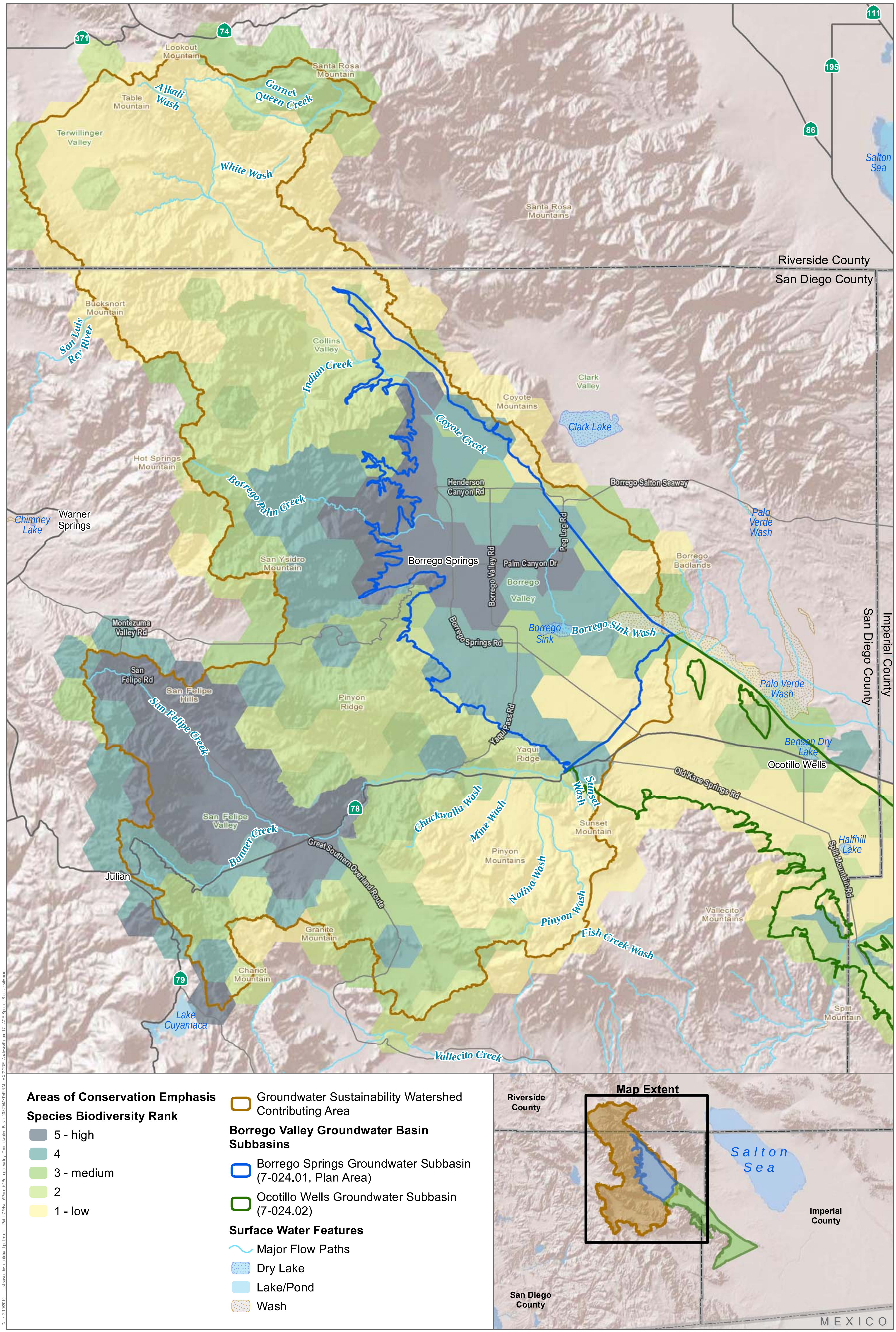
DUDEK

0 2 4 Miles

Figure 16

Areas of Conservation Emphasis (ACE) - Significant Terrestrial Habitat

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

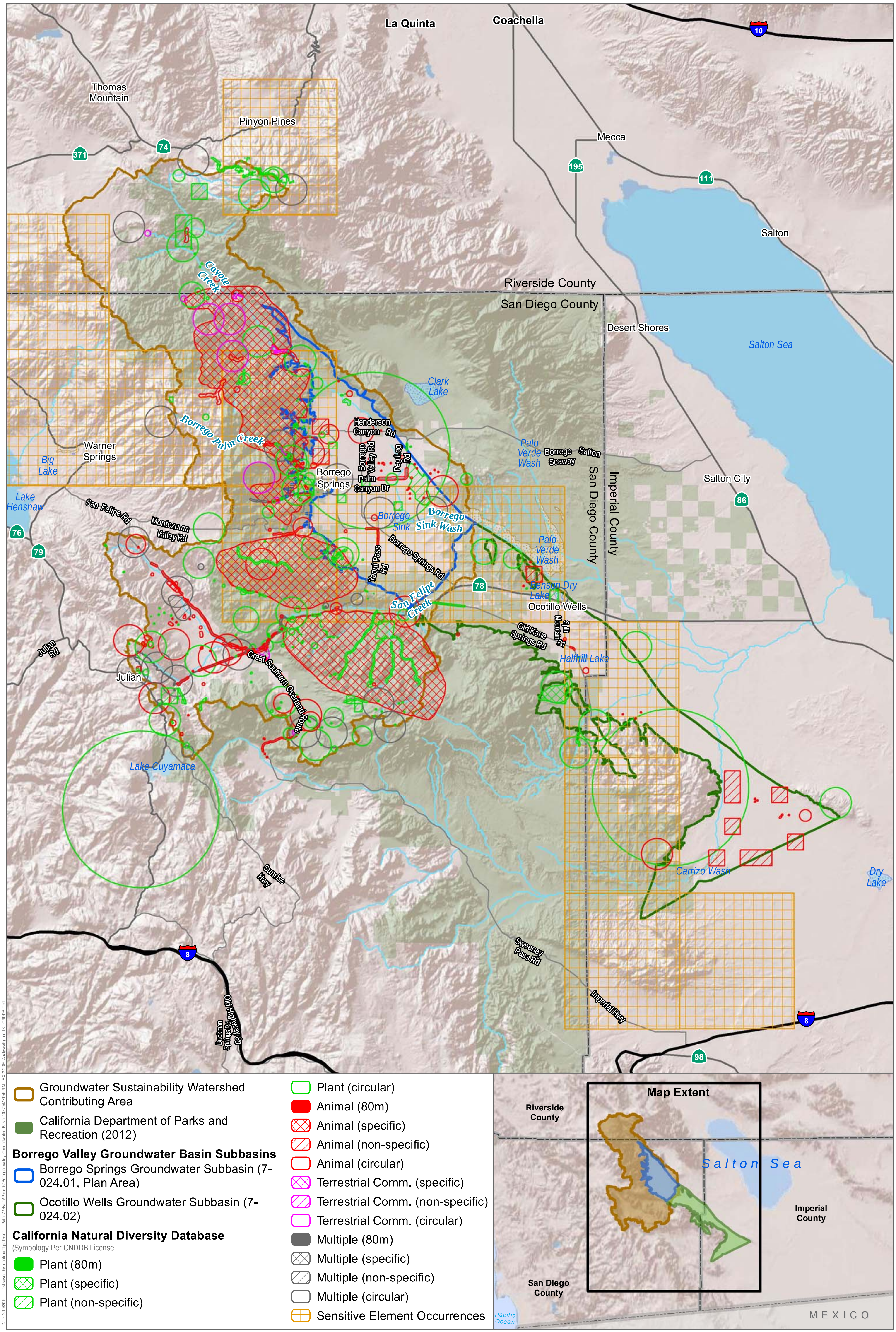
DATUM: NAD 1983. DATA SOURCE: CDFW 2018

DUDEK

0 2 4 Miles

Figure 17
Areas of Conservation Emphasis (ACE) - Species Biodiversity

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

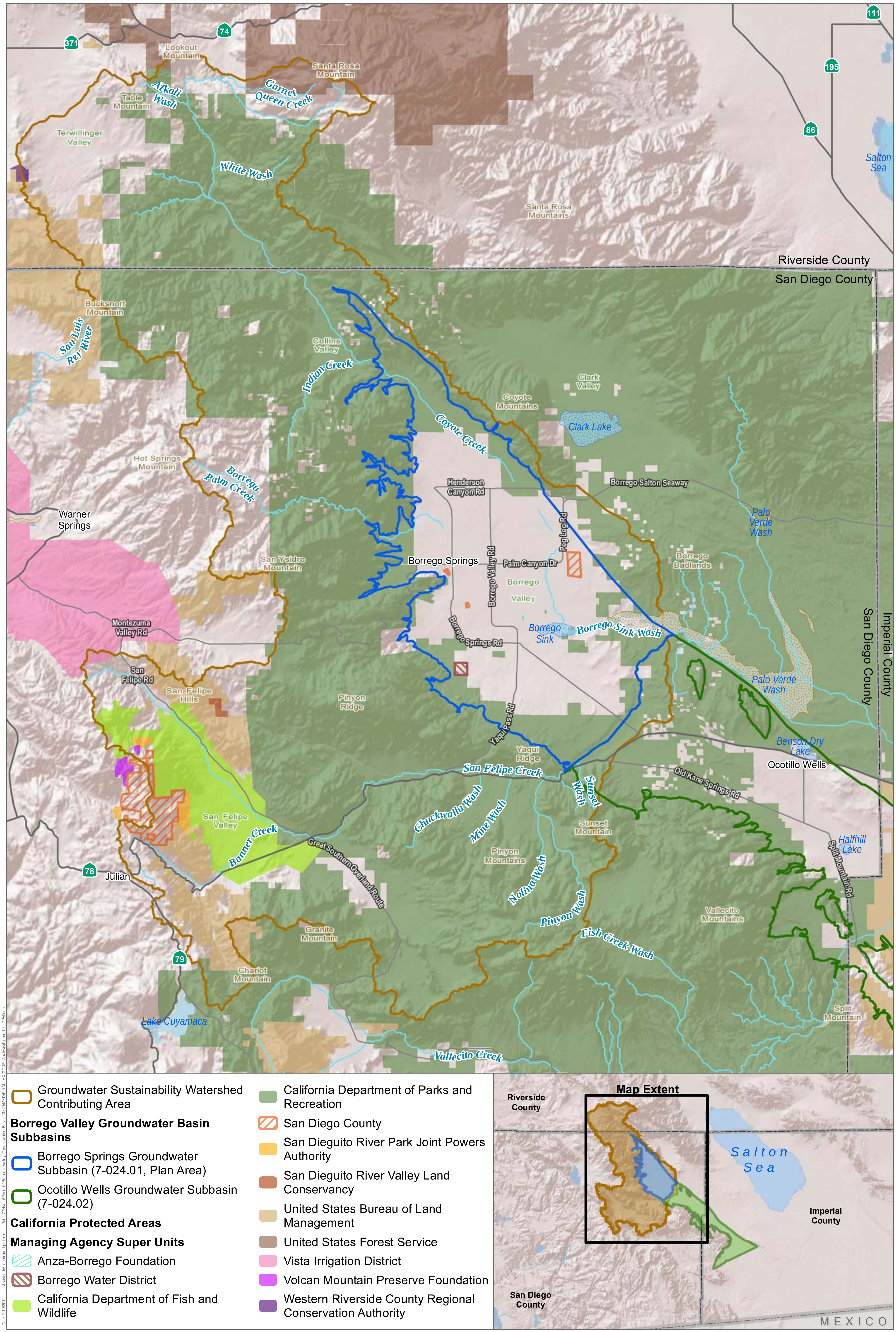
DATUM: NAD 1983. DATA SOURCE: CDFW 2018

DUDEK

0 2.5 5 Miles
Scale Per CNDDB License Agreement

Figure 18
California Natural Diversity Database (CNDDB)

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



DRAFT February 2019

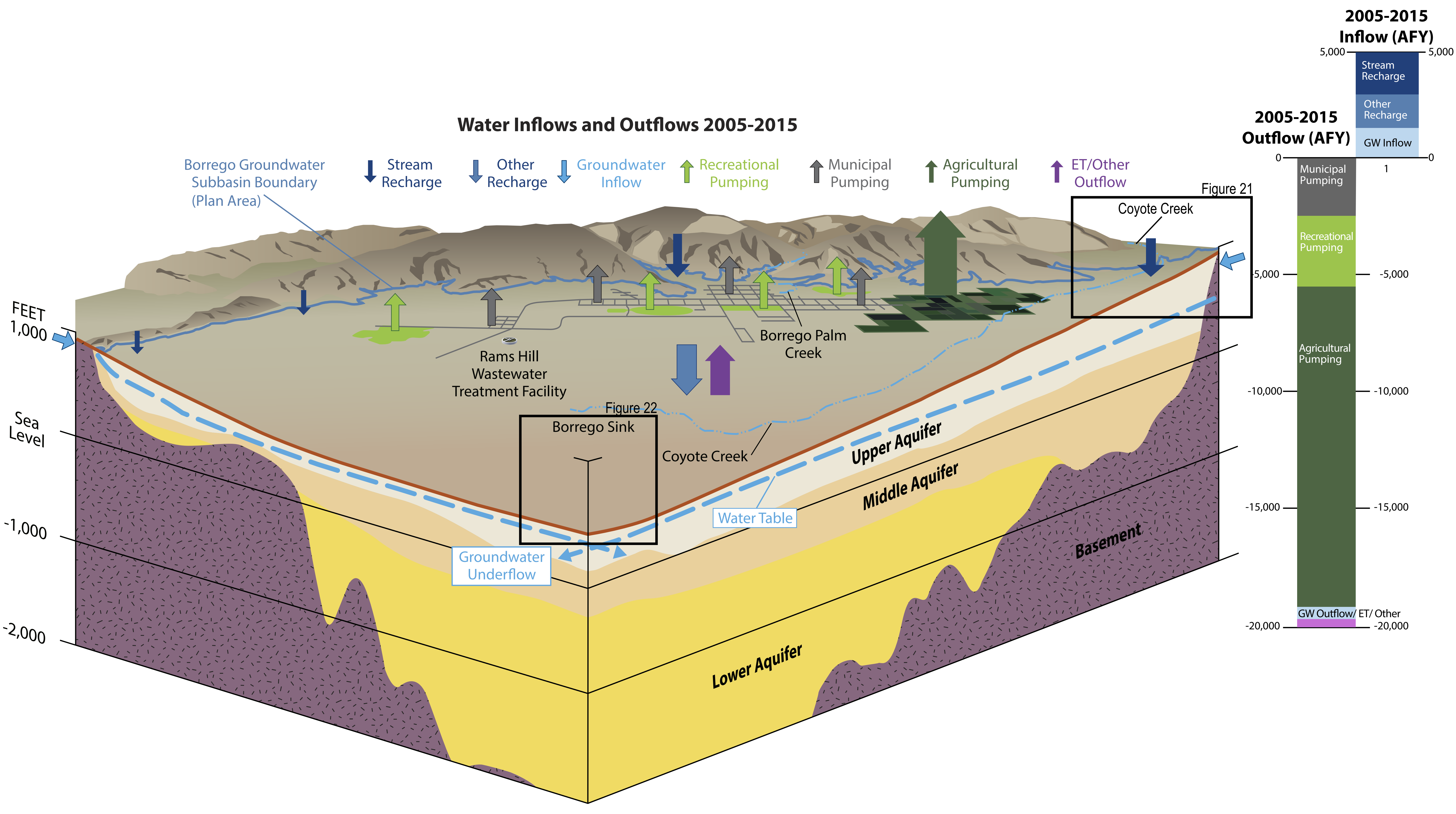
DATUM: NAD 1983. DATA SOURCE: CPAD 2017a

DUDEK

Figure 19

California Protected Areas Database (CPAD)

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems



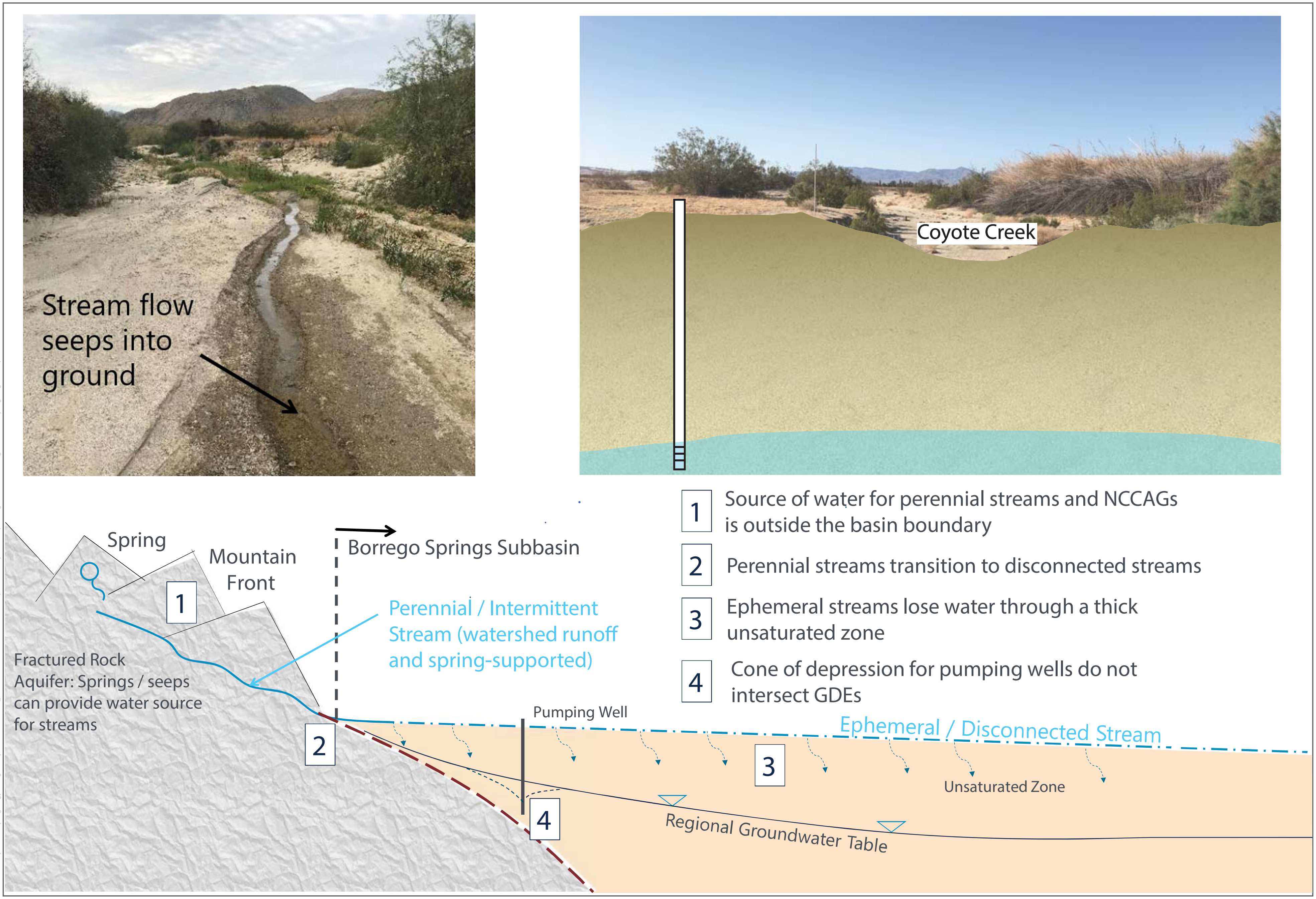
SOURCE: USGS 1982 and USGS 2015

FIGURE 20

Borrego Valley Hydrogeologic Conceptual Model

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems

DUDEK



1 Source of water for perennial streams and NCCAGs is outside the basin boundary

2 Perennial streams transition to disconnected streams

3 Ephemeral streams lose water through a thick unsaturated zone

4 Cone of depression for pumping wells do not intersect GDEs

FIGURE 21

Contributing Watersheds Hydrogeologic Conceptual Model

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems

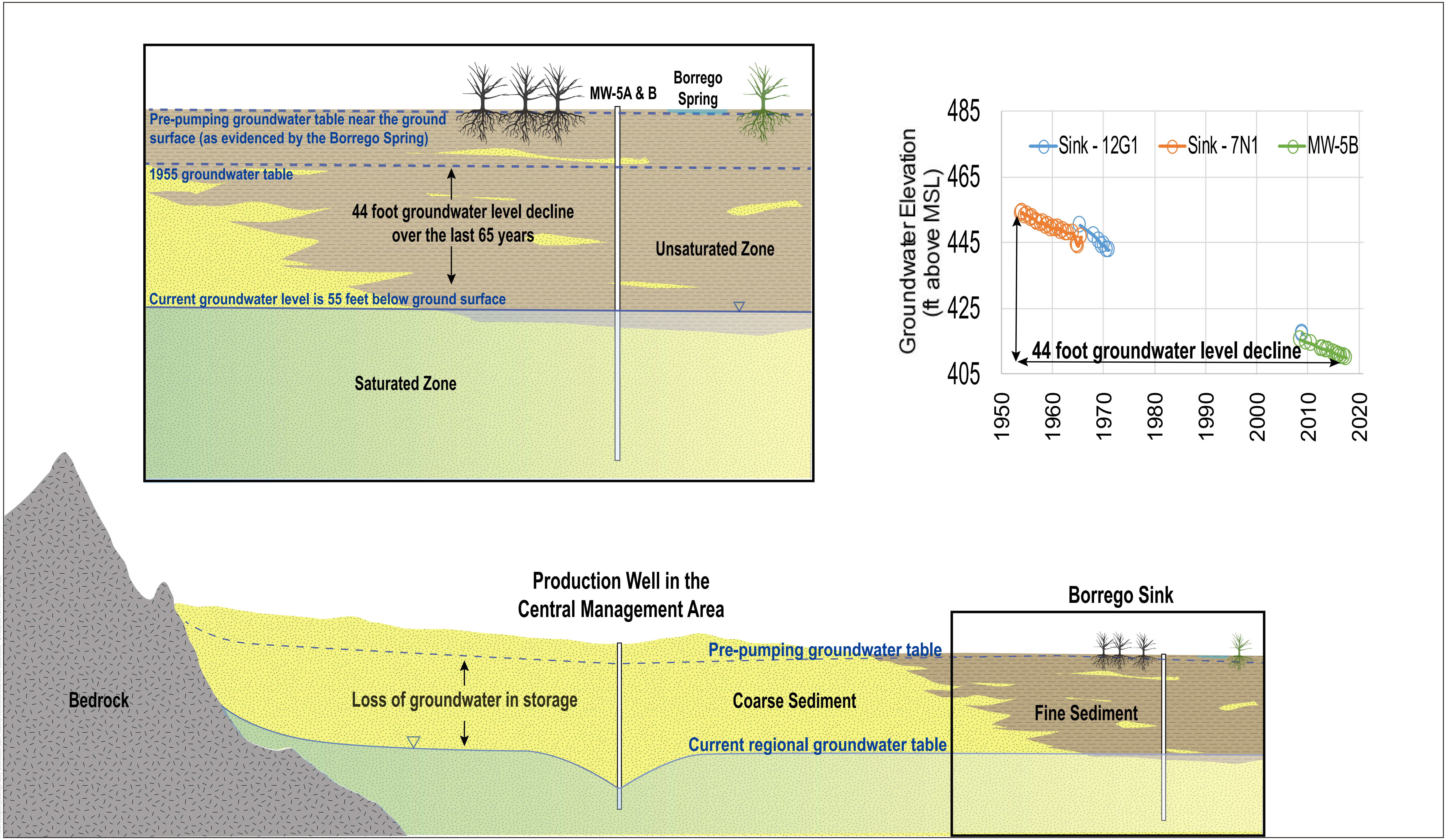


FIGURE 22

Borrego Sink (Mesquite Bosque) Hydrologic Conceptual Model

Borrego Springs Subbasin Potential Groundwater Dependent Ecosystems

APPENDIX E

Monitoring Protocols and Metering Plan

E1: Borrego Sampling and Analysis Plan and Quality Assurance Plan

E2: Borrego Metering Plan

APPENDIX E1

Borrego Sampling and Analysis Plan and Quality Assurance Plan

SAMPLING AND ANALYSIS PLAN AND QUALITY ASSURANCE PROJECT PLAN

Borrego Springs Subbasin

Prepared for

Borrego Valley Groundwater Sustainability Agency

Prepared by

Geosyntec consultants

engineers | scientists | innovators

2355 Northside Drive, Suite 250
San Diego, California 92108

OCTOBER 2017

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TABLE OF CONTENTS

Section **Page No.**

TABLE OF CONTENTS (CONTINUED)

Section **Page No.**

APPENDICES

TABLES

ACRONYMS AND ABBREVIATIONS

COPC	constituent of potential concern
DMS	data management system
DQO	data quality objective
DWR	California Department of Water Resources
EPA	United States Environmental Protection Agency
GSP	Groundwater Sustainability Plan
HDPE	high-density polyethylene
LCS	laboratory control sample
LIMS	laboratory information management system
mL	milliliter
MDL	method detection limit
MS	matrix spike
MSD	matrix spike duplicate
QAPP	Quality Assurance Project Plan
QA	quality assurance
QC	quality control
SAP	Sampling and Analysis Plan
SOP	standard operating procedure
Subbasin	Borrego Springs Subbasin

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1 INTRODUCTION

The Borrego Springs Subbasin (Subbasin) of the Borrego Valley Groundwater Basin has been identified by the California Department of Water Resources (DWR) as subject to critical conditions of overdraft (DWR 2016a). As such, in accordance with California's Sustainable Groundwater Management Act, a Groundwater Sustainability Agency has been formed to develop and implement a basin-specific Groundwater Sustainability Plan (GSP). The general purpose of the GSP is to facilitate a long-term groundwater withdrawal rate less than or equal to the sustainable yield of the Subbasin within the 20-year implementation period mandated by the Sustainable Groundwater Management Act.

The objective of this Sampling and Analysis Plan (SAP) is to establish consistent field data collection and laboratory analytical procedures, including protocols for measuring groundwater levels and protocols for sampling groundwater quality. The SAP incorporates pertinent protocols presented in DWR's Best Management Practices for the Sustainable Groundwater Management of Groundwater Monitoring Protocols, Standards, and Sites (DWR 2016b).

1.1 Project Overview and Applicability of the SAP/QAPP

The GSP is currently being developed for the Subbasin. An interim Monitoring Plan was prepared in support of the GSP that outlines the types of monitoring necessary to address the six DWR-designated sustainability indicators in the Subbasin (Dudek 2017). This SAP serves to supplement the Monitoring Plan by establishing consistent monitoring procedures associated with the two primary sustainability indicators for the Subbasin: (1) chronic lowering of groundwater levels and (2) degraded water quality. The Monitoring Plan identifies these two sustainability indicators as the primary drivers of the anticipated undesirable effects from overdraft in the Subbasin. Although the data collected to address the above-referenced sustainability indicators will also be used to evaluate reduction in groundwater storage, other DWR-designated sustainability indicators (i.e., seawater intrusion, depletion of interconnected surface water, and land subsidence) are not considered significant in the Subbasin at this time (Dudek 2017). Therefore, this SAP does not provide protocols for monitoring seawater intrusion, measuring streamflow, or measuring subsidence.

Included within this SAP is a Quality Assurance Project Plan (QAPP). The QAPP provides a framework for implementing procedures for field sampling, chain-of-custody, sample transportation, laboratory analysis, and reporting that will yield defensible data of known quality. Together, the SAP and QAPP are designed to facilitate data collection such that data are of acceptable quality to meet project requirements.

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2 SAMPLING AND ANALYSIS PLAN

The following section describes the sampling methodology, analytical parameters, and sample handling procedures to be followed for routine groundwater monitoring activities in the Subbasin. Specific sampling locations and pertinent well specifications are identified in the Monitoring Plan (Dudek 2017).

2.1 Health and Safety

A project-specific Health and Safety Plan will be prepared and implemented to address potential hazards that may be encountered in the field. Safety meetings will be held at the commencement of the project and each day before work begins to discuss safe work practices during field activities.

2.2 Sampling Objectives

The objectives of monitoring activities are to collect accurate and defensible groundwater elevation data, and to collect representative groundwater samples to evaluate concentrations of constituents of potential concern (COPCs) in groundwater. The purpose of monitoring activities is to track groundwater conditions in the Subbasin throughout implementation of the GSP to evaluate progress toward achieving measurable objectives and sustainable management of the Subbasin, as defined in the Monitoring Plan (Dudek 2017).

2.3 Constituents of Potential Concern

Groundwater samples collected from the site will be analyzed for the site-specific COPCs defined in the Monitoring Plan, including the following:

Routine Constituents

- Arsenic
- Fluoride
- Nitrate
- Sulfate
- Radionuclides (gross alpha particle activity)
- Total dissolved solids

Baseline Constituents

- Anions (bicarbonate, carbonate, chloride, fluoride, hydroxide, nitrate, sulfate, total alkalinity)

- Cations (calcium, magnesium, potassium, sodium, and total hardness)

Additional detail regarding COPCs is presented in Section 3.5, Analytical Methods, of this SAP.

2.4 Groundwater Monitoring Frequency

Groundwater elevation measurements and water quality sampling will be performed on a semi-annual schedule. The initial water quality sampling event will include sampling and analysis for cations and anions to establish baseline chemistry; analysis for cations and anions in subsequent sampling events is not currently planned.

2.5 Groundwater Monitoring Methods

Groundwater monitoring procedures described herein were compiled in consideration of the DWR's best management practices (DWR 2016b), the County of San Diego's Site Assessment and Mitigation Manual (County of San Diego 2012), and professional judgment. See Appendix A for an example groundwater elevation monitoring field form.

2.5.1 Groundwater Elevation Monitoring

Groundwater elevation monitoring will be conducted using the following procedures:

- Groundwater elevation data should approximate conditions at a discrete period in time; therefore, groundwater levels will be collected within as short a time interval as possible, preferably within a 1- to 2-week period.
- The sampler will have the previous depth to water measurements available in the field.
- The water level indicator will be decontaminated after each well.
- An electronic water level that employs a battery-powered probe assembly attached to a cable marked in 0.01-foot increments will be used. When the probe makes contact with the water surface, an electrical impulse is transmitted in the cable to activate an audible alarm. The equipment will be equipped with a sensitivity adjustment switch that enables the operator to distinguish between actual and false readings caused by the presence of conductive, immiscible components on top of groundwater. The manufacturer's operating manual should be consulted for instructions on use of the sensitivity adjustment.
- The well cap or cap covering the access port will be unlocked and removed.
- The sampler will listen for pressure release while removing the lid. If a release is observed, the measurement will wait to allow the water level to equilibrate. Additionally, multiple measurements will be collected to ensure that the well has reached equilibrium such that no significant changes in water level are observed.

- All parts of the water level indicator that may come into contact with liquids in the well will be thoroughly rinsed or sprayed with deionized water immediately prior to lowering the probe into the well.
- The probe will be lowered through the access port or well casing to the anticipated depth of water.
- When the water level probe signals contact with water, the depth will be read on the tape from a datum point permanently marked on the well casing. Continue until two consecutive readings are within 0.01 foot of each other. The depth will be recorded on the Water Level Measurement Log.
- Measurements will be taken at an established reference point, generally at the top of the casing at the surveyor's mark. The mark should be permanent (e.g., a notch or mark at the top of casing). If the surveyor's point is not marked at the time of the water level, the north side of the casing will be used and marked.
- If water is not encountered in the well, the depth to water will be recorded as "dry" on the Water Level Measurement Log.
- If the water level in the well has dropped below the top of the dedicated pump, the probe will not be lowered past the pump. If feasible, remove the dedicated pump. Once the pump has been removed, allow the water level to equilibrate and measure the water level according to the method described above.
- Rewind the probe, replace the well cap, and relock the well.
- The sampler will calculate the groundwater elevation by subtracting the depth to water from the reference point elevation. The sampler must ensure that all measurements are consistent units of feet, tenths of feet, and hundredths of feet. Measurements at reference point elevations should not be recorded in feet and inches.
- The sampler will record the well identifier, date, time (24-hour format), reference point elevation, height of reference point above the ground surface (stick-up), depth to water, groundwater elevation, and comments regarding any factors that may affect the depth to water readings such as weather, recent well pumping or nearby irrigation cascading water, or well condition. If there is a questionable measurement or the measurement cannot be obtained, it will be noted.
- All relevant data will be entered into the Groundwater Sustainability Agency's data management system (DMS) as soon as possible. Care will be taken to avoid data entry mistakes, and the entries will be checked by a second person for compliance with data quality objectives (DQOs).

Pressure Transducers

Groundwater levels and/or calculated groundwater elevations may be recorded using pressure transducers equipped with data loggers installed in monitoring wells. When installing pressure transducers, care must be exercised to ensure that the data recorded by the transducers is confirmed with hand measurements.

The following general protocols will be followed when installing a pressure transducer in a monitoring well:

- The sampler will use an electronic sounder and follow the protocols listed above to measure the groundwater level and calculate the groundwater elevation in each well to properly program and reference the installation. It is recommended that samplers use transducers to record measured groundwater levels to conserve data capacity; groundwater elevations can be calculated at a later time after downloading.
- The sampler will note the well identifier, the associated transducer serial number, transducer range, transducer accuracy, and cable serial number.
- Transducers must be able to record groundwater levels with an accuracy of at least 0.1 foot. The installer of the transducer will consider battery life, data storage capacity, range of groundwater level fluctuations, and natural pressure drift of the transducers at the time of installation.
- The sampler will note whether the pressure transducer uses a vented or non-vented cable for barometric pressure compensation; appropriate corrections for natural barometric pressure changes will be implemented.
- Manufacturer specifications will be followed for installation, calibration, data logging intervals, battery life, correction procedure (if non-vented cables used), and anticipated life expectancy to assure that DQOs are being met for the GSP.
- The cable will be secured to the well head with a well dock or another reliable method. The cable will be marked at the elevation of the reference point with tape or an indelible marker to allow for estimate of potential future cable slippage.
- The transducer data will be regularly checked against hand-measured groundwater levels to monitor electronic drift or cable movement. This will happen during routine site visits, at least semi-annually, or as necessary to maintain data integrity.
- Data will be downloaded as necessary to ensure no data is lost and will be entered into the Groundwater Sustainability Agency’s DMS following the established quality assurance/quality control (QA/QC) program. Data collected with non-vented data logger cables will be corrected for atmospheric barometric pressure changes, as appropriate. After

the sampler is confident that the data have been safely downloaded and stored, the data will be deleted from the data logger to ensure that adequate data logger memory remains.

2.5.2 Groundwater Quality Monitoring

Groundwater quality monitoring and sampling will be conducted using the following procedures. See Appendix B for an example groundwater quality monitoring field form.

- Prior to sampling, the sampler must contact the selected California-certified environmental laboratory to schedule laboratory time, obtain appropriate sample containers, and clarify any sample holding times or sample preservation requirements.
- Each well used for groundwater quality monitoring must have a unique identifier. This identifier must appear on the well housing or the well casing to avoid confusion.
- Groundwater elevation will be measured in the well following appropriate protocols, as described above.
- General well specifications for the wells to be sampled should be available in the field, most notably the screened interval and total well depth.
- Sample containers will be labeled prior to sample collection. The sample label must include sample ID, sample date and time, sample personnel, sample location, preservative used, and analyses and analytical method.
- Samples will be collected under laminar flow conditions. Laminar flow occurs when fluid flows in parallel layers, with limited lateral disruption or mixing of the layers. This may require reducing pumping rates prior to sample collection to minimize turbulent flow of groundwater entering the well screen.
- All field instruments will be calibrated daily and evaluated for drift throughout the day. Calibration will be documented in field logs.
- All samples requiring preservation must be preserved as soon as practically possible, ideally at the time of sample collection. Samples will be appropriately filtered, as recommended for the specific analyte. Samples to be analyzed for metals (i.e., arsenic) will be field-filtered prior to preservation; unfiltered samples will not be collected in a preserved container.
- If pumping during sampling or purging causes a well to go dry, the condition will be documented and the well will be allowed to recovery to within 90% of the original level measured prior to pumping. Professional judgement should be used about to whether the sample will meet the DQOs, and will be adjusted as necessary.

- The following will occur for groundwater wells equipped with a functioning dedicated pump:
  1. Samples will be collected at or near the wellhead. Samples will not be collected from storage tanks, at the end of long pipe runs, or after any water treatment.
  2. After cleaning the sampling port, a new, clean length of flexible clear plastic tubing will be connected to the sample access port. The tubing will be inserted into the sample bottle. The sample access port will be opened slowly. It will be verifies that the liquid stream is not flowing greater than 100 milliliters (mL) per minute.
  3. The sample bottle will be filled so that no air space remains. The bottle will be capped and then wiped clean after capping. The completed label will then be adhered to the sample bottle.
  4. Field measurements for depth to water, pH, specific conductance, temperature, turbidity, dissolved oxygen, oxygen-reduction potential, and color will be collected and documented after the samples are collected.
- The following will occur for groundwater wells requiring sample collection using a temporary pump:
  1. The pump will be lowered slowly down the well, positioning the well intake at the middle of the well screen or at the predetermined selected sampling depth.
  2. Disturbance of the water column in the well will be minimized by initiating pumping at a low rate (see below). Dedicated tubing (left in place between sampling events) is recommended to minimize disturbance to the water column before and during sampling.
  3. Pumping will begin at a steady rate of 100 mL per minute and the depth to water will be measured frequently (e.g., every 1 minute for the first few minutes) to ensure that less than 0.1 feet of drawdown occurs. The pumping rate may be increased if drawdown is less than 0.1 feet, but the pumping rate will not exceed 500 mL per minute.
  4. Field parameters and depth to water will be recorded on field data sheets a minimum of every 5 minutes while purging. Purging will continue until pH, temperature, specific conductance, oxidation reduction potential, dissolved oxygen, and turbidity stabilize (three consecutive readings), which is defined as follows:
     a. ±0.2 units for pH
     b. ±3%–5% for specific conductance
     c. ±20 millivolts (mV) for oxidation reduction potential
     d. ±10% for temperature
     e. ±10% for turbidity

    f. ±0.2 milligrams per liter for dissolved oxygen

5. Dissolved oxygen and turbidity tend to stabilize last and are better measures of sufficient purging. Drawdown will be minimized during purging and/or sampling, not exceeding 0.1 feet, if possible.
6. In the case that the above criteria for stabilization are not met before three well volumes have been pumped, then a maximum of five well volumes will be pumped before samples are taken. Also, if stabilization has not occurred after 2 hours of purging regardless of well volume status, samples will be collected at this point. In the spirit of water conservation, this method will be avoided if possible.
7. For protocol regarding variances, consult the Site Assessment and Mitigation Manual (County of San Diego 2012).

- If pumping during sampling or purging causes a well to go dry, the condition will be documented and the well will be allowed to recovery to within 90% of the original level measured prior to pumping. Professional judgement will be used as to whether the sample will meet the DQOs and adjusted as necessary.
- After sample collection, the sealed sample bottle will be placed in a "zip-lock" style bag and placed inside an ice chest filled with ice to maintain a sample temperature of 4°C to prevent degradation of the sample. At the completion of sampling, the completed chain-of-custody will be placed in the ice chest, which will be sealed and labeled. The samples will be transported from the site to the laboratory by courier service or other means. The samples will be delivered to the laboratory within 24 hours after the sample has been collected.

2.6 Sample Handling

The following section details methods that are to be used for sample labeling, identification, containerizing, preservation, transportation, and maintaining proper chain-of-custody. Samples will be handled in accordance with San Diego County's Site Assessment and Mitigation Manual (County of San Diego 2012) and the United States Geological Survey's National Field Manual for the Collection Water Quality Data sampling protocols (USGS 2014).

2.6.1 Sample Handling and Identification

Each groundwater sample collected for analysis will be designated with a unique identification (ID) number. The sample identification number will include information to identify the sample location, date, and field QC classification, if applicable.

The following identifying factors will be used:

- Local well ID (e.g., ID4-18)
- Date (i.e., year, month, day)
- Field QC classification, if applicable (e.g., "D" for field duplicate)

For example:

- Sample identification number "ID4-18-20170704" would represent a groundwater sample collected from well ID4-18 on July 4, 2017.

2.6.2 Sample Containers and Transportation

Groundwater samples will be collected in the following containers:

- Arsenic by United States Environmental Protection Agency (EPA) Method 6010B: 250 mL high-density polyethylene (HDPE) bottle preserved with hydrochloric acid
- Cations and anions: 1 liter unpreserved HDPE
- Fluoride by SM 4500-F C: 250 mL unpreserved HDPE
- Nitrate by EPA 300.0: 250 mL unpreserved HDPE
- Radionuclides (gross alpha particle activity) by EPA 900.0: 1 liter unpreserved HDPE
- Sulfate by EPA 300.0: 250 mL unpreserved HDPE
- Total dissolved solids by SM 2540 C: 1 liter unpreserved HDPE

Analyte-specific laboratory holding times as described in Section 3.5.3 will be reviewed to plan for samples to be received by the laboratory within the appropriate timeframe.

2.6.3 Chain-of-Custody Procedures

A chain-of-custody form will be used to record possession of the samples from the time of collection to the time of arrival at the laboratory. The individual who collects the samples will prepare them for shipment, complete the chain-of-custody form, and sign the form when transferring the samples to the laboratory courier. The samples will be released to the laboratory by the courier signature on the chain-of-custody form and signed as received by laboratory receiving personnel. The laboratory receiving personnel will verify that all samples listed on the chain-of-custody form are present, sample integrity, and that proper sample preservation procedures were used.

2.6.4 Equipment Decontamination

Prior to sampling, re-usable sampling equipment (e.g., submersible pumps) will be decontaminated using an Alconox wash, a potable water rinse, then a distilled water final rinse (i.e., the three-bucket wash method).

2.6.5 Investigative-Derived Waste

Evidence of hazardous concentrations of COPCs has not been identified in Subbasin wells. If purge water is generated from a groundwater well it will be discharged to the ground away from the wellhead. Additionally, investigative-derived wastes (e.g., sampling gloves, disposable sampling devices, tubing) will be disposed of off site as municipal solid waste.

2.6.6 Field Documentation

Field logbooks will be maintained during confirmation sampling field activities. The field logbooks will serve to document observations, personnel on site, equipment activity, field procedures, and other vital information. Logbook entries will be complete and accurate enough to permit reconstruction of field activities. The following information for each sampling area will be documented on field forms:

- Field crew names
- Date of sampling
- Wells names
- Names and times of samples collected
- Chain-of-custody number
- General observations

2.6.7 Photographs

Photographs will be taken at sample locations and other relevant areas on site. The photographs will serve to verify information entered in the field logbooks.

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3 QUALITY ASSURANCE PROJECT PLAN

3.1 Roles and Responsibilities

Brief descriptions of key personnel responsibilities are provided below.

The sampling project manager is a member of the project team who will provide oversight and serve as the point of contact for the responsible parties. The sampling project manager will have responsibility for the overall project performance.

The QA manager will be responsible for ensuring the integrity of the SAP/QAPP and will coordinate all QA-specific activities. The QA manager will do the following:

- Ensure that the appropriate analytical methods and sampling equipment are selected.
- Be responsible for data validation and advise the sampling project manager with respect to data management and statistical evaluation of the data.
- Be responsible for performance and/or systems audits of the laboratory, should they be required.

The field manager or designated representative will be located at the site during field activities and will coordinate the technical field activities in accordance with approved plans, including the Monitoring Plan (Dudek 2017), QAPP, and Health and Safety Plan. The field manager will be responsible for verifying that the field work (to include sampling operations and sampling QC) is performed within the approved guidelines. The field manager will be responsible for implementing and maintaining overall operating standards and field QA responsibilities. Such responsibilities will include the following:

- Appropriate calibration and maintenance of field instruments
- Appropriate equipment decontamination
- Compliance with QA/QC sampling requirements (e.g., field duplicate collection)

In addition, the field manager will coordinate safety and technical activities occurring at the site, and conduct daily briefing sessions prior to work on the site. Although various field functions will be performed by individuals, the field manager will bear field responsibilities.

The laboratory project manager will be responsible for the day-to-day management of the laboratory work, to include data processing and data processing QA, verification that laboratory QA/QC procedures are being maintained, and verification that technical review of reports has been performed. Although various laboratory functions will be performed by different individuals, the laboratory project manager will provide signature approvals to laboratory-generated information and bear laboratory responsibilities.

3.2 Quality Objectives and Criteria

The DQO process is used to derive qualitative and quantitative statements in relation to a particular data collection event (or group of events). Performing the DQO process is generally one of the prerequisite steps to data collection. The DQO process is described in EPA Guidance (EPA 2006). The steps of the DQO process are as follows:

- State the problem
- Identify the goals of the study
- Identify information inputs
- Define the boundaries of the study
- Develop the analytic approach
- Specify performance or acceptance criteria
- Develop the plan for obtaining data

The steps of the DQO process for the project are summarized below:

- The problem: Groundwater quality in the Subbasin, as observed through groundwater samples collected from monitoring and production wells, is potentially degrading. Overdraft conditions are potentially exacerbating impacts from naturally occurring COPCs, which may result in undesirable effects such as degraded water quality that is unsuitable for irrigation and/or drinking.
- The goals: Evaluate baseline and long-term trends in COPC concentrations for comparison to measurable objectives to be established in the GSP.
- Information inputs: Obtain analytical data for groundwater samples using the tests outlined in Section 3.5.1 of this SAP.
- The boundaries of the study: Samples will be collected from groundwater wells within the Subbasin, as designated in the Monitoring Plan (Dudek 2017).
- The analytic approach: Concentrations of COPCs will be tracked and studied throughout implementation of the GSP, as described in the Monitoring Plan.
- Performance or acceptance criteria: The usability of the data collected for this phase of work will be based on measurement activities, consistent with accepted guidance

documents such as SW846 Test Methods. Testing results will be evaluated against performance-based acceptance criteria.

- The plan for obtaining data: The overall plan is outlined within the Monitoring Plan (Dudek 2017), and sampling details are presented in Section 2 of this SAP.

3.3 Special Training/Certification

No specialized training is required. Standard training specifications will be outlined in the project-specific Health and Safety Plan.

3.4 Documentation and Records

Documentation will involve generating, maintaining, and controlling field data, laboratory analytical data, field logs, reports, and any other data relevant to the project. Bound field log books, loose-leaf drilling logs, or automated field data entry records generated with personal data assistants are examples of documents. This project will have dedicated field log books, forms, and a DMS that will not be used for other projects. Entries will be dated and the time of entry will be recorded. Sample collection data and visual observations will be documented on forms or personal data assistants, or, when forms are not available or applicable, in the field log book. Any sample collection equipment, field analytical equipment, and equipment used to make physical measurements will be identified in the field documentation. Calculations, results, equipment usage, maintenance, and repair and calibration data for field sampling, and analytical and physical measurement equipment will also be recorded in field documentation. Once completed, the field forms, field databases, and field log book will become part of the project file.

Office data management will involve establishing and maintaining a project file. The project file will include the following:

- Planning documents, such as the QAPP
- Plans and schedules
- Standard operating procedures (SOPs) (for both the field and laboratory)
- Field sampling logs
- Field screening data
- QA auditing and inspection reports
- Laboratory analytical data
- Calculations
- Drawings and figures

- Reports
- External and internal correspondence
- Notes/minutes of meetings and phone conversations
- Contract/purchase orders
- Change orders
- Bid evaluations

All project-related information will be routed to the sampling project manager who will be responsible for distributing the information to appropriate personnel. Project documentation will be archived for a minimum of 15 years. Pertinent documentation will be uploaded to the project's online DMS.

3.5 Analytical Methods

3.5.1 Laboratory Methods

The following laboratory methods will be used during groundwater sample analysis activities:

- Arsenic by EPA Method 6010B
- Cations and anions by Methods 300.0, SM 2340C, and SM 2320B
- Fluoride by SM 4500 F C
- Nitrate by EPA 300.0
- Radionuclides by EPA 900.0
- Sulfate by EPA 300.0
- Total dissolved solids by SM 2540 C

3.5.2 Required Reporting Limits and Method Detection Limits

Reporting limits represent the lowest normally obtainable measurement level achieved and reported by the laboratory under practical and routine laboratory conditions for a variety of sample matrices. The method detection limit (MDL) is the minimum concentration that can be measured with 99% confidence that the analyte concentration is greater than zero by an analytical procedure in a given matrix containing the analyte. Sample-specific reporting limits may vary as a result of sample matrix and compound concentration. Samples with no positive results (down to the MDL) are typically reported as "ND" (indicating "not detected") by the laboratory. Positive results below the reporting limit but above the MDL are reported as estimated values by the laboratory. Reporting limits and MDLs are adjusted for dilutions, as necessary, by the laboratory. A summary of the MDLs and reporting limits for the COPCs is presented in Table 1.

Table 1
Summary of Method Detection Limits and Reporting Limits

COPC	Method	Reporting Limit (mg/kg)
Fluoride	SM 4500-F C	0.10
Arsenic	6010B	0.0100
Calcium	6010B	0.100
Magnesium	6010B	0.100
Potassium	6010B	0.500
Sodium	6010B	0.500
Total Dissolved Solids	SM 2540 C	1.0
Chloride	300.0	1.0
Nitrate (as N)	300.0	0.10
Sulfate	300.0	1.0
Hardness (as $CaCO_3$)	SM 2340 C	2.0
Alkalinity	SM 2320B	1.0
Bicarbonate	SM 2320B	1.0
Carbonate	SM 2320B	1.0
Hydroxide	SM 2320B	1.0
Radionuclides (Gross Alpha Particle Activity)	900.0	Variable

COPC = constituent of potential concern; mg/kg = milligrams per kilogram

Laboratory analytical methods specified in Section 3.5.1 are generally consistent with those used during previous sampling performed in the Subbasin.

3.5.3 Holding Times

Knowledge of required holding times will have a direct impact on scheduling of sample collecting, packing, and shipping activities. To ensure proper sample handling, the sample container, volume, preservation, and holding times applicable to each analytical method are shown in Table 2.

Table 2
Borrego Springs Subbasin – Groundwater Sample Analytical Suite

Constituent	Method	Sample Container	Preservative	Holding Time (days)
Fluoride	SM 4500-F C	250 mL HDPE	Ice 4°C	28
Arsenic	6010B	250 mL HDPE	Ice 4°C	28
Calcium	6010B	250 mL HDPE	Ice 4°C	28

Table 2
Borrego Springs Subbasin – Groundwater Sample Analytical Suite

Constituent	Method	Sample Container	Preservative	Holding Time (days)
Magnesium	6010B	250 mL HDPE	Ice 4°C	28
Potassium	6010B	250 mL HDPE	Ice 4°C	28
Sodium	6010B	250 mL HDPE	Ice 4°C	28
Total Dissolved Solids	SM 2540 C	1 L HDPE	Ice 4°C	7
Chloride	300.0	125 mL HDPE	Ice 4°C	28
Nitrate (as N)	300.0	125 mL HDPE	Ice 4°C	2
Sulfate	300.0	125 mL HDPE	Ice 4°C	28
Hardness (as $CaCO_3$)	SM 2340 C	250 mL HDPE	Ice 4°C	180
Alkalinity	SM 2320B	250 mL HDPE	Ice 4°C	14
Bicarbonate	SM 2320B	250 mL HDPE	Ice 4°C	14
Carbonate	SM 2320B	250 mL HDPE	Ice 4°C	14
Hydroxide	SM 2320B	250 mL HDPE	Ice 4°C	14
Radionuclides	900.0	1 L HDPE	Ice 4°C	5

mL = milliliters; L = liters; HDPE = high-density polyethylene bottle

3.5.4 Field Methods

Procedures for using field measurement devices are presented in Section 3.6.4.

3.6 Quality Control

3.6.1 Introduction

This section addresses QC procedures associated with field sampling and analytical efforts. Included are general QC considerations, as well as specific QC checks that provide ongoing control and assessment of data quality in terms of precision and accuracy.

3.6.2 Field Quality Assurance/Quality Control

QA/QC for fieldwork refers to methods of measuring the quality of the field sampling techniques. Drilling, sampling, and field record keeping will be conducted in accordance with current sampling protocols for groundwater sampling, as applicable. Field instrumentation will be calibrated in accordance with the manufacturer’s instructions at the beginning of each field day.

In addition to the primary samples, the following QA/QC samples will be collected:

- **Field Duplicate**. One field duplicate sample will be collected for every 20 samples collected. The field duplicates will be analyzed for the same COPCs as the primary samples, and will be used to evaluate field sample collection reproducibility. The location where the field duplicate is collected will be noted on the sampling logs. The duplicate sample name will be different than the original sample name.
- **Matrix Spike/Matrix Spike Duplicate (MS/MSD)**. One MS/MSD sample will be selected as applicable, and noted on the chain-of-custody. The MS/MSD samples will be analyzed for the same COPCs as the primary samples, and will be used by the laboratory to check for the ability to accurately and precisely recover compounds of interest from the site-specific matrix.

Field blanks will not be collected for this scope of work because easily transferable constituents such as volatile organic compounds are not anticipated to be encountered. The results of the analyses of these QC sample types are used as independent, external checks on field sample collection techniques.

3.6.3 Laboratory Quality Control

To obtain data on precision and accuracy, the analytical laboratory will analyze the QC samples described below. The control limits and corrective actions for each parameter are specified in the pertinent laboratory analytical method SOPs. The analytical methods require analyses of the following QC samples:

- Calibration verification following instrument calibration and continuing calibration verification.
- Laboratory blank verification at instrument calibration and at the method required frequency thereafter for continuing blank verification.
- Method blank analysis at a rate of once per batch of samples or one per 20 samples of a single matrix, whichever is more frequent, to determine contamination levels during sample preparation.
- Laboratory control sample (LCS) analyses at a rate of one per batch. The LCS is used to verify that the analytical system is in control based on the percent recovery of the analyte(s).
- MS/MSD or MS/Laboratory Duplicate analyses will be conducted as applicable. The MS/MSDs and/or MS/Laboratory Duplicate are used to check for the ability to accurately and precisely recover compounds of interest from the matrix.

3.6.4 Field Procedures

Field monitoring and analytical equipment will be maintained in accordance with the manufacturers' recommended schedules and procedures. Maintenance activities will be documented by either field or laboratory personnel. Calibration will be performed on a routine basis and as otherwise required. Calibrating equipment or calibration standards will also be routinely recalibrated or replaced and documented. Routine inspection of equipment is intended to identify problems requiring maintenance before they cause a major disruption in field monitoring or analytical activities, or adversely affect the validity and precision of the data being measured.

3.6.5 Laboratory Procedures

The laboratory is responsible for maintaining laboratory equipment in accordance with manufacturers' recommended maintenance and procedures in order to minimize downtime of the analytical systems. Each analyst is responsible for conducting a daily inspection of critical systems on instruments under their charge. Inspections will include vacuum lines and pumps for the gas chromatograph/mass spectrometer, automatic injection systems, controlled reagent-feed motors, temperature-controlled ovens in gas chromatographs, capillary columns, detectors and support systems, gas control system for atomic adsorptions, and many others. Wear-dependent items, such as septa on gas chromatograph injection systems, will be replaced as needed. The performance of instruments will be checked against known standards at the beginning of each working day or shift. Failure to achieve proper performance indicates a system problem, which will be addressed by laboratory personnel or by the manufacturer's service representative.

In addition, laboratory personnel or the manufacturer's service representative will service working systems according to a fixed schedule. A record of service and repairs, whether accomplished by laboratory personnel or by the manufacturer's service representative, will be maintained in a log book kept with each instrument.

3.7 Inspection/Acceptance of Supplies and Consumables

Critical field supplies and consumables include the following:

Sample bottleware

- Decontamination fluids
- Personal protective equipment
- General sampling consumables (e.g., ice, plastic bags, paper towels, aluminum foil)

For bottleware, the acceptance criteria will entail an inspection upon receipt of analytical testing to confirm the absence of cross-contamination and the presence of appropriate preservatives. For decontamination fluids, field staff will ensure that the fluids meet the necessary requirements for concentration and quality grade (e.g., reagent-grade methanol). Personal protective equipment will be inspected to confirm integrity and ensure that the appropriate sizes are available as required by sampling team members.

3.7.1 Laboratory Supplies

The inspection and acceptance criteria for analytical reagents will be performed in accordance with the selected California-certified laboratory's SOPs.

3.8 Assessments and Response Actions

The project team may conduct performance and systems audits of field and laboratory activities, as necessary. Following is a discussion of audits, corrective action, and reporting procedures.

3.8.1 Systems Audit

A systems audit consists of the evaluation of key components of the measurement systems to determine their proper selection and use. When required by the EPA or alternative regulatory authority, systems audits are performed prior to or shortly after systems are operational. This audit includes a careful evaluation of field and laboratory QC procedures, which are explained below.

Field Systems Audits

Field systems audits are on-site audits that focus on data collection systems, using the appropriate SAP/QAPP as a reference. Specific activities vary with the scope of the audit, but can include a review of sample collection activities, decontamination practices, equipment calibration techniques and records, decontamination and equipment cleaning, background and training of personnel, sample containers and preservation techniques, and chain-of-custody procedures.

Laboratory Systems Audit

The laboratory systems audit is a review of laboratory operations to verify that the laboratory has the necessary facilities, equipment, staff, and procedures to generate acceptable data.

Specific activities vary with the scope of the audit, but can include a review of equipment suitability and maintenance/repair; SOPs; background and training of personnel; laboratory control charts and support systems; and QA samples, including performance evaluation samples, chain-of-custody procedures, data logs, data transfer, data reduction, and validation.

3.8.2 Performance Audits

After systems are operational and generating data, a performance audit may be requested to determine the accuracy of the total measurement system(s) or component parts thereof. Similar to the systems audit, there are two types of performance audits, as explained below.

Field Performance Audit

Performance audits of sampling activities will be conducted using review of laboratory sample receipt forms.

An inspection for suitability of the samples for proper laboratory analysis will serve as the performance audit of the sample collection procedures. Insufficient sample volume for analysis, or improper preservation of samples, will be noted by the analytical laboratory. A preponderance of such reports of unsuitable samples will indicate that the sampling procedures are poor or unacceptable. Analytical results will be reviewed by the sampling project manager and the QA manager to assess the performance and adequacy of sample collection procedures.

Proper execution of sampling procedures will be audited by the sampling project manager and the QA manager. The sampling project manager and QA manager will audit these project operations on a regular basis over the life of the project through review of the field log book and audit forms, and through discussion with the field manager.

Laboratory Performance Audits

The project laboratories participate in a variety of federal and state programs that subject laboratories to stringent performance audits on a regular basis. QA policies and procedures currently in place at the laboratories, and actions that will be included in sampling activities to ensure QA, include the following:

- Inter-laboratory check samples
- Periodic audits
- Laboratory control samples analyzed at applicable analytical method frequencies
- Performance evaluation samples to be submitted to laboratories by the project team to each laboratory during major sampling events that use the particular laboratory

Laboratory performance in these areas will be monitored by the project team QA manager. If necessary, the project team QA manager will conduct an on-site audit of field operations or the analytical laboratory.

3.8.3 Corrective Action for Measurement Systems

When a problem situation arises regarding any significant impediment to the progress of the SAP during site characterization, corrective action will be implemented to identify the problem and its source. Appropriate documentation of this action will be recorded in the project file.

Personnel responsible for the initiation and approval of corrective action will be the laboratory QA manager (for corrective action at the laboratory) and the project team project manager (for corrective actions identified during field activities and/or during the data validation effort).

3.8.4 Quality Assurance Reporting Procedures

Below are the QA reporting procedures that will be implemented for this project.

Reporting Responsibility and Recordkeeping

Comprehensive records will be maintained by the project team to provide evidence of QA activities. These records will include the following:

- Results of performance and systems audits
- Data validation summary
- QA problems and proposed corrective action
- Changes to the project documents

The proper maintenance of QA records is essential to provide support in any evidentiary proceedings. The original QA records will be kept in the QC manager's records.

Access to working files will be restricted to project personnel.

Audit Reports

Should audits be requested, the corresponding audit reports will be distributed to the following project personnel, as appropriate:

- Project Manager/Project Director
- Field Manager
- Laboratory QA/QC Manager

3.9 Data Reduction, Review, Verification, and Validation

This section addresses the stages of data quality assessment after data have been received. It addresses data review, verification, and validation. It also sets procedures for evaluating the usability of data with respect to the DQOs set forth in Section 3.2.

3.9.1 Data Reduction

Raw analytical data generated in the laboratory are collected on printouts from the instruments and associated data system, generated electronically and stored in a laboratory information management system (LIMS), or manually recorded into bound notebooks. Analysts review data as they are generated to determine that the instruments are performing within specifications. This review includes calibration checks, surrogate recoveries, blank checks, retention time reproducibility, and other QC checks as specified in the laboratory's SOPs. If problems are noted during the analytical run, corrective action will be taken and documented.

Each analytical run is reviewed for completeness prior to interpretation and data reduction.

3.9.2 Data Review

Data review is an initial and relatively non-technical step of data assessment that primarily addresses issues of completeness and data handling integrity. In data review, the reviewer will ensure that all necessary reporting components have been included in laboratory reports, such as necessary fields (e.g., collection/analysis dates, units) and the presence of (but not implications of) QA/QC data components (e.g., LCS records, surrogate results).

3.9.3 Data Verification and Validation

Data verification is a more technical process than data review in that the core technical aspects of data quality (e.g., precision, accuracy) are evaluated through a review of the results of QA/QC measures, such as LCSs and surrogates.

Following interpretation and data reduction by an analyst, data are transferred to the LIMS either by direct data upload from the analytical data system or manually. The data are reviewed by the group leader or another analyst and recorded in the LIMS as being verified. The person performing the verification reviews all data, including QC information, prior to verifying the data. The laboratory will complete the appropriate forms summarizing the QC information and transfer copies of all raw data (e.g., instrument printouts, spectra, chromatograms) to the project management group for the final laboratory deliverable. This laboratory project manager will combine the information from the various analytical groups and the analytical reports from the LIMS into one package. This package will be reviewed by the laboratory project manager for conformance with SOPs and to ensure that all project QC goals have been met. Any analytical problems are discussed in the case narrative, which is also included with the data package deliverables. A Level 2 data deliverable will be required for this project.

Following data verification by the laboratory, data validation will be conducted on 100% of the laboratory data by an entity independent of the laboratory. The following level of validation will be performed:

- Stage 1: 100% of samples collected

If systematic errors with the laboratory data are identified, further validation may be necessary. Data validation may be performed on hard-copy data or electronically, as applicable. General compliance to the August 2014 National Functional Guidelines for Inorganic Data Review and the National Functional Guidelines for Superfund Method Organic Data Review (EPA 2014), and EPA Region 9 validation guidance will be used as the basis for the validation. The guidance documents provide structured approaches for the assignment of data qualifiers based on observations made in the data verification process, and will be used in conjunction with the specific EPA method criteria and the QA criteria set forth in the project-specific SAP.

3.9.4 Data Validation and Usability Determination

Data verification is a technical process to evaluate data, but it does not answer the final question of the usability of the data and the implications of any departures from data expectations. The data validation process is designed to assign data qualifiers based on the data verification results, and provide a case-by-case review of data quality issues with respect to QAPP objectives to render a final assessment of data usability.

3.10 Data Evaluation Roles and Responsibilities

The following components of data evaluation will be performed:

- Data reduction will be performed by the analytical laboratory
- Data review will be performed by both the laboratory and by the project team
- Data verification will be performed by the laboratory
- Data validation and usability determination will be performed by the project team

3.11 Data Reporting

Laboratory reports will contain the following:

- **Case Narrative:** Description of sample types, tests performed, any problems encountered, corrective actions taken, and general comments.
- **Analytical Data:** Data are reported by sample or by test. Pertinent information, such as dates sampled, received, prepared, and extracted, will be included on each results page. The reporting limit and method detection limit for each analyte will also be recorded. In addition to a report saved as a pdf, the laboratory will provide an electronic data deliverable in a text format corresponding to each analytical report.
- **Laboratory Performance QC Information:** The results for all of the associated laboratory QC samples and practices will be reported (e.g., LCS, method blanks, surrogate recoveries).
- **Matrix-Specific QC Information:** Results of any sample duplicates, MSs, MSDs, or other project-specific QC measures that are requested will be reported.
- **Methodology:** The reference for the applied analytical methodology will be cited.

4 REFERENCES

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APPENDIX A

Example Groundwater Elevation Monitoring Field Form

Geosyntec
consultants

SAN DIEGO COUNTY WELL MONITORING DATA SHEET
BORREGO SPRINGS SUBBASIN
GROUNDWATER GAUGING SHEET

Date: ____________________

Sampler: ____________________

State Well #	No Measurement	Questionable Measurement	Depth to Water	Groundwater Elevation	Previous DTW	Gauge Time	Well Box Type	Well Cap Type	Survey Point (Reference Point)	Comments

Notes:

NO MEASUREMENT: 0. Measurement discontinued 1. Pumping 2. Pump house Locked 3. Tape hung up 4. Can't get tape in casing 5. Unable to locate well 6. Well has been destroyed 7. Special 8. Casing leaky or wet 9. Temporarily inaccessible

QUESTIONABLE MEASUREMENT: 0. Caved or deepened 1. Pumping 2. Nearby pump operating 3. Casing leaky or wet 4. Pumped recently 5. Air or pressure gauge measurement 6. Other 7. Recharge operation at or nearby well 8. Oil in casing

Notate depth in feet, tenths of feet, and/or hundredths of feet. Do not notate in inches.

APPENDIX B

Example Groundwater Quality Monitoring Field Form

SAN DIEGO COUNTY LOW FLOW WELL MONITORING DATA SHEET

DATE:_________

Project Name: Borrego Springs Subbasin	Project Address:
Sampled by:	Project Number:
Sampling Company:	Well GPS Latitude: _________
Well ID:	Longitude:
Borehole Diameter: inches	Well Diameter: inches
Static Water Level (ft. btc): Time______	Referenced to: Top of PVC Casing

Reference Point Elevation (ft. MSL):

Total Well Depth (ft. btc) (WD):

Meter type/ID: Ultrameter YSI 556 YSI 550 ID:_________________

Water Level Indicator Type: GeoSlope Indicator ID:_________________

Decontamination Method: Steam/High Pressure Wash 3 Stage Rinse Other

Sampling Equipment: __Other: ___________________

Purge Method: Low Flow __________

Pump Depth (ft btc): ____________________ Date Pump Installed: ____________________

Purge Rate:________________ Start Purge:________________

Time	Temp (^{o}C)	pH	Cond. (mS or µS)	Turbidity (NTUs)	D.O. (mg/L)	ORP (mV)	Depth to Water (ft btc)	Water Removed (ml)	Observations
Stabilization Parameters*	+/-3%	+/0.2 units	+/-3-5%	+/-10%	+/0.2 units	+/-20 mV			

Sampling Date:	Sampling Time:	Depth to Water:

Sample I.D.:	Laboratory:

Analyzed for:	Volume	Container	Filtered	Pres.	Parameters

EB I.D. (if applicable): Time	Duplicate I.D. (if applicable):
Field Sheet Checked By:	License #:

COMMENTS:

* 3 Consecutive Readings

APPENDIX E2

Borrego Metering Plan

DRAFT

GROUNDWATER EXTRACTION METERING PLAN
BORREGO SPRINGS GROUNDWATER SUBBASIN

Prepared for

Borrego Valley Groundwater Sustainability Agency
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DECEMBER 2018

TABLE OF CONTENTS

Section **Page No.**

APPENDICES

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1 INTRODUCTION

The Borrego Springs Groundwater Subbasin (Subbasin) of the Borrego Valley Groundwater Basin (BVGB) has been identified by the California Department of Water Resources (DWR) as subject to critical conditions of overdraft (DWR 2016). As such, in accordance with California's Sustainable Groundwater Management Act (SGMA), a Groundwater Sustainability Agency (GSA) has been formed to develop and implement a basin-specific Groundwater Sustainability Plan (GSP). The general purpose of the GSP is to facilitate a long-term groundwater withdrawal rate less than or equal to the sustainable yield of the Subbasin within the maximum 20-year implementation period mandated by SGMA.

This Groundwater Extraction Metering Plan (Metering Plan) is a foundational component of the GSP that will facilitate the reporting of groundwater extraction data. Collection and reporting of these data are integral to enable proactive and adaptive management of groundwater resources and documentation of seasonal fluctuation in water demand. Agricultural pumping was identified as one of the greatest sources of uncertainty in the Borrego Valley Hydrological Model (BVHM), because the groundwater use was indirectly estimated using potential evapotranspiration, crop coefficients, and irrigation efficiencies. Collecting metered data is one of the three primary recommendations proposed to improve the accuracy of the BVHM, which in turn improves the GSA's tools for adaptive management. Furthermore, the collection of metered pumping data is a key metric for evaluating the effectiveness of four out of the six projects and management actions being undertaken by the GSA (i.e., the water trading program, water conservation, pumping reduction program, and the voluntary fallowing of agricultural land). The GSA derives its authority to require groundwater extraction metering pursuant to the SGMA § 10731.

This plan has also been prepared consistent with Borrego Valley GSP Advisory Committee (AC) Policy Recommendation #1 – Questions #1 and #2 (AC Agenda and Minutes November 2017). AC Policy Recommendation #1 – Question #1 recommended meters to be installed on all wells with the exception of wells that use two acre-feet per year (AFY) (651,702 gallons/year) or less within the Subbasin.

AC Policy Recommendation #1 – Question #2 provided two options to the AC for consideration as follows:

> <u>Option 1</u>: The GSA inspects and monitors/reads the meter on a monthly basis and ensures the accuracy of the data including meter calibration. The GSA would provide an annual statement setting forth the total extraction in gallons from each

well. The GSA will keep data confidential to the maximum extent allowed by law (California Govt. Code 6254(e)).

Option 2: The property owner (or third-party contractor acceptable to the GSA) monitors/reads the meter on a monthly basis. A third-party contractor acceptable to the GSA would inspect and read the meter on a semi-annual basis to verify the accuracy of data including meter calibration. On behalf of the property owner, the third-party contractor would provide an annual statement to the GSA with verification of the total extraction in gallons from each well and verification that each flow meter is calibrated to within factory acceptable limits. The GSA will keep data confidential to the maximum extent allowed by law (California Govt. Code 6254(e)).

Although the AC did reach consensus on requiring meters to be installed on all wells except those wells that use two AFY or less, consensus was not achieved for AC Policy Recommendation #1 – Questions #2 as indicated by Level 5 and 6 AC member votes. As such, that issue was returned to the Core Team without a recommendation as per the Borrego Valley GSP AC By-laws adopted and approved January 29, 2017. This Plan has been prepared under the presumption that the Core Team accepts both Option 1 and Option 2 presented in AC Policy Recommendation #1 – Question #2 as acceptable.

1.1 Applicability of the Metering Plan

An interim Monitoring Plan was prepared in support of the GSP, outlining the types of monitoring necessary to address the applicable DWR-designated SGMA sustainability indicators in the Subbasin (Dudek 2017). This Metering Plan serves to supplement the Monitoring Plan by outlining consistent groundwater extraction metering procedures required for all groundwater production wells in the Subbasin which pump in excess of two AFY. However, *de minimis* groundwater production wells that pump less than two AFY are exempt from the metering requirement defined herein pursuant to SGMA § 10721e.

Implementation and compliance with this Metering Plan will be mandatory for all non-*de minimis* wells in the Subbasin beginning 90 days from adoption of the GSP. The GSA may require metered data from any well located in the Subbasin if it is uncertain whether it qualifies as de minimis groundwater production.

This Metering Plan will be implemented to address the following:

- The GSA is currently relying on estimates of pumping, which is considered a source of uncertainty in the Subbasin's numeric groundwater model at this time. Initially these data will be used to refine existing groundwater extraction estimates for non-de minimis groundwater production wells in the subbasin. Additionally, the data will be used to verify and refine the sustainable yield of the Subbasin.

- Groundwater extraction metering data will be integrated with other data being collected (i.e., groundwater level data) to track changing conditions in the Subbasin in order to evaluate the SGMA sustainability indicators: chronic lowering of groundwater levels, reductions in groundwater storage, and the potential for water quality impacts to municipal supply as groundwater levels decline.
- Groundwater extraction metering data will be used throughout the GSP implementation period to quantitatively track compliance with prescribed pumping allocations and reductions.

The Metering Plan outlines a procedure that will facilitate confidential collection and reporting of groundwater extraction data to the GSA, which will not be subject to public review pursuant to Government Code 6254(e).

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2 METERING PLAN

This section describes the metering objectives and acceptable approaches, meter types and installation configurations, and meter maintenance and calibration requirements for routine groundwater extraction metering activities in the Subbasin.

2.1 Metering Objectives

The purpose of this Metering Plan is to outline the procedures for the metering of all non-*de minimis* groundwater extraction wells (>2 AFY) within the Subbasin to enable proactive management of water resources. The GSA may request metered data from any well located in the Subbasin if it is uncertain whether it qualifies as *de minimis* groundwater production.

2.2 Approach

All non-*de minimis* wells will be required to register with the GSA upon GSP adoption, which will include identification of flow meter type, San Diego County Assessor's Parcel Number (APN) for each parcel served by each well and farm identification, golf course identification or other type of water use identification. Figure 1 illustrates an example of one well serving multiple parcels within a farm:

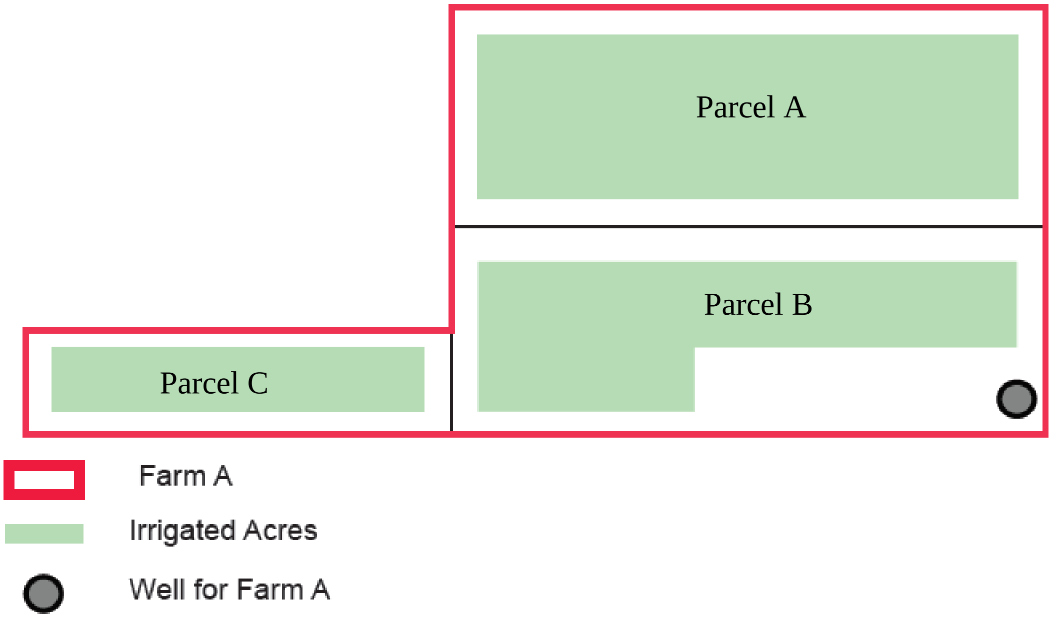

Figure 1. Example Documentation of Parcels Served by a Well for a Farm

Registration of non-*de minimis* production wells is achieved by submittal of the registration form to the GSA and is due within 90 day of GSP adoption. A copy of the registration form is provided as **Attachment A**, which specifies details for electronic submittal of the form. At the time of form submittal, the GSA will verify parcels served by each well and current area of irrigation based on aerial photography and GIS analysis.

Subsequent to registration, each applicable well owner that does not already have an appropriate flowmeter installed (as reported on registration form and verified by GSA) will be required to have one installed near the wellhead. The registrants will be required to install the flowmeter within 60 days of registration, or as determined appropriate by the GSA at time of GSP adoption. The meter is required to be read and recorded monthly and reported to the GSA annually. Registrants will be required to begin recording groundwater production immediately following installation. A third-party contractor acceptable to the GSA would inspect and read the meter on a semi-annual basis to verify the accuracy of data including meter calibration. An annual report will be required to be submitted to the GSA to demonstrate compliance with the Metering Plan.

2.3 Meters

Historically, basin-wide monitoring has included municipal reading of Borrego Water District Wells and San Diego County Major Use Permit readings for golf courses in the basin. Additional meters are required in the Subbasin to more accurately measure and document water usage.

Flow meters must be installed on existing production wells and should be installed at easily accessible above-ground portions of the well. Flow meters should be installed according to the meter’s installation specification (e.g., correct upstream and downstream pipe length). Flow meters must include both an instantaneous flow rate and a totalizer recording the total volume of water extracted from the well. Appropriate meter types are described in the following subsections.

2.3.1 Meter Types

Wells owners can select the brand of flow meter to be installed on their well(s); however, meters must be calibrated as described in Section 3 of this Metering Plan. The propeller-type flow meter is recommended for installation as part of the GSP. Propeller-type meters have been used throughout the Subbasin, and have proven to be a reliable mechanism for long term monitoring. Also, additional implementation of propeller type meters would ensure data comparability to previous historical data.

Propeller Flow Meter:

- Propeller type flow meters use mechanical parts to record production and/or measure flow rate.
- Commonly used in agriculture and municipal settings (majority of meters in Borrego Valley are propeller meters).
- Propeller meters must be sized based on expected flow rate and pipe diameter.
- Historically reliable for long-term use.
- May require maintenance, as bearing wear can occur from the internal propeller, and calibration is also periodically required.
- Future data collected would be of comparable accuracy to historically collected flow meter data.
- Flow meter accuracy is commonly plus or minus 2%.

Figure 2. Example Propeller Type Flowmeter

Source: McCrometer 2017

Additionally, Automated Meter Infrastructure (AMI) can be implemented to remotely report measurements. AMI can be implemented to minimize visits to the wellhead, and remote communication options include satellite and cellular connections. Power options for AMI can include grid, battery-only, and rechargeable solar power.

Figure 3. Example Automated Meter Infrastructure

Source: McCrometer 2017

2.3.2 Typical Installation Configurations

Many wells in the Subbasin already have flow meters installed; however, many wells will require new flow meter installation, retrofits, or meter calibration. Installing each flow meter typically requires 4-8 hours, and must be performed by a licensed pump contractor. Well owners may have the option to allow installation of the flow meter through the GSA for a limited time with a subsidized program, or through an independent pump company at the expense of the well owner.

The meters must be installed in accordance with manufacturer’s specifications. A typical installation configuration is depicted in Figure 4.

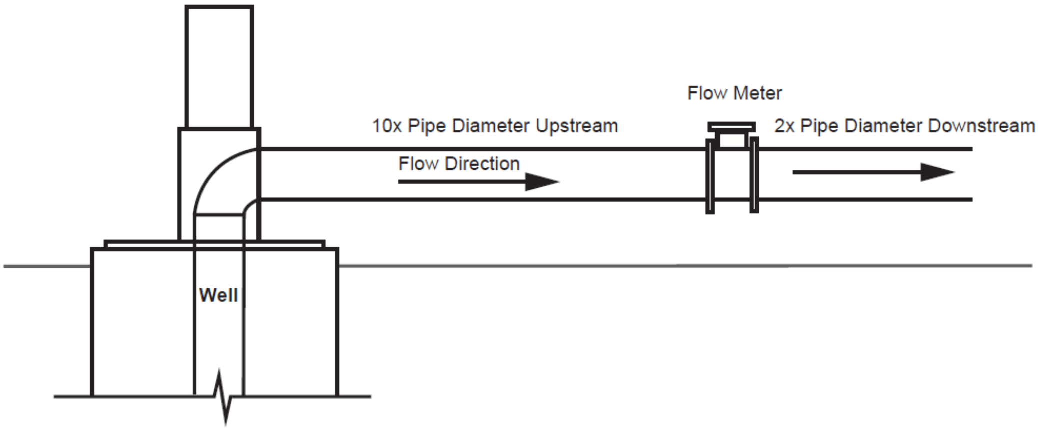

Figure 4. Typical Flowmeter Configuration

2.3.3 Maintenance and Calibration Considerations

Propeller flow meters are considered to be reliable for long-term use; however, routine maintenance of the flow meter will be required, and will be the responsibility of the well owner. Calibration will be conducted as needed semi-annually for propeller type flow meters, and annual meter accuracy checks must be conducted by a GSA-approved vendor. Calibration specifications are presented in Section 3 of this Metering Plan.

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3 GROUNDWATER METERING COMPLIANCE REQUIREMENTS

3.1 Calibration and Validation

Proper calibration and verification is important for ensuring data quality, and necessary for meeting the objectives of the Metering Plan. Well owners are responsible for costs for installation (if needed), calibration, verification, and maintenance of meters. Under certain parameters, a flow meter may be deemed “commercial.” The County of San Diego, Department of Agriculture, Weights and Measures (AWM) considers a meter to be commercial if it is being used to determine a fee or penalty charged to pumpers, and the meter is owned by the property owner. AWM requires commercial meters to be tested and sealed at the AWM testing facility prior to installation, and to be retested every ten years.

The AWM testing facility has the capability of testing flow meters up to two inches in diameter. Most of the meters subject to the Metering Plan are larger than two inches, and therefore, cannot be tested at the AWM laboratory. In lieu of AWM facility testing, flow meter testing and calibration shall be conducted by the meter manufacturer in conformance with National Institute of Standards and Technology (NIST) Handbook 44, as referenced in California Code of Regulations, Title 4, Division 9 Weights and Measures Field Reference Manual (2018) Section 3.36 Water Meters. Based on the GSA’s review of existing, accessible meters in the Subbasin, most meters are manufactured by McCrometer, based in Hemet, California. McCrometer’s calibration Standard Operating Procedure for applicable meters has been reviewed by the GSA and determined to be compliant with above-referenced NIST standards. Therefore, McCrometer’s two California calibration facilities (Hemet and Porterville) are considered acceptable for meter calibration. Other meter manufacturers may also be acceptable for calibration procedures pending confirmation of NIST compliance.

Initial Calibration/Validation of Existing Meters

New meters will require a certificate of calibration which must be provided to the GSA and recorded. Existing meters in the Subbasin will need to be inspected and validated to ensure proper function and calibration. These activities must be conducted by a California-licensed pump contractor or GSA-approved vendor. This initial calibration and validation will be conducted at the beginning of the schedule of routine metering activities, and a certificate of calibration must be produced and recorded. Certificates of calibration for new and existing meters must be submitted with the initial semi-annual report (Section 3.4 of this Monitoring Plan).

Routine Calibration/Validation

Routine calibration checks (i.e., validation) must be conducted semi-annually. If variability exceeds 5% then manufacturer recalibration will be required. This typically involves removing the meter and having it factory calibrated. Routine validation can be conducted using either a temporary ultrasonic meter test to measure instantaneous flow rate, or other approved recalibration methods performed through professional services. Calibration can also include motor efficiency testing by the pump contractor or vendor to determine current efficiency and remaining useful life of the well motor. Replacing well motors when they become inefficient can save on electrical cost with the potential for regular maintenance resulting in cost savings to the pumper.

3.2 Meter Reads and Monthly Data Reporting

Upon GSP adoption, meter reads must be recorded monthly and submitted to the GSA team electronically on an annual basis with third party validated reports for pumpers who elect to not have GSA staff perform the meter reads. Compliance with GSA meter reading requirements can be achieved by one of two approaches:

3.2.1 Option 1 - GSA Performed Meter Reading

Provide access for the GSA to perform monthly visual meter reading. Enrollment in this approach requires execution of the access agreement provided in **Attachment A** of this Metering Plan. Currently numerous groundwater flow meters within the Subbasin are visually read and documented on a monthly basis.

3.2.2 Option 2 - Third-Party Contractor Performed Meter Reading

The property owner (or third-party contractor acceptable to the GSA) monitors/reads the meter on a monthly basis. A third-party contractor acceptable to the GSA would inspect and read the meter on a semi-annual basis to verify the accuracy of data including meter calibration. On behalf of the property owner, the third-party contractor would provide an annual statement to the GSA. Third party contractors shall possess an appropriate license, including Professional Geologist, Professional Engineer, California Well Drilling License (C-57), or other applicable professional license approved by the GSA.

3.3 Annual Reporting

Annual reports shall be submitted to the GSA on or before October 31st of each year. The reporting year will be defined as the water year from October 1st through September 30th. The water year is designated by the calendar year in which it ends.

Annual reports must contain the following:

- **Total Annual Water Use Per Well:** Tabulated results of monthly meter reads and cumulative annual water production amount.
- **Meter Calibration/Validation Documentation:** Semi-annual validation and annual calibration certificates produced by an appropriate pump or meter company.
- **Representative Parcel Numbers:** San Diego County APN for each parcel served by each well.
- **Farm Identification, if applicable**: Name of farm or farms served water by each well.
- **Meter Reading Method and Qualification:** Description of the meter reading method (e.g., visual read by Borrego Water District, remote automated reading infrastructure with confirmation by third party, etc.) and certification that the individual collecting that data meets the minimum qualifications of the GSA.

Annual reports shall be submitted electronically to the GSA in the required format. An example annual report template is provided as **Attachment B** to the Metering Plan which also specifies submittal details.

3.4 Data Confidentiality

To address concerns regarding the confidentiality of pumping data, the raw data will remain confidential pursuant to Government Code 6254(e). These data will be maintained for use by the GSA, and only publicly available as aggregate values by water use sector (i.e., Agriculture, Municipal, and Recreation).

3.5 Enforcement and Penalties

The GSA’s enforcement of compliance with the Metering Plan is imperative to ensure effective implementation. Pump owners who fail to comply with the Metering Plan or who provide inaccurate data to the GSA will be subject to penalties. Specific enforcement and penalties will be outlined in a Fees and Penalties Plan to be approved by the GSA.

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4 REFERENCES

Advisory Committee (AC) Agenda. 2017. Borrego Valley Groundwater Basin: Borrego Springs Subbasin. Sustainable Groundwater Management Act (SGMA). AC Meeting. November 27, 2017

Dudek. 2017. *Borrego Springs Subbasin, Draft Interim Monitoring Plan*. August 21, 2017.

DWR. 2016. *Best Management Practices for the Sustainable Groundwater Management of Groundwater – Monitoring Protocols, Standards, and Sites.* California Department of Water Resources, Sustainable Groundwater Management Program. December 2016.

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ATTACHMENT A

Groundwater Extraction Facility Registration Form

Groundwater Extraction Facility Registration Form

Owner Information

Contact Name ______________________________

Business Name ______________________________

Farm/Entity ______________________________

Address ______________________________

City/State/Zip ______________________________

Phone No. ____________________

Email Address ____________________

Operator Information *(if different than above)*

Contact Name ______________________________

Business Name ______________________________

Address ______________________________

City/State/Zip ______________________________

Phone No. ____________________

Email Address ____________________

Well Information

Owner's Well Name/No. ______________________________

Well Location/Address ______________________________

Public Land Survey Location; Township _________ Range _________ Section _______________

GPS Coordinates; Latitude_______________ Longitude _______________

State Well No. (SWN) ______________________________

State Well ID ______________________________

Additional Well Information

County Well Permit No. ______________________________

Date Drilled ______________________________

Well Depth _____________________feet

Casing Diameter _________________inches

Perforations ________________________________ feet from ground surface

Groundwater Extraction Facility Registration Form

Motor Type: Submersible or Turbine *(circle one)*

Motor/Engine ___________________HP

Existing Water Meter: Yes or No *(circle one)*

Manufacturer of Water Meter ____

Water Meter Size ________________ inches

Water Flow Meter (state what flowmeter reads in: acre-feet (AF), gallons, cubic feet (CF))

Serial No. of Water Meter ____

Electric Meter No. ____

Assessor's Parcel No. (APN) ____

Hydrogeologic Data (If any of the below data are available, check box and please provide documentation.)

☐ Driller Well Completion Report Available

☐ Groundwater Quality Data Available

☐ Groundwater Level Data Available

☐ Geologist Log Available

☐ Aquifer Test Data Available

☐ Geophysical (E-log) Available

Well Water Use Type

☐ Agricultural/Irrigation *(list number of acres and crop category(ies))* __________________________

☐ Stock Watering *(number and type of animals)* _____________________________________

☐ Domestic *(number of persons served)* ____

☐ Municipal or Industrial ____

☐ Other *(describe)*

Groundwater Extraction Facility Registration Form

Property Access for Meter Readings and Groundwater Level Monitoring

Please provide your printed name and signature to allow for monthly meter readings and approximately semi-annual groundwater level monitoring.

Contact information for property access notification:

Contact Name ___________________________________

Phone No. ______________________________________

Email Address ___________________________________

Signature _____________________ Date __________

Are additional active or inactive well located on the property? If so, provide number of well:

Number of Active Wells ______________________

Number of Inactive Wells _____________________

Please complete a separate Groundwater Extraction Facility Registration Form for each additional active well.

ATTACHMENT B

Example Data Submittal Format

BORREGO VALLEY GROUNDWATER SUSTAINABILITY AGENCY
ANNUAL
GROUNDWATER EXTRACATION STATEMENT

Contact: **Telephone:**

Well Operator: **Email:**

Address: **Usage/Acreage:** ______________________________

City, State, Zip:

☒ Please check box if your well(s) is/are used for domestic purposes (human or animal consumption) and delineate which well(s) by highlighting, circling, or "*" - noting which well (if more than 1).

Please carefully fill out the fields (1 - 10) in this form. You have well(s) within the Borrego Springs Subbasin. The Borrego Valley GSA requires that this form be completed, signed and submitted by each well owner and/or operator within 45 days of the due date. If this completed form and required payment is not received by the due date, Ordinance requires that the Borrego Valley GSA charge you interest at X% per month, as well as a late penalty assessed at X% per month.

State Well Number **Flow Meter Readings**

___N___W______	**Current**	**-**	**Previous**	**=**	**Difference**	**x Mult**	**= Extraction (Units)**
	_____________		____________		__________	_______	____________

Gallons _____________

Acre-feet _____________

**** PLEASE CALCULATE ACRE-FEET (AF) TO THE 3rd DECIMAL PLACE ****

If you get 50.0019 AF, correct entry = 50.002 AF

Annual Pumping Allocation **Extraction Charge**

Baseline Pumping Allocation ____________ AF ____________ **AF** x $X.00/AF = $ __________

Pumping Allocation _____ % Reduction Interest 1.5% x Months: + $ __________

Available Pumping Allocation ____________ **AF** Late Penalty: + $ __________

Actual Groundwater Extraction ____________ **AF** Overpumping Surcharge: + $ __________

(see rate breakdown below)

TOTAL AMOUNT ENCLOSED = $ __________

Overpumping Surcharge Rates

___________AF @ $X = $ ___________

Payment must be received within 45 days of the date the Annual Statement is issued by Borrego Valley GSA to avoid late penalties and interest.

I DECLARE under penalties of perjury that this groundwater extraction statement has been examined by me, and to the best of my knowledge and belief is a true, correct and complete statement.

Print Name: ______________________________ Date: __________________________

Signature:_______________________________

THIS STATEMENT IS NOT COMPLETE UNLESS ALL QUESTIONS ARE ANSWERED AND SIGNATURE PROVIDED.

APPENDIX F

Baseline Pumping Allocation

APPENDIX F
Baseline Pumping Allocation Methodology

The Groundwater Sustainability Plan (GSP) includes a baseline pumping allocation for each identified non-de minimis groundwater user in the Borrego Springs Subbasin (Subbasin). The "baseline pumping allocation" is defined as the amount of groundwater each pumper in the Subbasin is allocated prior to SGMA-mandated reductions. It is further defined as the verified maximum annual production, in acre-feet per year (AFY), for each well owner over the baseline pumping period. The baseline pumping period is the 5-year period from January 1, 2010 through December 31, 2014. This was to consider water use that was being used prior to SGMA taking effect on January 1, 2015 (California Water Code 10720.5(a)).

The County of San Diego (County) sent letters via U.S. Mail to each non-de minimis pumper in January 2018, July 2018, and January 2019 with a request to provide the Groundwater Sustainability Agency (GSA) any historical groundwater production data or other information to help the GSA develop the baseline pumping allocation. Any data provided by pumpers was agreed to be kept confidential by the GSA to the maximum extent allowed by law including but not limited to Government Code 6254. Identified non-de minimis pumpers included one municipal pumper (Borrego Water District), 30 agricultural pumpers, 6 golf courses, and 4 other pumpers (Anza-Borrego Desert State Park, Borrego Air Ranch Water Company, Borrego Springs Elementary School, and La Casa Del Zoro Resort and Spa [Figure F-1]. In cases where the GSA could validate submitted historical groundwater data, the GSA used the data to develop the baseline pumping allocation.

After the GSA reviewed data submitted from pumpers, baseline pumping allocations utilizing validated historical production data were determined for Borrego Water District, Anza-Borrego Desert State Park (Palm Canyon), and one agricultural pumper. The GSA further determined for the Borrego Air Ranch Water Company (provides water to individual residences) that the baseline pumping allocation would be estimated based on a demand of 0.5 acre-feet per year for each residential unit. For all other pumpers, the GSA developed a water-use estimate approach (Evapotranspiration Method) discussed below. The County sent letters via U.S. Mail to each non-de minimis pumper in March 2019 to provide individual baseline pumping allocations. The baseline pumping allocations are summarized by beneficial use categories in GSP Chapter 2, Table 2.1-7.

EVAPOTRANSPIRATION METHOD

This approach includes the use of available aerial imagery to determine irrigated areas on each parcel, which is multiplied by a water use factor for each crop type. The following outlines the methodology for measuring total irrigated area and calculating the water use factor.

Area Irrigated: The area of irrigation was determined using ArcGIS (GIS), a computer based mapping and data analysis software. A 1:2,000 scale was used to create polygons of irrigated area over available aerial imagery from the National Agriculture Imagery Program (NAIP). Available years of aerial imagery included 2010, 2012, and 2014. The total area of each polygon was calculated using coordinate system NAD 1983, State Plane California VI, feet. One exception to this approach was for Rams Hill Golf Course. It was not in full production during the baseline period of 2010 through 2014 due to closure of the golf course that occurred in 2010. It was in full production prior to 2010 and again after 2014. Aerial imagery from 2017 was selected to capture full golf course irrigation.

Water Use Factor: The water use factor estimates the total applied groundwater lost through the evaporation from soil and transpiration from plants (evapotranspiration). These factors are specific to each vegetation type. Turf, ponds, palms, citrus, nursery, and potatoes were identified and considered for all sectors. Table F-1 provides the water use factors for each irrigation use type.

Table F-1
Water Use Factors

Use Type	Water Use Factor (Feet per Year)
Citrus	6.29
Date Palms[a]	7.74
Landscape (Decorative)	3.63
Landscape (Native)	2.76
Nursery	4.84
Palms (Ornamental)	4.03
Ponds[b]	5.75
Potatoes[c]	2.50
Turf	6.45

Source: Water Use Classification Landscape Species IV (WUCOLS IV), DWR 2018, Borrego Water District and County of San Diego 2013.
Notes:
[a] Includes additional water required for a 30% cover crop (turf) that is irrigated in the understory of the date palms.
[b] Applied to golf courses only. Surface water evaporation based on pan evaporation data from the Imperial Valley (Salton Sea Salinity Control Research Project U.S. Department of Interior 2004).
[c] Approximately 2.5 acre-feet per acre are applied to potato fields per information obtained from the potato farmer in the Subbasin.

The water use factor is calculated using local station specific evapotranspiration (ETo), documented plant factors, and irrigation efficiency by irrigation type (Equation A). The water use factor for citrus and date palms also includes a factor for leaching (Equation B).

The equations below present the calculations used to determine the water use factor.

Equation A

$$Annual\ Water\ Use\ Factor = \frac{ETo * PF * 1\ Acre}{IE}$$

Equation B

$$Annual\ Water\ Use\ Factor = \left(\frac{ETo * PF * 1\ Acre}{IE} * CLF\right) + \left(\frac{ETo * PF * 1\ Acre}{IE}\right)$$

Where:

ETo = Reference Evapotranspiration (feet/year)
PF = Plant Factor
IE = Irrigation Efficiency
CLF = Citrus and Date Palms Leaching Factor

The following section describes the factors, which contribute to calculating the water use factors.

Reference Evapotranspiration: Reference evapotranspiration (ETo) is based on potential evapotranspiration (ET) from turf grass/alfalfa crop, which assumes a continuous source of moisture and does not consider summer plant dormancy. Therefore, ETo is an overestimation of actual ET, which varies with the vegetation type since some plants consume significantly more water than others. The ETo was determined from the California Irrigation Management Information System (CIMIS) station #207 located in Borrego Springs (DWR 2018). ETo was selected as 6.45 feet from 2010, which was the highest year during the 2010-2014 baseline period.

Table F-2
2010-2014 Reference Evapotranspiration (ETo) for Borrego Springs

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Total (Inches)	Annual Total (Feet)
2010	2.41	3.21	8.81	9.84	8.58	9.22	9.51	9.11	7.44	4.36	2.88	1.98	77.35	**6.45**
2011	2.68	3.35	5.55	7.12	8.77	8.23	7.98	8.47	6.43	4.92	2.72	2.11	68.33	5.69
2012	2.85	3.56	5.33	6.77	7.66	9.47	8.77	8.04	7.09	5.04	3.2	2.23	70.01	5.83
2013	2.54	3.57	5.75	7.56	8.64	9.02	8.01	7.57	6.46	5.05	3	2.27	69.44	5.79
2014	2.67	3.66	5.94	7.23	8.66	9.13	8.83	8	6.97	4.55	3.14	1.58	70.36	5.86

Source: Borrego Springs CIMIS Station #207 (DWR 2018).

Plant Factor: The plant factor is the percentage of evapotranspiration needed to maintain acceptable health, appearance, and growth of a specific plant type. Plant factors were obtained from the Water Use Classification of Landscape Species (WUCOLS) database. Additionally, the County has relied on documented plant factors used for assigning water credits, which are outlined in the Memorandum of Agreement between the Borrego Water District and the County of San Diego Regarding Water Credits (MOA). The plant factor used in this report either was based on an average of recent WUCOLS data or documented County plant factors, whichever was higher. For Date Palms, the highest plant factor range was selected.

Table F-3
Plant Factors

Type	Plant Factor (MOA)	Plant Factor Range (WUCOLS VI)	Proposed Plant Factor Used
Citrus	0.65[a]	0.4 - 0.6	0.65
Date Palms	N/A	0.4 – 0.6	0.6
Landscape (Decorative)	N/A	0.30 – 0.6	0.45
Landscape (Native)	N/A	>0.1 – 0.6	0.3
Nursery	0.6	0.4 - 0.6	0.6
Palms (Ornamental)	0.5	0.4 – 0.6	0.5
Potatoes	N/A	N/A[b]	N/A
Turf	0.63[c]	0.6 – 0.8	0.7

Source: BWD and County 2013, WUCOLS 2014, UCCE CDWR 2000

N/A = not available

[a] Source: UC Cooperative Extension and Department of Water Resources, A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California, 2000

[b] There is no plant factor for potatoes in WUCOLS VI. Approximately 2.5 acre-feet per acre are applied to potato fields per information obtained from the potato farmer in the Subbasin.

[c] An average of warm and cool season.

Irrigation Efficiency: Irrigation efficiency is the amount of water supplied to a plant type compared to the amount consumed. Two common irrigation methods in the Subbasin are rotor and drip. The irrigation efficiency was determined from the Turf and Landscape Irrigation Best Management Practices prepared by the Water Management Committee of the Irrigation Association (Water Management Committee of the Irrigation Association 2004). Table 4 presents the irrigation efficiencies used by irrigation method.

Table F-4
Irrigation Efficiency

Irrigation Method	Irrigation Efficiency
Rotor[a]	0.7
Drip[b]	0.8

Source: BWD and County 2013, Water Management Committee of the Irrigation Association 2004.

[a] Rotor used for turf and decorative landscaping

[b] Drip used for citrus, nursery, palms, and native landscaping

Salt Leaching: Leaching for salts is the overwatering of an area to flush excessive salts below the root zone. Leaching typically occurs in arid environments with high evapotranspiration rates. Because leaching is necessary for the health of citrus and date palms in the Subbasin, a leaching requirement of 20% of the water use factor is assumed based on optimal crop yield and source water with total dissolved solids (TDS) concentration of less than 1,000 mg/L.[1] The leaching requirement is provided in Equation C (Rhoades 1974; and Rhoades and Merrill 1976):

Equation C

$$LR = ECw/\ 5(ECe) - ECw$$

where:

LR = the minimum leaching requirement needed to control salts within the tolerance (ECe) of the crop with ordinary surface methods of irrigation
ECw = salinity of the applied irrigation water in deciSiemens per meter[2] (dS/m)
ECe = average soil salinity tolerated by the crop as measured on a soil saturation extract.

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[1] A 20% leaching requirement for citrus and date palms is assumed taking into account typical Subbasin water quality (i.e. <1,000 mg/L TDS and average soil salinity tolerated by grapefruit of 1.8 dS/m for optimal yield (Ayers and Westcot 1985).

[2] Soil and water salinity is often measured by electrical conductivity (EC). A commonly used EC unit is deciSiemens per metre (dS/m). The ratio of total dissolved solids (TDS) to EC of various salt solutions ranges from 550 to 700 ppm per dS/m, depending on the compositions of the solutes in the water. Simple relationships are used to convert EC to TDS, or vice Versa:
TDS (mg/L or ppm) = EC (dS/m) x 640 (EC from 0.1 to 5 dS/m)
TDS (mg/L or ppm) = EC (dS/m) x 800 (EC > 5 dS/m)
Source University of California Salinity management: http://ucanr.edu/sites/Salinity/Salinity_Management/Salinity_Basics/Salinity_measurement_and_unit_conversions/

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APPENDIX G

GSP Comments and Responses