Indian Wells Valley Groundwater Basin

Salt and Nutrient Management Plan

Prepared by:

RMC water and environment

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PARKER GROUNDWATER, INC.

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List of Abbreviations

AF	Acre-feet
AFY	Acre-feet per year
Basin	Indian Wells Valley groundwater basin
Basin Plan	Lahontan Region Basin Plan
BMPs	Best Management Practices
BPOs	Basin Plan Objectives
CDPH	California Department of Public Health
CSD	Inyokern Community Services District
DWR	Department of Water Resources
ET	Evapotranspiration
ETo	Reference Evapotranspiration
GAMA	Groundwater Ambient Monitoring and Assessment Program
GIS	Geographic Information System
gpd	Gallons per day
GSA	Groundwater Sustainability Agency
GSP	Groundwater Sustainability Plan
IWV Coop Group	Indian Wells Valley Cooperative Groundwater Management Group
IWVGA	Indian Wells Valley Groundwater Agency
IWVWD	Indian Wells Valley Water District
MCL	Maximum Contaminant Level
MG	Million gallons
mg/L	Milligrams per liter
MGD	Million gallons per day
NAWS	China Lake Naval Air Weapons Station
NL	Notification Level
ppb	Parts per billion
ppm	Parts per million
PBP	GAMA Program's Priority Basin Project
SGMA	Sustainable Groundwater Management Act
SMCL	Secondary Maximum Contaminant Level
SNMP	Salt and Nutrient Management Plan
SVM	Searles Valley Minerals
SWRCB	State Water Resources Control Board
TAC	Technical Advisory Committee
TDS	Total Dissolved Solids
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
UWMP	Urban Water Management Plan

1 Background

In February 2009, the State Water Resources Control Board (SWRCB) adopted Resolution No. 2009-0011, which established a statewide Recycled Water Policy. The policy encourages increased use of recycled water and local stormwater capture. It also requires local water and wastewater entities, together with local salt and nutrient contributing stakeholders to develop a Salt and Nutrient Management Plan (SNMP) for each groundwater basin or subbasin in California. The Indian Wells Valley SNMP was developed through a collaborative process starting in 2016.

This SNMP was prepared for the Indian Wells Valley Groundwater Subbasin (Basin) in Inyo, Kern, and San Bernardino Counties, California. The community overlying the Basin includes urban areas as well as a significant amount of rural and agricultural land. Groundwater is the sole source of drinking water to the area. Recycled water is currently used for golf course and agricultural irrigation and there are plans for assessing expanded use of recycled water to augment or offset existing water supplies, both through the development of plans for a new wastewater treatment plant and the Groundwater Sustainability Plan (GSP) preparation process. As the primary local distributor of recycled water, the City of Ridgecrest, is leading the development of this SNMP with the support of the Indian Wells Valley Water District (IWVWD). This SNMP was developed as a high-level planning document to be responsive to the Recycled Water Policy, however since establishment of the Policy, groundwater management in the basin has evolved under the Sustainable Groundwater Management Act (SGMA) and basin characterization, monitoring and management is being extensively studied under leadership of the Groundwater Sustainability Agency (GSA). Therefore the SNMP took a high-level approach which will inform the monitoring and implementation elements being developed through the GSP.

1.1 Process to Develop this Salt and Nutrient Management Plan

This SNMP was initially drafted by the Navy in cooperation with the Technical Advisory Committee (TAC) of the Indian Wells Valley Cooperative Groundwater Management Group (IWV Coop Group) and a preliminary version was reviewed by the Regional Water Quality Control Board (RWQCB) in 2016. The preliminary review indicated the SNMP was deficient in technical analysis and several required sections of the Recycled Water Policy were not yet incorporated. A salt and nutrient loading analysis and mixing model was developed in 2016 and 2017 to provide the technical basis of the plan. The technical analysis included key stakeholder input to refine the analysis. Following the technical analysis, the preliminary SNMP has been updated to be responsive to requirements in the Recycled Water Policy. The TAC of the Indian Wells Valley Groundwater Agency (IWVGA) reviewed and provided input on the Draft SNMP in December 2017.

1.2 Plan Purpose and Objectives

The purpose of this SNMP is to:

1. Promote reliance on local sustainable water sources such as recycled water and stormwater
2. Manage salts and nutrients from all sources on a sustainable basis to ensure attainment of water quality objectives and protection of beneficial uses

Key objectives of the SNMP are:

1. Better understand the trend and linkages between increasing salinity in the basin, groundwater overdrafting and natural processes.
2. Slow and, if possible, stabilize the trend of increasing salinity in the basin.

1.3 Regulatory Framework

The SWRCB adopted a Recycling Water Policy in 2009 that requires the development of an SNMP to manage salts, nutrients, and other significant chemical compounds in every groundwater basin or sub-basin in the State. The SNMPs are intended to help streamline permitting of new recycled water projects while ensuring attainment of water quality objectives and protection of beneficial uses.

1.3.1 Basin Plan Beneficial Uses and Water Quality Objectives

Designated beneficial uses of groundwater are provided in the Water Quality Control Plan for the Lahontan Region Basin Plan (Basin Plan), updated February 2016:

- Agricultural Supply - Beneficial uses of waters used for farming, horticulture, or ranching, including, but not limited to, irrigation, stock watering, and support of vegetation for range grazing.
- Freshwater replenishment - Beneficial uses of waters used for natural or artificial maintenance of surface water quantity or quality (e.g., salinity).
- Industrial Service Supply - Beneficial uses of waters used for industrial activities that do not depend primarily on water quality including, but not limited to, mining, cooling water supply, geothermal energy production, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.
- Municipal and Domestic Supply - Beneficial uses of waters used for community, military, or individual water supply systems including, but not limited to, drinking water supply. The MUN designation does not apply to the groundwater within the shallow groundwater (above the top of the low-permeability lacustrine clay sediments) in the eastern Indian Wells Valley groundwater basin.

These designated beneficial uses are the basis for the designation of Water Quality Objectives within the Basin Plan, as follows:

Bacteria, Coliform - In ground waters designated as MUN, the median concentration of coliform organisms over any seven-day period shall be less than 1.1/100 milliliters.

Chemical Constituents - Ground waters designated as MUN shall not contain concentrations of chemical constituents in excess of the maximum contaminant level (MCL) or secondary maximum contaminant level (SMCL) based upon drinking water standards specified in the following provisions of Title 22 of the California Code of Regulations, which are incorporated by reference into the Basin Plan: Table 64431-A of Section 64431 (Inorganic Chemicals), Table 64431-B of Section 64431 (Fluoride), Table 64444-A of Section 64444 (Organic Chemicals), Table 64449-A of Section 64449 (Secondary Maximum Contaminant Levels-Consumer Acceptance Limits), and Table 64449-B of Section 64449 Secondary Maximum Contaminant Levels-Ranges). This incorporation-by-reference is prospective including future changes to the incorporated provisions as the changes take effect. Waters designated as AGR shall not contain concentrations of chemical constituents in amounts that adversely affect the water for beneficial uses (i.e., agricultural purposes). Ground waters shall not contain concentrations of chemical constituents that adversely affect the water for beneficial uses.

Radioactivity - Ground waters designated as MUN shall not contain concentrations of radionuclides in excess of the limits specified in Table 4 of Section 64443 (Radioactivity) of Title 22 of the California Code of Regulations, which is incorporated by reference into this plan. This incorporation-by-reference is prospective including future changes to the incorporated provisions as the changes take effect.

Taste and Odor - Ground waters shall not contain taste or odor-producing substances in concentrations that cause nuisance or that adversely affect beneficial uses. For ground waters designated as MUN, at a minimum, concentrations shall not exceed adopted secondary maximum contaminant levels specified in Table 64449-A of Section 64449 (Secondary Maximum Contaminant Levels-Consumer Acceptance Limits), and Table 64449-B of Section 64449 (Secondary Maximum Contaminant Levels-Ranges) of

Title 22 of the California Code of Regulations, which is incorporated by reference into this plan. This incorporation-by-reference is prospective including future changes to the incorporated provisions as the changes take effect.

In 2014, the Water Quality Control Plan for the Lahontan Region (Basin Plan) was amended to remove the Municipal and Domestic Supply (MUN) beneficial use designation from groundwater located within the NAWS China Lake. The groundwater proposed for de-designation is located beneath Salt Wells Valley and within the shallow groundwater in the eastern IWV groundwater basin (both areas are within NAWS China Lake). Water Board staff concluded that the MUN use is not an existing use of the affected groundwater and cannot feasibly be attained through permit conditions or treatment. Due to naturally-occuring high concentration of constituents such as arsenic and TDS, removal of the MUN beneficial use designation was justified and approved on November 26, 2014.

1.3.2 Sustainable Groundwater Management Act

Signed by Governor Brown on September 16, 2014, the Sustainable Groundwater Management Act (SGMA) creates a framework for sustainable groundwater management over a long-term horizon by empowering local agencies to tailor plans to their regional economic and environmental needs. SGMA requires locals to form a Groundwater Sustainability Agency (GSA) and to create a Groundwater Sustainability Plan (GSP). For medium and high priority basins (including the Indian Wells Valley Groundwater Basin) GSAs must be formed by June 30, 2017 and have a GSP in place by January 31, 2020 (IWVWD UWMP, 2016).

In accordance with SGMA, DWR developed the California Statewide Groundwater Elevation Monitoring (CASGEM) program to track seasonal and long-term trends in groundwater elevations in California's groundwater basins. Through its CASGEM program, DWR ranked the priority of each groundwater basin in California as either very low, low, medium, or high. The Indian Wells Valley Groundwater Basin has been designated as Medium priority.

In addition, DWR, as required by SGMA, identified the basins and subbasins that are in conditions of critical overdraft. Twenty-one basins and subbasins, including the Indian Wells Valley Groundwater Basin, were identified as critically-overdrafted basins.

This SNMP will help inform the development of the Indian Wells Valley GSP, which will include comprehensive monitoring and implementation strategies.

1.4 Stakeholder Roles and Responsibilities

The Indian Wells Valley groundwater basin includes a number of water agencies and other stakeholders with groundwater management interests. These stakeholders have a long history of collaboration. This plan was developed with input from stakeholders as described below.

1.4.1 Indian Wells Valley Cooperative Management Group

Formed in 1995, the IWV Coop Group is a public water data-sharing group consisting of the major water producers, other government agencies, and concerned citizens in the Basin to coordinate management efforts, share data, and avoid the redundancy of effort. The IWV Coop Group has had open public meeting monthly since forming and has been updated on the scope and progress on this SNMP.

The IWV Coop Group early on formed a TAC consisting of specialists from several agencies that continually review and monitor ongoing management efforts, current state and federal groundwater legislation, and the most recent scientific studies to better understand our local water resources. The TAC has been responsible for an extensive, valley-wide well monitoring program and water recharge study, monitoring over 100 wells bi-annually. Numerous studies have also been conducted using data collected from weather and stream gages placed by the TAC strategically throughout the Basin.

In 2006, stakeholders in the Basin developed the Indian Wells Valley Cooperative Groundwater Management Plan. Signatories to the plan included:

- Indian Wells Valley Water District (IWVWD),
- China Lake Naval Air Weapons Station (NAWS),
- North American Chemical Company (now Searles Valley Minerals),
- City of Ridgecrest,
- Bureau of Land Management,
- Inyokern Community Services District (CSD),
- Eastern Kern County Resource Conservation District,
- Indian Wells Valley Airport District,
- Kern County,
- and Kern County Water Agency.

The IWV Coop Group TAC was initially consulted on the SNMP scope. Progress updates were provided and the TAC was asked for input on the SNMP. The IWV Coop Group TAC has since disbanded, deferring technical input from the new TAC this is part of the new Groundwater Sustainability Agency, Indian Wells Valley Groundwater Authority (IWVGA), formed in 2016.

1.4.2 Indian Wells Valley Groundwater Authority

Following passage of the SGMA, staff from local GSA-eligible agencies cooperated to develop a proposed governance structure for the Indian Well Valley Groundwater Sustainability Agency (Indian Wells Valley Groundwater Authority - IWVGA). These agencies consisted of the Indian Wells Valley Water District, City of Ridgecrest, Kern County, Inyo County, and San Bernardino County. Additionally, the US Navy and Bureau of Land Management joined the new GSA as non-voting members. In forming the IWVGA, the GSA-eligible local agencies proactively engaged over a one-and-one-half-year period in the challenging process of collaboratively negotiating the formation of a single GSA to cover the entire Indian Wells Valley groundwater basin.

The GSA was formed through a Joint Exercise of Powers Agreement (JPA) entered into by the Indian Wells Valley Water District, City of Ridgecrest, Kern County, Inyo County, San Bernardino County, US Navy and Bureau of Land Management. The IWVGA held its public meeting to consider formation of the IWVGA as the sole GSA for the Indian Wells Valley groundwater basin on December 8, 2016, followed by filing a Groundwater Sustainability Agency Formation Notification with DWR in late December 2016, and DWR posted the GSA notice on the SGMA website on January 4, 2017.

The GSA Board formed a Policy Advisory Committee (PAC) comprised of 12 voting and 3 non-voting members appointed by the GSA Board:

2 representatives from Large Agriculture
1 representative from Small Agriculture
2 representatives from Business Interests
2 representatives from Domestic Well Owners
2 representatives from residential customers of a public agency water supplier
1 representative from Eastern Kern County Resource Conservation District
1 representative from Wholesaler and Industrial User
1 representative from the Inyokern Community Services District
1 representative from the Indian Wells Valley Water District*
1 representative from the Department of the Navy*
1 representative from the Bureau of Land Management*
** Non-Voting Member*

The GSA Board has formed a Technical Advisory Committee (TAC) comprised of 11 voting and 3 non-voting members appointed by the GSA Board:
2 representatives from Large Agriculture
1 representative from Small Agriculture
2 representatives from Business Interests
2 representatives from Domestic Well Owners
2 representatives from residential customers of a public agency water supplier
1 representative from Eastern Kern County Resource Conservation District
1 representative from Wholesaler and Industrial User
1 representative from the Indian Wells Valley Water District*
1 representative from the Department of the Navy*
1 representative from the Bureau of Land Management*
** Non-Voting Member*

The GSA Board receives updates on SNMP development progress and considers recommendations from the PAC and TAC at its monthly public meetings and provides input on key components of the SNMP. The PAC and TAC meet monthly and have received updates and been provided the opportunity for input on the SNMP.

A list of the Basin's stakeholders, as well as their respective roles and responsibilities is outlined in **Table 1-1**.

Table 1-1: Indian Wells Valley Groundwater Stakeholder Roles and Responsibilities

IWV Groundwater Stakeholder Roles and Responsibilities	
Stakeholders	**Roles and Responsibilities**
Indian Wells Valley Water District (IWVWD)	Operates a State Water Resources Control Board (SWRCB)-approved water system and is the primary domestic/commercial water purveyor in the Basin. Operates 10 wells with 17 million gallons (MG) of storage and two arsenic treatment plants (coagulation/filtration).
Searles Valley Minerals	Operates five groundwater production wells in the Basin for domestic and industrial uses in Trona. Arsenic treatment is provided through coagulation/filtration treatment.
Naval Air Weapons Station-China Lake (China Lake NAWS)	Operates a SWRCB-approved water system to support domestic/commercial/industrial water to support the Navy facilities at China Lake. Water system includes 8 groundwater production wells with 15 MG of storage. Arsenic treatment is provided through blending of selected wells.
Kern County Water Agency	Provides groundwater monitoring and management expertise for the Basin
City of Ridgecrest	Domestic and commercial water is delivered to the City by the IWV Water District. City of Ridgecrest owns and operates four groundwater wells to support several City/County parks and associated ball field areas. City owns and operates a Waste Water Treatment Facility capable of 3.2 million gallons per day (MGD) inflow with secondary treatment and a series of 240 acres of facultative/evaporation/percolation ponds.
Bureau of Land Management	Authority for the management of all federal lands in and adjacent to the Basin
County of Kern	Provides planning expertise and environmental regulatory oversight for the Basin
Eastern Kern County Resource Conservation District	Non-Profit organization established to address the needs of the private land owner through resource conservation and management practices.
Inyokern Community Services District (CSD)	Operates a SWRCB-approved water system. Owns and operates two groundwater production wells and a Waste Water Treatment Facility that serves the town of Inyokern, located about 10 miles west of Ridgecrest.
Indian Wells Valley Airport District	Operates the County airport in the town of Inyokern.
Local pistachios orchards/alfalfa farms	Approximately 3,000 acres of pistachios and 1150 acres of alfalfa is produced within the Basin. Most agriculture operations are located in the northwestern portion of the Basin.
Private Domestic Wells Owners /Rural Cooperatives	An estimated 800 private groundwater production wells are located throughout the Basin to support private land owner water needs.

1.5 Plan Limitations

Limitations and uncertainties associated with the development of this SNMP are due to data restrictions and the evolving groundwater management structure within the Basin. Specifically, the passage of SGMA has led to the formation of the IWVGA which will be developing a comprehensive GSP that includes extensive monitoring and management actions. Key limitations/uncertainties of this SNMP are described briefly below.

Data for the analysis plan comes from the preliminary SNMP, which was developed in 2016 by the Navy in cooperation with the TAC of the IWV Coop Group. A more extensive data compilation was not completed because effort is underway on the GSP, therefore the SNMP took a streamlined approach with the intent of being incorporated in the more comprehensive GSP analysis and structure. For background water quality, the SNMP utilized existing data from the preliminary SNMP rather than complete an extensive data complication exercise that is underway in a parallel process for the GSP. The data set from the Navy included 41 wells, 35 of which had spatial location information. One of the wells was a strong outlier for water quality and was dropped, so a dataset of 34 wells was used with data from 1982-2015 for water quality conditions.

The mixing model to predict future conditions is limited in scope because it simulates the Basin as one aquifer and assumes mixing is instantaneous, which is an appropriate planning assumption for the scale of a high-level planning document such as this SNMP. Additionally, verification of assumptions/estimates for individual anthropogenic loading sources during the calibration process was limited. Data collected as part of the SNMP Groundwater Monitoring Program will help in determining if trends predicted by the SNMP are verified.

Information used to derive future conditions was obtained from planning documents such as the Indian Wells Valley Water District 2015 Urban Water Management Plan (UWMP); however, this information is projected on a 20-year planning horizon and can change. For example, recycled water expansion is planned to serve additional irrigation customers in the City of Ridgecrest, but exact sites and demands may shift as projects are implemented in the future and conservation is not accounted for.

1.6 Findings and Conclusions

This SNMP was conducted using a simplified, streamlined analysis which is an appropriate level of detail for this planning document in recognition that a more comprehensive effort is currently underway as part of the development of the GSP. Key findings, conclusions, and recommendations of the SNMP are summarized below.

1.6.1 Current Basin Groundwater Quality

Groundwater quality varies significantly within the Basin. The quality is generally good along the margins and southern portion, and more degraded in the central and eastern portions of the Basin. In its report *Indian Wells Valley Groundwater Project* (1993), the United States Department of the Interior Bureau of Reclamation (USBR) found that the southwest area of the Basin contains a significant quantity of high-quality groundwater. In contrast, groundwater in the northwest area was found to be of the poorest quality and has historically been used primarily for agricultural purposes.

From the existing dataset of 41 wells compiled by the Navy in 2016, salinity concentrations over time are relatively stable with a few localized hotspots. Aside from hotspot areas, average salinity across the Basin is 310 mg/L TDS. Nitrate concentrations for most wells in the dataset are decreasing, and average nitrate-N across the basin is 0.70 mg/L.

1.6.2 Loading and Assimilative Capacity

Loading model results indicated the highest TDS loading was found within the agricultural and urban residential land use groups. The highest nitrate loading was found within the agricultural land use groups and septic system point loads. The analysis shows there is assimilative capacity in the Basin for both TDS and nitrate relative to basin water quality objectives (500 mg/L and 10 mg/L respectively), however concentrations are projected to increase over time by the mixing model developed for this analysis.

1.6.3 Recycled Water Use and Antidegradation

The Recycled Water Policy and other state-wide planning documents recognize the tremendous need for and benefits of increased recycled water use in California. There are no existing Title 22 recycled water projects in the Basin, however there are reclaimed wastewater projects which include irrigation (golf course and agricultural) and percolation for environmental enhancement. Even with their projected increase through the end of the future planning period in 2040, minimal negative impacts to water quality are associated with reclaimed wastewater use; reclaimed wastewater irrigation contributes very minor salt and nutrient loading and reclaimed wastewater projects do not use more that 10% of the available assimilative capacity.

The SNMP analysis finds that reclaimed wastewater use can be used to augment or offset existing and future water supplies while still protecting and improving groundwater quality for beneficial uses.

1.6.4 Future Water Quality Trends

Communities overlying the Basin include urban areas as well as a significant amount of rural and agricultural land, and are reliant on groundwater is their sole source of drinking water. Significant drawdown in the regional aquifer is occurring at a rate of 1 to 1.5 feet per year (particularly in the eastern and east-central portion of the Basin) has caused the Basin to be designated as critically overdrafted by the California Department of Water Resources (DWR). As such, effective use of reclaimed wastewater and management of associated salts and nutrients is important for the long-term sustainability of basin groundwater resources.

Utilizing a spreadsheet-based mass balance model, loading results are projected to increase over 25 years (starting in 2015) from 310 mg/L to 446 mg/L for TDS and from 0.70 mg/L to 1.05 mg/L for nitrate as nitrogen with existing reclaimed water usage, or increase to 452 mg/L for TDS and stays at 1.05 mg/L for nitrate as nitrogen accounting for increased reclaimed wastewater usage up to 4,600 AFY from 3,115 AFY in 2015. Although the simplified SNMP analysis models a trend of slowly increasing salinity and nutrients in the basin, this increasing trend is not seen as a strong trend in the historical dataset utilized for this analysis. This indicates the modeling approach is conservative and management measures in place are effective at mitigating accumulation in the Basin. Additionally, a new brackish groundwater study which would export salt from the basin is underway and would further support stabilization of any future increases.

1.6.5 Implementation Measures Underway

Several programs which help manage groundwater supplies and quality are already underway in the Basin. These programs fall under five categories:

- Agricultural
- Reclaimed Wastewater Irrigation
- Groundwater Management
- Onsite Wastewater Treatment System Management
- Municipal Wastewater Management

In addition, stormwater recharge is being evaluated in an ongoing parallel effort as part of the integrated regional water management planning effort.

1.6.6 Conclusions and Recommendations

A source loading and groundwater quality trend analysis was completed at a planning level scale to support the technical analysis for development of the SNMP. Salt and nutrient loading to the Basin are due to various surface activities associated with rural and agricultural areas, including:

- Irrigation water (privately produced groundwater, municipal water supplies, and reclaimed wastewater)
- Agricultural inputs (fertilizer)
- Urban inputs (septic systems, wastewater treatment plants, fertilizer, and applied water)

Salt and nutrient estimated loads were determined using a GIS-based model that incorporated land use, irrigation water (sources and associated quality and loading), septic inputs, and wastewater discharge loads. Water sources for loading included water from the City of Ridgecrest, private groundwater use and reclaimed wastewater. Irrigation loading was calculated for three crop types in the Basin (alfalfa, pistachios, and turfgrass), and adjusted based on stakeholder comments following an August 18, 2016 meeting sharing preliminary results with the Cooperative Groundwater Stakeholder Group.

Loading model results indicated the highest TDS loading was found within the agricultural and urban residential land use groups. The highest nitrate loading was found within the agricultural land use groups and septic system point loads.

Results of the loading analysis were then used to estimate water quality concentrations and simulate regional water quality trends within the Basin over a 25-year planning horizon. Utilizing a spreadsheet-based mass balance model, loading results are projected to increase over 25 years from 310 mg/L to 446 mg/L for TDS and from 0.70 mg/L to 1.05 mg/L for nitrate as nitrogen. The analysis shows there is assimilative capacity in the basin for both TDS and nitrate relative to basin water quality objectives (500 mg/L and 10 mg/L respectively), however loading increases over time. The analysis did not account for localized salinity issues which exist in portions of the Basin.

Given current Basin conditions and the comprehensive GSP process underway, no new implementation measures or Best Management Practices (BMPs) are recommended as part of the SNMP process. The SNMP recommends the following to help meet the SNMP objectives of better understanding salinity and nutrients in the basin and stabilizing salinity in the Basin:

1. Conduct salinity monitoring, both through the monitoring outlined in this plan (to be incorporated into the GSP) and through additional characterization and monitoring as part of the Brackish Groundwater Resources Feasibility Study, which includes aerial electromagnetic survey of the Basin, revised hydrogeologic conceptual model, drilling of additional monitoring wells, water quality sampling and analysis, pilot brackish water extraction well and modeling. Development of the GSP will also include additional basin characterization activities including installation of additional weather and stream gaging stations and groundwater monitoring wells.
2. Evaluate implementation of the Brackish Groundwater Resources Project, which will result in an export of high salinity water out of the Basin and reduce salt loading basin-wide. Implementation of the GSP is intended to stabilize the groundwater levels in the basin and water balance, which should also help stabilize increasing salinity trend.

2 Groundwater Basin Characteristics

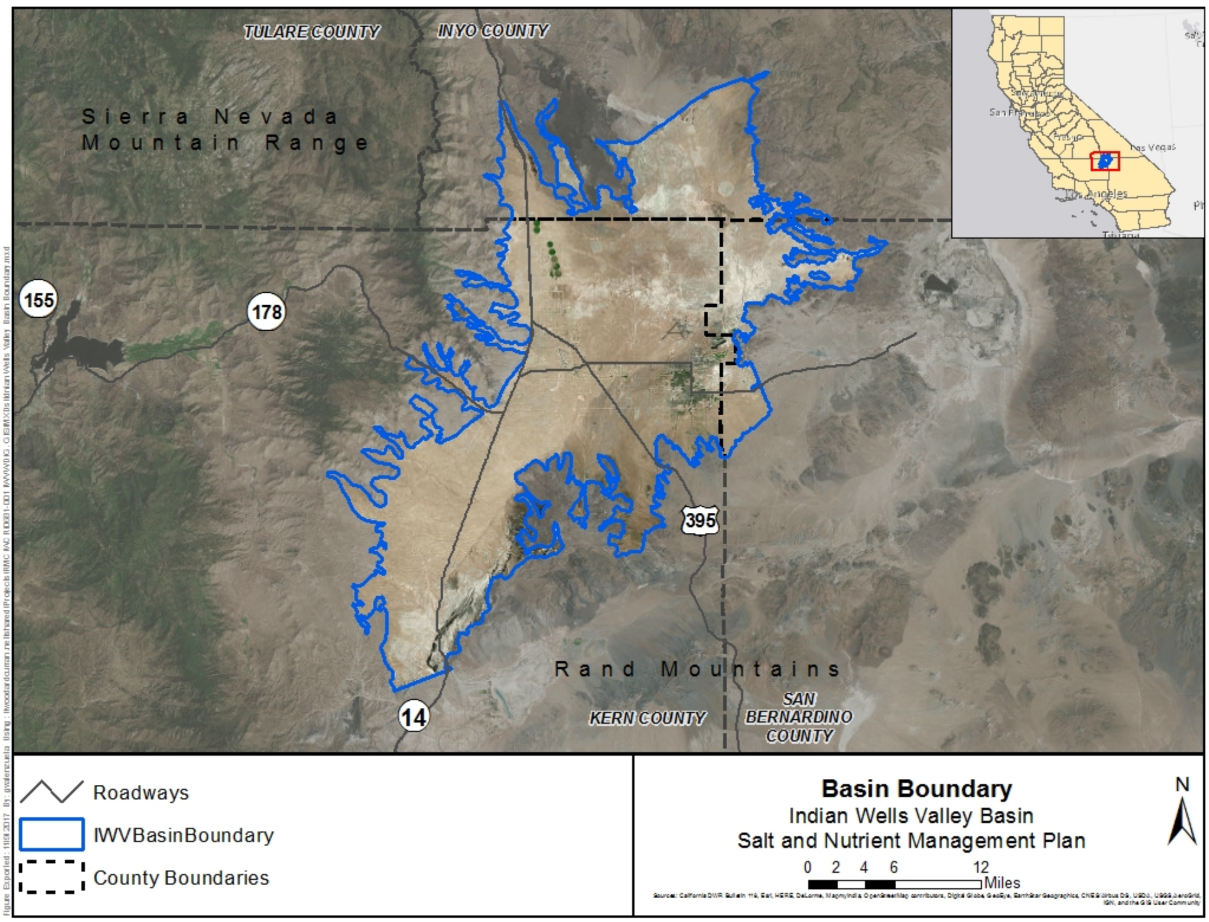
The following section provides an overview on groundwater conditions within the Basin.

2.1 Groundwater Basin Overview

Physiographic Description

The Indian Wells Valley groundwater basin is located east of the southern Sierra Nevada Range, encompassing a surface area of 382,000 acres (597 square miles) within portions of Kern, Inyo, and San Bernardino Counties (**Figure 2-1**). Average annual precipitation in the valley is 2-5 inches, although some years there is none. Surface elevation in the central Basin ranges from 2,150 to 2,400 feet above sea level.

Figure 2-1: Indian Wells Valley Groundwater Basin

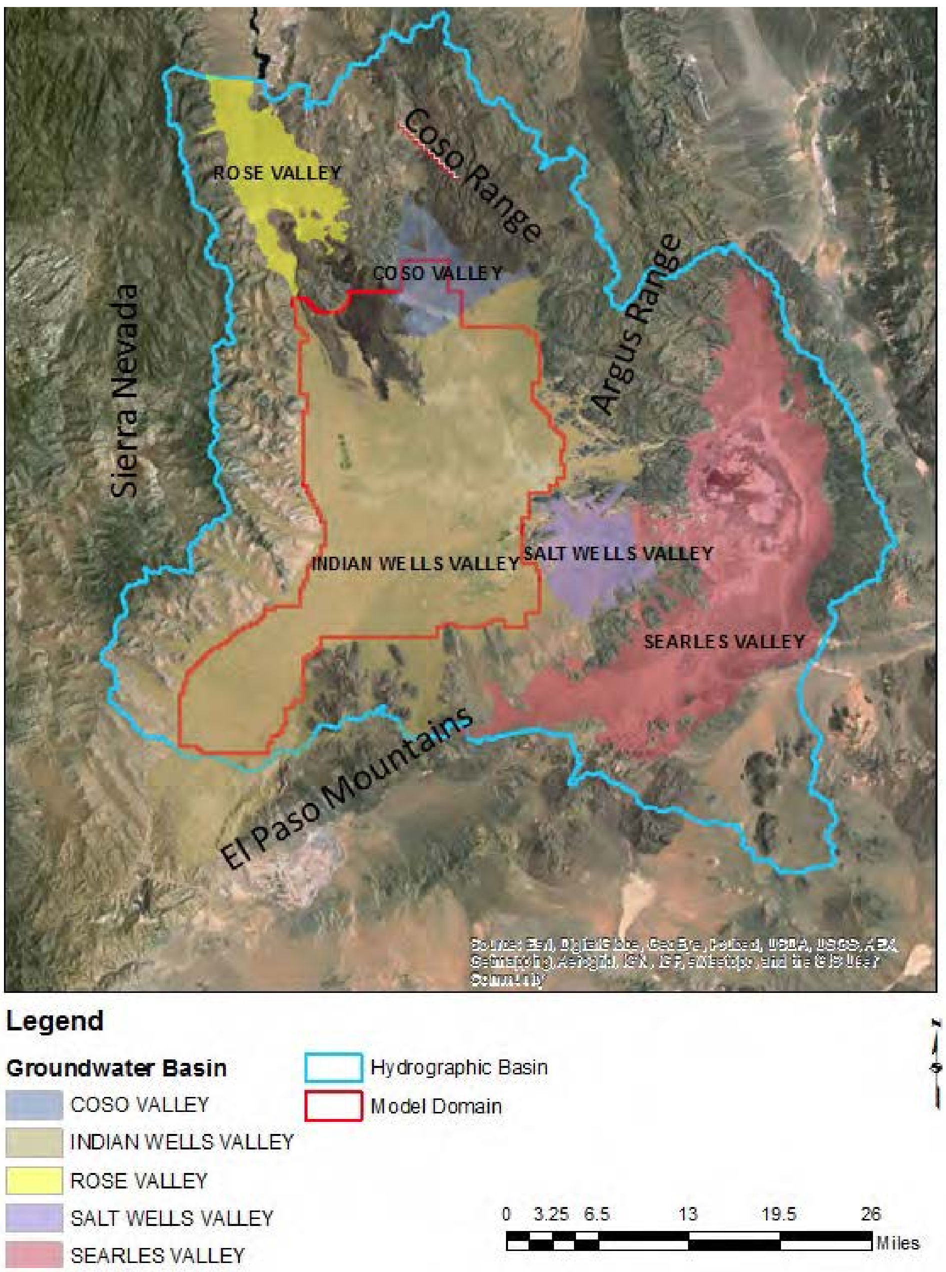


Groundwater Basin and/or Sub-Basin Boundaries

The Indian Wells Valley groundwater basin underlies approximately 600 square miles of land area and is located at the southeastern terminus of the Sierra Nevada Mountain range and western edge of the Basin and Range geologic province (**Figure 2-2**). The Basin width and length are similar, 30 km by 35 km, respectively, making it an anomalous piece of terrain for the central Basin and Range geography. It is bounded to the north by the Coso Range, to the east by the Argus Range, to the west by the Sierra Nevada, and to the south by the El Paso Mountains. These mountains all consist of granitic bedrock, with some volcanic deposits in the Coso Range. Adjacent and nearby basins include Rose Valley, Coso Valley, Salt Wells Valley, and Searles Valley.

Indian Wells Valley groundwater basin's modern surface drainage is all internal, making it a prime example of a closed basin. There are also no perennial streams feeding the valley. The surficial cover of the valley floor is from recent alluvium of either playa, lake or fluvial origin with minor sand dune deposits. Sedimentation is dominated by alluvial fans emanating from canyons of the Sierra Nevada on the west and the Argus Range on the east, and there are small deposits of older alluvial material that protrude through the recent sediments on the northern, northwestern, and eastern sides. Three small playas occupy the southeast part of the valley and are the primary surface water and groundwater discharge points.

Figure 2-2: Indian Wells Valley Model Boundary (DRI, 2016)



Watershed Boundaries

Spanning roughly 860 square miles of mountains, hills, and valley floor, the Indian Wells Valley watershed occupies part of the Mojave Desert and experiences its arid climate. This area is bounded by the Sierra Nevada on the west, the Coso Range on the north, the Argus range on the east, and the El Paso mountains on the south.

Structural Setting and Basin Geometry

The geology and structure of the Basin has been well studied using geophysics, gravity and magnetics, deep boreholes and monitoring wells (**Figure 2-3**). Indian Wells Valley is a structural graben produced by faulting, primarily along the Sierra Nevada frontal fault and Argus frontal fault. The basin structure is further complicated by the location of the Garlock left lateral strike slip fault to south, which appears to have dragged open the southwest El Paso area portion of the basin, giving it is anomalous shape. Additional major mapped faults in the basin include the Little Lake and Airport; there are numerous smaller faults making the basin geology and structure complex. The deepest area of the valley (based on drilling data) is in the west-central area with basement encountered at approximately 6,500 feet below land surface (Monastero et. al. 2002). The basement is generally tilted upward towards the east.

It is not currently known how much these faults affect groundwater flow, but previous studies suggest that in general the stratigraphy rather than faulting may more strongly influence flow in the Basin. One western-most, unnamed fault that trends diagonally along the west side of the Basin from Highway 178 displaces older sediments upward on the western side and may be a restrictive feature. The northwest-southeast trending Little Lake Fault Zone displaces local sediments and abruptly separates the shallow aquifer from the deep aquifer in the areas south of Armitage Airfield at China Lake NAWS.

Figure 2-3: Generalized Geologic Structure of the Indian Wells Valley (Monastero et. al., 2002)

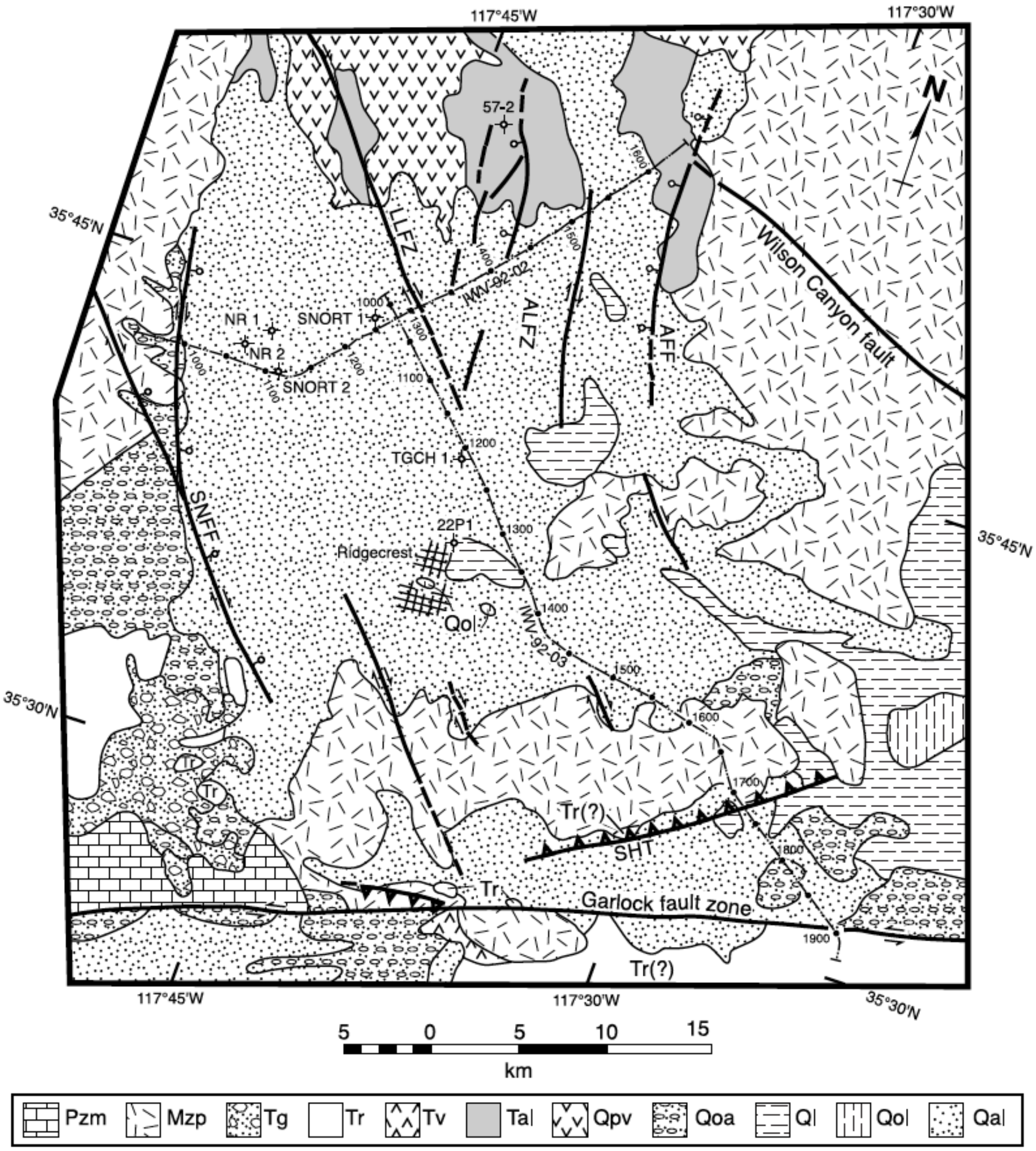


Figure 4. General geologic map of the Indian Wells Valley and surrounding areas. Heavier lines represent faults, dashed where approximate. Dash and double-dot lines are locations of seismic reflection lines discussed in the text and shown in Plates 2, 3, and 4; numbers represent every hundredth shot point. ALFZ—Airport Lake fault zone, AFF—Argus frontal fault, LLFZ—Little Lake fault zone, SHT—Spangler Hills thrust, SNFF—Sierra Nevada frontal fault. Geologic units (oldest to youngest; some are unpatterned on the map): Pzm—Paleozoic metamorphic rocks, Mzp—Mesozoic plutonic rocks (undifferentiated), Tg—Paleocene–lower Eocene Goler Formation, Tr—Ricardo Group consisting of lower Miocene Cudahy Camp Formation and middle to upper Miocene Dove Spring Formation, Tv—Miocene Lava Mountains volcanic rocks, Tal—Pliocene White Hills sequence, Qpv—Pliocene-Pleistocene volcanic rocks of the Coso Range, Qoa—older alluvium for which there are no conclusive data to permit assignment to a specific formation, Qol—older lacustrine rocks for which there are no conclusive data to permit assignment to a specific formation, Qal—Quaternary alluvium, Ql—Quaternary lacustrine deposits. Basic geology from Jenkins (1963) with some areas remapped by Monastero.

Water Sources

The main water-bearing sediments in the Basin are gravel, silt, and clay derived from the Sierra Nevada and other surrounding mountains. Runoff from these mountain ranges is the primary source of recharge for the Basin, as well as direct infiltration from irrigation and septic systems. The primary sources of discharge are pumping wells and evapotranspiration near the dry lakebeds.

Geology and Hydrostratigraphy

The base and highlands of the Basin are of late-Cretaceous igneous and metamorphic rocks of low permeability, except in fault origin shear zones. Surficial geology in the Basin generally consists of alluvium, lacustrine and playa deposits, sand dunes, and consolidated rock (**Figure 2-4**). The lower-most alluvial materials are of early Tertiary age, consisting of the Goler Formation. The Goler Formation is a compact, dense formation of mostly grus and alluvium derived from the basement rocks. The Ricardo Formation and Rose Springs Formations are lacustrine beds containing pyroclastic materials and minor volcanics. These are all quite compact and have low storage capacities. The valley floor dropped notably in Pliocene time and these materials began to wash into the depression. A lower alluvial formation is dense and compact, probably of Pliocene or early-Pleistocene age. This material does not transmit water well. A major portion of this formation is exposed in contact with the igneous basement where State Highway 14 enters the southwest side of the valley to its intersection with State Highway 178.

Most groundwater within the Basin is contained in the largely unconsolidated Pliocene, Pleistocene and Holocene alluvial beds, estimated to be approximately 2,000 feet thick (Brown and Caldwell, 2009). This includes lacustrine, playa and sand dunes as mapped by Berenbrock and Martin (1991).

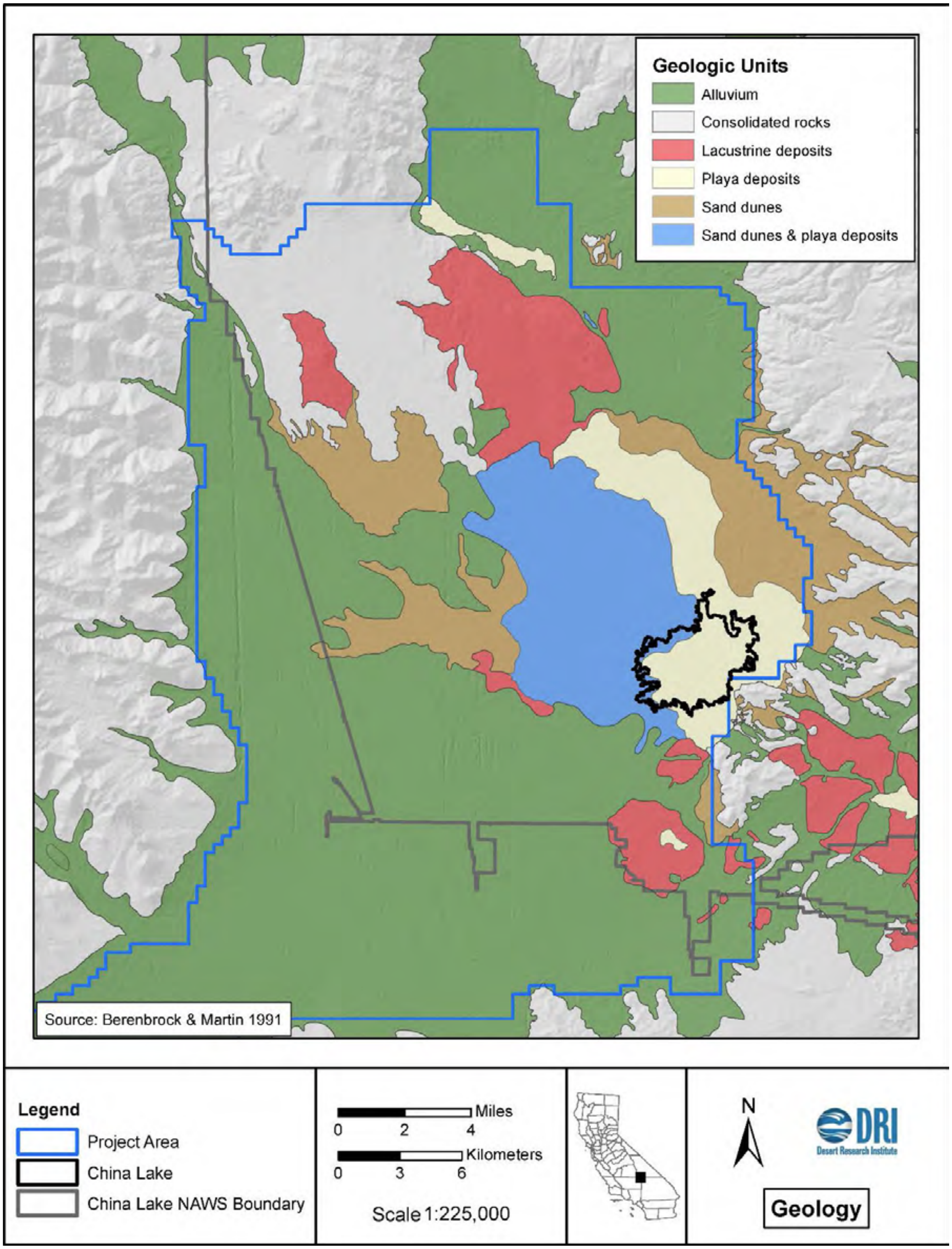
Alluvium consists of moderately to well-sorted gravel, sand, silt, and clay of Pleistocene and Holocene age and is considered to have a high permeability. Thickest along the western and southern edges, alluvium extends across the Basin, emanating largely from the Sierra Nevada and to a lesser extent from the Argus Mountains.

Poorly permeable and having storage coefficients of less than one percent, lacustrine clays are widespread especially in the central and eastern portions of the Basin. Locally, they confine the aquifer by decreasing the mobility of the water. Intercalated with the clays are some poorly interconnected pods of high permeability and high storage capacity beds consisting of aeolian sands and slope wash material. On the northern end of the valley, beds of pumice and a few intercalated basaltic lava flows occur within the water producing zones.

Figure 2-4: Surficial Geology of the Indian Wells Valley (DRI, 2016, after Berenbrock and Martin, 1991)

Hydrogeology

Before intensive pumping began, a layer of about 200-300 feet of high quality water was deposited on beds of clay since the last glacial stage. In many places such as the southeastern part of the valley, this water has been almost entirely removed by pumping. Lower quality water is usually found in and beneath



the clays. Where glacial lakes did not exist, the sediments contain excellent water to depths greater than 1,000 feet. This condition has given rise to the oversimplified concept of two different aquifers but depends more upon the well depth, condition of the well, and the size and power of the pump. Pumping rates greater than 2,000 gallons per minute are possible in some areas.

Aquifers

Two principal aquifer units were defined by Kunkel and Chase (1969) as the shallow and deep (or main regional) aquifers. The shallow aquifer extends from land surface through the sand dune deposits, younger lacustrine deposits, and shallow alluvium. The shallow aquifer is comprised of fine sand, silt, and clay, resulting in low permeability that can confine (or partly confine) the deeper aquifer. Additionally, water quality is generally poor in the shallow aquifer with total dissolved solids (TDS) greater than 1,000 mg/L. The base of the shallow aquifer is not well defined, but has been estimated from 1,950 ft above mean sea level at its western edge to 1,850 ft above mean sea level near China Lake. The maximum saturated thickness of the shallow aquifer is approximately 100 feet.

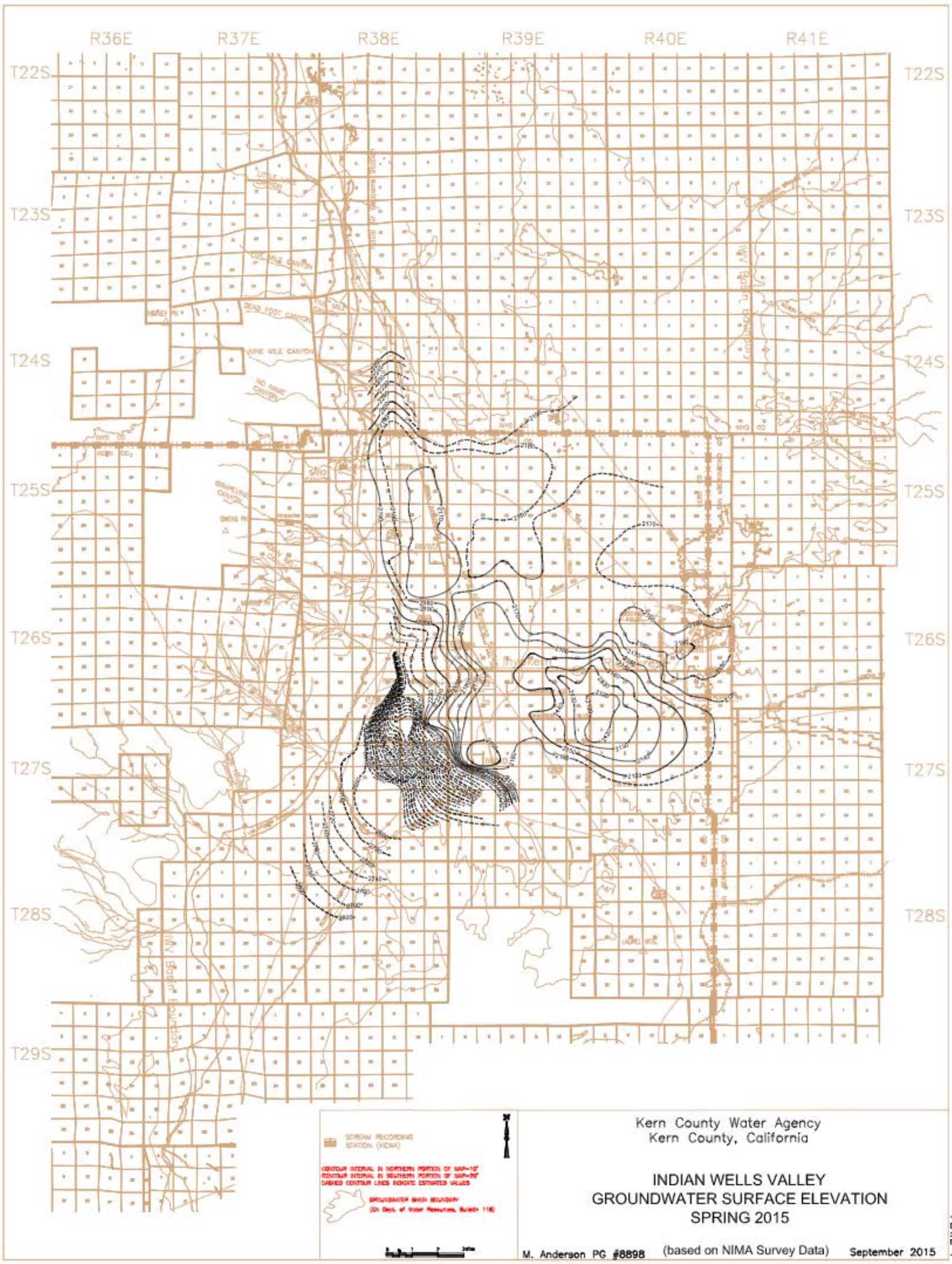
Tetra Tech (Tetra Tech EM 2003) defined an intermediate hydrogeologic unit consisting mainly of low permeability lacustrine and playa clays, but containing sand stringers that create transmissive water bearing zones that can be highly productive. The unit acts as a confining bed to deeper, productive eater bearing zones, but also can be screened by wells and be considered part of the deeper aquifer.

The deep aquifer is likely semiconfined to confined in the eastern portion of the basin because of silt and clay from the overlying lacustrine and playa deposits, but otherwise it is mostly unconfined. The medium-to-coarse sands and gravels have an estimated saturated thickness of 1,000 ft and are the main source of water to the Basin because they generally produce adequate flow rates and TDS is less than 1,000 mg/L (DRI, 2016).

Groundwater Recharge

Recharge to the Basin groundwater is dominantly from Sierra Nevada Mountain snowmelt and mountain block. Additional smaller sources of recharge include inflows from the adjacent Rose Valley, Coso Valley and El Paso subbasins/subareas. **Figure 2-5** shows contours of groundwater elevation in spring 2015 delineated by Kern County Water Agency (Kern County Water Agency, 2016). Groundwater flows perpendicular to the contours, from high elevations to low elevations, from the El Paso basin to the northeast, the Rose Valley to the southeast, from the Sierra Nevada to the west, towards China Lake and the two pumping depressions visible in the figure. Discharge primarily occurs through the China, Mirror and Satellite playa lakes located in the east-central portion of the Basin. Decades of groundwater pumping have lowered water levels throughout the area and created these two pumping troughs: one extending west from the Ridgecrest area and one extending north from the Inyokern area.

Figure 2-5: Indian Wells Valley Spring 2015 Groundwater Elevation Contours (Kern County Water Agency, 2016)



Stable isotope and age dating data from an AB 303 project indicates that shallow groundwater and the few recharge samples are consistently of Holocene Age (<10,000 years) while the deeper groundwater is generally between 10,000 and 40,000 years. Good groundwater quality in the southwestern portion of the Basin may provide evidence that these are younger (Holocene?) waters that originated in the higher elevations of the Sierra Nevada. A few wells completed in the deeper hydrologic zones indicate the potential for poorer quality groundwater at greater depth in certain areas.

Significant drawdown in the regional aquifer is occurring at a rate of 1 to 1.5 feet per year, particularly in the eastern and east-central portion of the Basin, and the possibility exists of drawing poorer quality groundwater from the eastern portion of the basin or deeper zones. These groundwater declines indicate that recharge is lagging or insufficient to replace losses associated with groundwater production. The Basin is designated as critically overdrafted by the California DWR (http://www.water.ca.gov/groundwater/sgm/cod.cfm). As such, effective use of recycled water and management of associated salts and nutrients is important for avoidance of “undesirable results,” as defined in SGMA, promoting long-term sustainability of basin groundwater resources.

Climate

Temperatures in the region often exceed 100 degrees Fahrenheit during summer months, with an annual average rainfall of less than 5 inches; most rainfall occurs between November and March, with thunderstorm events occurring during the summer monsoons (IWVWD UWMP, 2016).

The maximum and minimum monthly average temperatures, as well reference evapotranspiration rates (ETo), within the Basin are shown in **Table 2-1** below.

Table 2-1: Indian Wells Valley Climate (IWVWD, 2015)

	Jan	Feb	Mar	Apr	May	Jun	
Average Maximum Temperature (°F)	59.6	64.8	70.3	77.7	87	96.7	
Average Minimum Temperature (°F)	30.8	34.6	38.7	44.3	52.9	60.5	
Average Total Precipitation (in)	0.74	0.95	0.55	0.17	0.07	0.02	
Monthly Average Reference ETo (in.)	1.86	2.80	4.65	6.00	8.06	9.00	
	Jul	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Average Maximum Temperature (°F)	102.7	101.2	94.2	83.2	69.0	59.7	80.5
Average Minimum Temperature (°F)	66.2	64.6	58.1	48.2	37.3	30.2	47.2
Average Total Precipitation (in)	0.16	0.22	0.20	0.10	0.38	0.59	4.17
Monthly Average Reference ETo (in)	9.92	8.68	6.60	4.34	2.70	1.86	66.47

Notes: Average Rainfall and Temperature data was obtained from the Inyokern, California Station (044278) for the period of record 11/17/1940 to 12/27/2012 as provided by the Western Regional Climate Center (WRCC) on their website https://wrcc.dri.edu. Evapotranspiration rate (ETo) data was based on the monthly average reference evapotranspiration by ETo for Zone 17 (High Desert Valleys), as provided by the California Irrigation Management Information System (CIMIS) on their website http://www.cimis.water.ca.gov.

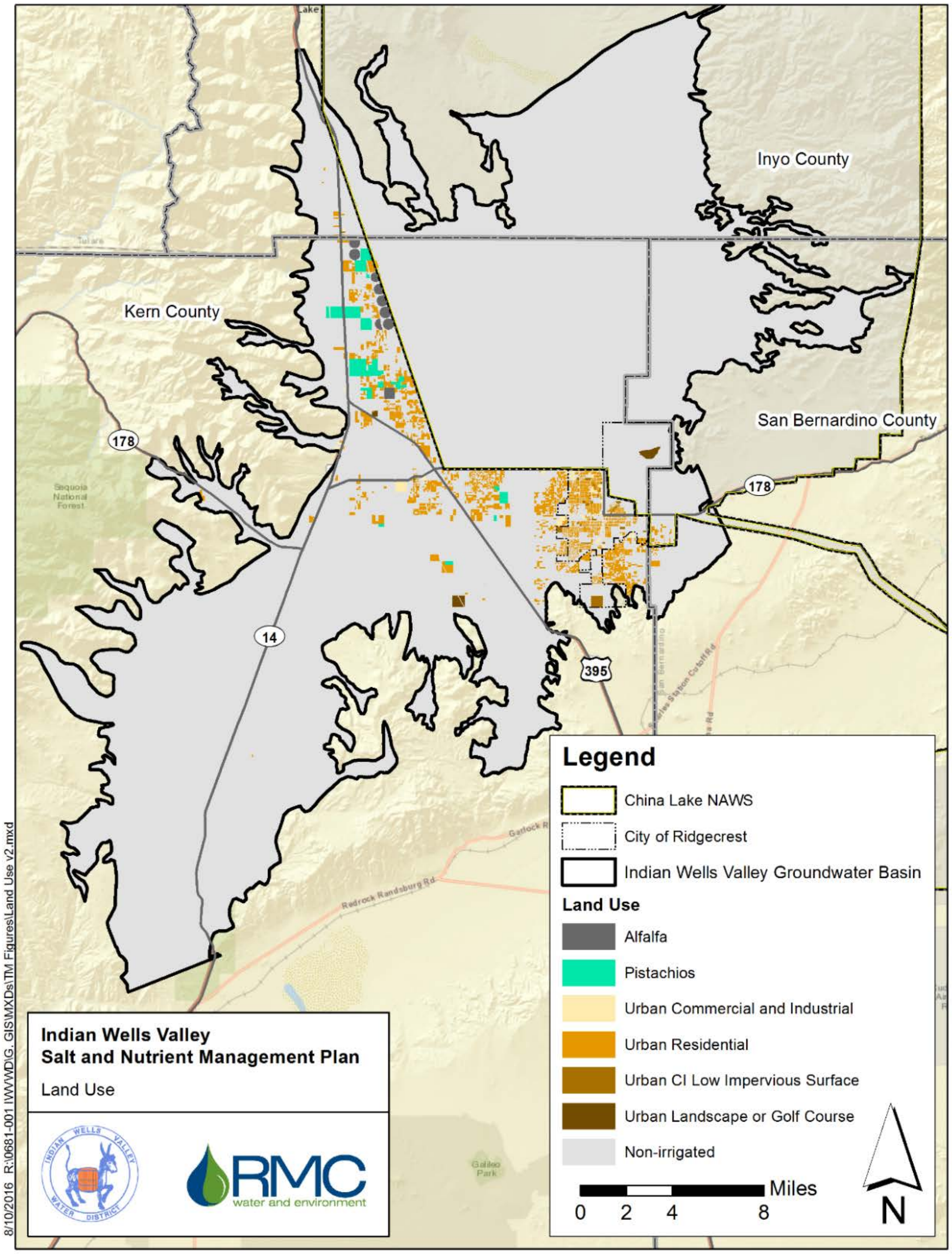
Land Cover and Land Use

Land use in Basin is predominantly natural, primarily shrubland, with a small percentage of urban sprawl and agricultural lands (U.S. Geological Survey, 2013). The largest urban area in the basin is the City of Ridgecrest with an estimated population of 28,701 through July 2016 (United States Census Bureau, 2016)

As part the loading analysis, land use data from the 2014 Kern County General Plan, Inyo County May 2016 parcel data, and San Bernardino County May 2016 parcel data was obtained. These datasets contain several hundred discrete land use categories, which were consolidated into the following land use groups for the Basin area (**Figure 2-6**):

- Alfalfa
- Pistachio
- Urban commercial and industrial
- Urban commercial and industrial, low impervious surface (e.g. maintenance yards, schools)
- Urban landscape or golf course
- Urban residential
- Non-irrigated

Figure 2-6: Indian Wells Valley Land Use



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2.2 Groundwater Inventory

Groundwater Level Trends and Water Budget

Groundwater levels have been declining an average of 1 to 1.5 feet across a good portion of the Basin since approximately the 1960's. Selected hydrographs and location map are provided as **Figure 2-7**. For this SNMP the average annual recharge ranges between 7,000AFY to 11,000 AFY (Brown & Caldwell 2009, DRI 2016). The average annual pumping is estimated at 27,000 AFY (DRI, 2016) and projected to rise.

For the purposes of monitoring, the Basin is delineated into four sections representative of the largest sources of groundwater flow (**Figure 2-8**).

Figure 2-7: Indian Wells Valley Groundwater Basin Monitoring Well Locations

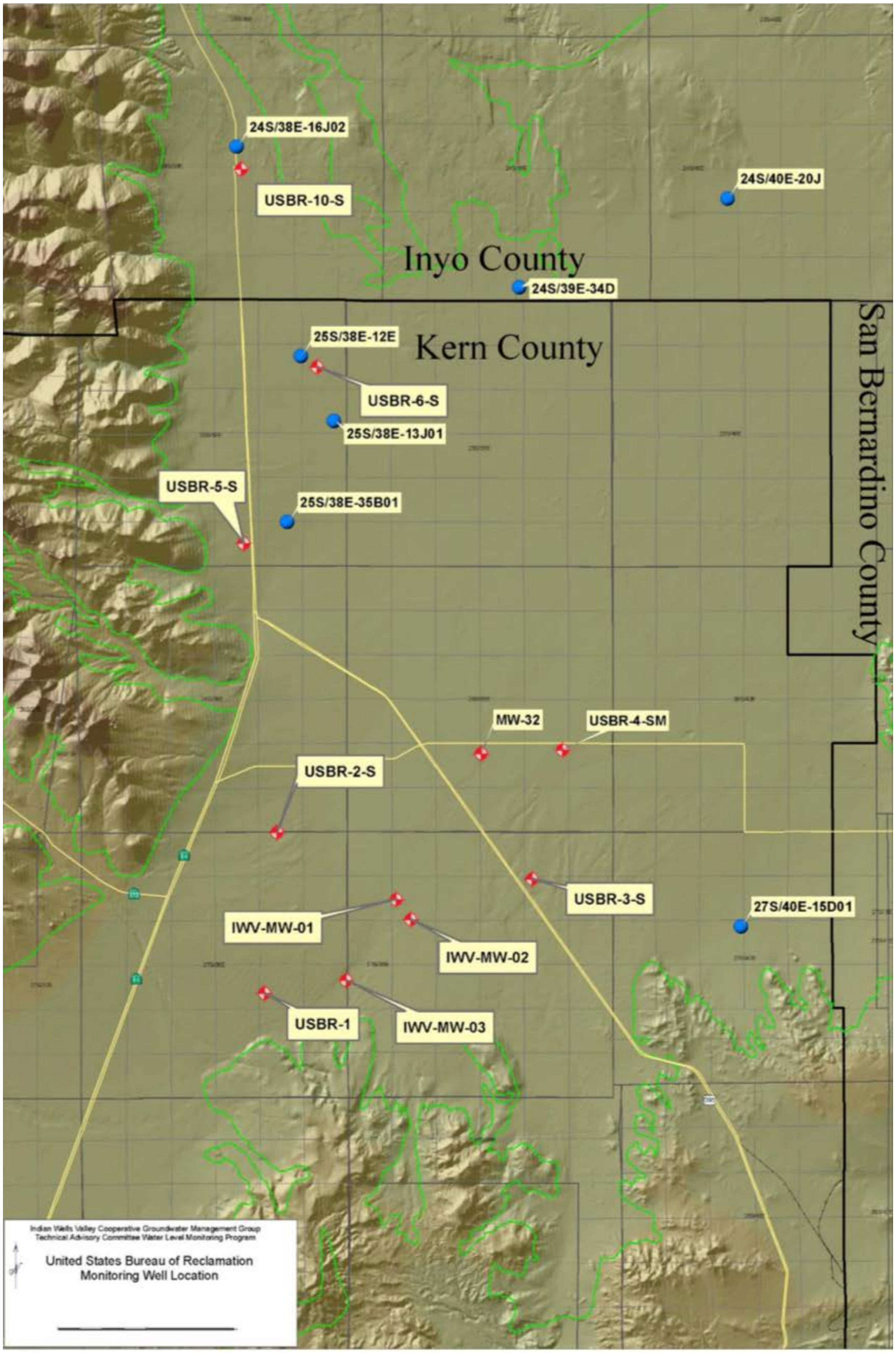
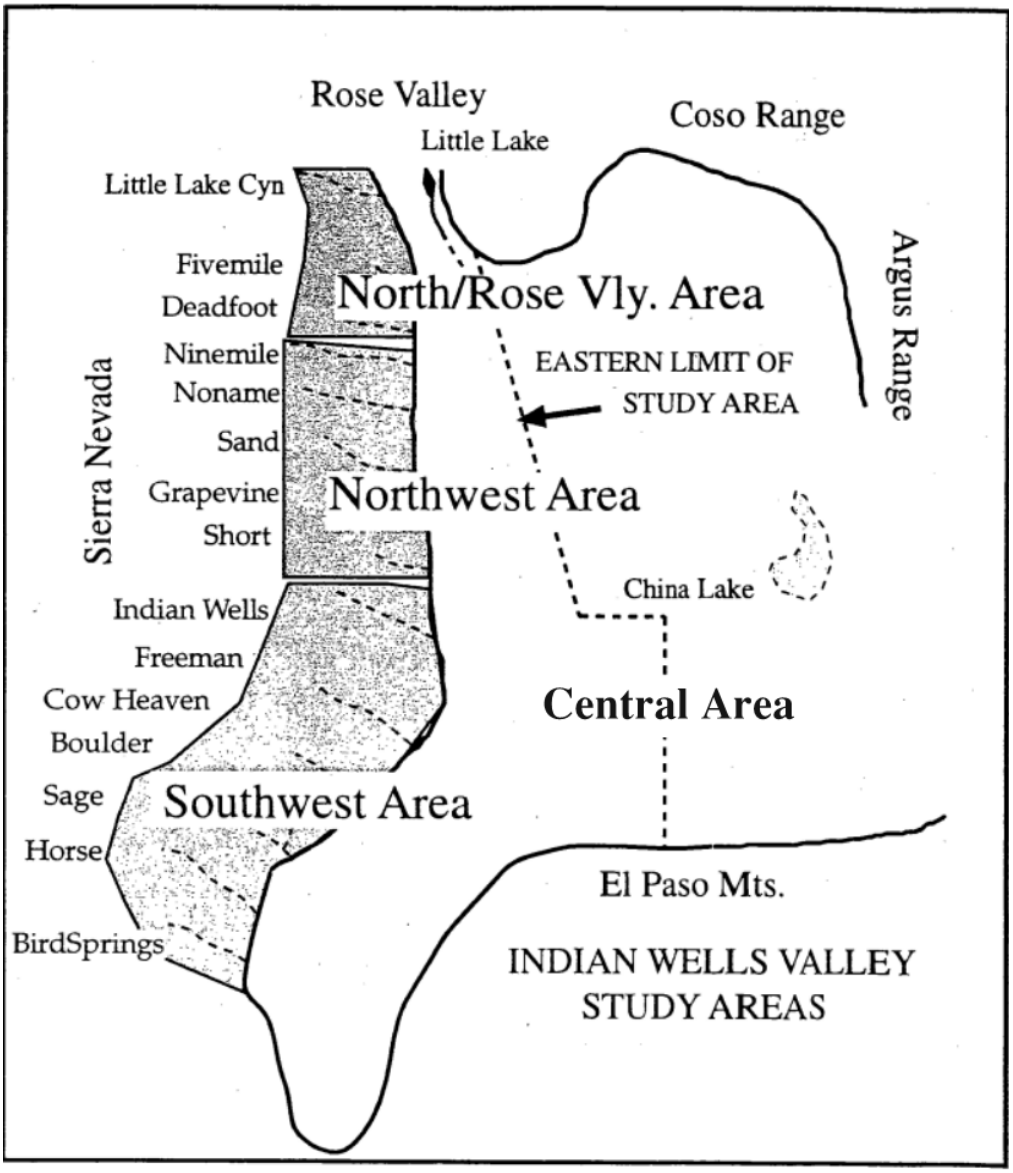


Figure 2-8: Indian Wells Valley Groundwater Basin Monitoring Sections



Part of the Basin's Cooperative Groundwater Management Plan (outlined in Section 6.1 Groundwater Management Goals and Objectives), Planning Objective #2 states "Future groundwater development by the Parties will be distributed within the Valley [Basin] in a manner that is designed in accordance with aquifer characteristics. The Parties will consider developing, to the fullest extent possible, individually or as a cooperating group, wells in the outlying areas of the Valley [Basin]. Areas such as IWVWD's southwest well field should be considered as should wells designed to capture recharge from all areas of the watershed. As a general guideline, the location and capacity of new production wells (excluding domestic wells) should not unreasonably interfere with existing wells."

Hydrographs for the monitoring wells are shown in **Appendix A** and represent water level trends in the different groundwater delineated areas within the Basin.

Groundwater Storage

Currently the Basin is not adjudicated, and its groundwater budget is categorized as Type A under the California Department of Water Resources (DWR) Bulletin 118. This categorization indicates that "much of the information needed to characterize the groundwater budget for the basin or subbasin [is] available" (DWR, 2004).

Groundwater Storage Capacity

Bulletin 118 reports two potential storage capacities for the Basin: 5,120,000 AF reported by the DWR in 1975 and 2,200,000 AF calculated by Dutcher and Moyle (1973) using 1921 water levels as the steady state limit and 200 feet below this level as the economically feasible limit to extract groundwater (DWR 2004).

A publication by Bean (1989) reported storage had declined by about 150,000 AF between the years 1921 and 1985 based on water level studies by the USGS, resulting in a storage volume of roughly 2,050,000 AF. This shows that the Basin was in overdraft and that the amount of current storage is potentially less than the 1985 amount as a result (DWR 2004).

Groundwater Mixing and Movement

While the natural flow of groundwater in the Basin progresses from areas of recharge along the southwest, west, north, and northeast edges toward China Lake playa (Kern County, 2006), human activities such as pumping and sewage effluent recharge can alter these influx points.

Groundwater Production

As reported through several agencies and study measures, the Basin is in a state of high overdraft.

Table 2-2 depicts the groundwater production estimates for the Basin since 1975.

Table 2-2: Indian Wells Valley Groundwater Production Estimates 1975 – 2010

Year	Brown Road Farming	China Lake Acres	City of R/C	SVM	IWVWD	Inyokern CSD (d)	NAWS (c)	Neal Ranch
1975	1516	400		2781	2983	300	5000	2000
1976	1494	400		2911	3099	300	5000	2000
1977	2702	400		3315	3063	300	5000	2000
1978	3216	400		3081	3357	300	5000	2000
1979	3257	400		3081	3402	300	5154	2000
1980	7515	400		2887	3319	300	4995	2041
1981	10036	400		3065	4223	300	4804	2002
1982	10324	400		2887	3963	300	4450	1478
1983	10087	400		2476	4316	300	4402	1752
1984	10312	400		2307	4940	300	4694	1568
1985	10100	400		2397	4981	300	4002	2450
1986	5389	400		2557	5901	300	4430	2353
1987	4141	Purchased by IWVWD		2560	7426	300	4422	1447
1988	5255			2560	7889	173	3980	1195
1989	7064			2320	8725	175	4205	Purchased by IWVWD
1990	6187			2505	8600	170	3667	
1991	6737			2406	7700	150	3364	
1992	7104			2528	7650	141	3351	
1993	7701			2607	7800	150	3411	
1994	7504			2607	8300	146	3684	
1995	7427			2710	8100	125	3848	
1996	7807			2620	8504	134	3367	
1997	7800			2522	8534	139	2983	
1998	7800			2527	7719	102	3018	
1999	7800			2537	8242	104	2541	
2000	7800			2701	8148	111	2690	
2001	8150			2732	8392	97	2840	
2002	8460		445	2564	8865	115.6	3138	
2003	9420		616	2561	9098	126	3325	

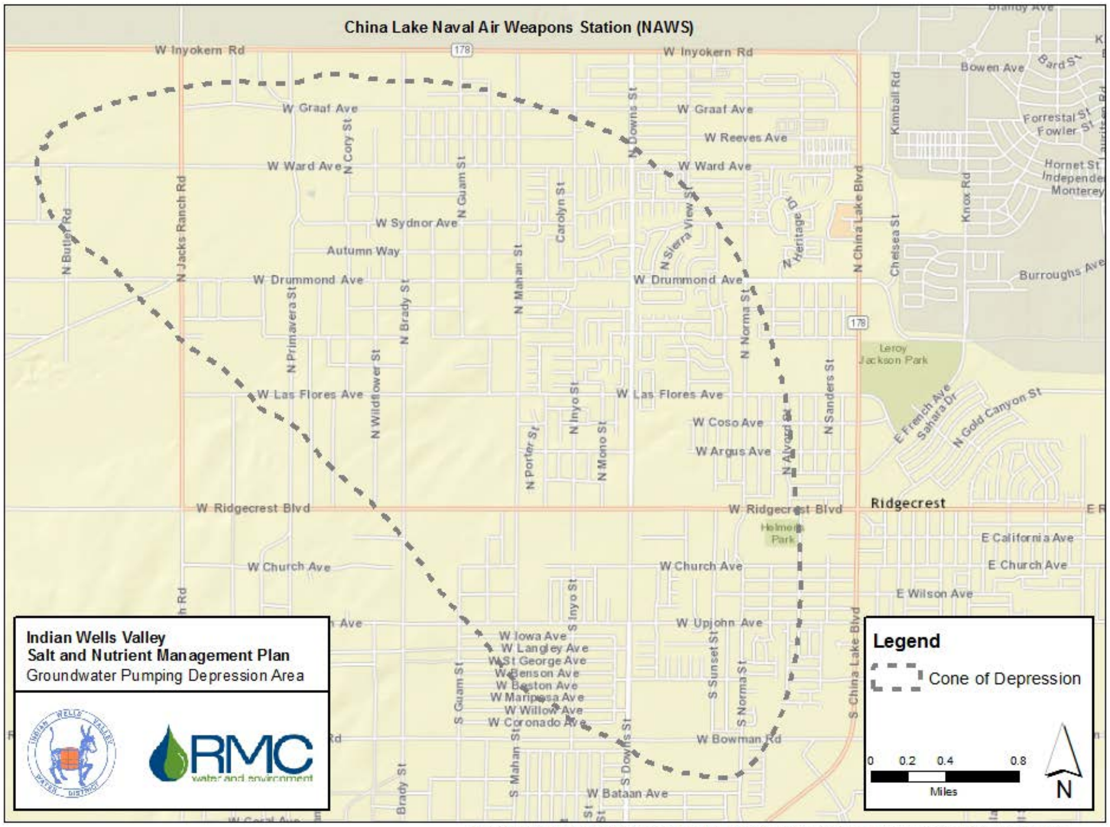
Year	Brown Road Farming	China Lake Acres	City of R/C	SVM	IWVWD	Inyokern CSD (d)	NAWS (c)	Neal Ranch
2004	9370		413	2470	8992	118.4	2331	
2005	9580		366	2504	8545	135	2288	
2006	9460		385	2591	8864.4	135	2440	
2007	9270		420	2530	9198.5	90.7	2533	
2008	8957		392	2521	8564.8	118	2119	
2009	9536		400	2535	8398.2	118	1883	
2010	9437		339	2587	7570	118	1710	
Year	**Private Wells (b)**	**Quist Farms**	**Orchards**	**R/C Heights**	**S. Leroy (a)**	**Annual Totals**	**% Ag Use**	
1975				1000		15980	22.00%	
1976				1000	1600	17804	25.20%	
1977				1000	1600	19380	29.40%	
1978				1000	1600	19954	31.20%	
1979	2100			1000	1600	22294	28.10%	
1980	2100			1000	1600	26157	40.40%	
1981	2100			1000	1600	29530	44.20%	
1982	2100			1000	1600	28502	44.90%	
1983	2400			1000	1600	28733	44.70%	
1984	2400			1000	1600	29521	43.60%	
1985	2500			1000	1600	29730	45.60%	
1986	2500			1000	1600	26430	33.10%	
1987	2500			Purchased by IWVWD	Ranch Closed	22796	24.50%	
1988	2500					23552	27.40%	
1989	2650		500			25639	29.50%	
1990	2650		525			24304	27.60%	
1991	2650		525			23532	30.90%	
1992	2650		550			23974	31.90%	
1993	2650		575			24894	33.20%	
1994	2650		575			25466	31.70%	
Year	**Private**	**Quist**	**Orchards**	**R/C**	**S. Leroy**	**Annual**	**% Ag**	

	Wells (b)	Farms		Heights	(a)	Totals	Use
1995	2650		595			25455	31.50%
1996	2650		600			25682	32.70%
1997	2650		625			25253	33.40%
1998	2700		640			24506	34.40%
1999	2700		690			24614	34.50%
2000	2800		725			24975	34.10%
2001	2800		750			25761	34.50%
2002	2800	750	750			27888	35.70%
2003	2800	750	775			29471	37.10%
2004	2800	750	800		950	28994	40.90%
2005	2800	750	825		1025	28818	42.30%
2006	2800	750	840		1050	29316	41.30%
2007	2800	750	840		1000	29433	40.30%
2008	2800	750	900		1200	28322	41.70%
2009	2800	750	925		1125	28470	43.30%
2010	2800	750	925		1050	27286	44.60%

Notes: (a) Spike Leroy ranch started back up in 2004 with approx. 150 acres of alfalfa x 7 (b) Private well owner figures to be verified by Leroy Marquardt (c) Navy began aggressive water conservation program in 2007 (d) Estimate based on UC Davis Farm Advisors Office (e) Ag Total 17890.5

Due to excessive pumping, a regional cone of depression has formed west of the City of Ridgecrest (**Figure 2-9)**. Hydraulic heads have changed in the shallow aquifer, due to effluent recharge, causing it to leak into the deep aquifer and migrate towards the cone of depression. This leakage is of concern because of the shallow aquifer's historically poor water quality and was addressed in Planning Objective #1 of the Cooperative Groundwater Management Plan for the Basin, which states that "no Signatory producing water will increase its annual production of water from the groundwater depression (applied to extractions greater than 5 AFY). The water producing Signatories' long-term goal is to limit new and reduce existing production in this area to the fullest extent possible over an economically reasonable time frame" (Kern County, 2006). IWVWD has moved a significant amount of pumping with development of the Southwest Wellfield to address the issue of the cone of depression.

Figure 2-9: Groundwater Pumping Depression Area



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2.3 Groundwater Conceptual Model

Three local stakeholders (IWVWD, Searles Valley Minerals, and the China Lake NAWS) funded development of a conceptual model and a numerical model by Brown-Caldwell in 2009, which was updated in 2016 by the Desert Research Institute on behalf of the Navy. The conceptual model of the Basin was based on reviews of previous studies and compilations of available geologic, geophysical and hydrologic data. It includes:

1) Physical basin boundaries (both lateral and vertical);
2) Estimated spatial distributions of the alluvial aquifer material properties, including hydraulic conductivity and storage parameters;
3) Estimated water flow into the basin (“inflows”) from precipitation along the western and northern margins of the Indian Wells Valley basin and subflows from Rose Valley and Coso Basins;
4) Estimated water flow out of the basin (“outflows”) from evapotranspiration (ET), groundwater withdrawals, and subflows out of the basin; and
5) A basin scale groundwater budget

Upon completion of the conceptual model, a three-dimensional, MODFLOW-based numerical groundwater flow model for the Basin was developed using the common project databases and a fully integrated combination of three software packages, which included:

1) ESRI ArcGIS geographic system (GIS);
2) Environmental Visualization System (EVS) by Ctech for 3-dimensional (3-D) geologic modeling and visualizations, and;

3) Groundwater Vistas (GV) by ESI for pre-processing, execution, and post-processing of the numerical groundwater flow model.

The Basin numerical groundwater flow model was developed using MODFLOW-2000 (Harbaugh et al., 2000) to simulate historical groundwater conditions from approximately 1920 to 2006. During this process, the aquifer material properties, boundary conditions, recharge, and ET were varied to best match available measured data. Future use of this calibrated model may assess the potential impacts of projected groundwater withdrawals on the Indian Wells Valley subsurface flow system.

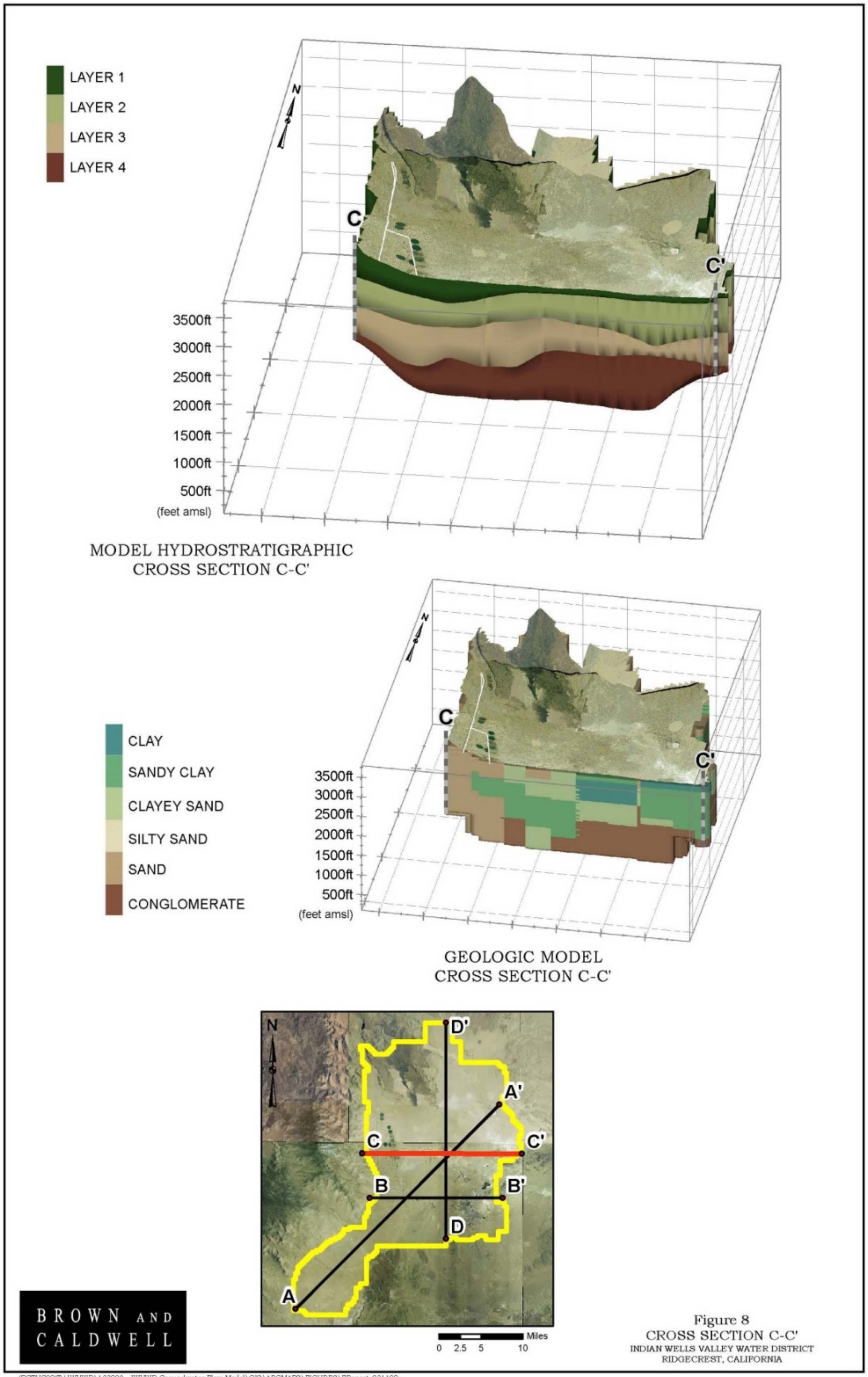
Cross Sections A-A' (**Figure 2-10**), B-B' (**Figure 2-11**), C-C' (**Figure 2-12**), and D-D' (**Figure 2-13)** are included below for graphic representation of the Basin from various locations.

Figure 2-10: Geologic Model Cross Section A-A'

Figure 2-11: Geologic Model Cross Section B-B'

Figure 2-12: Geologic Model Cross Section C-C'

Figur



del Cross Section D-D’

2.4 Groundwater Budget

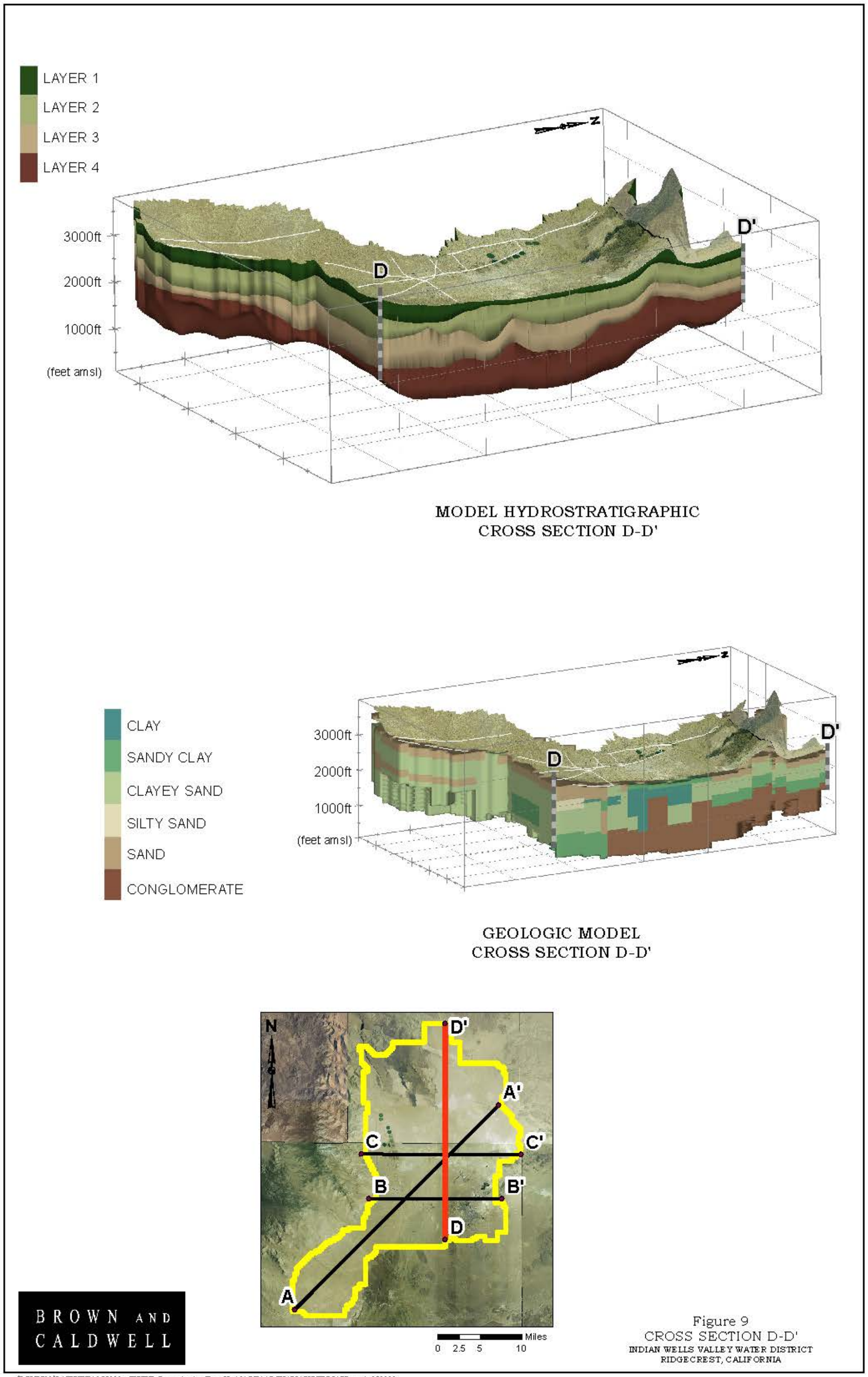


Figure 9
CROSS SECTION D-D'
INDIAN WELLS VALLEY WATER DISTRICT
RIDGECREST, CALIFORNIA

To facilitate trend analysis, a thorough review of previous basin studies and models was undertaken to determine annual flows. Following this effort, the Indian Wells Valley Resource Opportunity Plan: Water Availability and Conservation Report was used in conjunction with the loading analysis (described in Section 4 Salt and Nutrient Sources and Loading) to establish the annual groundwater budget shown in **Table 2-3**.

Due to a lack of detailed water quality data for all groundwater budget components, subsurface inflows to the Basin are assumed to reflect equivalent levels of quality.

Table 2-3: Indian Wells Valley Groundwater Budget (Todd, 2013)

Budget Component	AFY
Basin Inflows	
Irrigation Deep Percolation	7,428
Surface drainage from the Sierra Nevada	4,490
Surface drainage from the Argus Range	1,600
Inflow from Rose Valley	1,000
Surface drainage from the Coso Range	300
Leakage from the IWVWD water distribution system	80
Surface drainage from the El Paso Mountains	50
Basin Outflows	
Groundwater Production	28,848
Playa evapotranspiration	1,900
Subsurface flows to Salt Wells Valley	50

3 Basin Water Quality

This section describes the Basin's current water quality conditions and regulatory water quality objectives. Sections that follow describe technical analysis to assess salt and nutrient loading and projected water quality trends in the basin.

3.1 Basin Water Quality Overview

Groundwater quality varies significantly within the Basin. As described in Section 1.6.1 Current Basin Groundwater Quality, in general water quality is good along the margins and in the southern portion, where recharge to the Basin has been more recent, and poorer in the central and eastern portions of the Basin where water quality has been degraded by long residence times and past and present evapo-concentration of solutes. In its report *Indian Wells Valley Groundwater Project* (1993), the USBR found that the southwest area of the Basin contains a significant quantity of high-quality groundwater. In contrast, groundwater in the Northwest area was found to be of poorer quality than anywhere else in the Basin and has historically been used primarily for agricultural purposes. Groundwater produced from this area may not be usable for domestic purposes unless it receives a significant amount of treatment or is blended with higher quality water (Kern County, 2006).

3.2 California's Groundwater Ambient Monitoring and Assessment (GAMA) Program

In January 2013 the Basin was evaluated through the GAMA Program's Priority Basin Project (PBP), which assesses water quality in aquifer areas used for drinking water (USGS and SWRCB, 2013). GAMA's PBP, using both data collected through the program and routinely for regulatory compliance, assessed groundwater quality in two parts: first, a statically based assessment on the status of water quality was performed using data collected from a network of wells; second, an assessment of the factors that affect the water quality was performed using data from additional wells.

Methodology

Because they collect their own data, the PBP includes chemical analyses not generally available as part of regulatory monitoring, including measurements at concentrations much lower than standard human health benchmarks. Federal and California regulatory benchmarks (Maximum Contaminant Level, MCL) are used when available, otherwise nonregulatory benchmarks (Notification Level, NL, and Lifetime Health Advisory, HAL) for protecting human health and non-regulatory benchmarks (Secondary Maximum Contaminant Level, SMCL) for protecting aesthetic properties, such as taste and odor, are used.

1) High concentrations: Concentrations that are greater than a benchmark
2) Moderate concentrations: For inorganic constituents, if they are greater than one-half of the benchmark; for organic and special-interest constituents, if they are greater than one-tenth of the benchmark (a lower threshold is used because organic constituents are generally less prevalent and have smaller concentrations than inorganic constituents)
3) Low concentrations: Include non-detections and values less then moderate concentrations.

Results

For this assessment, the USGS sampled 13 wells and measured both organic and inorganic constituents. Results are summarized in **Table 3-1** and described in more detail below:

Table 3-1 GAMA Program Water Quality Sampling Results for Indian Wells Valley Basin Wells

Constituent	Detected at high or moderate concentrations?	Note
Volatile Organic Compounds	No	56 VOCs analyzed
Pesticides	No	20 pesticides analyzed
Trace Elements with Human Health Benchmarks	Yes	5 detected at high levels: arsenic, boron, molybdenum, strontium, and vanadium
Radioactivity	Yes	Uranium and gross alpha detected in high concentrations in 15% of samples
Nutrients	No	3 analyzed
Inorganics with Non-Health Benchmarks	Yes	Chloride, manganese, TDS, and sulfate
Perchlorate	Yes	Present at moderate concentrations in 15% of the primary aquifer

Organic Constituents

The PBP used lab methods to detect the presence of volatile organic compounds (VOCs) and pesticides, which can help trace water from the land surface into the aquifer system.

Volatile Organic Compounds

VOCs are characterized by their tendency to volatilize into the air and are present in many household, commercial, industrial, and agricultural products. Of 56 VOCs with health-based benchmarks analyzed, none were detected at high or moderate concentrations in the primary aquifers.

Pesticides

Used to control weeds, insects, fungi, and other pests, pesticides can be present on lawns, in gardens, around buildings, along roads, and in agricultural fields. Of the 20 pesticides with health-based benchmarks analyzed, none were detected at high or moderate concentrations in the primary aquifers.

Inorganic Constituents

Inorganic constituents are trace elements naturally present in the minerals in rocks and the water they encounter.

Inorganic Constituents with Human-Health Benchmarks

In the Basin, trace elements were present at high and moderate concentrations in 54% and 31%, respectively, of the primary aquifers. Of the 17 trace elements analyzed, 5 were detected in high concentrations: arsenic, boron, molybdenum, strontium, and vanadium.

The IWVWD 2015 UWMP identified four district wells that produce water containing arsenic at levels exceeding the 10 parts per billion (ppb) MCL. This MCL was reduced from 50 ppb by the United States Environmental Protection Agency (USEPA) in 2006 and adopted by the California Department of Public Health (CDPH) in 2008. In response, the District constructed two arsenic removal facilities and since operations started in 2011, water entering the distribution system after treatment has been below the MCL.

Radioactivity, the release of energy or energetic particles during structural changes in the nucleus of an atom, mostly occurs in groundwater from decay of naturally occurring isotopes of uranium and thorium present in minerals in the aquifer. In the Basin, radioactive constituents were detected at high and moderate concentrations in 15% and 8%, relatively, of the primary aquifers. Of the six radioactive constituents analyzed, 2 were detected at high concentrations: uranium and gross alpha.

Nutrients naturally present at low concentrations in groundwater, such as nitrate and nitrite, may occur at high and moderate concentrations because of human activities such as fertilizer application, livestock waste, or septic-system seepage. Of the three nutrients analyzed, none were detected at concentrations above the benchmark.

Inorganic Constituents with Non-Health Benchmarks

Other inorganic constituents, such as total dissolved solids (TDS) and manganese, affect the aesthetic properties of water such as taste, color, or odor. In the Basin, these constituents were present at high and moderate concentrations in 23% and 31%, respectively, of the primary aquifers. Of the seven constituents analyzed, three were detected at high concentrations (chloride, manganese, and TDS) and one at moderate concentrations (sulfate).

Special Interest: Perchlorate

Although perchlorate naturally occurs in groundwater in low to moderate concentrations, it has the potential to occur at high concentrations as an ingredient in rocket fuel, fireworks, safety flares, and some fertilizers. In the Basin, perchlorate was present at moderate concentrations in 15% of the primary aquifers.

3.3 Salts and Nutrients Water Quality

Salinity in the deep aquifer generally increases from west to east. Elevated concentrations are primarily the result of hundreds of years of evaporative concentration at China Lake playa. The Water Quality Control Plan for the Lahontan Region (Basin Plan) was amended to remove the Municipal and Domestic Supply (MUN) beneficial use designation from two groundwater areas located within the NAWS China Lake. The groundwater proposed for de-designation is located beneath Salt Wells Valley and within the shallow groundwater in the eastern IWV groundwater basin (both areas are within NAWS China Lake). Water Board staff concluded that the MUN use is not an existing use of the affected groundwater and cannot feasibly be attained through permit conditions or treatment. Due to naturally-occurring high concentration of constituents such as arsenic and TDS, removal of the MUN beneficial use designation was justified and approved on November 26, 2014. Many wells show trends slowly increasing in salinity, which may be a result of lateral inflow from the adjacent high salinity containing formations of the shallow aquifer. Additionally, naturally occurring arsenic has been detected and is being treated in a few of the water supply wells.

TDS and nitrate are the salts and nutrients indicators selected for this SNMP. Other parameters of interest will be evaluated within the GSP process. Total salinity is commonly expressed in terms of TDS in mg/L, and TDS (and electrical conductivity data that can be converted to TDS) are available for source waters in the Basin. While TDS can be a sign of anthropogenic impacts such as infiltration of runoff, soil leaching, and land use, there is also a natural background TDS concentration in groundwater.

Nitrate, the primary form of nitrogen detected in groundwater, is a widespread contaminant in California groundwater. Since natural nitrate levels in groundwater are generally very low (typically around <2.0 mg/L – 10 mg/L), high levels are associated with agricultural activities, septic systems, confined animal facilities, landscape fertilization, and wastewater treatment facility discharges. Nitrate-N is selected for assessment in this SNMP, however nitrate is commonly reported as either nitrate-NO_3 or nitrate-N and one can be converted to the other.

3.3.1 Water Quality Objectives for Salts and Nutrients

Water quality objectives provide a reference for assessing groundwater quality in the basin. The SWRCB has adopted a SMCL for TDS. Although SMCLs address aesthetic issues rather than health effects, elevated TDS concentrations in water can damage crops, affect plant growth, and damage municipal and industrial equipment. The recommended SMCL for TDS is 500 mg/L with an upper limit of 1,000 mg/L. It has a short-term limit of 1,500 mg/L. As shown in **Table 3-2**, the Regional Water Board has established a water quality objective of 500 mg/L for TDS for groundwater designated as municipal and domestic supply (MUN) in their Basin Plan (September 2015).

For nitrate plus nitrite as nitrogen (as N), the Regional Water Board has established a water quality objective of 10 mg/L for groundwater designated as municipal and domestic supply (MUN) in their Basin Plan (September 2015).

Table 3-2: Basin Plan Water Quality Objectives

Constituent	Basin Plan Objectives (BPOs)
TDS	SMCL, 500
Nitrate as Nitrogen	MCL, 10
Nitrate as NO3	MCL, 45
Notes: Units in mg/L	

3.3.2 Fate and Transport of Salt and Nutrients

Fate and transport describes the way salts and nutrients move and change through an environment or media. In groundwater, fate and transport is determined by groundwater flow directions and rate, the characteristics of individual salts and nutrients, and the characteristics of the aquifer media.

Because water can naturally dissolve salts and nutrients throughout the hydrologic cycle, the types and quantity of salts and nutrients present determine whether the water is of suitable quality for its intended use(s). Numerous natural sources (such as atmospheric gases and aerosols, weathering and erosion of soil and rocks, and dissolution of existing minerals below the ground surface) and anthropogenic activities can contribute to salts and nutrients found in natural water. Additional changes in concentrations can be due to ion exchange, precipitation of minerals previously dissolved, and reactions resulting in conversion of some solutes from one form to another (such as the conversion of nitrate to gaseous nitrogen).

TDS and nitrate are contained in the source water that recharges the Basin. Addition of new water supply sources, either through intentional or unintentional recharge, can change the groundwater quality either for the worse, by introducing contaminants, or for the better, by diluting existing contaminants in the aquifer. Another important influence on salts and nutrients in groundwater is unintentional recharge, which can occur, for example, when irrigation water exceeds evaporation and plant needs and infiltrates into the aquifer (i.e., irrigation return flow). A common irrigation management practice is to water to a leaching fraction of about 15% to avoid harmful concentrations of sale in the root zone, so it can also be intentional. Irrigation return flows can carry fertilizers high in nitrogen and soil amendments high in salts from the yard or field into the aquifer. Similarly, reclaimed wastewater used for irrigation also introduces salts and nutrients.

TDS is considered conservative since it does not readily diminish in the environment. In contrast, processes that affect the fate and transport of nitrogen compounds are complex, with transformation, attenuation, uptake, and leaching in various environments. Nitrogen is relatively stable once in the saturated groundwater zone and nitrate is the primary form of nitrogen detected in groundwater.

3.3.3 Current Groundwater Quality with Respect to Salt and Nutrients

The IWVWD recognized TDS as an issue in their 2015 UWMP. TDS was found to be highest in the northeasterly potion of the Basin (where levels can exceed 5,000 mg/L) and lowest in the intermediate area and areas located southerly and southwesterly of the City of Ridgecrest (where levels are typically below 500 mg/L). Water levels in the Basin are decreasing by approximately 0.5 to 1.5 feet per year as an average over the whole of the Basin. Although degradation has not affected the areas of large well production, a continuing decline of water levels can increase the threat of saline water intrusion for underlying playas. In 2001, the IWVWD developed wells west of the City of Ridgecrest. Their production has augmented the IWVWD's water supply and as a result, static levels in prior areas of large production have improved.

Appendix B shows water quality data from selected wells within the Basin. This data includes water quality results from 1986 - 2013 and represents both central and outlying wells. These data represent groundwater quality of the deep aquifer utilized for all residential, rural, agricultural, industrial and military purposes within the Basin and Searles Valley.

In most wells, the data shows that TDS is below 500 mg/L and nitrates as nitrogen are below 10mg/L. Trends in wells with historical records show that TDS concentrations are generally stable (with some exceptions) and that nitrate concentrations in many of the wells are slightly decreasing. Section 5 of this SNMP discusses projected future trends in groundwater quality.

3.4 Indian Wells Valley Brackish Groundwater Resources Feasibility Study

Poorer-quality groundwater (TDS concentrations >3,000 mg/L) is present to the west, north, and east in the Basin and represents a potential alternate source of water. A Brackish Groundwater Resources Feasibility Study is being conducted to identify and quantify brackish groundwater resources and evaluate its development as an alternate water supply source. The study is being funded through cash and in-kind contributions by the Brackish Groundwater Resources Study Group, which includes Coso Geothermal, IWVWD, Meadowbrook Dairy, Mojave Pistachio, Searles Valley Minerals, and the US Navy. The IWVWD has also applied for a grant from the state on behalf of the Group.

Ultimately, the implementation of a brackish water resource will not only improve water supply reliability and longevity, but also mitigate the adverse environmental and public health impacts associated with freshwater overdraft. Appropriate disposal of reverse osmosis (RO) concentrate would be accomplished by exporting the byproduct to adjacent basins for use as process water by two potential industrial users.

4 Salt and Nutrient Sources and Loading

Salt and nutrient loading to the Basin is due to various surface activities, including:

- Irrigation water (privately produced groundwater, municipal water supplies, and reclaimed wastewater)
- Agricultural inputs (fertilizer)
- Urban inputs (septic systems, wastewater treatment plants, fertilizer, and applied water)

Most of these sources, or “inputs,” are associated with rural and agricultural areas. Within the City of Ridgecrest, urban area salt and nutrient loads (e.g. due to indoor water use) are assumed to be primarily routed to the municipal wastewater system for reclamation or discharge rather than to groundwater, except for landscape irrigation. Discharge and percolation from wastewater treatment plants are considered and calculated separately. Outside the City of Ridgecrest, groundwater serves as the primary source of water, supplying both urban and agriculture use. Other surface inputs of salts and nutrients, such as atmospheric loading, are not considered a significant net contributing source of salts and nutrients and are not captured in the loading analysis.

4.1 Loading Analysis Methodology

A GIS-based loading model was developed to better understand the significance of various loading factors. The loading model is a spatially based mass balance tool that represents TDS and nitrogen loading on an annual-average basis.

Primary inputs to the model are land use, irrigation water source and quality, septic system areas and loading.

The general methodology used to determine the salt and nutrient loads is outlined below:

- Identify the analysis units to be used in the model: Parcels from the Kern County, Inyo County, and San Bernardino County general plans served as the analysis units.
- Categorize land use categories into discrete groups: These land use groups represent land uses that have similar water demand as well as salt and nutrient loading and uptake characteristics. Each land use group is assigned characteristics including: percent irrigated, applied water, applied nitrogen, applied TDS
- Identify concentrations of TDS and nitrogen for private groundwater and municipal water supplies: Concentrations of TDS and nitrogen in the City of Ridgecrest are assumed to be uniform as they come from the same municipal water supply. Concentrations of TDS and nitrogen in groundwater are derived from a series of monitoring wells.
- Apply the irrigation water source to the analysis units: Each water source is assigned concentrations of TDS and nitrogen.
- Apply the septic system assumption to the analysis units.
- Estimate the water demand for the parcel: Water demand is based on the irrigated area of the parcel and the land use group.
- Estimate the TDS load applied to each parcel: TDS load is based on the land use practices, irrigation water source and quantity, septic load, and wastewater infrastructure load. The loading model makes the conservative assumption that no salt is removed from the system once it enters the system.
- Estimate the nitrogen load applied to each parcel: Nitrogen load is based on the land use practices, irrigation water source and quantity, and septic load. The loading model assumes that a portion of the applied nitrogen is taken up by plants and (in some cases) removed from the system (through harvest of plant material). Additional nitrogen is converted to gaseous forms and lost to the atmosphere. A 10% volatilization rate is applied, based on the average

soil pH of soils, the relatively coarse texture of soils and a semi-arid climate. Remaining nitrogen is assumed to convert to nitrate and to be subject to leaching.

4.2 Data Inputs

Data inputs to the model include land use (spatial distribution and associated loading), irrigation water (sources and associated quality and loading), septic inputs, and wastewater discharge loads. These inputs are discussed below.

4.2.1 Land Use

Land use within the Basin is described under “Land Cover and Land Use” within Section 2.1 Groundwater Basin Overview and shown in **Figure 2-6**.

Table 4-5 below consists of a matrix of values for the land use categories and characteristics.

4.2.2 Irrigation Water Sources

The irrigation water source data input is the result of compiling two primary datasets, one for within and one for outside the City of Ridgecrest. Within the City of Ridgecrest, all water demands are assumed to be met through the IWVWD. Water quality parameters for the City of Ridgecrest is taken from the sampling results from the IWVWD 2015 Annual Drinking Water Quality report. Outside the City of Ridgecrest, the water quality parameters were generated using measured TDS and nitrate concentrations at 34 monitoring wells in the basin. The median TDS and nitrate values are used to calculate the loads from applied water.

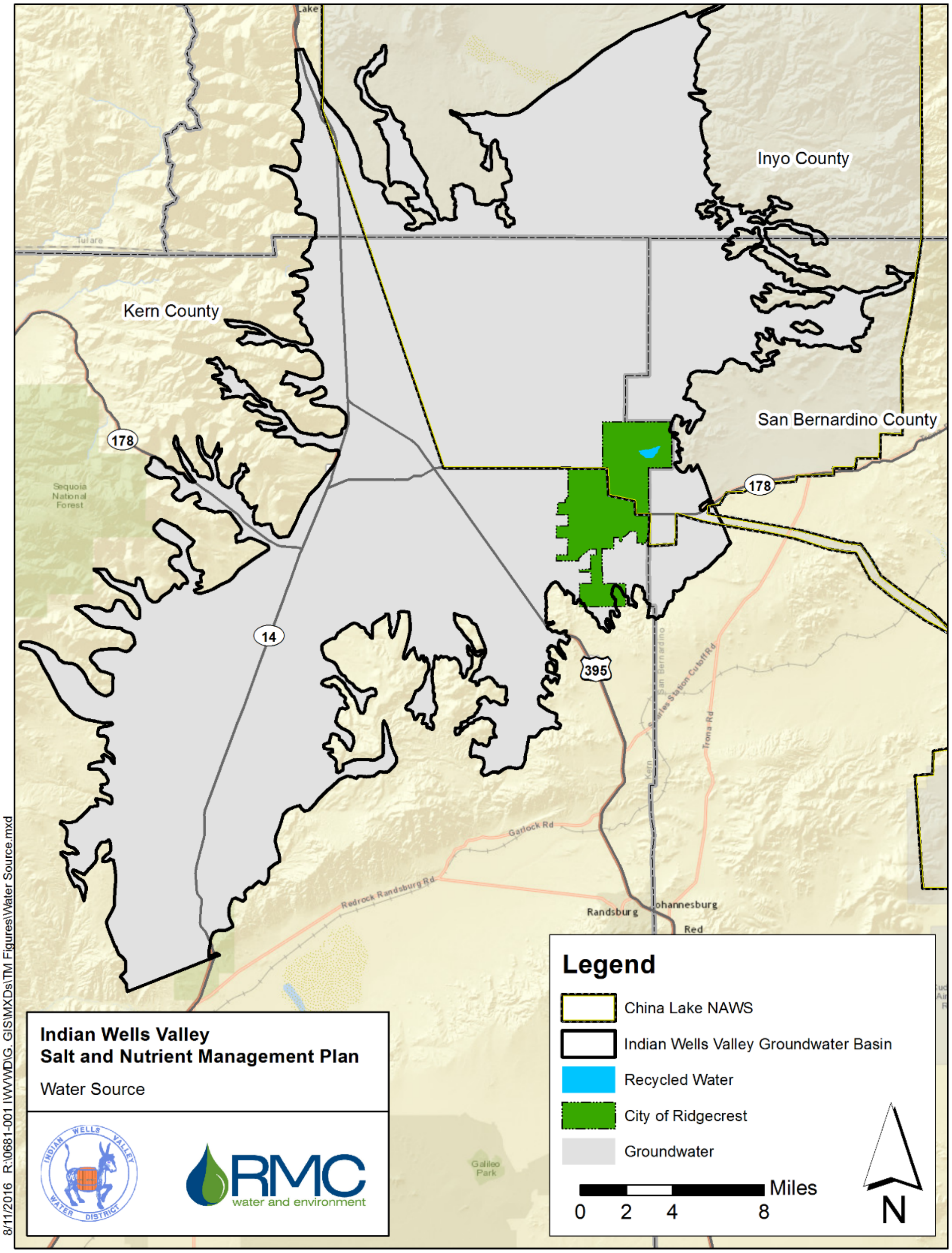
The golf course at the China Lake NAWS irrigates using reclaimed wastewater from the City of Ridgecrest wastewater treatment plant. TDS and nitrate values are taken as the effluent water quality values from the treatment plant.

Table 4-1 summarizes the water quality inputs used for each irrigation water source. The spatial distribution of water sources is shown in **Figure 4-1**.

Table 4-1: Water Quality Parameters for Loading Model Water Sources

Source	TDS (mg/L)	Nitrate (mg/L)
City of Ridgecrest	347	6 mg/L as NO3 1.36 mg/L Nitrate-N
Private groundwater*	310	3.07 as NO3 0.70 Nitrate-N
Reclaimed wastewater	670	3.36 as NO3 0.76 as Nitrate-N
Notes: *Median well values		

Figure 4-1: Water Sources



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4.2.3 Irrigation Loading

There are three typical uses of irrigation water in the Basin: alfalfa, pistachios, and turfgrass. These three crop types are evaluated to estimate overall irrigation water use as well as water quality of the water used for leaching. Total quantity of each of the three water sources is discussed **Table 4-5**. Crop water use is calculated using monthly average ETo for the region and the corresponding crop coefficient. Best available information is used for estimating the crop demand for alfalfa.

Salt accumulates in the root zone by salts left in the soil due to insufficient leaching. Leaching is the process of applying more water to the field than can be held by the soil in the crop root zone such that the excess water drains below the root system, carrying salts with it. The more water that is applied in excess of the crop water requirement, the less salinity there is left in the root zone despite the fact that more salt has actually been added to the field. The objective of leaching is to maintain or reduce soil salinity levels to levels that are equal to or less than the threshold salinity for the particular crops selected. Some crops are very sensitive to salts, while others can tolerate much higher concentrations. **Table 4-2** gives the salt tolerance threshold (EC_{ct}), above which yield reductions are likely.

Table 4-2: Salt Tolerance of Representative Indian Wells Valley Crops

Crop	Salt Tolerance Threshold ECct
Alfalfa	2
Pistachios	8.4
Turfgrass	6.9
Notes: units in mmoh/cm	

These crop tolerances, along with irrigation efficiency, are used to estimate the leaching fraction. The leaching fraction is the minimum fraction of the applied water that must pass through the crop root zone to prevent a reduction in yield from excessive accumulation of salts. Irrigation efficiency, considered when calculating the gross irrigation requirement, varies by crop type. For instance, turfgrass is irrigated through conventional irrigation methods while high frequency irrigation is more commonly used for tree crops.

This analysis assumes that the proper irrigation methods, tailored to the water, crop, and site conditions, and a high level of management are available to accomplish the efficiencies anticipated in this study for golf courses, sports fields, and other larger landscaping projects. Residential irrigation systems, on the other hand, are anticipated to have a lower application efficiency. Conveyance efficiency is assumed to be 95% while application efficiency varies with application system. Conveyance efficiency refers to losses during the delivery of water to the application system. Microsystems are assumed to operate at 90% efficiency while sprinkler systems are assumed to operate at 80% efficiency. However, the potential for increased water use and leachate production in residential irrigation systems is most likely offset by decreasing water use as more water efficient landscaping is installed, and in many cases, replacing existing turfgrass.

With trickle irrigation, very little of the fertilizer spread over the soil surface moves into the root zone. Therefore, much of the required fertilizer, especially nitrogen, must be added directly in the water through fertigation. From an agricultural perspective, the nitrogen content in the irrigation water can be viewed as a resource. Most of the nitrogen salts and urea dissolve readily in water and may be injected with no side effects in the water or irrigation system. Urea (44-0-0) is a soluble nitrogen fertilizer that is common in combination with trickle irrigation systems. It is a neutral molecule that does not react with water to form ions. Urea and ammonium nitrate are mixed in water to give a concentrated liquid mixture marketed as

32-0-0 Urea Ammonium Nitrate Solution (UAN) ammonium form. It is assumed for the purposes of this study that N loss through NH_3 volatilization is limited to 10 percent for high frequency UAN applications.

Given the following bulleted conditions in the Basin, an average regional Nitrogen Update Efficiency (NUE) between the state average and the practical upper limit of 80% can be reasonably expected at the individual farm level. Thus, for the purposes of this study, it is assumed that the NUE for all crops is 70 percent.

- Hot, dry climate,
- High irrigation efficiencies for pistachios,
- High percentage of groundcover and root coverage for alfalfa and turfgrass, and
- Controlled nitrogen fertilizer applications coupled with modest leaching (salinity) requirements.

Historical and recommended nitrogen fertilizer application rates and assumed NUE for the three key crops are shown in **Table 4-3**.

Table 4-3: Nitrogen Fertilizer Application Rates, lbs N/acre - year

Crop	Application Rates in CA	Published UC Guidelines		This Study	Crop Utilization Rate
	2005	Min	Max		
Alfalfa	10	20	60	10	70%
Pistachios	155	40	240	155	70%
Turfgrass	N/A	174	261	45[i]	70%
Notes: i) Peter Brown, owner of a local landscape company, noted that little fertilizer is used on lawns in the area. The value of 45 lbs/acre is based on Technical Report 2: Nitrogen sources and Loading to Groundwater, page 166 which notes this value as an overall national average.					

4.2.4 Septic Systems

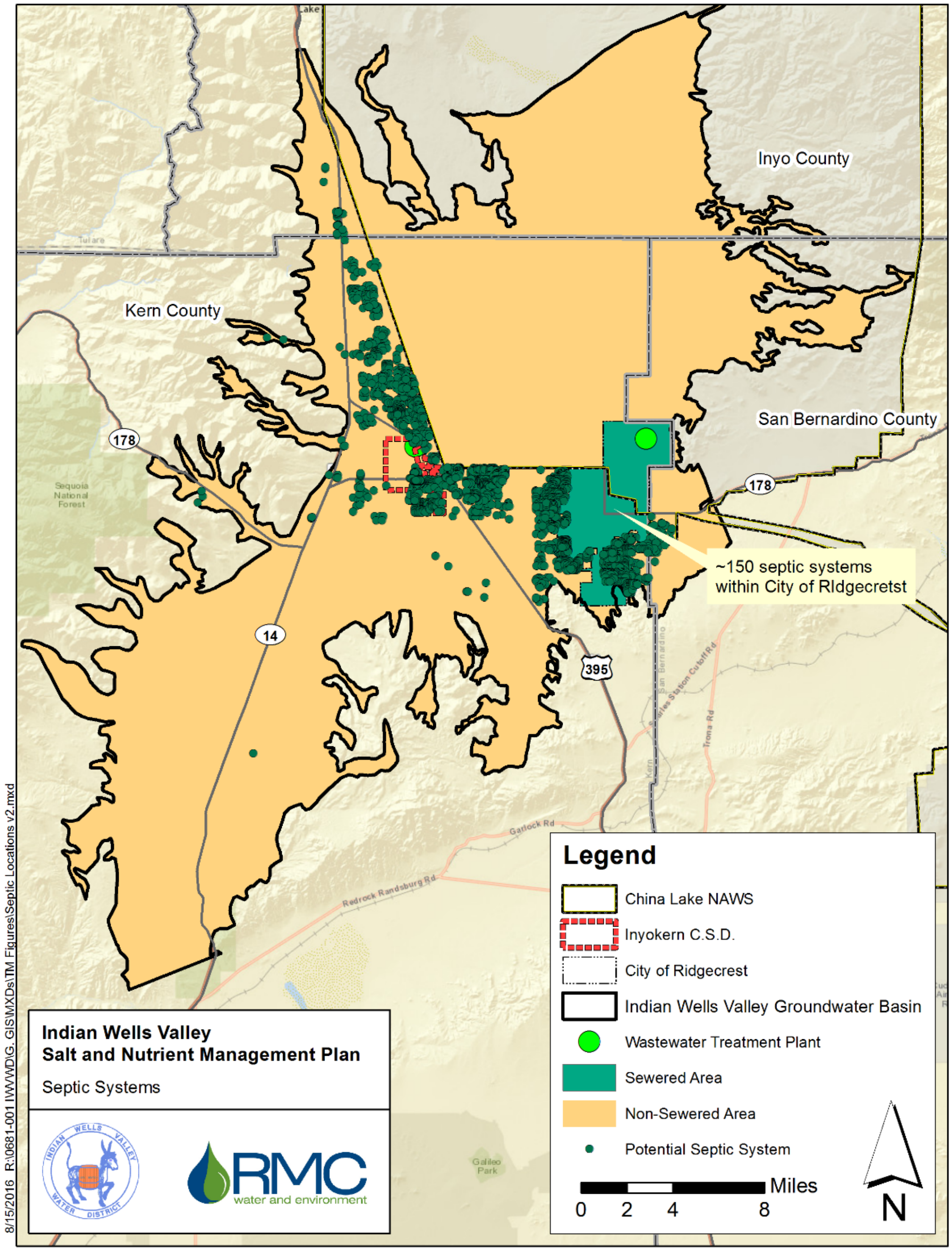
While a septic system dataset was not available, approximately 150 parcels within the City of Ridgecrest are not connected to the City system and are assumed to use individual septic systems. For parcels outside the City of Ridgecrest, it is assumed that any residence identified in the land use dataset has a septic system. Given the lack of flow or water quality information for the Inyokern CSD, any potential septic systems within the Inyokern CSD boundary were assumed to flow to the wastewater treatment plant. Each parcel with a septic system is assumed to produce 263 gallons per day (gpd), based on 75 gpd per person with an average of 3.5 people per system.

The 75 gpd per person estimate is based domestic use quantity estimates contained in the California Code of Regulations, Title 23, Section 697. An estimate of 3.5 persons per household is a conservative estimate which assumes that household size for homes with septic is larger than that that of homes within the City[1]. TDS concentrations in septic system effluent are assumed to be 670 mg/L across the basin, equivalent to the reported effluent concentration from the City of Ridgecrest wastewater treatment plant. Nitrate-N concentrations were assumed to be 30 mg/L, based on typical wastewater concentrations for medium strength wastewater of 40 mg/L minus an assumed volatilization rate of 25 percent within the

[1] Persons per household for 2010-2014 is 3.20 in Kern County, 3.34 in San Bernardino County, and 2.27 in Inyo County, with 2.56 people per household in the City of Ridgecrest. (United States Census Bureau, 2014)

septic system (Metcalf & Eddy, 2003). The areas within the basin that could potentially have septic systems based on the above assumptions are shown in **Figure 4-2**.

Figure 4-2: Potential Septic Systems



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4.2.5 Wastewater and Recycled Water Infrastructure

There are two wastewater treatment plants that are accounted for in the loading analysis. The City of Ridgecrest wastewater treatment plant operates with an average flowrate of 2.24 MGD based on 2014 and 2015 operation records provided by the City. Effluent water has a TDS concentration of 670 mg/L and a nitrate-N concentration of 0.76 mg/L (or 3.36 mg/L NO3). In addition, the Inyokern CSD operates a 0.035 MGD wastewater treatment plant. The effluent is assumed to have a TDS concentration of 670 mg/l, consistent with the reported effluent from the City of Ridgecrest, and has an assumed nitrate-N concentration of 30 mg/l, which is a typical value for medium-strength wastewater (Metcalf & Eddy, 2003).

Wastewater effluents are modeled as point loads applied to the Basin and nitrate loads are scaled based on the soil type where loads are applied. This is discussed in Section 4.5 Loading Model Results below.

A portion of the effluent from the City of Ridgecrest wastewater treatment plant is used for irrigation at the golf course at the China Lake NAWS. The applied water loads are calculated using the methodology described in Section 4.4 Input Factors.

4.3 Stakeholder Input on Loading Calculations

After the first iteration of the loading model, preliminary results were presented to the Cooperative Groundwater Stakeholder group on August 18, 2016 to collect comments regarding input assumptions. Several comments were received, which are discussed in further detail below.

A 2013 letter from local farmers suggested that the water use of mature pistachios ranges from 4 feet per year to 6.9 feet per year, with an average of 4.3 feet per year (Indian Wells Valley Farmers Group, 2013). This compares to the 4.8 feet per year in the existing analysis. This value was left unchanged as it is within the range indicated in the 2013 letter.

Meadowbrook Dairy provided information regarding fertilizer use and alfalfa through a survey (Imsand, 2016). The survey indicated alfalfa is rotated out into grain or grass. As the number of years in alfalfa versus grain or grass was not provided, this item was left as alfalfa in the analysis. The survey also indicated a mono ammonium phosphate (11-52-0) application rate of 300 pounds per acre per year; 300 lbs at 11% N is 33 lbs of N per acre per year. The analysis assumed 10 pounds per acre per year. This value was left unchanged in this study as it is within the range of values cited by stakeholders. The survey also indicated that no soil amendments were applied, which is consistent with the salt loading assumptions in the existing analysis.

Finally, IWVWD board member Peter Brown, a licensed landscape professional with over 30 years of experience, provided further insight into ET and fertilizer use. Mr. Brown cited a value of 81 inches per year for “basic evaporation” for alfalfa (Brown, 2016). This compares to 74 inches per year for ET used in this analysis and between 99 to 103 inches per year when considering leaching and irrigation efficiency. During the August 18, 2016, Cooperative Groundwater Stakeholder meeting, a range of 88 to 90 inches of applied water per year was given for alfalfa. Applied water for alfalfa is calculated using ET based on Brawley, California in the Imperial Valley, and standard conveyance and application efficiency for irrigation. When accounting for ET, and standard conveyance and application efficiency, the total annual applied water for alfalfa is 88 to 90 inches.

Mr. Brown also noted that alfalfa does not require nitrogen, while the analysis assumed 10 pounds per acre per year. This value was left unchanged in the analysis as it is within the range of values cited by stakeholders (Brown, 2016). Mr. Brown further noted that little fertilizer is used on lawns, compared to 200 pounds per acre used in this study. To address this comment, the value for fertilizer use on lawns was reduced to 45 pounds per acre. The updated value is based on page 166 of the Technical Report 2: Nitrogen Sources and Loading to Groundwater, which notes this value as an overall national average

(Vires et al, 2012). The previous value of 200 pounds per acre was based on an application rate of 4 to 6 pounds per 1,000 square feet.

4.4 Input Factors

Based on land use characterization, loading factors were associated with each land use grouping.

Table 4-4: Land Use Related Loading Factors

Land Use Group	Total Area (acres)	Percent Cultivated/ Landscaped[1]	Applied Water[2] (in/acre-year)	Applied Nitrogen[3] (lbs/acre-year)	Applied TDS[4] (lbs/acre-year)
Alfalfa	1,023	100%	89.5	4.35	6,293
Pistachio	2,001	100%	58	42.1	4,078
Urban Commercial and Industrial Outside Ridgecrest	573	5%	70.2	12.5	4,934
Urban CI Low Impervious Surface Outside Ridgecrest	28	30%	70.2	12.5	4,934
Urban Residential Outside Ridgecrest	8,068	15%	70.2	12.5	4,934
Urban Landscape or Golf Course Outside Ridgecrest	200	75%	70.2	12.5	4,934
Urban Commercial and Industrial Within Ridgecrest	416	5%	70.3	12.8	5,527
Urban CI Low Impervious Surface Within Ridgecrest	442	30%	70.3	12.8	5,527
Urban Residential Within Ridgecrest	1,919	15%	70.3	12.8	5,527
Urban Landscape or Golf Course on Recycled Water	179	5%	70.9	12.5	10,763

Notes:

1) Percent of land area assumed to be cultivated/landscaped within each class is estimated based on review of aerial photography and agricultural scientist professional judgment of a reasonable, broad average for each class.

2) Applied water values and other climatic data are calculated based on crop evapotranspiration, reference evapotranspiration, leaching fraction for salinity control, and irrigation efficiency.

3) Applied nitrogen estimates are based on literature review for individual land cover classes and professional judgment.

4) Applied TDS estimates are based on literature review for individual land cover classes and professional judgment.

4.5 Loading Model Results

Based on the loading parameters and methodology described above, the loading model was used to develop TDS and nitrogen loading rates across the Basin (**Table 4-6**).

Table 4-5 summarizes the overall contribution of each land use group to total TDS and nitrogen loading. The spatial distribution of TDS and nitrogen loading rates are shown in **Figure 4-3** and **Figure 4-4**, respectively. Loads from septic systems and wastewater treatment plants were calculated as point loads and then applied (**Table 4-6**).

Table 4-5: TDS and Nitrate Loading Results

Land Use Group	Total Acres	Percent of Total Area	Total TDS Load (lbs)	Percentage of Total TDS Loading	Total N Load (lbs)	Percentage of Nitrogen Loading
Alfalfa	1,023	7%	6,440,000	20%	2,200	2%
Pistachio	2,001	13%	8,160,000	26%	41,500	44%
Urban Commercial and Industrial	989	7%	260,000	1%	300	0%
Urban CI Low Impervious Surface	470	3%	770,000	2%	900	1%
Urban Residential	9,987	67%	7,560,000	24%	9,300	10%
Urban Landscape or Golf Course	379	3%	2,180,000	7%	1,800	2%
WWTP			4,640,000	15%	4,100	4%
Septic			1,510,000	5%	33,200	36%
Note: Loading factors are reflective of existing conditions within the basin.						

The relative proportion of the land uses by area, TDS loading, and nitrogen loading are shown in **Figure 4-5**, **Figure 4-6**, and **Figure 4-7**, respectively.

Figure 4-3: Estimated TDS Loading

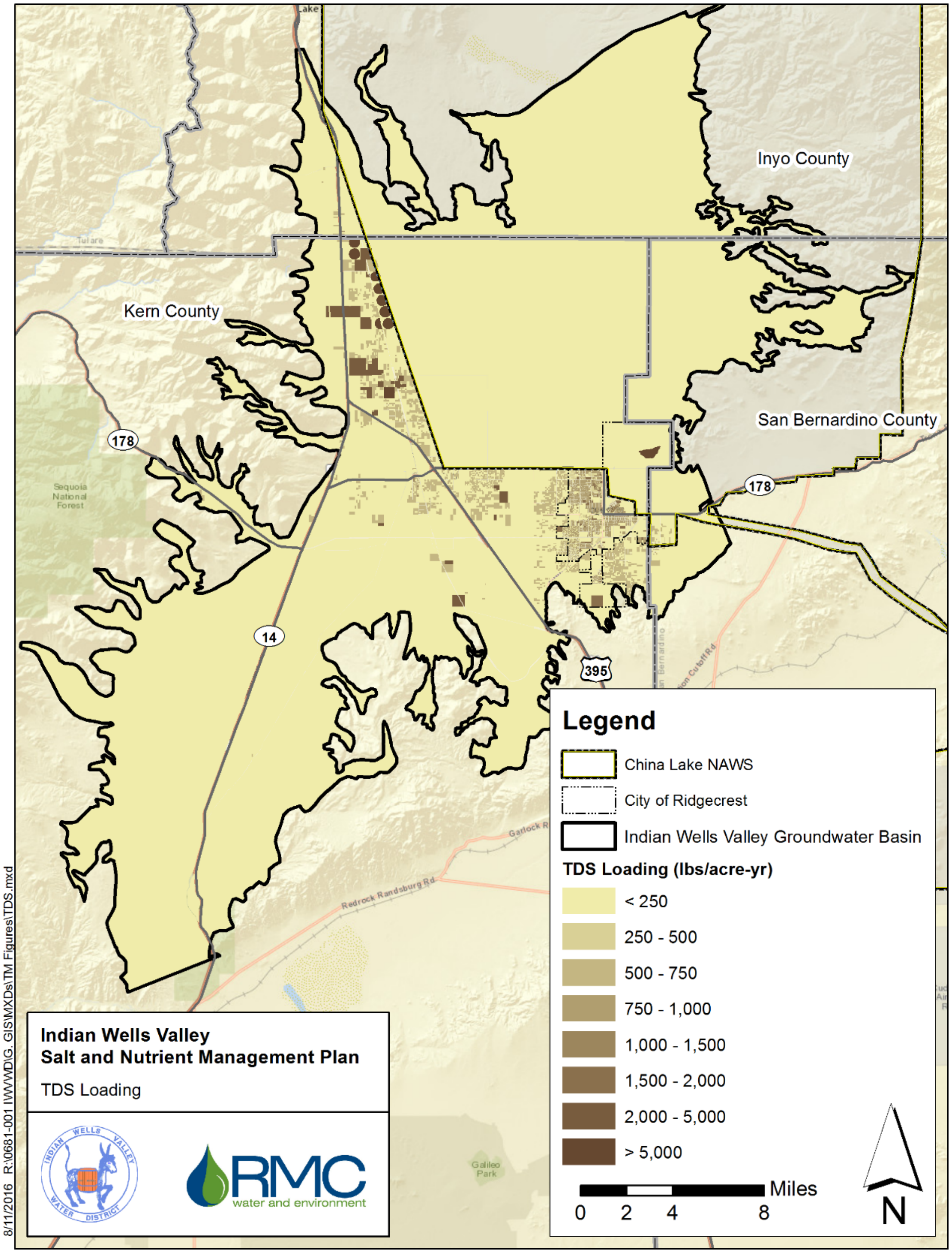

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Figure 4-4: Estimated Nitrate Loading

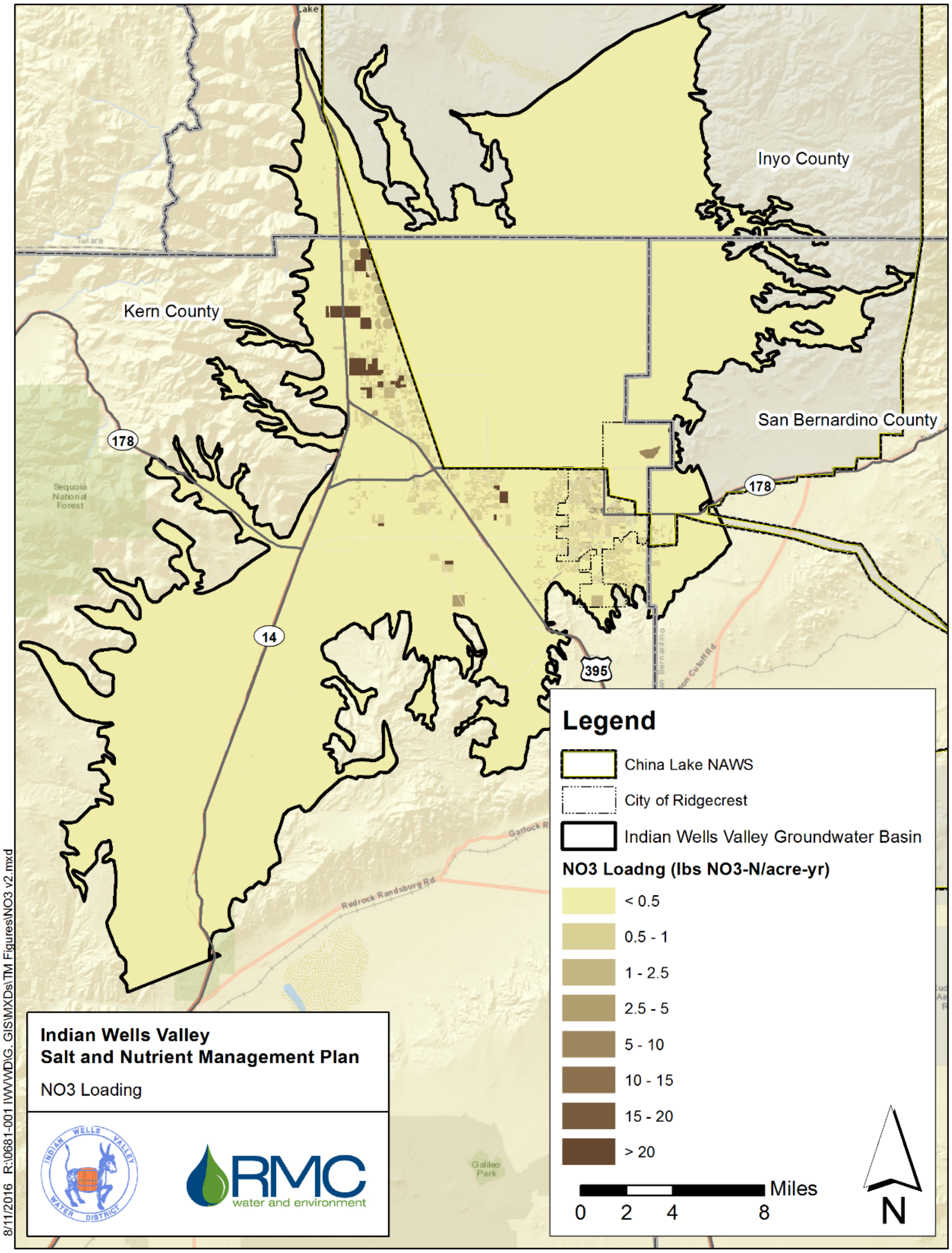

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Figure 4-5: Total Developed Land Use in Study Area

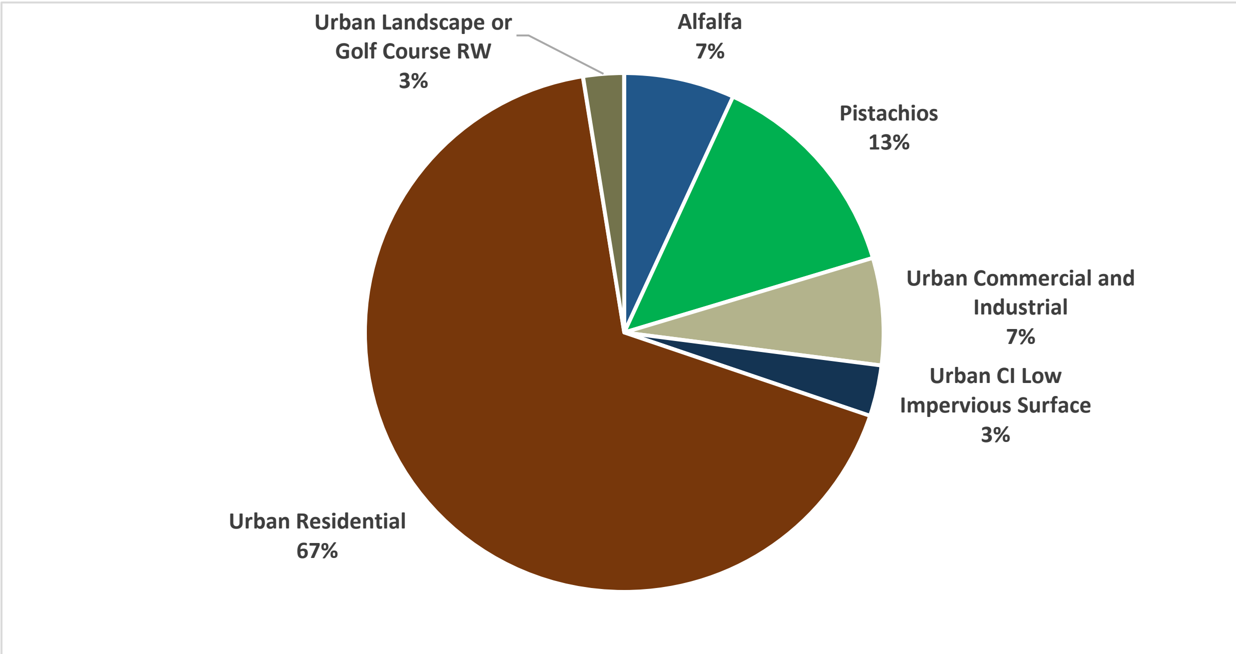


Figure 4-6: Total TDS Loading in Study Area, by Land Use

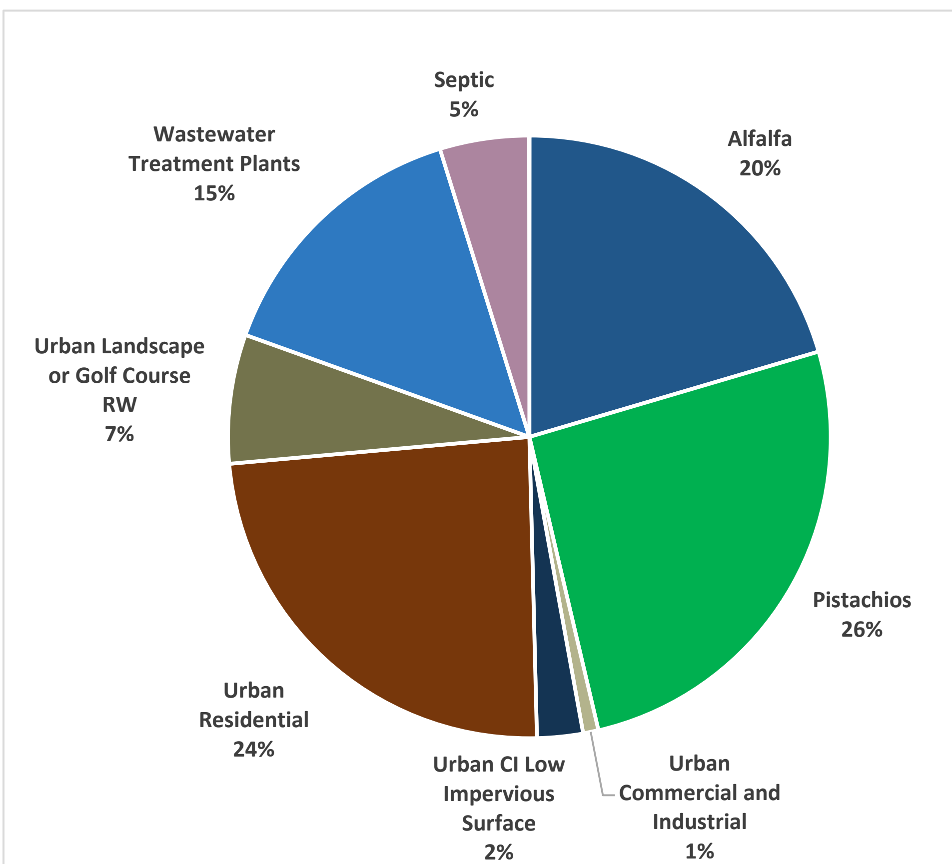
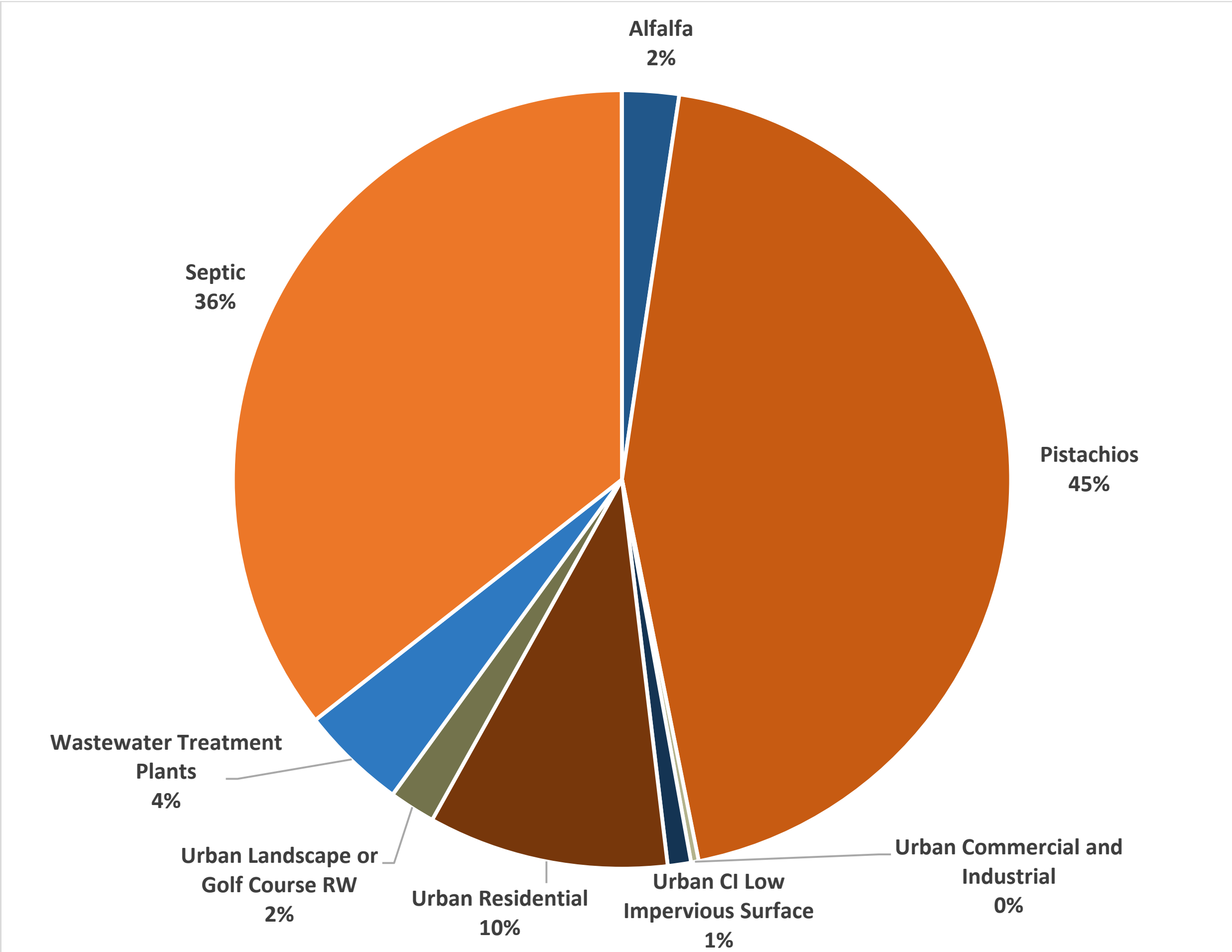


Figure 4-7: Total Nitrogen Loading in Study Area, by Land Use



4.6 Basin Assimilative Capacity for Salt and Nutrients

In accordance with the Recycled Water Policy, the available assimilative capacity shall be calculated by comparing the water quality objectives with the average ambient salt and nutrient concentrations in the Basin over the most recent five years of available data over a period approved by the Regional Water Board. Average concentrations were developed using a longer time period for this analysis due to the limitation of data available. The data set utilized for baseline water quality was a subset of 34 monitoring wells over a period of 1986 to 2013. The resulting average TDS concentration is 310 mg/L, and the Basin Plan water quality objectives for TDS are SMCLs of 500 mg/L. Therefore, there is an assimilative capacity of 190 mg/L for TDS within the Basin. For nitrate as nitrogen, the average concentration is 0.70 mg/L, and the Basin Plan water quality objectives are MCLs of 10 mg/L. Therefore, there is an assimilative capacity of 9.3 mg/L for nitrate as nitrogen within the Basin.

Loading model results indicated the highest TDS loading was found within the agricultural and urban residential land use groups. The highest nitrate loading was found within the agricultural land use groups and septic system point loads. Utilizing a spreadsheet-based mass balance model, loading results are projected to increase over 25 years from 310 mg/L to 446 mg/L for TDS and from 0.70 mg/L to 1.05 mg/L for nitrate as nitrogen. The analysis shows there is assimilative capacity in the basin for both TDS and nitrate relative to basin water quality objectives of 500 mg/L of TDS and 10 mg/L nitrate, however loading increases over time.

5 Projected Water Quality Trends

5.1 Groundwater Quality Trend Analysis

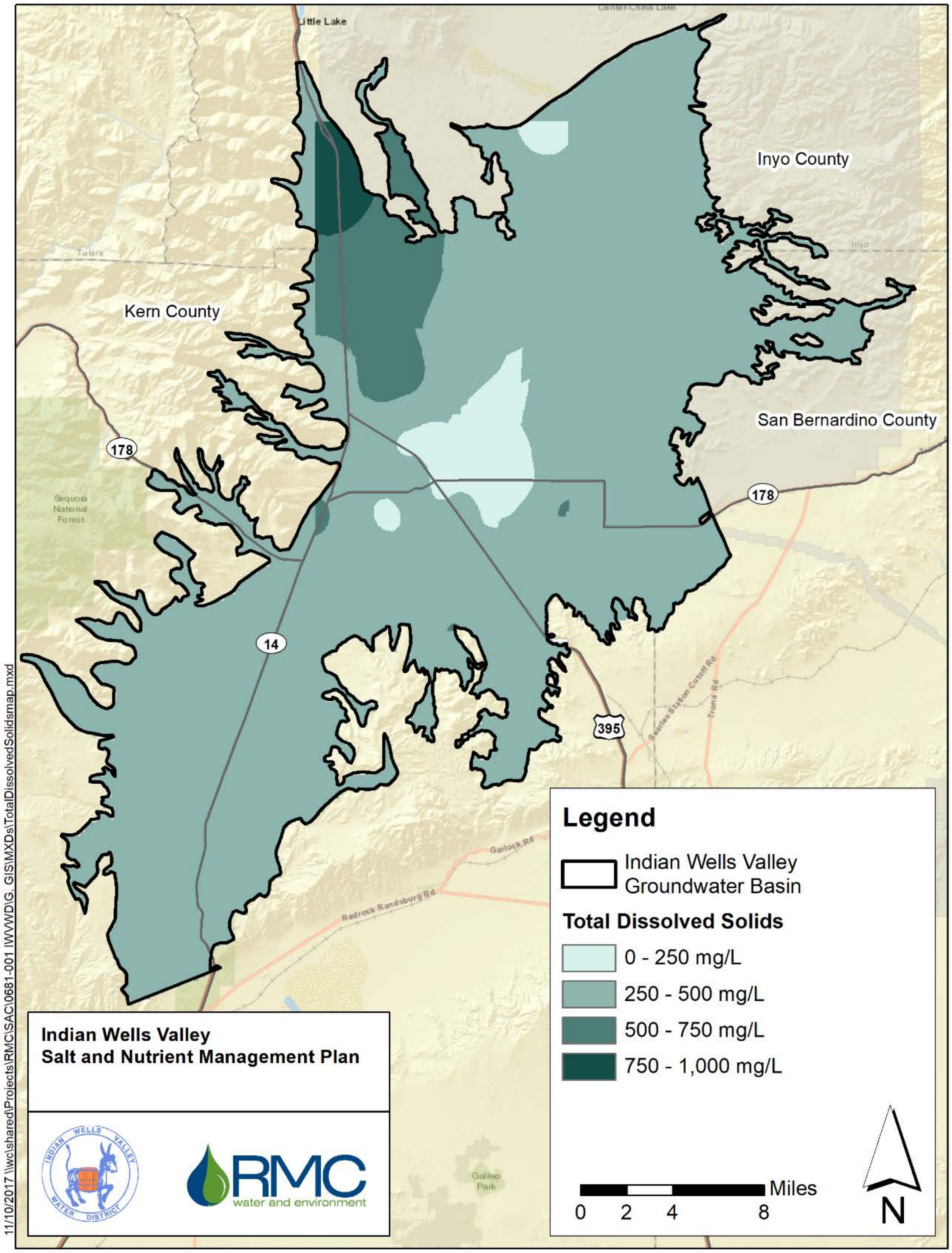
For this analysis, a groundwater mixing model was developed to:

1) Simulate trends in water quality,
2) Quantify the impacts of future scenarios on the Basin, and
3) Evaluate those potential impacts against water quality objectives set forth for the groundwater basin in the Basin Plan.

To facilitate trend analysis, a thorough review of previous basin studies and models was undertaken to determine annual flows. Concluding this effort, the Indian Wells Valley Resource Opportunity Plan: Water Availability and Conservation Report was used in conjunction with the loading analysis (Section 4 Salt and Nutrient Sources and Loading) to establish the annual groundwater budget shown in **Table 2-3** (Todd, 2013).

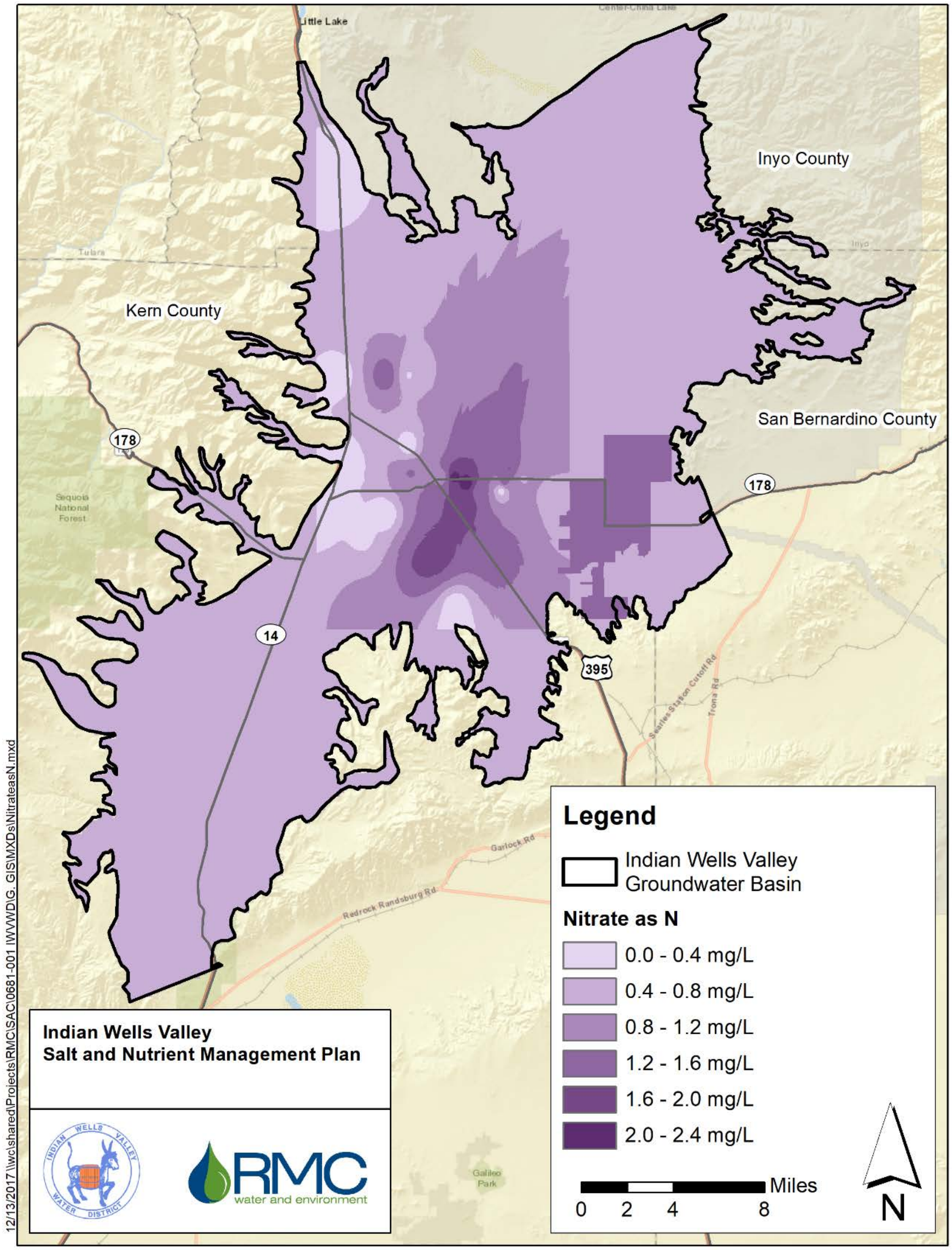
As described in Section 4.7 Basin Assimilative Capacity for Salts and Nutrients, water quality parameters for the Basin were generated using TDS and nitrate concentrations at the 34 monitoring wells in the basin. These 34 wells are a combination of navy wells, IWVWD wells, and outlying USBR wells which have historical water quality concentration data and were reported on in the early draft version of the SNMP. Spatial averaging across the basin using these 34 monitoring wells shows a basin-wide average TDS concentration of 310 mg/L and 0.70 mg/L of nitrate as nitrogen. These are average concentrations for the entire basin, a simplification of actual conditions, but appropriate for this high-level planning and trend analysis. These basin wide average concentrations for TDS and nitrate and nitrogen are shown in **Figure 5-1 and Figure 5-2**, respectively.

Figure 5-1: Basin-wide Average Concentration of TDS



Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap

Figure 5-2: Basin-wide Average Concentration of Nitrate as Nitrogen



Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap

5.2 Methodology for Groundwater Quality Trend Analysis

Groundwater quality concentrations for TDS and nitrate were simulated using a spreadsheet-based mass balance model. To simulate the effect of current and future loading on groundwater quality, the spreadsheet model dynamically calculated the loading factors of each component based on the conditions at the simulated time step. Under this model, each flow component listed in the groundwater budget was combined with its respective concentration of either TDS or nitrate to determine loading from the constituent's mass. These transfers of mass were then completely mixed with groundwater in the aquifer system on an annual time-step to determine the resulting concentrations in the basin.

Water quality modeling is intended to evaluate and simulate trends in TDS and nitrate as nitrogen. The surface and aquifer loading, used to determine water quality, was calculated utilizing the following equations:

Surface Loading:

$$X_t = X_{t-1} + \sum_{j=1}^{m} Q_{t\,j} C_{t-1\,j}$$

Aquifer Loading:

$$M_t = M_{t-1} + \sum_{i=1}^{n} Q_{t\,i} C_{t-1\,i}$$

$$C_t = M_t / S_t$$

Where: $\mathbf{X_t}$ is the mass of the constituent in the root zone available for deep percolation.

$\mathbf{M_t}$ is the mass of the constituent in the subregional aquifer at timestep t.

m is the total number of budgetary flow components (j) experienced by the root zone (applied water, fertilizers, septic systems, and waste water facility discharge).

n is the total number of budgetary flow components (i) experienced by the groundwater system (deep percolation, subsurface boundary flows, and groundwater pumping).

$\mathbf{Q_t}$ is the flow into, out of, or between adjacent basins at timestep t.

$\mathbf{C_t}$ is the concentration of the constituent at timestep t.

$\mathbf{S_t}$ is the end-of-year storage in the groundwater system at timestep t.

5.3 Basin Loading Results

Based on the analysis documented herein, it is estimated that on a 25-year time horizon (starting in 2015), the average TDS across the Basin will rise from the current basin-wide average of 310 mg/L to 446 mg/L and nitrate as nitrogen will increase slightly from the current basin-wide average of 0.70 mg/L to 1.05 mg/L. This is based on a regional scale analysis, looking at the groundwater basin and multiple aquifers as one unit. This level of analysis is an appropriate scale for the high-level, regional planning purposes required under the Recycled Water Policy. These trends are shown in **Figure 5-3** and **Figure 5-4** below.

Figure 5-3: Simulated Average Basin-wide Groundwater Concentration of TDS (including Reclaimed Water Buildout Scenario)

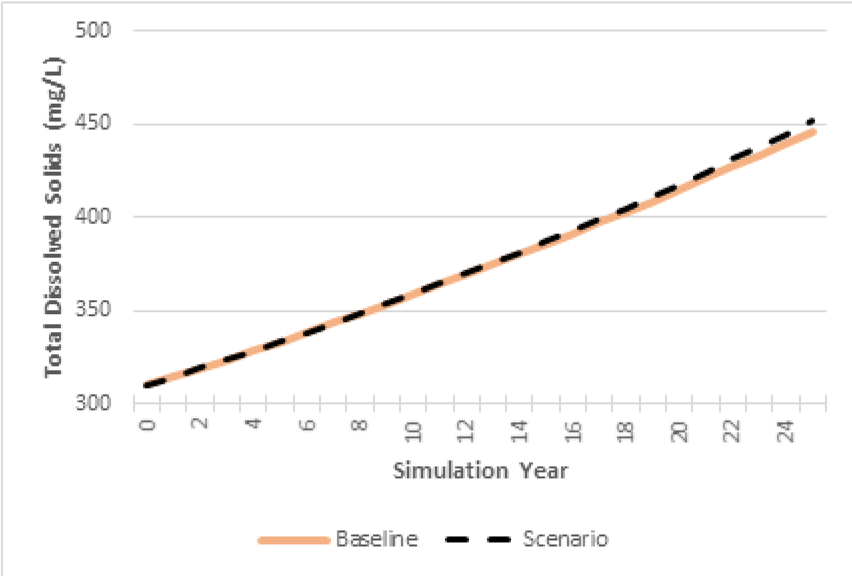
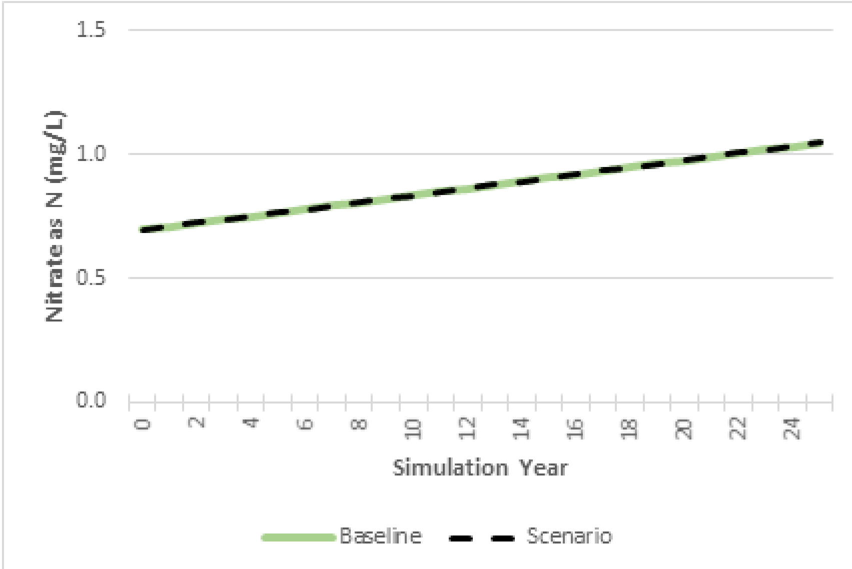


Figure 5-4: Simulated Average Basin-wide Groundwater Concentration of Nitrate as Nitrogen (including Reclaimed Water Buildout Scenario)



A future scenario incorporating projected expanded recycled water use (from 3,115 AFY in 2015 to 4,600 AFY in 2040) was also modeled. Future loading results are projected to increase over 25 years from 310 mg/L to 452 mg/L for TDS and from 0.70 mg/L to 1.05 mg/L for nitrate as nitrogen accounting for increased recycled water usage (little change in nitrate-N given background concentrations are similar to reclaimed water from City). Although the simplified SNMP analysis models a trend of increasing salinity and nutrients in the basin, this increasing trend is not seen as a strong trend in the historical dataset utilized for this analysis. This indicates the modeling approach is conservative and management measures in place are effective at mitigating accumulation in the Basin. Additionally, a new brackish groundwater study which would export salt from the basin is underway and would further support stabilization of any future increases.

6 Recycled Water and Stormwater Reuse/Recharge

6.1 Recycled Water and Stormwater Reuse/Recharge Goals and Objectives

The goals for use of recycled water and stormwater recharge in the subasin were developed based on collaboration with other planning exercises within the basin and on the information contained in the UWMP and other planning documents.

Goals are:

- Recycled Water: Expand reclaimed wastewater use in the basin from 3,115 AFY in 2015 to 4,600 in 2040
- Stormwater: Explore the potential for utilization of stormwater for recharge purposes collaboratively through the IRWM program partnership

Currently, approximately 3,115 AFY of reclaimed wastewater is utilized within the basin for golf course irrigation, agriculture and percolation for environmental benefit. Future planned use, and hence the recycled water goal for the basin is 4,600 AFY which would expand irrigation. This future estimate does not account for aggressive conservation which would decrease the demand. Recycled water use may be a key management measure that emerges from the GSP. Current and future recycled water use is detailed below.

Agencies and stakeholders in the basin are planning to increase the ability to put stormwater to beneficial use. Currently, IWVWD is coordinating with other stakeholders through the Inyo-Mojave IRWM to identify potential stormwater reuse/recharge projects. However, the benefit of recharging stormwater (which is likely to be low in TDS) is not included in the groundwater quality analyses in this Plan due to uncertainties in the projected quantity and volumes of stormwater recharge at this time.

Current Wastewater Reclamation

Within the Basin, reclaimed wastewater is currently used only by the City of Ridgecrest and the Navy. Through an agreement for coordination of facilities in exchange for use of recycled water, the Navy is provided (and typically uses entirely) an allotment of 748 AFY of treated effluent. This water is used to irrigate a golf course after disinfecting with chlorine. In addition, approximately 224 AFY of secondary-treated effluent is used for irrigation on an alfalfa farm managed by the City of Ridgecrest. The remainder of treated effluent is evaporated (averaging 96-inches of evaporative loss) or percolated in evaporation/facultative ponds (IWVWD, 2016).

These evaporation ponds must be constantly supplied to provide adequate percolation into the nearby Lake Seep, which serves as endangered species habitat for the Mohave tui chub (*Gila bicolor mohavensis*). At times, for example drought years with stringent water conservation measures, there is only enough effluent to supply the Navy and endangered fish habitat. **Table 6-1**, prepared for the IWVWD 2015 UWMP, shows the quantities of secondary-treated effluent used during the period 2005 through 2010.

Table 6-1: Historical Wastewater Reclamation(1) (AFY)

	2010	2011	2012	2013	2014	2015
Navy(2)	748	748	748	748	748	748
City of Ridgecrest(3)	2,189	2,010	2,053	1,831	1,842	2,367
IWVWD	0	0	0	0	0	0
Total	**2,937**	**2,758**	**2,801**	**2,579**	**2,590**	**3,115**

Note:
1) All treatment plant effluent is either treated further and used for irrigation or is percolated into the ground to supply water to the Lark Seep
2) Fixed allotment
3) Source: *Wastewater Treatment Plant Facility Plan, City of Ridgecrest, CA, October 2015 Review Draft*, prepared by Provost & Pritchard Consulting Group

Potential Future Recycled Water Use

Future wastewater reclamation opportunities within the Basin are primary landscape irrigation projects, such as roadway medians, freeway landscape, schools, cemeteries, golf courses, parks, and equestrian properties throughout the Indian Wells Valley. It is difficult however to quantify potential uses due to seasonal variations in supply since there is not a constant source beyond what is already committed to the Navy, endangered fish refuge, and City of Ridgecrest's alfalfa farm. For the IWVWD, even when there is a temporary surplus of recycled water supply, construction of a tertiary treatment facility and recycled water conveyance pipelines would be required for the effluent to meet recycled water standards for use within its service area (IWVWD, 2016).

Additionally, the City of Ridgecrest is designing a new wastewater treatment plant, with 30 percent design and EIR documentation completed. The current new plant design is planning for tertiary treatment, a capacity of 3.6 to 4.0 MGD, and will either be at the current water treatment plant (WTP) location on China Lake NAWS property, or at the former WTP on City of Ridgecrest property. Potential recycled water uses will be the golf course, parks, school athletic fields, China Lake NAWS turf and irrigated areas, and indirect potable reuse. A recycled water study is planned as part of the GSP preparation to determine demand, availability, cost, use and to set goals and objectives.

In accordance with the Cooperative Groundwater Management Plan Objective #4 "The Parties will consider, individually or collectively, use of non-potable water, such as treated sewage effluent or poorer quality sources, for appropriate re-use applications. The Parties will consider constructing, individually or collectively, recharge facilities including spreading basins and other types of facilities to capture and conserve storm water flows to augment efforts to replenish groundwater reserves. Water treatment and blending of different quality waters should be pursued to extend the life of the groundwater resource" (Kern County, 2006). Projected use of secondary-treated effluent for the period 2020 through 2040 is shown in **Table 6-2** (IWVWD, 2015).

Table 6-2: Projected Recycled Water Use[1] (AFY)

	2020	2025	2030	2035	2040
Navy[2]	748	748	748	748	748
City of Ridgecrest[3]	2,750	3,066	3,410	3,784	3,852
IWVWD	0	0	0	0	0
Total	**3,498**	**3,814**	**4,158**	**4,532**	**4,600**

Note:
1) All treatment plant effluent is either treated further and used for irrigation or is percolated into the ground to supply water to the Lark Seep
2) Fixed allotment
4) Source: City of Ridgecrest (based on 1.8% per year estimated growth)
5) 4) 2040 estimates do not account for increased conservation, so future estimates may be much lower than stated

7 Groundwater Monitoring Plan for SNMP

A comprehensive groundwater monitoring plan will be developed for the GSP. For this SNMP, a preliminary subset of wells has been identified by the Navy which should ultimately be incorporated into the monitoring plan for the GSP. It is recommended that wells selected for SNMP monitoring be sampled on an annual basis. Results of the monitoring should be submitted triennially to the Lahontan Region Water Board. The GSA will determine who will be the responsible party for collecting samples, compiling the results in tabular form, updating/revising the Monitoring Plan and submitting it to the GSA. The GSA will submit the Monitoring Report to the Lahontan Region Water Board.

7.1 Monitoring Program Goals

The groundwater level and water quality monitoring program for this SNMP (to be incorporated into the larger GSP monitoring program) is designed to accomplish the following:

1) Document groundwater level and groundwater quality trends through time;
2) Identify salt and nutrient constituents of concern;
3) Identify potential sources of salts and nutrients;
4) Identify existing monitoring well locations that will be used to track potential changes in water quality over time; and
5) Conduct fate/transport evaluations of the constituents of concern.

7.2 Water Quality Parameters

7.2.1 Primary Parameters

The recommended parameters to be monitored for SNMP purposes include electrical conductivity (EC), TDS and nitrate, in addition to general minerals and physical constituents. The general mineral constituents to be analyzed may include: calcium, magnesium, sodium, potassium, carbonate, bicarbonate, hydroxide, chloride, sulfate, nitrate, nitrite, MBAS, TDS, pH, copper, iron manganese, zinc, conductivity, hardness, fluoride, color, odor, and turbidity.

Additional parameters may be monitored as determined by the GSA as part of the GSP Monitoring Plan.

7.2.2 Other Constituents of Concern

As described in Section 3.2 California's Groundwater Ambient Monitoring and Assessment (GAMA) Program, five constituents with human health benchmarks (arsenic, boron, molybdenum, strontium, and vanadium) and three with non-health benchmarks (chloride, manganese, TDS, and sulfate) were detected at high concentrations. In addition, radioactivity (uranium and gross alpha) were detected in high concentrations in 15% of samples, and perchlorate present at moderate concentrations in 15% of the primary aquifer.

Existing data needs to be assessed for effects of these constituents on beneficial uses of water and should be considered for inclusion in the GSP Monitoring Program.

7.2.3 Constituents of Emerging Concern

Constituents of Emerging Concern (CECs) is a term used to describe a broad range of unregulated chemical components, including pharmaceuticals and personal care products, that are being found at trace levels in many water supplies. A "blue ribbon" science advisory panel, convened by the State Water Board, prepared a report titled, "Monitoring Strategies for Chemicals of Emerging Concern in Recycled Water", which presented recommendations for monitoring CECs in municipal recycled water used for groundwater recharge. The Recycled Water Policy Attachment A states that "Monitoring of health-based CECs or performance indicator CECs is not required for recycled water used for landscape irrigation due to the low risk for ingestion of the water."

The SNMP monitoring plan does not include a recommendation for monitoring CECs. Future monitoring of CECs will be incorporated, as applicable, through the GSP process and under the direction of the State Water Board.

7.3 Sampling Frequency

Each well will be sampled on an annual basis or until such time the data provides sufficient evidence to extend or reduce the sampling frequency. Rationale to decrease sampling frequency may include repeated constituent levels well below MCL's, while rationale to increase the sampling frequency may include a constituent continuing to exceed MCL's and its proximity to public supply wells and/or domestic wells. No temporal or seasonal changes in groundwater quality are expected because very little, if any, precipitation infiltrates the ground surface and percolates to the top of the shallow aquifer, much less the deep aquifer(s), where the SNMP sampling points are located.

7.4 Quality Assurance/Quality Control

7.4.1 Data Reliability

Anomalous results from sampling may be a result of well construction problems, faulty monitoring equipment or localized groundwater contamination. Data obtained from wells should be scrutinized to determine if the data is representative of groundwater levels or water quality conditions of the area. This can be done by repeat measurement (water levels) to make sure that obstructions or cascading water in the well is not giving false readings. Groundwater quality sampling should include travel blanks and spikes to ensure that contamination of the sample or mishandling by the laboratory has not occurred.

7.4.2 Field Equipment Calibration

Water quality parameters (pH, specific conductance, and temperature) will be monitored while groundwater is purged via a flow-through cell. The water will pass through the cell, and measurements will be made with probes installed in the cell. Equipment used to measure these parameters will be calibrated according to manufacturer instructions. Each probe will be calibrated at the beginning of each day of sample collection. The pH probe will be calibrated to bracket pH values of 7.4-10.4. While the temperature probe has an internal electronic calibration, the specific conductance probe is not calibrated and rather checked against a standard (the meter cannot be adjusted).

7.4.3 Field Duplicate Samples

Field duplicate samples (laboratory quality check) are two samples collected at the same time, by the same method, from the same source, and submitted as separate samples for analysis. Duplicate samples for this plan will be collected at a frequency of 10 percent. Each duplicate will be analyzed for the same parameters as the real sample. All duplicate samples will be collected, numbered, packaged, and sealed in the same manner as the real samples.

7.5 Field Sampling Procedures

The field sampling procedures are outlined in **Table 7-1**.

Table 7-1: Field Sampling Procedures

Method	Description	Minimum Requirements	Comments
Bailing	Removing water with a bailer	Remove 3-5 well volumes or until pH, conductivity, and temperature stabilize*	
Submersible Pump	Removal of water with a submersible pump	Same as above	
Air Lifting	Displacing volume of water with compressed air	Same as above	
Micropurge	Slow removal of water with pump set within the screened interval	Remove water that is contained within the casing from pump depth to surface**	1) Depth limitations due to pump capacity 2) When using portable pump, samples should not be collected until 24 hours after setting pump in the well bore

Notes:
* Complete description of requirements given in EPA Guidance Document.
** Complete description of requirements given in Barcelona & Puls, 1996.

7.5.1 Record Keeping

Each time that a water level or water quality sample is collected from a monitoring program well, the water level and/or the water quality analysis results will be recorded into the Kern County Water Agency database. Currently, water level readings are recorded into a bound field notebook and then transferred into the database maintained by the agency. In the future, all data transferred into the agency's database should also be archived at the Eastern Kern County Resource Conservation District or IWVWD.

Each time a well is sampled for water quality, the field notes should specify analysis methods, how and when the well was purged and sampled, amount of water removed during the purging, and general field comments. This field data and all the analytical results should be archived in the Kern County Water Agency's database.

7.5.2 Groundwater Sampling Protocol

Groundwater samples collected as part of the SNMP should be collected using the following guidelines:

1) Prior to sampling, a water level measurement will be obtained from each well. Water levels will be used to construct a water elevation contour map and to determine volume of water in the well.
2) Wells shall be purged with a submersible pump until 3-5 well volumes of water (not including development) were removed or until consecutive readings of conductivity, temperature, pH, and dissolved oxygen were within 10% of the previous two readings. Readings shall be collected every 5 to 10 minutes dependent on the discharge rate. At least 5 consecutive readings should be

collected regardless of field parameters. Readings shall be collected by passing water through a flow-through cell connected to a meter.

3) Samples shall be filtered in the field (where possible) with a disposable in-line 0.45 micron filter prior to being placed in the sample container.
4) Samples for water quality analysis shall be collected in containers appropriate for the analysis intended.
5) Each sample container shall be labeled with the well number/location, date/time of sample collection, and sampler's name. The samples shall be delivered to the laboratory under chain-of-custody.

7.5.3 Sample Analysis

Field parameters of conductivity, pH, temperature and dissolved oxygen shall be monitored during purging. Samples shall be filtered and preserved as specified for each analyte (TDS/nitrate/etc.) and shipped to the appropriate laboratories for analysis.

7.6 Water Quality Data Management

All data collected and analyzed for this sampling program will be compatible with the existing CALABASH database utilized by the Kern County Water Agency. Responsibility for data input will be decided as part of the GSP Monitoring Plan and will depend on personnel availability, computer (hardware and software) capabilities, and schedules.

7.7 Sampling/Monitoring Areas

Five areas of the Basin (23 wells total) have been selected to be the focus of this SNMP sampling program based on previous sampling completed by the Navy, IWVWD, SVM, and University of Utah along with that completed during the AB303 and one subsequent round of sampling conducted by the Navy in 2008. The five areas include; the Southwest Area, West Area, North-Northwest Area, Central Area, and the Southeast Area (see **Figure 2-7** for well locations). All areas except the North-Northwest Area and Southeast area are currently monitored by individual entities including the IWVWD, Searles Valley Minerals (SVM), China Lake NAWS, and ICSD as part of their respective State water permit requirements. However, no comprehensive or cooperative sampling program has been established for any of the five areas.

7.8 Sampling Plan Well Types

A combination of monitoring wells, domestic wells, and public supply wells that have been sampled since the late-1980s will be utilized in the sampling program well network. All well sites are accessible through permission of the private and public land owners (domestic well owners/SVM/IWVWD/SVM), and federally-managed lands (China Lake NAWS/Bureau of Land Management). All wells incorporated into the sampling well network have complete well construction records including known perforated intervals to allow evaluation of both vertical and horizontal components of the aquifer system(s) and the knowledge of which water-bearing zone is being sampled and analyzed.

7.8.1 Southwest Area

The southwest area encompasses the portion of the Basin located south of West Ridgecrest Boulevard and west of the southern extension of Brown Road (Water District Well #34 is included in the Southwest Area since it is located approximately 1000 ft. east of southern Brown Road). This area covers over 90 square miles of coalescing alluvial fans dissected by two large washes (Little Dixie and Freeman). Monitoring wells drilled and sampled during the most recent AB 303 Project show fairly high water quality throughout the northern portion of the Southwest Area. There are approximately fifteen monitoring wells now located in the area although the majority of those wells are concentrated in T27S/R28E and were drilled during the AB 303 Project. Additional sampling points could be used in this area by either contacting local well owners for permission to sample or by drilling additional monitoring wells further to the south of the AB 303 Study Area. **Table 7-2** shows the sampling points (monitoring wells) in the Southwest Area that have at least three or more water analyses collected since 1990.

Table 7-2: Southwest Area Monitoring Well Information

Well Location	Well Type	Well Diameter/ Material	Pump Installed (?)	Owner	TD	Perforated Interval(s)	Wellhead Elevation
BR#1 (S)	M	2”	No	BLM	635’	61’5-635’	2852.20’
BR#2 (S)	M	2”/S	No	BLM	640’	620’-640’	2658.80’
WD Well #18	P	16”/S	Yes	WD	1020’	560’-890’	2560.74’
WD Well #33	P	16”/S	Yes	WD	1020’	560’-1000’	2558.25’
WD Well #34	P	20”/S	Yes	WD	955’	550’-86’5; 895’-935’	2440.52’

Notes:
1) Well Type: M =Monitoring, P = Public Water Supply
2) TD = Total depth of well
3) Well Diameter/Material: 12"/P = 12 inch well cased with PVC; 8"/S = 8 inch well cased with steel

7.8.2 West Area

The west area includes the general area from West Ridgecrest Boulevard (southern boundary) to the Leliter Road (northern boundary) and from Hwy 14 to China Lake NAWS western boundary fence line. The area encompasses approximately 35 square miles and is characterized by wide, coalescing alluvial fans along the eastern slope of the Sierra Nevada and fairly flat, low-gradient desert toward the middle of the Basin. The China Lake NAWS, Inyokern CSD, IWVWD, and many domestic wells produce high quality ground water from this area. Groundwater levels range from over 400 feet in depth along the western edge of the area to less than 100 feet to groundwater in the eastern portion of the West Area. Four groundwater wells will be used for sampling purposes in this area as shown in **Table 7-3**.

Table 7-3: West Area Monitoring Well Information

Well Location	Well Type	Well Diameter/ Material	Pump Installed (?)	Owner	TD	Perforated Interval(s)	Wellhead Elevation
Navy #15	P	16”/S	Yes	Navy	600’	320’-360’	2417’
						390’-590’	
Navy #30	P	16”/S	Yes	Navy	1015’	600’-900’	2420’
WD Well #31	P	16”/S	Yes	WD	1220’	600’-1200’	2445’
26/39-17 M01	M	16”/S	No	Navy	943’	681’-881’	

Notes:
1) Well Type: M =Monitoring, P = Public Water Supply
2) TD = Total depth of well
3) Well Diameter/Material: 12"/P = 12 inch well cased with PVC; 8"/S = 8 inch well cased with steel

7.8.3 North-Northwest Area

The north-northwest area consists of the area generally north of Hwy 395, between the western China Lake NAWS boundary fence line and the foot of the Sierra Nevada, although the Baker LB well is included which is located on Navy property near the Inyo County and Kern County lines. The source of the groundwater and subsequent interaction with the extensive clay deposits centered near Brown Road and Leliter Road have resulted in some of the highest TDS concentrations near the southern end of the area (within the low-energy sediment sink described in the BOR Project Report). Although the potential for the lower quality groundwater (with respect to both water quality and potential agricultural nutrients) to reach the nearest public supply wells in Inyokern (China Lake NAWS and Inyokern CSD) is considered moderate under current groundwater production activities, potential adverse impact to local domestic wells is considered high. Current potentiometric surface maps show a localized pumping depression in the area probably due to unrestricted agricultural water use. Monitoring in this area should be focused between Hwy 14 and the China Lake NAWS boundary and include the area along the entire western boundary of China Lake NAWS from Inyokern to the north end of Brown Road where it terminates into Hwy 395.

In general, there are few monitoring wells in this area (outside of China Lake NAWS boundaries), however, that are many low-volume domestic wells available for sampling purposes. **Table 7-4** shows the wells used for sampling purposes in the north-northwest area.

Table 7-4: North-Northwest Area Monitoring Well Information

Well Location	Well Type	Well Diameter/ Material	Pump Installed (?)	Owner	TD	Perforated Interval(s)	Wellhead Elevation
Baker LB	P	10”/S	Yes	Navy	250’	100’-200’	????.?
BR #5	M	2”/S	No	BLM	890	850-870	2521.3
BR #6	M	2”/S	No	BLM	390’	350’-370’	2354.1
BR #10	M	2”/S	No	BLM	660	640-660	2561.1
NR-1	M	2”/S	No	Priv.	290’	250’-270’	2278.6
NR-2	M	2”/S	No	Priv.	370’	330’-350’	2317.7
25/38-35	M	6”/PVC	No	Priv.	289’	200’-289’	2402.8

Notes:
1) Well Type: M =Monitoring, P = Public Water Supply
2) TD = Total depth of well
3) Well Diameter/Material: 12"/P = 12 inch well cased with PVC; 8"/S = 8 inch well cased with steel

7.8.4 Central Area

The central area, which encompasses about 20 square miles, is located in the central portion of the Indian Wells Valley and is a major pumping center utilized by SVM, IWVWD, China Lake NAWS, Quist Farms, and many privately-owned, low-volume domestic wells. This area is important for monitoring due to the potential for migration of low quality water into the intermediate well field due to lower potentiometric surface elevations within the pumping depression, fairly high hydraulic conductivities, extensive thickness of naturally-occurring lacustrine deposits, and their proximity to the well field. Although no known migration of contaminated water exists, due to localized geologic structures which may be acting as barriers to migration, the central area is proximal to the Navy’s Installation Restoration Site #12. An additional concern is the proximity and potential influences of the Little Lake fault zone which trends through the eastern portion of the intermediate well field pumping depression. Although there are 60'-90' of vertical displacement of sediments underlying Site 12, no known adverse influences can be attributed to the fault.

The sampling points for the central area include mostly the China Lake NAWS and IWVWD wells. **Table 7-5** shows the locations of the wells and their respective well information.

Table 7-5: Central Area Monitoring Well Information

Well Location	Well Type	Well Diameter/ Material	Pump Installed (?)	Owner	TD	Perforated Interval(s)	Wellhead Elevation
Navy Well #18	P	16"/S	Yes	Navy	1000	503'-583'	2358
						651'-731'	
BR #3	M	2"/S	No	BLM	690'	650'-670'	2511.9
IWV 10	P	16"/S	Yes	IWVWD	800'	250'-800'	????.?
IWVWD 11	p	16"/s	Yes	IWVWD	620'	260'-310'	????.?
						340'-380'	
						470'-500'	
						520'-600'	
SV Well	P	16"/S	Yes	SVM	???	???-???	????.?

Notes:
1) Well Type: M =Monitoring, P = Public Water Supply
2) TD = Total depth of well
3) Well Diameter/Material: 12"/P = 12 inch well cased with PVC; 8"/S = 8 inch well cased with steel

7.8.5 Southeast Area

The southeast area consists of about 10-12 square miles. Water used in this area for domestic purposes is served by the IWVWD although there are a few domestic wells scattered throughout the region. **Table 7-6** shows the two wells to be used in the monitoring program.

Table 7-6: Southeast Area Monitoring Well Information

Well Location	Well Type	Well Diameter/ Material	Pump Installed (?)	Owner	TD	Perforated Interval(s)	Wellhead Elevation
27/40-1K02	M	6"	No	Navy	520'	400'-500'	2288.9
27/40-02J01	P	10"	Yes	Priv.	220'	???'-???'	2300

Notes:
1) Well Type: M =Monitoring, P = Public Water Supply
2) TD = Total depth of well

7.9 Ongoing Sampling Programs

All local water purveying entities within the Basin including Inyokern CSD, IWVWD, SVM, China Lake NAWS, and several mutual water companies are mandated to collect weekly-monthly bacteriological samples (depending on population served/service connections, etc.), annual nitrate, TTHMs, and HAA5 analyses, tri-annually for general mineral/volatile/semi-volatile compounds, radiological analyses every four years and other requirements. Since 1990, China Lake NAWS has sampled various monitoring wells within the Basin for general mineral analyses, although neither consistent sampling frequency nor consistent sample locations have been used other than the Title 22 requirements at production well sites. Historical water quality data are available from the USBR, California DWR, USGS, and the Kern County Water Agency.

8 Antidegradation Analysis

8.1 SWRCB Recycled Water Policy Criteria

Section 9 Anti-Degradation of the SWRCB's Recycled Water Policy states, in part:

a. *The State Water Board adopted Resolution No. 68-16 as a policy statement to implement the Legislature's intent that waters of the state shall be regulated to achieve the highest water quality consistent with the maximum benefit to the people of the state.*

b. *Activities involving the disposal of waste that could impact high quality waters are required to implement best practicable treatment or control of the discharge necessary to ensure that pollution or nuisance will not occur, and the highest water quality consistent with the maximum benefit to the people of the state will be maintained.*

d. *Landscape irrigation with recycled water in accordance with this Policy is to the benefit of the people of the State of California. Nonetheless, the State Water Board finds that the use of water for irrigation may, regardless of its source, collectively affect groundwater quality over time. The State Water Board intends to address these impacts in part through the development of salt/nutrient management plans described in paragraph 6.*

(1) *A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is in place may be approved without further antidegradation analysis, provided that the project is consistent with that plan.*

(2) *A project that meets the criteria for a streamlined irrigation permit and is within a basin where a salt/nutrient management plan satisfying the provisions of paragraph 6(b) is being prepared may be approved by the Regional Water Board by demonstrating through a salt/nutrient mass balance or similar analysis that the project uses less than 10 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin (or multiple projects using less than 20 percent of the available assimilative capacity as estimated by the project proponent in a basin/sub-basin).*

8.2 Assessment

Reclaimed wastewater project(s) in the basin include existing irrigation (golf course and agricultural) and percolation water for environmental enhancement; and projected increased use of reclaimed wastewater for irrigation and environmental enhancement through the end of the future planning period in 2040. Irrigation with reclaimed wastewater contributes only very minor salt and nutrient loading to the basin and reclaimed wastewater projects do not use more that 10% of the available assimilative capacity.

In addition to the minimal negative water quality impacts associated with reclaimed wastewater irrigation project(s) in the Basin, the Recycled Water Policy and other state-wide planning documents recognize the tremendous need for and benefits of increased recycled water use in California. As stated in the Recycled Water Policy "*The collapse of the Bay-Delta ecosystem, climate change, and continuing population growth have combined with a severe drought on the Colorado River and failing levees in the Delta to create a new reality that challenges California's ability to provide the clean water needed for a healthy environment, a healthy population and a healthy economy, both now and in the future. We strongly encourage local and regional water agencies to move toward clean, abundant, local water for California by emphasizing appropriate water recycling, water conservation, and maintenance of supply infrastructure and the use of stormwater (including dry-weather urban runoff) in these plans; these sources of supply are drought-proof, reliable, and minimize our carbon footprint and can be sustained over the long-term.*"

The SNMP analysis finds that reclaimed wastewater use can be utilized while still protecting and improving groundwater quality for beneficial uses. **Table 8-1** provides an explanation of why proposed future expansion of reclaimed wastewater is compliance with SWRCB Resolution No. 68-16.

Table 8-1: Antidegradation Assessment

SWRCB Resolution No. 68-16 Component	Anti-Degradation Assessment
Water quality changes associated with proposed recycled water project(s) are consistent with the maximum benefit of the people of the State.	• The irrigation projects will not use more than 10% of the available assimilative capacity • Reclaimed wastewater irrigation project(s) will not cause groundwater quality to exceed applicable BPOs • Use of reclaimed wastewater for irrigation reduces groundwater pumping
The water quality changes associated with proposed recycled water project(s) will not unreasonably affect present and anticipated beneficial uses.	
The water quality changes will not result in water quality less than prescribed in the Basin Plan.	
The projects are consistent with the use of best practicable treatment or control to avoid pollution or nuisance and maintain the highest water quality consistent with maximum benefit to the people of the State.	• Concentrations of TDS and nitrate-N in reclaimed wastewater produced by the City of Ridgecrest are 670 mg/L and 0.76 mg/L, respectively.
The proposed project(s) is necessary to accommodate important economic or social development.	• The reclaimed wastewater projects are an integral part of IWVWD's UWMP and groundwater sustainability planning in the basin.
Implementation measures are being or will be implemented to help achieve BPOs in the future.	• Various measures, as described in Chapter 8 have been or will be implemented in the basin to address salts and nutrients

9 Plan Implementation

The findings from the technical analysis completed for the SNMP indicate that there is assimilative capacity for salt and nutrients when considering the Basin as a whole. Analysis of anticipated future water quality (projected 25 years) indicates an increasing trend in salinity and nutrients, but concentrations in the period analyzed would remain under BPOs. A new demineralization project is being studied to determine the feasibility of exporting salt out of the Basin. No new implementation measures or BMPs as part of the SNMP process are recommended; however, the SNMP recommends continuation of existing measures and practices to manage groundwater quality.

9.1 Existing Implementation Measures and Ongoing Management Programs to Manage Salt and Nutrient Loading

Given that future groundwater quality concentration estimates are not expected to exceed BPOs for TDS and nitrate, and reclaimed wastewater projects are not anticipated to use more than 10% of the Basin's assimilative capacity, no new implementation measures are recommended to manage salts and nutrients within the Basin. Several programs are already underway which help manage groundwater supplies and quality. These programs fall under five categories:

- Agricultural
- Reclaimed Wastewater Irrigation
- Groundwater Management
- Onsite Wastewater Treatment System Management
- Municipal Wastewater Management

Implementation measures that are underway in the basin within these broad categories are described in detail below.

9.1.1 Agricultural BMPs

Land management practices within fields include various on-going BMPs, which include:

- Drip irrigation – water application is minimized by focusing the amount and area applied.
- Soil and petiole testing – it is common practice for land managers to conduct annual soil testing to understand soil characteristics for crop production and flavor. Soil testing includes review of TDS and nitrate. Land managers also typically test petioles to further refine crop nutrient needs.
- Focused application of fertilizer and soil amendments – application of salts and nutrients is limited to the area at the point of the irrigation drip emitter, rather than broadcast across a large area

9.1.2 Reclaimed Wastewater Irrigation BMPs

The implementation of recycled water is regulated by the Title 22 California Code of Regulations (Title 22). Numerous BMPs and operating procedures are required to be followed when using recycled water for irrigation to ensure safety. The following BMPs are implemented in the reclaimed wastewater operations:

- Water quality monitoring at the treatment plant to ensure regulatory compliance, and meet monitoring requirements for indicator emerging contaminants as part of the Recycled Water Policy.
- Irrigation at agronomic rates – irrigation is applied at a rate that does not exceed the demand of the plants and does not exceed the field capacity of the soil.

- Site Supervision – a site supervisor who is responsible for the system and for providing surveillance at all times to ensure compliance with regulations and permit requirements are designated for each site. The site supervisor is trained to understand reclaimed wastewater and supervision duties. In addition to monitoring the reclaimed wastewater system, the site supervisor must also conduct an annual self-inspection of the system.
- Minimize runoff from irrigation –Irrigation is not allowed to occur at any time when uncontrolled runoff may occur, such as during times of rainfall or very low evapotranspiration; and any overspray must be controlled.

9.1.3 Groundwater Sustainability Plan Development

The GSA for the Basin will identify and prioritize projects and management actions to maintain the health of the groundwater basin. The GSP may include the following:

- Basin-wide groundwater level monitoring
- Groundwater quality monitoring
- Installation and monitoring of new groundwater wells
- Plans for additional monitoring well installation and development of grants to fund installation
- Groundwater studies, including the SkyTEM work being conducted under the Stanford Groundwater Architecture Project that consists of high level testing and aerial geophysical work, to develop a 3D model of water levels, salinity, geological features, and stratigraphy.
- Brackish water study
- Stormwater management-groundwater recharge studies (conducted in conjunction with the Inyo-Mono Integrated Regional Water Management Plan)
- Water recycling projects to offset groundwater pumping
- Public Outreach Plan
- Rainfall monitoring program (including considerations for installing additional units)
- Encouraging conservation and BMPs for agriculture
- Update to land cover maps
- Maintaining a robust groundwater flow model

9.1.4 Onsite Wastewater Treatment System Management

A percentage of the groundwater basin is overlain by ranchettes and farmsteads with houses and structures that manage waste through individual onsite wastewater treatment system (OWTS), also known as septic systems. Individual property owners are responsible for managing their own system and employ a variety of BMPs such as monitoring and frequent pumping to manage the operation of the system. In June of 2012, the SWRCB adopted the Water Quality Control Policy for Siting, Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems. The intent of the policy is “to allow the continued use of OWTS, while protecting water quality and public health”. BMPs required in the policy include site evaluations, setbacks, and percolation tests for new systems.

9.1.5 Municipal Wastewater Management

The City of Ridgecrest owns and operates the only large-scale wastewater treatment plant within the groundwater basin, and must implement a host of source control and industrial waste management measures to control salinity and nutrients in influent waters.

9.2 Periodic Review of Salt/Nutrient Management Plan

Adaptive Management Plan

Adaptive management involves implementing a management strategy where goals, objectives and/or actions may be further developed, modified, or replaced based on monitoring and collection of new information in response to changing physical conditions or reduction in uncertainty. In this way, groundwater managers simultaneously apply management practices and learn from those management practices.

Adaptive management is typically broken into several general steps:

1. Assess/reassess current groundwater conditions and develop hydrogeologic conceptual model.
2. Design/modify management and monitoring plan.
3. Implement the management/monitoring plan.
4. Evaluate monitoring results and use to revise HCM and management plan.

Based on the monitoring program requirements of annual sampling and analysis, adaptive management will involve reviewing the monitoring results on an annual basis and determining whether results are in the anticipated range of analytical results expected based on the hydrogeologic conceptual model and predictive modeling of the Basin. If analytical results are significantly different than anticipated, the need for reassessing the HCM and management and monitoring plan will be assessed and modified if appropriate. This would include assessing the potential need for additional BMPs if warranted to protect water quality objectives and SNMP goals.

Performance Measures

The following are performance measures to be used to assess whether the goals and objective of the SNMP are being met:

- Monitor for salinity and plot trends and review the actions outlined in the approach to meet the objectives were obtained.
- Assess whether sufficient information was obtained to better understand the relationship between overdraft and the increasing trend in salinity in the basin to assist in managing the basin moving forward.
- Conduct basin-wide salinity mass balance during brackish groundwater resources project implementation and compare to fate and transport model projects and new simulations.
- Determine if sufficient characterization data was collected to better understand and inform future actions and decisions in managing the basin moving forward.

9.3 Cost Analysis

A cost analysis was not completed for implementation measures since no new measures are recommended for implementation as part of this SNMP.

9.4 CEQA Analysis

CEQA compliance is not applicable to this plan because no new implementation measures are being recommended and no Basin Plan Amendment is required.

9.5 Implementation Schedule

All programs considered are ongoing or being developed through the GSP planning process. An implementation schedule was not prepared as no new implementation measures are recommended. An implementation plan and schedule for groundwater sustainability (including water quality and groundwater levels) will be part of the GSP.

9.6 Plan Approval Process

The Draft SNMP was submitted to the TAC on November 22, 2017 and an overview was presented at the December 6, 2017 public meeting. Public comments on the Draft SNMP Report were considered and incorporated into a Draft Final SNMP Report. The Draft Final SNMP was submitted to the Regional Water Board on December 11, 2017 for their review and incorporation to their Basin Planning process and subsequent environmental documentation process.

The Draft Final SNMP Report (dated December 2017) will be posted online.

It is anticipated that this SNMP will be incorporated into the GSP under development in the future and that updates will happen through adaptive management of the GSP. The timing of an update is not tied to a scheduled reoccurrence interval; however, an update could be triggered by the following:

- Major changes in land use or land management practices
- New information from the Groundwater Monitoring Program
- Changes in basin management

Any future updates would be conducted utilizing a similar collaborative process as was utilized for development of this SNMP.

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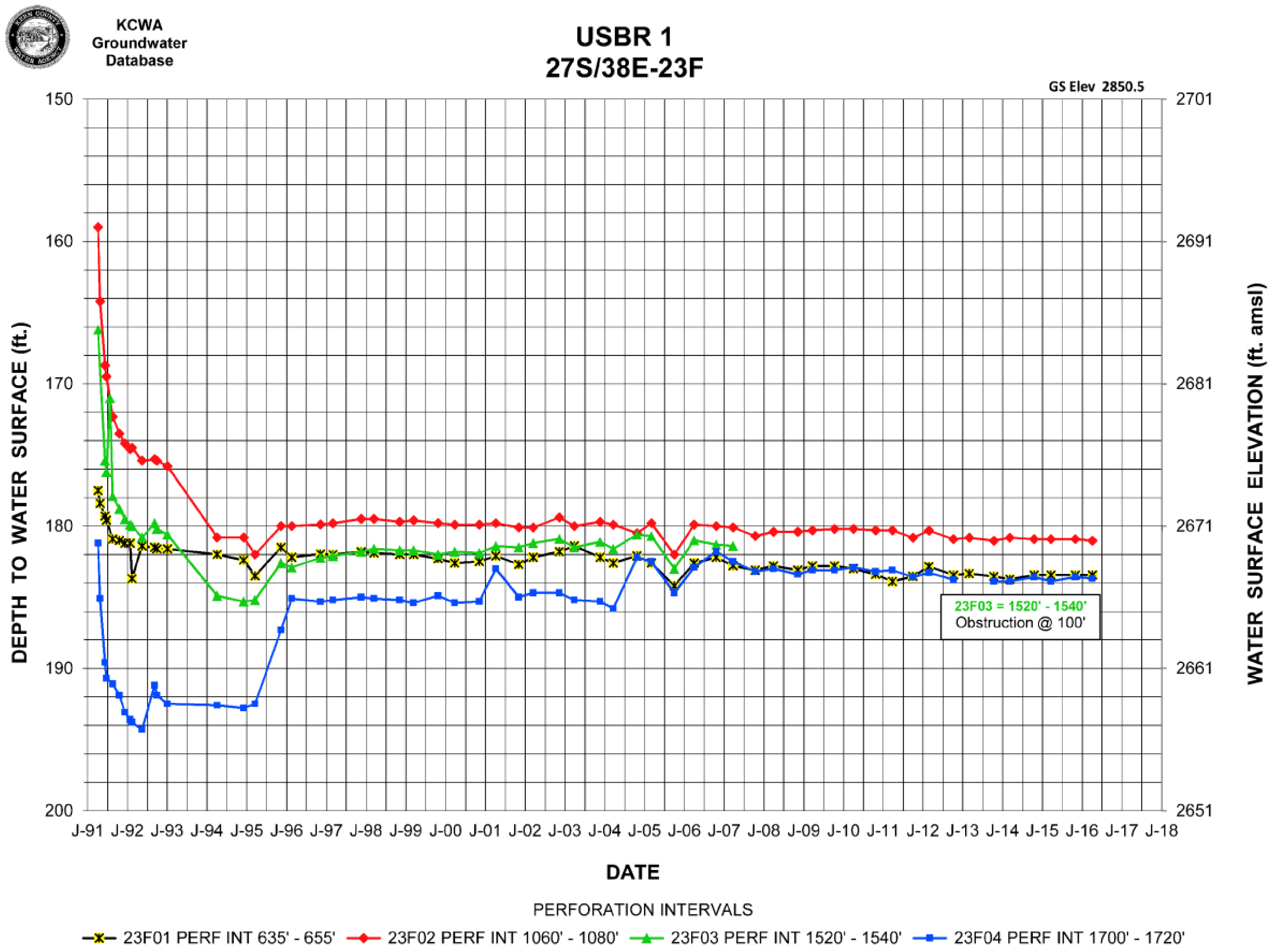
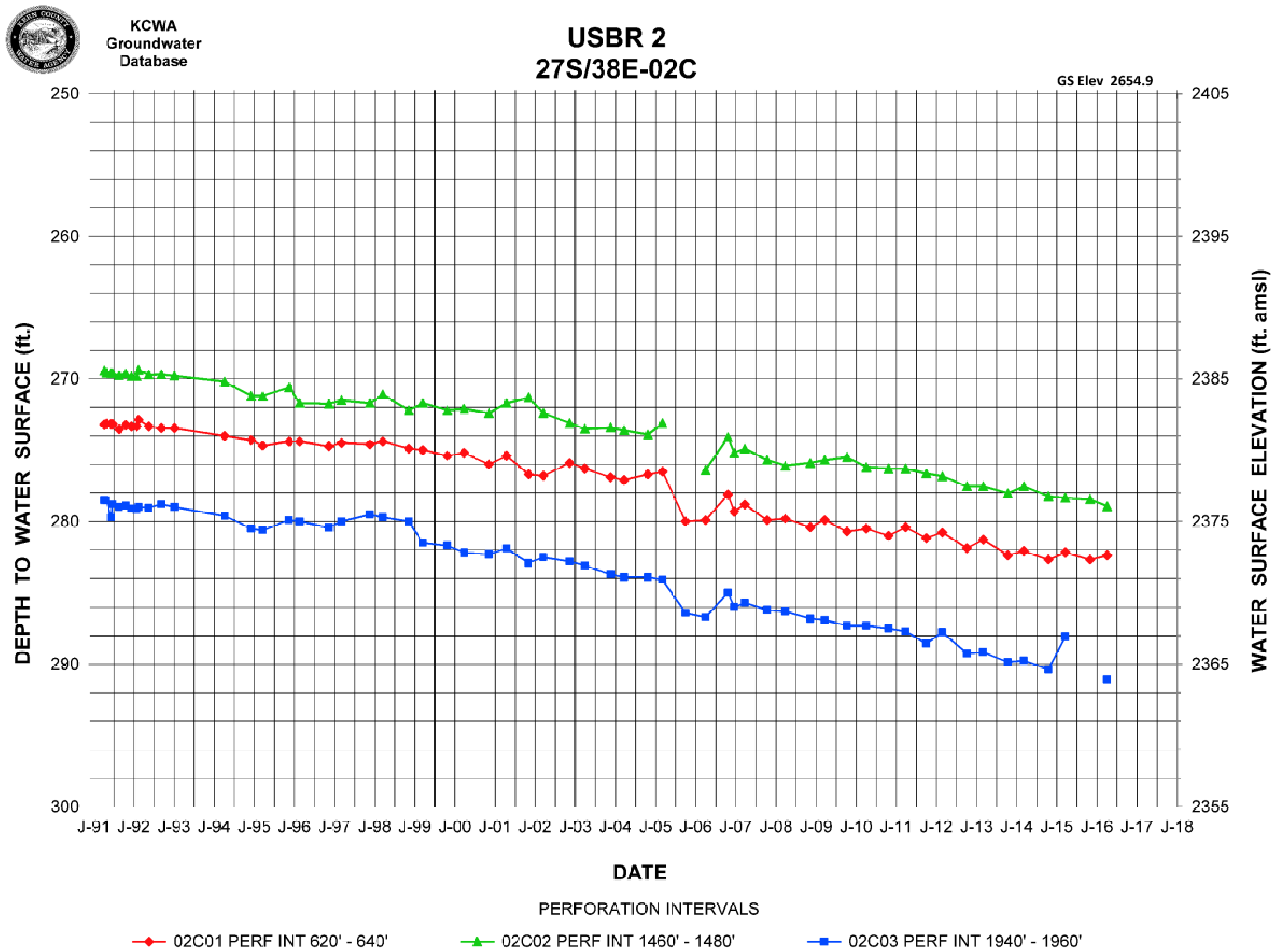
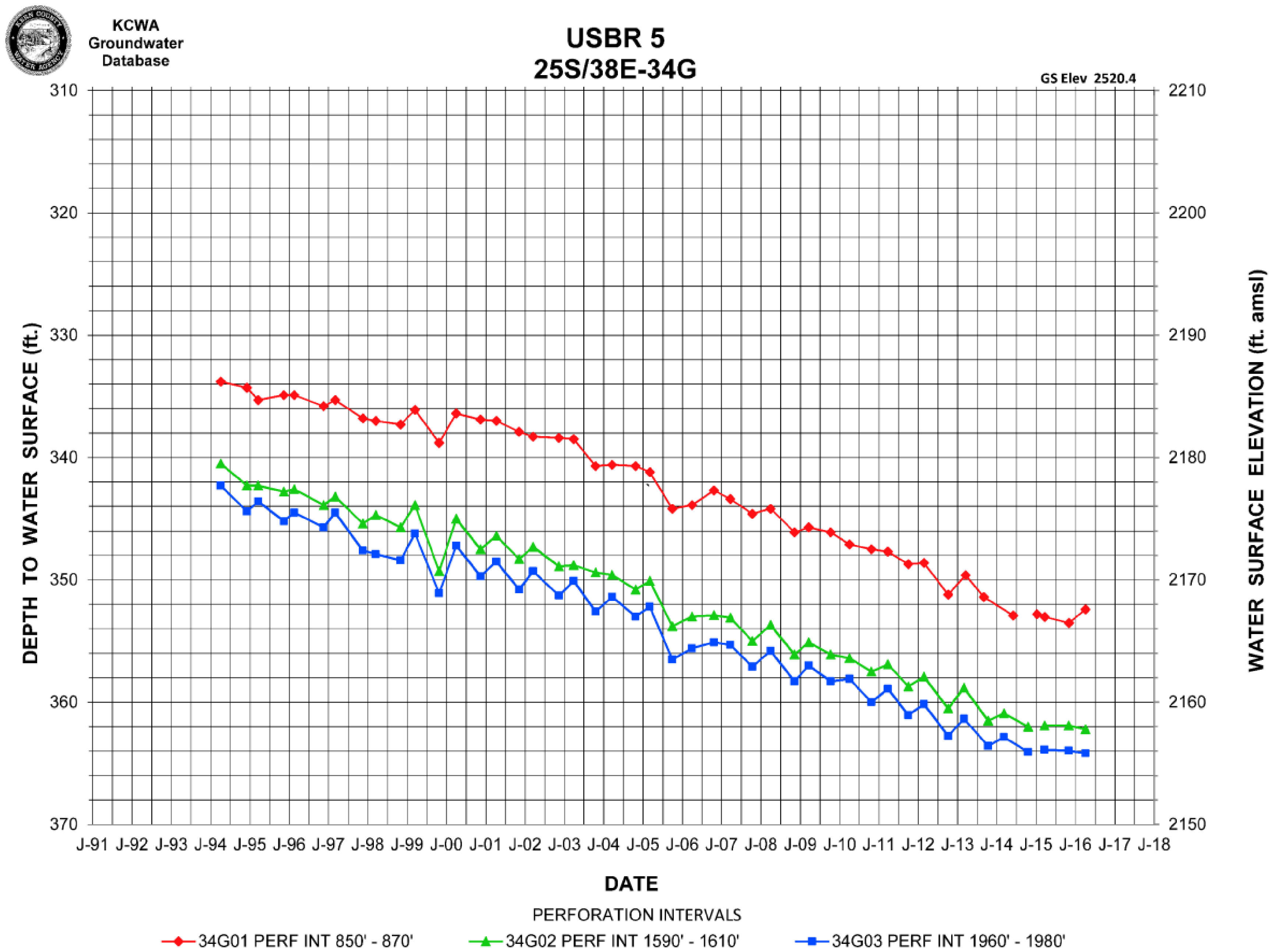
Appendix A – U.S. Bureau of Reclamation Monitoring Well Hydrographs

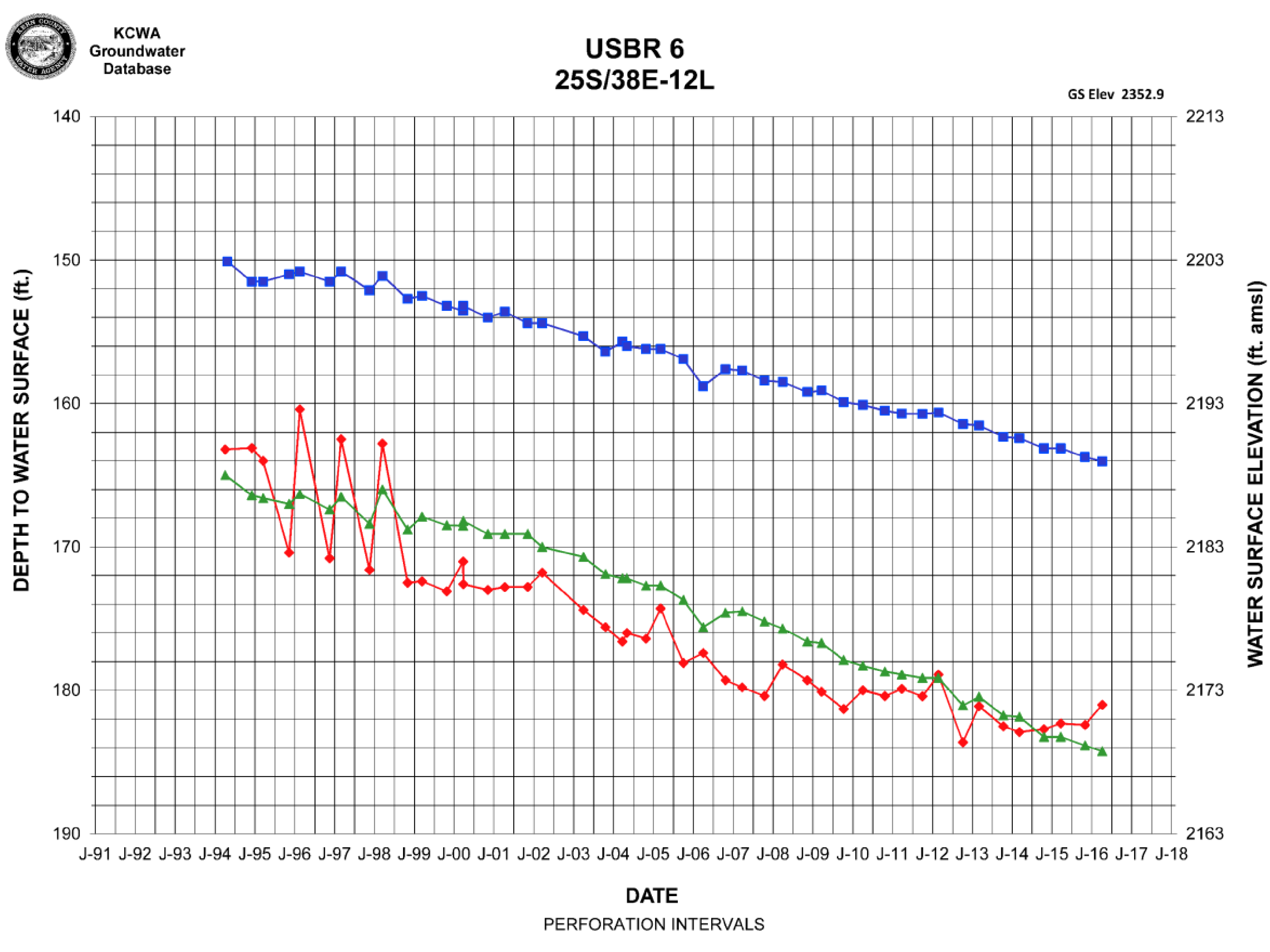
Southwest Area Hydrographs

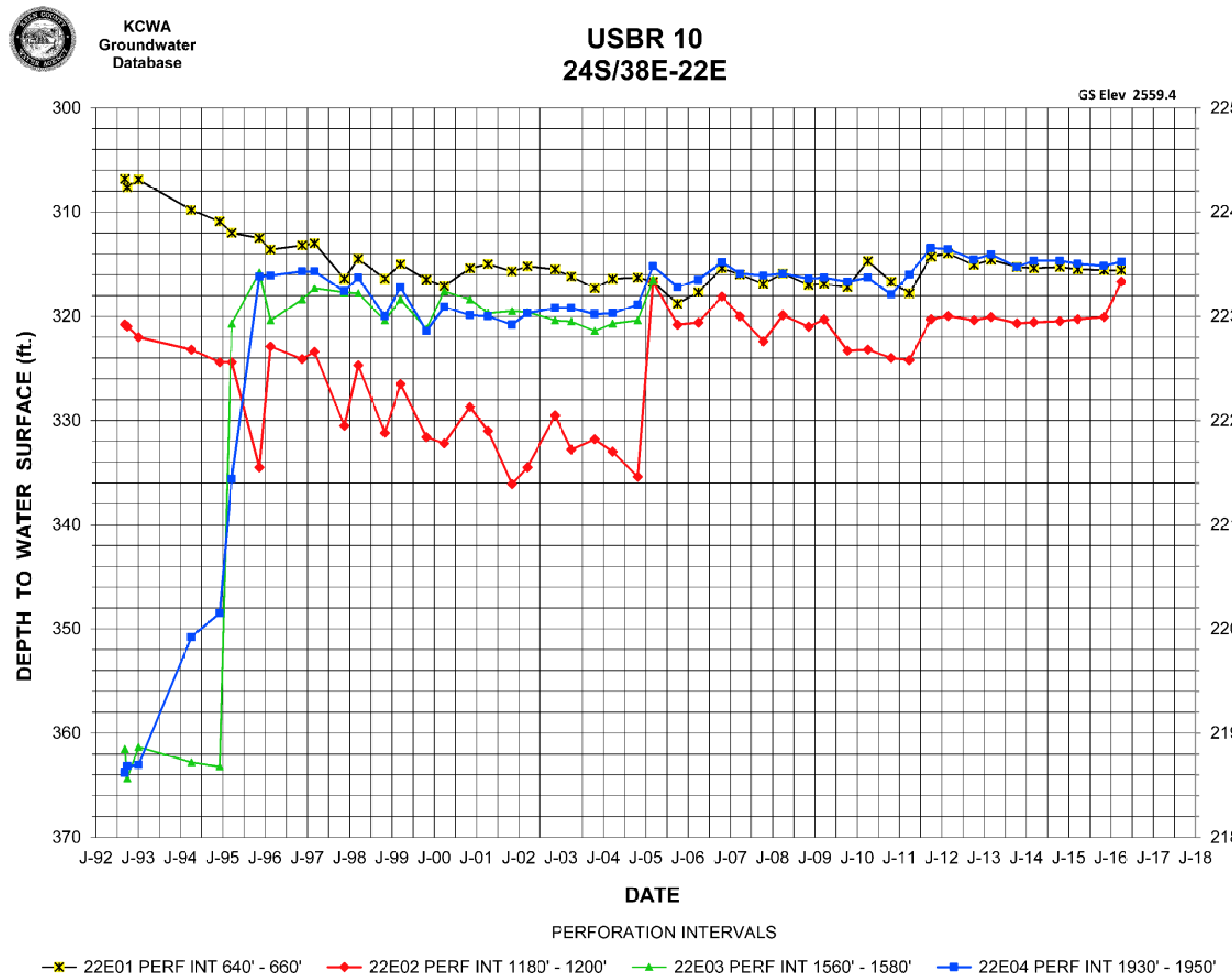




North-Northwest Area Hydrographs






KCWA Groundwater Database
USBR 10
24S/38E-22E
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DEPTH TO WATER SURFACE (ft.)
WATER SURFACE ELEVATION (ft. amsl)
DATE
PERFORATION INTERVALS
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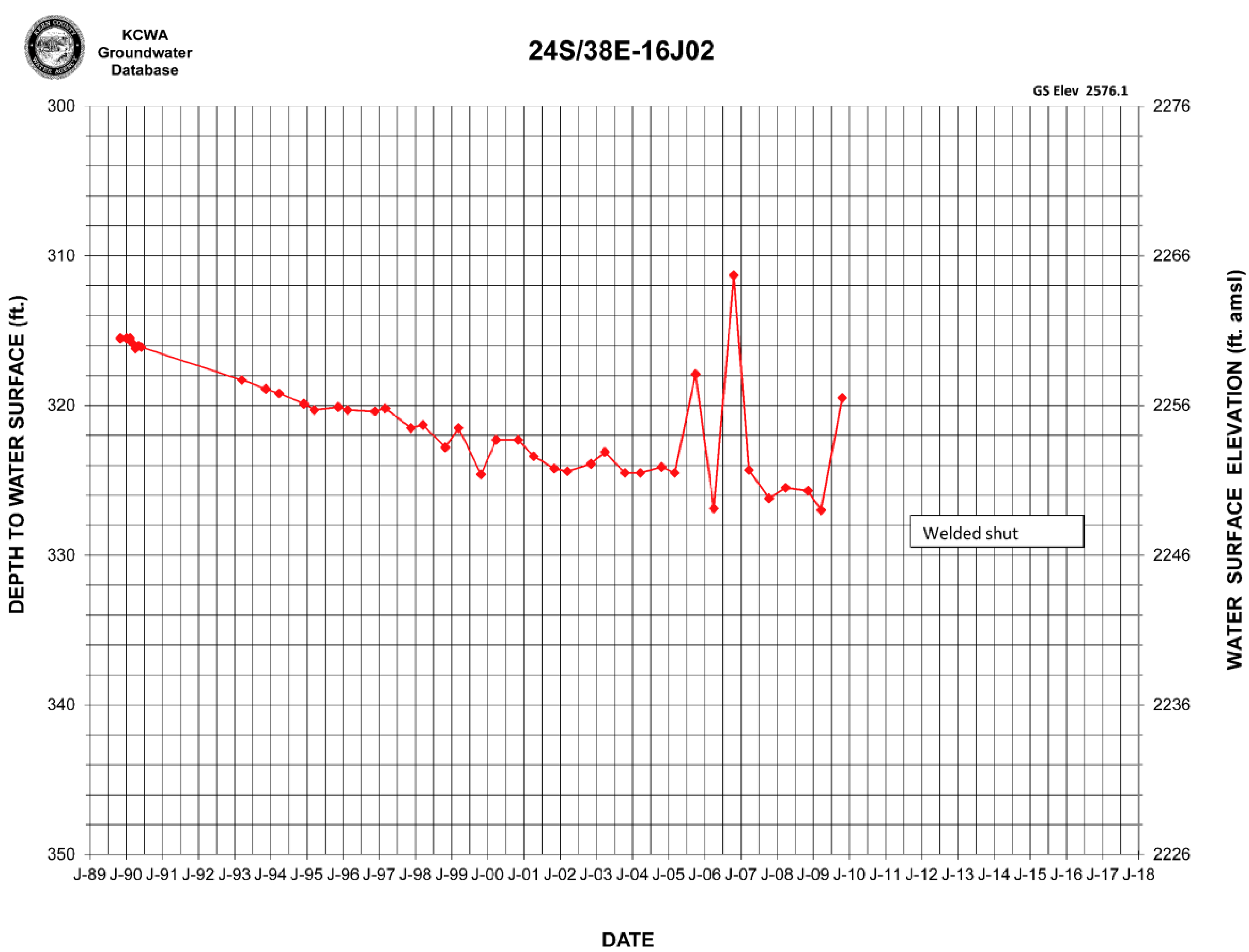
22E02 PERF INT 1180' - 1200'
22E03 PERF INT 1560' - 1580'
22E04 PERF INT 1930' - 1950'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WATER SURFACE ELEVATION (ft. amsl)
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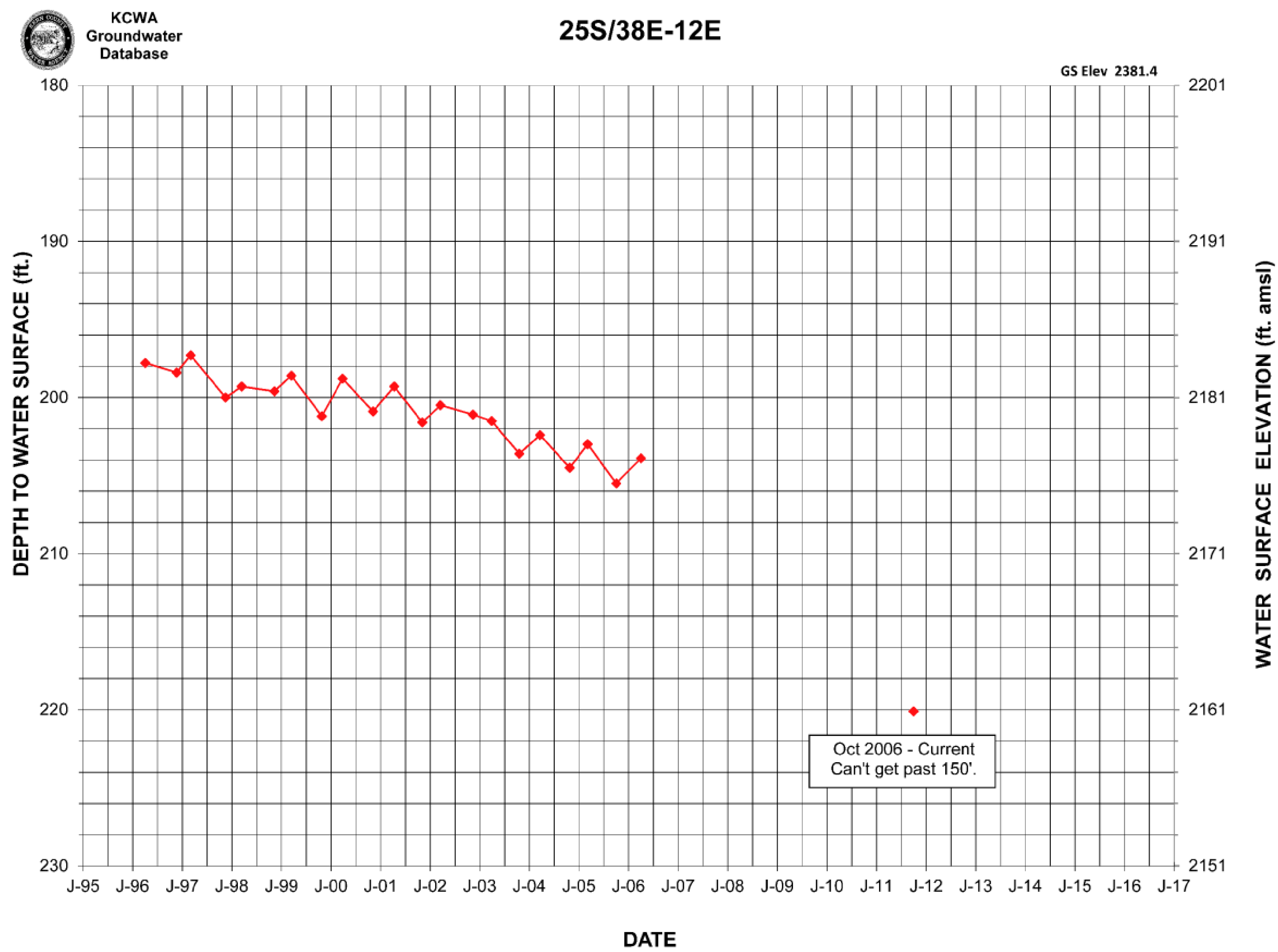
DATE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Groundwater
Database
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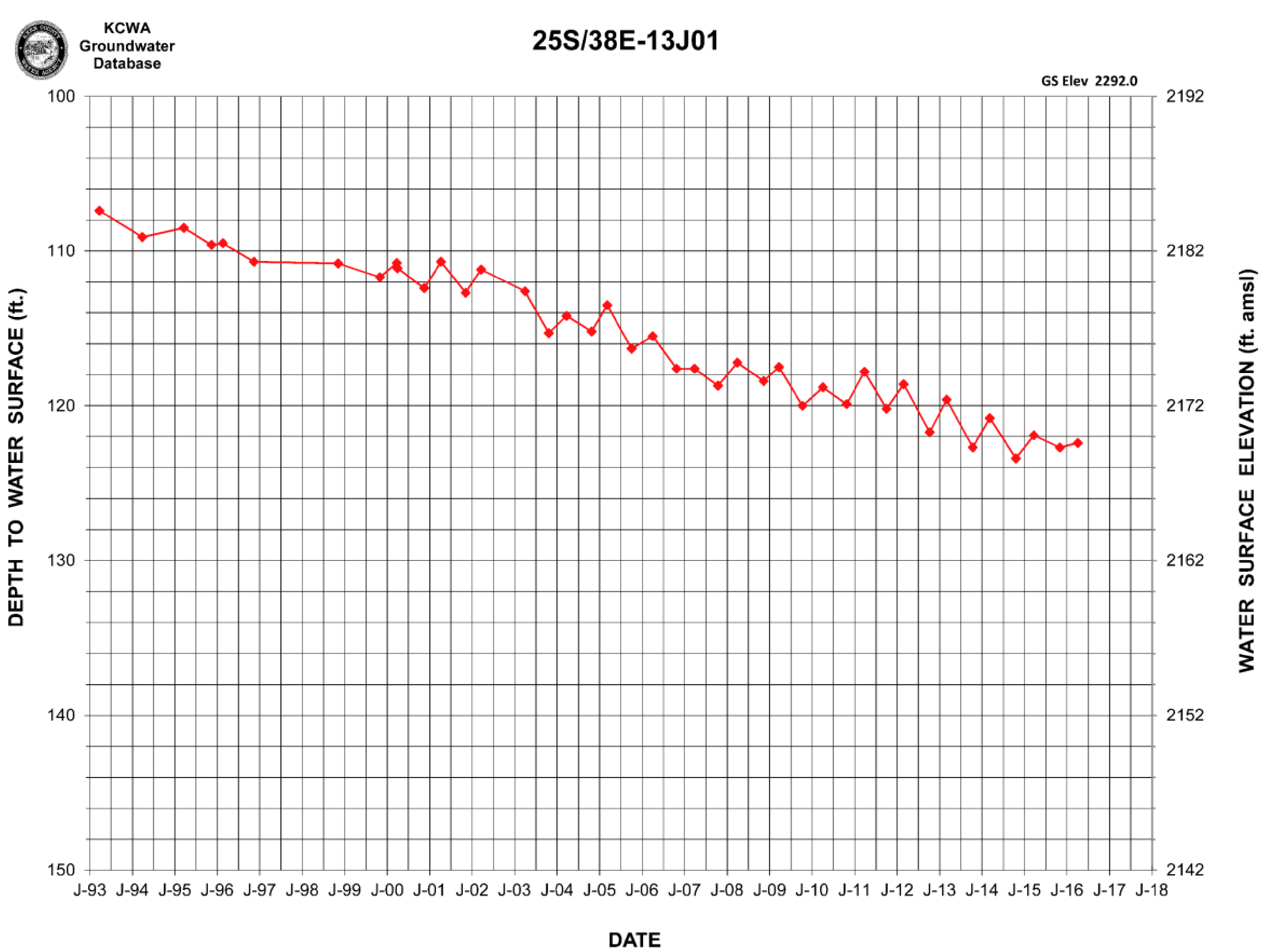
WATER SURFACE ELEVATION (ft. amsl)
Oct 2006 - Current
Can't get past 150'.
DATE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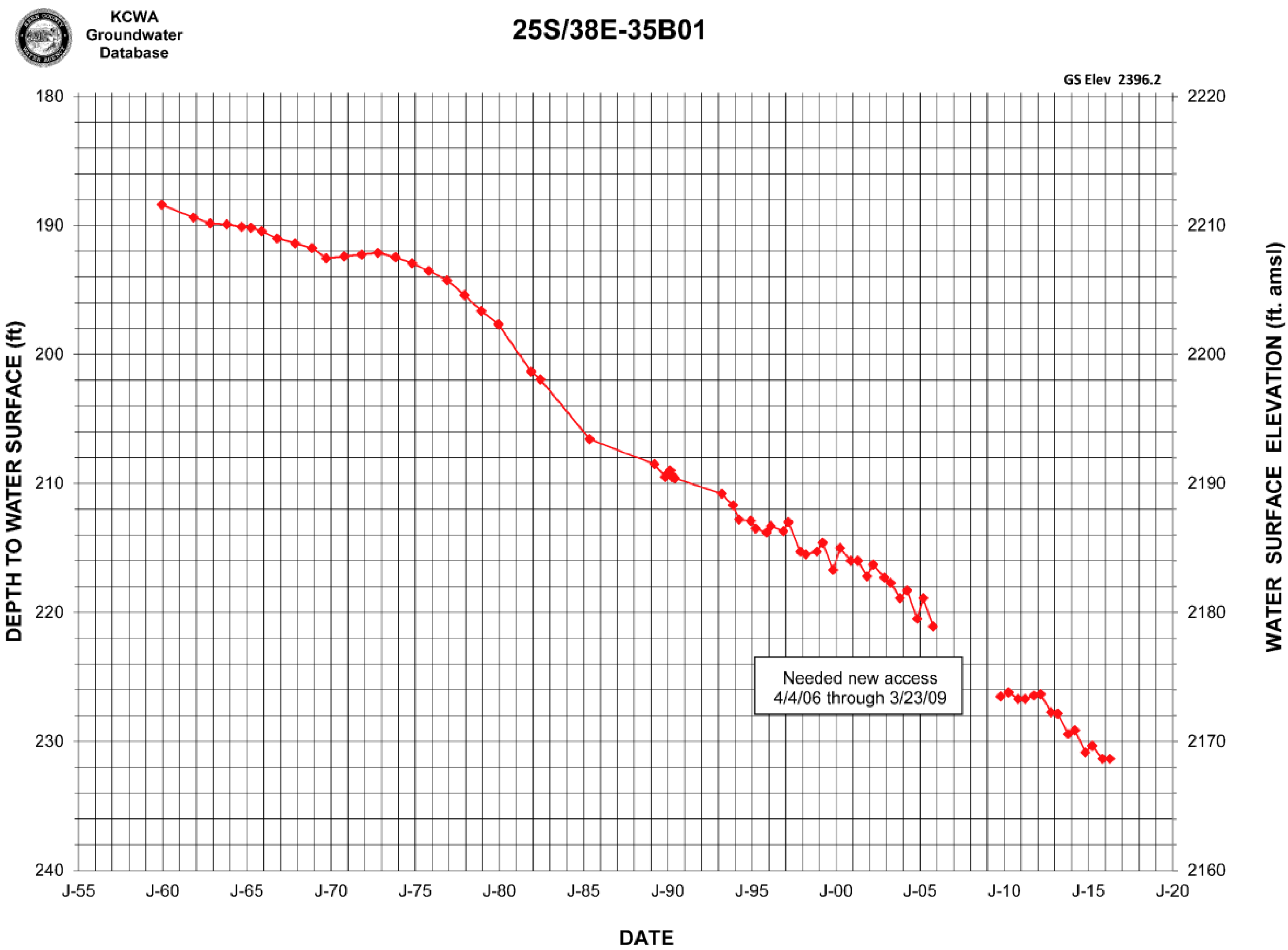
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WATER SURFACE ELEVATION (ft. amsl)
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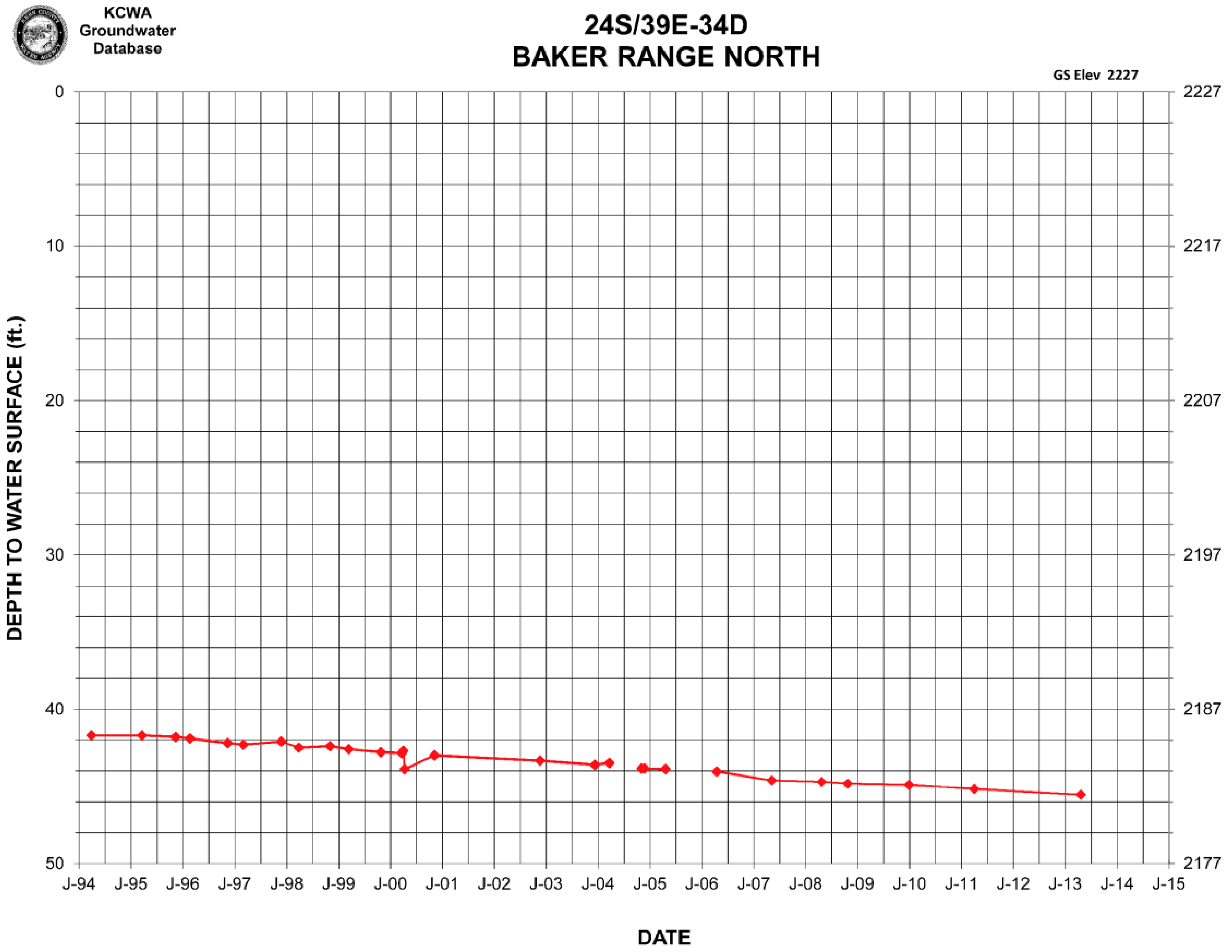
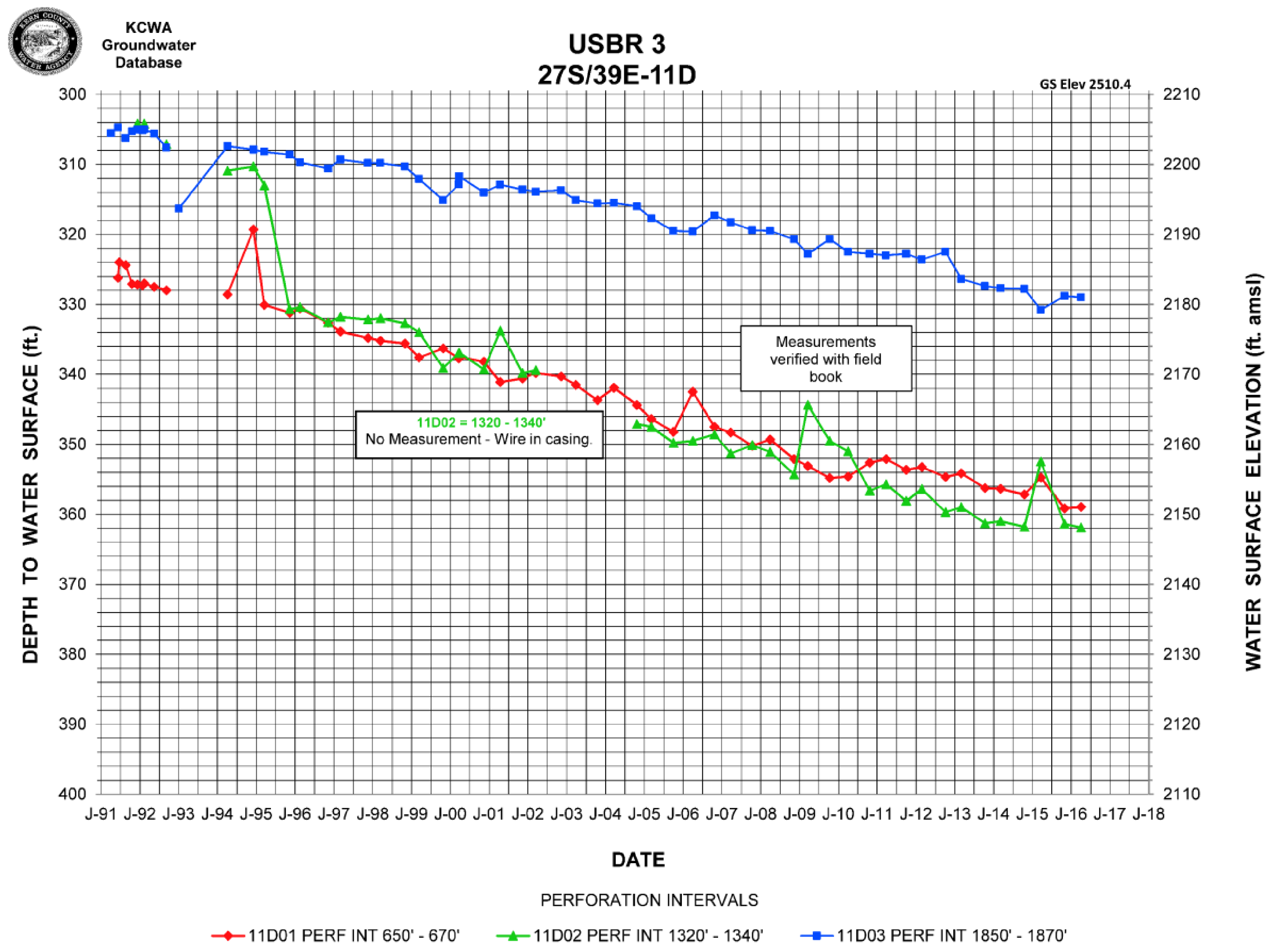
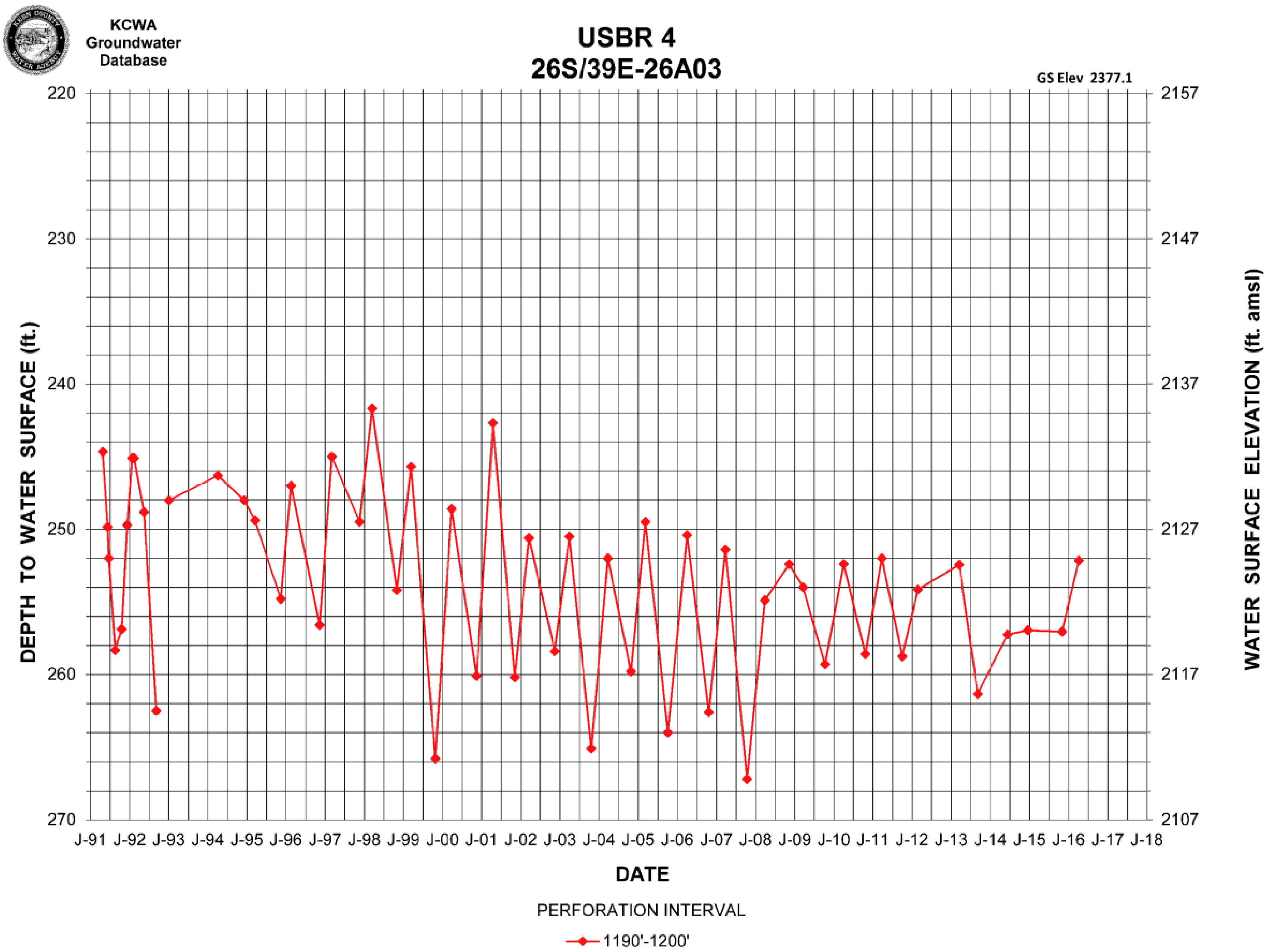
190
200
210
220
230
240
2220
2210
2200
2190
2180
2170
2160
J-55
J-60
J-65
J-70
J-75
J-80
J-85
J-90
J-95
J-00
J-05
J-10
J-15
J-20
DATE
Needed new access
4/4/06 through 3/23/09

Central Area Hydrographs



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WATER SURFACE ELEVATION (ft. amsl)
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230
240
250
260
270
2157
2147
2137
2127
2117
2107
J-91 J-92 J-93 J-94 J-95 J-96 J-97 J-98 J-99 J-00 J-01 J-02 J-03 J-04 J-05 J-06 J-07 J-08 J-09 J-10 J-11 J-12 J-13 J-14 J-15 J-16 J-17 J-18
DATE
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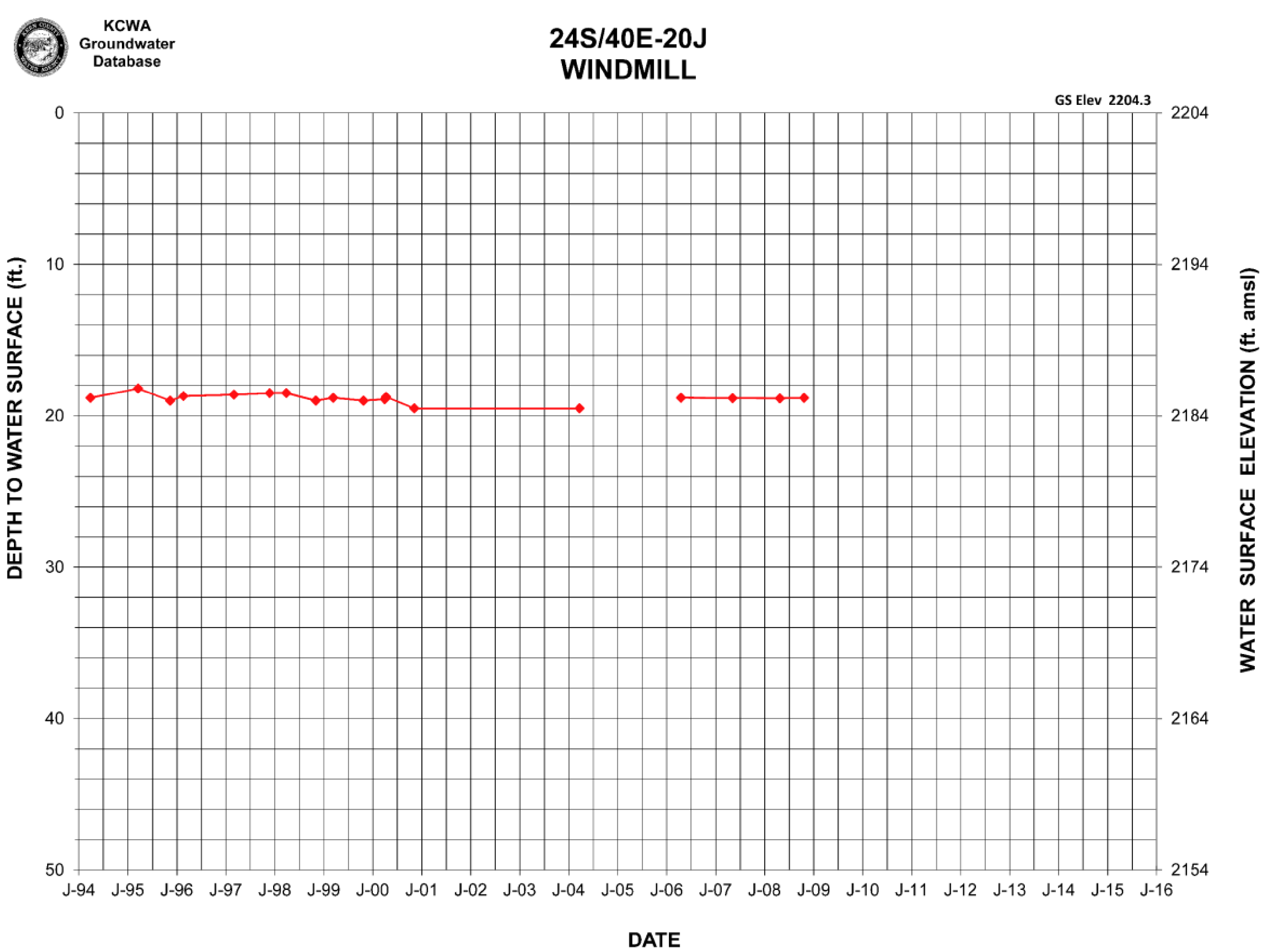
KCWA
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Database
24S/40E-20J
WINDMILL
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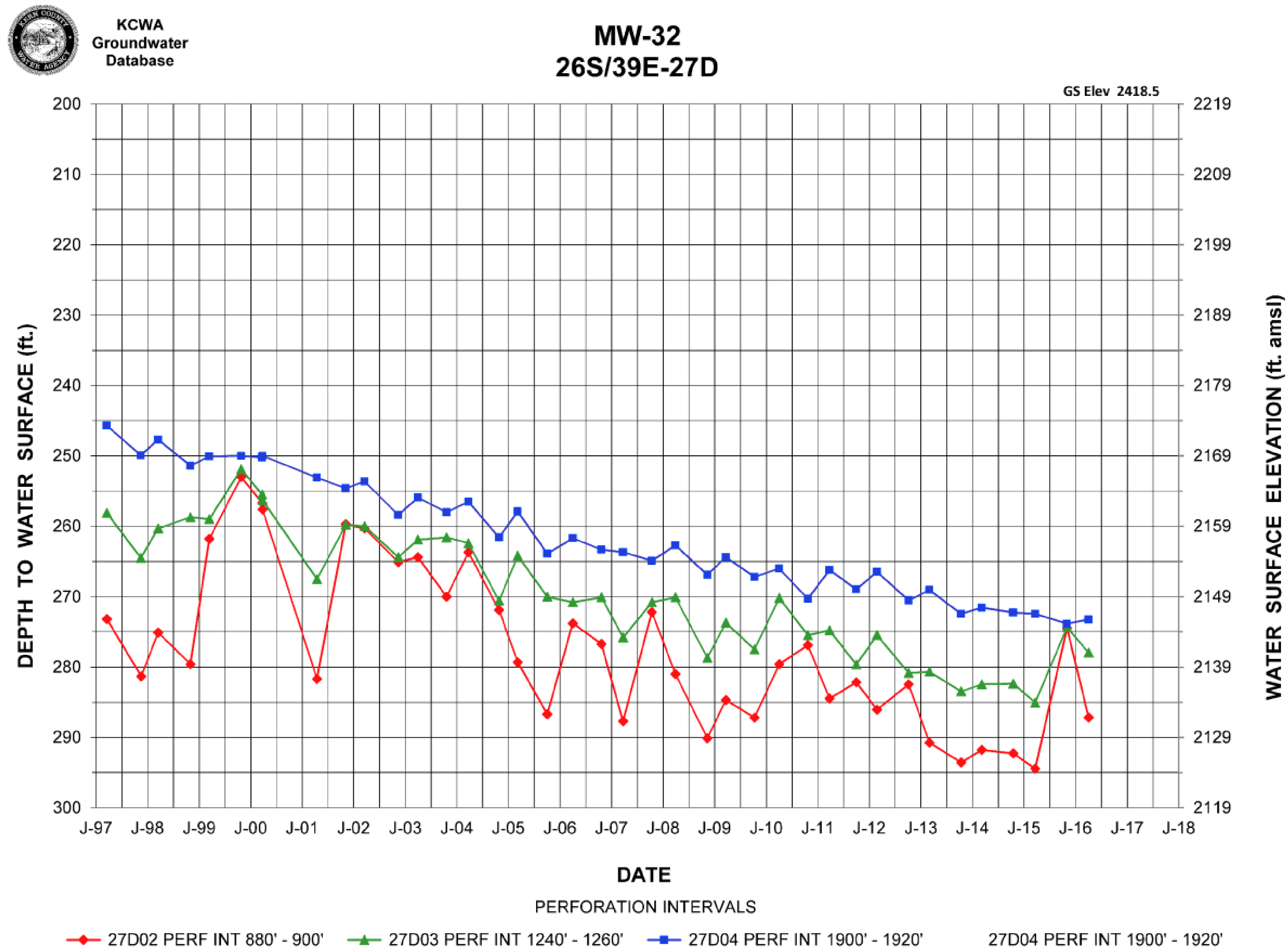
10
20
30
40
50
2204
2194
2184
2174
2164
2154
J-94 J-95 J-96 J-97 J-98 J-99 J-00 J-01 J-02 J-03 J-04 J-05 J-06 J-07 J-08 J-09 J-10 J-11 J-12 J-13 J-14 J-15 J-16
DATE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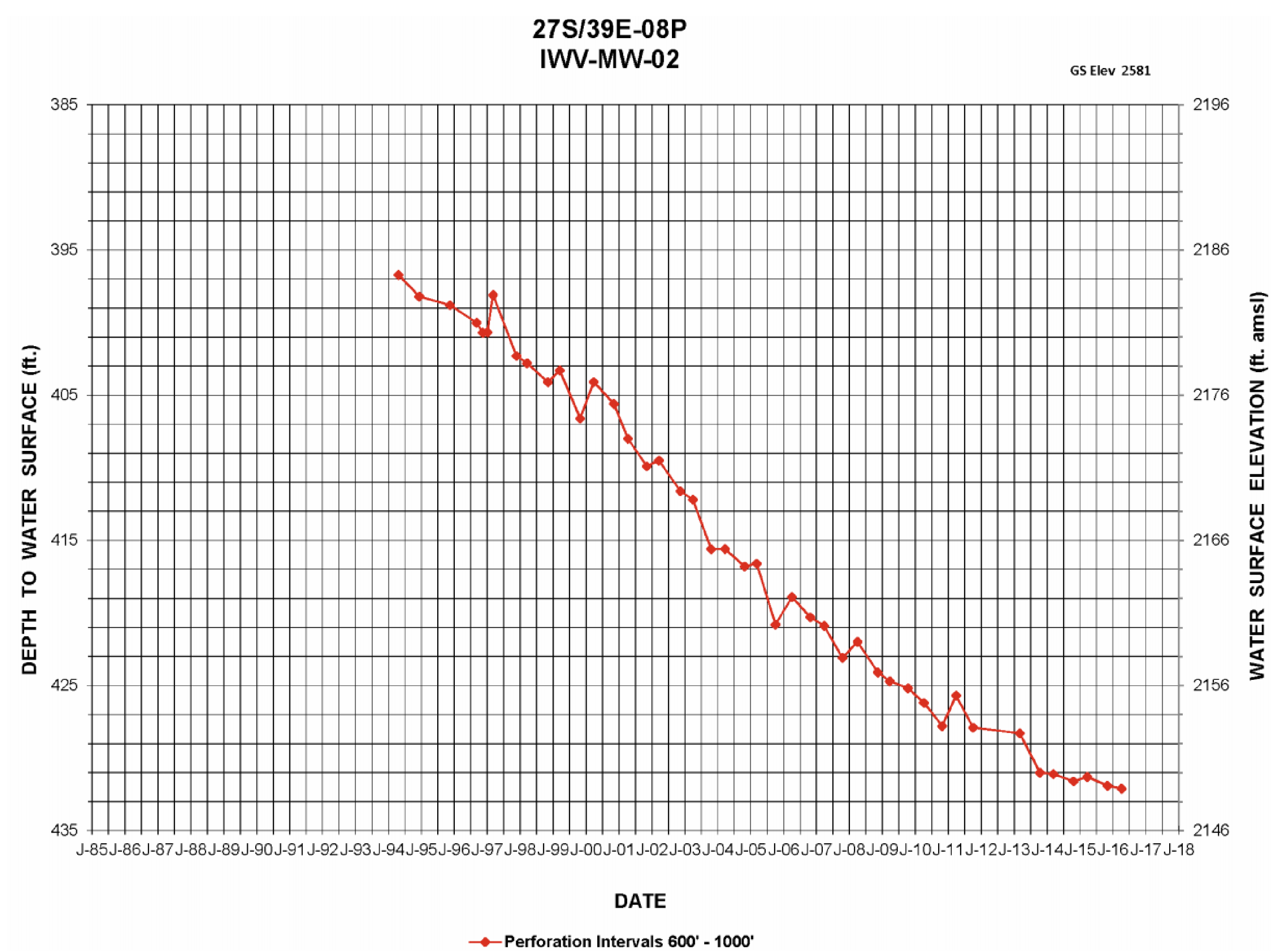
27D04 PERF INT 1900' - 1920'
27D04 PERF INT 1900' - 1920'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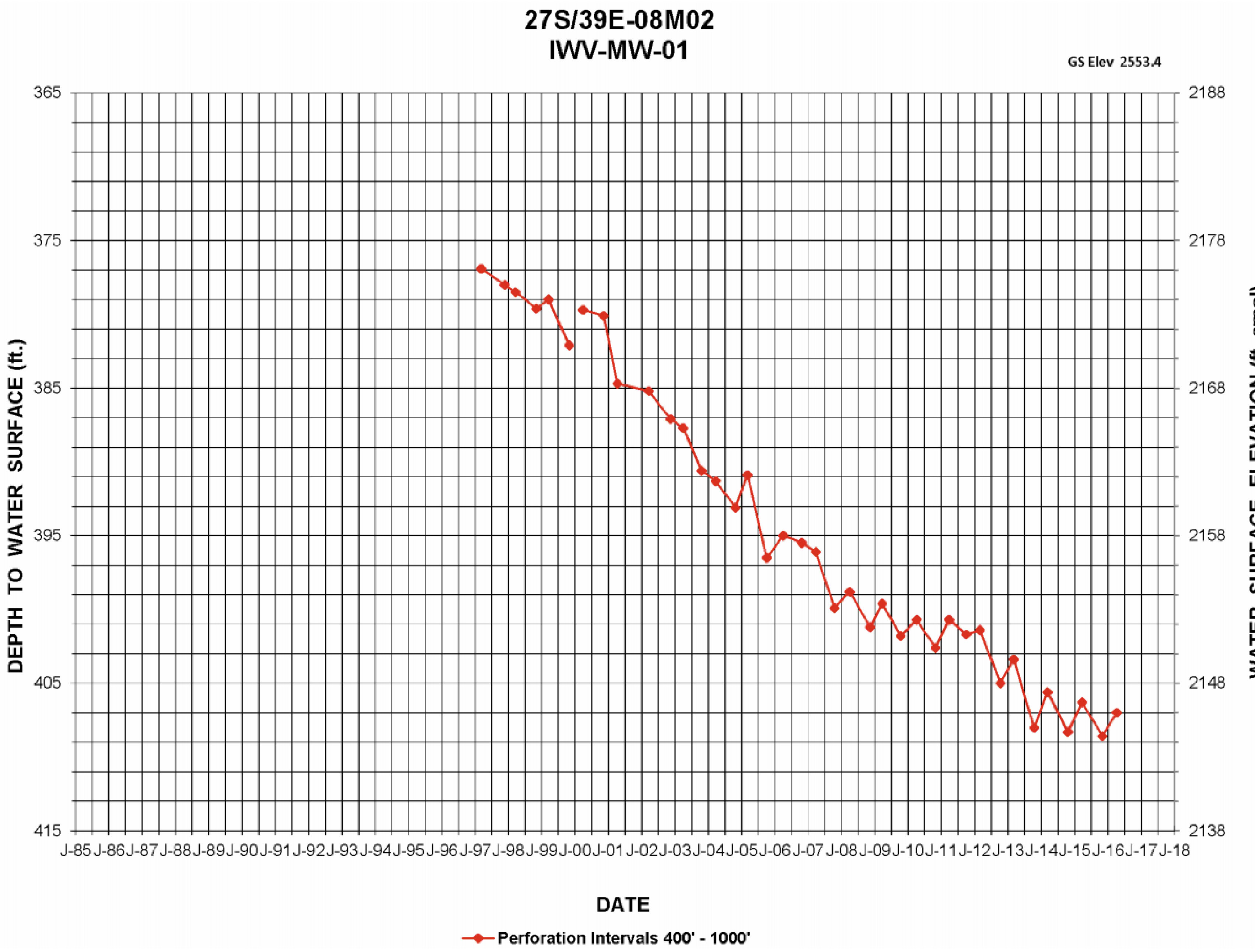
DATE
Perforation Intervals 600' - 1000'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IWV-MW-01
GS Elev 2553.4
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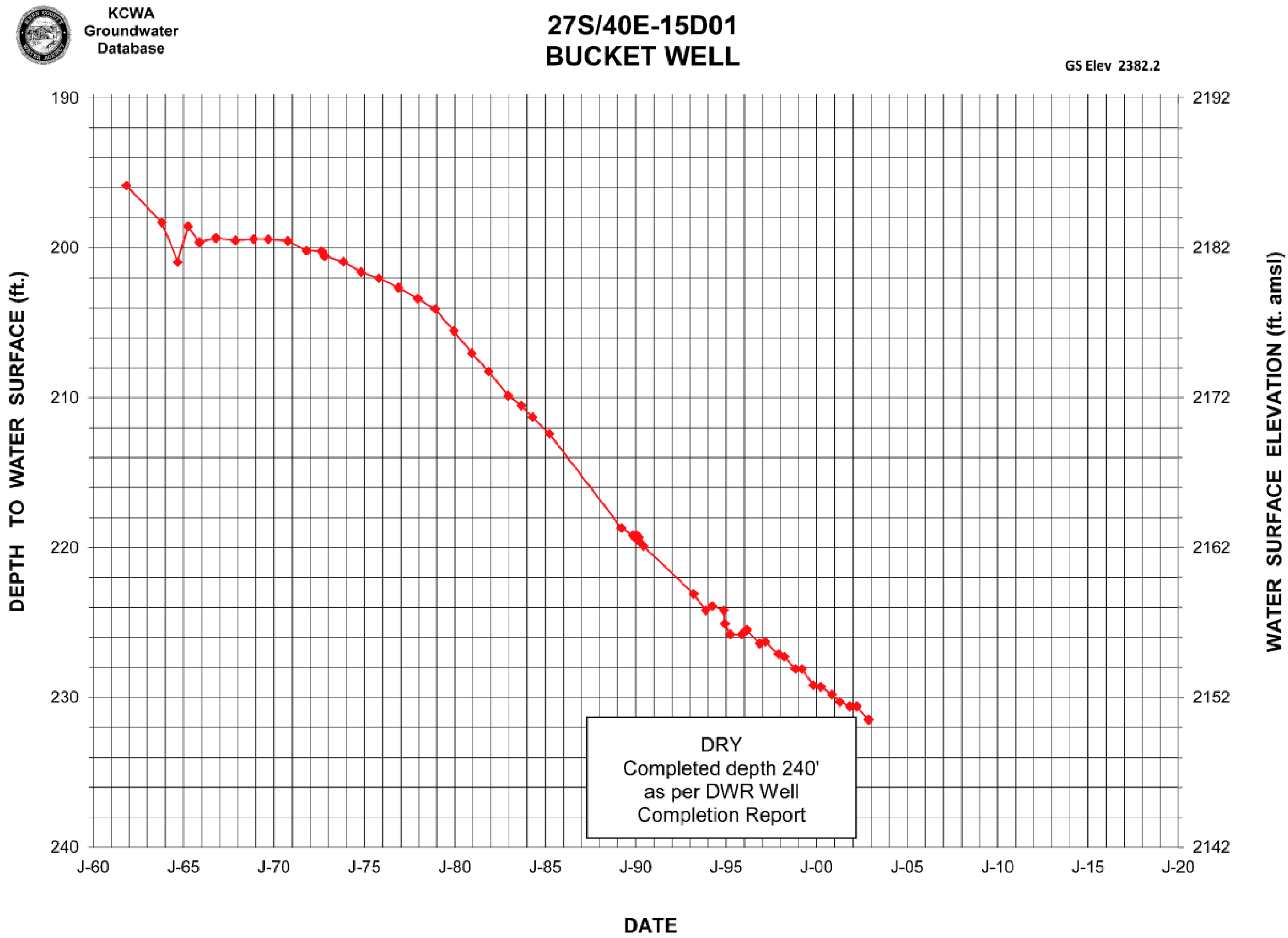
WATER SURFACE ELEVATION (ft. amsl)
365
375
385
395
405
415
2188
2178
2168
2158
2148
2138
J-85 J-86 J-87 J-88 J-89 J-90 J-91 J-92 J-93 J-94 J-95 J-96 J-97 J-98 J-99 J-00 J-01 J-02 J-03 J-04 J-05 J-06 J-07 J-08 J-09 J-10 J-11 J-12 J-13 J-14 J-15 J-16 J-17 J-18
DATE
Perforation Intervals 400' - 1000'

Southeast Area Hydrographs



Appendix B – Indian Wells Valley Groundwater Water Quality

Navy Production Wells									
Well 15	Cl-	SO4-	NO3-N	TDS	Well 30	Cl-	SO4-	NO3-N	TDS
1990	57.4	104	1.4	355	1990	27.3	46	1.8	225
1993	98	42	0.2	255	1993	28	48	1.8	225
1995	39.6	105	1.4	350	1995	27.1	42	1.4	195
2000	52	111	1.3	376	2000	22	43	1.7	222
2003	33	115	1.3	346	2003	29	33	1.3	200
2006	36	130	1.2	380	2006	24	50	1.7	270
2009	42	120	0.9	370	2009	24	48	1.6	220
2011	41	120	1.3	370	2011	29	48	1.6	220
Average	49.9	105.9	1.1	350.3	Average	26.3	44.8	1.6	222.1
Well 28	Cl-	SO4-	NO3-N	TDS	Well 18	Cl-	SO4-	NO3-N	TDS
1990	34.3	45	1.2	250	1990	26.9	35	1.2	215
1993	33.9	48	1.3	265	1993	21.9	26	1.3	205
1995	NR	NR	NR	NR	1995	14	15	0.5	200
2000	16	19	0.3	187	2000	NR	NR	NR	NR
2003	11	14	0.7	191	2003	16	20	1.1	180
2006	13	17	0.6	190	2006	30	34	1.8	230
2009	NR	NR	NR	NR	2009	17	15	0.5	160
2011	16	18	0.5	180	2011	20	13	0.5	200
Average	20.7	26.8	0.7	210.5	Average	20.8	22.6	1.0	198.6
Well 27	Cl-	SO4-	NO3-N	TDS	Well 31	Cl-	SO4-	NO3-N	TDS
1990	131	78	1.1	450	1990	NR	NR	NR	NR
1993	123	76	1.3	480	1993	NR	NR	NR	NR
1995	126	83	1.1	480	1995	24	35	2.3	225
2000	NR	NR	NR	NR	2000	20	35	1.9	212
2003	43	80	1.4	332	2003	19	30	2.3	192
2006	44	91	1.5	350	2006	22	36	2.2	220
2009	56	89	1.0	330	2009	NR	NR	NR	NR
2011	52	93	1.4	340	2011	27	41	2.1	210
Average	82.1	84.3	1.3	394.6	Average	22.4	35.4	2.2	211.8
Notes: units in mg/l									

Indian Wells Valley Water District Wells											
Well 7	Cl-	SO4-	NO3-N	As	TDS	Well 9A	Cl-	SO4-	NO3-N	As	TDS
26/39-						26/39-					
2005			1.8			2005	62	27	<0.5	46	310
2007						2007	91	27	1.3	29	330
2008						2008	94	37	<0.5	38	440
2009						2009			<0.5	44	
2010						2010			0.7	26	
2011						2011	57	25	<0.5	41	300
2012						2012			<0.5	34	
2013						2013			<0.5	40	
Average	-	-	1.8	-	-	Average	76.0	29.0	0.6	37.3	345.0
Well 10	Cl-	SO4-	NO3-N	As	TDS	Well 11	Cl-	SO4-	NO3-N	As	TDS
26/39-						26/39-					
2005	46	27	<0.5	11	260	2005	140	40	0.6	9.8	440
2007	97	24	0.8	11	350	2007	140	44	0.6	12	440
2008	40	23	0.7		280	2008	140	39	0.5	11	530
2010			0.6	14		2009			0.8	11	
2011	48		<0.5	13	280	2010			0.5	9.4	
2012			0.9	13		2011	180	51	0.8	8.6	500
2013			0.5	15		2012			0.7	3.8	
						2013			0.5	12	
Average	57.8	24.7	0.6	12.8	292.5	Average	150.0	43.5	0.6	9.7	477.5

Well 13	Cl-	SO4-	NO3-N	As	TDS	Well 17	Cl-	SO4-	NO3-N	As	TDS
26/39-						26/39-					
2005	240	53	<0.5	17	600	2005			1.6		
2007	180	38	<0.5	22	500	2007	19	29	1.5	6.7	200
2008	210	46	<0.5	20	670	2008	21	31	1.3		220
2009			<0.5	19		2009			1.8		
2010			<0.5	16		2010			1.2	8.2	
2011	200	45	<0.5	18	570	2011	16	24	1.2		190
2012			<0.5	16		2012			1.3		
2013			<0.5	18		2013			1.2		
Average	207.5	45.5	0.5	18.3	585.0	Average	18.7	28.0	1.4	7.5	203.3
Well 18	Cl-	SO4-	NO3-N	As	TDS	Well 30	Cl-	SO4-	NO3-N	As	TDS
26/39-						26/39-					
2005	26	47	1.7		270	2005	24	32	2.7		210
2007			1.8	3.1		2007				2.4	
2008	25	43	1.7		290	2008	22	31	2.7		220
2009			1.8			2009			2.7		
2010			1.7	2.2		2010			1.9	<2.0	
2011	24	46	1.7		270	2011	21	31	2.2		220
2012			1.8			2012			2.1		
2013			1.5			2013			1.7		
Average	25.0	45.3	1.7	2.7	276.7	Average	22.3	31.3	2.3	2.4	216.7
Well 31	Cl-	SO4-	NO3-N	As	TDS	Well 33	Cl-	SO4-	NO3-N	As	TDS
26/39-						26/39-					
2005	27	41	2.0		240	2005	32	46	1.9		280
2007			2.1	3.3		2007			1.9	3.8	
2008	190	41	1.4		550	2008	30	43	1.8		280
2009			2.1			2009			1.9		
2010			1.9	2.8		2010			1.9	3.6	
2011	25	39	2.1		230	2011	29	45	2.0		260
2012			1.8			2012			1.9		
2013			1.7			2013			1.7		
Average	80.7	40.3	1.9	3.1	340.0	Average	30.3	44.7	1.9	3.7	273.3
Well 34	Cl-	SO4-	NO3-N	As	TDS						
26/39-											
2005											
2007	31	46	2.0	4	290						
2008			1.8								
2009			1.9								
2010			1.9	3.3							
2011			1.8								
2012	30	45	1.8	4	280						
2013			1.7								
Average	30.5	45.5	1.8	3.8	285.0						

Notes: units in mg/l

Outlying Wells											
USBR-1	Cl-	SO4-	NO3-N	TDS	Sampler	USBR-2	Cl-	SO4-	NO3-N	TDS	Sampler
1991	17.1	27.9	2.2	212	Bur Rec	1990	20.8	27.6	0.4	240	USBR
1993	18	44	0.2	370	Stoner	1995	30.6	63	0.0	540	Hanson
1995	8.96	11.8	0.3	249	CSUB	1996	23.8	55.5	0.0	485	CSUB
1995	7.6	10.3	1.5	250	Hanson	1996	23	58	0.2	450	Stoner
1996	9.6	12	0.2	270	Stoner	2004	6.7	49	0.7	303	Stoner
2004	8	12	1.6	282	Stoner						
Average	11.5	19.7	1.0	272.2		Average	21.0	50.6	0.3	403.6	
USBR-3	Cl-	SO4-	NO3-N	TDS	Sampler	USBR-4	Cl-	SO4-	NO3-N	TDS	Sampler
1991	47.3	78.5	2.5	360	USBR	1990	15.9	19.1	0.2	183	USBR
1995	44.2	80	1.8	330	Hanson	1995	11.5	13	0.1	210	Hanson
1996	50.2	74.9	0.4	326	CSUB	1996	14	0.3	0.2	180	Stoner

USBR-3	Cl-	SO4-	NO3-N	TDS	Sampler	USBR-4	Cl-	SO4-	NO3-N	TDS	Sampler
1996	36	72	1.5	290	Stoner	2005	17	3.2	0.2	200	Stoner
Average	44.4	76.4	1.6	326.5		Average	14.6	8.9	0.2	193.3	
USBR-5	Cl-	SO4-	NO3-N	TDS	Sampler	USBR-6	Cl-	SO4-	NO3-N	TDS	Sampler
1992	85.5	149.6	0.2	534	USBR	1992	76	168	1.4	596	USBR
1995	92.8	66.9	0.2	484	CSUB	1995	117	109	0.4	675	Hanson
1996	120	35	0.2	440	Stoner	1996	119	70.8	0.2	581	CSUB
2004	110	1.5	0.2	412	Stoner	1996	120	30	0.2	380	Stoner
						2004	109	70	0.2	641	Stoner
Average	102.1	63.3	0.2	467.5		Average	108.2	89.6	0.5	574.6	
USBR-10	Cl-	SO4-	NO3-N	TDS	Sampler	NR-1	Cl-	SO4-	NO3-N	TDS	Sampler
1992	176	225	0.6	1000	USBR	1991	291	1095	58.8	2406	USBR
1993	61	64	0.1	310	Stoner	1995	218	96	0.5	1120	Hanson
1995	205	194	0.1	1120	CSUB	1995	981	83.3	0.0	3390	CSUB
1995	208	211	0.4	1140	Hanson	2005	960	100	0.2	3100	Stoner
1996	210	190	0.2	980	Stoner						
2005	213	219	0.2	1190	Stoner						
Average	178.8	183.8	0.2	956.7		Average	612.5	343.6	14.9	2504.0	
NR-2	Cl-	SO4-	NO3-N	TDS	Sampler	MW-32	Cl-	SO4-	NO3-N	TDS	Sampler
1991	85	232.8	5.8	808	USBR	1991	40.2	57	1.6	252	USBR
1995	69.3	133	0.3	645	Hanson	1995	30.6	43	1.3	260	Hanson
1995	62.3	105	0.0	617	CSUB	1996	27.6	38.7	0.3	245	CSUB
2005	57	130	0.1	640	Stoner	1996	26	13	0.2	140	Stoner
						2006	18	19	3.4	220	Stoner
Average	68.4	150.2	1.6	677.5		Average	28.5	34.1	1.4	223.4	
24/39-34 D01	Cl-	SO4-	NO3-N	TDS	Sampler	26/39-17 KM	Cl-	SO4-	NO3-N	TDS	Sampler
1993	40	9	0.3	500	Stoner	1982	27	20	2.0	173	Kerr-McGee
1995	40.6	5	0.4	465	Hanson	1995	13.1	3.7	0.2	110	Hanson
2008	38	6.4	0.5	480	Stoner	2013	7.1	4.9	ND	150	Stoner
Average	39.5	6.8	0.4	481.7		Average	15.7	9.5	1.1	144.3	
25/29-31 R01	Cl-	SO4-	NO3-N	TDS	Sampler	Campbell	Cl-	SO4-	NO3-N	TDS	Sampler
1993	89	181	0.3	590	Stoner	2007	130	140	0.7	560	Stoner
1995	91.1	162	0.7	550	Hanson						
2007	92	160	0.1	550	AB 303						
Average	90.7	167.7	0.4	563.3		Average	130	140	0.7	560	
Notes: units in mg/l											