Final Technical Report

Fort Irwin Salt and Nutrient Management Plan, CIP WW59

Prepared for
U.S. Army, Fort Irwin, CA
Task Order 0052
Contract DACA 87-02-D-0037

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September 2015

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Abbreviations and Acronyms

af	acre-feet
afy	acre-feet per year
CA DWR	California Department of Water Resources
CEQA	California Environmental Quality Act
CIP	Capital Improvement Project
CIMIS	California Irrigation Management Information System
CRWQCB	California Regional Water Quality Control Board
deg F	degrees Fahrenheit
DO	domestic water
gpd	gallons per day
gpd/ft	gallons per day per foot
in	inch
mg/L	milligrams per liter
MCL	maximum contaminant level
mo	month
NADP	National Atmospheric Deposition Program
NEPA	National Environmental Policy Act
NTN	National Trends Network
Plan	Salt and Nutrient Management Plan
Pro2D	Professional Process Design and Dynamics
RO	reverse osmosis
SNMP	Salt and Nutrient Management Plan
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
TKN	Total Kjeldahl Nitrogen
USGS	U.S. Geological Survey
WDMP	Water Demand Management Plan
WDR	waste discharge requirements
WTP	water treatment plant
WWTP	wastewater treatment plant
yr	year

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Executive Summary

Fort Irwin, home to the U.S. Army National Training Center, is located approximately 37 miles northeast of Barstow, California in the High Mojave Desert midway between Las Vegas, Nevada and Los Angeles, California. The water supply for Fort Irwin comes from three local groundwater basins—Bicycle, Irwin, and Langford—located within the Fort Irwin Military Reservation. The water is used for residential and commercial purposes at Fort Irwin. Nearly all of the water use occurs within the boundaries of the Irwin Basin.

Wastewater generated at Fort Irwin is treated at a wastewater treatment plant (WWTP) also located in the Irwin Basin. A portion of the treated wastewater is used as recycled water for irrigation within the Irwin Basin, and the remainder is discharged to evaporation and percolation ponds that make up the WWTP effluent disposal facilities. Water discharged to the evaporation and percolation ponds recharges the Irwin Basin only.

Because nearly all water use, including domestic (DO), reverse osmosis (RO), and recycled water, is within the Irwin Basin, and all wastewater effluent is either evaporated or returned to the Irwin Basin, this Salt and Nutrient Management Plan (SNMP) focuses on the Irwin Basin.

Salt and nutrient loading to the Irwin Basin was evaluated with regard to recent water demands in the absence of recycled water use, termed the "Baseline" condition. A set of management strategies, collectively referred to as the "Scenario," was developed to address salt and nutrient loading. Future salt and nutrient loading under the Scenario was evaluated, and the outcomes of Baseline conditions, strategies included in the Scenario, and implementation of the Scenario are presented below. It should be noted that quantification of water, salt, and nutrient balances presented herein are estimates and therefore approximate. Precision of the values presented is intended to facilitate consistency between the values and is not intended to imply that the values are accurate to this same degree.

Baseline Conditions

While a portion of the water pumped from the three local basins is used consumptively through evaporation or plant transpiration, the naturally occurring salt in that water is not consumed. Nearly all of the salt pumped from the three local basins (about 1,796 tons/yr), less net export of 34 tons/yr, is returned to the groundwater in Irwin Basin either through percolation of treated wastewater, pipe leakage, or deep percolation of applied irrigation water. An additional 295 tons/yr of salt are added to the system through imported salts in the wastewater stream, an additional 213 tons/yr of salt are estimated to be leached from the unsaturated zone (that is, the zone between ground surface and the water table; the water table represents the upper extent of the saturated zone) near the WWTP, and about 34 tons/yr are estimated as inflow with natural recharge. Total salt entering the Irwin Basin is estimated to be about 2,304 tons/yr.

After accounting for salt removal from Irwin Basin via groundwater pumping (432 tons/yr) and outflow to Langford Basin (107 tons/yr), the net accumulation of salts in Irwin Basin is about 1,764 tons/yr[1]. The Irwin Basin water balance suggests that the net accumulation of salts is accompanied by net recharge of water of about 706 afy, which together would result in an increase of average total dissolved solids (TDS) in Irwin Basin groundwater from about 700 mg/L currently to about 905 mg/L in 25 years in the absence of management strategies.

Nitrogen is also naturally occurring in the local basins, with the predominate source assumed to be historic atmospheric deposition. Additional nitrogen is imported via fertilizers and produced in human waste. Total nitrogen entering the Irwin Basin is estimated to be about 13.7 tons/yr from a combination of deep percolation of applied irrigation water, including fertilizers, pipe leakage, and treated wastewater. After accounting for nitrogen removal from Irwin Basin via groundwater pumping (2.65 tons/yr) and outflow to Langford Basin (0.48 tons/yr), the net addition of nitrogen to Irwin Basin is estimated to be about 10.6 tons/yr. The net addition of nitrogen is accompanied by net recharge of about 706 afy of water to Irwin Basin, which would result in an increase of average nitrogen in Irwin Basin groundwater from about 3.25 mg/L currently to about 4.6 mg/L in 25 years in the absence of management strategies.

Salt and Nutrient Management Plan

Planned salt and nutrient management strategies evaluated and collectively described as the "Scenario" include the following:

- **New water treatment plant (WTP).** A new WTP, Irwin Water Works, is under construction. Based on the design (CDM Smith, 2013), the plant will remove between 75 percent and 86 percent of salts and between 84 percent and 92 percent of nitrates, depending on the source water concentration.
- **Increased use of recycled water.** The recycled water system at Fort Irwin is currently being expanded. Future recycled water use in the Scenario is based on planned and funded expansion of the recycled water system, as summarized in the Recycled Water Master Plan (CH2M HILL, 2014a). Increased recycled water use will reduce dependence on Bicycle and Langford Basins, thereby reducing the amount of salts and nutrients imported and increasing long-term sustainability of water use at Fort Irwin.
- **Increased nitrogen removal at the wastewater treatment plant.** Upgrades to the WWTP are under construction, including a new anoxic basin and oxidation ditch to provide nitrogen removal as described in the Revised Waste Discharge Requirements from the California Regional Water Quality Control Board (CRWQCB, 2012).
- **Increased water supply from the Irwin Basin.** With the new Irwin Water Works, there will be more flexibility in the water quality of source water. Well I-9 has been rehabilitated, allowing more water to be pumped from Irwin Basin and reducing dependence on Bicycle and Langford Basins.
- **Install additional water meters to collect water use data.** Water meter data will help with accountability, potentially reducing water loss. The first group of area water meters have been installed; the next group of meters should be installed in 2016.

[1] All numbers are rounded to the nearest whole number. Accordingly, the sum of individual rounded values presented in the report may not always equal the rounded totals.

Anticipated Results of Plan Implementation

The salt mass balance under the Scenario suggests that there will be net removal of salt from the Irwin Basin of about 71 tons/yr while the water budget will be balanced (inflow equals outflow). This can be compared with the Baseline condition, in which there is a net *addition* of about 1,764 tons/yr of salt to the Basin. The result under the Scenario is a projected slight decline in future average TDS concentration in the Basin, compared with an increase of about 205 mg/L (to 905 mg/L in 25 years, from 700 mg/L currently) in the Baseline condition.

The nitrogen balance under the Scenario suggests that there will be net addition of nitrogen to the Irwin Basin of about 1.3 tons/yr. This can be compared with a net addition of about 10.6 tons/yr in the Baseline condition, or a decrease of about 9.3 tons/yr of net nitrogen entering the Basin under the Scenario. The result under the Scenario is a projected slight increase in future average nitrate concentration in the Basin (to 3.6 mg/L in 25 years from 3.25 mg/L currently) compared with a greater increase in the Baseline condition (to 4.6 mg/L in 25 years).

Summary

Salt has accumulated historically in the Irwin Basin, and it continues to accumulate. Nearly all of the salt that is pumped from the three local basins for water supply returns to the Irwin Basin through percolation of treated wastewater, pipe leakage, and deep percolation of applied irrigation water. A portion of the water evaporates or is consumed by plants, but salts are left behind by these processes, thereby resulting in relatively high TDS water being returned to the groundwater system. Planned management strategies are expected to result in a large reduction in the net salt loading to the Basin and likely a net removal of salts from the Basin. This is primarily due to the Irwin Water Works project that will remove salts for landfill disposal.

In contrast to salts, nitrogen does not simply cycle through the current system and accumulate in Irwin Basin. The primary sources of nitrogen to the system are domestic, and the primary sink is the WWTP where nitrification, denitrification, and solids removal occur. Nitrogen is currently accumulating in the Irwin Basin at a slow rate. Planned management strategies, primarily upgrades to the WWTP, are expected to reduce the nitrogen loading to the Basin and slow the rate of accumulation in the Irwin Basin.

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1.0 Introduction and Background

This Salt and Nutrient Management Plan for Fort Irwin, CA was prepared by CH2M HILL Constructors, Inc. (CH2M) for Capital Improvement Project (CIP) WWS9—Develop Salt and Nutrient Management Plan under Task Order 52 of Contract DACA87-02-C-0037 for the U.S. Army.

1.1 Water and Wastewater System Overview

Fort Irwin, home to the U.S. Army National Training Center, is located approximately 37 miles northeast of Barstow, California, in the High Mojave Desert midway between Las Vegas, Nevada and Los Angeles, California. Fort Irwin has a permanent population of about 11,900 people (military and family members), an additional 6,300 rotational soldiers, and a civilian workforce of about 5,600 for a daily population total of about 24,000 (U.S. Army, 2014).

Water supply for Fort Irwin comes from three local groundwater basins—Bicycle, Irwin, and Langford—located within the Fort Irwin Military Reservation (Figure 1-1; California Department of Water Resources [CA DWR], 2004). Water is used for residential and commercial purposes at Fort Irwin. Nearly all of the water use occurs within the boundaries of the Irwin Basin.

Two water distribution systems exist at Fort Irwin: the domestic water (DO) system and the reverse osmosis (RO) drinking water system. Up to 150,000 gallons per day (gpd) of DO water is processed in a RO treatment plant to produce drinking water that meets all applicable standards. The drinking or RO water is distributed to all residences and most other facilities through an independent distribution system. DO water is also distributed to all residences and other facilities through its independent system. DO water is intended for uses other than personal consumption, including irrigation, toilet flushing, laundry, industrial uses, etc.

A new water treatment plant (WTP), Irwin Water Works, is currently under construction and is anticipated to begin operation in early 2016. Water pumped from the Bicycle, Langford, and Irwin Basins will be delivered to the WTP for treatment rather than discharged directly into the distribution system. The WTP will supply water directly to the onsite storage tanks; additional transmission and distribution piping is planned to provide similar connectivity through the existing water distribution system.

Wastewater generated at Fort Irwin is treated at a wastewater treatment plant (WWTP) that is also located in the Irwin Basin. A portion of the treated wastewater is used as recycled water for irrigation within the Irwin Basin, and the remainder is discharged to evaporation and percolation ponds that make up the WWTP effluent disposal facilities (Figure 1-2). Water discharged to the evaporation and percolation ponds recharges the Irwin Basin only. Biosolids from the WWTP are conveyed to the local lined landfill on post for permanent disposal.

Because nearly all water use, including DO, RO, and recycled, is within the Irwin Basin and all wastewater not recycled either recharges the Irwin Basin or evaporates, this Salt and Nutrient Management Plan (SNMP) focuses on the Irwin Basin. The Irwin Basin is herein referred to as "the Basin" or "Basin."

1.2 Regulatory Framework

On February 10, 2004, California Regional Water Quality Control Board (CRWQCB), Lahontan Region, adopted Board Order No. R6V-2004-0005, "Revised Waste Discharge Requirements (WDR), Including Water Recycling Requirements" for Fort Irwin (CRWQCB, 2004). The Board Order was subsequently amended in 2012 (CRWQCB, 2012); the amendment included implementation of the 2009 State Water Resources Control Board (SWRCB) Recycled Water Policy (SWRCB, 2009). The overarching purpose of the Recycled Water Policy is to protect beneficial uses of groundwater and to promote sustainability of water resources. In support of protecting beneficial uses of groundwater, the Recycled Water Policy includes a requirement for development of an SNMP. This SNMP was developed to comply with the 2012 amendment R6V-2004-0005-A1, Finding 4.g., and to be consistent with Paragraph 6 of the Recycled Water Policy.

1.3 Purpose of Report

The purpose of this report is to present a stakeholder-driven SNMP for the Basin with the following objectives:

- Assess sources and loads for the identified constituents
- Identify salt and nutrient management strategies
- Evaluate effectiveness of the salt and nutrient management strategies in protecting Basin water quality
- Develop a plan for implementing salt and nutrient management strategies, including implementation schedule, stakeholder responsibilities, and monitoring program

1.4 Stakeholders

CH2M operates the water system at Fort Irwin and owns and operates the wastewater treatment facilities under the Utility Privatization Program. Transfer of the water system is in process and once completed (expected in 2016) CH2M will own the water system.

The Fort Irwin contract (DACA87-02-D-0037) was awarded to CH2M in September 2002 with the initial Task Order to perform System Characterization Studies. The studies resulted in negotiation and award of the long-term (50-year) ownership and operation of the wastewater utilities and long-term operation of the water utilities to CH2M. Operations and maintenance activities at Fort Irwin began on April 1, 2005. Ownership of the wastewater utility at Fort Irwin was transferred to CH2M on June 14, 2005. The transfer of ownership of the water system has been deferred to date because of system non-compliance with State of California regulations for fluoride and arsenic. As indicated above, Fort Irwin is constructing a WTP that is expected to resolve the water system compliance, and ownership of the water system is expected to be transferred to CH2M after completion of the WTP project.

This Plan identifies the Army and CH2M as the only stakeholders with regard to the SNMP for the following reasons:

- The Board order designates both CH2M and the U.S. Army as the Discharger, owing to the fact that CH2M owns the facility and the Army owns the land.
- The U.S. Army Corps of Engineers owns all of the land contributing source water to Fort Irwin, as well as all of the land area of receiving waters.

- The groundwater basins are closed hydrologic basins, both with respect to surface water and groundwater. There is no drainage of water from Irwin, Langford, and Bicycle Basins to any non-Federal lands and no importation of water from outside of Fort Irwin.

1.5 Document Organization

This document is organized to be consistent with the SWRCB's draft SNMP guidelines and suggested elements. The organization provides information in a sequential manner that considers the procedures undertaken to develop the information and analyses considered in this study. Each section's title and a brief summary follow:

- **Section 1, Introduction and Background:** Provides background information on Fort Irwin and the study.
- **Section 2, Groundwater Basin Characteristics:** Presents a summary description of the hydrogeology and water quality of the Irwin Basin.
- **Section 3, Basin Evaluation:** Provides details of the water balance, and salt and nutrient balance.
- **Section 4, Salt and Nutrient Management Strategies:** Presents management strategies and estimates of future water, salt, and nutrient balances after management strategies are implemented.
- **Section 5, Basin Management Plan Elements:** Summarizes the management plan goals and monitoring programs to evaluate whether the goals are being met.
- **Section 6, California Environmental Quality Act (CEQA) Analysis:** Summarizes the applicability of CEQA to implementation of management strategies.
- **Section 7, Antidegradation Analysis:** Summarizes the management strategies in the context of antidegradation policies.
- **Section 8, Plan Implementation:** Provides implementation and review schedule, and defines stakeholder responsibilities.
- **Section 9, References:** Provides a list of documents referenced for the study.

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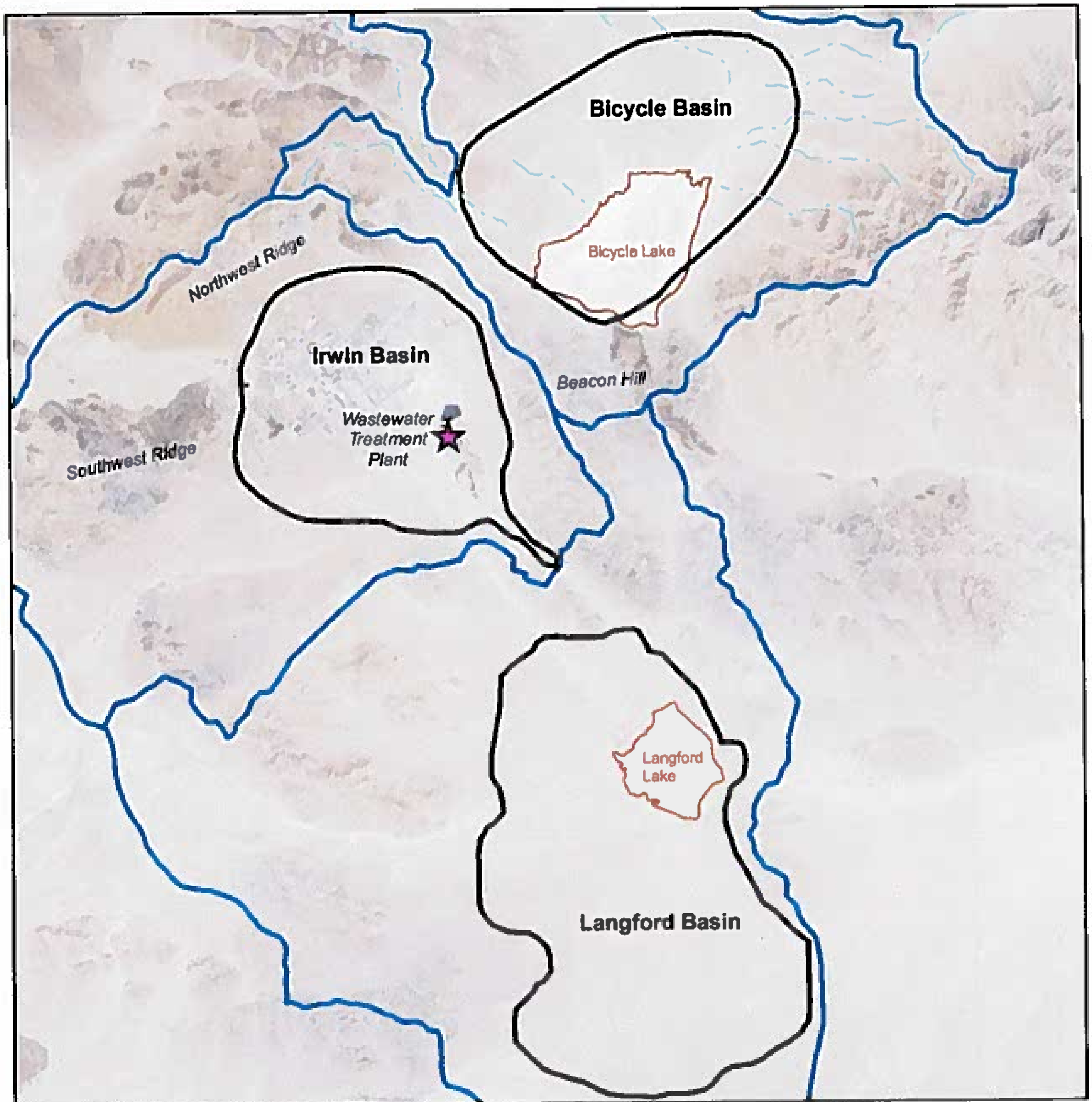

LEGEND

- Watershed Boundary
- Extent of Saturated Alluvium
- Dry Lake bed

VICINITY MAP

N

0 0.5 1 2
Miles

FIGURE 1-1
Area Map
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m:

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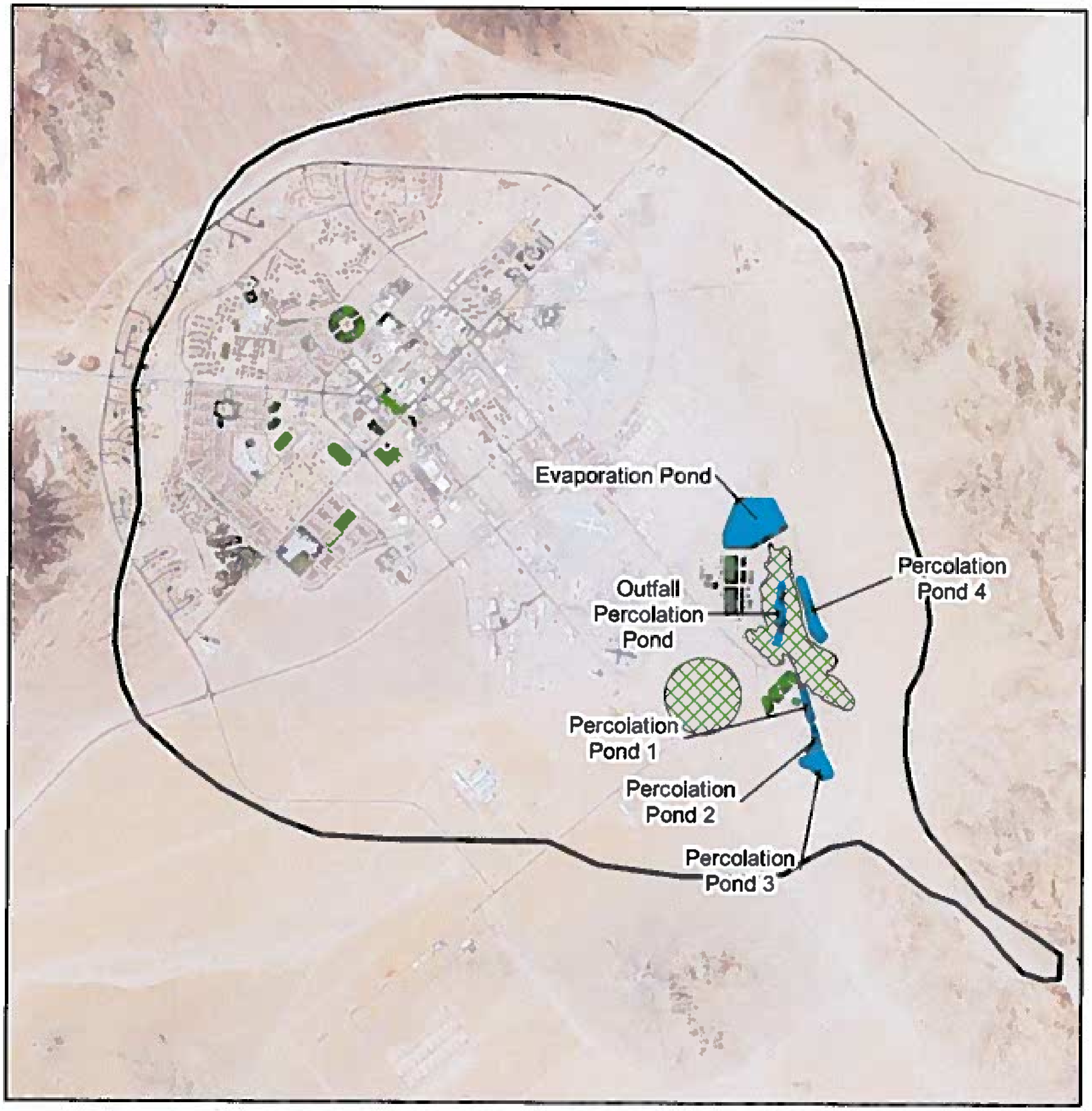


LEGEND

Current and Historical Wastewater Disposal

- Current Evaporation/Percolation
- Current Irrigation (Tertiary)
- Former Irrigation
- Approximate Extent of Saturated Alluvium

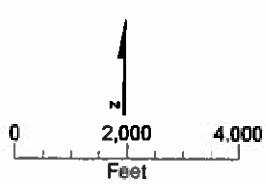


FIGURE 1-2
Wastewater Effluent Disposal Facilities
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

2.0 Groundwater Basin Characteristics

The purpose of this section is to present a summary description of the hydrogeology of the Irwin Basin. While the emphasis of this Plan is the Irwin Basin, the Fort Irwin water supply that is imported from Bicycle and Langford Basins is a source of salts and nutrients to Irwin Basin. Accordingly, pumping rates, water quality, and water storage summaries are provided for Bicycle and Langford Basins as well. For additional information about hydrogeology of Bicycle and Langford Basins, the reader is referred to the U.S. Geological Survey's (USGS's) recent study on Langford Basin (USGS, 2013) and CH2M's Regional Water Supply Investigation (CH2M HILL, 2007a).

This section relies on previous work, notably USGS studies (USGS, 1997 and 2003), previous work by CH2M (CH2M HILL, 2007a and 2007b), and previous work by MWH (MWH, 2011). Discussion is relatively brief as in-depth reports on the hydrogeology of these basins are available in these references.

2.1 Groundwater Basin Overview

An overview of the Irwin Groundwater Basin is provided in this section. Subsections describe the setting, climate, geology, and aquifers.

2.1.1 Land Use, Geographic Setting, and Hydrologic Setting

Fort Irwin is located in the High Mojave Desert, 37 miles northeast of Barstow, CA. Developed residential and commercial areas, locally referred to as the "cantonment," make up approximately half of the land area of the Irwin Basin (Figure 1-1). Irrigated landscape within the cantonment, consisting of turf grass, shrubs, and trees, is a contrast to the sparse natural vegetation of mesquite, creosote, yucca, and other low-growing desert plants.

Land surface of the cantonment is relatively flat with a gentle downward slope from west to east. Elevation ranges from about 2,600 feet in the west to about 2,400 feet in the east. The Irwin Basin is bordered to the east by Beacon Hill, to the north-northwest by Northwest Ridge, and to the west by Southwest Ridge. Low-lying hills to the south separate Irwin Basin from Langford Basin.

The Irwin Basin resides within a watershed of approximately 17,000 acres (Figure 1-1). No additional hydrologic areas are tributary to the Basin, and there are no perennial streams within the Basin (USGS, 1997). Surface water flow occurs in dry washes occasionally during and after large storms. If surface water flow is sufficient, it may leave the Basin through an unnamed wash in the southeast toward Langford Basin, where the ultimate surface water discharge is to a normally dry lakebed, Langford Lake (USGS, 2003; USGS, 2013). Accordingly, the Irwin and Langford Basins together form a closed surface water system.

2.1.2 Climate

Average annual precipitation at Fort Irwin ranges from 4 to 6 inches. About 75 percent of annual precipitation in the Mojave Desert occurs in the cool season (October through April) as widespread rainfall of relatively long duration. Occasional thunderstorms bring heavy rainfall and flash flooding during the summer months (USGS, 2005). The highest daytime temperatures typically occur during July when the average high temperature is 104 degrees Fahrenheit (deg F) and average low temperature is 73 deg F. The coolest temperatures occur in December when the average high temperature is 60 deg F and average low temperature is 36 deg F.

2.1.3 Geology

A map showing the generalized surficial geology of the three local groundwater basins is presented as Figure 2-1. Principal water-bearing sediments in these three basins are older alluvium of late Tertlary (38 million years ago) to Quaternary age (the past 2 million years) and younger alluvium of Quaternary age (USGS, 1997). Based on USGS estimates, the bedrock-alluvial interface elevation is as low as about 1650 feet (Figure 2-2; see also CA DWR, 2004), with alluvial thickness in the Irwin Basin as great as 950 feet.

2.1.4 Hydrogeology and Aquifers

Quaternary alluvium forms the primary water-bearing formation in Irwin Basin. Alluvial deposits are underlain by volcanic, igneous, and metamorphic rocks that convey little water except where they are fractured and jointed (USGS, 2003). The unconfined upper aquifer lies primarily within the saturated younger alluvium of Quaternary age to depths of about 200 feet below ground surface. The lower aquifer is confined through most of the Basin and can reach depths of more than 600 feet in the central portion of the Basin (USGS, 2003).

Transmissivity is a measure of the ease with which a volume of water can flow through an aquifer. It is expressed in terms of the volume of water flowing through a unit cross-sectional area of the entire aquifer thickness under a unit hydraulic gradient in a given amount of time (usually a day). Transmissivity estimates in the Irwin Basin range from about 20,000 to 30,000 gallons per day per foot (gpd/ft) (CH2M HILL, 2007a).

While historically there were as many as 14 production wells in the Irwin Basin, there is currently only one active production well in the Irwin Basin, Well I-7 (Figure 2-3). Well I-7 is located in the north-central portion of the Basin near the intersection of Barstow Road and 7th Street, and pumps at a rate of 650 gallons per minute.

In conjunction with the construction of the Irwin Water Works, two existing inactive Irwin wells are planned to be returned to service. Well I-2A will be rehabilitated and connected via a storage tank and booster pump station to the recycled water irrigation system for surge capacity and for a supply when recycled water systems are receiving repair and or maintenance. Well I-9 has been rehabilitated and connected to the Langford raw water supply system that will convey raw water to the Irwin Water Works.

2.2 Groundwater Inventory

Groundwater in the Irwin Basin, including a summary of inflow and outflow, groundwater levels, and movement, and groundwater in storage is discussed in this section.

2.2.1 Groundwater Budget Summary

Sources and sinks of water that flow into or out of the Basin are summarized in this section. The water budget is quantified in Section 3.1.

2.2.1.1 Groundwater Discharge

Groundwater is currently pumped from one well in Irwin Basin (I-7), three wells in Langford Basin (L-1, L-2, and L-3), and two wells in Bicycle Basin (B-4 and B-S) (Figure 2-3). Nearly all water pumped from these three basins is used in Irwin Basin, with a small amount exported to NASA Goldstone (see Section 3). Water has very limited use within Langford or Bicycle Basins. Recent total pumping has been about 2,200 acre-feet per year (afy), and distribution of pumping among the three basins has varied considerably recently (Figure 2-4).

Monthly distribution of pumping is typical of municipal water use, with the highest demand occurring during the summer months (Figure 2-5). Wastewater production, representative of indoor demand (see Section 3), is relatively constant, suggesting the monthly fluctuations in overall demand are largely due to irrigation demands. A more complete discussion of water demand is found in Section 3.1.

Additional discharge from Irwin Basin occurs as subsurface flow to the southeast toward Langford Basin. Previous studies estimate that discharge toward Langford Basin was about 50 afy (CA DWR, 1964; USGS, 1997) prior to groundwater development.

2.2.1.2 Groundwater Recharge

Natural recharge to the Irwin Basin occurs from infiltration of precipitation after it is channeled into ephemeral stream channels; it is assumed that rainfall recharge does not occur outside these channels (USGS, 2003). This is a common assumption in this area (see USGS, 2001; USGS 2004a; USGS 2004b). The USGS estimates that average annual natural recharge to the Irwin Basin is about 50 afy (USGS, 2003).

Additional sources of recharge to Irwin Basin include infiltration of treated wastewater through evaporation and percolation ponds in the southeast portion of the Basin and deep percolation of applied irrigation water and pipe leakage in the northwest part of the Basin. The quantity of recharge from these two sources far exceeds the natural recharge, as discussed and quantified in Section 3.

2.2.2 Groundwater Levels, Mixing, and Movement

Observed groundwater elevations obtained from the USGS National Water Information System and from CH2M sampling suggest that groundwater flows from the two primary recharge sources (WWTP area and irrigated areas) toward the center of the Basin where groundwater pumping occurs (Figure 2-6). Percolation ponds that recharge groundwater with treated wastewater have caused a groundwater "mound" to occur in the southeastern portion of the Basin. Groundwater flows radially outward from this area northwest toward the pumping well and, to a lesser degree, south toward Langford Basin.

There may be an additional area of relatively high groundwater elevations just west of the pumping well due to deep percolation of applied irrigation water; however, water elevation data in the northwest of the Basin are sparse. Water appears to flow from this area toward the pumping well where it is extracted for domestic and irrigation use in the Basin.

Observed data suggest that groundwater levels have risen throughout the Basin since the mid-1990s due to 1) a reduction of groundwater pumping from the Basin and 2) recharge due to deep percolation of applied irrigation water and percolation of treated wastewater. The greatest rise in water levels is observed in the north-central portion of the Basin, near the current and historic production wells, where groundwater elevations have risen by as much as 40 feet (Figures 2-7 and 2-8).

The reduction of pumping since about 1990 has allowed groundwater from adjacent areas to "fill in" the cone of depression caused by historical pumping. During this same period, groundwater has also risen on the order of 20 feet near the WWTP in response to recharge of treated wastewater.

Groundwater elevations were compared with land surface elevations to estimate depth to groundwater. Depth to groundwater ranges from about 20 feet in the southeast to about 300 feet in the northwest (Figure 2-9).

Groundwater elevations were combined with estimated elevations for the bedrock/alluvial interface obtained from the USGS to estimate the saturated thickness of the alluvial aquifer system. The estimated maximum saturated thickness of alluvium in the Basin is greater than 600 feet near its center (Figure 2-10).

2.2.3 Groundwater Storage

The specific yield of an aquifer represents the relative quantity of water that a unit volume of aquifer yields by gravity drainage of pore spaces. It is typically expressed as a percentage of the volume of the aquifer. Assuming a specific yield of 10 percent, there were about 80,000 acre feet of usable water in aquifer storage in the Irwin Basin in 2005 (CH2M HILL, 2007a). It should be noted that this estimate is highly dependent on the estimate of the elevation of the bedrock/alluvial interface, which is uncertain.

2.3 Basin Water Quality

This section summarizes water quality in the Irwin Basin, as well as imported water quality (from Bicycle and Langford Basins), delivered water quality, and water quality of treated wastewater.

2.3.1 Groundwater Quality

The following sections summarize water quality findings for the Irwin Basin. Sources of water quality data include JMM (1979 and 1981), Wilson F. So and Associates (1989), U.S. Army Center for Health Promotion and Preventive Medicine (2001), USGS (1980a, 1980b, 1997), USGS website, MWH (2011), results from CH2M's annual and semiannual groundwater sampling events (CH2M HILL, 2012), and CH2M's monitoring to support the State Board, Division of Drinking Water's Drinking Water Monitoring Program. Discussion in this section emphasizes total dissolved solids (TDS) and nitrate as representative of salts and nutrients. TDS and nitrate occurrence in the Basin are discussed spatially, through time, and by depth; summary conclusions about the sources of TDS and nitrate are also provided. Quantification of TDS and nitrogen loading to the Basin is summarized in Section 3.

2.3.1.1 TDS

The California Department of Health has established secondary maximum contaminant level (MCL) drinking water standards for TDS, which are set for taste and odor thresholds. The "recommended" secondary MCL for TDS is 500 mg/L; the "upper" secondary MCL is 1,000 mg/L.

TDS concentrations in groundwater in the Irwin Basin generally range from about 500 to 1,500 mg/L (Figure 2-11). The lowest TDS concentrations are in the southwest in areas presumably not influenced by human activity; these concentrations can be assumed to be representative of naturally occurring TDS concentrations. Higher concentrations are observed near the WWTP and sporadically around the developed portion of the cantonment. Each of these areas is discussed below.

Total Dissolved Solids near the Wastewater Treatment Plant

Near the WWTP, relatively high-TDS wastewater (on the order of 800 mg/L; see Section 2.3.2) is discharged to ponds where it is evapoconcentrated (increased in concentration due to evaporation) and percolated into the groundwater. The USGS (2003) concluded that the elevated TDS in groundwater near the WWTP cannot be explained by wastewater discharge and evapoconcentration alone and that some component of the high TDS was due to leaching of salts within the unsaturated zone (zone between ground surface and the water table; the water table represents the upper extent of the saturated zone) as infiltrating water moves down toward the water table. This hypothesis is supported by the fact that TDS concentrations are observed to increase with depth in samples taken from the unsaturated zone. It is possible that some of the salts in the unsaturated zone are naturally occurring or have accumulated through time due to historical irrigation in the area (notably the former golf course and former center-pivot irrigation field; see Figure 2-11).

In general, TDS concentrations at the water table near the WWTP, but away from current and former irrigated areas, are around 1,200 mg/L (Figure 2-11). Near irrigation areas, particularly the former center-pivot irrigation area and the current driving range, significantly higher TDS concentrations are observed likely due to evapoconcentration of applied irrigation water and potential leaching of salts from historical irrigation.

Generally, TDS concentrations near the WWTP have remained relatively stable or have decreased through time (Figure 2-12). Water from well STP-4, located just south of the WWTP, steadily decreased in concentration from the early 1990s until the early 2000s when it leveled off at around 1,200 mg/L. The historically high TDS may be due to leaching of salts that had accumulated in the soil due to irrigation of the former golf course, with more recent TDS concentrations representing an equilibrium state of leaching.

High TDS waters near the WWTP appear to migrate toward the northwest following the general groundwater flow pattern in the Basin from the WWTP toward the current and historical Irwin Basin production wells. Time-series plots of TDS in the "transition area" show increasing TDS concentrations, supporting the assumption that high TDS waters from wastewater irrigation and percolation are migrating toward the northwest.

As can be seen on Figures 2-13 through 2-16, TDS concentrations generally decrease with depth. It appears that the higher TDS water from the WWTP percolation ponds tends to stay near the water table as it spreads laterally away from the WWTP (USGS, 1997).

Total Dissolved Solids near the Developed Area of Cantonment

The sporadic high concentrations of TDS near the developed area may be due to irrigation and associated evapotranspiration (USGS, 1997). These processes are quantified in the Salt and Nutrient Balance section (Section 3.2). Wells with higher TDS water tend to be shallower wells, which would be consistent with deep percolation of irrigation water (see, for example, well 14/3/32P6, a shallow well, compared with 14/3/32P4, a deeper well, in Figure 2-12). In addition, TDS concentrations in all wells in the developed area of the cantonment appear to be relatively stable since the 1990s (Figure 2-12). Because the TDS concentrations in the transition area did not start increasing until the 1990s or later, the steady concentrations through time suggest that the source of sporadic high TDS in the cantonment area is not the higher TDS water from the wastewater treatment plant area.

2.3.1.2 Nitrogen

Ammonia, biological nitrogen, and nitrite are rarely found in water from wells in the region[2]. Accordingly, the analysis of nitrogen in groundwater and delivered water is based on measured nitrate concentrations in wells. California's nitrate drinking water MCL is 10 mg/L (nitrate as N).

---

[2] This conclusion is based on an analysis of water quality and well data in Irwin, Langford, Bicycle Basins, as well as other adjacent basins. Of 89 wells sampled for ammonia (as N) + organic nitrogen, only 1 had a sample with a value greater than 1 mg/L (13/3 4D3). That particular well had a sample result of 4 mg/L in 1993, followed by non-detect in 1994 and 0.12 mg/L in 2010. Of 91 wells sampled for nitrite (as N), the maximum sample result was 0.7 mg/L, and only 12 wells had samples with nitrite (as N) values between 0.1 mg/L and 0.7 mg/L.

Nitrate is widespread in groundwater in Irwin, Langford, and Bicycle Basins. It is assumed that one source of nitrate is natural atmospheric deposition and subsequent leaching from soils (Densmore and Bohlke, 2000) in all three basins. Some of this naturally occurring nitrate in Bicycle and Langford Basins is imported to Irwin Basin through the water supply system.

Nitrate concentrations show a similar spatial distribution as TDS, with higher concentrations near the WWTP and sporadically around the developed area of the cantonment (Figure 2-17). Each area is further discussed below.

Nitrate near the Wastewater Treatment Plant

Nitrate concentrations in groundwater near the WWTP have generally been declining in recent years (Figure 2-18). This decrease is likely due to historical changes in wastewater treatment and associated effluent nitrate concentrations as discussed in Section 2.3.3, "Recycled Water Quality." Prior to 1993, wastewater was treated using a lagoon plant with limited nitrogen removal capabilities. In 1993, the current WWTP was built. While it was not designed to remove nitrate, it is likely that the current WWTP removes more nitrate than the lagoon plant did previously, which likely explains the decline in nitrate concentrations in wells near the WWTP in the 1990s. Additional improvements to the WWTP are under construction, which are expected to further increase the nitrogen removal efficiency, as discussed in Section 4.

It is reasonable to assume that some of the higher values of nitrate appearing west and north of the WWTP are due to migration of high nitrate waters away from the WWTP. Those wells also have relatively high TDS and are downgradient from the WWTP, based on the recent groundwater elevation map (Figure 2-6). However, unlike TDS, nitrate concentrations have been decreasing in some of the transition area wells. It is possible that the decreasing concentrations reflect the assumed decrease in historical WWTP effluent nitrate concentration.

More high nitrate groundwater is found near current and former irrigated areas (STP-15, STP-8A, and STP-10). It is possible that fertilization of these areas, and/or historical irrigation using water with higher nitrate concentrations, has contributed to additional nitrate in the groundwater below them. Quantification of nitrate sources, including fertilizers, is found in Section 3.

The USGS reports that nitrate concentrations are generally greater in shallow wells (USGS, 1997), and that trend is generally observed here (Figures 2-13 through 2-16). Combined with observed TDS concentrations, this suggests that percolating wastewater and return flows from irrigation primarily mix with water near the top of the water table as it migrates laterally away from the WWTP and are not yet influencing groundwater at deeper depths in the aquifer. Tertiary lacustrine deposits and faults may slow down the vertical migration of nitrate and TDS (USGS, 1997).

Nitrate near Developed Areas of Cantonment

The sporadic high concentrations of nitrate near the developed area may be due to irrigation and associated fertilization, and evapotranspiration of applied irrigation water, in addition to the natural atmospheric deposition source discussed above. These processes are quantified in the Salt and Nutrient Balance section (Section 3.2).

2.3.2 Delivered Water Quality

As discussed above, the source water for Fort Irwin is a mix of water from the three local groundwater basins. There are currently two separate water delivery systems, the DO and the RO systems. Water from the RO system is treated at an RO plant and delivered to a separate drinking water tap at sinks for water consumption. DO water is used for all other purposes, including both indoor water use (laundry, showers, toilets, etc.) and outdoor water use (irrigation, vehicle washing, etc.). Accordingly, the DO system makes up the majority of water delivered; approximately 2,000 af of DO water is delivered annually, compared to about 100 afy of RO water.

It should be noted here again that Irwin Water Works is currently being constructed, which will eliminate the "split system" of DO and RO water. Irwin Water Works is discussed further in Section 4. Water quality for each of the existing delivery systems is discussed below.

2.3.2.1 DO Water

DO water quality was estimated by performing a mixing calculation using pumping rates of individual wells, along with their assumed concentrations. TDS and nitrate concentrations of water from all pumping wells, as well as the assumed concentrations used in the salt and nutrient balances, are presented in Figures 2-19 through 2-24.

Water imported from Bicycle Basin has average TDS concentrations ranging from approximately 540 to 750 mg/L. TDS in Langford Basin is slightly lower, with average TDS concentrations ranging from approximately 475 to 550 mg/L. TDS concentrations in irwin Well I-7 averages about 530 mg/L. Average nitrate (as N) concentrations in Bicycle Basin range from 4.5 to 5.5 mg/L depending on the pumping well, while Langford wells average between 1.S and 2.5 mg/L, and irwin Well I-7 averages 3.25 mg/L.

DO water quality was estimated in the following manner. For each well, total mass was calculated on a monthly basis by multiplying the metered volume of water pumped at the well by the average concentrations shown on Figures 2-19 through 2-24. The mass was then summed for all wells and divided by the total volume of water pumped in the month to obtain an average concentration. This calculation assumes that the water from all wells is fully mixed and approximates the average water quality of raw water over the course of a month. Resultant calculated delivered DO TDS concentrations are generally between about 520 and 640 mg/L (Figure 2-25), while nitrate (as N) concentrations are between about 2.3 and 5.1 mg/L (Figure 2-26). Concentrations of both TDS and nitrate have decreased in the past year as less water was pumped from Bicycle Basin where TDS and nitrate concentrations are generally the highest.

2.3.2.2 RO Water

The TDS concentration of RO-produced water typically ranges from near 0 to 160 mg/L, averaging less than 100 mg/L (Figure 2-27). RO water is not regularly sampled for nitrate.

It should be noted that the RO brine concentrate is currently returned to the WWTP. Therefore, salts and other constituents are still cycled through the system. Assuming that all RO water is used non-consumptively (that is, for indoor uses such as washing and drinking that do not remove water from the system) and returns to the WWTP where it is mixed back in with the RO brine, there is no net salt accumulation or removal from the system due to the RO plant.

2.3.3 Recycled Water Quality

The WWTP receives wastewater from both the DO and RO systems, as well as brine from the RO plant. TDS concentrations of the WWTP effluent vary between about 750 and 1,000 mg/L with recent concentrations averaging about 800 mg/L (Figure 2-28). Total nitrogen concentration in WWTP effluent have fluctuated historically, with values between 0 and 50 mg/L. Average total nitrogen concentration since 2010 has been about 8 mg/L[3] (Figure 2-29).

[3] Estimates are based on the average of sum of ammonia (as N) and nitrate (as N) between May 2010 (WWTP upgrades and change in operations) and March 2014. Actual total nitrogen concentration represents the sum of ammonia (as N) plus ammonium (as N) plus biological nitrogen (collectively analyzed in laboratories as Total Kjeldahl Nitrogen [TKN]), nitrate (as N), and nitrite (as N). Biological nitrogen or TKN in effluent was only measured starting in 2012. During the period in which TKN was measured, total concentration of other contributors to total nitrogen were generally less than 1 mg/L based on the difference between average ammonia (as N) plus nitrate (as N) and TKN.

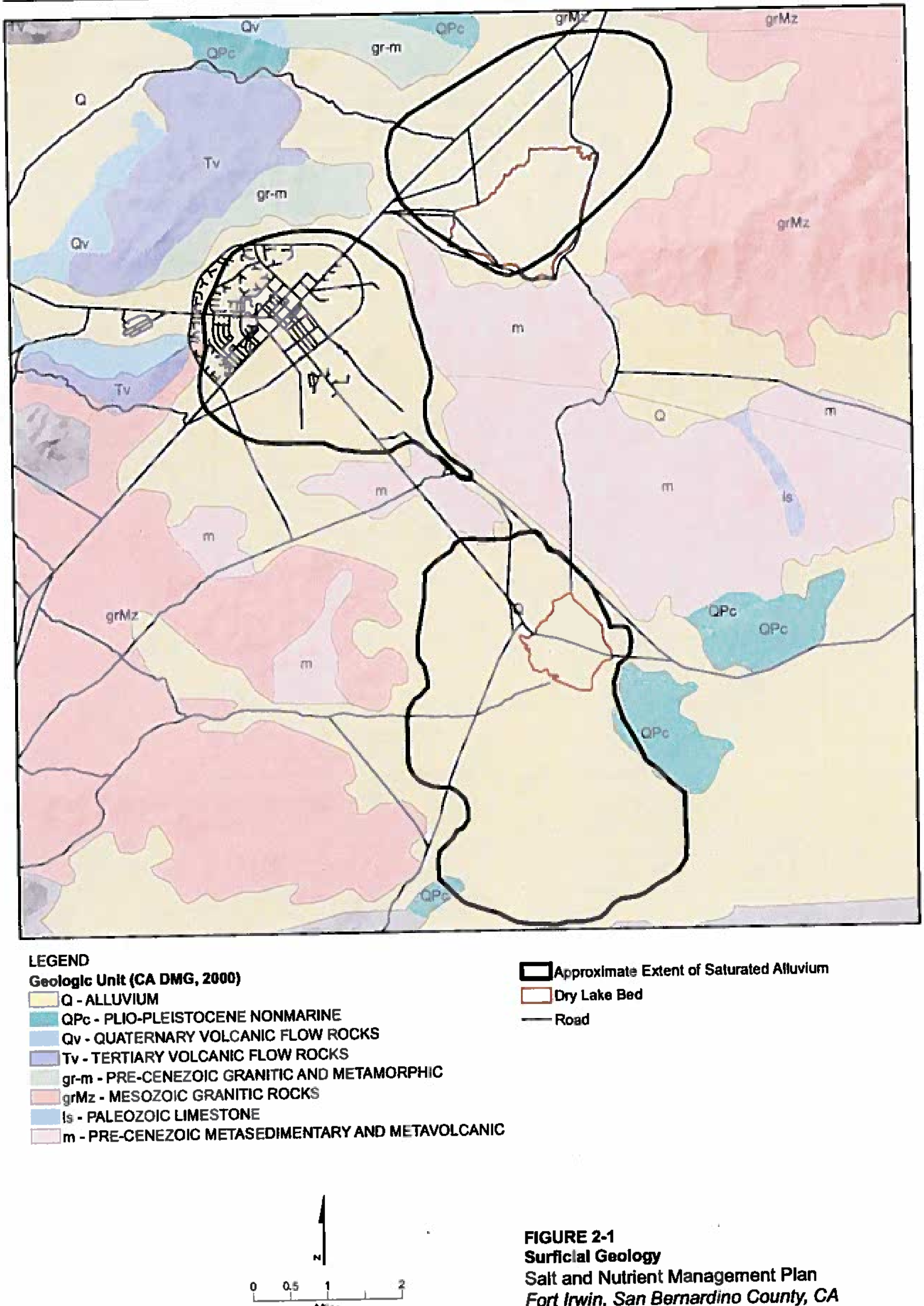


FIGURE 2-1
Surficial Geology
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m:

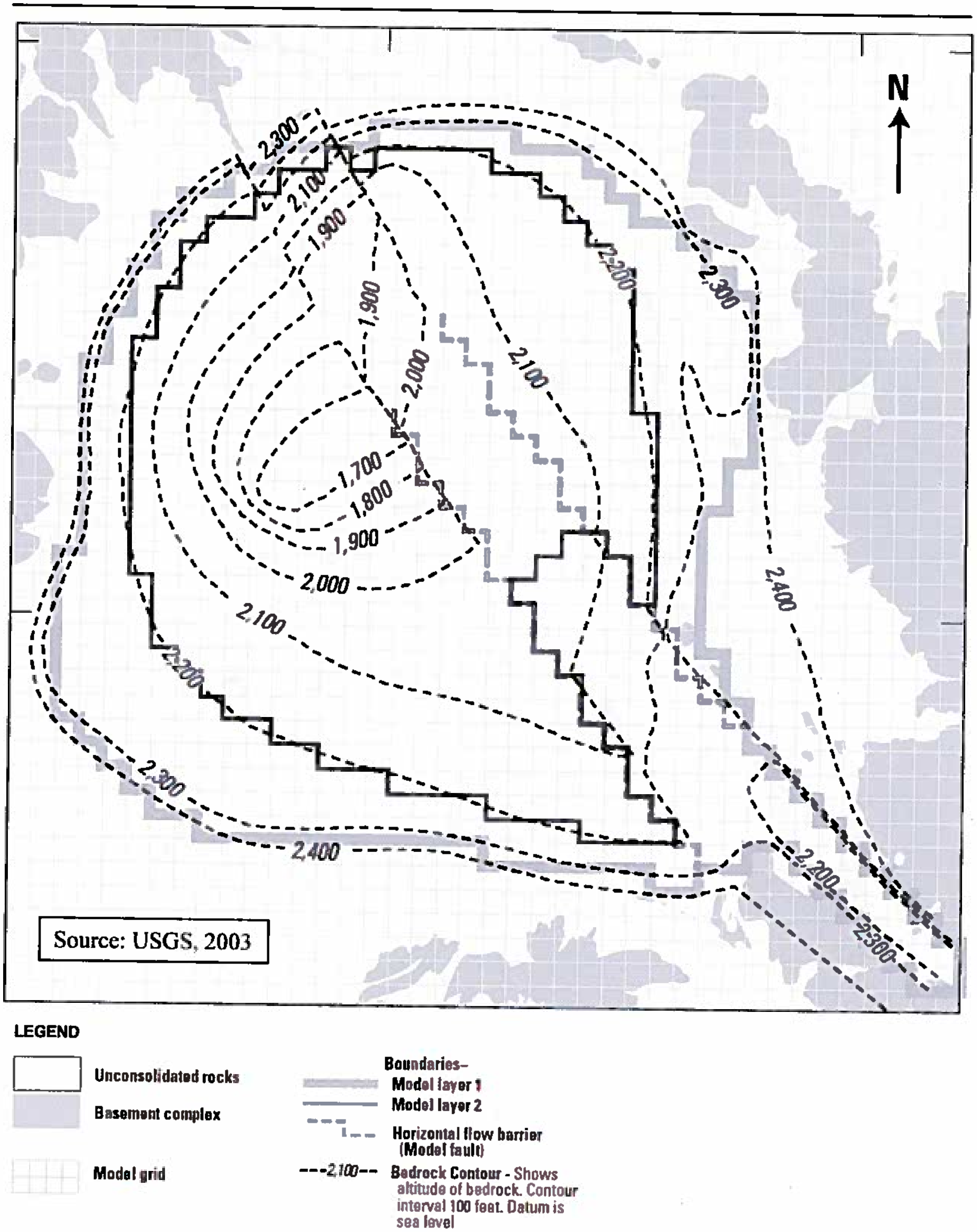


FIGURE 2-2
Irwin Basin Bedrock Elevation, USGS Model
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

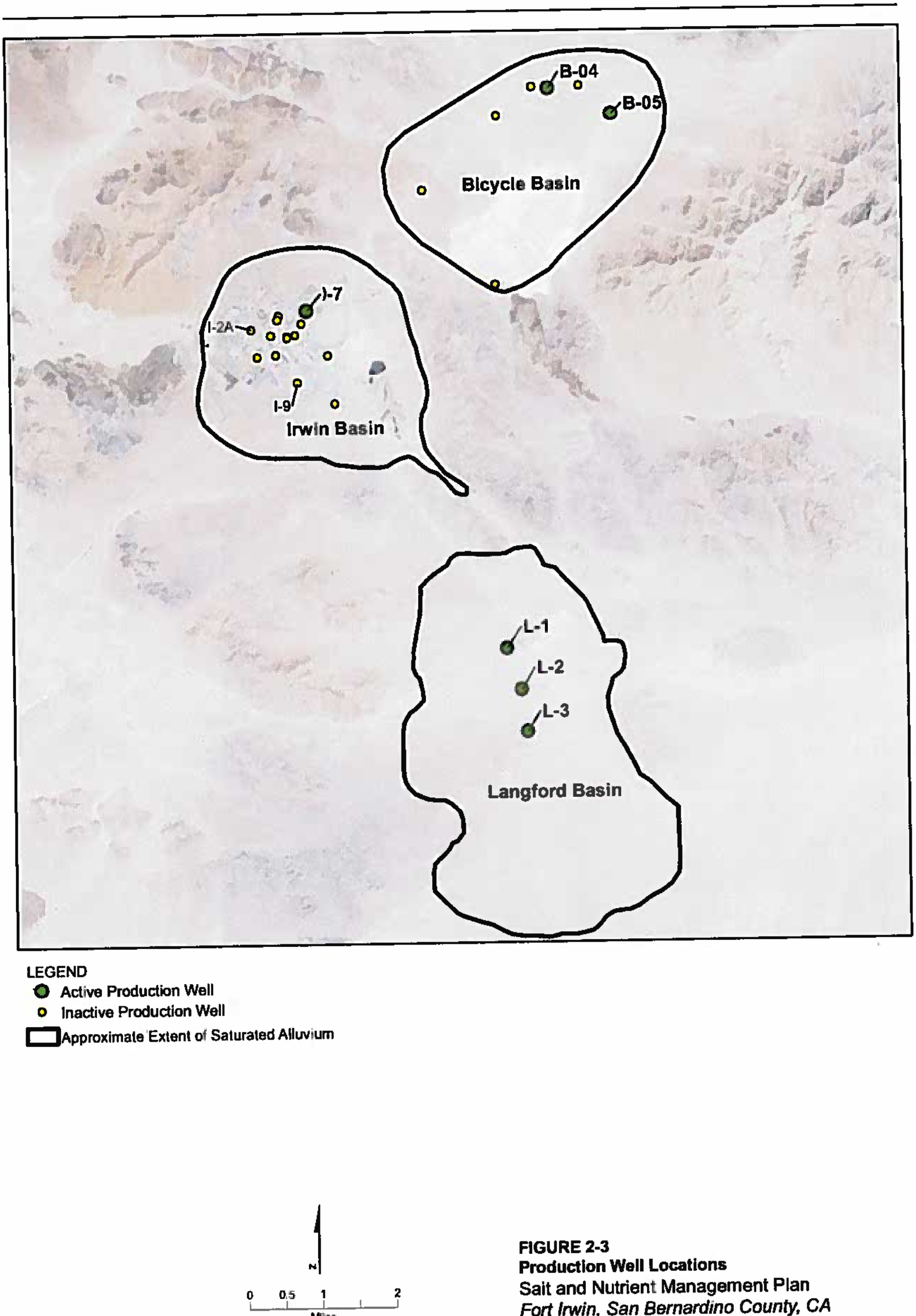


FIGURE 2-3
Production Well Locations
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m:

\04_PROJDOCS\03_DISCIPLINES\37_HYDROGEOLOGY\GIS\MAPFILES\SNMP\FIR_SNMP_PRODWELLS SSHULTZ

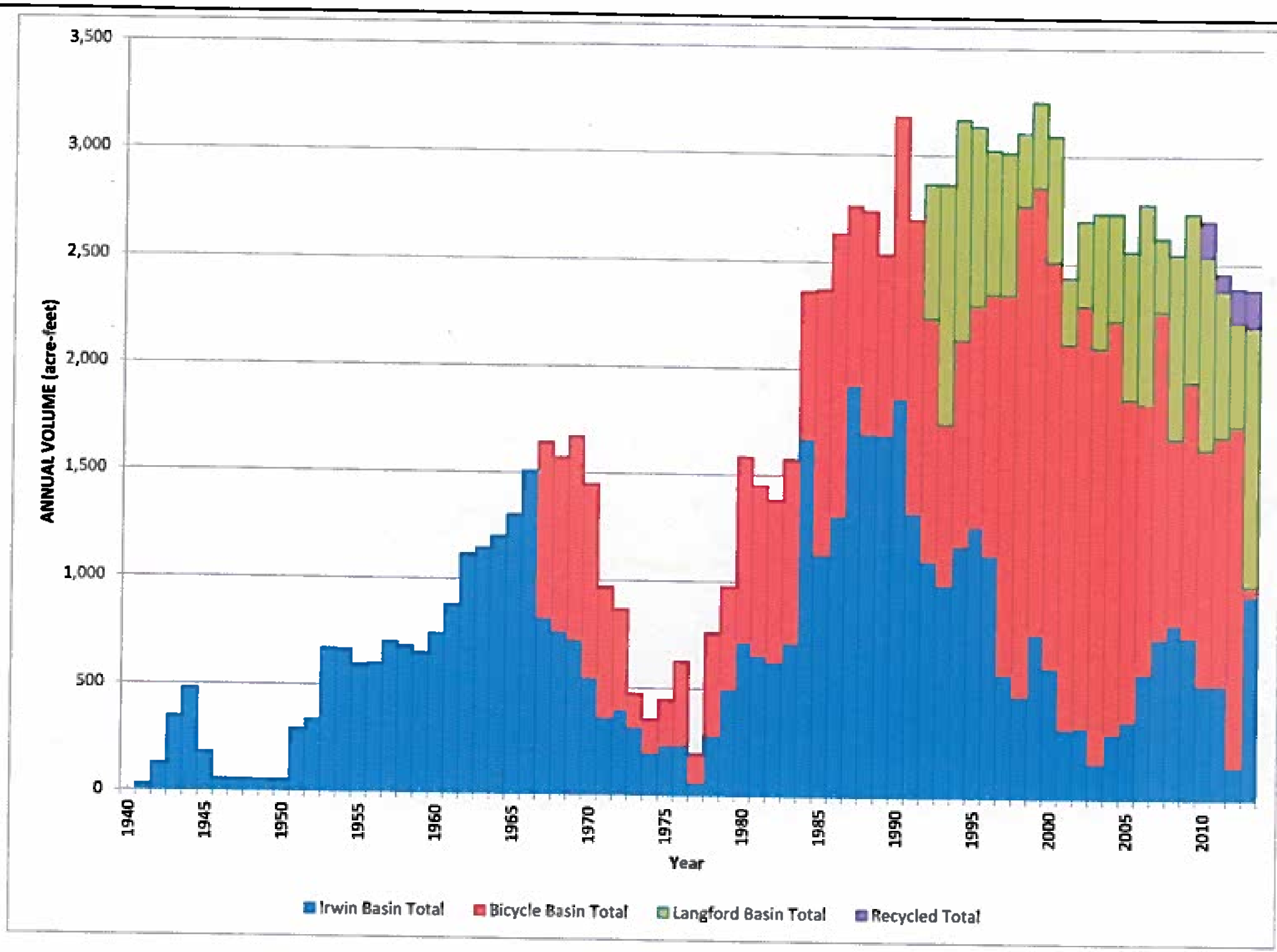


FIGURE 2-4
Annual Water Production
By Basin
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

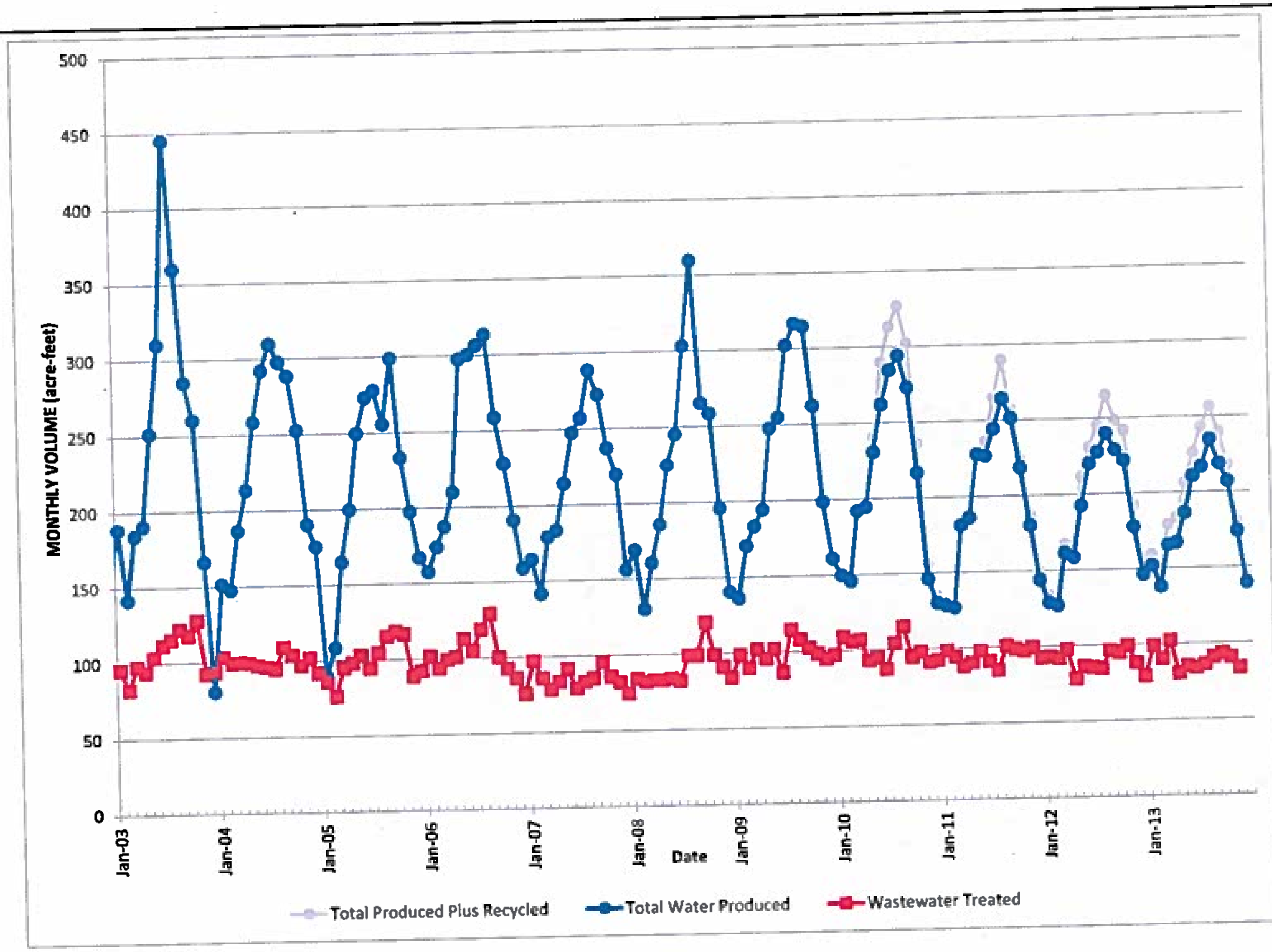


FIGURE 2-5
Monthly Water and Wastewater Produced
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

LEGEND

Groundwater Elevation

Approximate Extent of Saturated Alluvium

Active Production Well

Inactive or Abandoned Production Well

Monitoring Well

N

0 2,000 4,000

Feet

FIGURE 2-6
Groundwater Elevations, 2011
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

\04_PROJDOCS\03_DISCIPLINES\37_HYDROGEOLOGY\GIS\MAPFILES\SNMP\WL\FIR_SNMP_WATERLEVELMAP_V3 SSHULTZ

ch2m:

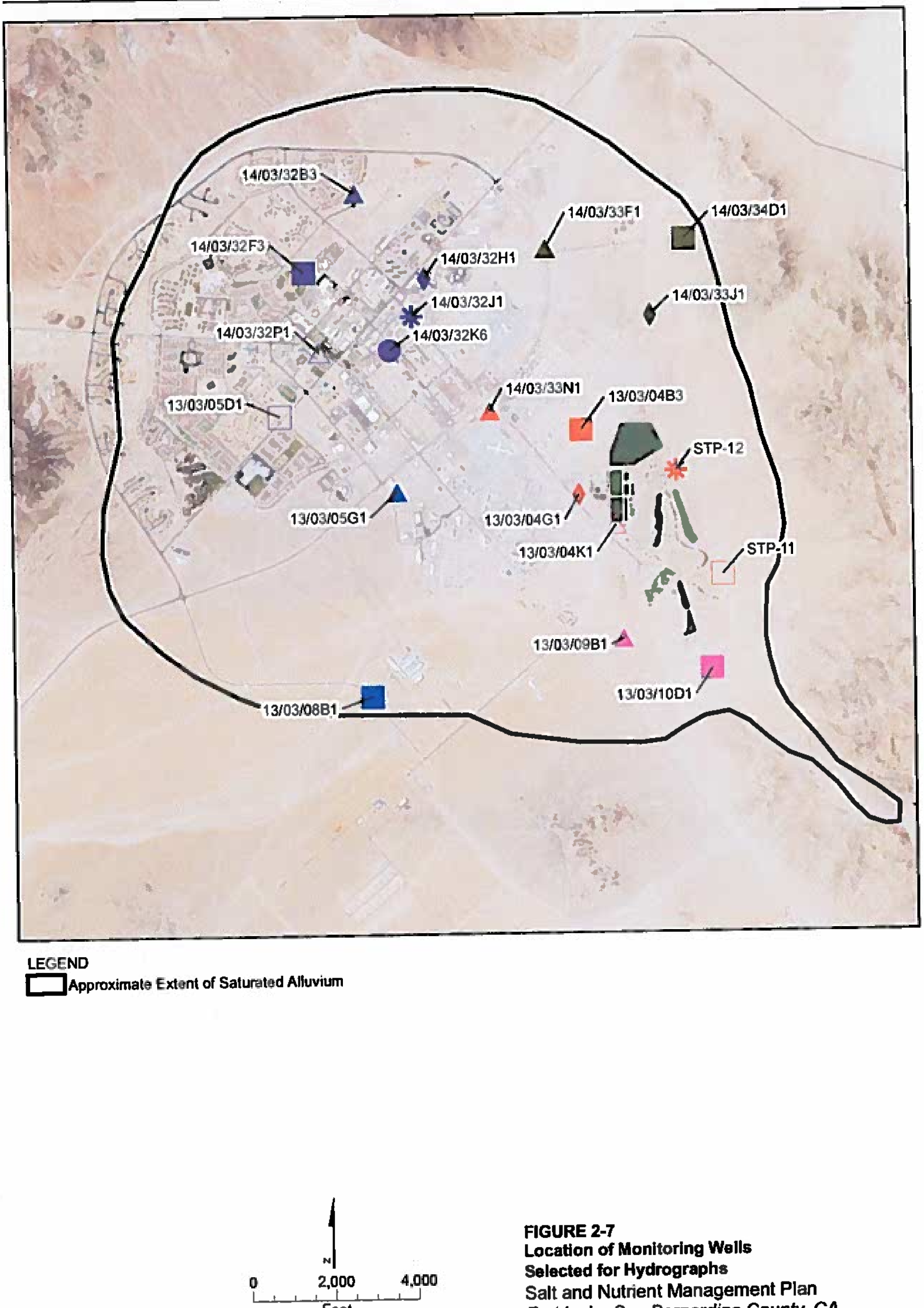


FIGURE 2-7
Location of Monitoring Wells
Selected for Hydrographs
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m:

\04_PROJDOCS\03_DISCIPLINES\37_HYDROGEOLOGY\GIS\MAPFILES\SNMP\WL\FIR_WL_HYDROGRAPHLOCS SSHULTZ

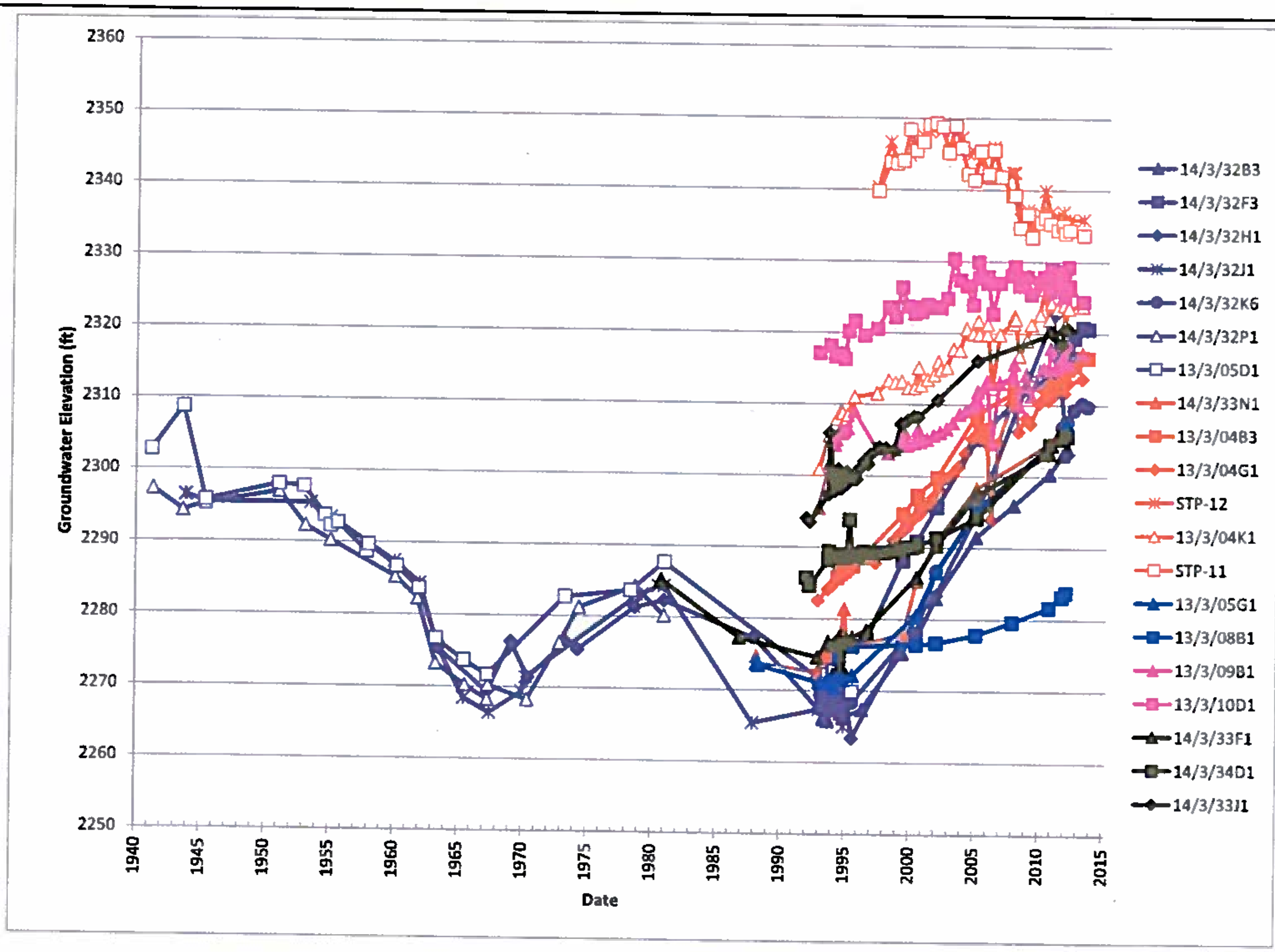


FIGURE 2-8
Hydrographs for Wells in Irwin Basin
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

\04_ProjDocs\03_Disciplines\37_Hydrogeology\Analysis\WLs\SNMP\Hydrographs\Excel\Hydrographs_IrwinBasin_rev(4).xlsx

ch2m

LEGEND

- Active Production Well
- Inactive or Abandoned Production Well
- Depth to Water Contour (ft)
- Approximate Extent of Saturated Alluvium

N

0 2,000 4,000
Feet

FIGURE 2-9
Depth to Water, 2011
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m:

\04_PROJDOCS\03_DISCIPLINES\37_HYDROGEOLOGY\GIS\MAPFILES\SNMP\WL\FIR_SNMP_DEPTHTOWATER SSHULTZ

LEGEND

Saturated Thickness (feet)

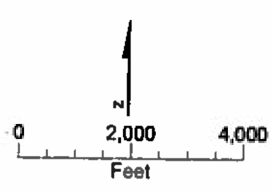
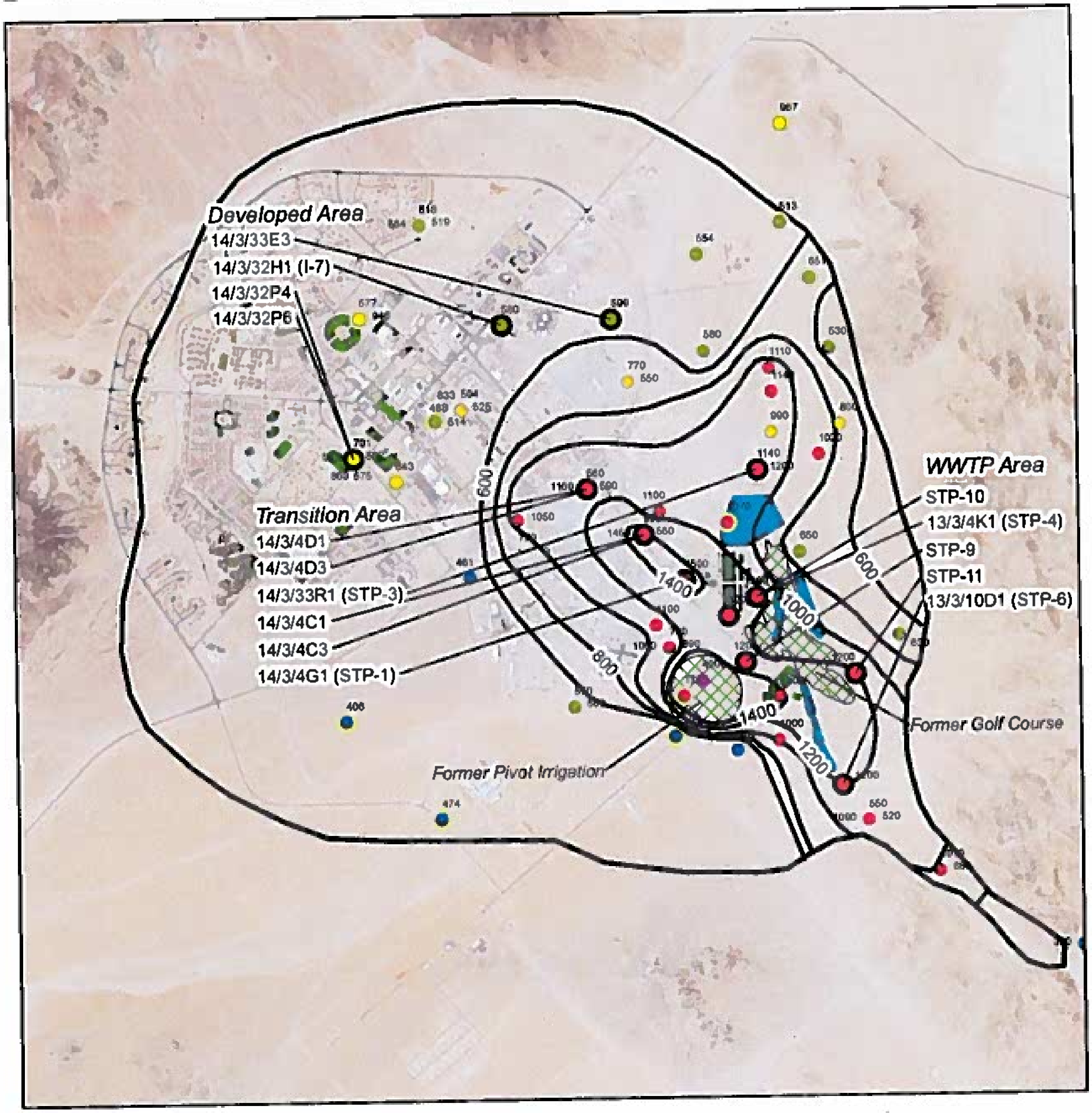


FIGURE 2-10
Saturated Thickness
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m:



LEGEND

TDS (mg/L) in wells

- < 500
- 500 - 750
- 750 - 1000
- 1000 - 2000
- 2000 - 5000
- Sampled before 2006
- Time-Series Plotted in Following Figure

TDS Contours

Approximate Extent of Saturated Alluvium

Current and Historical Wastewater Disposal

- Current Evaporation/Percolation
- Current Irrigation (Tertiary)
- Former Irrigation

NOTE: Water quality samples presented are the most recent sample availble for each well. Sample dates are generally between 2011 and 2013. Samples before 2006 are noted with green halo.

N

0 2,000 4,000

Feet

FIGURE 2-11

Spatial Distribution of TDS, Irwin Basin

Salt and Nutrient Management Plan

Fort Irwin, San Bernardino County, CA

ch2m:

\04_PROJDOCS\03_DISCIPLINES\37_HYDROGEOLOGY\GIS\MAPFILES\SNMP\WQ\TDS MAPS\TDS_SPATIAL SSHULTZ

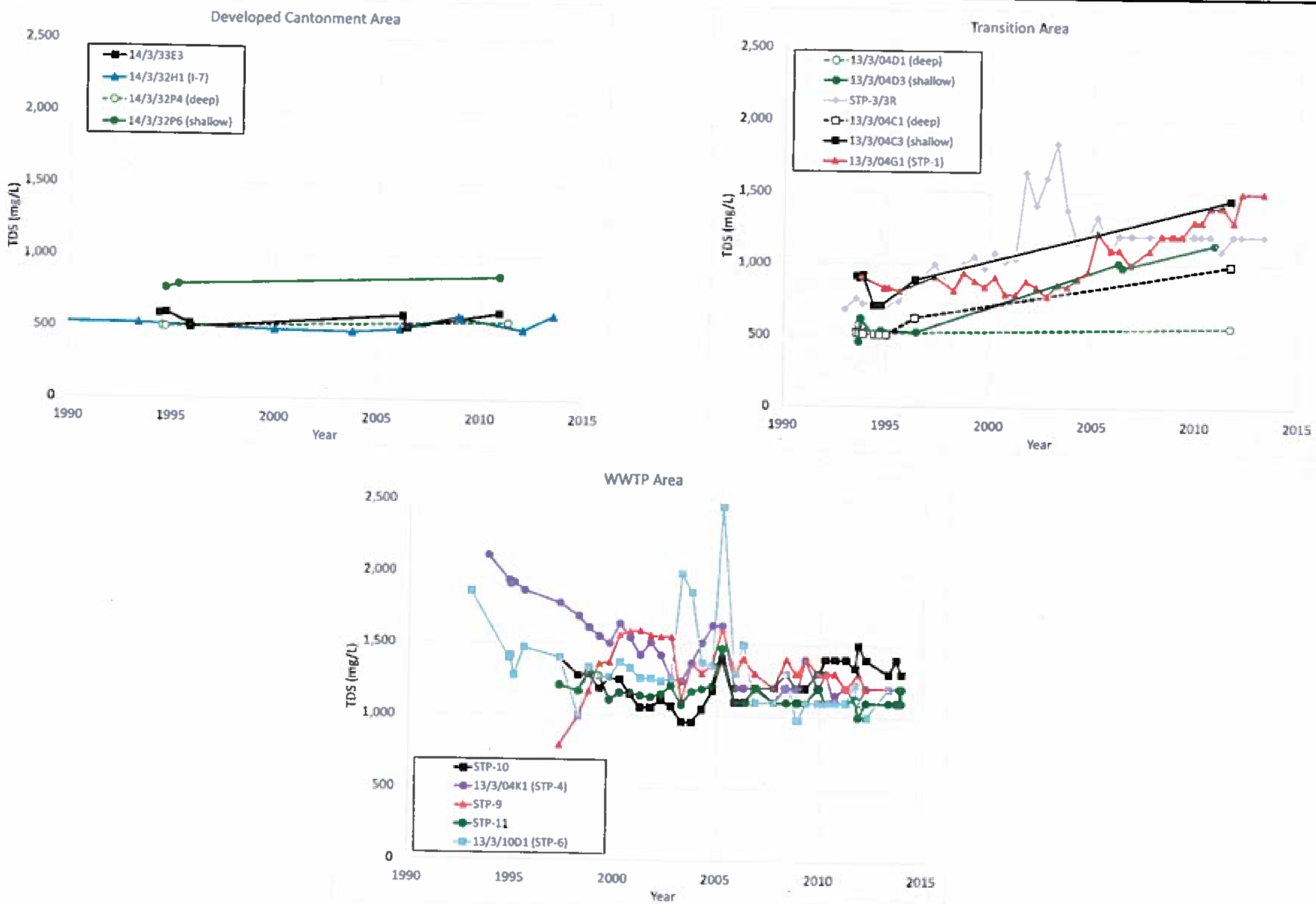


FIGURE 2-12
Time-Series of TDS, Irwin Basin
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

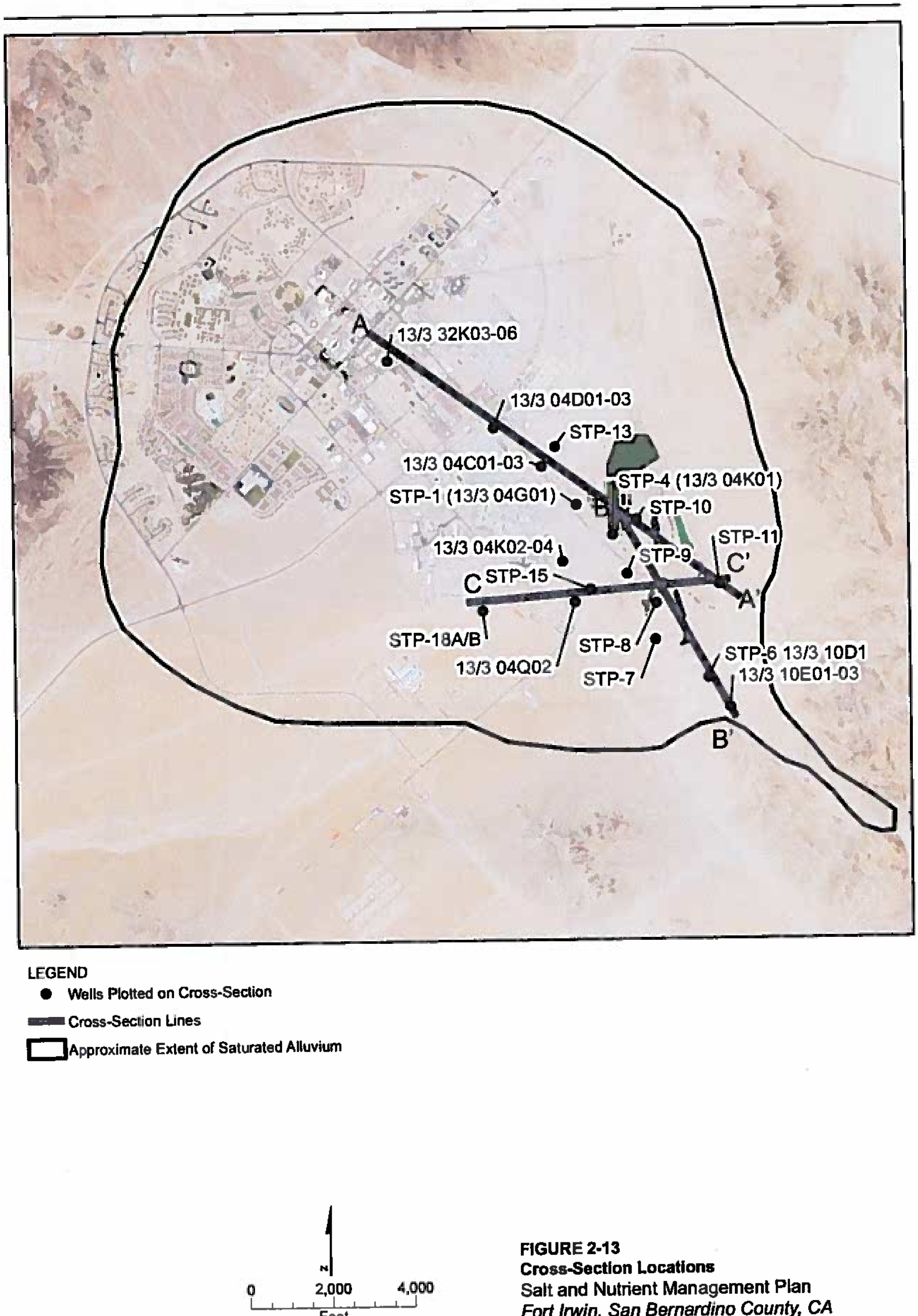


FIGURE 2-13
Cross-Section Locations
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m:

\04_PROJDOCS\03_DISCIPLINES\37_HYDROGEOLOGY\GIS\MAPFILES\SNMP\FT_IRWIN_XSECTLOCS SSHULTZ

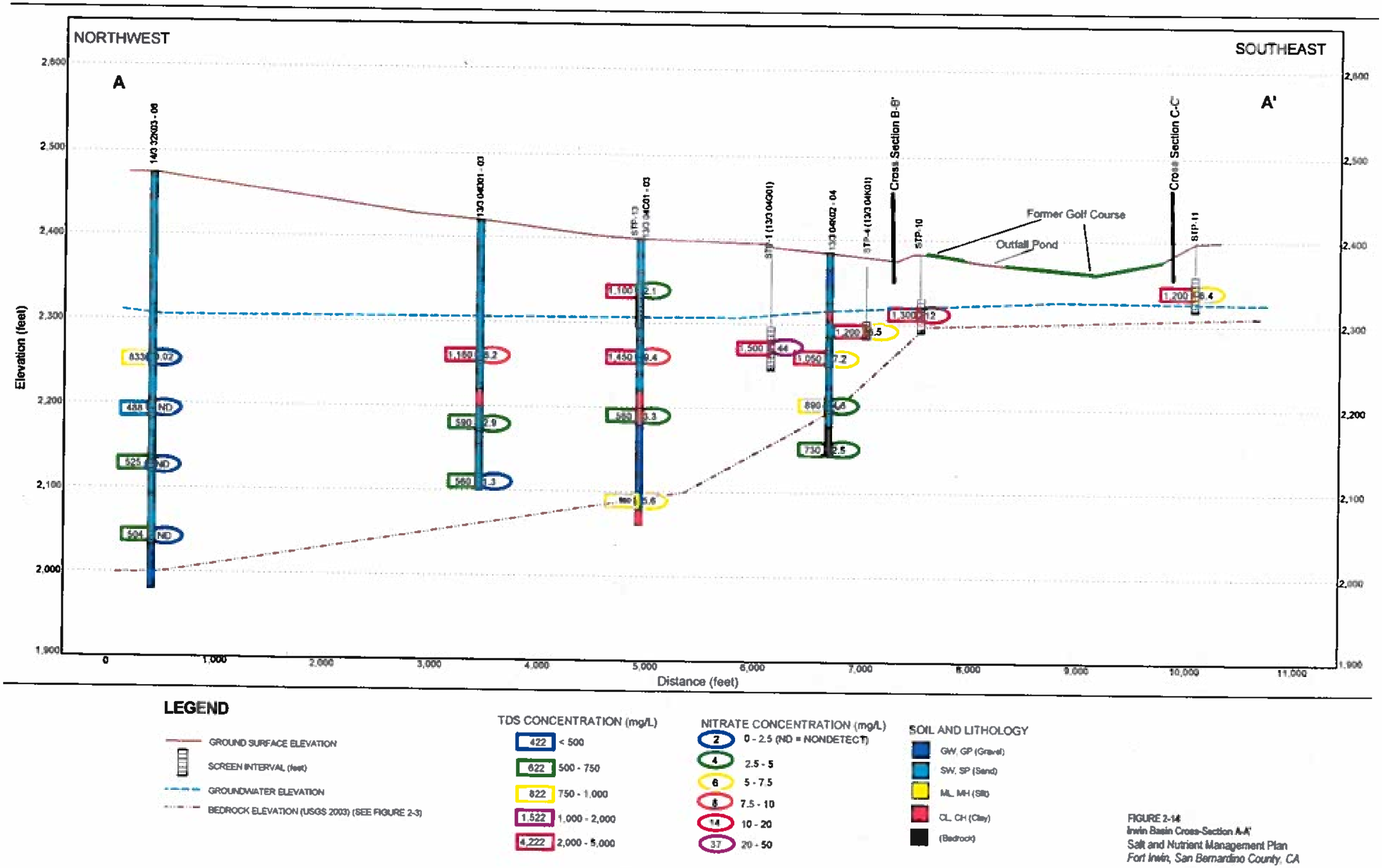


FIGURE 2-14
Irwin Basin Cross-Section A-A'
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m.

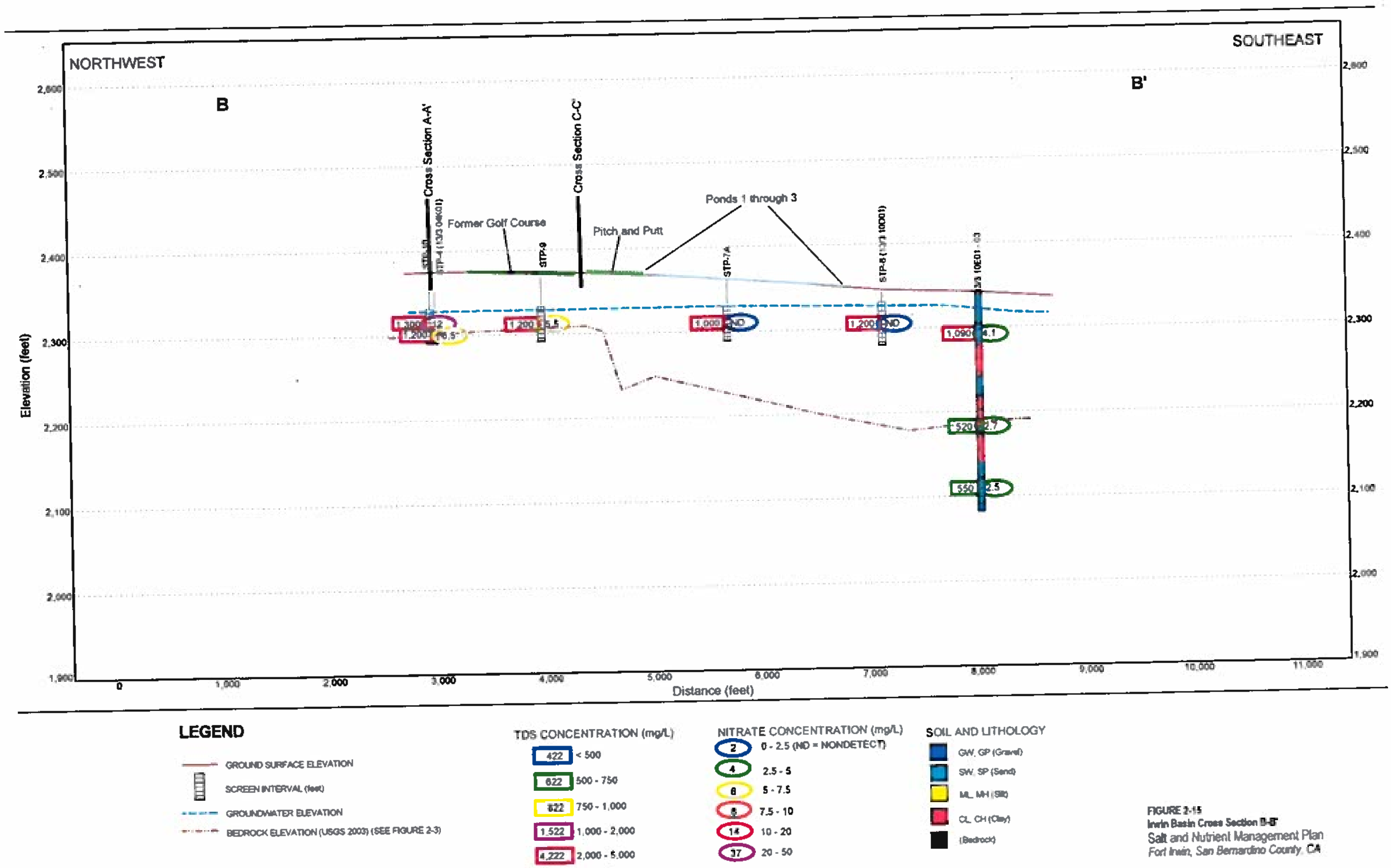


FIGURE 2-15
Irwin Basin Cross Section B-B'
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m

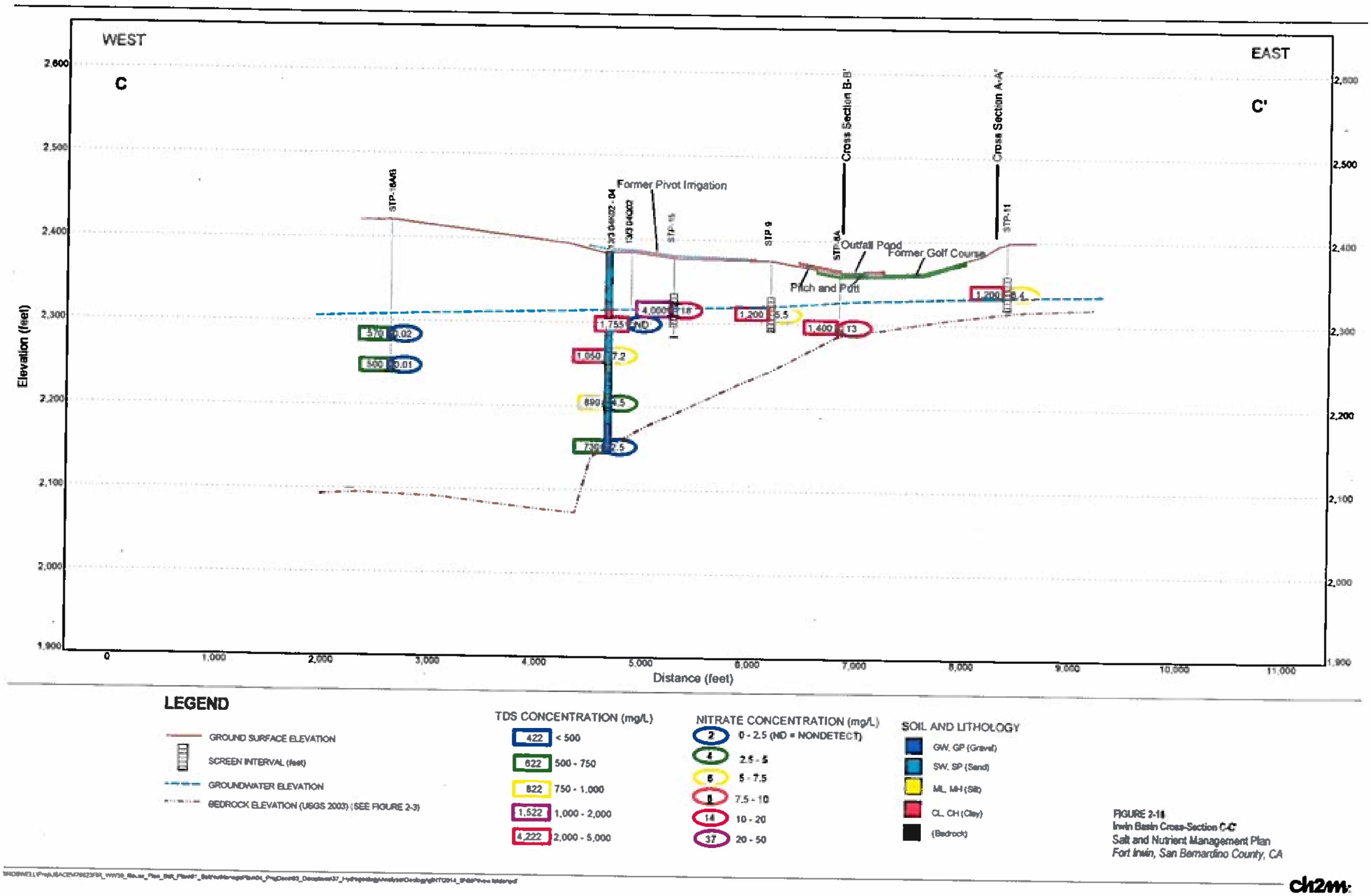
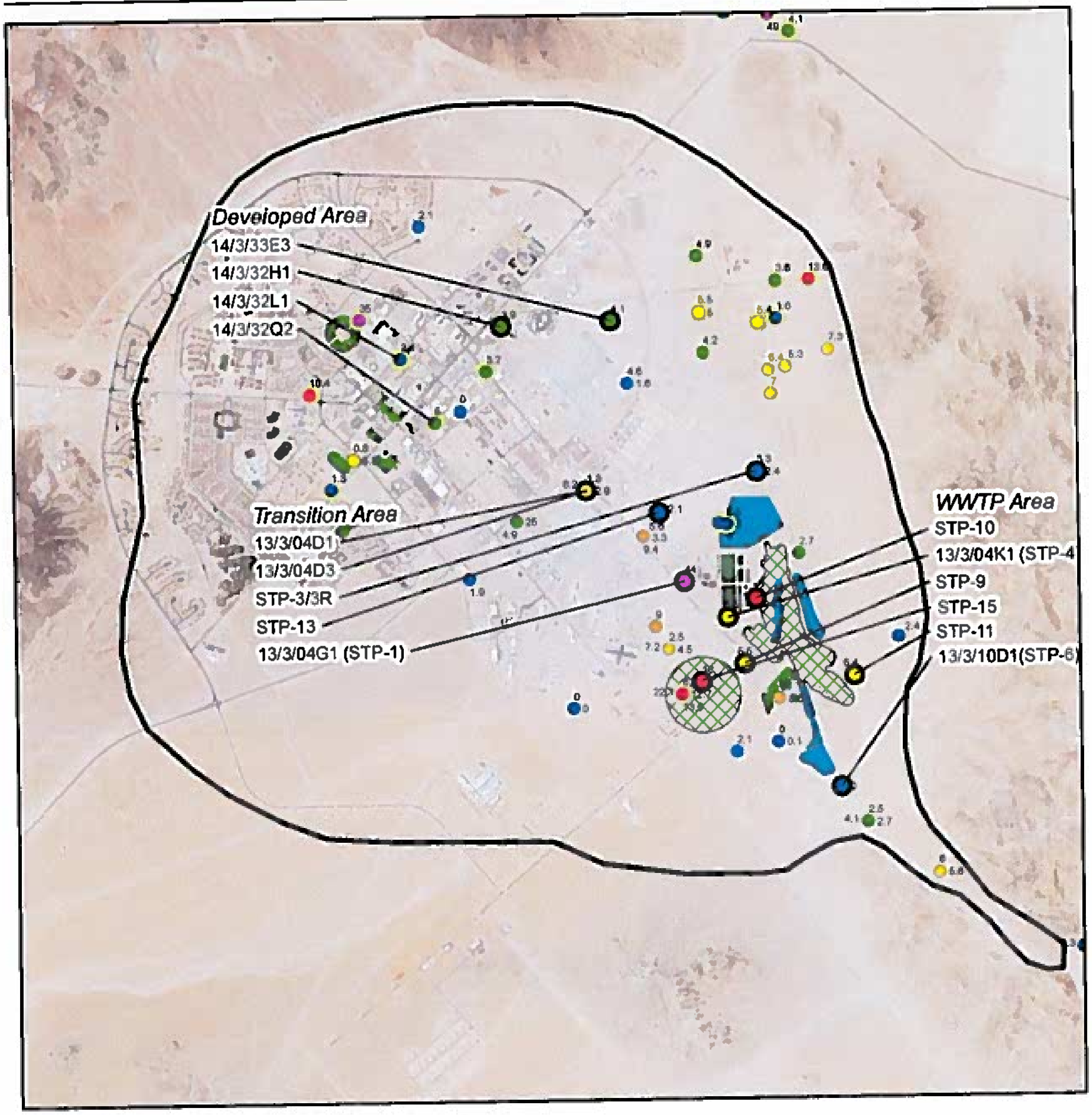


FIGURE 2-18
Irwin Basin Cross-Section C-C'
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m.



LEGEND

Nitrate as N (mg/L) in Wells

- 0 - 2.5
- 2.5 - 5
- 5 - 7.5
- 7.5 - 10
- 10 - 20
- 20 - 50
- Sampled before 2006
- Time-Series Plotted In Following Figure

Approximate Extent of Saturated Alluvium

Current and Historical Wastewater Disposal

- Current Evaporation/Percolation
- Current Irrigation (Tertiary)
- Former Irrigation

NOTE: Water quality samples presented are the most recent sample availble for each well. Sample dates are generally between 2011 and 2013. Samples before 2006 are noted with green halo.

N

0 2,000 4,000
Feet

FIGURE 2-17
Spatial Distribution of Nitrate, Irwin Basin
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m:

\04_PROJDOCS\03_DISCIPLINES\37_HYDROGEOLOGY\GIS\MAPFILES\SNMP\WQ\NO3N MAPS\NITRATE_SPATIAL SSHULTZ

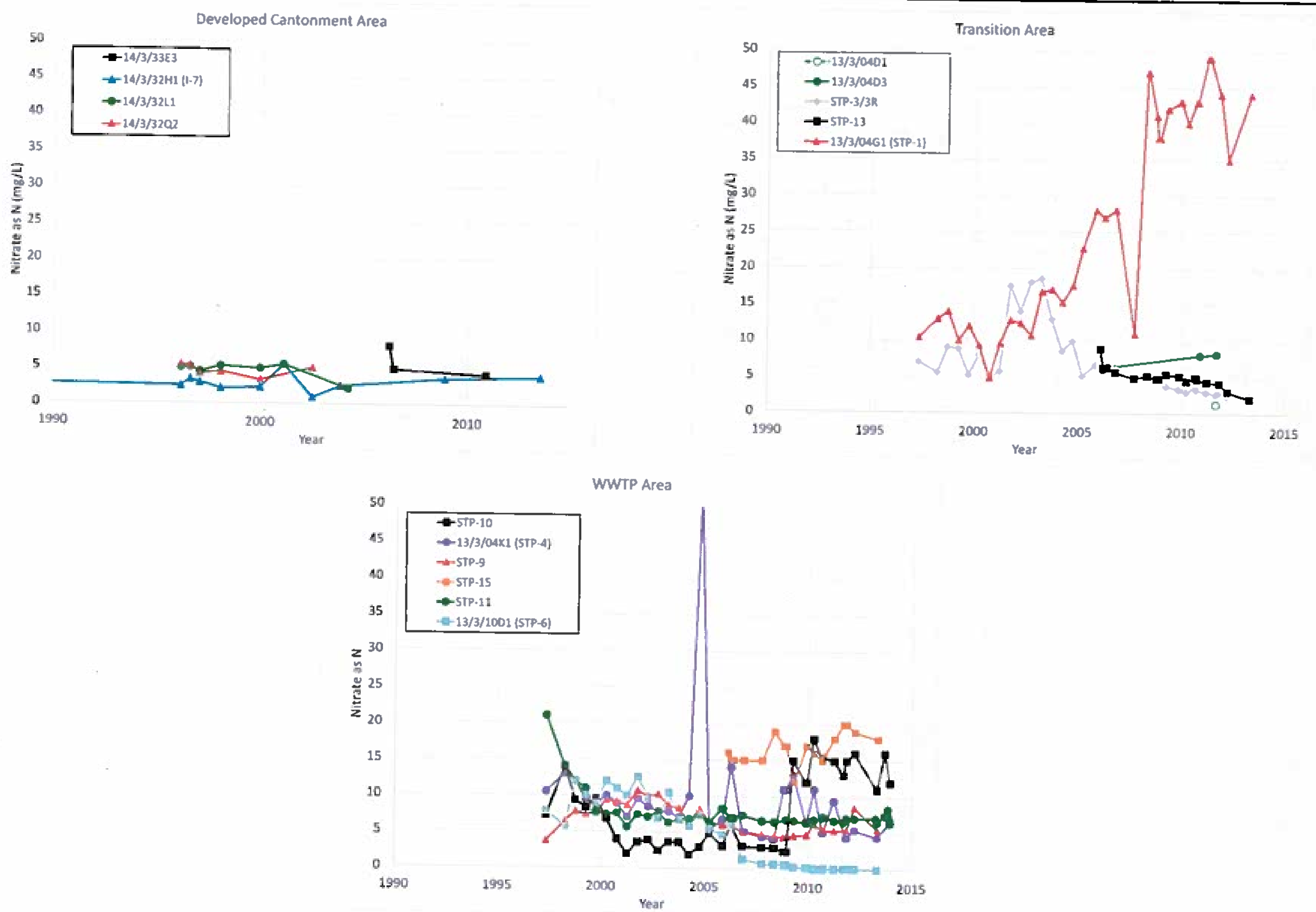
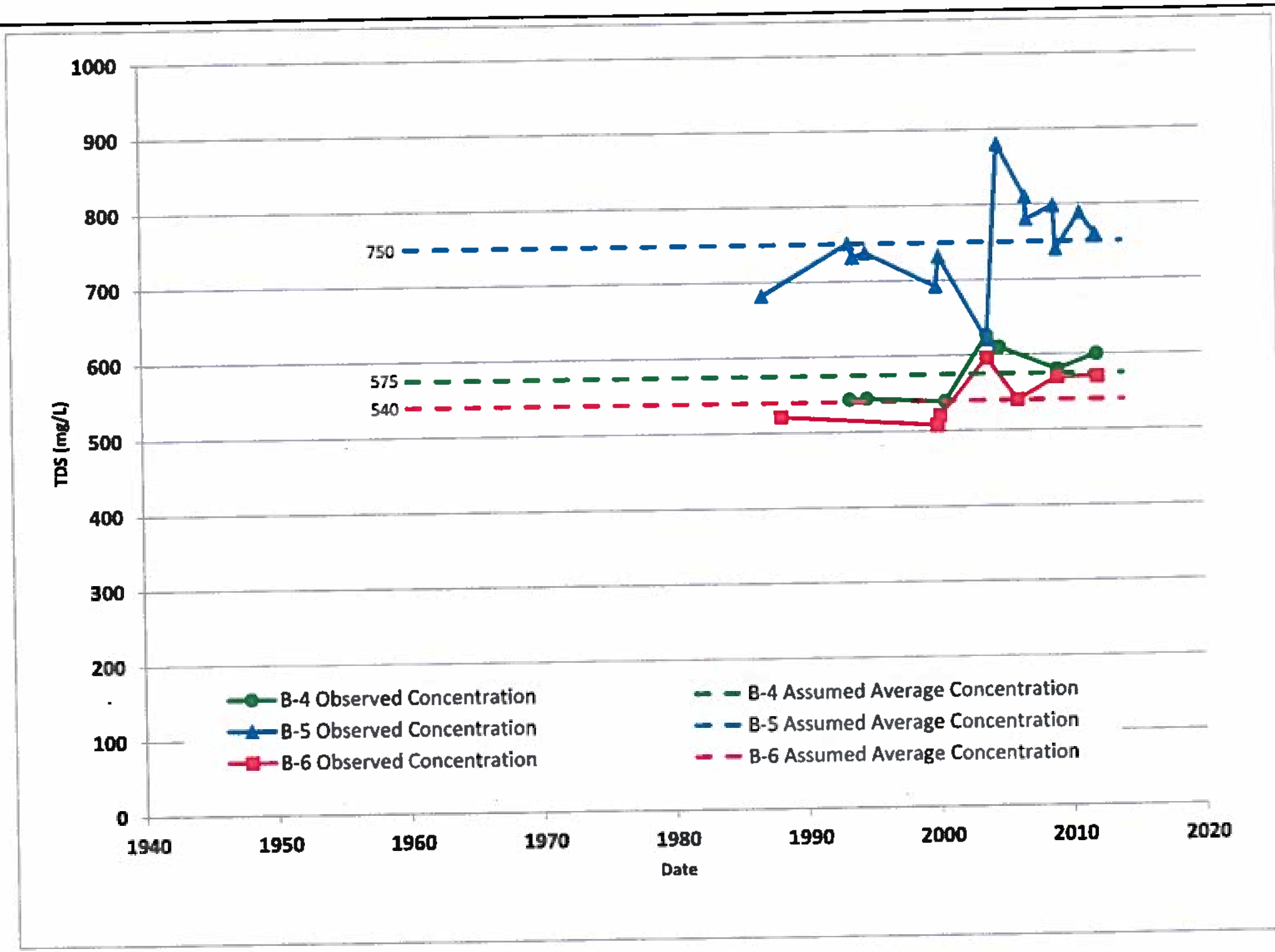


FIGURE 2-18
Time-Series of Nitrate, Irwin Basin
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA



Note: In 2015, well B-6 was taken out of production. Data for this well is included here because it was active during the defined "baseline" period (2012-2013).

FIGURE 2-19
TDS, Bicycle Basin
Production Wells
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

ch2m:

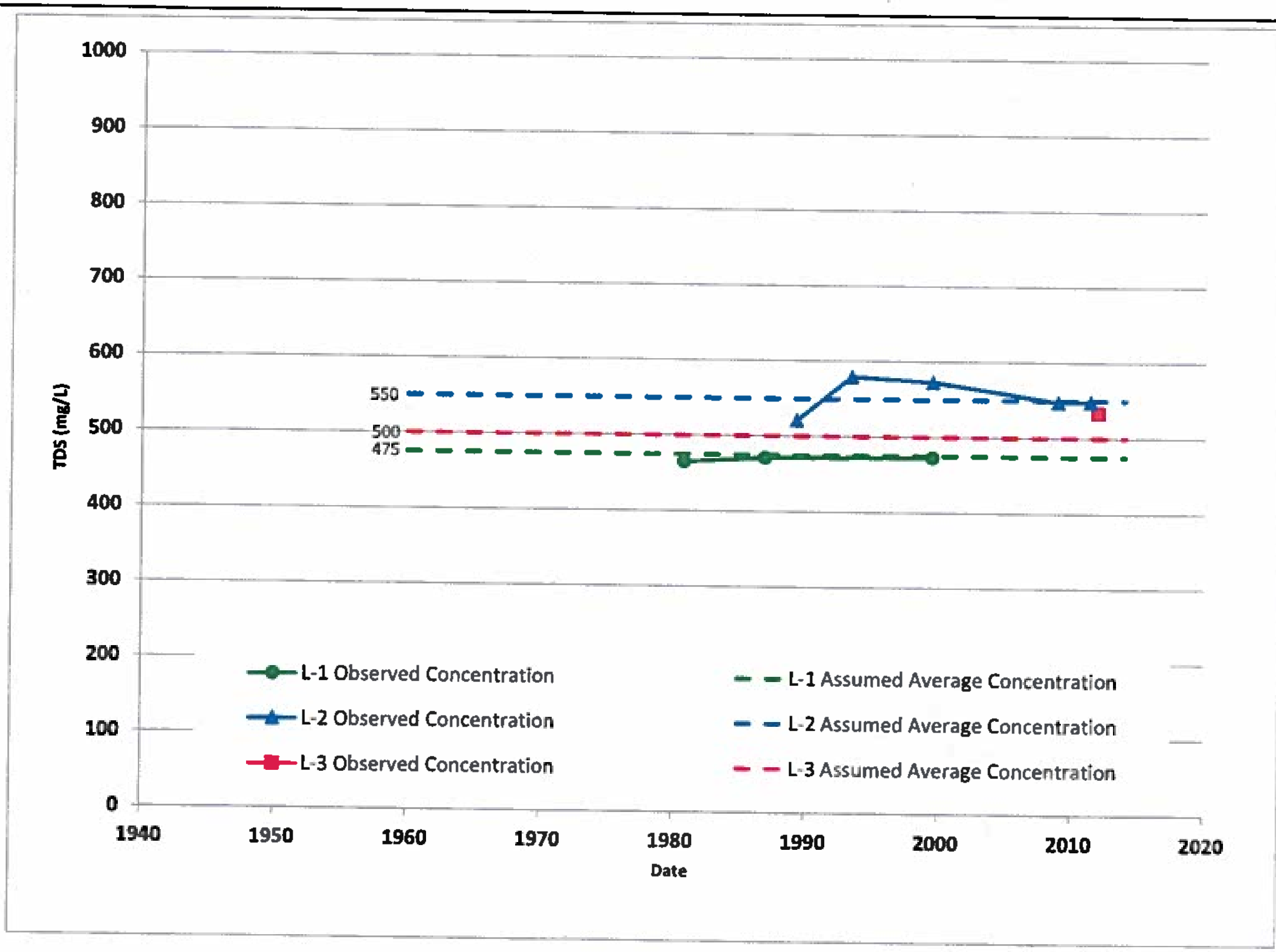


FIGURE 2-20
TDS, Langford Basin
Production Wells
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

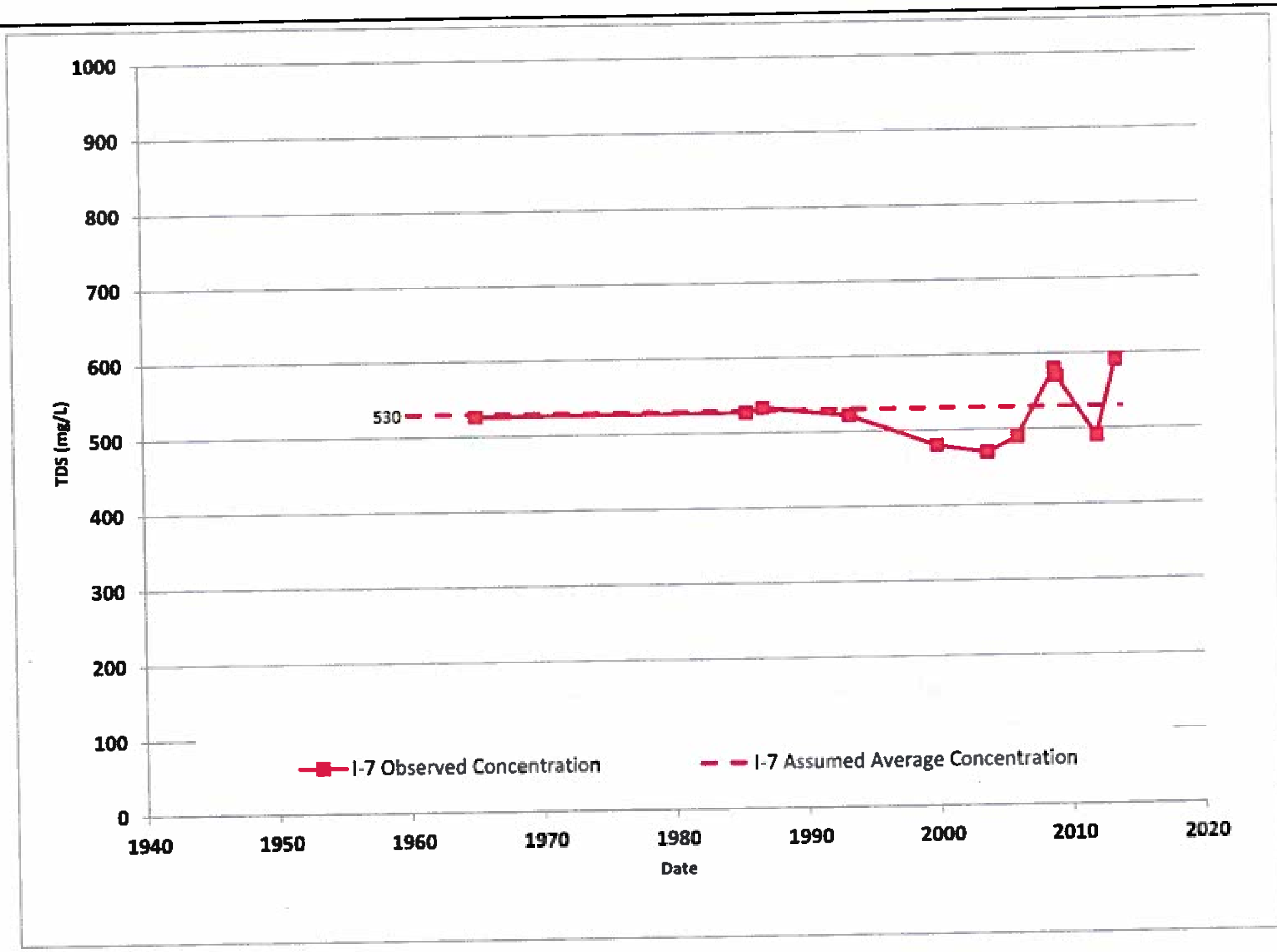
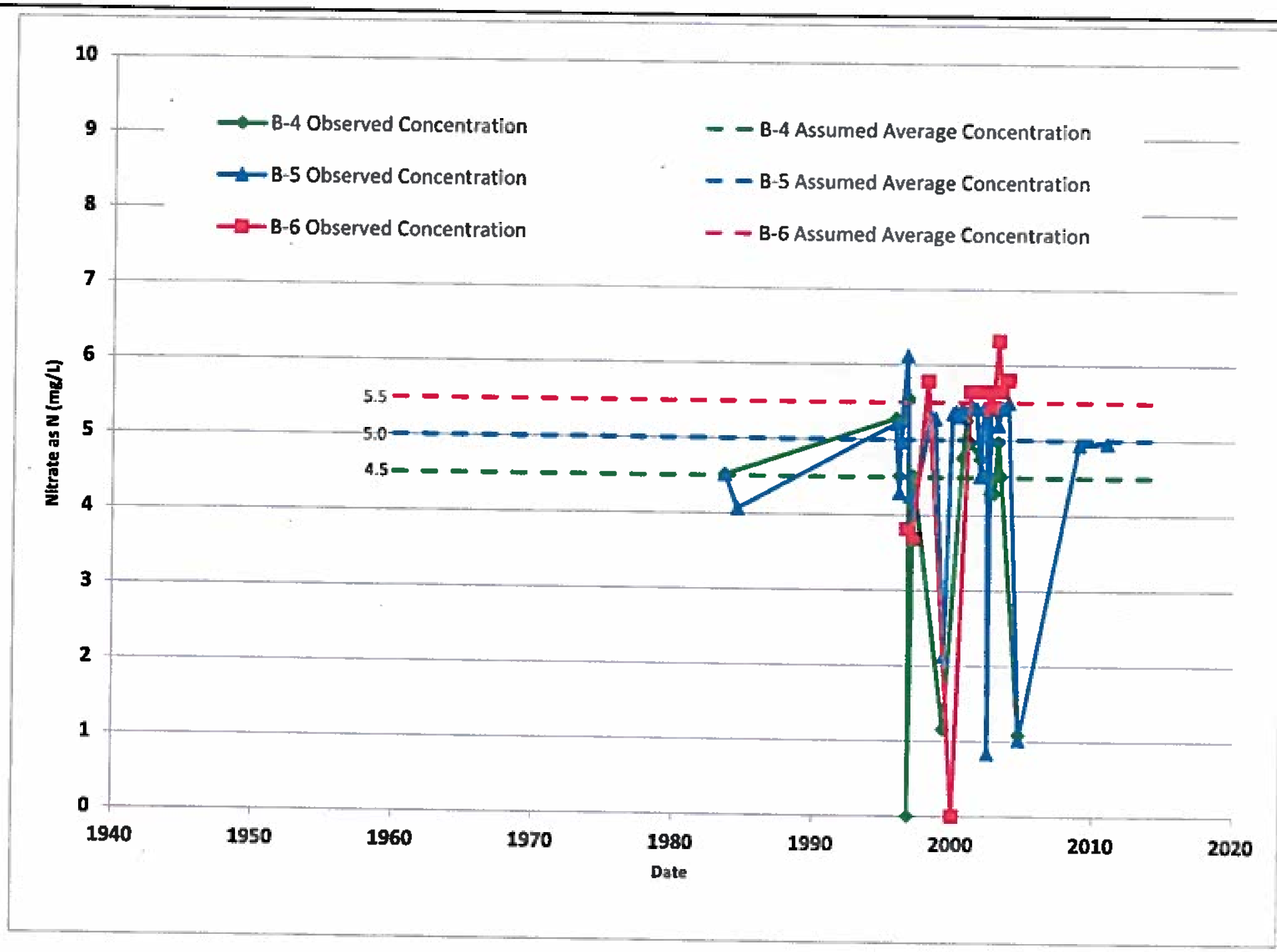


FIGURE 2-21
TDS, Irwin Basin
Production Well
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA



Note: In 2015, well B-6 was taken out of production. Data for this well is included here because it was active during the defined "baseline" period (2012-2013).

FIGURE 2-22
Nitrate, Bicycle Basin Production Wells
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

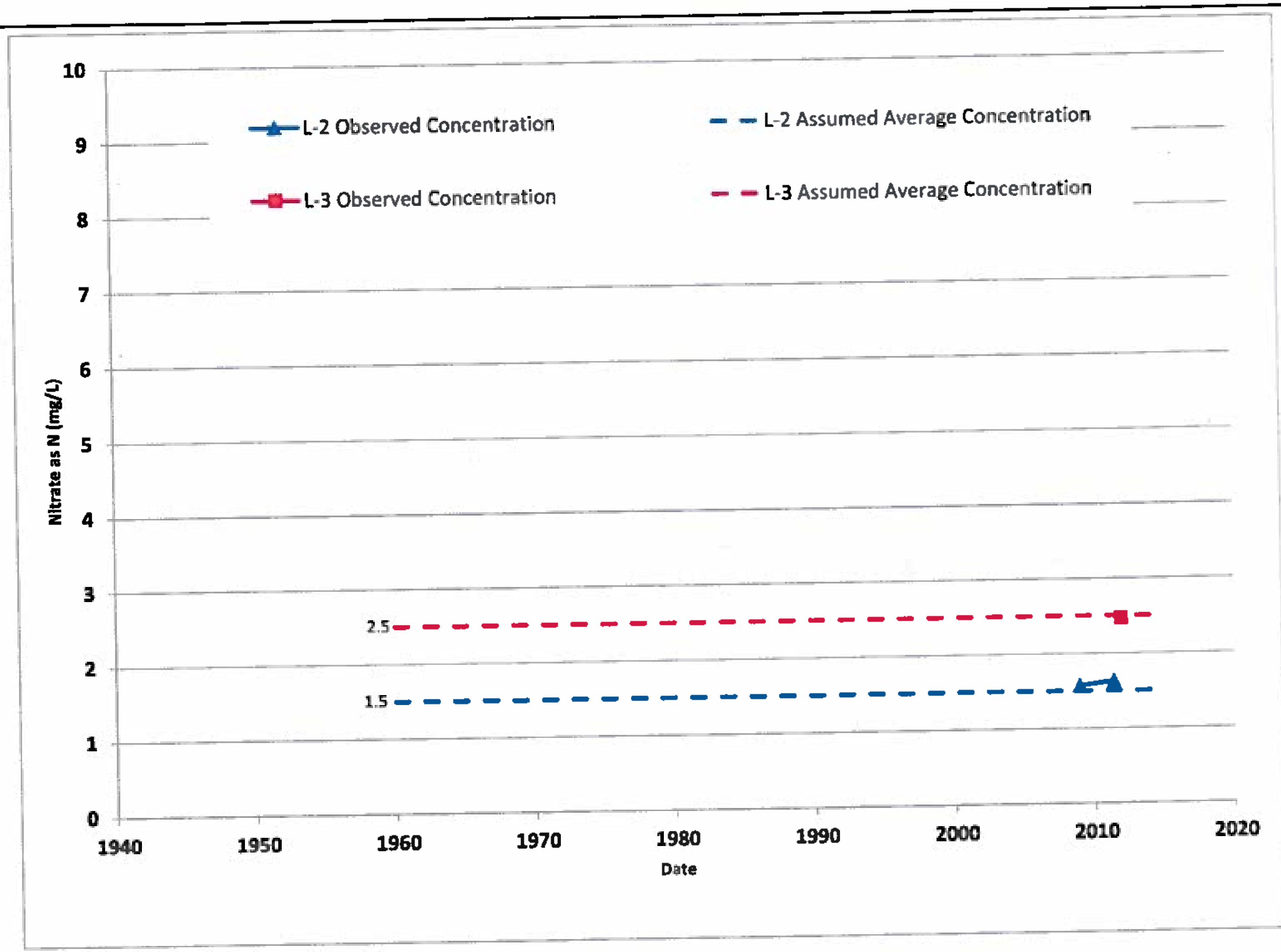


FIGURE 2-23
Nitrate, Langford Basin
Production Wells
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

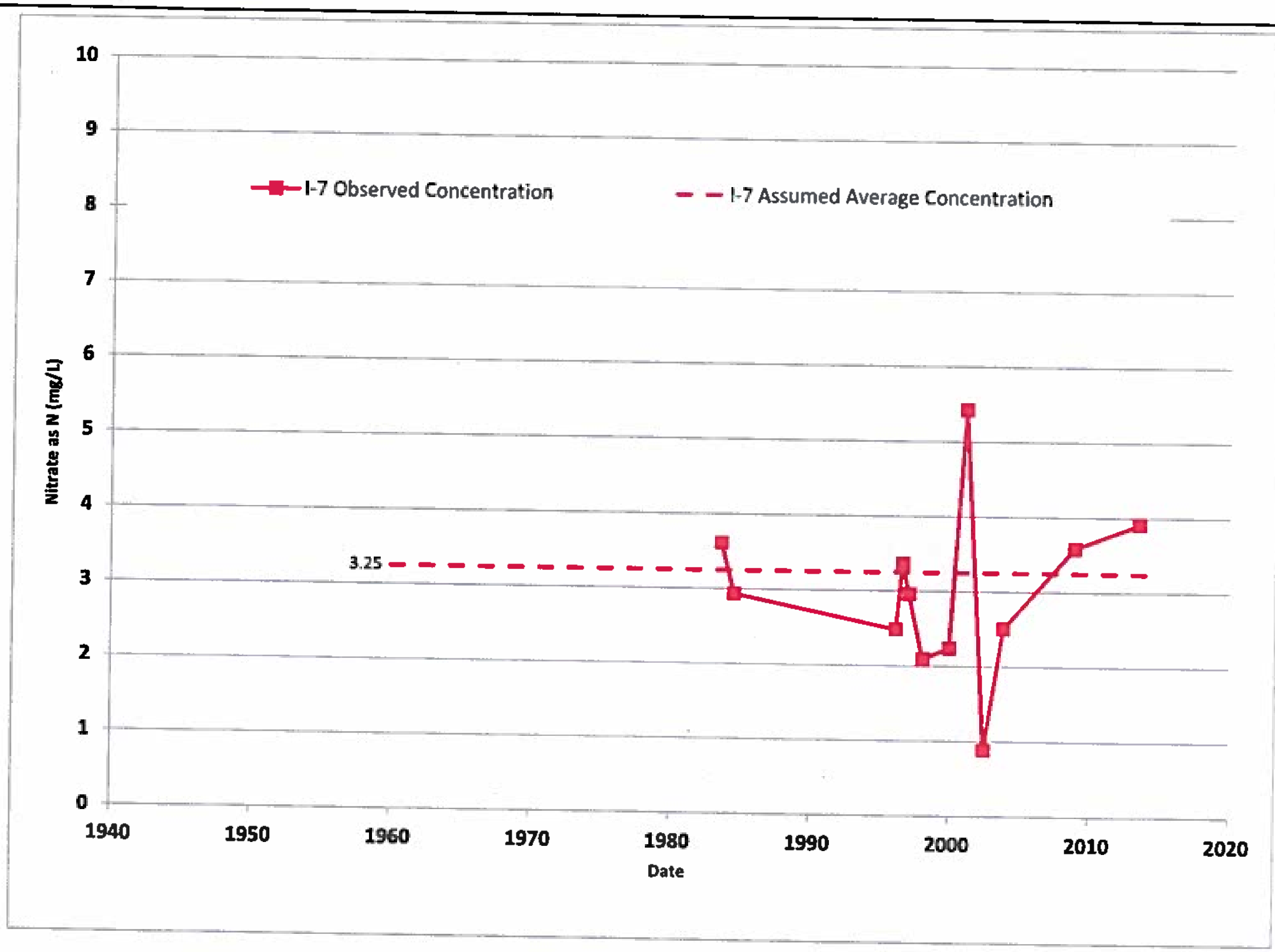


FIGURE 2-24
Nitrate, Irwin Basin
Production Well
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

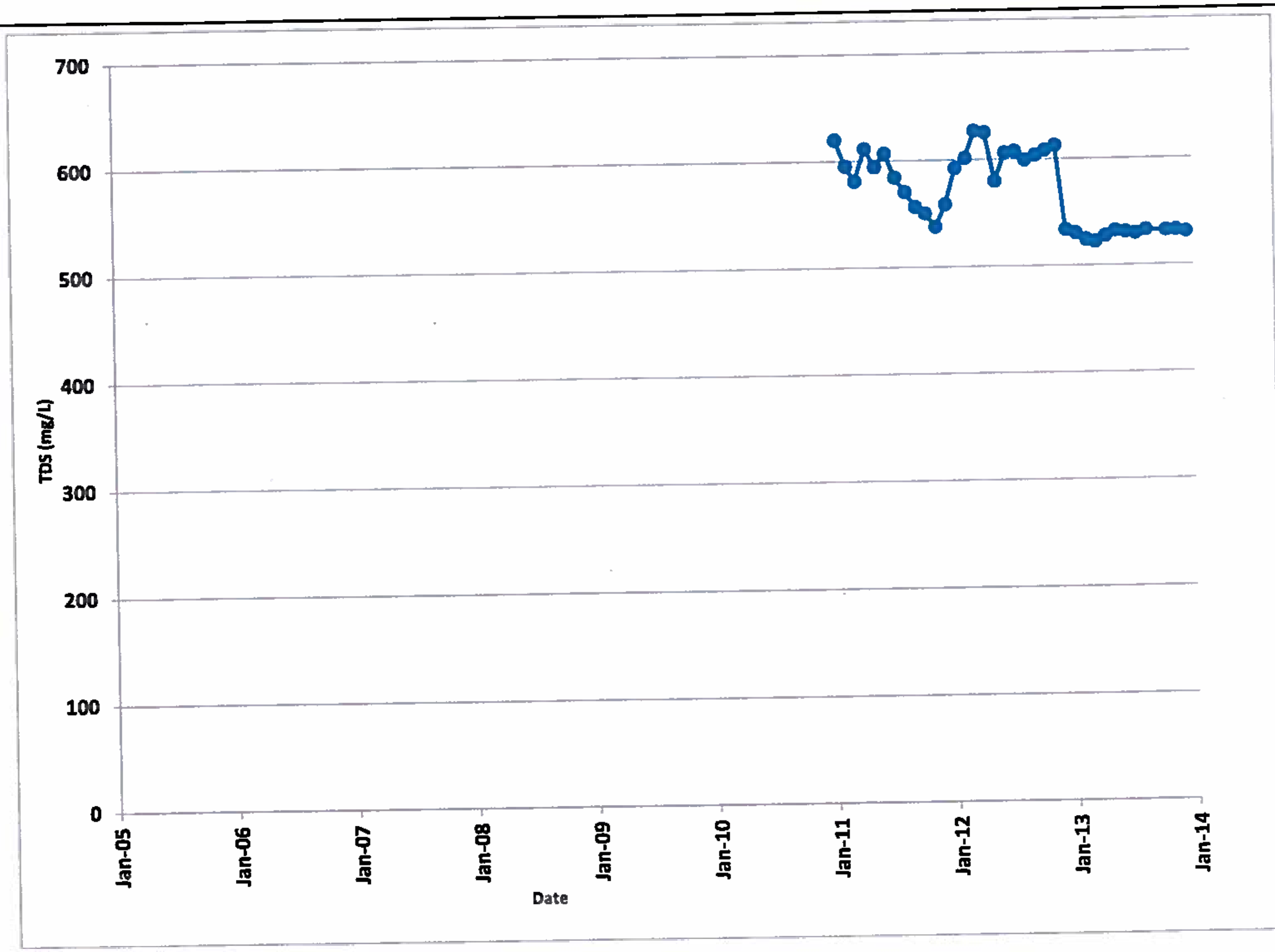


FIGURE 2-25
TDS in DO Delivered Water (calculated)
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

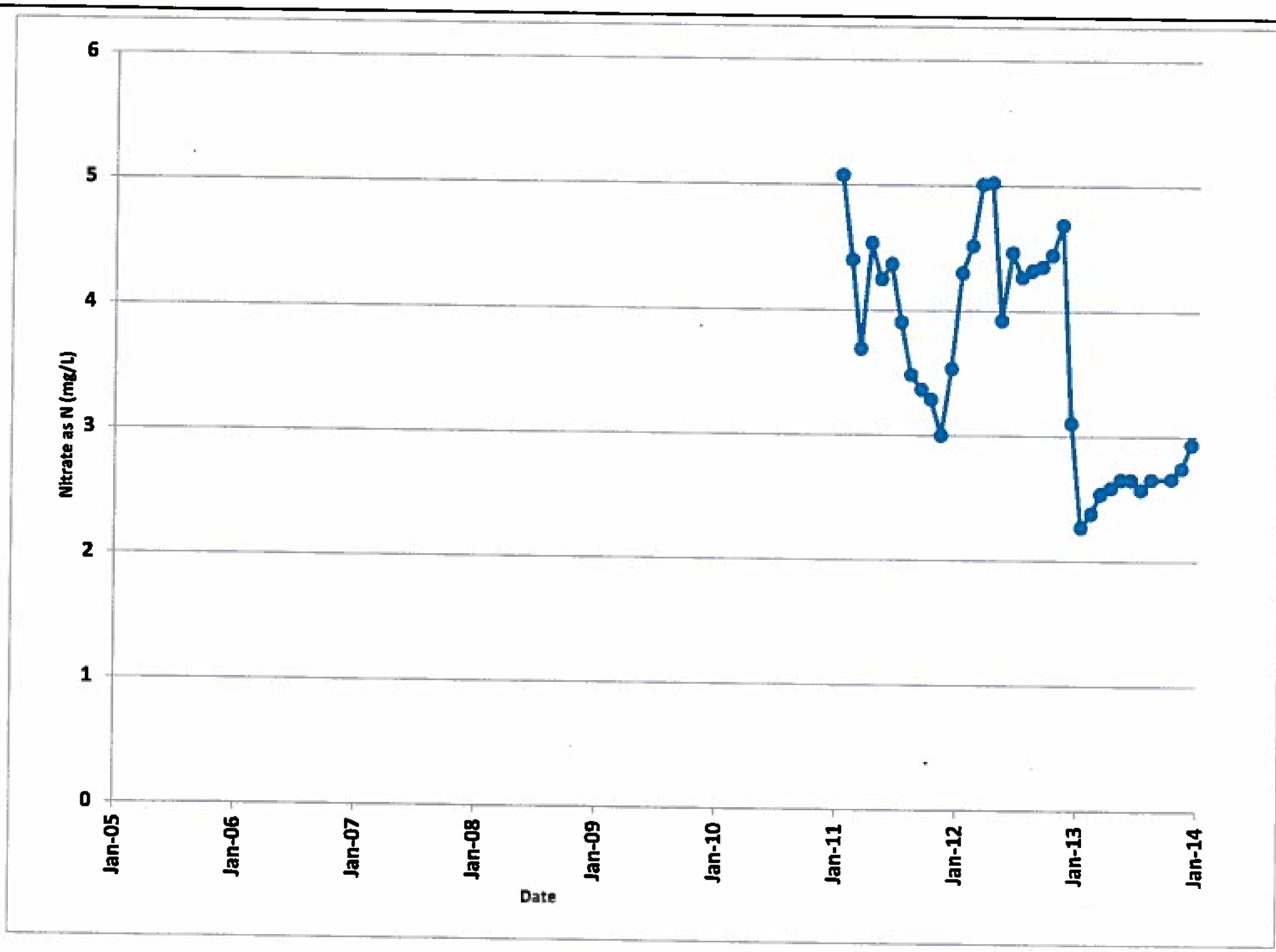


FIGURE 2-26
Nitrate in DO Delivered Water (calculated)
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

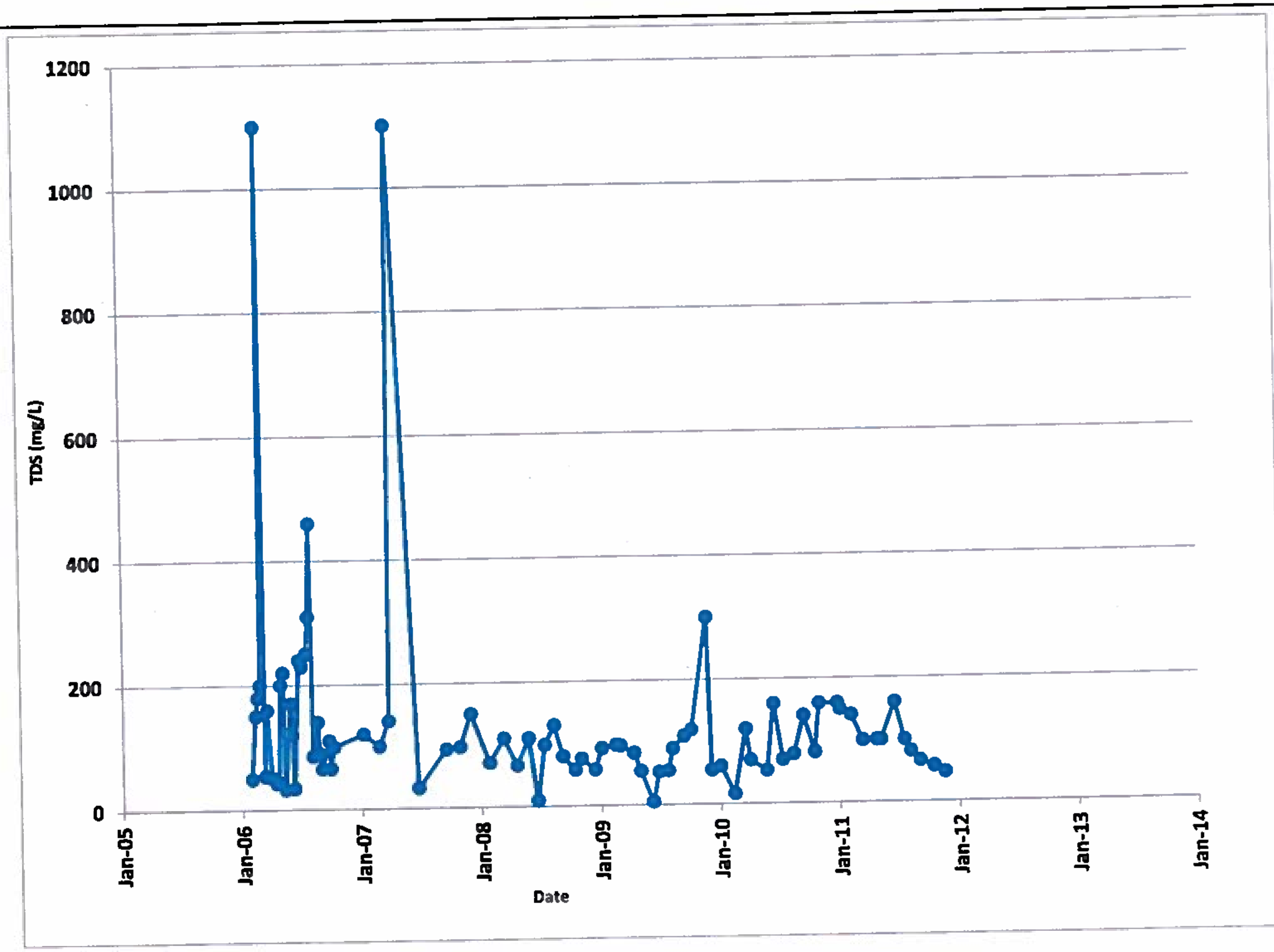


FIGURE 2-27
TDS in RO Product Water
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

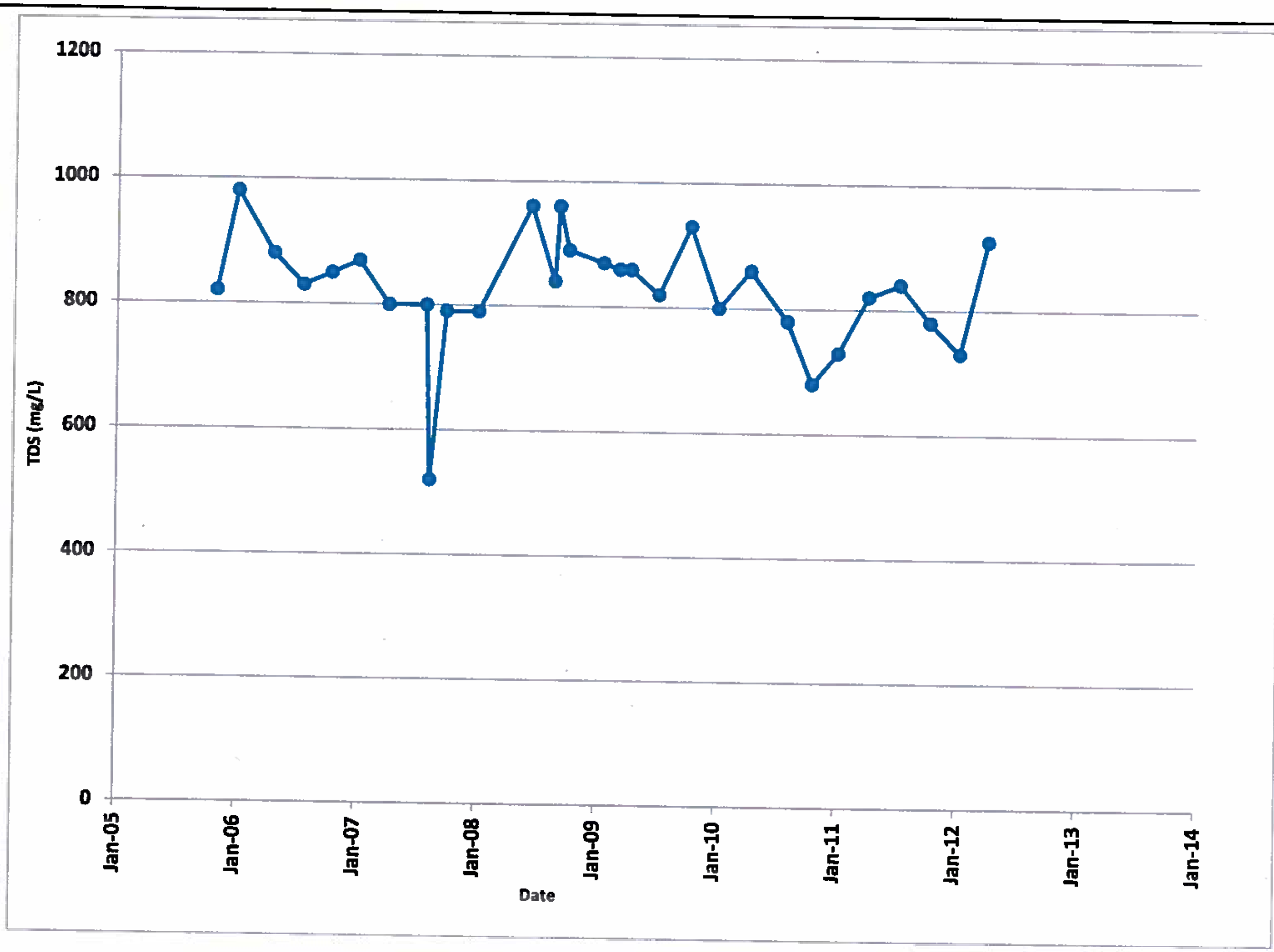


FIGURE 2-28
TDS in WWTP Effluent
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

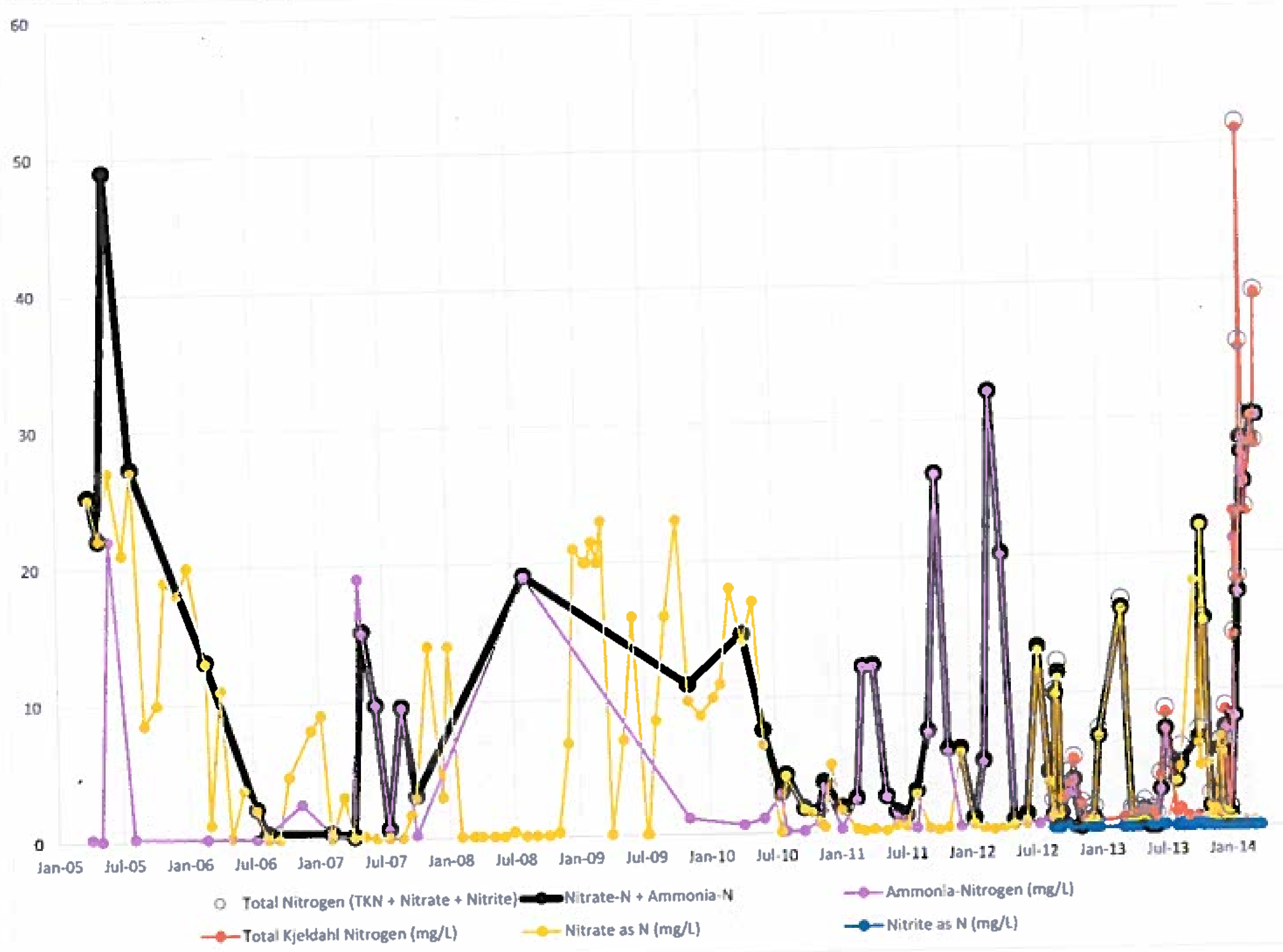


FIGURE 2-29
Nitrogen in WWTP Effluent
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

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3.0 Basin Evaluation

The purpose of this section is to provide the water balance of the Irwin Basin, followed by a salt and nutrient balance. Development of this Salt and Nutrient Management Plan was triggered by the use of recycled water for irrigation. To compare conditions with recycled water use to conditions without recycled water use, the water balance presented herein is quantified assuming current system water demands (2012-2013 average) without the use of recycled water. In other words, it is assumed that 2012-2013 demand for recycled water irrigation would have been met by DO water, so total water production would be equal to the sum of actual water production plus recycled water use.

Use of recycled water is considered in the following section where it is compared against the Baseline water balance and salt and nutrient balances. It should be noted that quantification of water, salt, and nutrient balances presented herein are estimates and therefore approximate. Precision of the values presented is intended to facilitate consistency between the values and is not intended to imply that the values are accurate to this same degree.

3.1 Water Balance

To arrive at a water balance for Fort Irwin, it is important to understand the key components of the water production, delivery, and wastewater treatment systems, which are summarized in Figure 3-1. Individual components of the systems, and items presented in Figure 3-1, are discussed in greater detail in the following subsections. In summary, groundwater is the only source of water supply to Fort Irwin. Currently, production comes from the three local groundwater basins: Irwin, Bicycle, and Langford Basins (Figure 2-4). Nearly all of the produced water is delivered to facilities in the Irwin Basin for residential and commercial uses, with a small amount being exported to NASA's Goldstone facility and for down-range uses such as drinking and showers. Of the delivered water, a portion is consumptively used (that is, removed from the system typically through evaporation and/or transpiration) for residential and commercial purposes on post, including irrigation. The remaining non-consumptive water use (that is, water not removed from the system) is either returned to the Irwin Basin groundwater system through deep percolation of applied irrigation water or pipe leakage, or treated and disposed of at the WWTP. A portion of the treated wastewater percolates back into the Irwin Basin as recharge, while the remaining either is used as recycled water irrigation or evaporates from the percolation ponds (Figure 3-1). Following is a quantification of the components of the Irwin Basin water balance.

3.1.1 Irwin Basin Groundwater Discharge

There are two forms of groundwater discharge from the Irwin Basin: groundwater pumping and subsurface discharge to Langford Basin. While total production from the three groundwater basins has remained relatively constant recently (see Section 2), distribution of pumping among the basins has fluctuated due to operational and water quality constraints. Between 2011 and 2013, groundwater pumping from Irwin Basin ranged from about 160 afy to about 960 afy with an average of about 560 afy. The average of 2011-2013 pumping is generally consistent with the long-term average pumping from Irwin Basin (Figure 2-4).

Recycled water use in 2012 and 2013 averaged 165 afy (Figure 2-4). The baseline water budget assumes that demand for recycled water irrigation during this timeframe would have been met by DO water (groundwater), a portion of which would have been met by additional pumping from Irwin Basin. Of the 165 afy of recycled water used, it was assumed that about 40 afy would have been pumped from Irwin Basin, based on the fact that water from Irwin Basin made up about 25 percent of total water pumped in 2012-2013 with the remaining pumped from Bicycle and Langford Basins. Accordingly, Baseline pumping from Irwin Basin is assumed to be about 600 afy.

Discharge toward Langford Basin has been estimated by the USGS to be about 105 afy, which is assumed to be constant through time (USGS, 2003; USGS, 2013). This is a greater rate than the estimated predevelopment rate of 50 afy due to higher groundwater elevations in response to recharge near the WWTP.

3.1.2 Irwin Basin Groundwater Recharge

The components of groundwater recharge to the Irwin Basin are 1) natural recharge (infiltration of precipitation), 2) pipe leakage, 3) deep percolation of applied irrigation water, and 4) percolation of treated wastewater. None of these components can be directly measured. Instead, they must be calculated based on available data and assumptions.

It is also important to distinguish natural recharge from the other two recharge sources. Pipe leakage, deep percolation of applied irrigation water, and percolation of treated wastewater are all from water originally pumped from local groundwater in the Irwin, Langford, and Bicycle Basins. While these sources are considered recharge components that offset the discharge through groundwater pumping in Irwin Basin, use of water from Bicycle and Langford Basins results in declining storage in those Basins as discussed in Section 3.1.4.

3.1.2.1 Natural Recharge

Natural recharge to the Basin occurs from infiltration or precipitation after it is channeled into ephemeral stream channels; it is assumed that rainfall recharge does not occur outside these channels (USGS, 2003). This is a common assumption in this area (see USGS, 2001; USGS 2004a; USGS 2004b). The USGS estimates that average annual natural recharge to the Irwin Basin is about 50 afy.

3.1.2.2 Recharge from Pipe Leakage

A leak detection survey was performed in 2011, which estimated the leakage rate to be about 35 afy or about 1.5 percent of total water use (Utility Services Associates, 2011). However, additional leakage occurs during discrete water line breaks and potential other unquantified leaks. Therefore, total pipe leakage was estimated at 5 percent of water use, or 119 afy. While it is acknowledged that some of the water leaking from pipes may evaporate from the ground surface or return to the wastewater treatment plant through the sanitary sewer, for the purposes of this analysis it is assumed that the entire 119 afy percolates into the ground and eventually recharges the groundwater system. It is also assumed that any errors associated with this assumption are within the range of uncertainty and will not have an appreciable overall effect on the water, salt, and nutrient balances developed as part of this Plan.

3.1.2.3 Deep Percolation of Applied Irrigation Water

Deep percolation of applied irrigation water is calculated based on the rate of applied irrigation water and irrigation efficiency (percent of water applied that is consumptively used by plants). Applied irrigation water is metered at some locations, but not across all of Fort Irwin. Accordingly, applied irrigation water use was calculated by parsing out total water use into its primary components: non-consumptive use returned to the WWTP, export, pipe leakage, other consumptive uses, and irrigation. A summary of the water use components is presented in Figure 3-2. Details of assumptions and calculations are summarized below.

Total indoor non-consumptive water usage was estimated in the following manner. Between 2003 and 2013, average annual WWTP influent has ranged from 1,020 afy to 1,250 afy, with 2012 and 2013 influent measured at 1,073 and 1,058 afy, respectively (Figure 3-2). Of this amount, about 90 afy is brine from the current RO plant, 20 afy is from non-consumptive cooling use (CH2M HILL, 2007b), and less than 5 afy is other septage, including septage hauled from down-range. It was assumed that the remaining WWTP influent, about 951 afy (1,066 wastewater flow less 90 afy RO brine, 20 afy cooling, and 5 afy other septage), is representative of non-consumptive indoor water demand.

Some water is exported from Irwin Basin. DO water export to NASA's Goldstone facility has recently been about 35 afy. It is estimated that an additional 40 afy is exported "down-range" or out of the basins to military training areas. Down-range water use consists of drinking, showers, dust control, and sanitation. About 75 percent of the water exported down-range is RO water. Only about 3 afy is returned to the WWTP as septage from portable toilets.

Additional non-irrigation consumptive use of water includes evaporative cooling, vehicle washing, dust control, evaporation from pools, and consumptive indoor water use. Combined consumptive use of evaporative cooling, vehicle washing, dust control, and evaporation from pools is estimated to be about 18 afy (CH2M HILL, 2007b). Consumptive indoor water use is estimated to be about 3 percent of total indoor water use (USGS, 2014), or an additional 29 afy. Total non-irrigation consumptive use, then, is estimated to be about 47 afy.

Irrigation is calculated based on total water delivered (produced water plus recycled water delivery), minus the components summarized above. Between 2003 and 2013, average total water delivered ranged between about 2,380 afy and 2,860 afy (Figure 3-2) with 2012 and 2013 water delivered measured at 2,389 and 2,382 afy, respectively. Irrigation is estimated to be about 1,083 afy (2,385 delivered, minus 119 afy pipe leakage, 951 afy indoor non-consumptive use, 20 afy non-consumptive cooling, 47 afy non-irrigation consumptive use, 75 afy export, and 90 afy RO brine).

To estimate deep percolation of applied irrigation water, irrigation efficiency must be estimated. Irrigated areas were estimated based on aerial photos from 2012. This analysis yielded about 55 acres of turf and 55 acres of trees and shrubs.

The net irrigation requirement (water consumed by plants minus effective precipitation) was calculated monthly based on historical data. Irrigation efficiency was estimated two ways. First, an irrigation efficiency of 59 percent was calculated for turf areas based on net irrigation requirement and the average metered rate of water applied to turf areas. Second, an irrigation efficiency of 62 percent was calculated based on estimated irrigated area and estimated irrigation water usage. Because the metered data only represent a subset of the total area, overall average irrigation efficiency was assumed to be 62 percent (Table 3-1). Based on irrigation efficiency, total recharge to Irwin Basin from deep percolation of applied irrigation water is assumed to be 38 percent of applied irrigation or about 406 afy (Figures 3-1 and 3-3).

TABLE 3-1
2012 Irrigation Water Use Assumptions

Parameter	Value	Notes
Irrigated turf area	55 acres	Estimated from aerial photo
Annual net irrigation water requirement[1] – turf	5.1 ac-ft/ac	Calculated[1]
Annual net irrigation water requirement[1] – turf	281 afy	Calculated[1]
Irrigated tree and shrub canopy area	55 acres	Estimated from aerial photo
Annual net irrigation water requirement[1] – trees and shrubs	7.2 ac-ft/ac	Calculated[1]
Annual net irrigation water requirement[1] – trees and shrubs	396 afy	Calculated[1]
Annual net irrigation water requirement – total	677 afy	Sum of turf + trees and shrubs
Total applied water	1,083 afy	
Estimated irrigation efficiency	62%	Annual net irrigation requirement divided by total applied water; compare with 59% observed at metered fields
Total deep percolation	406 afy	Applied water minus net irrigation requirement

[1] Crop evapotranspiration (ETc) – effective precipitation
ETc = reference grass evapotranspiration * crop coefficient (Kc), from California Irrigation Management Information System (CIMIS) Barstow NE site (Station #134). Kc turf = 0.85; Kc trees/shrubs = 1.2.
Effective precipitation estimated based on historical data used in CH2M HILL (2007b), in which it was calculated using a Soil Conservation Service method w/ monthly precipitation, ETc and effective soil water storage.

3.1.2.4 Percolation of Treated Wastewater

Treated wastewater is currently either discharged to an on-site 22-acre evaporation pond or on-site percolation ponds, or used as recycled water for irrigation. For the purposes of this Baseline analysis, it was assumed that all wastewater is discharged to the ponds (no recycled water use). Recycled water use is evaluated in Section 4: Salt and Nutrient Management Strategies.

Between 2003 and 2013, average annual WWTP influent ranged between about 1,020 afy and 1,250 afy (Figure 3-2), with 2012 and 2013 wastewater influent measured at 1,072 and 1,058 afy, respectively. Published reference evapotranspiration rates from the nearest California Irrigation Management Information System (CIMIS) station, in Barstow, were used to estimate evaporation from the ponds. Surface area for all ponds, including the recently constructed pond 4, was considered; however, in accordance with the current WWTP permit requirements, it was assumed that one of the ponds was out of service at any given time. The resultant surface area estimate is 39 acres. Evaporation from the ponds was estimated to be a factor of 1.05 times the reference envirotranspiration rate (Allen, et al., 1998). Percolation was calculated based on the remaining flow. These calculations were performed for each month, resulting in an average annual evaporation of 230 afy and percolation of about 836 afy (Table 3-2). It should be noted that it was assumed there is minimal evaporative loss in the wastewater treatment process.

TABLE 3-2
Percolation of Treated Wastewater

Month	Reference Evapotranspiration[1] (in/mo)	Evaporation[2] (af)	Average Wastewater Effluent (af)	Percolation (af)	Percent of Effluent That Percolates
Jan	2.24	7.6	95.7	88.1	92%
Feb	3.01	10.2	90.9	80.8	89%
Mar	5.18	17.5	99.9	82.4	82%
Apr	6.44	21.7	79.1	57.3	73%
May	8.26	27.9	85.6	57.7	67%
Jun	9.20	31.1	84.6	53.5	63%
Jul	9.52	32.1	85.3	53.2	62%
Aug	8.16	27.5	93.5	66.0	71%
Sep	6.37	21.5	93.8	72.3	77%
Oct	4.69	15.8	95.0	79.2	83%
Nov	2.83	9.6	85.7	76.1	89%
Dec	2.08	7.0	76.5	69.5	91%
Total	**68.0**	**230**	**1,066**	**836**	**78%**

[1] Data obtained from CIMIS. Average monthly ETc at Barstow NE (Station 134; data 1997-2013)

[2] Evaporation calculated as Reference ET * 38.6 acres (average area of the ponds with one pond out of service in accordance with permit requirements) * Kc factor of 1.05 (based on Allen, et al., 1998)

3.1.3 Irwin Basin Summary

A summary of the Irwin Basin water budget is presented in Figure 3-4. Data are presented for 2011-2013, along with Baseline conditions (recent conditions without recycled water use). Recharge has exceeded discharge in recent years with a net recharge of about 706 afy as evidenced by rising groundwater levels throughout the Basin (see Section 2). The ultimate source of recharge water is groundwater pumped from Irwin, Bicycle, and Langford Basins that is recharged to the Irwin Basin through deep percolation of applied irrigation water, pipe leakage, and percolation of wastewater effluent.

3.1.4 Regional Context on Previous Estimates of Basin Lifespan

While Irwin Basin has recently been experiencing net recharge, it is important to consider the broader local water balance. Natural recharge to Langford and Bicycle Basins is minimal (CH2M HILL, 2007a). A key issue surrounding the three local groundwater basins (Irwin, Bicycle, and Langford Basins) is their longevity: "How long can local groundwater basins continue to meet local water needs?" Two previous reports attempted to answer this question: the Regional Water Supply Investigation (CH2M HILL, 2007a) and the Water Demand Management Plan (WDMP) (CH2M HILL, 2007b).

Two key uncertainties affect estimates of Basin lifespan: 1) estimate of the operating water level "floor" of Bicycle and Langford Basins, or the water level elevation below which production begins to decline significantly, and 2) future groundwater pumping rates from the Basins. A range of water level floors was used in the previous studies to estimate basin lifespan with varying assumptions of future groundwater pumping rates. The Regional Water Supply Investigation concluded that, if pumping rates and distribution amongst the three basins continued at rates from about 2005, the basins could provide supply beyond year 2050 if the water elevation floor was at the lower end of the range, but that some declines in production could begin between about 2035 and 2050 if the water elevation floor was higher. However, the Regional Water Supply Investigation assumed a relatively high total demand of about 3,900 afy compared with recent raw water demand of 2,385 afy. The WDMP assumed a lower total raw water demand of about 2,700 afy, still higher than recent water demand, and estimated decline in production beginning in about year 2065 using the higher end of water elevation floor.

Both of the estimates above were developed using groundwater models and suggest that, for about every 650 af of combined groundwater withdrawal from Bicycle and Langford Basins, there is an average of about 1 foot of drawdown. The assumption of 1 foot of drawdown per 650 af of pumping was used to estimate projected basin lifespan after management alternatives are implemented (Section 4.2.1).

3.2 Salt and Nutrient Balance

The salt and nutrient balance was developed using Baseline pumping conditions and average concentrations of TDS and nitrate in each basin. Baseline pumping conditions are presented in Table 3-3.

TABLE 3-3
Baseline Pumping and Water Quality

Basin	Pumping (afy)	Average TDS (mg/L)	Average Nitrate (mg/L)
Irwin	600	530	3.25
Bicycle	875	600	5
Langford	910	525	2
Total	**2,385**	**554**	**3.42**

3.2.1 Total Dissolved Solids

As discussed in the water balance section (Section 3.1), water (and naturally occurring dissolved salt) is delivered to Irwin Basin for residential and commercial uses, part of it is consumptively used, and the remainder returns to the groundwater system through deep percolation of applied irrigation, leakage from pipes, and percolation from the wastewater ponds. The consumptive use of water in the Basin is evapotranspiration (primarily from irrigated plants and the evaporation and percolation ponds, but also cooking, vehicle washing, dust control, etc.). During this process, pure water is evaporated, but the salts are left behind in the remaining water. Therefore, it is assumed that all of the salts pumped from the three basins are either exported to NASA Goldstone or returned to the Irwin Basin, either as deep percolation of applied irrigation water (which has a lag time before reaching the groundwater system) or percolation from the evaporation and percolation ponds. Some additional imported salts are added to the wastewater stream, and additional salts may be leached from the unsaturated zone as wastewater percolates. Each of these processes is summarized below and plotted in Figures 3-1 and 3-5.

3.2.1.1 Deep Percolation of Pipe Leakage

As discussed in Section 3.1, an estimated 119 afy of leaks from pipes recharges the groundwater. For the purposes of this analysis, it is assumed that all of the leaking water from the pipes recharges the groundwater system. Accordingly, assuming a TDS concentration of 554 mg/L, total salt mass recharging the groundwater from pipe leakage is estimated to be about 90 tons per year (tons/yr).

3.2.1.2 Deep Percolation of Applied Irrigation Water

Assuming recent distribution of groundwater pumping among the three groundwater basins and average water quality from each of the wells as shown in Table 3-3, the average TDS of water delivered for irrigation in the Baseline condition (assuming no recycled water use) is estimated to be about 554 mg/L, which is consistent with observed DO water quality discussed in Section 2. Accordingly, the TDS mass of applied irrigation water is estimated to be about 815 tons/yr. It is assumed that all of the TDS is returned to the groundwater as deep percolation. While there is a lag time for water and salt to flow to the groundwater table, most irrigated areas have been irrigated for a long time. Therefore, recharge rates to the water table from older irrigation water are likely similar to the rate of water percolating through the root zone. While some additional salts may be added due to fertilizers and leaching of salts from the unsaturated zone, etc., it is assumed that these are small relative to the total mass (based on application rates in Henry et al., 2002, approximately 15 tons/yr of TDS may be added due to fertilizers).

Assuming an applied water rate of 1,083 afy and irrigation efficiency of 62 percent (see Section 3.1), the deep percolation rate is estimated to be about 406 afy with TDS concentration of about 1,476 mg/L or a total of 815 tons/yr (Figure 3-1). While some salt may accumulate in the soils, and it may take some time for the salt to travel to the water table, for the purpose of this long-term analysis it is assumed that the all salt reaches the water table and any error associated with this assumption is small relative to the overall uncertainty in quantification of water and salt balances. Nearly all of the salt associated with deep percolation of applied irrigation water was originally pumped from the local groundwater basins; it is not new salt being brought in.

3.2.1.3 Percolation of Wastewater, Salts from Local Basins and Imported Salts

Wastewater effluent is a key component of the salt mass balance. Wastewater effluent is sampled quarterly for TDS concentration. During the period 2012-2013, seven measurements of wastewater TDS concentration were available with values ranging between 720 mg/L and 910 mg/L and an average of 797 mg/L. Accordingly, average TDS concentration of 795 mg/L was assumed. When applied to Baseline (average 2012-2013) influent flow rates of 1,066 afy, the resulting estimate of mass flux is about 1,152 tons/yr (Figure 3-1). Based on mass balance calculations presented in Figure 3-1, only about 852 tons/yr of these salts are coming from indoor delivery (RO and DO) and the RO waste stream, plus an additional 5 tons/yr from other septage, suggesting that about 295 tons/yr of salt are imported (Figure 3-1).

As a check on the estimate of 295 tons/yr of imported salts, water quality of the WWTP effluent was compared with water quality of delivered water. For each effluent TDS sample, individual well pumping rates and assumed concentrations were used to calculate average delivered water quality for that day. Over the six sample dates, TDS of delivered water was estimated to be 590 mg/L, with wastewater effluent TDS concentration averaging about 800 mg/L. Considering wastewater flow rates, this difference in concentration resulted in an estimate of about 300 tons/yr of extra salt being added to the system.

Two known sources of imported salts are hypochlorite used as disinfectant in recycled effluent and commercial grade bleach for potable water treatment. These additives are estimated to be about

50 tons/yr. Other sources of imported salts may include coagulants added at the wastewater treatment plant, water softeners in businesses and homes, human waste, cleaning chemicals, and food waste. These other sources were not quantified individually as part of this work due the relatively small component of overall salt loading, but are qualitatively summarized as follows:

- Polyaluminum chloride (PACl) is added during tertiary treatment at the wastewater treatment plant for use as a coagulant. While alum, a common coagulant, may result in increased TDS concentrations of effluent of about 0.5 mg/L for each mg/L dosage of alum, "use of chemicals such as polyaluminum chloride and polyaluminum hydroxychloride could result in a smaller or even negligible increase in TDS" (Patoczka, 2007).
- Though known to be scarce at Fort Irwin, water softeners could account for about 100 tons/yr based on average salt consumption rates applied to 25 percent of residences (Eastern Municipal Water District, 2014).
- Human waste, cleaning, and food waste are assumed to account for the remaining 145 tons/yr.

3.2.1.4 Percolation of Wastewater and Leached Salts

Based on isotope data and observed TDS concentrations increasing with depth in the unsaturated zone, the USGS (1997 and 2003) concluded that the TDS concentrations in groundwater near the WWTP cannot be explained by wastewater alone. For the purposes of this Salt and Nutrient Management Plan, it was assumed that the difference between concentration of the percolating wastewater (evapoconcentrated) and the concentration in the groundwater can be attributed to leaching of salts from the unsaturated zone. Based on average evaporation rates discussed in Section 3.1, percolating wastewater is expected to have a TDS concentration of about 1,013 mg/L, compared with observed concentration at the water table in the area of about 1,200 mg/L. This increase in concentration, considering estimated flow rate, yields a mass loading rate of leached salts of about 213 tons/yr (see Figure 3-1).

As part of this evaluation, drillers' logs were evaluated, and locations of wells that the USGS suggested had a different salt source were evaluated. No evidence was found for a geologic layer, such as an evaporite bed, contributing salts to the groundwater. Rather, the highest observed concentrations in groundwater are both located under current or formerly irrigated areas. While it is not clear what the additional source of salts is, it is currently assumed that it is buildup of salts in the subsurface due to past irrigation and percolation of wastewater in the area. It is possible, therefore, that the amount of salts leached will be reduced in the future.

3.2.1.5 Summary of Salt Balance (TDS) and Assimilative Capacity

Figure 3-5 summarizes the salt balance of the local basins. In summary, nearly all of the salt pumped from the three local basins (about 1,796 tons/yr), less net of about 34 tons/yr of export (38 tons/yr less minor amount in other septage that is returned), is returned to the groundwater in Irwin Basin. An additional 295 tons/yr of salt is added to the system through imported salts in the wastewater stream, an additional 213 tons/yr of salt is estimated to be leached from the unsaturated zone near the WWTP, and about 34 tons/yr are estimated as inflow with natural recharge (assuming 50 afy of recharge, as discussed in Section 3.1, and background concentration of 500 mg/L). Total salt entering the Basin, then, is estimated to be about 2,304 tons/yr.

After accounting for salt removal from the Basin via groundwater pumping (432 tons/yr) and outflow to Langford Basin (107 tons/yr assuming 105 afy flow at concentration of 750 mg/L), the net accumulation of salts in the Basin is about 1,764 tons/yr. The water budget suggests that the net accumulation of salts is accompanied by a net recharge of water of about 706 afy (Section 3.1).

Assimilative capacity is defined as the difference between average concentration in the Basin and the water quality objectives. Average concentration was assumed to be 700 mg/L based on Figure 2-11. The water quality objective for TDS was assumed to be water with less than the secondary MCL of 1,000 mg/L. To evaluate future average water quality under the Baseline condition, a mixing calculation was performed by adding 706 afy of water and 1,764 tons/yr of salt to an assumed starting water volume in the basin of 79,900 af (CH2M HILL, 2007a). Using this methodology, average TDS in the Basin is expected to reach about 905 mg/L in 25 years (Figure 3-6). This amounts to using nearly 80 percent of the Basin's assimilative capacity.

3.2.2 Nitrogen

As discussed in Section 2, nitrate is found in water in most wells in Irwin, Bicycle, and Langford Basins, and is believed to have natural sources of historic atmospheric deposition followed by leaching from the soils (Densmore and Bohlke, 2000). It should be noted that the mobilization of historic atmospheric deposition is a one-time occurrence when an area is first irrigated (or first has treated wastewater percolated through), and is not considered an ongoing source of nitrogen in this section.

The process of accounting for nitrogen in this report is similar to that of TDS; however, there are a few differences as follows:

- Domestic sources of nitrogen make up a significant contribution of nitrogen in the WWTP influent.
- Fertilizers may be an additional source of nitrogen.
- Nitrogen does not behave conservatively in the water and wastewater system at Fort Irwin. Nitrogen occurs in a number of different compounds, can change form among the various compounds, can be converted to nitrogen gas through denitrification, and can be taken up by plants in irrigated areas.
- Some nitrogen is removed from the system at the WWTP through nitrification and denitrification processes as well as in solids removal process. Nitrogen is captured in the biosolids produced at the WWTP. Solids wasted from the treatment process are contained in concrete- or geotextile-lined drying ponds for drying by evaporation. Decant water from the ponds is pumped back to the head of the WWTP and the remaining dried biosolids are removed to the lined landfill on site.

A summary of the nitrogen balance is presented in Figures 3-7 and 3-8. Total nitrogen pumped from the local basins is about 11.1 tons/yr. Individual components of the Irwin Basin nitrogen balance are discussed below.

3.2.2.1 Deep Percolation of Applied Irrigation Water

Two sources of nitrogen are applied to irrigated areas: 1) naturally occurring nitrogen in DO water, and 2) nitrogen in fertilizers. Assuming recent distribution of groundwater pumping among the three basins and average water quality from each of the wells as shown in Table 3-3, the average nitrate concentration of water delivered for irrigation is estimated to be about 3.4 mg/L, which is consistent with observed DO water quality discussed in Section 2. Based on an applied irrigation rate of 1,083 afy (see Section 3.1), nitrogen mass of applied irrigation water is estimated to be about 5.0 tons/yr.

Based on an estimated fertilizer application rate of four pounds nitrogen per 1,000 square feet of turf per year (Henry, et al., 2002), it is estimated that about 4.8 tons/yr of nitrogen are applied to irrigated turf areas. Assuming fertilization of trees and shrubs at about half that rate (2 pounds nitrogen per 1,000 square feet of canopy), it is estimated that about 2.3 tons/yr of nitrogen needs to be applied to irrigated tree and shrub areas. Fertilizer application data were not available as part of this analysis. It was assumed that the total nitrogen requirement would be met by a combination of fertilizer and the nitrate in the delivered water. Accordingly, total fertilizer application rate in the Baseline condition is estimated to be about 2.1 tons/yr (7.1 tons/yr requirement minus 5.0 tons/yr in the delivered water).

Much of the applied nitrogen is taken up by the plants; whatever is not taken up by plants is assumed to enter the groundwater during the deep percolation of irrigation water. The nitrogen use efficiency describes the percent of applied nitrogen that gets taken up by plants. Nitrogen use efficiency can be greater than 90 percent (U.C. Davis, 2012), but could also be as low as the irrigation efficiency, which is estimated to be about 62 percent at Fort Irwin (Section 3.1). For the purposes of this analysis, a nitrogen use efficiency of 78 percent was used (average of 62 percent irrigation efficiency and an upper limit of about 95 percent). Based on 78 percent nitrogen use efficiency, it is estimated that of the 7.1 tons/yr of applied nitrogen, 5.5 tons/yr is taken up by plants and 1.6 tons/yr is added to the groundwater during deep percolation (Figures 3-7 and 3-8). The 1.6 tons/yr is further parsed out (as shown in Figure 3-8) into nitrogen that is from DO water (1.13 tons/yr) and fertilizers (0.46 tons/yr) based on the relative applied nitrogen from those two sources.

3.2.2.2 Percolation of Wastewater

Baseline (average 2012-2013) wastewater influent flow rate is 1,066 afy with average total nitrogen concentration of about 55 mg/L for a total of 79.7 tons/yr. Average total nitrogen concentration of wastewater effluent is about 8 mg/L (though it is highly variable; see Figure 2-29) or a total of about 11.6 tons/yr. The difference between influent and effluent total nitrogen suggests net nitrogen removal at the WWTP of about 68.1 tons/yr. Some of the nitrogen that is removed is contained in biosolids that are removed to the local lined landfill and do not contribute to the water cycle.

For purposes of this analysis, it is assumed that all of the nitrogen in the treated wastewater reaches the groundwater system. This is a conservative assumption as some denitrification may be occurring in and below the evaporation and percolation ponds (Viers, et al., 2012).

3.2.2.3 Other Potential Sources

Atmospheric deposition is a known source of nitrogen loading in most areas. The National Atmospheric Deposition Program (NADP)/National Trends Network (NTN) operates a network of monitoring stations around the United States that are used to measure the atmospheric deposition of various chemicals, including inorganic nitrogen. Based on 2000-2012 data from the closest operational station to Fort Irwin (Joshua Tree National Park), the annual average deposition of inorganic nitrogen is estimated at 0.5 lb per acre per year (NADP/NTN, 2014). While this could result in about 1.2 tons/yr over the saturated area of the Irwin Basin (about 4,500 acres), there is no mobilization mechanism to transport this nitrogen to the water table. If the rate is applied to the irrigated area only, about 0.03 tons/yr of nitrogen may reach the water table. Because this is a small value relative to the total, it is not considered in this study.

3.2.2.4 Summary of Nitrogen Balance and Assimilative Capacity

Figures 3-7 and 3-8 summarize the nitrogen balance of the three groundwater basins used for water supply. About 11.1 tons/yr of nitrogen is pumped from the groundwater in the three basins, with about 2.65 tons/yr being pumped from Irwin Basin. In addition, it is estimated that there is about 0.48 tons/yr of nitrogen that discharge out of the Basin to the southeast toward Langford Basin based on a flow rate of 105 afy and nitrate concentration of about 3.4 mg/L (average of concentrations at the southernmost well; see Figure 2-17). Total nitrogen removal from Irwin Basin is estimated to be about 3.1 tons/yr.

Total nitrogen entering the Irwin Basin is estimated to be about 13.7 tons/yr from a combination of deep percolation of applied irrigation water, including fertilizers, pipe leakage, and percolation of treated wastewater. After accounting for nitrogen removal from the Basin via groundwater pumping (2.65 tons/yr) and outflow to Langford Basin (0.48 tons/yr), the net addition of nitrogen to the Basin is estimated to be about 10.6 tons/yr. The net addition of nitrogen is accompanied by net recharge of about 706 afy of water to the Basin (see Section 3.1).

The assimilative capacity was defined based on an average nitrate concentration in the Basin of about 3.25 mg/L based on Figures 2-17 and 2-24. The water quality objective was defined as the MCL (< 10 mg/L), so the assimilative capacity is currently about 6.75 mg/L. To evaluate future average water quality under the Baseline condition, a mixing calculation was performed by adding 706 afy of water and 10.6 tons/yr of nitrate (as N) to an assumed starting water volume in the basin of 79,900 af (CH2M HILL, 2007a). Using this methodology, average nitrate in the Basin would be expected to increase in the future, in the absence of management strategies, to an average concentration of about 4.6 mg/L in 25 years (Figure 3-9). The projected increase is due to recharge water generally having higher total nitrogen concentration than that of the water supply being pumped out of the basin (see Figure 3-7). It should be reiterated that this projection includes a conservative assumption that no denitrification occurs in or below the evaporation and percolation ponds.

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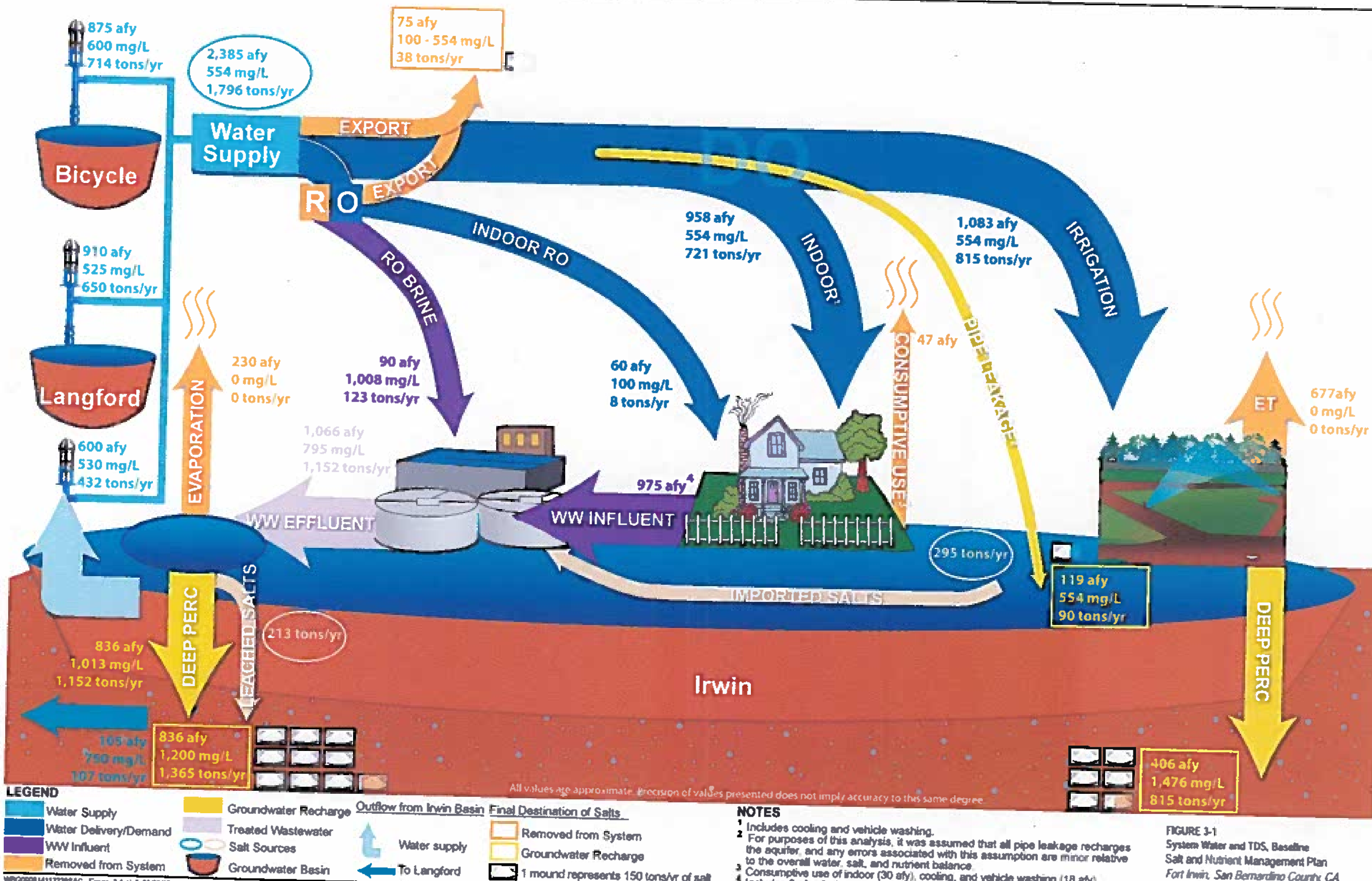

NOTES

1 Includes cooling and vehicle washing.
2 For purposes of this analysis, it was assumed that all pipe leakage recharges the aquifer, and any errors associated with this assumption are minor relative to the overall water, salt, and nutrient balance.
3 Consumptive use of indoor (30 afy), cooling, and vehicle washing (18 afy).
4 Includes 5 afy of other septage.

FIGURE 3-1
System Water and TDS, Baseline
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

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ch2m

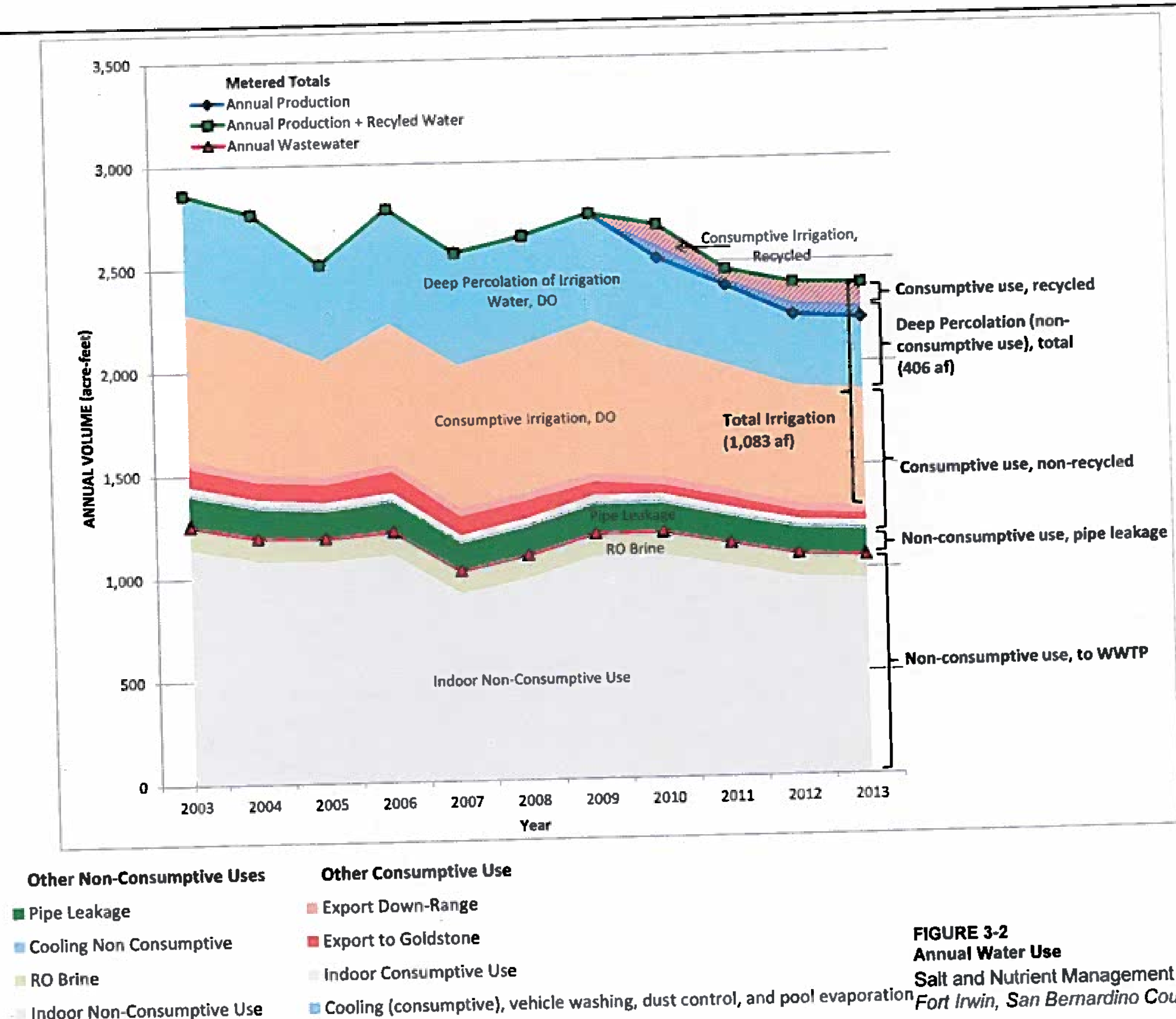

FIGURE 3-2
Annual Water Use
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

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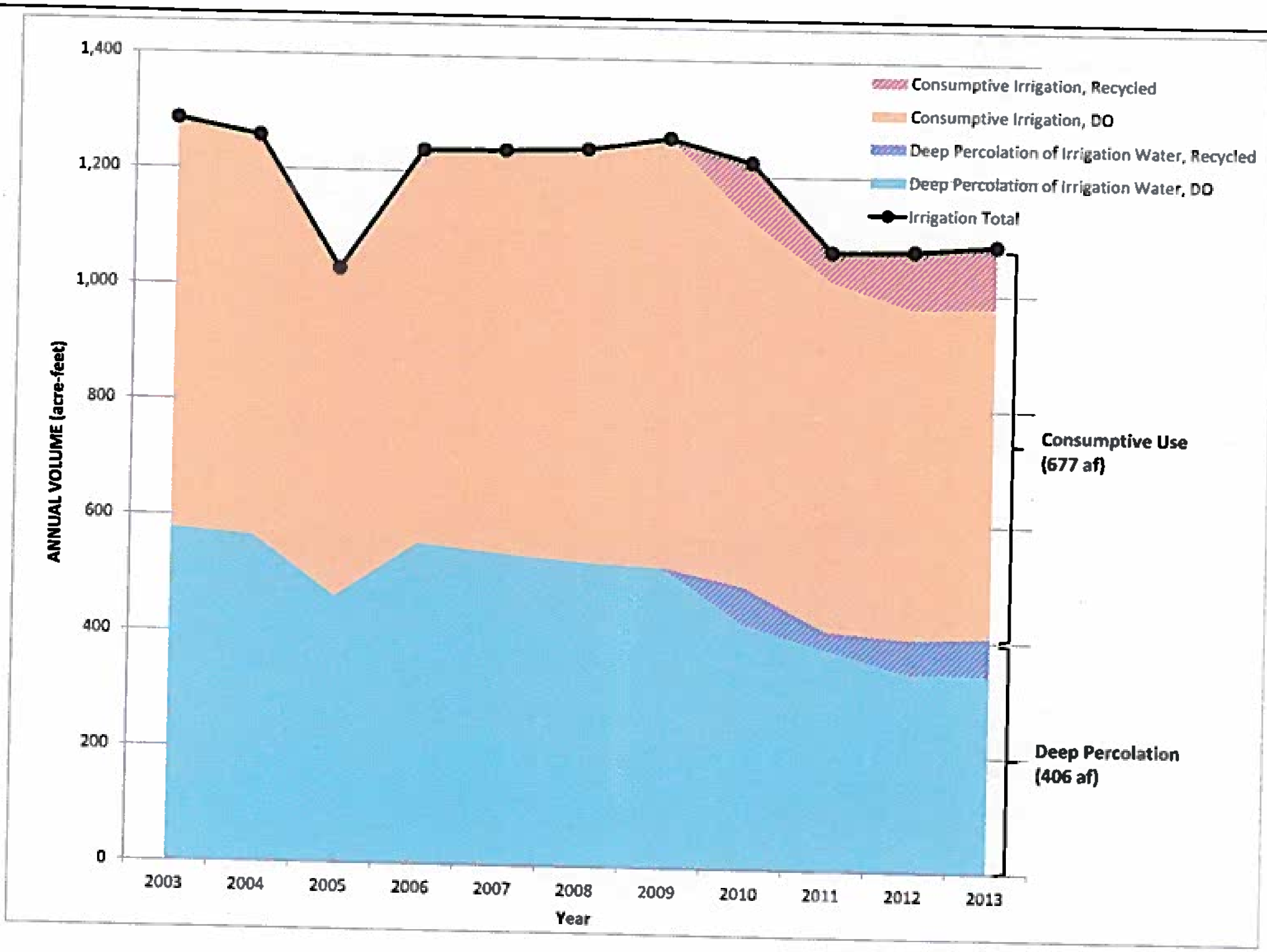

FIGURE 3-3
Annual Irrigation Water Use
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

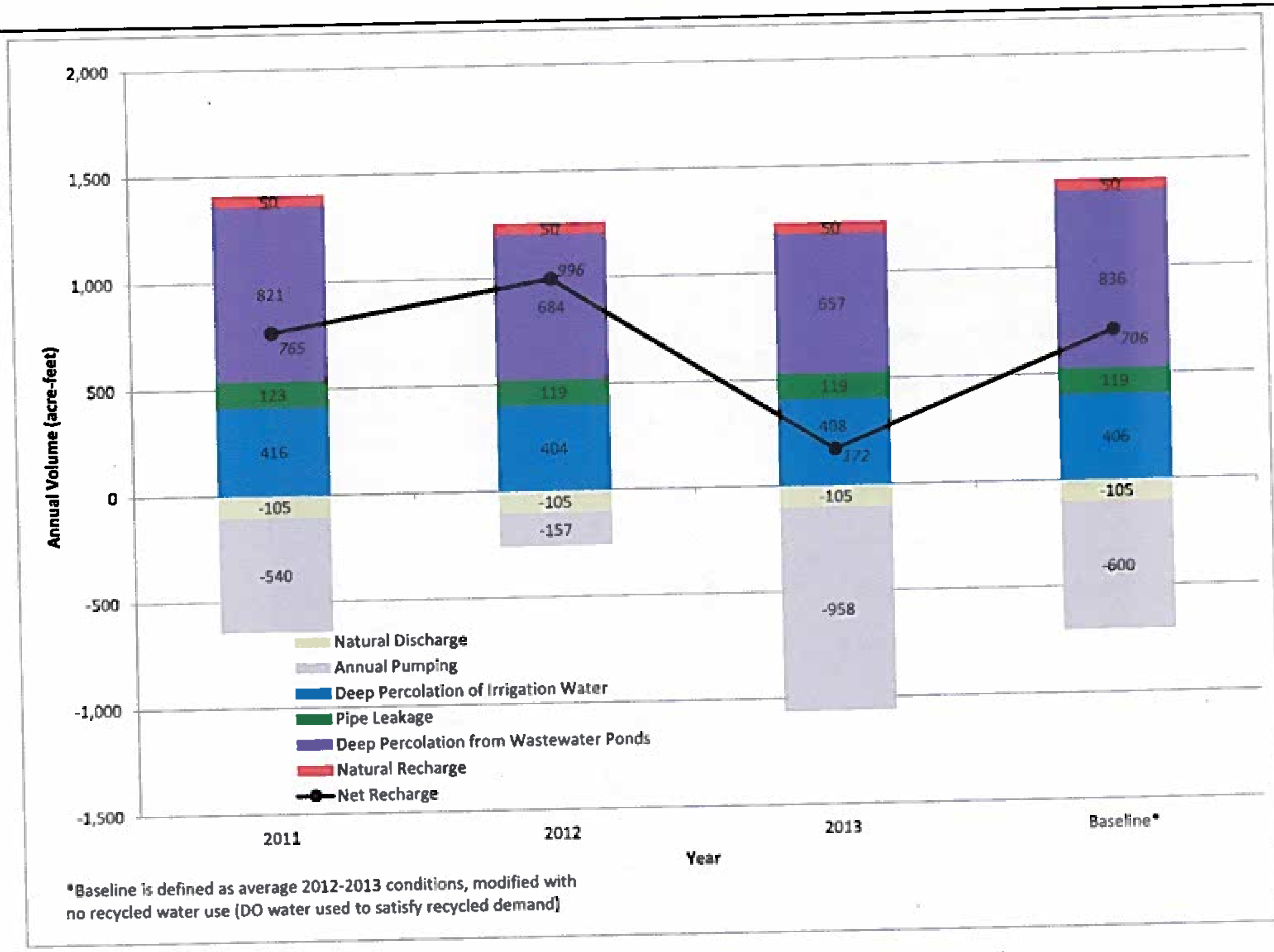

FIGURE 3-4
Irwin Basin Water Balance
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

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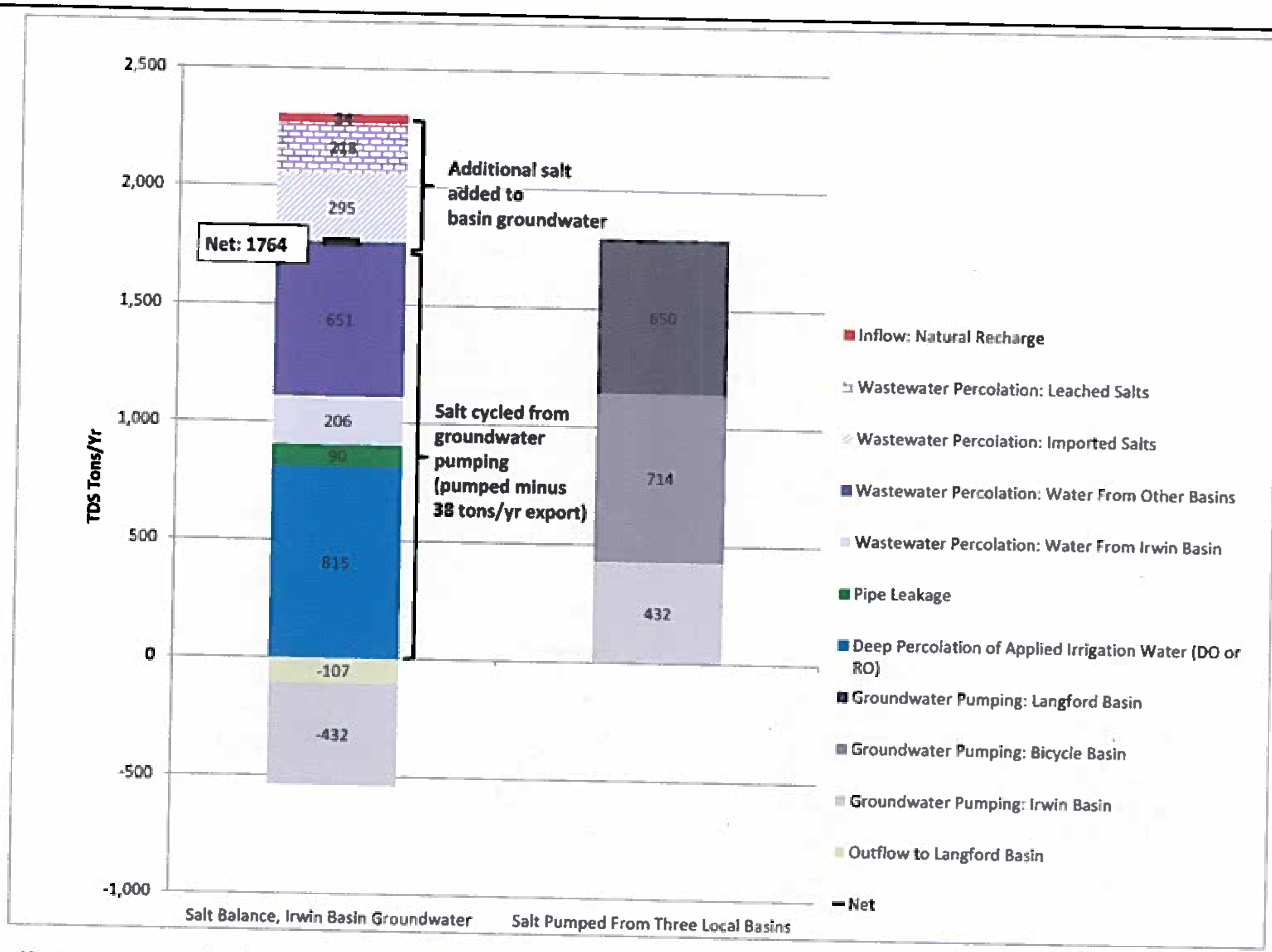


Note: wastewater percolation split calculated based on total of 857 (see Section 3.2.1.2), split proportionally according to relative groundwater pumping rates for Irwin Basin and other basins

All values are approximate. Precision of values presented does not imply accuracy to this same degree

FIGURE 3-5
Baseline Irwin Basin Salt Balance
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

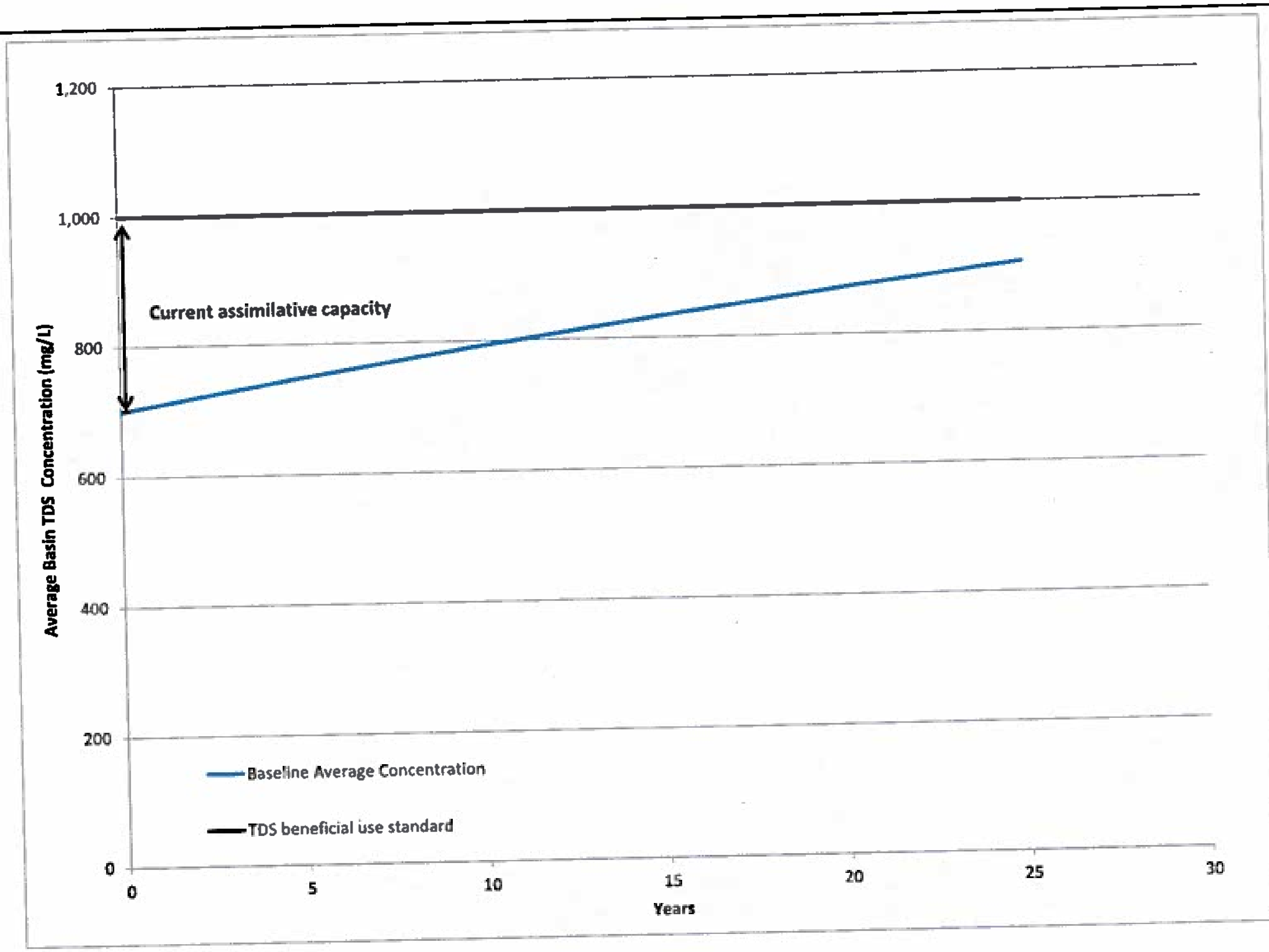


FIGURE 3-6
Baseline Assimilative Capacity, TDS
Irwin Basin
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

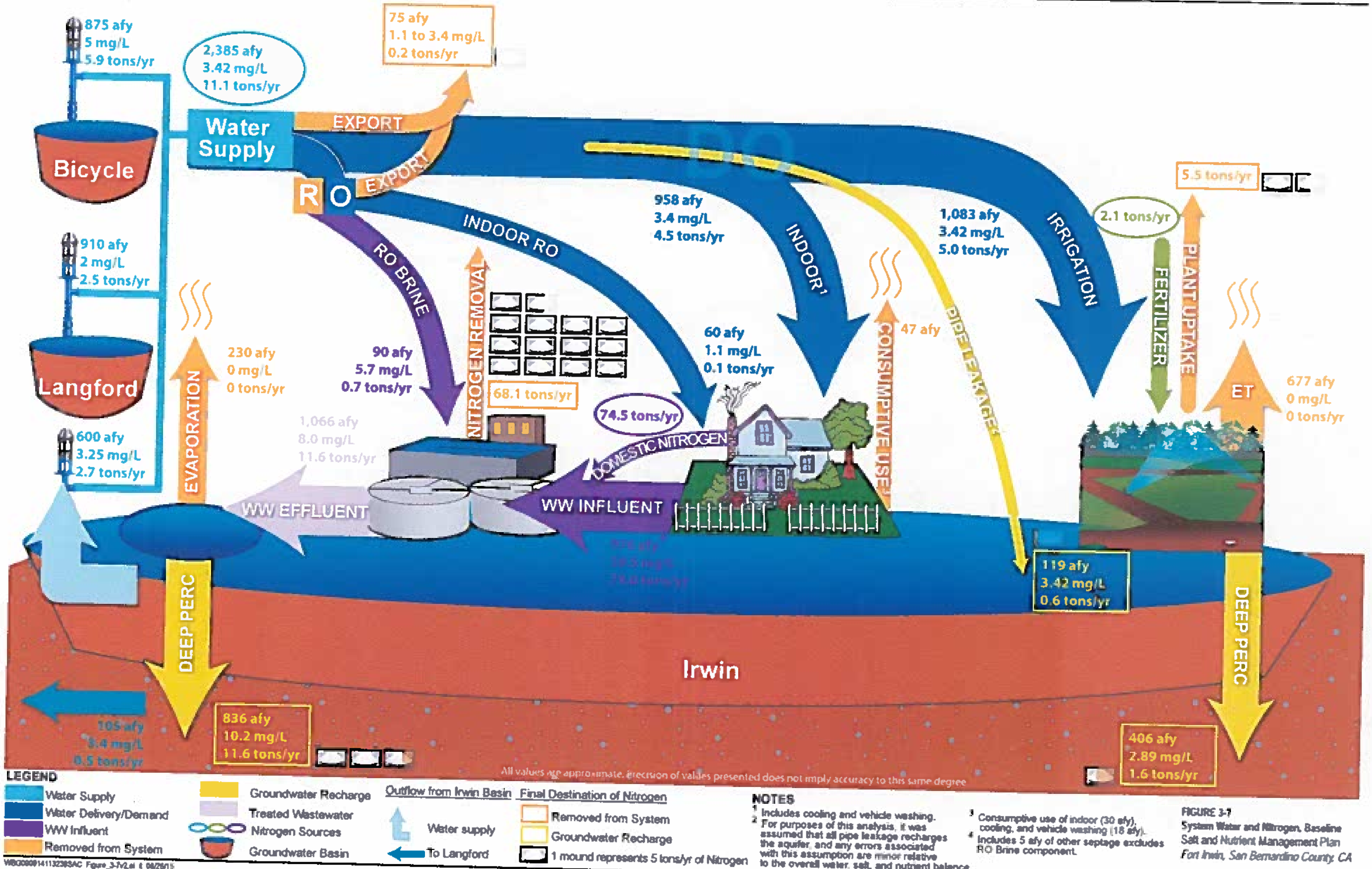
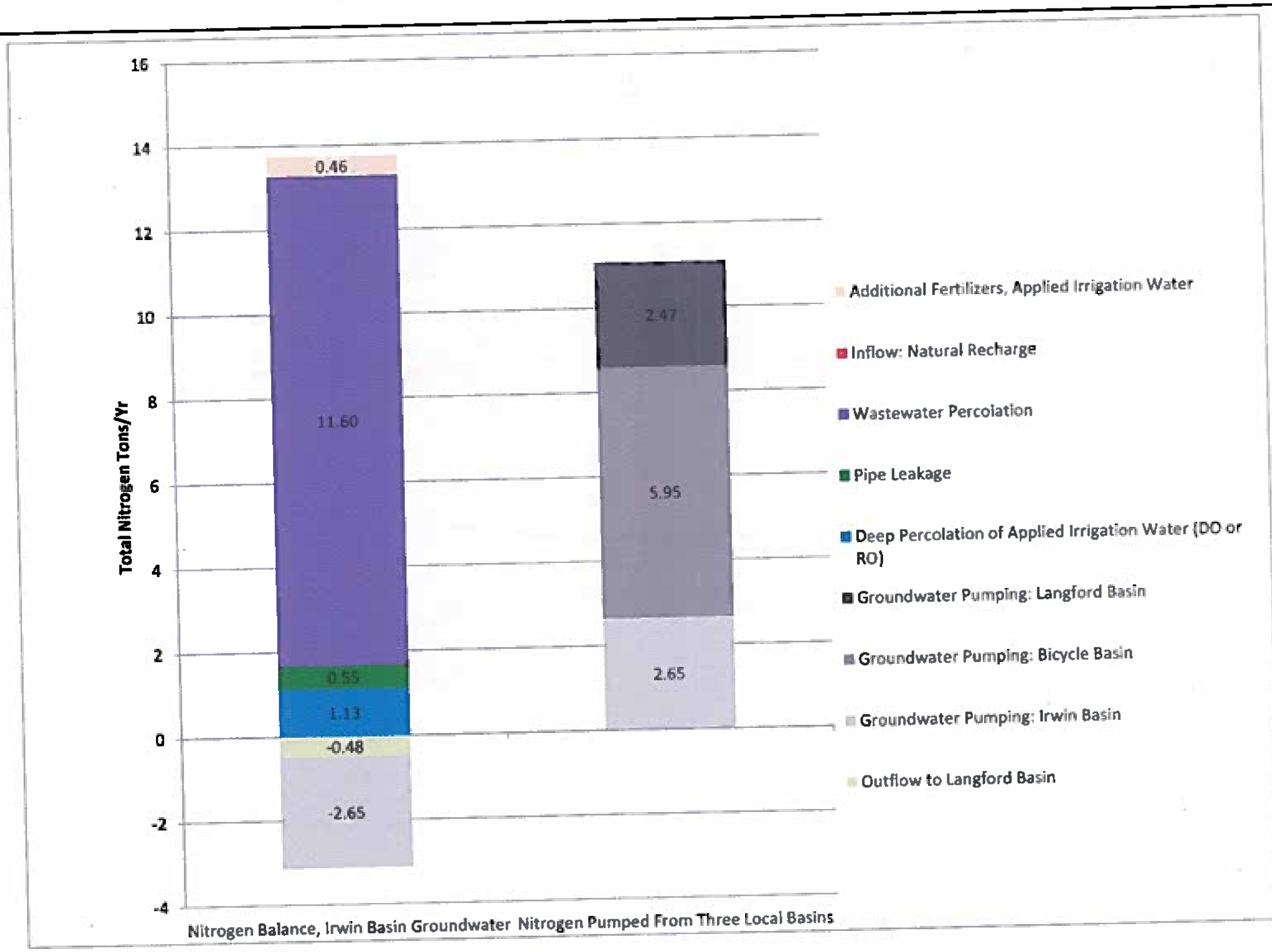


FIGURE 3-7
System Water and Nitrogen, Baseline
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA



All values are approximate. Precision of values presented does not imply accuracy to this same degree.

FIGURE 3-8
Baseline Irwin Basin Nitrogen Balance
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

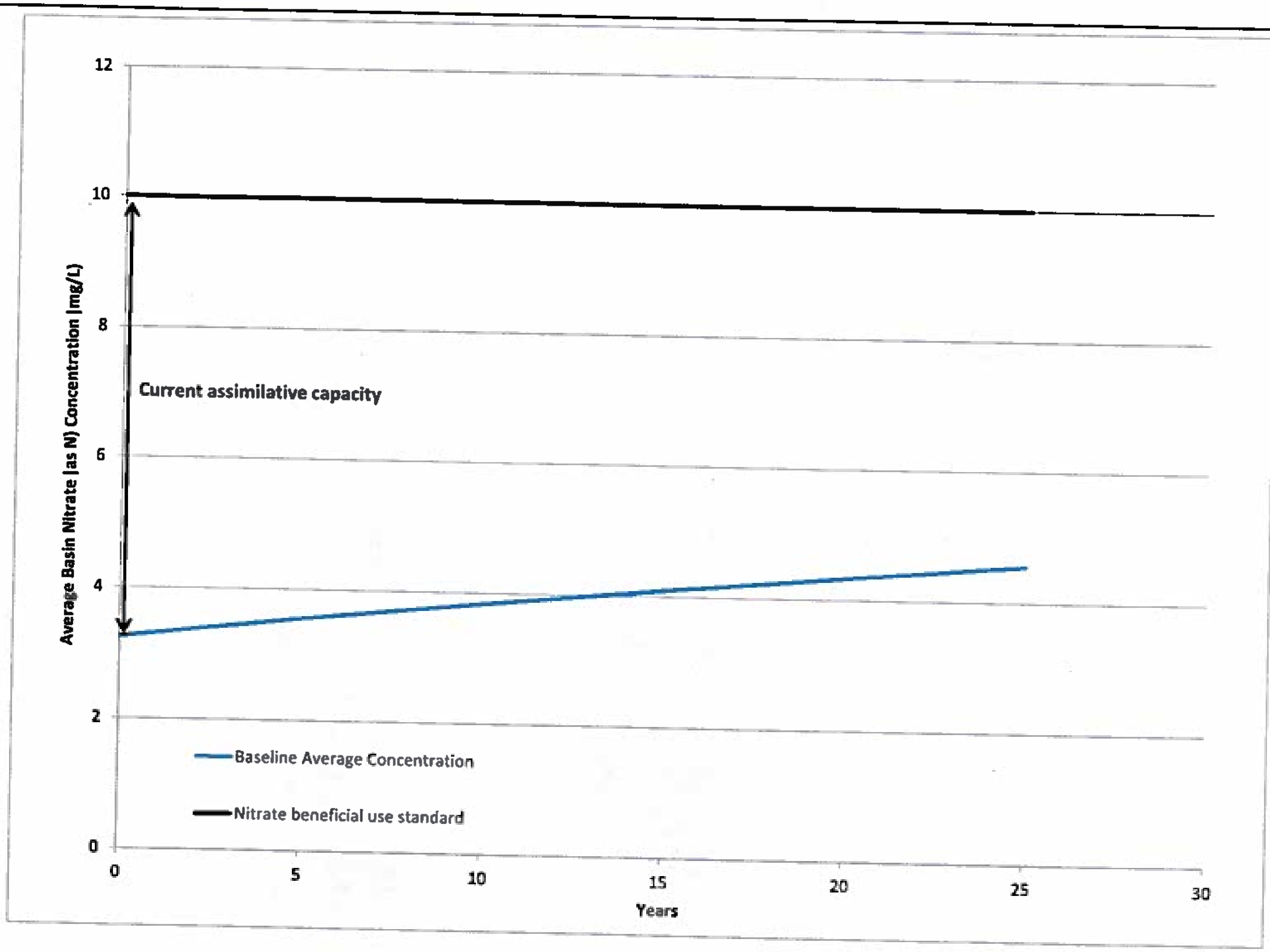


FIGURE 3-9
Baseline Assimilative Capacity, Nitrate
Irwin Basin
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

4.0 Salt and Nutrient Management Strategies

Currently several projects and operational changes are planned that will reduce the salt and nutrient loading to the Irwin Basin. This section summarizes the planned activities, followed by a summary of their effect on the TDS and nutrient loading of the Basin and assimilative capacity in the Basin.

4.1 Summary of Strategies

Planned salt and nutrient management strategies evaluated, and collectively described as the "Scenario" in subsequent figures and tables, include the following:

- **New water treatment plant.** A new WTP, Irwin Water Works, is currently under construction. Based on the design (CDM Smith, 2013), the plant will remove between 75 percent and 86 percent of salts and between 84 percent and 92 percent of nitrates depending on the source water concentration. For the purposes of this evaluation, the average removal percentages were assumed to be 79 percent removal of salts and 87 percent removal of nitrate. The new WTP is designed to be 99 percent efficient. Concentrate disposal will be through evaporation ponds with salts periodically collected and disposed of in a lined landfill, thereby removing salts from the local water system.
- **Increased use of recycled water.** The recycled water system at Fort Irwin is currently being expanded. Recycled water will be used to meet existing irrigation demands; total irrigation demand will not increase due to recycled water use. Future recycled water use of 297 afy in the Scenario is based on planned and funded expansion of the recycled water system as summarized in the Recycled Water Master Plan (CH2M HILL, 2014a). In addition to promoting water conservation and smart water use at Fort Irwin, recycled water use will support water sustainability at Fort Irwin in the following ways:
  - Recycled water will be used to supply existing irrigation demand in the Scenario. Therefore, less raw water will need to be pumped from the local groundwater basins to meet Fort Irwin's water demand.
  - Recycled water use reduces wastewater discharged to the evaporation and percolation ponds. This in turn will reduce the amount of salts leached from the subsurface below the ponds and might reduce evapoconcentration, both potentially resulting in improved water quality of percolating water. In addition, while recharge through deep percolation of irrigation water will not change with recycled water use (assuming the same applied water rates), less water will percolate from the evaporation and percolation ponds, thereby reducing the total volume of recharge to Irwin Basin and helping alleviate the water imbalance in the Basin.
- **Increased nitrogen removal at the wastewater treatment plant.** Upgrades to the WWTP are under construction, including a new anoxic basin and oxidation ditch to provide nitrogen removal as described in the WDR. These facilities are expected to increase nitrogen removal and consistently lower total nitrogen concentrations in the WWTP effluent.

- **Increased water supply from the Irwin Basin.** With the new Irwin Water Works, there will be more flexibility in the water quality of source water, thereby allowing more water to be pumped from Irwin Basin. As part of the Irwin Water Works project, an inactive industrial well, I-9, has been rehabilitated and connected to the water supply system. The addition of a second water supply well in Irwin Basin, once permitted, will allow pumping to increase and help alleviate the water imbalance. In addition, this will allow for reduced pumping from Bicycle and Langford Basins, thereby conserving the water supply in those basins.
- **Additional water meters to collect water use data.** Water meter data will promote accountability, potentially reducing water loss. Water meter installation is an ongoing capital improvement project. The first group of area water meters have been installed; the next group of meters should be installed in 2016.

4.2 Projected Scenario Water, Salt, and Nutrient Balances

This section summarizes the results of the planned Scenario activities. The management alternatives in some cases build upon each other; for example, when there are changes in delivered water quality from the new WTP, the water quality of wastewater, and therefore recycled water, will also change. Accordingly, the effects of the planned Scenario are evaluated together. Where possible, the effects of each individual management alternative are identified separately; however, because these are all planned activities, the net effects are emphasized in this section.

4.2.1 Projected Water Balance

The Scenario assumes that total water demand does not change from Baseline conditions. A schematic of the Scenario water demand is presented in Figure 4-1 and can be compared with the Baseline condition schematic in Figure 3-1. Figure 4-1 includes the following conditions, which result in a change in the total amount of raw water that needs to be supplied by local groundwater wells:

- A portion of the irrigation demand is met by recycled water (297 af of 1,200 af total demand), thereby reducing the raw water supply requirement by an equivalent amount.
- The WTP losses have changed. The existing RO WTP will be decommissioned, eliminating the RO brine of 90 afy. The new WTP is assumed to be 99-percent efficient (CDM Smith, 2013) with the new WTP waste concentrate being treated onsite and no discharge stream sent to the WWTP. It is estimated that 20 afy of water (1 percent of influent; also consistent with design criteria adjusted for scenario water demand) will be lost to evaporation in the ponds and elsewhere in the facility. Overall, the raw water supply need is reduced by an additional 70 afy in the Scenario due to the new WTP.

The total Scenario demand for raw water pumped from the local groundwater basins is estimated to be 2,018 afy. The portion of this water supply that will come from Irwin Basin will be based on the Irwin Basin water balance. The only other change from the Baseline condition Irwin Basin water balance is a reduction of deep percolation from treated wastewater at the evaporation and percolation ponds because that recycled water will be used for irrigation. For the purpose of quantifying the water budget under the Scenario, it was assumed that the ratio of evaporation to percolation will remain the same as under the Baseline condition. Accordingly, it is estimated that future deep percolation of treated wastewater at the evaporation and percolation ponds will decrease to about 544 afy from about 836 afy in the Baseline condition.

One of the management strategies was to increase Irwin Basin pumping to equal recharge to the basin. To balance the net recharge to the Irwin Basin (1,014 afy, calculated as 544 afy at WWTP plus 406 afy deep percolation of applied irrigation water, plus 119 afy of pipe leakage, plus 50 afy natural recharge, minus 105 afy discharge to Langford Basin), it was assumed that approximately 1,014 afy of water should be pumped from the Irwin Basin. The remaining 1,004 afy would come from Langford and Bicycle Basins, apportioned at the same ratio as in the Baseline condition (512 afy from Langford and 492 afy from Bicycle).

The resultant changes in the Irwin Basin water budget are presented in Figure 4-2. Under the Baseline conditions, a net of about 706 afy of water was being added to the Basin; under the Scenario, the Irwin Basin will be in balance, with recharge approximately equal to discharge.

Regionally, the local basin lifespan was estimated using the simplified relationship of one foot of drawdown per 650 af of combined groundwater pumping from Bicycle and Langford Basins (see Section 3.1.4). Using this approach, it is estimated that the local basin lifespan under the Scenario will extend beyond year 2100, using the conservatively high water level floor. The estimate of basin lifespan under the Scenario is significantly longer than the estimate of year 2065 presented in the WDMP (see Section 3.1.4) because estimates of total groundwater withdrawals from Bicycle and Langford Basins in the Scenario (1,004 afy) are less than half of the projected withdrawal rates assumed in the WDMP (2,250 afy). Reduced reliance on Bicycle and Langford Basins in the Scenario, as compared with the WDMP, is caused by a) lower total water demand (2,385 afy in this report compared to 2,700 afy in WDMP), b) increased use of recycled water resulting in further reduction in raw water demand, and c) increased groundwater pumping from Irwin Basin.

4.2.2 Projected Salt Balance

This section summarizes the projected salt balance in the Irwin Basin under the Scenario. It is broken into two sections: methods and results.

4.2.2.1 Projected Salt Balance Methods

The water balance described above forms the basis of the salt balance. As discussed, it is assumed that the new WTP would remove 79 percent of the TDS in the influent water. Based on the ratio of groundwater pumping among the three basins, influent TDS concentration will be about 546 mg/L with a salt mass of 1,498 tons/yr. The estimated WTP finished water TDS concentration is 115 mg/L, and will form the basis of the water supply for both potable (non-recycled water) irrigation and indoor demand.

The estimated wastewater effluent TDS concentration was calculated assuming the same volume of water would be treated and the same amount of imported salts would continue in the Scenario. Accordingly, wastewater effluent is estimated to have a TDS concentration of about 342 mg/L. This is the assumed TDS concentration of both effluent flow to the evaporation and percolation ponds as well as recycled water used for irrigation purposes. To estimate the water quality of water percolating from the wastewater evaporation and percolation ponds, it was assumed that the same percent of discharged water evaporates as in the Baseline condition. It was also assumed that salts are leached from the subsurface at a rate that is proportional to the flow rate of percolating water.

4.2.2.2 Projected Salt Balance Results

The salt mass balance under the Scenario suggests that there will be net removal of salt from the Irwin Basin of about 71 tons/yr once the Basin has equilibrated to the new management strategies (particularly deep percolation of applied irrigation water, which may take years to reach the water table). This can be compared with a net addition of about 1,764 tons/yr in the Baseline condition

(Figure 4-3) or a decrease of about 1,835 tons/yr of net salt entering the Basin. To better understand the effect of individual management strategies on the overall salt balance, the total change in salt loading was broken out into individual components.

The greatest change in the salt balance is due to removal of salts at the new WTP, comprising about 65 percent of the total change (Table 4-1). Increasing pumping from Irwin Basin results in an increased removal of salts from the Basin by about 298 tons/yr or 16 percent of the total change in net salt loading to the Basin. Recycled water use makes up the remainder of the difference. Because recycled water replaces existing raw water demand, less water and salt enter the system through the raw water supply. In addition, less wastewater is discharged to the wastewater evaporation and percolation ponds, thereby reducing the amount of salts leached from the subsurface.

TABLE 4-1
Components of the Net Change in Salt Mass Loading

Description	Mass (tons/yr)	Percent of total
New WTP salt removal and disposal	1,186	65%
Increased pumping from Irwin Basin (increased removal of salts from the Basin) (change in "out" term)	298	16%
Decreased salt in raw water supply, due to less raw water demand and different distribution of pumping among basins	298	16%
Less leaching (less percolation at WWTP)	74	4%
Change in salts exported from Basin (export water will be treated at Irwin Water Works)	-26	-1%
Total	**1,830**	**100%**

In consideration of water quality in the Irwin Basin, it is important to consider both the water balance and the salt balance of the Basin together. This can be accomplished by looking at a plot showing the change in average concentration in the Basin through time compared with the assimilative capacity. Figure 4-4 shows that the average TDS concentration in the Basin is projected to decline slightly under the Scenario, whereas it was projected to increase under Baseline conditions. It should be noted that it may take some time for water quality improvements to take effect in the groundwater due to travel time for recharge water to reach the groundwater system.

The combined effect of the management strategies included in the Scenario results in TDS concentrations of groundwater recharge being lower than the background groundwater concentrations in the Basin (Figure 4-1). Concentration of percolating wastewater is expected to be less than 700 mg/L after salts are leached from the subsurface. Concentration of deep percolation of applied irrigation water is expected to be about 472 mg/L (the average of areas irrigated with recycled water and potable water).

4.2.3 Projected Nitrogen Balance

This section summarizes the projected nitrogen balance in the Irwin Basin under the Scenario. It is broken into two sections: methods and results.

4.2.3.1 Projected Nitrogen Balance Methods

The water balance described above forms the basis of the nitrogen balance. As discussed, it is assumed that the new WTP would remove 87 percent of nitrate (and therefore total nitrogen) in the influent water. Based on the ratio of groundwater pumping among the three basins, influent nitrate concentration will be about 3.4 mg/L with a nitrogen mass of about 9.2 tons/yr. The estimated WTP effluent nitrate concentration is 0.44 mg/L and is assumed to be the delivered water quality (Figure 4-5).

Future wastewater effluent total nitrogen concentration was estimated using CH2M's Pro2D model developed to support design of the WWTP upgrades. Pro2D (Professional Process Design and Dynamics) is a steady state and dynamic whole WWTP simulator that has been developed by CH2M to perform complete wastewater treatment plant simulations and calculate full-plant mass balances. The model results suggest that the average wastewater effluent total nitrogen concentration in the Scenario will be about 5 mg/L[4].

Biosolids produced at the WWTP will capture nitrogen along with other nutrients (phosphorus and potassium), pathogens, metals, and organics. Solids wasted from the treatment process are contained in concrete- or geotextile-lined drying ponds for drying by evaporation. Decant water from the ponds is pumped back to the head of the WWTP and the remaining dried solids are removed to the lined landfill on the Post.

For Scenario irrigation, it is important to note that with the reduced nitrate concentration in delivered water, more fertilizer would be required to maintain healthy turf and plants. It was assumed that the same nitrogen requirement of 7.1 tons/yr (see Section 3.2.2.1) would be met through a combination of recycled water and fertilizer. Because delivered water, including recycled water, only supplies about 2.5 tons/yr in the Scenario, fertilizer application rate would need to be increased to about 4.6 tons/yr (Figure 4-5).

4.2.3.2 Projected Nitrogen Balance Results

The nitrogen balance under the Scenario suggests that there will be net addition of nitrogen to the Irwin Basin of about 1.3 tons/yr (Figure 4-6). This can be compared with a net addition of about 10.6 tons/yr in the Baseline condition or an overall decrease of about 9.3 tons/yr of net nitrogen entering the Basin.

In consideration of water quality in the Irwin Basin, it is important to consider both the water balance and nitrogen balance of the Basin together. This can be accomplished by looking at a plot showing the change in average concentration in the Basin through time and comparing the change with assimilative capacity. Figure 4-7 shows that the average nitrate concentration in the Basin is projected to increase slightly under the Scenario to about 3.6 mg/L in 25 years (compared with 4.6 mg/L in the Baseline condition) from current average concentration of about 3.25 mg/L. Total nitrate concentration of recharge water is, on average, slightly greater than the assumed average Basin nitrate concentration of 3.25 mg/L, but is well below the water quality objective of 10 mg/L.

[4] It should be noted that the process development modeling for the WWTP upgrade simulates average nitrate (as N) concentration of 6.4 mg/L (CH2M HILL, 2014b). However, the simulations assume annual average influent flow rate of 2,240 afy (2 million gallons per day) compared with the SNMP scenario assumption of 975 afy influent, which is based on recent demand. The lower influent flow rate results in greater nitrogen removal.

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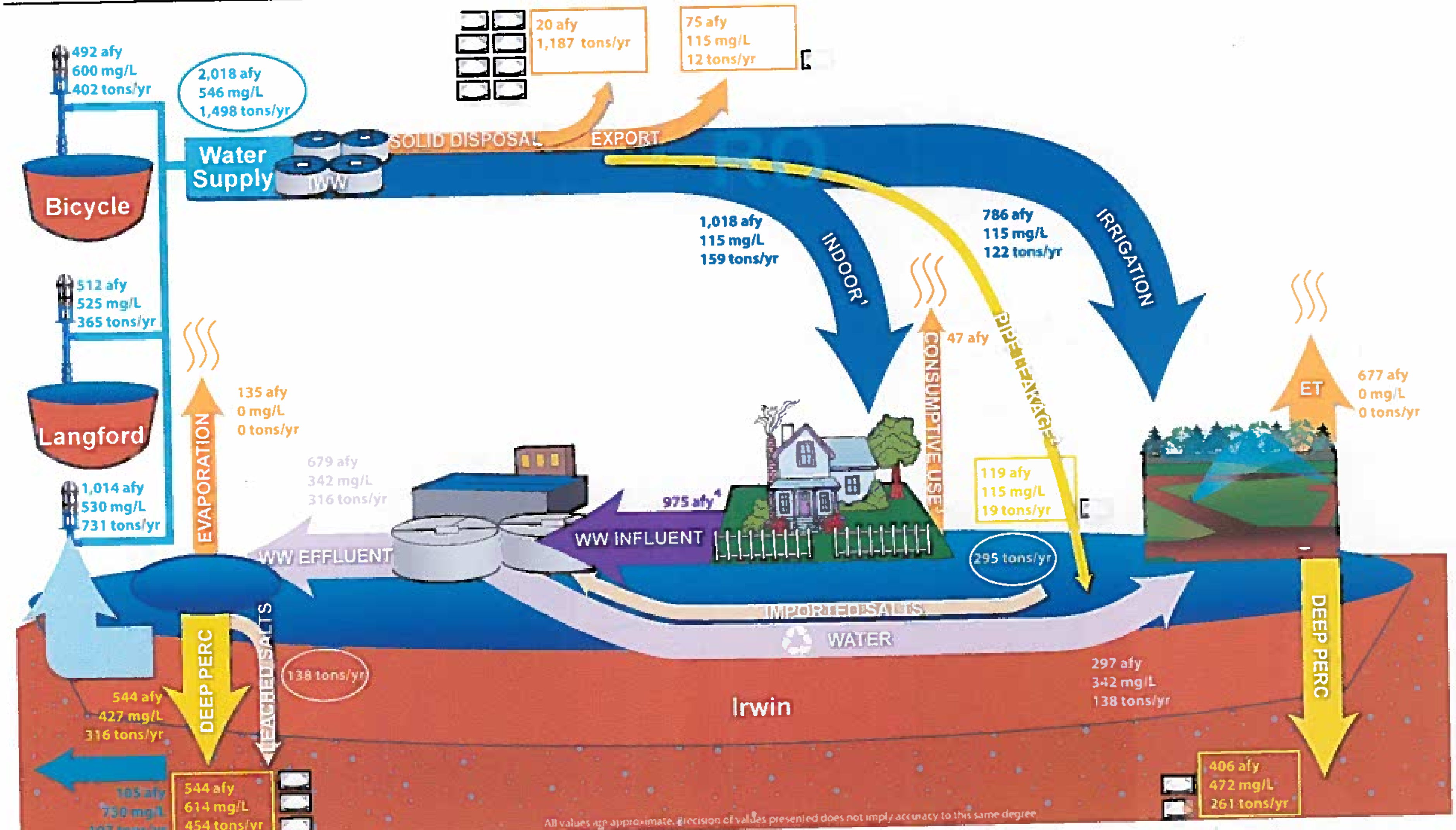

LEGEND

- Water Supply
- Water Delivery/Demand
- WW Influent
- Removed from System
- Groundwater Recharge
- Treated Wastewater
- Salt Sources
- Groundwater Basin

Outflow from Irwin Basin
- Water supply
- To Langford

Final Destination of Salts
- Removed from System
- Groundwater Recharge
- 1 mound represents 150 tons/yr of salt

NOTES

1 Includes cooling and vehicle washing.
2 For purposes of this analysis, it was assumed that all pipe leakage recharges the aquifer, and any errors associated with this assumption are minor relative to the overall water, salt, and nutrient balance.
3 Consumptive use of indoor (30 afy), cooling, and vehicle washing (18 afy).
4 Includes 5 afy of other septage.

FIGURE 4-1
System Water and TDS, Scenario
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

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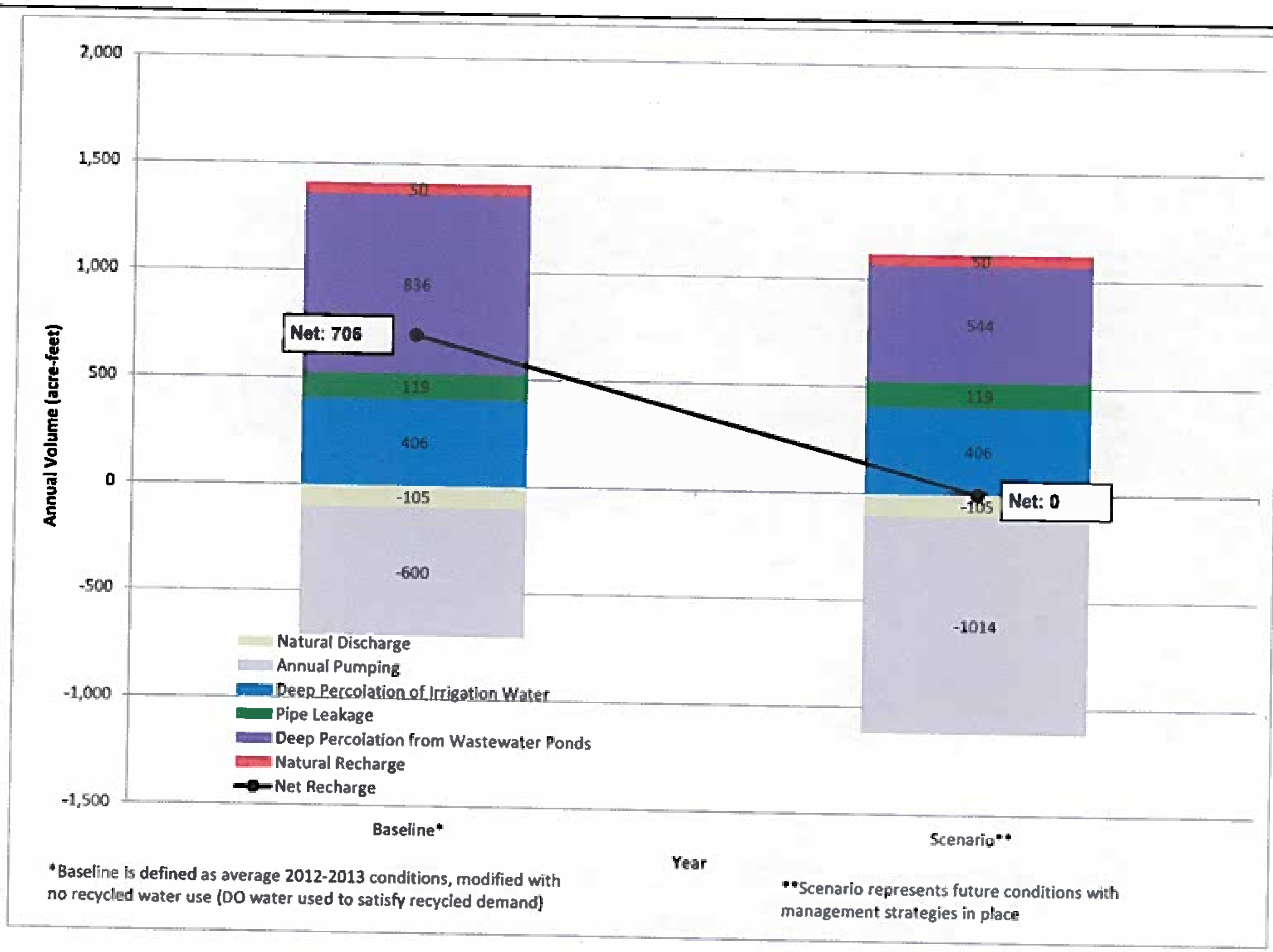
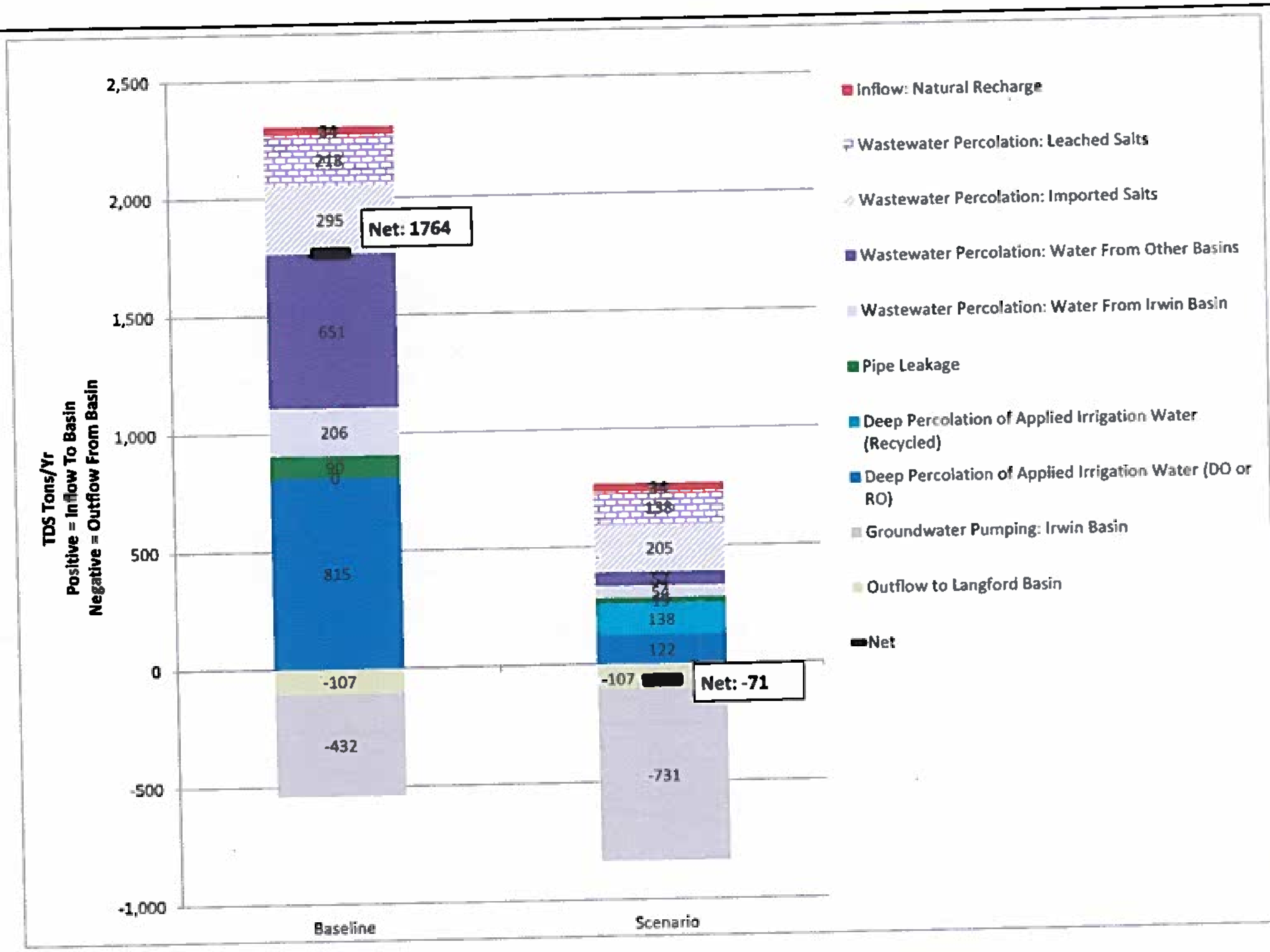


FIGURE 4-2
Scenario Irwin Basin Water Balance
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA



All values are approximate. Precision of values presented does not imply accuracy to this same degree.

FIGURE 4-3
Scenario Irwin Basin Salt Balance
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

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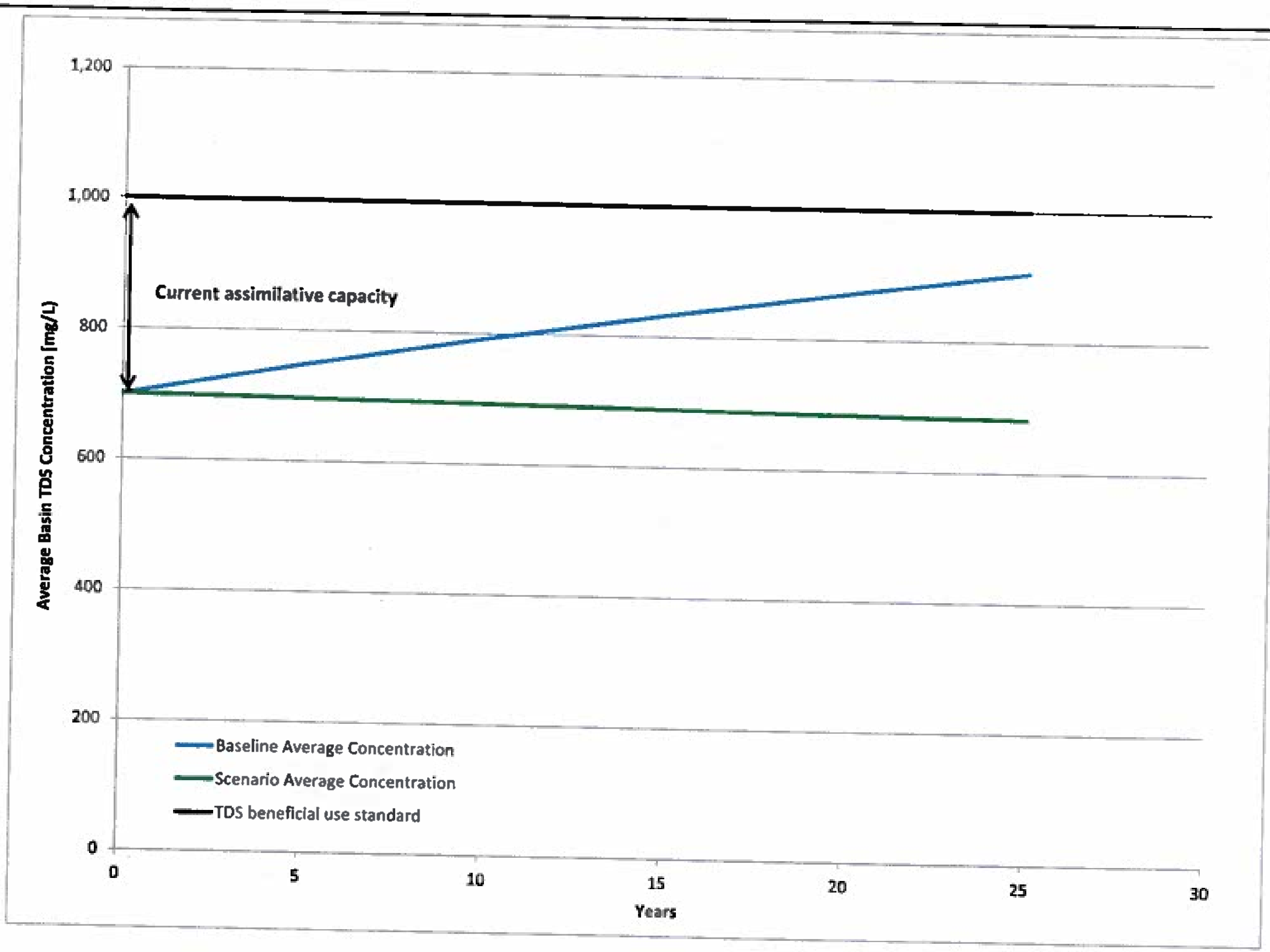
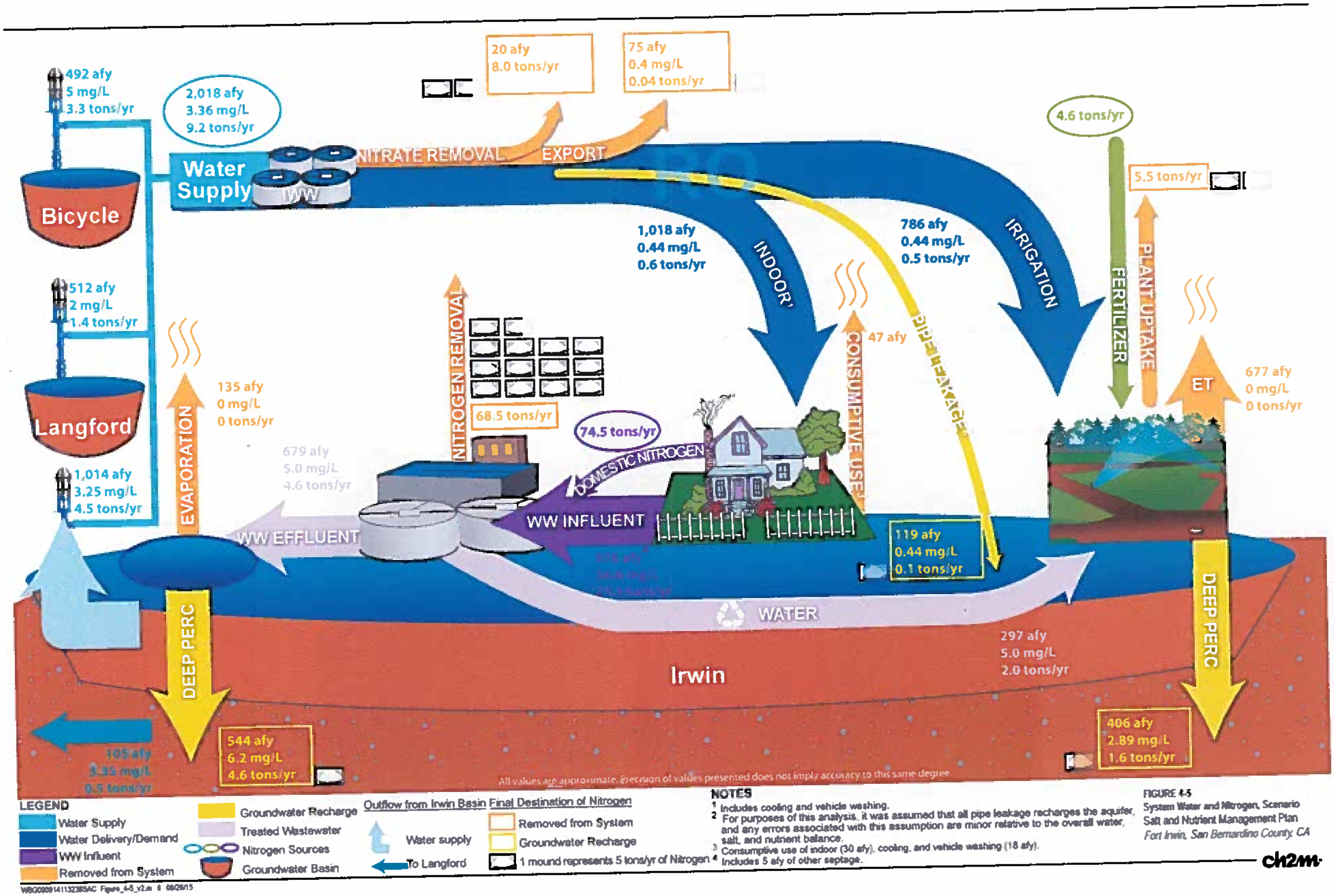


FIGURE 4-4
Scenario Assimilative Capacity, TDS
Irwin Basin
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA



NOTES

1 Includes cooling and vehicle washing.
2 For purposes of this analysis, it was assumed that all pipe leakage recharges the aquifer, and any errors associated with this assumption are minor relative to the overall water, salt, and nutrient balance.
3 Consumptive use of indoor (30 afy), cooling, and vehicle washing (18 afy).
4 Includes 5 afy of other septage.

FIGURE 4-5
System Water and Nitrogen, Scenario
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

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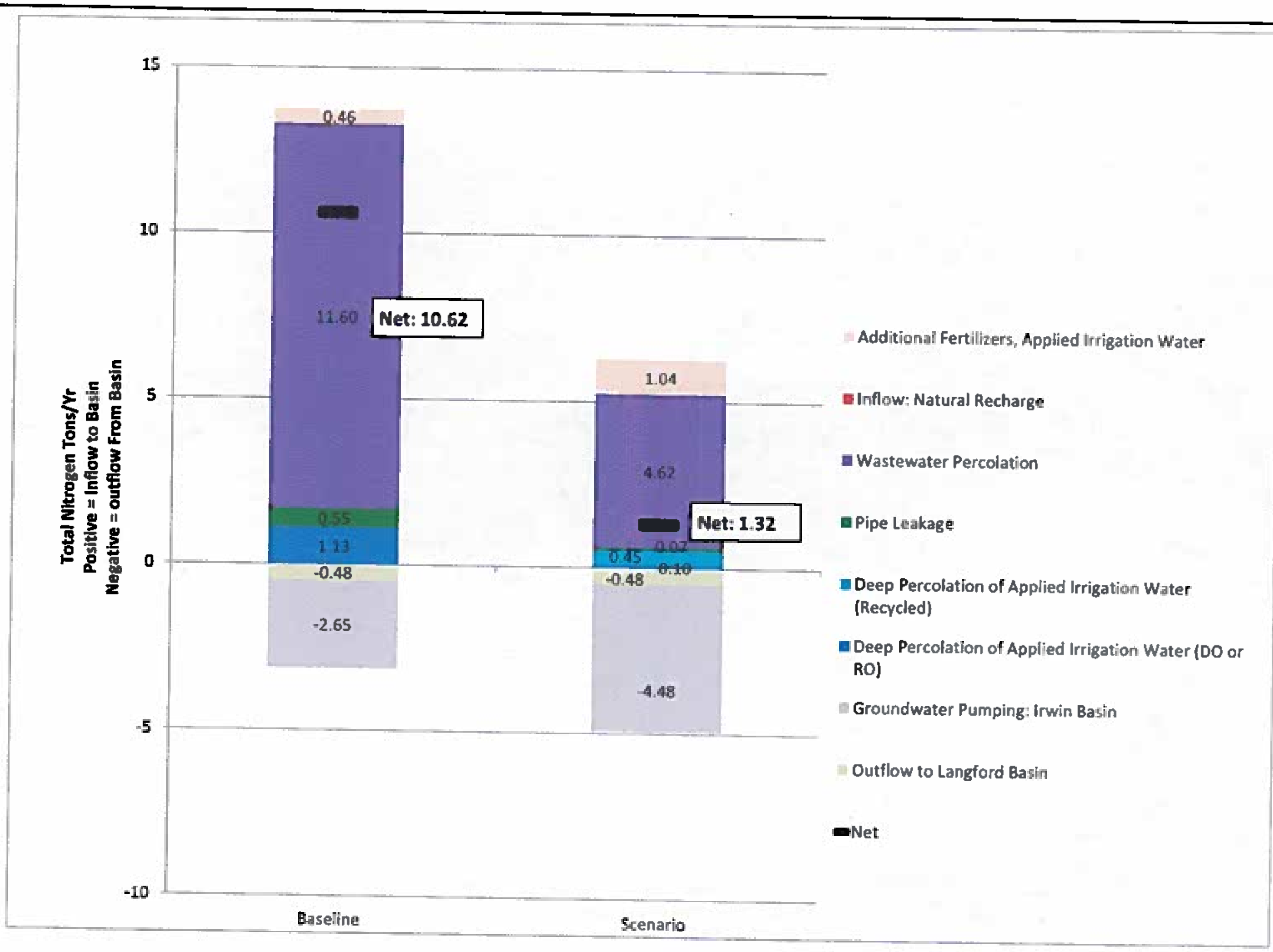

All values are approximate. Precision of values presented does not imply accuracy to this same degree.

FIGURE 4-6
Scenario Irwin Basin Nitrogen Balance
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

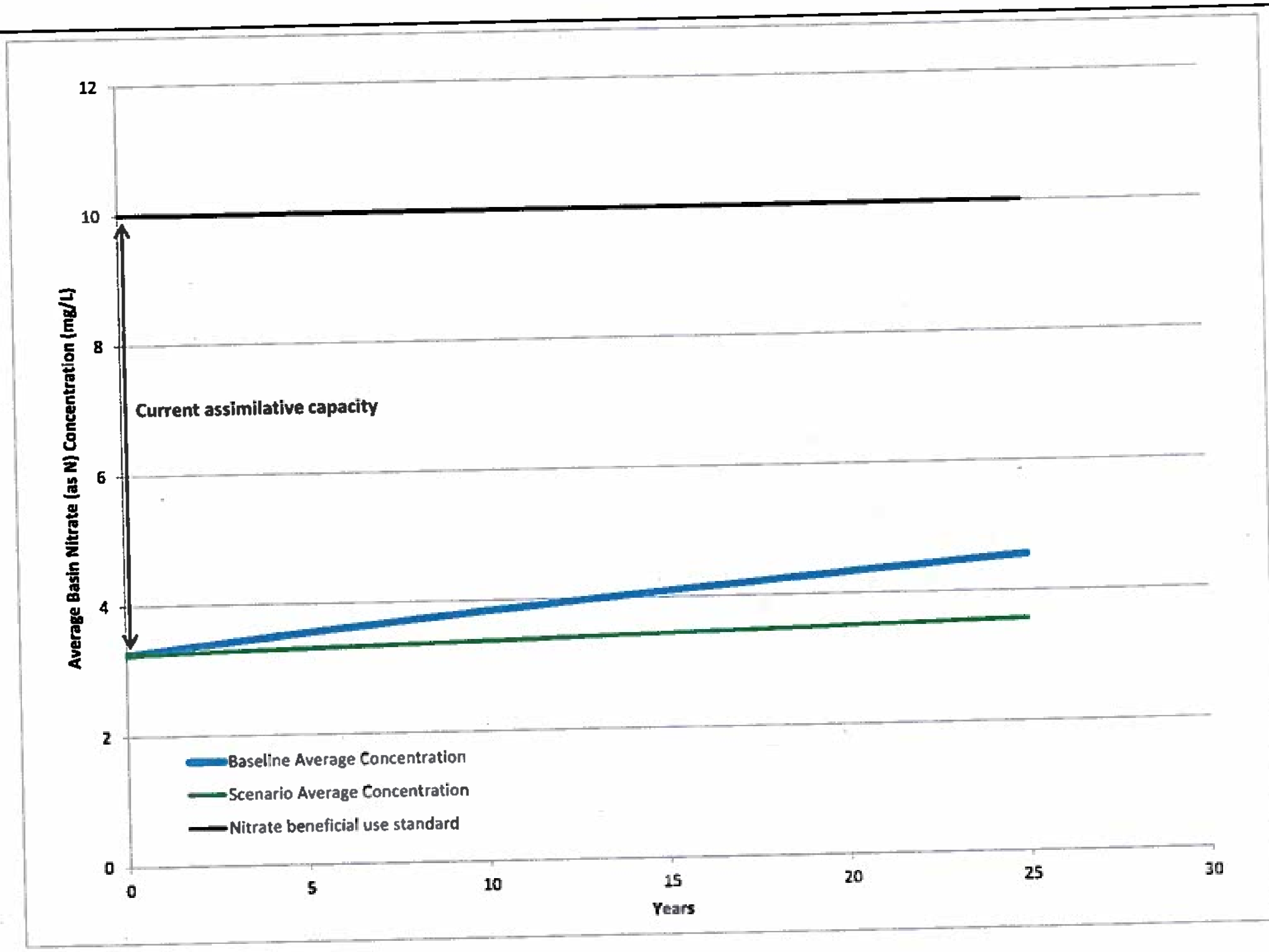

FIGURE 4-7
Scenario Assimilative Capacity, Nitrate
Irwin Basin
Salt and Nutrient Management Plan
Fort Irwin, San Bernardino County, CA

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5.0 Basin Management Plan Elements

This section summarizes the SNMP goals and monitoring programs.

5.1 Goals

As part of the development of the SNMP, CH2M and the U.S. Army-Fort Irwin developed specific goals with the overarching intent of increasing sustainability of water resources in the Basin. The goals of the SNMP are defined below. Each goal is followed by a description of how it is being met under this SNMP:

- **Goal:** Reduce the quantity of salts and nutrients cycling in to the Irwin Basin.

  Approach to Meeting Goal: Under Baseline conditions, salts, and to some extent nutrients, are accumulating in Irwin Basin. The accumulation of salts is primarily due to importation of salt with the water supply from Bicycle and Langford Basins. While a portion of the water is used consumptively, the salts are left behind (evapoconcentrated) in recharge to Irwin Basin, both from deep percolation of applied Irrigation water and from percolation of treated wastewater at the WWTP. As discussed in Section 4, the management strategies are estimated to reduce or even eliminate cycling of salts in the Irwin Basin. A significant portion of salt in the water supply will be removed at the new Irwin Water Works. The primary sources of nitrogen are domestic. While most nitrogen is removed at the WWTP, the nitrogen concentration of WWTP effluent is currently greater than the average groundwater concentration. The management strategies are expected to reduce the total nitrogen concentration of the WWTP effluent to a level closer to that of naturally occurring nitrate in local groundwater.

- **Goal:** Reduce the water Imbalance in Irwin Basin.

  Approach to Meeting Goal: Under Baseline conditions, groundwater recharge through deep percolation of applied irrigation water and percolation of treated wastewater exceeds the extraction rates from water supply wells. In response, the Irwin Basin water levels are rising while there is an increased reliance on the Langford and Bicycle Basins. With the management strategies implemented, groundwater pumping will be increased in the Irwin Basin. In addition, groundwater recharge from the wastewater percolation ponds will be reduced with increased recycled water use (less discharge to the ponds).

- **Goal:** Reduce dependence on Bicycle and Langford Basin water supply sources.

  Approach to Meeting Goal: By using additional water from Irwin Basin, the finite Bicycle and Langford Basin water sources can be conserved for future use.

- **Goal:** Promote water conservation and smart water use through use of recycled water for irrigation.

  Approach to Meeting Goal: Recycled water use is a visible activity that promotes awareness of a limited water supply. In addition, it has an added benefit of reducing consumptive use of water at Fort Irwin. With less water discharging to the wastewater evaporation and percolation ponds, less water is lost through evaporation. One of the management strategies is to increase use of recycled water. Another management strategy is to continue to install water meters and collect water use data to promote accountability and reduce water loss.

- **Goal:** Be consistent with nondegradation policies in the Lahontan Region Water Quality Control Plan.

  Approach to Meeting Goal: The management strategies should result in recharging the Irwin Basin with water that has a lower TDS concentration than background conditions and a total nitrogen concentration well below the water quality objective of 10 mg/L.

5.2 Basin Monitoring Programs

During preparation of this Salt and Nutrient Management Plan, no significant data gaps were identified. Therefore, existing monitoring programs will continue without modification. Data collected from these programs can be used to support subsequent periodic review of the SNMP as discussed in Section 8. A partial list of the applicable monitoring plans follows:

- California Regional Water Quality Control Board Lahontan Region - Fort Irwin Monitoring and Reporting Program No. R6V-2004-0005 (adopted November 14, 2012)
- California State Water Resources Control Board, Division of Drinking Water - Drinking Water Monitoring Schedule, District 13 San Bernardino – US Army Fort Irwin System Number: 3610705 (issued August 24, 2014)
- CH2M Fort Irwin Wastewater Sampling and Analysis Plan (updated January 28, 2011)
- CH2M Fort Irwin Water Sampling and Analysis Plan (updated January 28, 2011)
- CH2M Fort Irwin Vadose Zone Monitoring Plan (submitted to CRWQCB June 6, 2011)

Included in the above-listed monitoring plans are the following types of data that will continue to be collected in support of periodic review of the Salt and Nutrient Management Plan and effectiveness of management strategies:

- Groundwater extraction rates from all water supply wells
- Water quality from all water supply wells
- Water quality of water produced at the WTP
- Wastewater influent flow rates and water quality
- Wastewater effluent flow rates and water quality
- Rates of recycled water use
- Rates of wastewater discharge to the percolation ponds
- Monitoring of groundwater quality at monitoring wells throughout Irwin Basin, particularly the wells near the WWTP

5.3 Salt and Nutrient Load Allocations

This subsection is included to be consistent with State guidelines for Salt and Nutrient Management Plans. The reader is referred to Section 4 for a summary of projected salt and nutrient load allocations under the planned Scenario.

6.0 California Environmental Quality Act Analysis

As a Federal facility, Fort Irwin is required to comply with the National Environmental Policy Act (NEPA), which requires federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. Certain project actions trigger California Environmental Quality Act (CEQA) compliance for Fort Irwin (as a Federal entity), but most actions do not have a CEQA compliance aspect. Permit revisions, such as changes to the WDR, are one of those triggers. The management strategies discussed in Section 4 would not result in modifications to the WWTP or to the existing WDR for the WWTP. Therefore, the SNMP does not trigger CEQA compliance.

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7.0 Antidegradation Analysis

The planned Scenario elements are intended to reduce the salt and nutrient loading in Irwin Basin. As discussed in Section 4.2, it is expected that, with implementation of the management strategies, TDS concentrations of waters recharging the Irwin Basin under the Scenario will be lower than average concentrations in the receiving groundwater, thereby improving the quality of water in the Basin and promoting the longevity of the local water supply. Planned management strategies, primarily upgrades to the WWTP, are expected to reduce nitrogen loading to the Basin, slowing the rate of accumulation.

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8.0 Plan Implementation

This section summarizes implementation of the Salt and Nutrient Management Plan including the management strategies to be implemented, schedule of implementation, and stakeholder responsibilities.

8.1 Salt and Nutrient Management Program and Implementation Schedule

The salt and nutrient management program consists of the salt and nutrient management strategies identified in Section 4.1 and collectively referred to as the "Scenario" in Section 4.2. All activities in the program are currently planned and scheduled. Anticipated timing of implementing these strategies are as follows:

- Irwin Water Works. The Irwin Water Works (new WTP and associated pipelines) is currently under construction. It is expected to be operational by early 2016.
- Increased Recycled Water Use. Currently funded expansion of the recycled water system quantified in Section 4 is expected to be complete in 2016. Additional expansion is anticipated as funding is available.
- Additional nitrogen removal at the WWTP. The WWTP upgrades (a new oxidation ditch and anoxic basin) are expected to be completed and operational prior to a regulatory deadline of November 15, 2017.
- Increased water supply from the Irwin Basin. Rehabilitation of Irwin Basin Well i-9 is complete. Accordingly, it is anticipated that Irwin Basin pumping will be increased in 2016 when Irwin Water Works is operational.

A cost analysis is not provided for these implementation measures as all measures are either under construction, already funded, or in the current capital improvement program for Fort Irwin's water and wastewater infrastructure.

8.2 Periodic Review of SNMP

The salt and nutrient balances presented in Section 4 are estimated results of implementing the salt and nutrient management strategies. It is important to periodically review data collected in the monitoring programs (Section 5.2) to evaluate the effectiveness of the strategies. Considering that the strategies will not be fully implemented until the end of 2016, CH2M and the U.S. Army plan to perform the first periodic review of the Salt and Nutrient Management Plan in year 2020, and perform subsequent reviews every 5 years.

8.3 Stakeholder Responsibilities

CH2M will continue to hold primary responsibility for carrying out the monitoring programs described in Section 5.2 as well as the periodic reviews of the Salt and Nutrient Management Plan. CH2M will continue to work closely with the U.S. Army, the other stakeholder.

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9.0 References

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