Case No. 84739

IN THE SUPREME COURT OF THE STATE OF NEVADA

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ADAM SULLIVAN, P.E., NEVADA
STATE ENGINEER, et al.

Appellants,

vs.

LINCOLN COUNTY WATER
DISTRICT, et al.

JOINT APPENDIX

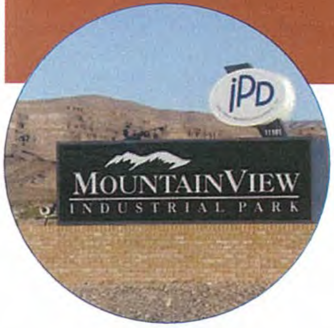
VOLUME 16 OF 49

WATER AND WASTEWATER MASTER PLAN

for

APEX INDUSTRIAL PARK

CITY OF NORTH LAS VEGAS



Submitted: December 28, 2012

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TABLE OF CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

∅	diameter
@	at
AC	Acre
AFA	acre-feet per annum
avg	average
BLM	Bureau of Land Management
CNLV	City of North Las Vegas
E	East
EA	each
ESFR	Early Suppression Fast Response
eww	wire to water efficiency
ft	feet
FU	Fixture Unit
gpd	gallons per day
gpm	gallons per minute
HGL	Hydraulic Grade Line
I	Interstate
in	inches
IP	motor horsepower
LF	Linear Feet
LVVWD	Las Vegas Valley Water District
MG	million gallons
MGD	million gallons per day
NDEP	Nevada Division of Environmental Protection
NWR	National Wildlife Refuge
ppm	parts per million
psi/PSI	pounds per square inch
PRV	Pressure Reducing Valve
PZ	Pressure Zone
R	Range
RO	Reverse Osmosis
S	South
SID	Special Improvement District
T	Township, Tank
TDS	Total Dissolved Solids
UDACS	Uniform Design and Construction Standards
VFD	variable frequency drives
WP	Water Horsepower
WWTP	Wastewater Treatment Plant

EXECUTIVE SUMMARY

The Apex Industrial Park Water and Wastewater Master Plan presents the “backbone” infrastructure required for water and wastewater systems to serve the proposed Apex Industrial Park. The Apex Industrial Park is located at the northern edge of the City of North Las Vegas with US Highway 93 as its northern boundary, see Figure 1 (page 5) for a location map. The Master Plan includes connection to the potable water system of the City of North Las Vegas system as the source of water supply and connection to the wastewater collection system of the City of North Las Vegas for treatment and disposal.

The Apex Industrial Park comprises a total of approximately 11,478 acres of which approximately 7,523 acres are suitable for development. Areas with a ground slope exceeding 15% are not considered developable and are not included as service territory of the master planned water and wastewater systems. The Apex Industrial Park includes 16 subparks as shown in Figure 2 (page 7) and is within land zoned as General Industrial District M2 as shown in Figure 3 (page 8).

Existing water and wastewater facilities within the limits of the Apex Industrial Park will mostly be abandoned upon construction of the master planned improvements. If existing water system infrastructure, including water supply wells, are slated for continued use, they will require upgrade to meet current City of North Las Vegas standards.

The Master Plan estimates the annual average water demand to be 1,225 million gallons which is equal to 3,761 acre-feet the required water right. The master planned water system infrastructure is shown in Exhibit A2 in Appendix A. The Master Plan presents the water system infrastructure necessary to serve the entire Apex Industrial Park and generally includes the following components.

- 157,298 linear feet (29.8 miles) of water main pipelines varying in diameter from 16 to 42 inches
- Four water storage reservoir sites including three with a total storage of 5 million

gallons and one site with 10 million gallons of water storage. Water storage will be provided in ground level, welded steel storage tanks, of varying size.

- Two water pump stations one with a 2,739 gallon per minute capacity and the other with a 2,143 gallon per minute capacity.
- Ten pressure reducing valve facilities serving six different water pressure zones.

The target water pressure range within four of the six pressures zones of the Apex Industrial Park is 90 to 150 psi. This pressure range is higher than normal and intends to reduce the need for additional fire suppression booster pumps within the individual building structures of the Apex Industrial Park. The higher pressures result in some locations within the water transmission pipelines to exceed the typical water system maximum of 150 psi and will require a higher pressure class of pipe. Individual pressure reducing valves will be utilized to reduce the domestic water pressure at the water service connection for each user within the Apex Industrial Park.

The water distribution system of smaller diameter pipelines and service laterals are not included in the Master Plan. Facility planning and detailed design of the water distribution system would be performed as the Apex Industrial Park is further planned and developed.

Based on an average daily flow of 0.707 gpm/acre (see Appendix D Item D1) over 7,670 acres, including 147 acres of utility corridor, the Master Plan estimates the annual volume of wastewater generated to be 2,850 million gallons which is equal to 7.81 million gallons per day. This value considerably exceeds the estimated annual water demand. The wastewater infrastructure was master planned based on City standards whereas the water demand is based on a assumed annual water demand of 0.5 acre feet per acre (1,225 million gallons per year). The wastewater infrastructure was conservatively planned in the event water demand in the Apex Industrial Park exceeds the estimated value. The master planned wastewater system is shown in Exhibit A4 in Appendix A. The wastewater system infrastructure necessary to collect all the wastewater generated in the Apex Industrial Park and generally includes the following components.

- 228,854 linear feet (43.34 miles) of wastewater collection gravity pipelines varying in diameter from 8 inches to 48 inches.
- Five wastewater lift stations including the following
    - Lift Station 1A - 7752 gallons per minute
    - Lift Station 1B - 8006 gallons per minutes
    - Lift Station 1C - 12587 gallons per minute
    - Lift Station 2 - 2359 gallons per minute
    - Lift Station 3 - 2468 gallons per minute
- 44,493 linear feet of force main (8.43 Miles) with force main diameters varying from 14 to 30 inches including 16002 linear feet of 14-inch diameter force main, 23373 linear feet of 24-inch diameter force main, and 5118 linear feet of 30-inch diameter force main.

The wastewater collection system of smaller diameter pipelines and service laterals within each subpark are not included in the Master Plan. Facility planning and detailed design of the smaller diameter wastewater collection system within each subpark would be performed as the Apex Industrial Park is further planned and developed.

The estimated cost for on site and off site water system infrastructure varies from $78.5 million to $79.0 million with the difference being the point of connection to the existing City of North Las Vegas water distribution system. The estimated cost of the wastewater collection and export infrastructure and off site improvements is $90.6 million.

PURPOSE

The Apex Industrial Park Water and Wastewater Master Plan (Master Plan) identifies the necessary “backbone” water and wastewater infrastructure to support the Apex Industrial Park Special Improvement District (SID). The Master Plan addresses water and wastewater service, identifying demands and design flows for potable water, fire protection and wastewater discharges. A system of potable water pipelines, tanks, pump stations and pressure reducing valves (PRV) is preliminarily sized based upon a water network computer model analysis.   A system of gravity sewer lines, lift stations and force mains is also preliminarily sized. This information will be useful for providing estimated project costs in support of the proposed City of North Las Vegas SID.

The Master Plan establishes service locations to address potential development areas within Apex Industrial Park as well as regional service connection locations. The utility service for each parcel shall be the owner's responsibility.

LOCATION

The Apex Industrial Park encompasses a total of approximately 11,478 acres and is located in the northeast portion of North Las Vegas, Nevada. The developable acreage is approximately 7,523 acres when slope limited and right of way limited areas are excluded. The development is bound on the north by US 93, on the west by a Bureau of Land Management (BLM) utility corridor (this utility corridor separates Apex from the Desert National Wildlife Refuge) and on the south and east by Interstate Highway 15 (I-15). Three portions of the Apex Industrial extend east I-15 and consist of roughly 619 acres on portions of Sections 26 and 35 of T18S, R63E and Sections 2, 3, and 9 of T19S and R63E. See Figure 1 for the location of the Apex Industrial Park and Figure 2 for the layout of the Apex Industrial Park.

The Apex Industrial Park topography is relatively unique for the Las Vegas metropolitan area as much of the development is considered mountainous, with elevations ranging from 2,150 feet to 3,375 feet. The predominantly developable areas range from 2,430 to 2,680 feet, which encompass 60% to 70% of the total available land.

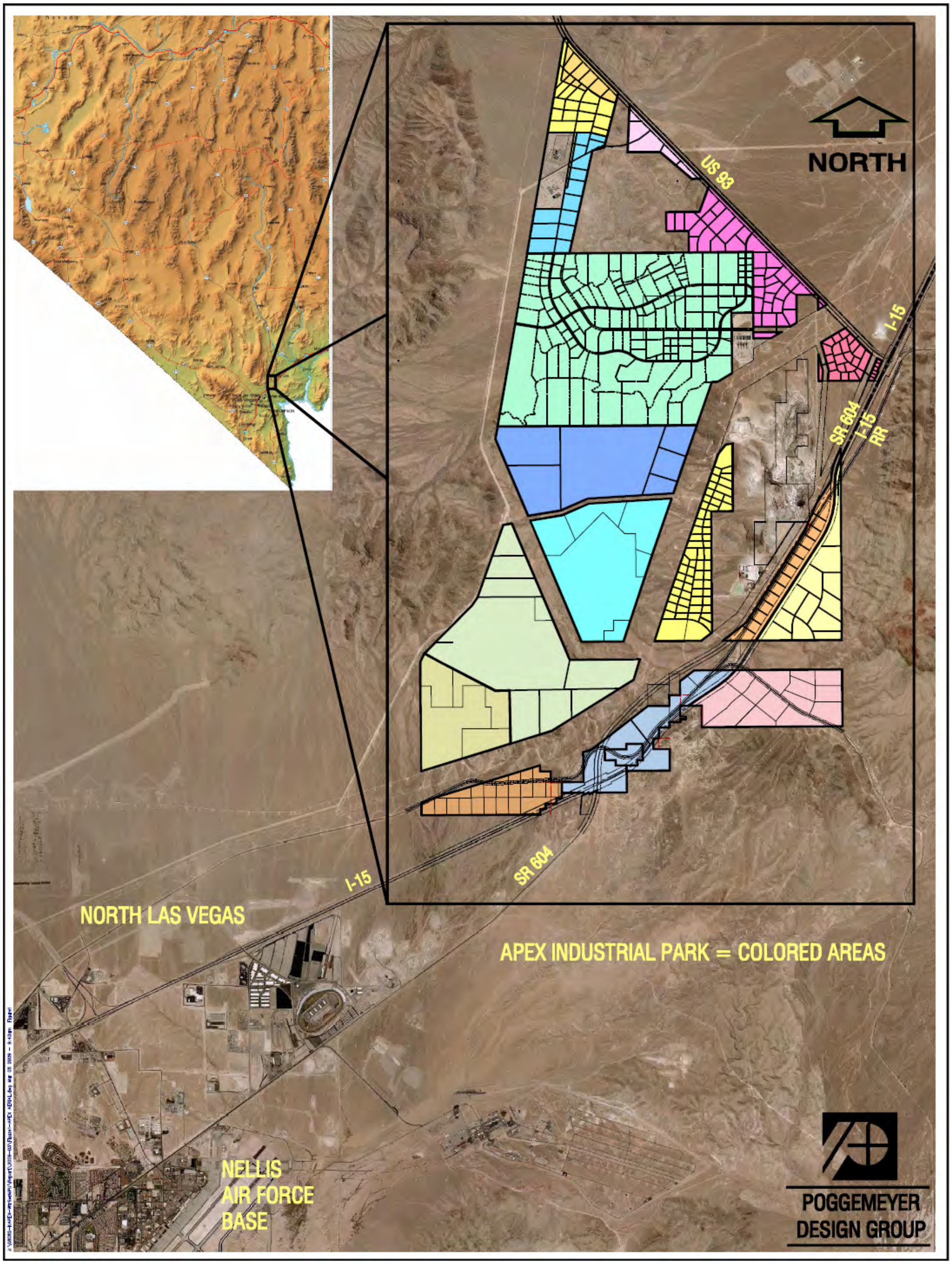


Figure 1 - Location Map

APEX INDUSTRIAL PARK PROJECT

The Apex Industrial Park is comprised of 16 separate industrial subparks crisscrossed by Bureau of Land Management utility corridors. The utility corridors are not included as developable land however they are planned to be used for a portion of the water and sewer pipeline alignments. Use of the utility corridors is allowable by the BLM. Use requires attendance of a pre-application meeting, submission of a right of way application, and BLM approval. The majority of Apex is zoned General Industrial District M-2* (see Figure 1-3), with a Heavy Industrial land-use designation. See Figure 2 for a site plan of the Apex Industrial Park and the 16 individual subparks.

**(per CNLV Zoning Map - http://www.cityofnorthlasvegas.com/Departments/PlanningAndZoning/PDFs/ZoningMap.pdf December 31, 2008)*

The 16 subparks include the following.

1. Black Mountain
2. Central
3. Commercial Center North
4. Commercial Center South
5. Foothills
6. Industrial Rail
7. Kapex
8. Miners Mesa
9. Northern Apex
10. Northern Flats
11. Northern Flats West
12. Northern Highlands
13. North Hills
14. Pinnacle
15. Solo Mountain
16. Vegas Vista

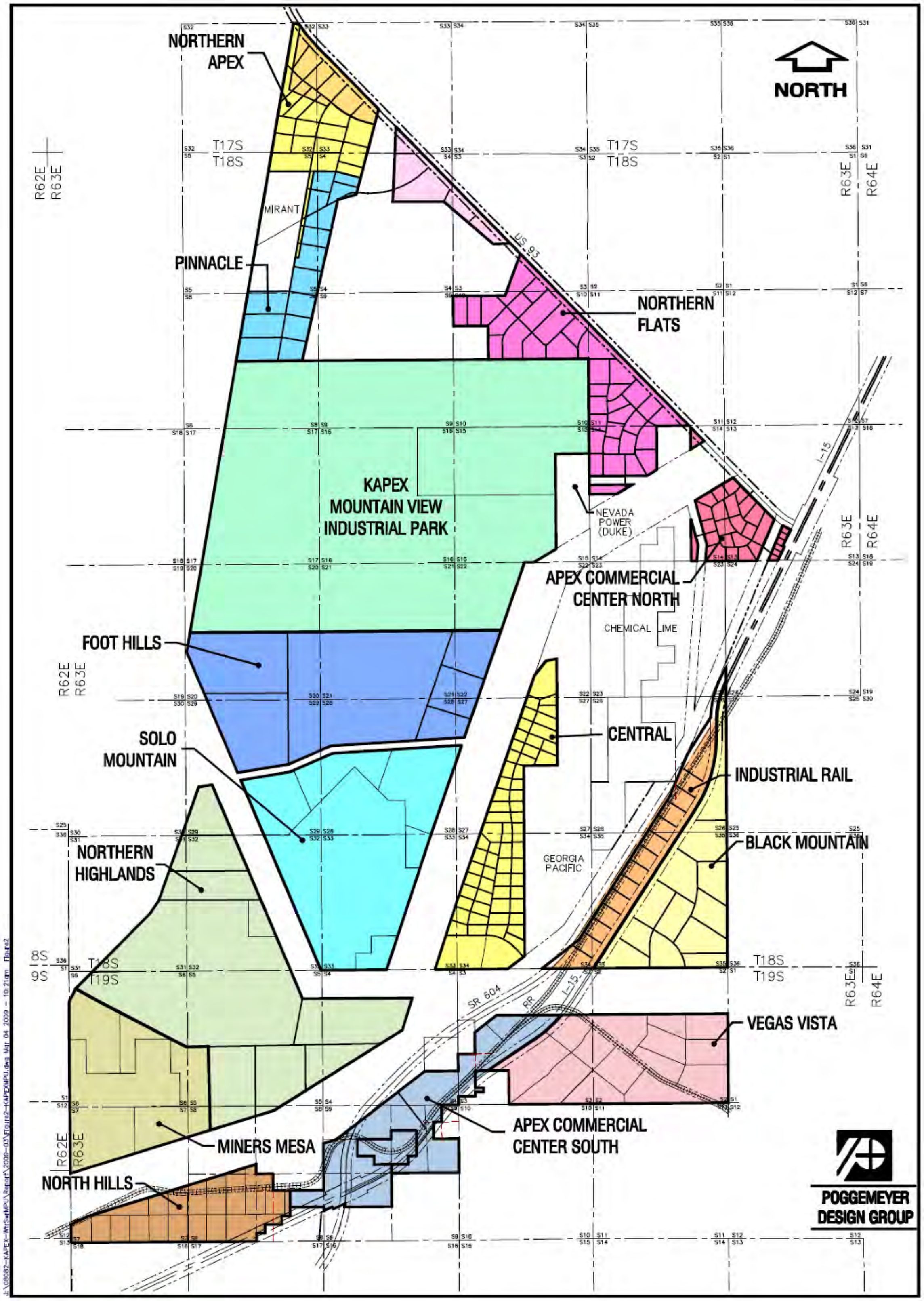


Figure 2 - Site Plan

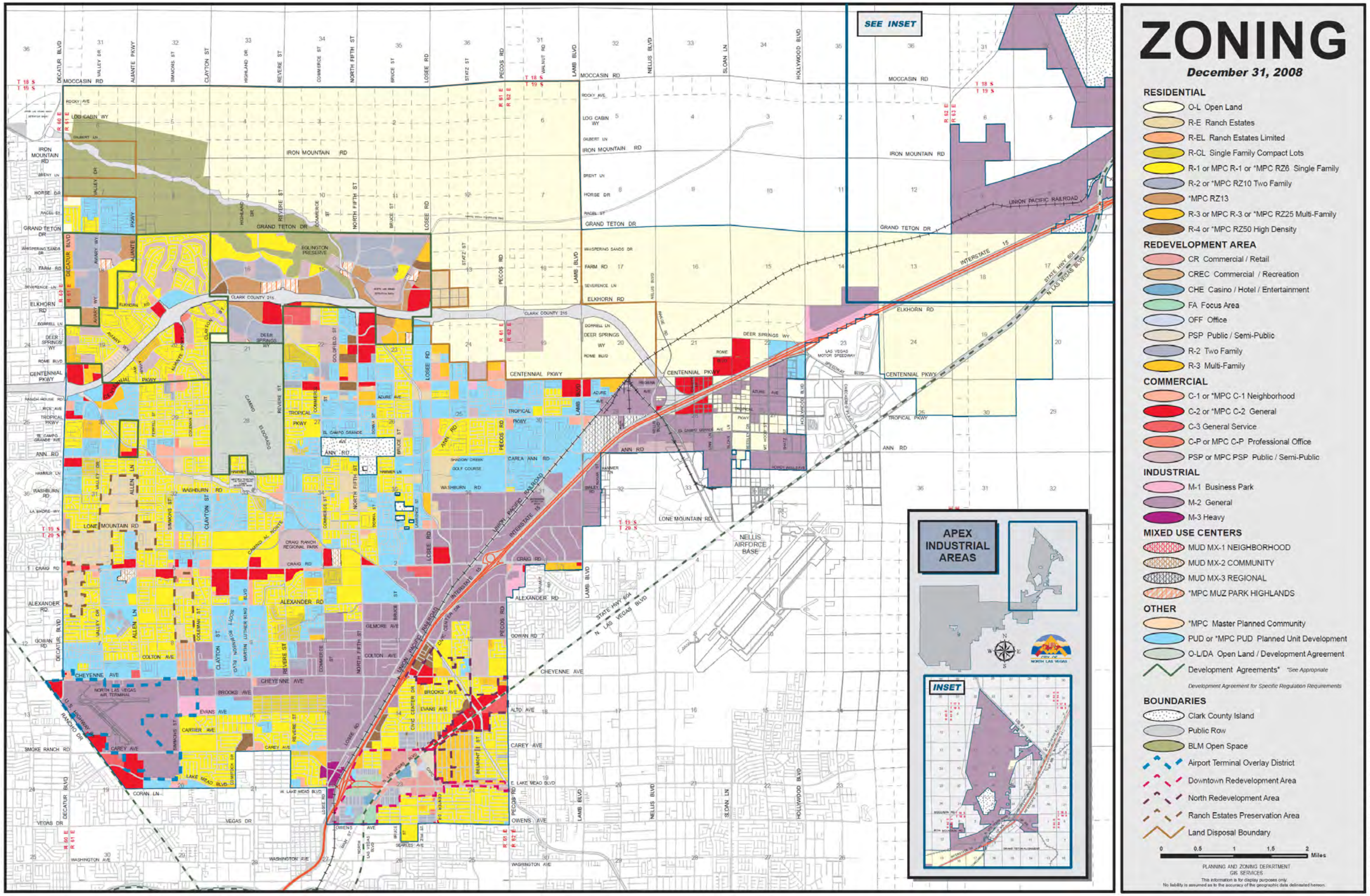


Figure 3 CNLV Zoning Map

EXISTING WATER FACILITIES

There are existing water and wastewater facilities at various locations throughout Apex Industrial Park. It's assumed that the existing facilities will remain in service until the Master Plan is implemented. Upon master plan implementation the existing facilities will either be abandoned or incorporated into the master planned water or wastewater systems. Existing water and wastewater facilities incorporated into the Master Plan water and wastewater systems will require upgrade to meet City of North Las Vegas Standards. It's also assumed that any development prior to the SID Master Plan implementation will be constructed in accordance with the Master Plan requirements. When the SID is complete, these improvements will be incorporated into the SID (this is applicable for the Apex Industrial Park water and wastewater developments). There are several existing wells, including one in the Kapex subpark, one in the Central subpark (Dry Lake Water) and two near the Vegas Vista subpark see Appendix E for the Kapex and Central well driller's reports.

A portion of Kapex was owned and operated by the Kerr-McGee Chemical Corporation. Kerr-McGee utilized a 10 acre-feet per annum water righted potable water supply well, two reverse osmosis (RO) water treatment systems, a 1.2 million-gallon fire water storage tank, two 2,000 gpm fire pumps, a 50,000 gallon potable water tank and three high service pumps. This infrastructure provided the potable water distribution and fire service systems.

The dual water distribution systems of potable water and fire suppression water supply a portion of the development, including the former Kerr McGee Chemical plant. The fire system pipelines range between 6-inch and 12-inch in diameter and the potable water pipelines are 2-inch and 3-inch diameter. There are fire hydrants included in the fire water system and a 29,000 cubic foot (200,000 gallon) fire water containment pond.

Although both RO systems are no longer active and appear neglected, some of the equipment may be salvageable, subject to removal, cleaning, testing and service. The existing equipment includes the following.

Existing On-Site Water Facilities (see Appendix E)

Fire Water Storage Reservoir
1,200,000 gallon ground-mounted steel tank
90'∅ x 28' tall, Pitt-Des Moines 59302, 1990 AWWA D100-84
high water line (HGL): 2289 feet
floor elevation: 2261 feet

Potable Water Storage Reservoir
50,000 gallon, ground mounted steel tank
20'∅ x 24' tall, Pitt-Des Moines 50142, 1990
high water line (HGL): 2285 feet
floor elevation: 2261 feet

RO System #1 (at tank)
RO System #2 (at process building)
2 - 500 gallon diesel fuel tanks

Well Pump (permit 77745)
200 gpm with 21' drawdown
(Driller's Log - Appendix E)
1145' depth, 578' water level
1000 ppm TDS
250 gpm avg for 24 hour (owner data)

Gorman-Rupp fire pumps
Patterson Pump 89PT14043L6
Caterpillar engines 266 bhp
2 @ 10x8m
2000 gpm, 1750 rpm
148 psi capacity
101# max suction
149# discharge
(pump curve - Appendix E)
Generator CAT PA0067 90
(for emergency power)

Baldor jockey pump
3,450 rpm
2 hp
Grundfos
CR2

300 psi Max

Rated: 254' head
@11 gpm

High Service Potable Pumps
3 @ 5 hp (inoperative)
3,500 rpm
230 volt, 3-phase
Motor: Reliance XE
87.5% efficiency
ID#2YAB60465A3
180TC
(Pump curve not available)
1 Goulds Pump , 55 gpm,
Model #2SVBK3, 3HP motor

The 1.2 million gallon storage reservoir contains untreated well water for the fire water system. The fire pump house, located on the west side of the water storage reservoir, has a concrete floor and concrete block walls. The pump house contains two diesel powered engines which operate the two 2,000 gpm fire water pumps supplying the fire water distribution system. A diesel powered emergency generator is located on the south side of the pump building to operate the water components. A jockey pump maintains fire water pipeline pressure when the fire pumps are inactive. None of the pumps are equipped with variable frequency drives (VFD)

Located to the east of the 1.2 million gallon tank is a 50,000 gallon potable water tank with three (3) high service pumps serving the existing potable water system. Adjacent to the potable water tank is a concrete water treatment building containing the reverse-osmosis units, water softener and disinfection equipment. See Appendix E for the existing Kapex facility water system plan and water system schematic diagram.

WATER DEMAND FORECAST

The domestic water demands of average day, maximum day and peak hour are calculated using an estimated annual average water consumption of 0.5 acre-feet per acre year. This rate is less than City of North Las Vegas standards and its use is based in the fact that water demand for the Apex Industrial Park will be less than typical because of the fact that no landscaping will be utilized and the implementation of other water conservation measures. Maximum day and peak hour demands were established using heavy industrial use factors of 1.36 (the maximum day standard of 1.5 gpm/acre divided by average day standard of 1.1 gpm/acre) and 2.09 (peak hour standard of 2.3 gpm divided by average day standard of 1.1 gpm/acre) in accordance with City of North Las Vegas Network Hydraulic Analysis Guidelines Average Water Consumption of Various Types of Development.

The total developable acreage excluding areas with average ground slopes exceeding 15% and the Bureau of Land Management utility corridors is approximately 7,523 acres. Using an annual average demand of 0.5 acre feet per acre (per year), the average daily water demand at buildout is 3.36 million gallons per day (MGD), the maximum day demand is 4.56 MGD and the peak hour demand is 4,874 gallons per minute. See Table 1 for the tabulated water demands for each of the 16 subparks of the Apex Industrial Park.

Table 1 Apex Industrial Park Water Demands by Subpark

Subpark Name	Water Service Territory Acreage (acres)	Average Day Water Demand (gpm)	Maximum Day Water Demand (gpm)	Peak Hour Water Demand (gpm)
Black Mountain	444.2	137.7	187.3	287.8
Central	492.6	152.7	207.7	319.2
Commercial Center North	174.5	54.1	73.6	113.1
Commercial Center South	333.9	103.5	140.8	216.3
Foothills	326.1	101.1	137.5	211.3
Industrial Rail	131.1	40.6	55.3	84.9
Kapex	2,504.2	776.3	1,055.8	1,622.5
Miners Mesa	238.1	73.8	100.4	154.3
Northern Apex	354.3	109.8	149.4	229.6
Northern Flats	556.3	172.5	234.5	360.4
Northern Flats West	103.4	32.1	43.6	67.0
Northern Highlands	362.7	112.4	152.9	235.0
North Hills	333.3	103.3	140.5	215.9
Pinnacle	297.5	92.2	125.4	192.8
Solo Mountain	348.0	107.9	146.7	225.5
Vegas Vista	523.0	162.1	220.5	338.9
Totals	7,523	2,332	3,172	4,874
Totals (MGD)	NA	3.36	4.57	7.02

The total average day water demand of 3.36 million gallons equates to an annual water demand of 3,761 acre-feet which represents the annual water right required for the Apex Industrial Park.

It was determined that the area should be served, to the extent possible, by a looped system of high pressure water mains accessing all projected development with one or more connection points. This looped system will normally operate as two pressure zones, 2795 and 2920, that are interconnected by PRV's to supply water to the other four pressure zones, 2430, 2445, 2545 and 2670 and jointly supply water to pressure zones 2670 and 2445.

The fire flow rate throughout the Apex Industrial Park is 6,000 gpm for a duration of 4 hours. This fire flow rate intends to meet the highest fire flow requirement expected in the Apex Industrial Park. Distribution system pressures will operate to a maximum pressure of 150 PSI, with four exceptions (as determined by hydraulic modeling) including junctions J-SID04, J-SID12, J-SID39, and J-SID61, see Appendix C. Of these the maximum pressure is 190 (junction J-SID61), to address the pressure exceeding 150 psi, 200 psi rated pipes will be used for the distribution mains. The transmission system pressures will operate to 231 PSI maximum (computer model junction J-SID57), and therefore the transmission mains will utilize 250 psi rated pipes. Four junctions will operate below 90 psi including junctions J-SID30, J-SID31, J-SID32, and J-SID33, the buildings on the parcels served by these junctions will have to have a separate fire pump system to provide adequate pressure for a fire sprinkler system. Pressure reducing valves (PRV) will regulate pipeline pressures between 90 PSI and 150 PSI. The higher than standard water distribution system pressures will require individual pressure reducing valves for the domestic water service for each building structure.

WATER SOURCE

The source of water supply serving the Apex Industrial Park will be by connection to the existing City of North Las Vegas water transmission and distribution system. There are two proposed CNLV connection points for the buildout water system condition. The first connection point is Las Vegas Boulevard at the Las Vegas Speedway (known as the North Las Vegas point of connection), where two (2) 16-inch pipelines currently terminate (PZ 2145) and where a 5-MGD pump station is proposed. The existing source for this connection is a 3-MG storage reservoir located at Carey, east of

Hollywood Boulevard. A supplemental 3-MG storage reservoir is proposed at this location to offset the projected system demands. The second CNLV source is the connection to an existing 24-inch pipeline near the Auto Auction site (Centennial Parkway and Hollywood Boulevard) known as the North Hills point of connection. Improvements for this connection point include a 5 MGD pump station and approximately 15,000 linear feet of 24-inch diameter water pipeline. See Exhibit A-3 for the proposed points of connection and alignment of connecting pipelines.

Both sources are connected upstream of a proposed booster pump station along the Farm Road alignment. The proposed 30-inch Apex pipeline will begin at the Farm Road alignment, and the Speedway Eastern property line extension north, approximately 1.5 miles north of Centennial and one mile east of the Hollywood Boulevard alignment.

WATER PRESSURES AND PRESSURE ZONES

Six water system pressure zones are required for the developable areas of the Apex Industrial Park. Except for PZ 2430 and PZ 2920, the established Apex Industrial Park pressure zones are planned to provide static pressures between 90 and 150 PSI. The ground elevations for each pressure zone are provided in Table 2.

Table 2 Water System Pressure Zones

BASIN	PZ	CONTROL SOURCE(S)	GROUND ELEV RANGE	
			LOW (FT)	HIGH (FT)
Las Vegas Valley	2430	T-SID2	2200	2325
Garnet Valley	2445	PRV	2100	2200
	2545	PRV	2200	2325
	2670	T-SID1, PRV	2325	2450
	2795	T-SID3, PRV	2450	2575
	2920	T-SID4	2575	2815

Since the ground elevations vary from 2150 to 3375, the higher elevation service areas are excluded. These areas will remain undeveloped due to the mountainous terrain (slopes greater than 15%) and are not part of the master planned water system. Only the areas below elevation 2815 are being addressed at this time and considered in the developable land area calculations. There is no significant land area above this elevation considered developable (for the purpose of this master plan, developable is defined as land with average ground slopes of 15% or less). See Exhibit A-1 in Appendix A for the limits of the six water system pressure zones.

The water system is master planned such that these pressure zones will allow each building or parcel to utilize an Early Suppression Fast-Response (ESFR) fire suppression system without the need for fire suppression booster pumps. The sprinkler system demand will vary with the building design but the minimum demand is approximately 2000 gpm. The Uniform Design and Construction Standards (UDACS) minimum pressures are presented in Table 3.

Table 3 Minimum Water Pressures - Standards

MINIMUM WATER PRESSURE STANDARDS (UDACS Section 2.01.03)	
STATIC PRESSURE	45 PSI
MAXIMUM DAY	40 PSI
PEAK HOUR	30 PSI
MAXIMUM DAY + FIRE	20 PSI

Ultimately, the Apex Industrial Park pressure zones will have static pressures between 90 and 150 PSI. In most cases, this pressure range should allow each building protection from an Early Suppression Fast-Response (ESFR) fire suppression system without the addition of building fire suppression booster pumps. Due to ESFR system pressure requirements, the water system is sized to maintain pressures 50 PSI greater than standard pressures as presented in Table 4.

Table 4 Minimum Water Pressures - Apex

MINIMUM WATER PRESSURES APEX INDUSTRIAL PARK UDACS + 50 PSI	
STATIC PRESSURE	95 PSI
MAXIMUM DAY	90 PSI
PEAK HOUR	80 PSI
MAXIMUM DAY + FIRE	70 PSI

MASTER PLAN WATER FACILITIES

Exhibit A-2 in Appendix A depicts the proposed water system overlaid on the pressure zones for the Apex Industrial Park. Exhibit A-2 also includes the hydraulic model junction nodes and pipe numbers. The City of North Las Vegas water is pumped through a series of tanks and pressure zones to four ground level storage tank areas. Proposed is 5 million gallon reservoir storage site(T-SID4) at the top of the hill at the northern edge of the Foothills subpark directly serving pressure zone 2920, one site with 10 million gallons of reservoir storage (T-SID3) and one other 5 million gallon reservoir storage site (T-SID1). A fourth reservoir site with 5 million gallons of reservoir storage (T-SID2) with a Pump Station B1, serves as the supply to Tank T-SID3 and in turn the northern portion of the Apex Industrial Park. Tank T-SID2 also serves as the gravity reservoir for the North Hills subpark and parts of Commercial Center South subpark, which are all part of the Apex Industrial Park. This results in a total of 25 million gallons of system storage. All booster pump stations will provide 100% pumping capacity redundancy of the peak hour flow demand and include an auxiliary power supply engine generator. The booster pump stations will be equipped with variable frequency drives and slow-acting valves to control water hammer potential. The potable water storage tank facilities would be made of welded steel, designed to local, regional, and state standards and would include intrusion alarming, level monitoring instrumentation and telemetry (for pump control), electrical power supply, and security fencing.

Due to elevation differential, all four reservoir storage sites act to maintain system pressure in various pressure zones. Two reservoir storage sites also provide supplemental storage for pumping to fill higher pressure zone tanks. The tanks are utilized to offset maximum day demands, peak hour demands, and supply fire flow duration volumes during fire events.

The proposed Apex development water system storage tanks are summarized in Table 5.

Table 5 Proposed Water Storage Reservoirs

Reservoir	Location by Section, Township & Range	Total Storage Capacity (million gallons)	Maximum Elevation	Minimum Elevation
T-SID1	S22 T18S R 63E	5	2,670	2,640
T-SID2	S08 T19S R63E	5	2,430	2,400
T-SID3	S04 T19S R63E	10	2,795	2,765
T-SID4	S20 T18S R 63E	5	2,950	2,920

Tank sizing criteria is based on Nevada Administrative Code Chapter 445A requirements which requires storage tank volume provide operating storage plus an emergency reserve and the required fire demands. Operating storage is based on maximum day demand and must be at least 700 gallons per ERU. Emergency reserve storage requirement is 75% of the operating storage. Fire storage for the Apex Industrial Park is based on providing 6000 gallons per minute for a duration of 4 hours. The operating storage for Apex Industrial Park is 10.7 million gallons, the emergency reserve storage is 8.0 million gallons, and the fire storage is 1.44 million gallons. Collectively, the tank storage volume requirement is 20.14 million gallons. A total of 20 million gallons of potable water storage is required for the Apex Industrial Park based on NAC Chapter 445A requirements. See Appendix D Item D9 for tank sizing calculations based on NAC Chapter 445A requirements. Computer modeling indicated that additional tank storage is required to meet fire demand requirements. A criterion was established whereby no more than one half of any tank volume be consumed during a fire event which increased the total storage volume requirement to a total of 25 million gallons.

With reservoir sizing based on NAC 445A and water demands based on an assumed 0.5 acre-feet per acre per year the resultant reservoir sizes are relatively large compared to planned water demand. While the reservoir provides sufficient storage to meet state of Nevada requirements it also results in potential water quality problems due to stagnation. To address the water quality concerns this Master Plan recommends initially constructing smaller size storage tanks, At the 5 million gallon reservoir sites (Tanks T-SID1, T-SID2, and T-SID4) tank construction should initially be 2.5 million gallons with additional tankage provided as required. For the 10 million gallon reservoir site initial; tank construction should be 3 million gallon tank with additional tankage added as required.

Once gravity storage tanks are in service, the water system is pressurized by gravity and controlled by PRVs to provide water to the lower pressure zones. With the use of a bypass valve and a PRV (PRV-SID16) at Booster Pump Station PMP-B2, Tank T-SID4 at PZ 2920 can serve the entire Apex Industrial Park in an electrical outage emergency.

The water transmission system pipelines are master planned using ductile iron pipe with design and construction complying with Uniform Design and Construction Standards for Potable Water Systems and includes in-line isolation valves, air and vacuum release valves, blow-off facilities, and fire hydrants.

The water system is designed to be completed as a single improvement phase with interim improvements by developers potentially constructing portions of the SID system in early phases along with their development. These phases would be constructed to SID standards and become part of the master planned water system.

HYDRAULIC MODELING

The master planned water system was modeled using computer software to establish pipeline diameters and to verify required pressures and demand conditions are met. The buildout condition model depicts the entire SID water system of storage tanks, pumps, and pressure reducing valve facilities supplying water to the six water system pressure zones of the Apex Industrial Park. The existing water supply wells could potentially remain in service and serve as supplemental source of supply utilizing the existing ground water rights. If utilized, the existing wells will require upgrade to meet City of North Las Vegas standards.

The master planned water system was analyzed using a computer model to verify that maximum day, peak hour, and maximum day plus fire flow demands are met. The hydraulic model identifies the areas that exceed the target 150 psi desired maximum pressures as well as where pressure could be expected to be below 90 psi minimum static pressure conditions. These pressure variances outside the target pressure of range of 90 to 150 psi occur in transmission lines outside of a designated service area and in a couple of locations within the distribution system as noted previously.

The expected minimum and maximum system pressures, excluding surge pressures, are provided in Table 6.

Table 6 Minimum & Maximum System Pressures

CONDITION	SYSTEM DEMAND (gpm)	DIST. MIN PRESSURE (PSI)	NODE #	DIST. MAX PRESSURE (PSI)	NODE #	TRANS. MAX PRESSURE (PSI)	NODE #
MAX DAY +FIRE (Pumps Off)	9,172	40.7	J-SID32	190.3	J-SID12	176.7	J-SID49
AVG DAY (Pumps On)	2,332	67.0	J-SID33	187.52	J-SID12	231.4	J-SID57
AVG DAY (Pumps Off)	2,332	40.7	J-SID32	190.3	J-SID12	176.8	J-SID49
MAX DAY (Pumps Off)	3,172	40.7	J-SID32	190.3	J-SID12	176.7	J-SID49
PEAK HOUR (Pumps Off)	4,874	40.7	J-SID32	190.2	J-SID12	176.7	J-SID49

In each case, the minimum pressure requirements are attained except for those previously discussed. The ESFR sprinkled buildings located on parcels served from junctions J-SID30, J-SID 31, J-SID32, and J-SID33, will need fire suppression booster pumps. A worst case scenario of peak hour demands plus a fire flow of 6000 gpm was modeled with results presented in Appendix C, Item C6.

Two water system pump stations are planned. The pump station locations are shown in Exhibit A-2. Each pump station has three pumps with a single large pump sized to meet peak hour plus fire flow demands and two smaller pumps each sized to meet peak hour flow rates. While reservoir storage provides the flow rate and residual pressure required to meet fire flow demands, the large pump provides redundant fire protection in the event a reservoir is out of service. The two smaller pumps provide 100% pump capacity redundancy for peak hour flow rate demands. Typical pump station operation will utilize only one of the two smaller pumps with alternating starts based on tank filling demands. Pump station pump design flow and head values are provided in Table 7.

Table 7 Water System Pump Stations

PUMP	PUMP STA SECTION TOWNSHIP RANGE	Pump Station Elev (ft)	Discharge Grade (ft)	Flow Rate (gpm)	Pump Head (ft)
PMP-B1A	S08 T19S R63E	2400	2850	8615	420
PMP-B1B		2400	2850	2739	420
PMP-B1C		2400	2850	2739	420
PMP-B2A	S04 T19S R63E	2580	3115	8223	332
PMP-B2B		2580	3115	2143	332
PMP-B2C		2580	3115	2143	332

Reservoir filling is accomplished using pump stations and flow from higher elevation reservoirs to lower elevation reservoirs through pressure reducing valves. Reservoir T-SID2 with base elevation of 2400 feet is filled directly from the City of North Las Vegas water system. Pump station B1 draws from reservoir T-SID2 and pumps water to reservoir T-SID3 with a base elevation of 2765 feet. Pump station B2 boosts water from reservoir T-SID3 to reservoir T-SID4 with a base elevation of 2920 feet. Reservoir T-SID1 with a base elevation of 2640 feet is master planned to be filled from reservoir T-SID4 with pressure reduced at pressure reducing valves PRV-SID05 and PRV-SID14. As an alternative Reservoir T-SID1 could be filled directly from reservoir T-SID3. Exhibit A-2 shows a dashed line connecting junction J-SID12 to reservoir T-SID2. If this configuration is pursued detailed design will require establishing an engineered system for reservoir filling without overflowing the tank. A redundant system would also be required in the event the primary engineered system fails.

EXISTING WASTEWATER FACILITIES

There are existing wastewater facilities within the Apex Industrial Park. These existing facilities are not part of the master plan and would be abandoned once the master plan wastewater infrastructure is in place. The area of the Kapex subpark that contained the former Kerr McGee Chemical Corporation includes four existing septic systems/leach fields permitted by NDEP. The four existing on-site septic systems consist of two 1,000 gallon septic tanks, one 1,500 gallon septic tank and one 2,500 gallon septic tank and associated leach fields. See Appendix F for information on existing wastewater facilities within the Kapex subpark. The NDEP wastewater discharge permit (NEV89052) is limited to ten (10) outfalls. Two (2) have been discontinued with the closure of the Kerr McGee processing facilities. Four (4) septic system outfalls remain unused.

MASTER PLAN WASTEWATER FACILITIES

The wastewater master plan is based on buildout flow rates with export of raw sewage to the City of North Las Vegas for treatment. The buildout flow rates are the basis for sizing the wastewater facilities, including sewer trunk mains, lift stations and force mains. The flows are estimated using City of North Las Vegas Code Section 13.24.070 with the Office/Warehouse use classification and is assigned 0.45 Equivalent Residential Units (ERU) per fixture unit (FU). Wastewater design flow is based on a typical building with 208 fixture units on a 23 acre site. Using a typical 250 gpd/ERU and a peaking factor of 2.2 taken from the Design and Construction Standards for Wastewater Collection Systems (DCSWCS) Table C, wastewater flows are estimated using 1.94 gpm/acre. This value includes a 25% wet weather factor as required by the Design and Construction Standards for Wastewater Collection System. See item D1 in Appendix D for the wastewater design flow rate calculation.

The Master Plan estimates the annual volume of wastewater generated to be 2,850 million gallons which is equal to 7.66 MGD. This value considerably exceeds the master planned annual water demand. The wastewater infrastructure was master planned based on City standards whereas the water demand is based on a assumed annual water demand of 0.5 acre feet per acre (1,225 million gallons per year). The wastewater infrastructure was conservatively planned in the event water demand in the Apex Industrial Park exceeds the master planned value.

Topographic based sewersheds were established for the Apex Industrial Park as shown in item D2 in Appendix D. The total acreage of the sewersheds is 7,670 acres which exceeds by 147 acres the developable acreage of 7,523 acres. The sewershed acreage is greater then the developable acreage because the sewershed boundaries extend into BLM utility corridors. The extra acreage results in a more conservative design. Design flow rates were determined for design points identified in Exhibit A-4 (Appendix A) and item D3 of Appendix D. Gravity wastewater pipes are sized using multiple DCSWCS requirements including: (1) determining the capacity of a given pipe size at DCSWCS minimum pipe slopes for each design point and comparing that with the design flow based on the tributary sewershed to the design point to verify the conveyance capacity exceeds the design flow (see Appendix D, Item D4), (2) minimum pipe slope requirements to achieve a minimum flow velocity of 2 feet per second velocity flowing half full, (see Appendix D, Item D5), and, (3) using DCSWCS maximum pipe slopes with pipe flowing 3/4 full to verify pipeline flow velocities do not exceed 10 feet per second, (see item D6 in Appendix D). The gravity wastewater pipelines must be constructed within the maximum and minimum slope limits presented in Items D5, and D6 at the sizes provided in Appendix D, Items D4, D5, and D6 to meet DCSWCS and CNLV flow requirements. The Apex Industrial Park wastewater collection system gravity pipelines shall fall within these slope limits. Detailed design of gravity sewer pipes should take into account site topography and the installed slope of the pipe. Gravity driven sewer pipe diameters could be reduced if installed pipe slopes exceed the minimum presented in Appendix D, Item D6.

Lift station force mains sizes are based on the flow velocity not exceeding 6 feet per second. Lift stations and force mains are sized to pass the design flow rate including a wet weather allowance as presented in item D7 of Appendix D. Wastewater lift station pumping heads are presented in item D8 in Appendix D. A minimum of three pumps are required for each lift station providing 100% pumping capacity of the design flow rate and each lift station is planned to be equipped with an auxiliary power supply engine generator in the event of loss of electrical power supply.

As depicted in Exhibit A-4 (Appendix A) a series of three lift stations along US93 and SR604 (Las Vegas Boulevard) are used to convey flows back to the City of North Las Vegas for treatment. If the North Hills sewer does not exist as a point of connection, the gravity main will extend to Sloan Lane and Ann Road alignments and connect to a planned City of North Las Vegas wastewater collection system at that point. Refer to

Exhibit A-5 in Appendix A for the point of connection configuration and pipeline alignment.

The topography of the Apex Industrial Park allows gravity flow from the southern portion of the master plan area to the City of North Las Vegas. The northern portion of the Apex Industrial Park requires lift stations to lift the wastewater over the ridgeline separating Apex from the Las Vegas Basin. A total of five lift stations are required. Lift stations 1A, 1B, and 1C operate in series with corresponding force mains running generally parallel to Interstate 15. Lift station 2 serves subparks including Northern Highlands, Foothills, Solo Mountain and Central. Lift station 3 serves the Black Mountain subpark area.

The lift stations are planned based on using self priming centrifugal wastewater pumps capable of passing a 3-inch sphere drawing from a wet well. Wet well level monitoring instrumentation and telemetry will control lift station pumps. The lift stations are master planned to pump the design flow based on the peak hour flow rate plus a 25% wet weather factor. The lift stations utilize a three pump configuration with one large pump sized to pump the design flow and two smaller pumps working together capable of providing the design flow for a 100% of design flow pumping capacity redundancy. The smaller pumps operating more frequently handle average day flow rates. Lift station information including power requirements are presented in Table 8.

Table 8 Wastewater Lift Stations

LIFT STA	SECTION TOWNSHIP RANGE	ELEV1	ELEV2	STATIC HEAD (FT)	TOTAL HEAD (FT)	FLOW (gpm)	WP (HP)	eww	IP (HP)	IP (kW)
1A	S14 T18S R63E	2160	2335	175	235	7752	460	64%	714	533
1B	S26 T18S R63E	2335	2450	115	165	8006	333	64%	518	386
1C	S03 T19S R63E	2450	2550	100	132	12587	419	64%	652	486
2	S27 T18S R63E	2428	2500	72	120	2359	71	64%	111	83
3	S26 T18S R63E	2380	2500	120	188	2468	117	64%	182	136

WP = Water Horsepower, eww = wire to water efficiency, IP = Motor Horsepower

Approximately 1.2 Megawatts of power is needed for the five lift stations.

The master planned wastewater system includes manholes and other wastewater collection system appurtenances installed in accordance with the Design and Construction Standards for Wastewater Collection Systems.

WASTEWATER MANAGEMENT CONSIDERATIONS

Until the buildout wastewater flows are reached the master planned wastewater export system presents potential operation and maintenance issues including odors and septicity. To combat this potential, smaller parallel force mains installed in the same trench along with the buildout capacity force main could be considered to minimize these issues. Additionally, for initial cost and operational considerations, smaller pumps could be used initially until wastewater flow rates reach higher levels.

Another consideration for wastewater management during development and occupancy of the Apex Industrial Park includes the use of a wastewater treatment plant (WWTP) until wastewater flows reach a level that warrants export to the City of North Las Vegas. This concept involves directing wastewater flows generated outside of the Las Vegas basin (i.e. the northern portion of the Apex Industrial Park) northwards to the site of planned lift station 1A where a wastewater treatment plant providing tertiary treatment would be constructed. The WWTP would be a phased facility starting with a treatment capacity of 50,000 gallons per day with expansion to an ultimate capacity of perhaps 250,000 to 500,000 gallons per day. When wastewater flows exceed the maximum treatment capacity of the interim WWTP the wastewater export system would be constructed. The WWTP could be sequencing batch reactor type to account for variable influent flow rates and diurnal flow patterns and to allow for phased expansion. Alternatively, the WWTP could utilize other methods of treatment such as a conventional activated sludge plant with tertiary treatment, or a membrane bioreactor (MBR) plant. The WWTP would require a solids dewatering system with off site disposal of dewatered solids. The treated wastewater effluent would either be disposed to groundwater or potentially re-used for local industry use as process water and other uses. The collection system for this interim condition would be the same as the buildout configuration except an additional gravity flow pipeline constructed parallel to the force mains for Lift Stations 1A and 1B would be used to convey wastewater flows generated in the Foothills, Solo Mountain, Central, Industrial Rail, Black Mountain and Vegas Vista subparks to the interim WWTP. The wastewater flows generated in the Northern Highlands, Miners Mesa, North Hills and Commercial Centre South subparks would still flow by gravity to the North Las Vegas Central Wastewater Treatment Plant.

The capital, operations, and maintenance costs associated with an interim wastewater treatment plant are significantly higher than the master planned wastewater export pumping costs. A permanent WWTP serving the buildout configuration of the Apex Industrial Park is not favorable to the master planned export system since the treated wastewater is not returned to the Las Vegas Valley and ultimately Lake Mead with the corresponding credit for return flows. Lastly, with the unpredictable phased growth in the Apex Industrial Park the potential for reuse is also difficult to predict.

With the capital cost difference and the operational cost increases associated with a wastewater treatment facility within the Apex Industrial park along with the unpredictable potential for treated wastewater reuse, it makes a treatment plant alternative a less cost-effective solution than the master planned wastewater export. To run the WWTP serving the Apex Industrial park at buildout, roughly 8.6 megawatts of electrical power would be needed. A sizable power supply would need to be extended to the WWTP and electrical infrastructure costs would be considerable.

OPINION OF PROBABLE COSTS

The probable costs for the master planned water and wastewater systems are presented in Table 9.

Table 9 Water and Wastewater System Probable Costs

System	Description	Cost (M$)
Water	Water System with North Hills Point of Connection	$78.5
Water	Water System with North Las Vegas Pont of Connection	$79.0
Wastewater	Master Plan Wastewater System	$90.6
Wastewater	Interim 250,000 Gallon Wastewater Treatment Plant	$7.5

See Appendix B for a breakdown of probable construction costs.

CONCLUSION

This Master Plan presented the “backbone” infrastructure of water transmission mains, water storage tanks, water pump stations, and pressure reducing valve facilities of the master planned water system and wastewater collection main pipelines, wastewater lift stations and their corresponding force mains of the master planned wastewater system required to serve the Apex Industrial Park. The water distribution system and wastewater collection system within each subpark are not presented. This level of detail would be performed by the industrial park’s design engineers during preliminary and detailed design within each subpark as the Apex Industrial Park is further planned and developed.

APPENDIX A EXHIBITS

Exhibit A-1 - Water System Pressure Zone Map

Exhibit A-2 - Master Planned Water System

Exhibit A-3 - Water System Points of Connection to CNLV Supply

Exhibit A-4 - Master Planned Wastewater System

Exhibit A-5 - Wastewater Point of Connection to CNLV System

APPENDIX B OPINION OF PROBABLE COSTS

Item B1 - Water System with North Hills Point of Connection

Item B2 - Water System with North Las Vegas Point of Connection

Item B3 - Master Plan Wastewater System

Item B4 - Opinion of Probable Cost Notes

APPENDIX C WATER NETWORK ANALYSIS REPORTS

Item C1 - Maximum Day Plus Fire Flow Demand - Pumps Off

Item C2 - Average Day Demand - Pumps Off

Item C3 - Maximum Day Demand - Pumps Off

Item C4 - Peak Hour Demand - Pumps Off

Item C5 - Average Day Demand - Pumps On

Item C6 - Peak Hour Plus Fire Flow Demand - Pumps Off (worst case)

APPENDIX D WASTEWATER AND WATER DESIGN DATA

Item D1 - Wastewater Design Flow Calculations

Item D2 - Sewershed Acreages and Design Flows

Item D3 - Wastewater Collection System Pipeline Design Point Tributary Acreages

Item D4 - Wastewater Collection System Gravity Pipe Sizes

Item D5 - Maximum Velocity Met Calculations

Item D6 - Minimum Velocity Met Calculations

Item D7 - Force Main Sizing

Item D8 - Lift Station Discharge Head Calculations

Item D9 - Water Demands and Required Tank Storage Volume

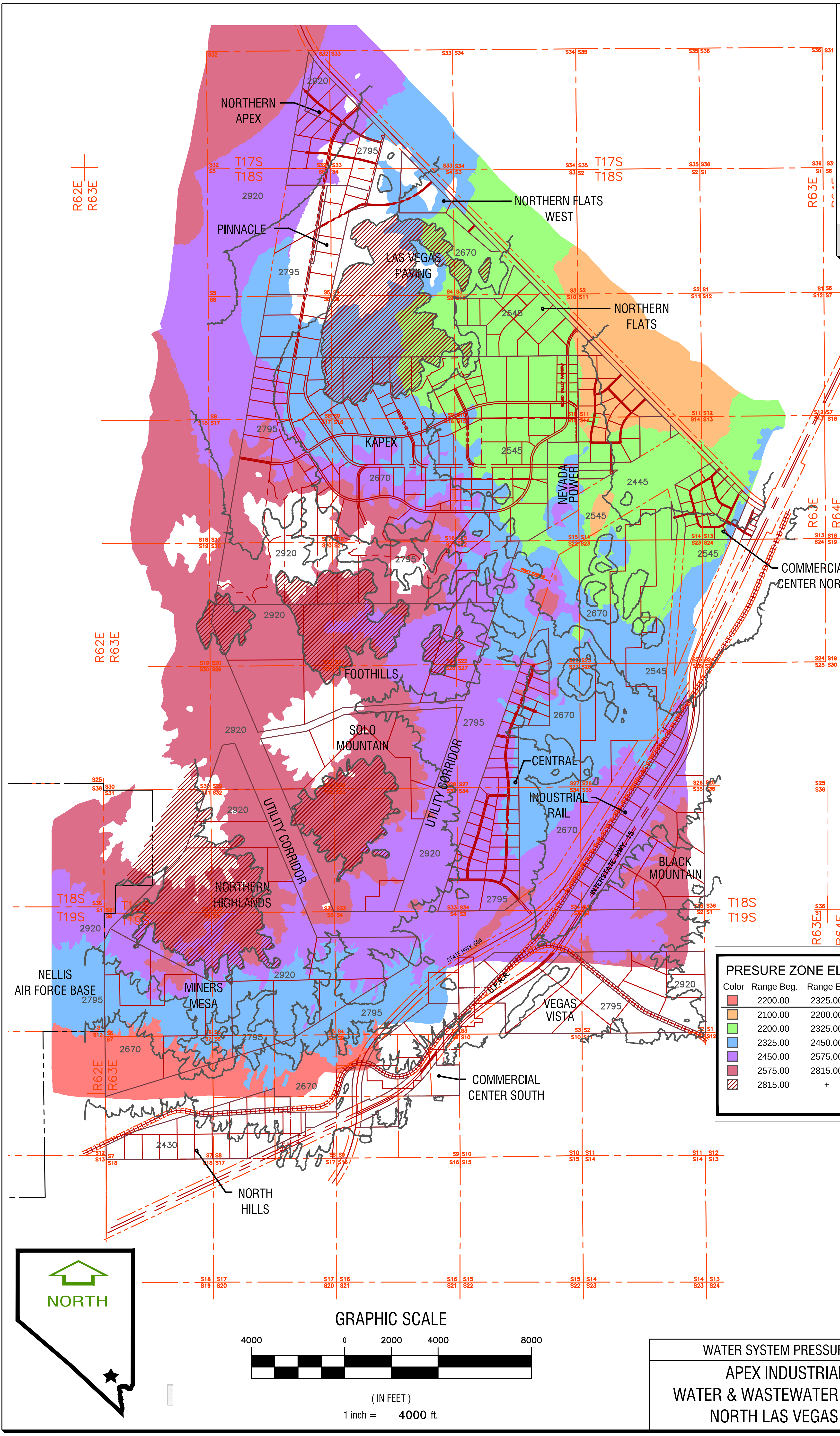
APPENDIX E EXISTING WATER FACILITIES

- **June 2004, Apex Nevada Plant Water System Site Plan**
- **April 2004, Apex Nevada Plant Battery Testing Center Civil Site Utilities Plan**
- **June 2004, Apex Nevada Plant Water System Diagram**
- **November 1995, Ammonium Perchlorate (APEX) Water Purification, Chemical Bldg**
- **February 1990, Well Driller's Report, Permit 54232 / 55674**
- **July 2001, Well Driller's Report, Permit 66784**
- **May 1990, Patterson Pump Company pump data**
- **January 2008, Gesco Pump Test Reports**

APPENDIX F EXISTING WASTEWATER FACILITIES

June 2004, Apex Nevada Plant Water System Site Plan

APPENDIX A



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PRESURE ZONE ELEVATION RANGE

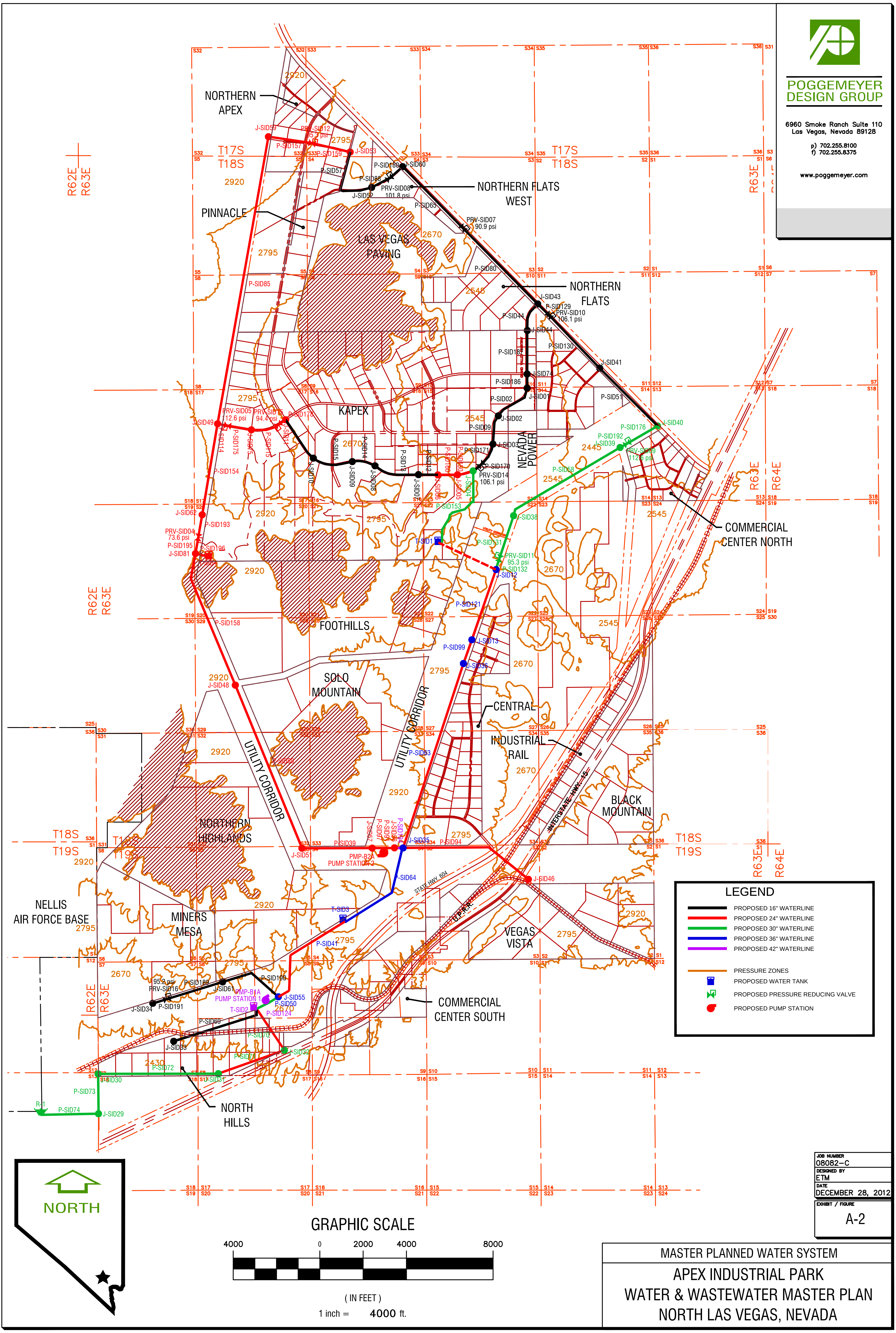
Color	Range Beg.	Range End	ZONE	
🟥	2200.00	2325.00	2430	LV VALLEY
🟧	2100.00	2200.00	2445	GARNET
🟩	2200.00	2325.00	2545	VALLEY
🟦	2325.00	2450.00	2670	
🟪	2450.00	2575.00	2795	
🟥	2575.00	2815.00	2920	
▨	2815.00	+	NO SERVICE	

JOB NUMBER
08082-C
DESIGNED BY
ETM
DATE
DECEMBER 28, 2012
EXHIBIT / FIGURE
A-1

WATER SYSTEM PRESSURE ZONE MAP

APEX INDUSTRIAL PARK
WATER & WASTEWATER MASTER PLAN
NORTH LAS VEGAS, NEVADA

J:\08082-Kapex-wtrswrmpu\Apex Master Plan Water and Wastewater June 2011\Apex 2011\exhibit-A-1_A-2_recover.dwg Dec 27 2012 - 10:15am Exhibit A-1_11X17

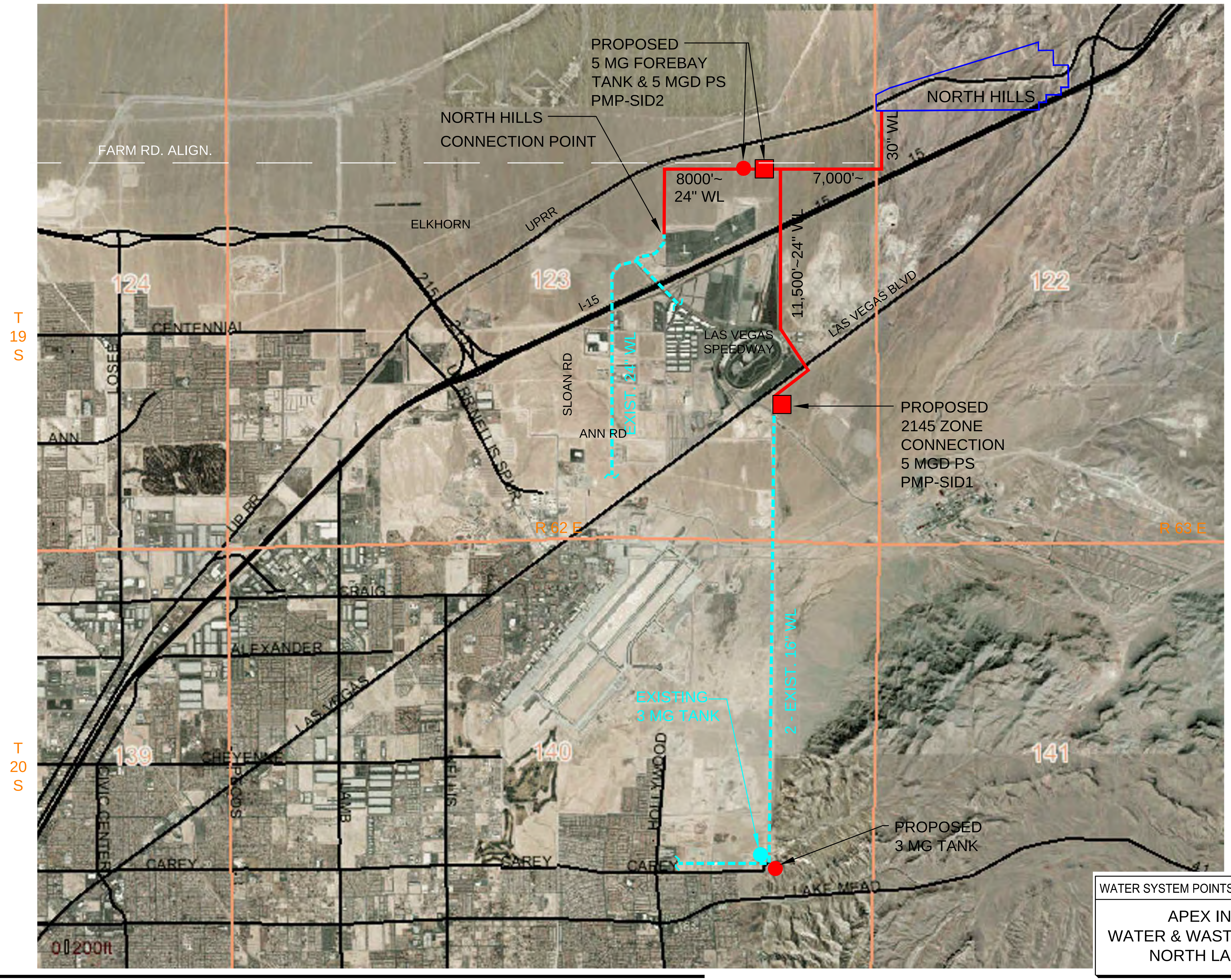


JOB NUMBER
08082-C
DESIGNED BY
ETM
DATE
DECEMBER 28, 2012
EXHIBIT / FIGURE
A-2

MASTER PLANNED WATER SYSTEM

APEX INDUSTRIAL PARK
WATER & WASTEWATER MASTER PLAN
NORTH LAS VEGAS, NEVADA

J:\08082-Kapex-wtrswrmpu\Apex Master Plan Water and Wastewater June 2011\Apex 2011\exhibit-A-1_A-2_recover.dwg Dec 27 2012 – 12:15pm Exhibit A-2_11X17



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NORTH

LEGEND

- - - EXISTING
— PROPOSED

GRAPHIC SCALE
2000 0 1000 2000 4000
(IN FEET)
1 inch = 4000 ft.

JOB NUMBER
08082-C

DESIGNED BY
ETM

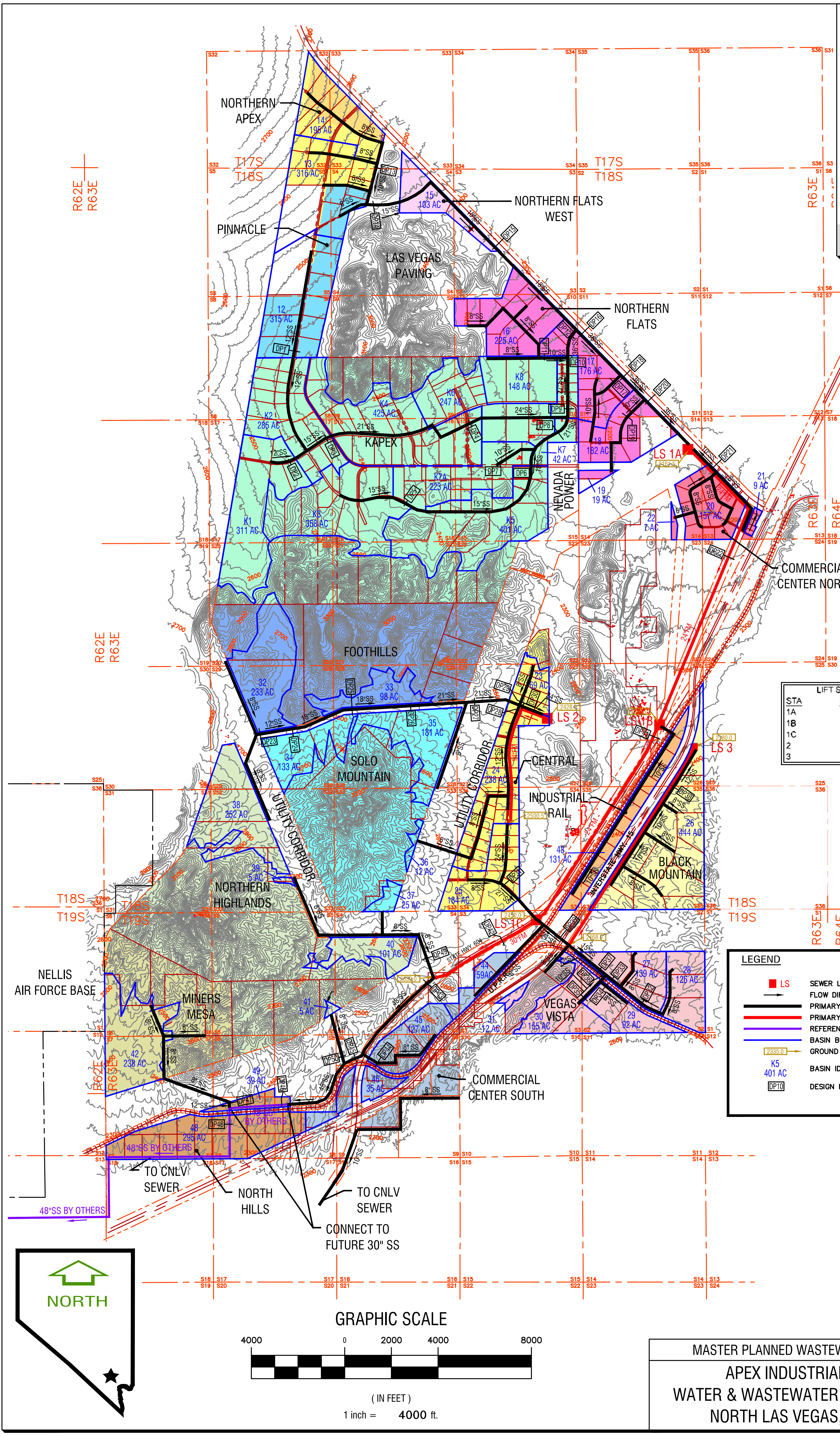
DATE
DECEMBER 28, 2012

EXHIBIT
A-3

WATER SYSTEM POINTS OF CONNECTION TO CNLV SUPPLY

APEX INDUSTRIAL PARK
WATER & WASTEWATER MASTER PLAN
NORTH LAS VEGAS, NEVADA

J:\08082-Kapex-wtrswrmpu\Apex Master Plan Water and Wastewater June 2011\Apex 2011\exhibit-A-3_A-5.dwg Dec 27 2012 - 11:35am Exhibit A-3_11X17



LIFT STATION SCHEDULE			
STA	ELEV1	ELEV2	LIFT (FT)
1A	2160	2335	175
1B	2335	2450	115
1C	2450	2560	100
2	2428	2500	72
3	2380	2468	88

LEGEND

🟥 LS	SEWER LIFT STATION
→	FLOW DIRECTION
━	PRIMARY SEWER GRAVITY LINE
━	PRIMARY SEWER FORCE MAIN
━	REFERENCE EXHIBIT A-5
─	BASIN BOUNDARY
2335.0 →	GROUND ELEVATION
K5 401 AC	BASIN ID AND AREA
DP10	DESIGN POINT ID

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A-4

MASTER PLANNED WASTEWATER SYSTEM

APEX INDUSTRIAL PARK
WATER & WASTEWATER MASTER PLAN
NORTH LAS VEGAS, NEVADA

J:\08082-Kapex-wtrswrmp\Apex Master Plan Water and Wastewater June 2011\Apex 2011\exhibit-A-4.dwg Dec 27 2012 - 11:46am Exhibit A-4_11X17

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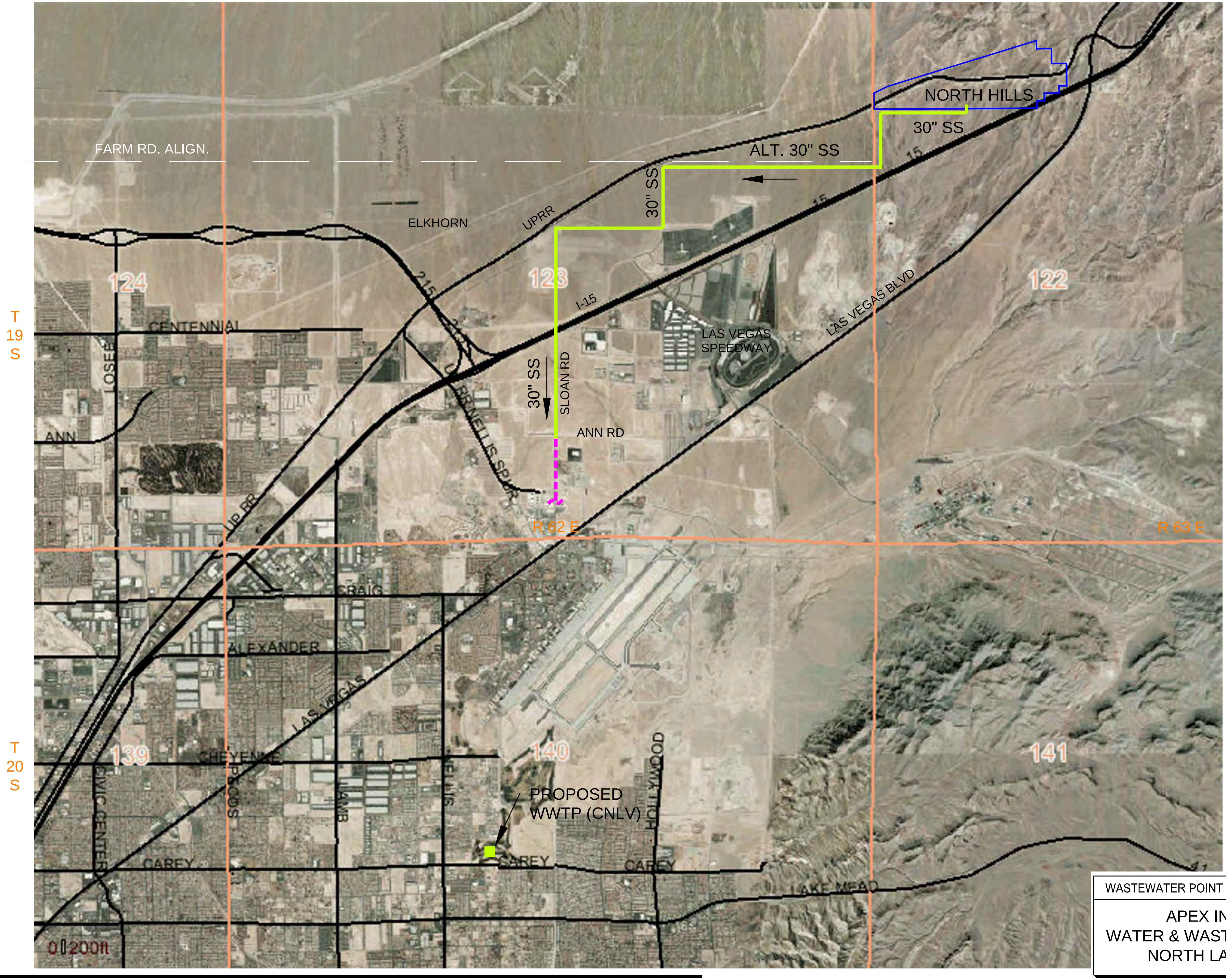

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NORTH

LEGEND

━ (green)	PROPOSED
┅ (magenta)	FUTURE

GRAPHIC SCALE
2000 0 1000 2000 4000
(IN FEET)
1 inch = 4000 ft.

JOB NUMBER
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DATE
DECEMBER 28, 2012
EXHIBIT
A-5

WASTEWATER POINT OF CONNECTION TO CNLV SYSTEM

APEX INDUSTRIAL PARK
WATER & WASTEWATER MASTER PLAN
NORTH LAS VEGAS, NEVADA

APPENDIX B

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Apex Industrial Park
Water and Wastewater Master Plan, December 28, 2012
Appendix B - Item B1
Opinion of Probable Costs
Water System with North Hills Point of Connection

Construction of On-Site Improvements

Description	Quantity	Unit	Unit Cost	Cost
16-inch diameter Water Pipeline	49,675	LF	$160	$7,948,000
24-inch diameter Water Pipeline	77,684	LF	$195	$15,148,380
30-inch diameter Water Pipeline	24,848	LF	$255	$6,336,240
36-inch diameter Water Pipeline	4,531	LF	$300	$1,359,300
42-inch diameter Water Pipeline	560	LF	$345	$193,200
48-inch diameter Boring	400	LF	$1,030	$412,000
42-inch diameter Boring	400	LF	$990	$396,000
30-inch diameter Boring	1,200	LF	$800	$960,000
5.0 million gallon Water Storage Tank	3	EA	$3,500,000	$10,500,000
10.0 million gallon Water Storage Tank	1	EA	$7,500,000	$7,500,000
Pump Station No. 1	1	EA	$1,000,000	$1,000,000
Pump Station No. 2	1	EA	$750,000	$750,000
			On-Site Improvements Subtotal	***$52,503,120***

Construction of Off-Site Improvements

Description	Quantity	Unit	Unit Cost	Cost
5 MGD Pump Station	1	EA	$375,000	$375,000
5 MG Tank	1	EA	$3,500,000	$3,500,000
24-inch diameter Water Pipeline	15000	LF	$195	$2,925,000
			Off-Site Improvements Subtotal	***$6,800,000***

Other Project Costs

Contingency (15%)	$8,895,468
Engineering, Administration, Construction Management (17.5%)	$10,378,046
Other Project Costs Subtotal	***$19,273,514***

Total Cost

On-Site Improvements Subtotal	$52,503,120
Off-Site Improvements Subtotal	$6,800,000
Other Project Costs Subtotal	$19,273,514
Total Cost	**$78,576,634**

Note: Excludes land and easement costs

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix B - Item B2
Opinion of Probable Costs
Water System with North Las Vegas Point of Connection

Construction of On-Site Improvements

Description	Quantity	Unit	Unit Cost	Cost
16-inch diameter Water Pipeline	49,675	LF	$160	$7,948,000
24-inch diameter Water Pipeline	77,684	LF	$195	$15,148,380
30-inch diameter Water Pipeline	24,848	LF	$255	$6,336,240
36-inch diameter Water Pipeline	4,531	LF	$300	$1,359,300
42-inch diameter Water Pipeline	560	LF	$345	$193,200
48-inch diameter Boring	400	LF	$990	$396,000
42-inch diameter Boring	400	LF	$1,030	$412,000
30-inch diameter Boring	1,200	LF	$800	$960,000
5.0 million gallon Water Storage Tank	3	EA	$3,500,000	$10,500,000
10.0 million gallon Water Storage Tank	1	EA	$7,500,000	$7,500,000
Pump Station No. 1	1	EA	$1,000,000	$1,000,000
Pump Station No. 2	1	EA	$750,000	$750,000
			On-Site Improvements Subtotal	***$52,503,120***

Construction of Off-Site Improvements

Description	Quantity	Unit	Unit Cost	Cost
3 MG Tank at Carey	1	EA	$2,500,000	$2,500,000
5 MGD Pump Station	1	EA	$375,000	$375,000
24-inch diameter Water Pipeline	18500	LF	$195	$3,607,500
30-inch Boring	800	LF	$800	$640,000
			Off-Site Improvements Subtotal	***$7,122,500***

Other Project Costs

Contingency (15%)	$8,943,843
Engineering, Administration, Construction Management (17.5%)	$10,434,484
Other Project Costs Subtotal	***$19,378,327***

Total Cost

On-Site Improvements Subtotal	$52,503,120
Off-Site Improvements Subtotal	$7,122,500
Other Project Costs Subtotal	$19,378,327
Total Cost	**$79,003,947**

Note: Excludes land and easement costs

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Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix B - Item B3
Opinion of Probable Costs
Master Plan Wastewater System

On-Site Improvements

Description	Quantity	Unit	Unit Cost	Cost
8-inch diameter Gravity Pipeline	97659	LF	$120	$11,719,080
10-inch diameter Gravity Pipeline	35018	LF	$130	$4,552,340
12-inch diameter Gravity Pipeline	17104	LF	$140	$2,394,560
15-inch diameter Gravity Pipeline	18983	LF	$160	$3,037,280
18-inch diameter Gravity Pipeline	12484	LF	$175	$2,184,700
21-inch diameter Gravity Pipeline	12230	LF	$200	$2,446,000
24-inch diameter Gravity Pipeline	9619	LF	$230	$2,212,370
27-inch diameter Gravity Pipeline	8780	LF	$275	$2,414,500
36-inch diameter Gravity Pipeline	8203	LF	$325	$2,665,975
48-inch diameter Gravity Pipeline	8774	LF	$450	$3,948,300
14-inch diameter Force Main	16002	LF	$150	$2,400,300
24-inch diameter Force Main	23373	LF	$195	$4,557,735
30-inch diameter Force Main	5118	LF	$255	$1,305,090
42-inch diameter Boring	400	LF	$990	$396,000
30-inch diameter Boring	1600	LF	$800	$1,280,000
24-inch diameter Boring	400	LF	$700	$280,000
7,752 gpm Lift Station	1	EA	$2,000,000	$2,000,000
8,006 gpm Lift Station	1	EA	$2,000,000	$2,000,000
12,587 gpm Lift Station	1	EA	$4,000,000	$4,000,000
2,359 gpm Lift Station	1	EA	$1,500,000	$1,500,000
2,468 gpm Lift Station	1	EA	$1,500,000	$1,500,000
			On-Site Improvements Subtotal	***$58,794,230***

Off-Site Improvements

Description	Quantity	Unit	Unit Cost	Cost
30-inch diameter Gravity Pipeline	32000	LF	$275	$8,800,000
42-inch diameter Boring	800	LF	$990	$792,000
			Off-Site Improvements Subtotal	***$9,592,000***

Other Project Costs

Contingency (15%)	$10,257,935
Engineering, Administration, Construction Management (17.5%)	$11,967,590
Other Project Costs Subtotal	$22,225,525

Total Cost

On-Site Improvements Subtotal	$58,794,230
Off-Site Improvements Subtotal	$9,592,000
Other Project Costs Subtotal	$22,225,525
Total Cost	**$90,611,755**

Note: Excludes land and easement costs

APPENDIX B, ITEM B4
OPINION OF PROBABLE COSTS - NOTES

The probable costs presented include the following associated work.

Tank	Site work, site security, instrumentation, telemetry, electrical power supply, fencing, valves and fittings.
Water Pump Stations Reservoir, and Well Sites	Site work, site security improvements, instrumentation, telemetry
Waterlines	In line isolation valves, fire hydrants, air release valves, blow-off facilities, site preparation and restoration, rock excavation, anchoring/blocking, fittings, trenching and installing pipe to grade, and backfilling.
Sewers	Manholes, rock excavation, granular tiered grade, grade anchors, fittings for services, and restoration
Site Security	Site security improvements including fencing, alarming, and telemetry is included for all major facilities including water system pump stations, reservoirs, well sites and wastewater collection system lift stations.
Cost Estimates	All costs are probable costs based on similar projects and are presented without the benefit of sufficient geotechnical information. Electrical power utility transmission improvements are not included. Land and easement costs are not included.

APPENDIX C

Apex Master Plan Revisions 2012

Active Scenario: Backbone Fire Flow MAX Day Demands

Junction FlexTable: Fire Flow Node Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Satisfies Fire Flow Constraints?	Demand (gpm)	Fire Flow (Needed) (gpm)	Fire Flow (Available) (gpm)	Pressure (psi)	Pressure (Calculated System Lower Limit) (psi)	Pressure (System Lower Limit) (psi)	Is Fire Flow Run Balanced?	Zone
J-SID01	True	81.22	6,000.00	6,001.00	131.9	40.7	20.0	True	Zone - 2545
J-SID02	True	81.22	6,000.00	6,001.00	125.4	40.7	20.0	True	Zone - 2670
J-SID03	True	81.22	6,000.00	6,001.00	123.3	40.7	20.0	True	Zone - 2670
J-SID04	True	81.22	6,000.00	6,001.00	155.8	40.7	20.0	True	Zone - 2670
J-SID05	True	81.22	6,000.00	6,001.00	149.3	40.7	20.0	True	Zone - 2670
J-SID06	True	81.22	6,000.00	6,001.00	145.0	40.7	20.0	True	Zone - 2670
J-SID07	True	81.22	6,000.00	6,001.00	132.2	40.7	20.0	True	Zone - 2670
J-SID08	True	81.22	6,000.00	6,001.00	128.3	40.7	20.0	True	Zone - 2670
J-SID09	True	81.22	6,000.00	6,001.00	124.2	40.7	20.0	True	Zone - 2670
J-SID10	True	81.22	6,000.00	6,001.00	105.3	40.7	20.0	True	Zone - 2670
J-SID11	True	81.22	6,000.00	6,001.00	95.2	40.7	20.0	True	Zone - 2670
J-SID12	True	34.38	6,000.00	6,001.00	190.3	40.7	20.0	True	Zone - 2670
J-SID13	True	34.38	6,000.00	6,001.00	136.2	40.7	20.0	True	Zone - 2795
J-SID29	True	0.00	6,000.00	6,001.00	95.2	38.1	20.0	True	Zone - 2430
J-SID30	True	0.00	6,000.00	6,001.00	71.0	38.1	20.0	True	Zone - 2430
J-SID31	True	0.00	6,000.00	6,001.00	56.2	38.1	20.0	True	Zone - 2430
J-SID32	True	140.76	6,000.00	6,001.00	40.7	53.7	20.0	True	Zone - 2430
J-SID33	True	140.49	6,000.00	6,001.00	67.0	40.7	20.0	True	Zone - 2430
J-SID34	True	50.18	6,000.00	6,001.00	113.4	40.7	20.0	True	Zone - 2430
J-SID35	True	36.69	6,000.00	6,001.00	93.0	40.7	20.0	True	Zone - 2795
J-SID36	True	244.36	6,000.00	6,001.00	125.4	40.7	20.0	True	Zone - 2795
J-SID38	True	0.00	6,000.00	6,001.00	123.4	40.7	20.0	True	Zone - 2545
J-SID39	True	36.79	6,000.00	6,001.00	153.7	40.7	20.0	True	Zone - 2545
J-SID40	True	36.79	6,000.00	6,001.00	121.2	40.7	20.0	True	Zone - 2445
J-SID41	True	0.00	6,000.00	6,001.00	119.1	40.7	20.0	True	Zone - 2445
J-SID43	True	234.60	6,000.00	6,001.00	136.2	40.7	20.0	True	Zone - 2545
J-SID44	True	81.22	6,000.00	6,001.00	136.2	40.7	20.0	True	Zone - 2545
J-SID46	True	462.94	6,000.00	6,001.00	149.2	40.7	20.0	True	Zone - 2795
J-SID48	True	71.07	6,000.00	6,001.00	116.8	40.7	20.0	True	Zone - 2920
J-SID49	True	0.00	6,000.00	6,001.00	176.7	40.7	20.0	True	Zone - 2920
J-SID51	True	189.56	6,000.00	6,001.00	139.2	40.7	20.0	True	Zone - 2795
J-SID52	True	0.00	6,000.00	6,001.00	118.9	40.7	20.0	True	Zone - 2795
J-SID53	True	74.66	6,000.00	6,001.00	121.2	40.7	20.0	True	Zone - 2795
J-SID55	True	0.00	6,000.00	6,001.00	168.7	40.7	20.0	True	Zone - 2795
J-SID56	True	0.00	6,000.00	6,001.00	90.8	40.7	20.0	True	Zone - 2795
J-SID57	True	0.00	6,000.00	6,001.00	157.9	40.7	20.0	True	Zone - 2795
J-SID59	True	74.66	6,000.00	6,001.00	126.8	40.7	20.0	True	Zone - 2920
J-SID60	True	43.66	6,000.00	6,001.00	99.6	40.7	20.0	True	Zone - 2670
J-SID61	True	50.18	6,000.00	6,001.00	157.9	40.7	20.0	True	Zone - 2670
J-SID62	True	34.38	6,000.00	6,001.00	149.0	40.7	20.0	True	Zone - 2920
J-SID74	True	81.22	6,000.00	6,001.00	138.4	40.7	20.0	True	Zone - 2545
J-SID75	True	125.39	6,000.00	6,001.00	131.5	40.7	20.0	True	Zone - 2795
J-SID81	True	0.00	6,000.00	6,001.00	110.3	40.7	20.0	True	Zone - 2920

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow MAX Day Demands
FlexTable: Junction Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Demand (gpm)	Pressure (psi)	Hydraulic Grade (ft)	Zone	Is Active?
J-SID01	2,240.0	81.22	131.9	2,544.9	Zone - 2545	True
J-SID02	2,255.0	81.22	125.4	2,544.9	Zone - 2670	True
J-SID03	2,260.0	81.22	123.3	2,545.0	Zone - 2670	True
J-SID04	2,305.0	81.22	155.8	2,665.0	Zone - 2670	True
J-SID05	2,320.0	81.22	149.3	2,665.0	Zone - 2670	True
J-SID06	2,330.0	81.22	145.0	2,665.1	Zone - 2670	True
J-SID07	2,360.0	81.22	132.2	2,665.4	Zone - 2670	True
J-SID08	2,370.0	81.22	128.3	2,666.5	Zone - 2670	True
J-SID09	2,380.0	81.22	124.2	2,667.1	Zone - 2670	True
J-SID10	2,425.0	81.22	105.3	2,668.4	Zone - 2670	True
J-SID11	2,450.0	81.22	95.2	2,670.0	Zone - 2670	True
J-SID12	2,350.0	34.38	190.3	2,789.8	Zone - 2670	True
J-SID13	2,475.0	34.38	136.2	2,789.8	Zone - 2795	True
J-SID29	2,210.0	0.00	95.2	2,430.0	Zone - 2430	True
J-SID30	2,266.0	0.00	71.0	2,430.0	Zone - 2430	True
J-SID31	2,300.0	0.00	56.2	2,430.0	Zone - 2430	True
J-SID32	2,336.0	140.76	40.7	2,430.0	Zone - 2430	True
J-SID33	2,275.0	140.49	67.0	2,429.9	Zone - 2430	True
J-SID34	2,408.0	50.18	113.4	2,670.1	Zone - 2430	True
J-SID35	2,575.0	36.69	93.0	2,790.0	Zone - 2795	True
J-SID36	2,500.0	244.36	125.4	2,789.8	Zone - 2795	True
J-SID38	2,260.0	0.00	123.4	2,545.2	Zone - 2545	True
J-SID39	2,190.0	36.79	153.7	2,545.2	Zone - 2545	True
J-SID40	2,165.0	36.79	121.2	2,445.2	Zone - 2445	True
J-SID41	2,170.0	0.00	119.1	2,445.2	Zone - 2445	True
J-SID43	2,230.0	234.60	136.2	2,544.9	Zone - 2545	True
J-SID44	2,230.0	81.22	136.2	2,544.9	Zone - 2545	True
J-SID46	2,445.0	462.94	149.2	2,789.8	Zone - 2795	True
J-SID48	2,675.0	71.07	116.8	2,944.9	Zone - 2920	True
J-SID49	2,535.0	0.00	176.7	2,943.3	Zone - 2920	True
J-SID51	2,623.0	189.56	139.2	2,944.8	Zone - 2795	True
J-SID52	2,520.0	0.00	118.9	2,794.9	Zone - 2795	True
J-SID53	2,515.0	74.66	121.2	2,795.2	Zone - 2795	True
J-SID55	2,400.0	0.00	168.7	2,790.0	Zone - 2795	True
J-SID56	2,580.0	0.00	90.8	2,790.0	Zone - 2795	True
J-SID57	2,580.0	0.00	157.9	2,944.8	Zone - 2795	True
J-SID59	2,650.0	74.66	126.8	2,943.0	Zone - 2920	True
J-SID60	2,440.0	43.66	99.6	2,670.1	Zone - 2670	True
J-SID61	2,425.0	50.18	157.9	2,790.0	Zone - 2670	True
J-SID62	2,600.0	34.38	149.0	2,944.4	Zone - 2920	True
J-SID74	2,225.0	81.22	138.4	2,544.9	Zone - 2545	True
J-SID75	2,491.0	125.39	131.5	2,794.9	Zone - 2795	True
J-SID81	2,690.0	0.00	110.3	2,944.9	Zone - 2920	True

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow MAX Day Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID02	J-SID01	J-SID02	1,946	16	Ductile Iron	130.0	1.690	0.30	-188.45	0.06	Zone - 2545
P-SID09	J-SID02	J-SID03	1,356	16	Ductile Iron	130.0	1.690	0.43	-269.66	0.08	Zone - 2670
P-SID12	J-SID06	J-SID07	898	16	Ductile Iron	130.0	0.960	1.23	-769.29	0.37	Zone - 2670
P-SID13	J-SID07	J-SID08	2,112	16	Ductile Iron	130.0	1.960	1.36	-850.51	1.03	Zone - 2670
P-SID14	J-SID08	J-SID09	1,090	16	Ductile Iron	130.0	1.960	1.49	-931.73	0.66	Zone - 2670
P-SID15	J-SID09	J-SID10	1,871	16	Ductile Iron	130.0	0.960	1.62	-1,012.95	1.24	Zone - 2670
P-SID16	J-SID10	J-SID11	2,206	16	Ductile Iron	130.0	0.960	1.75	-1,094.16	1.67	Zone - 2670
P-SID39	J-SID57	J-SID51	3,462	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID41	J-SID55	T-SID3	5,187	24	Ductile Iron	130.0	0.250	0.07	-100.38	0.01	Zone - 2795
P-SID44	J-SID44	J-SID43	1,387	16	Ductile Iron	130.0	1.690	0.09	-55.21	0.00	Zone - 2545
P-SID50	PMP-B1A	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID51	J-SID40	J-SID41	3,772	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID57	J-SID53	J-SID52	3,295	16	Ductile Iron	130.0	1.690	0.53	333.47	0.28	Zone - 2795
P-SID58	J-SID38	J-SID39	5,926	30	Ductile Iron	130.0	0.500	0.03	73.58	0.00	Zone - 2445
P-SID63	J-SID35	J-SID36	8,958	24	Ductile Iron	130.0	0.500	0.27	386.70	0.13	Zone - 2795
P-SID64	T-SID3	J-SID35	4,531	36	Ductile Iron	130.0	0.250	0.28	886.34	0.04	Zone - 2795
P-SID65	PRV-SID07	J-SID60	3,972	16	Ductile Iron	130.0	1.690	0.46	-289.81	0.26	Zone - 2670
P-SID69	T-SID2	J-SID33	4,302	16	Ductile Iron	130.0	1.690	0.22	140.49	0.07	Zone - 2430
P-SID70	J-SID32	T-SID2	2,303	24	Ductile Iron	130.0	0.500	0.10	-140.77	0.01	Zone - 2430
P-SID71	J-SID31	J-SID32	3,237	24	Ductile Iron	130.0	0.500	0.00	-0.01	0.00	Zone - 2430
P-SID72	J-SID30	J-SID31	5,555	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID73	J-SID29	J-SID30	1,841	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID77	PMP-B1C	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID80	J-SID43	PRV-SID07	4,919	16	Ductile Iron	130.0	1.690	0.46	-289.81	0.32	Zone - 2545

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow MAX Day Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID81	PMP-B2B	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID84	J-SID56	PMP-B2B	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID85	J-SID49	J-SID59	13,461	24	Ductile Iron	130.0	1.690	0.34	482.80	0.31	Zone - 2920
P-SID86	PMP-B2C	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID87	J-SID56	PMP-B2C	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID88	PRV-SID08	J-SID52	960	16	Ductile Iron	130.0	1.690	0.53	-333.47	0.09	Zone - 2795
P-SID89	J-SID51	J-SID48	8,137	24	Ductile Iron	130.0	0.600	0.13	-189.56	0.03	Zone - 2795
P-SID90	PMP-B1B	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID91	J-SID56	PMP-B2A	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID94	J-SID35	J-SID46	6,307	24	Ductile Iron	130.0	1.690	0.33	462.94	0.13	Zone - 2795
P-SID97	PMP-B2A	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID99	J-SID36	J-SID13	1,169	24	Ductile Iron	130.0	0.500	0.10	142.34	0.00	Zone - 2795
P-SID114	J-SID49	PRV-SID05	149	24	Ductile Iron	130.0	0.960	0.92	1,300.78	0.03	Zone - 2920
P-SID115	J-SID75	PRV-SID15	1,533	24	Ductile Iron	130.0	0.960	0.83	1,175.38	0.19	Zone - 2795
P-SID121	J-SID13	J-SID12	3,415	24	Ductile Iron	130.0	0.250	0.08	107.96	0.00	Zone - 2795
P-SID122	T-SID2	PMP-B1C	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID123	T-SID2	PMP-B1B	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID124	T-SID2	PMP-B1A	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID129	J-SID43	PRV-SID10	747	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2545
P-SID130	PRV-SID10	J-SID41	3,377	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID131	J-SID38	PRV-SID11	2,293	30	Ductile Iron	130.0	0.500	0.03	-73.58	0.00	Zone - 2670
P-SID132	PRV-SID11	J-SID12	327	30	Ductile Iron	130.0	0.500	0.03	-73.58	0.00	Zone - 2670
P-SID150	J-SID04	J-SID05	748	24	Ductile Iron	130.0	0.960	0.43	-606.85	0.03	Zone - 2670
P-SID153	T-SID1	J-SID04	4,087	30	Ductile Iron	130.0	0.960	0.08	-174.75	0.00	Zone - 2670

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow MAX Day Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID154	J-SID62	J-SID49	4,256	24	Ductile Iron	130.0	0.960	1.26	1,783.57	1.10	Zone - 2920
P-SID157	J-SID59	PRV-SID12	2,038	24	Ductile Iron	130.0	0.980	0.29	408.13	0.03	Zone - 2920
P-SID158	J-SID48	J-SID81	6,506	24	Ductile Iron	130.0	0.600	0.18	-260.64	0.05	Zone - 2920
P-SID159	PRV-SID12	J-SID53	1,807	24	Ductile Iron	130.0	0.980	0.29	408.13	0.03	Zone - 2795
P-SID160	J-SID05	J-SID06	908	24	Ductile Iron	130.0	0.960	0.49	-688.07	0.04	Zone - 2670
P-SID164	R-1	PMP-A	296	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID165	PMP-A	J-SID29	2,377	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID166	J-SID81	J-SID62	1,823	24	Ductile Iron	130.0	0.000	1.29	1,817.95	0.48	<None >
P-SID170	J-SID04	PRV-SID14	146	16	Ductile Iron	130.0	1.690	0.56	350.88	0.02	Zone - 2670
P-SID171	PRV-SID14	J-SID03	1,443	16	Ductile Iron	130.0	1.690	0.56	350.88	0.14	Zone - 2670
P-SID175	PRV-SID05	J-SID75	1,437	24	Ductile Iron	130.0	0.960	0.92	1,300.78	0.22	Zone - 2795
P-SID176	PRV-SID09	J-SID40	1,782	30	Ductile Iron	130.0	0.500	0.02	36.79	0.00	Zone - 2445
P-SID178	PRV-SID15	J-SID11	175	24	Ductile Iron	130.0	0.960	0.83	1,175.38	0.03	Zone - 2670
P-SID180	J-SID60	PRV-SID08	781	16	Ductile Iron	130.0	1.690	0.53	-333.47	0.07	Zone - 2670
P-SID186	J-SID01	J-SID74	660	16	Ductile Iron	130.0	1.690	0.17	107.23	0.01	Zone - 2545
P-SID187	J-SID74	J-SID44	2,003	16	Ductile Iron	130.0	1.690	0.04	26.01	0.00	Zone - 2545
P-SID189	J-SID61	PRV-SID16	2,700	16	Ductile Iron	130.0	0.000	0.08	50.18	0.01	Zone - 2670
P-SID190	J-SID55	J-SID61	3,051	16	Ductile Iron	130.0	0.000	0.16	100.37	0.03	Zone - 2795
P-SID191	PRV-SID16	J-SID34	681	16	Ductile Iron	130.0	0.000	0.08	50.18	0.00	Zone - 2430
P-SID192	J-SID39	PRV-SID09	214	30	Ductile Iron	130.0	0.500	0.02	36.79	0.00	Zone - 2445
P-SID194	J-SID35	J-SID56	560	42	Ductile Iron	130.0	0.000	0.00	0.00	0.00	Zone - 2795
P-SID196	T-SID4	J-SID81	218	24	Ductile Iron	130.0	0.000	1.47	2,078.59	0.07	Zone - 2920

Apex Master Plan Revisions 2012

Active Scenario: Backbone Fire Flow MAX Day Demands

FlexTable: PRV Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Diameter (Valve) (in)	Hydraulic Grade Setting (Initial) (ft)	Pressure Setting (Initial) (psi)	Flow (gpm)	Pressure (From) (psi)	Pressure (To) (psi)	Downstream Pipe	Zone
PRV-SID05	2,535.0	24	2,795.1	112.6	1,300.78	176.7	112.6	P-SID175	Zone - 2920
PRV-SID07	2,335.0	16	2,545.0	90.9	289.81	144.9	90.9	P-SID80	Zone - 2670
PRV-SID08	2,435.0	16	2,670.0	101.7	333.47	155.7	101.8	P-SID180	Zone - 2795
PRV-SID09	2,185.0	30	2,445.0	112.6	36.79	155.8	112.6	P-SID176	Zone - 2545
PRV-SID10	2,200.0	16	2,445.1	106.1	0.00	149.2	106.1	P-SID130	Zone - 2445
PRV-SID11	2,325.0	30	2,545.0	95.2	73.58	201.1	95.3	P-SID131	Zone - 2670
PRV-SID12	2,575.0	24	2,795.0	95.2	408.13	159.2	95.3	P-SID159	Zone - 2920
PRV-SID14	2,300.0	16	2,545.1	106.1	350.88	157.9	106.1	P-SID171	Zone - 2670
PRV-SID15	2,452.0	24	2,670.0	94.4	1,175.38	148.3	94.4	P-SID178	Zone - 2795
PRV-SID16	2,450.0	16	2,670.0	95.2	50.18	147.1	95.2	P-SID191	Zone - 2670

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow MAX Day Demands
FlexTable: Pump Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Pump Definition	Status (Initial)	Intake Grade (ft)	Discharge Grade (ft)	Discharge (gpm)	Pump Head (ft)	Zone
PMP-A	2,210.0	PMP A	Off	2,220.0	2,430.0	0.00	0.00	Zone - 2430
PMP-B1A	2,400.0	B1A	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1B	2,400.0	B1B	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1C	2,400.0	B1C	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B2A	2,580.0	B2A	Off	2,790.0	2,944.8	0.00	0.00	Zone - 2795
PMP-B2B	2,580.0	B2B	Off	2,790.0	2,944.8	0.00	0.00	Zone - 2795
PMP-B2C	2,580.0	B2C	Off	2,790.0	2,944.8	0.00	0.00	Zone - 2795

Apex Master Plan Revisions 2012

Active Scenario: Backbone Fire Flow MAX Day Demands

FlexTable: Simulated Connection Point Reservoir - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Flow (In net) (gpm)	Flow (Out net) (gpm)	Zone
R-1	2,220.0	0.00	0.00	Zone - 2430

Apex Master Plan Revisions 2012

Active Scenario: Backbone Fire Flow MAX Day Demands

FlexTable: Tank Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Elevation (Base) (ft)	Elevation (Minimum) (ft)	Elevation (Initial) (ft)	Elevation (Maximum) (ft)	Diameter (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)	Volume Full (Calculated) (MG)	Volume Full (Input) (MG)	Zone
T-SID1	2,640.0	2,640.0	2,655.0	2,665.0	2,670.0	170	-174.75	2,665.0	2.55	5.00	Zone - 2670
T-SID2	2,400.0	2,400.0	2,420.0	2,430.0	2,430.0	170	281.25	2,430.0	1.70	5.00	Zone - 2430
T-SID3	2,765.0	2,765.0	2,780.0	2,790.0	2,795.0	240	986.72	2,790.0	5.08	10.00	Zone - 2795
T-SID4	2,920.0	2,920.0	2,935.0	2,945.0	2,950.0	170	2,078.59	2,945.0	2.55	5.00	Zone - 2920

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Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Junction Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Demand (gpm)	Pressure (psi)	Hydraulic Grade (ft)	Zone	Is Active?
J-SID01	2,240.0	59.72	132.0	2,545.0	Zone - 2545	True
J-SID02	2,255.0	59.72	125.5	2,545.0	Zone - 2670	True
J-SID03	2,260.0	59.72	123.3	2,545.1	Zone - 2670	True
J-SID04	2,305.0	59.72	155.8	2,665.0	Zone - 2670	True
J-SID05	2,320.0	59.72	149.3	2,665.1	Zone - 2670	True
J-SID06	2,330.0	59.72	145.0	2,665.1	Zone - 2670	True
J-SID07	2,360.0	59.72	132.2	2,665.5	Zone - 2670	True
J-SID08	2,370.0	59.72	128.3	2,666.6	Zone - 2670	True
J-SID09	2,380.0	59.72	124.3	2,667.3	Zone - 2670	True
J-SID10	2,425.0	59.72	105.3	2,668.5	Zone - 2670	True
J-SID11	2,450.0	59.72	95.2	2,670.1	Zone - 2670	True
J-SID12	2,350.0	25.28	190.3	2,789.9	Zone - 2670	True
J-SID13	2,475.0	25.28	136.2	2,789.9	Zone - 2795	True
J-SID29	2,210.0	0.00	95.2	2,430.0	Zone - 2430	True
J-SID30	2,266.0	0.00	71.0	2,430.0	Zone - 2430	True
J-SID31	2,300.0	0.00	56.2	2,430.0	Zone - 2430	True
J-SID32	2,336.0	103.50	40.7	2,430.0	Zone - 2430	True
J-SID33	2,275.0	103.30	67.0	2,430.0	Zone - 2430	True
J-SID34	2,408.0	36.90	113.4	2,670.1	Zone - 2430	True
J-SID35	2,575.0	26.98	93.0	2,790.0	Zone - 2795	True
J-SID36	2,500.0	179.68	125.4	2,789.9	Zone - 2795	True
J-SID38	2,260.0	0.00	123.4	2,545.2	Zone - 2545	True
J-SID39	2,190.0	27.05	153.7	2,545.2	Zone - 2545	True
J-SID40	2,165.0	27.05	121.2	2,445.2	Zone - 2445	True
J-SID41	2,170.0	0.00	119.1	2,445.2	Zone - 2445	True
J-SID43	2,230.0	172.50	136.3	2,545.0	Zone - 2545	True
J-SID44	2,230.0	59.72	136.3	2,545.0	Zone - 2545	True
J-SID46	2,445.0	340.40	149.2	2,789.9	Zone - 2795	True
J-SID48	2,675.0	52.26	116.8	2,944.9	Zone - 2920	True
J-SID49	2,535.0	0.00	176.8	2,943.7	Zone - 2920	True
J-SID51	2,623.0	139.38	139.3	2,944.9	Zone - 2795	True
J-SID52	2,520.0	0.00	119.0	2,795.0	Zone - 2795	True
J-SID53	2,515.0	54.90	121.2	2,795.2	Zone - 2795	True
J-SID55	2,400.0	0.00	168.7	2,790.0	Zone - 2795	True
J-SID56	2,580.0	0.00	90.8	2,790.0	Zone - 2795	True
J-SID57	2,580.0	0.00	157.9	2,944.9	Zone - 2795	True
J-SID59	2,650.0	54.90	127.0	2,943.5	Zone - 2920	True
J-SID60	2,440.0	32.10	99.6	2,670.2	Zone - 2670	True
J-SID61	2,425.0	36.90	157.9	2,790.0	Zone - 2670	True
J-SID62	2,600.0	25.28	149.1	2,944.6	Zone - 2920	True
J-SID74	2,225.0	59.72	138.4	2,545.0	Zone - 2545	True
J-SID75	2,491.0	92.20	131.5	2,795.0	Zone - 2795	True
J-SID81	2,690.0	0.00	110.3	2,944.9	Zone - 2920	True

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID02	J-SID01	J-SID02	1,946	16	Ductile Iron	130.0	1.690	0.21	-133.86	0.03	Zone - 2545
P-SID09	J-SID02	J-SID03	1,356	16	Ductile Iron	130.0	1.690	0.31	-193.58	0.04	Zone - 2670
P-SID12	J-SID06	J-SID07	898	16	Ductile Iron	130.0	0.960	1.30	-817.50	0.41	Zone - 2670
P-SID13	J-SID07	J-SID08	2,112	16	Ductile Iron	130.0	1.960	1.40	-877.22	1.09	Zone - 2670
P-SID14	J-SID08	J-SID09	1,090	16	Ductile Iron	130.0	1.960	1.50	-936.94	0.67	Zone - 2670
P-SID15	J-SID09	J-SID10	1,871	16	Ductile Iron	130.0	0.960	1.59	-996.66	1.20	Zone - 2670
P-SID16	J-SID10	J-SID11	2,206	16	Ductile Iron	130.0	0.960	1.69	-1,056.38	1.57	Zone - 2670
P-SID39	J-SID57	J-SID51	3,462	24	Ductile Iron	130.0	0.600	0.00	-0.01	0.00	Zone - 2795
P-SID41	J-SID55	T-SID3	5,187	24	Ductile Iron	130.0	0.250	0.05	-73.81	0.00	Zone - 2795
P-SID44	J-SID44	J-SID43	1,387	16	Ductile Iron	130.0	1.690	0.07	-45.30	0.00	Zone - 2545
P-SID50	PMP-B1A	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID51	J-SID40	J-SID41	3,772	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID57	J-SID53	J-SID52	3,295	16	Ductile Iron	130.0	1.690	0.40	249.91	0.16	Zone - 2795
P-SID58	J-SID38	J-SID39	5,926	30	Ductile Iron	130.0	0.500	0.02	54.10	0.00	Zone - 2445
P-SID63	J-SID35	J-SID36	8,958	24	Ductile Iron	130.0	0.500	0.20	284.34	0.08	Zone - 2795
P-SID64	T-SID3	J-SID35	4,531	36	Ductile Iron	130.0	0.250	0.21	651.72	0.02	Zone - 2795
P-SID65	PRV-SID07	J-SID60	3,972	16	Ductile Iron	130.0	1.690	0.35	-217.81	0.15	Zone - 2670
P-SID69	T-SID2	J-SID33	4,302	16	Ductile Iron	130.0	1.690	0.16	103.30	0.04	Zone - 2430
P-SID70	J-SID32	T-SID2	2,303	24	Ductile Iron	130.0	0.500	0.07	-103.50	0.00	Zone - 2430
P-SID71	J-SID31	J-SID32	3,237	24	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID72	J-SID30	J-SID31	5,555	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID73	J-SID29	J-SID30	1,841	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID77	PMP-B1C	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID80	J-SID43	PRV-SID07	4,919	16	Ductile Iron	130.0	1.690	0.35	-217.81	0.19	Zone - 2545

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID81	PMP-B2B	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID84	J-SID56	PMP-B2B	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID85	J-SID49	J-SID59	13,461	24	Ductile Iron	130.0	1.690	0.26	359.71	0.18	Zone - 2920
P-SID86	PMP-B2C	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID87	J-SID56	PMP-B2C	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID88	PRV-SID08	J-SID52	960	16	Ductile Iron	130.0	1.690	0.40	-249.91	0.05	Zone - 2795
P-SID89	J-SID51	J-SID48	8,137	24	Ductile Iron	130.0	0.600	0.10	-139.39	0.02	Zone - 2795
P-SID90	PMP-B1B	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID91	J-SID56	PMP-B2A	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID94	J-SID35	J-SID46	6,307	24	Ductile Iron	130.0	1.690	0.24	340.40	0.08	Zone - 2795
P-SID97	PMP-B2A	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID99	J-SID36	J-SID13	1,169	24	Ductile Iron	130.0	0.500	0.07	104.66	0.00	Zone - 2795
P-SID114	J-SID49	PRV-SID05	149	24	Ductile Iron	130.0	0.960	0.86	1,208.30	0.03	Zone - 2920
P-SID115	J-SID75	PRV-SID15	1,533	24	Ductile Iron	130.0	0.960	0.79	1,116.10	0.17	Zone - 2795
P-SID121	J-SID13	J-SID12	3,415	24	Ductile Iron	130.0	0.250	0.06	79.38	0.00	Zone - 2795
P-SID122	T-SID2	PMP-B1C	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID123	T-SID2	PMP-B1B	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID124	T-SID2	PMP-B1A	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID129	J-SID43	PRV-SID10	747	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2545
P-SID130	PRV-SID10	J-SID41	3,377	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID131	J-SID38	PRV-SID11	2,293	30	Ductile Iron	130.0	0.500	0.02	-54.10	0.00	Zone - 2670
P-SID132	PRV-SID11	J-SID12	327	30	Ductile Iron	130.0	0.500	0.02	-54.10	0.00	Zone - 2670
P-SID150	J-SID04	J-SID05	748	24	Ductile Iron	130.0	0.960	0.50	-698.06	0.04	Zone - 2670
P-SID153	T-SID1	J-SID04	4,087	30	Ductile Iron	130.0	0.960	0.17	-385.05	0.02	Zone - 2670

Apex Master Plan Revisions 2012

Active Scenario: Backbone Hyd AVG Day Demands

FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID154	J-SID62	J-SID49	4,256	24	Ductile Iron	130.0	0.960	1.11	1,568.01	0.87	Zone - 2920
P-SID157	J-SID59	PRV-SID12	2,038	24	Ductile Iron	130.0	0.980	0.22	304.81	0.02	Zone - 2920
P-SID158	J-SID48	J-SID81	6,506	24	Ductile Iron	130.0	0.600	0.14	-191.65	0.03	Zone - 2920
P-SID159	PRV-SID12	J-SID53	1,807	24	Ductile Iron	130.0	0.980	0.22	304.81	0.02	Zone - 2795
P-SID160	J-SID05	J-SID06	908	24	Ductile Iron	130.0	0.960	0.54	-757.78	0.05	Zone - 2670
P-SID164	R-1	PMP-A	296	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID165	PMP-A	J-SID29	2,377	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID166	J-SID81	J-SID62	1,823	24	Ductile Iron	130.0	0.000	1.13	1,593.29	0.37	<None>
P-SID170	J-SID04	PRV-SID14	146	16	Ductile Iron	130.0	1.690	0.40	253.30	0.01	Zone - 2670
P-SID171	PRV-SID14	J-SID03	1,443	16	Ductile Iron	130.0	1.690	0.40	253.30	0.08	Zone - 2670
P-SID175	PRV-SID05	J-SID75	1,437	24	Ductile Iron	130.0	0.960	0.86	1,208.30	0.19	Zone - 2795
P-SID176	PRV-SID09	J-SID40	1,782	30	Ductile Iron	130.0	0.500	0.01	27.05	0.00	Zone - 2445
P-SID178	PRV-SID15	J-SID11	175	24	Ductile Iron	130.0	0.960	0.79	1,116.10	0.03	Zone - 2670
P-SID180	J-SID60	PRV-SID08	781	16	Ductile Iron	130.0	1.690	0.40	-249.91	0.04	Zone - 2670
P-SID186	J-SID01	J-SID74	660	16	Ductile Iron	130.0	1.690	0.12	74.14	0.00	Zone - 2545
P-SID187	J-SID74	J-SID44	2,003	16	Ductile Iron	130.0	1.690	0.02	14.42	0.00	Zone - 2545
P-SID189	J-SID61	PRV-SID16	2,700	16	Ductile Iron	130.0	0.000	0.06	36.90	0.00	Zone - 2670
P-SID190	J-SID55	J-SID61	3,051	16	Ductile Iron	130.0	0.000	0.12	73.80	0.02	Zone - 2795
P-SID191	PRV-SID16	J-SID34	681	16	Ductile Iron	130.0	0.000	0.06	36.90	0.00	Zone - 2430
P-SID192	J-SID39	PRV-SID09	214	30	Ductile Iron	130.0	0.500	0.01	27.05	0.00	Zone - 2445
P-SID194	J-SID35	J-SID56	560	42	Ductile Iron	130.0	0.000	0.00	0.00	0.00	Zone - 2795
P-SID196	T-SID4	J-SID81	218	24	Ductile Iron	130.0	0.000	1.27	1,784.93	0.06	Zone - 2920

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Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: PRV Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Diameter (Valve) (in)	Hydraulic Grade Setting (Initial) (ft)	Pressure Setting (Initial) (psi)	Flow (gpm)	Pressure (From) (psi)	Pressure (To) (psi)	Downstream Pipe	Zone
PRV-SID05	2,535.0	24	2,795.1	112.6	1,208.30	176.8	112.6	P-SID175	Zone - 2920
PRV-SID07	2,335.0	16	2,545.0	90.9	217.81	144.9	90.9	P-SID80	Zone - 2670
PRV-SID08	2,435.0	16	2,670.0	101.7	249.91	155.7	101.8	P-SID180	Zone - 2795
PRV-SID09	2,185.0	30	2,445.0	112.6	27.05	155.8	112.6	P-SID176	Zone - 2545
PRV-SID10	2,200.0	16	2,445.1	106.1	0.00	149.3	106.1	P-SID130	Zone - 2445
PRV-SID11	2,325.0	30	2,545.0	95.2	54.10	201.1	95.3	P-SID131	Zone - 2670
PRV-SID12	2,575.0	24	2,795.0	95.2	304.81	159.4	95.3	P-SID159	Zone - 2920
PRV-SID14	2,300.0	16	2,545.1	106.1	253.30	157.9	106.1	P-SID171	Zone - 2670
PRV-SID15	2,452.0	24	2,670.0	94.4	1,116.10	148.3	94.4	P-SID178	Zone - 2795
PRV-SID16	2,450.0	16	2,670.0	95.2	36.90	147.1	95.2	P-SID191	Zone - 2670

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Pump Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Pump Definition	Status (Initial)	Intake Grade (ft)	Discharge Grade (ft)	Discharge (gpm)	Pump Head (ft)	Zone
PMP-A	2,210.0	PMP A	Off	2,220.0	2,430.0	0.00	0.00	Zone - 2430
PMP-B1A	2,400.0	B1A	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1B	2,400.0	B1B	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1C	2,400.0	B1C	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B2A	2,580.0	B2A	Off	2,790.0	2,944.9	0.00	0.00	Zone - 2795
PMP-B2B	2,580.0	B2B	Off	2,790.0	2,944.9	0.00	0.00	Zone - 2795
PMP-B2C	2,580.0	B2C	Off	2,790.0	2,944.9	0.00	0.00	Zone - 2795

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Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Simulated Connection Point Reservoir - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Flow (In net) (gpm)	Flow (Out net) (gpm)	Zone
R-1	2,220.0	0.00	0.00	Zone - 2430

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Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Tank Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Elevation (Base) (ft)	Elevation (Minimum) (ft)	Elevation (Initial) (ft)	Elevation (Maximum) (ft)	Diameter (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)	Volume Full (Calculated) (MG)	Volume Full (Input) (MG)	Zone
T-SID1	2,640.0	2,640.0	2,655.0	2,665.0	2,670.0	170	-385.05	2,665.0	2.55	5.00	Zone - 2670
T-SID2	2,400.0	2,400.0	2,420.0	2,430.0	2,430.0	170	206.79	2,430.0	1.70	5.00	Zone - 2430
T-SID3	2,765.0	2,765.0	2,780.0	2,790.0	2,795.0	240	725.53	2,790.0	5.08	10.00	Zone - 2795
T-SID4	2,920.0	2,920.0	2,935.0	2,945.0	2,950.0	170	1,784.93	2,945.0	2.55	5.00	Zone - 2920

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd MAX Day Demands
FlexTable: Junction Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Demand (gpm)	Pressure (psi)	Hydraulic Grade (ft)	Zone	Is Active?
J-SID01	2,240.0	83.01	131.9	2,544.9	Zone - 2545	True
J-SID02	2,255.0	83.01	125.4	2,544.9	Zone - 2670	True
J-SID03	2,260.0	83.01	123.3	2,545.0	Zone - 2670	True
J-SID04	2,305.0	83.01	155.8	2,665.0	Zone - 2670	True
J-SID05	2,320.0	83.01	149.3	2,665.0	Zone - 2670	True
J-SID06	2,330.0	83.01	145.0	2,665.1	Zone - 2670	True
J-SID07	2,360.0	83.01	132.1	2,665.4	Zone - 2670	True
J-SID08	2,370.0	83.01	128.3	2,666.5	Zone - 2670	True
J-SID09	2,380.0	83.01	124.2	2,667.1	Zone - 2670	True
J-SID10	2,425.0	83.01	105.3	2,668.4	Zone - 2670	True
J-SID11	2,450.0	83.01	95.2	2,670.0	Zone - 2670	True
J-SID12	2,350.0	35.14	190.3	2,789.8	Zone - 2670	True
J-SID13	2,475.0	35.14	136.2	2,789.8	Zone - 2795	True
J-SID29	2,210.0	0.00	95.2	2,430.0	Zone - 2430	True
J-SID30	2,266.0	0.00	71.0	2,430.0	Zone - 2430	True
J-SID31	2,300.0	0.00	56.2	2,430.0	Zone - 2430	True
J-SID32	2,336.0	143.87	40.7	2,430.0	Zone - 2430	True
J-SID33	2,275.0	143.59	67.0	2,429.9	Zone - 2430	True
J-SID34	2,408.0	51.29	113.4	2,670.1	Zone - 2430	True
J-SID35	2,575.0	37.50	93.0	2,790.0	Zone - 2795	True
J-SID36	2,500.0	249.76	125.4	2,789.8	Zone - 2795	True
J-SID38	2,260.0	0.00	123.4	2,545.2	Zone - 2545	True
J-SID39	2,190.0	37.60	153.7	2,545.2	Zone - 2545	True
J-SID40	2,165.0	37.60	121.2	2,445.2	Zone - 2445	True
J-SID41	2,170.0	0.00	119.1	2,445.2	Zone - 2445	True
J-SID43	2,230.0	239.78	136.2	2,544.8	Zone - 2545	True
J-SID44	2,230.0	83.01	136.2	2,544.8	Zone - 2545	True
J-SID46	2,445.0	473.16	149.2	2,789.8	Zone - 2795	True
J-SID48	2,675.0	72.64	116.8	2,944.9	Zone - 2920	True
J-SID49	2,535.0	0.00	176.7	2,943.3	Zone - 2920	True
J-SID51	2,623.0	193.74	139.2	2,944.8	Zone - 2795	True
J-SID52	2,520.0	0.00	118.9	2,794.9	Zone - 2795	True
J-SID53	2,515.0	76.31	121.2	2,795.2	Zone - 2795	True
J-SID55	2,400.0	0.00	168.7	2,790.0	Zone - 2795	True
J-SID56	2,580.0	0.00	90.8	2,790.0	Zone - 2795	True
J-SID57	2,580.0	0.00	157.8	2,944.8	Zone - 2795	True
J-SID59	2,650.0	76.31	126.8	2,943.0	Zone - 2920	True
J-SID60	2,440.0	44.62	99.6	2,670.1	Zone - 2670	True
J-SID61	2,425.0	51.29	157.9	2,790.0	Zone - 2670	True
J-SID62	2,600.0	35.14	149.0	2,944.4	Zone - 2920	True
J-SID74	2,225.0	83.01	138.4	2,544.8	Zone - 2545	True
J-SID75	2,491.0	128.16	131.5	2,794.9	Zone - 2795	True
J-SID81	2,690.0	0.00	110.3	2,944.9	Zone - 2920	True

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd MAX Day Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID02	J-SID01	J-SID02	1,946	16	Ductile Iron	130.0	1.690	0.31	-192.94	0.06	Zone - 2545
P-SID09	J-SID02	J-SID03	1,356	16	Ductile Iron	130.0	1.690	0.44	-275.95	0.08	Zone - 2670
P-SID12	J-SID06	J-SID07	898	16	Ductile Iron	130.0	0.960	1.22	-765.18	0.36	Zone - 2670
P-SID13	J-SID07	J-SID08	2,112	16	Ductile Iron	130.0	1.960	1.35	-848.19	1.03	Zone - 2670
P-SID14	J-SID08	J-SID09	1,090	16	Ductile Iron	130.0	1.960	1.49	-931.20	0.66	Zone - 2670
P-SID15	J-SID09	J-SID10	1,871	16	Ductile Iron	130.0	0.960	1.62	-1,014.21	1.24	Zone - 2670
P-SID16	J-SID10	J-SID11	2,206	16	Ductile Iron	130.0	0.960	1.75	-1,097.22	1.68	Zone - 2670
P-SID39	J-SID57	J-SID51	3,462	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID41	J-SID55	T-SID3	5,187	24	Ductile Iron	130.0	0.250	0.07	-102.59	0.01	Zone - 2795
P-SID44	J-SID44	J-SID43	1,387	16	Ductile Iron	130.0	1.690	0.09	-56.10	0.00	Zone - 2545
P-SID50	PMP-B1A	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID51	J-SID40	J-SID41	3,772	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID57	J-SID53	J-SID52	3,295	16	Ductile Iron	130.0	1.690	0.54	340.49	0.29	Zone - 2795
P-SID58	J-SID38	J-SID39	5,926	30	Ductile Iron	130.0	0.500	0.03	75.20	0.00	Zone - 2445
P-SID63	J-SID35	J-SID36	8,958	24	Ductile Iron	130.0	0.500	0.28	395.23	0.14	Zone - 2795
P-SID64	T-SID3	J-SID35	4,531	36	Ductile Iron	130.0	0.250	0.29	905.89	0.05	Zone - 2795
P-SID65	PRV-SID07	J-SID60	3,972	16	Ductile Iron	130.0	1.690	0.47	-295.87	0.27	Zone - 2670
P-SID69	T-SID2	J-SID33	4,302	16	Ductile Iron	130.0	1.690	0.23	143.59	0.08	Zone - 2430
P-SID70	J-SID32	T-SID2	2,303	24	Ductile Iron	130.0	0.500	0.10	-143.87	0.01	Zone - 2430
P-SID71	J-SID31	J-SID32	3,237	24	Ductile Iron	130.0	0.500	0.00	-0.01	0.00	Zone - 2430
P-SID72	J-SID30	J-SID31	5,555	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID73	J-SID29	J-SID30	1,841	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID77	PMP-B1C	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID80	J-SID43	PRV-SID07	4,919	16	Ductile Iron	130.0	1.690	0.47	-295.87	0.33	Zone - 2545

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd MAX Day Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID81	PMP-B2B	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID84	J-SID56	PMP-B2B	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID85	J-SID49	J-SID59	13,461	24	Ductile Iron	130.0	1.690	0.35	493.11	0.32	Zone - 2920
P-SID86	PMP-B2C	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID87	J-SID56	PMP-B2C	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID88	PRV-SID08	J-SID52	960	16	Ductile Iron	130.0	1.690	0.54	-340.49	0.09	Zone - 2795
P-SID89	J-SID51	J-SID48	8,137	24	Ductile Iron	130.0	0.600	0.14	-193.74	0.03	Zone - 2795
P-SID90	PMP-B1B	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID91	J-SID56	PMP-B2A	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID94	J-SID35	J-SID46	6,307	24	Ductile Iron	130.0	1.690	0.34	473.16	0.14	Zone - 2795
P-SID97	PMP-B2A	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID99	J-SID36	J-SID13	1,169	24	Ductile Iron	130.0	0.500	0.10	145.48	0.00	Zone - 2795
P-SID114	J-SID49	PRV-SID05	149	24	Ductile Iron	130.0	0.960	0.93	1,308.39	0.03	Zone - 2920
P-SID115	J-SID75	PRV-SID15	1,533	24	Ductile Iron	130.0	0.960	0.84	1,180.23	0.19	Zone - 2795
P-SID121	J-SID13	J-SID12	3,415	24	Ductile Iron	130.0	0.250	0.08	110.34	0.01	Zone - 2795
P-SID122	T-SID2	PMP-B1C	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID123	T-SID2	PMP-B1B	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID124	T-SID2	PMP-B1A	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID129	J-SID43	PRV-SID10	747	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2545
P-SID130	PRV-SID10	J-SID41	3,377	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID131	J-SID38	PRV-SID11	2,293	30	Ductile Iron	130.0	0.500	0.03	-75.20	0.00	Zone - 2670
P-SID132	PRV-SID11	J-SID12	327	30	Ductile Iron	130.0	0.500	0.03	-75.20	0.00	Zone - 2670
P-SID150	J-SID04	J-SID05	748	24	Ductile Iron	130.0	0.960	0.42	-599.16	0.03	Zone - 2670
P-SID153	T-SID1	J-SID04	4,087	30	Ductile Iron	130.0	0.960	0.07	-157.19	0.00	Zone - 2670

Apex Master Plan Revisions 2012

Active Scenario: Backbone Hyd MAX Day Demands

FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID154	J-SID62	J-SID49	4,256	24	Ductile Iron	130.0	0.960	1.28	1,801.50	1.12	Zone - 2920
P-SID157	J-SID59	PRV-SID12	2,038	24	Ductile Iron	130.0	0.980	0.30	416.80	0.04	Zone - 2920
P-SID158	J-SID48	J-SID81	6,506	24	Ductile Iron	130.0	0.600	0.19	-266.38	0.05	Zone - 2920
P-SID159	PRV-SID12	J-SID53	1,807	24	Ductile Iron	130.0	0.980	0.30	416.80	0.03	Zone - 2795
P-SID160	J-SID05	J-SID06	908	24	Ductile Iron	130.0	0.960	0.48	-682.17	0.04	Zone - 2670
P-SID164	R-1	PMP-A	296	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID165	PMP-A	J-SID29	2,377	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID166	J-SID81	J-SID62	1,823	24	Ductile Iron	130.0	0.000	1.30	1,836.64	0.49	<None>
P-SID170	J-SID04	PRV-SID14	146	16	Ductile Iron	130.0	1.690	0.57	358.96	0.02	Zone - 2670
P-SID171	PRV-SID14	J-SID03	1,443	16	Ductile Iron	130.0	1.690	0.57	358.96	0.14	Zone - 2670
P-SID175	PRV-SID05	J-SID75	1,437	24	Ductile Iron	130.0	0.960	0.93	1,308.39	0.22	Zone - 2795
P-SID176	PRV-SID09	J-SID40	1,782	30	Ductile Iron	130.0	0.500	0.02	37.60	0.00	Zone - 2445
P-SID178	PRV-SID15	J-SID11	175	24	Ductile Iron	130.0	0.960	0.84	1,180.23	0.03	Zone - 2670
P-SID180	J-SID60	PRV-SID08	781	16	Ductile Iron	130.0	1.690	0.54	-340.49	0.07	Zone - 2670
P-SID186	J-SID01	J-SID74	660	16	Ductile Iron	130.0	1.690	0.18	109.93	0.01	Zone - 2545
P-SID187	J-SID74	J-SID44	2,003	16	Ductile Iron	130.0	1.690	0.04	26.92	0.00	Zone - 2545
P-SID189	J-SID61	PRV-SID16	2,700	16	Ductile Iron	130.0	0.000	0.08	51.29	0.01	Zone - 2670
P-SID190	J-SID55	J-SID61	3,051	16	Ductile Iron	130.0	0.000	0.16	102.58	0.03	Zone - 2795
P-SID191	PRV-SID16	J-SID34	681	16	Ductile Iron	130.0	0.000	0.08	51.29	0.00	Zone - 2430
P-SID192	J-SID39	PRV-SID09	214	30	Ductile Iron	130.0	0.500	0.02	37.60	0.00	Zone - 2445
P-SID194	J-SID35	J-SID56	560	42	Ductile Iron	130.0	0.000	0.00	0.00	0.00	Zone - 2795
P-SID196	T-SID4	J-SID81	218	24	Ductile Iron	130.0	0.000	1.49	2,103.03	0.07	Zone - 2920

Apex Master Plan Revisions 2012

Active Scenario: Backbone Hyd MAX Day Demands

FlexTable: PRV Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Diameter (Valve) (in)	Hydraulic Grade Setting (Initial) (ft)	Pressure Setting (Initial) (psi)	Flow (gpm)	Pressure (From) (psi)	Pressure (To) (psi)	Downstream Pipe	Zone
PRV-SID05	2,535.0	24	2,795.1	112.6	1,308.39	176.6	112.6	P-SID175	Zone - 2920
PRV-SID07	2,335.0	16	2,545.0	90.9	295.87	144.9	90.9	P-SID80	Zone - 2670
PRV-SID08	2,435.0	16	2,670.0	101.7	340.49	155.7	101.8	P-SID180	Zone - 2795
PRV-SID09	2,185.0	30	2,445.0	112.6	37.60	155.8	112.6	P-SID176	Zone - 2545
PRV-SID10	2,200.0	16	2,445.1	106.1	0.00	149.2	106.1	P-SID130	Zone - 2445
PRV-SID11	2,325.0	30	2,545.0	95.2	75.20	201.1	95.3	P-SID131	Zone - 2670
PRV-SID12	2,575.0	24	2,795.0	95.2	416.80	159.2	95.3	P-SID159	Zone - 2920
PRV-SID14	2,300.0	16	2,545.1	106.1	358.96	157.9	106.1	P-SID171	Zone - 2670
PRV-SID15	2,452.0	24	2,670.0	94.4	1,180.23	148.3	94.4	P-SID178	Zone - 2795
PRV-SID16	2,450.0	16	2,670.0	95.2	51.29	147.1	95.2	P-SID191	Zone - 2670

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd MAX Day Demands
FlexTable: Pump Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Pump Definition	Status (Initial)	Intake Grade (ft)	Discharge Grade (ft)	Discharge (gpm)	Pump Head (ft)	Zone
PMP-A	2,210.0	PMP A	Off	2,220.0	2,430.0	0.00	0.00	Zone - 2430
PMP-B1A	2,400.0	B1A	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1B	2,400.0	B1B	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1C	2,400.0	B1C	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B2A	2,580.0	B2A	Off	2,790.0	2,944.8	0.00	0.00	Zone - 2795
PMP-B2B	2,580.0	B2B	Off	2,790.0	2,944.8	0.00	0.00	Zone - 2795
PMP-B2C	2,580.0	B2C	Off	2,790.0	2,944.8	0.00	0.00	Zone - 2795

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd MAX Day Demands
FlexTable: Simulated Connection Point Reservoir - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Flow (In net) (gpm)	Flow (Out net) (gpm)	Zone
R-1	2,220.0	0.00	0.00	Zone - 2430

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd MAX Day Demands
FlexTable: Tank Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Elevation (Base) (ft)	Elevation (Minimum) (ft)	Elevation (Initial) (ft)	Elevation (Maximum) (ft)	Diameter (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)	Volume Full (Calculated) (MG)	Volume Full (Input) (MG)	Zone
T-SID1	2,640.0	2,640.0	2,655.0	2,665.0	2,670.0	170	-157.19	2,665.0	2.55	5.00	Zone - 2670
T-SID2	2,400.0	2,400.0	2,420.0	2,430.0	2,430.0	170	287.46	2,430.0	1.70	5.00	Zone - 2430
T-SID3	2,765.0	2,765.0	2,780.0	2,790.0	2,795.0	240	1,008.48	2,790.0	5.08	10.00	Zone - 2795
T-SID4	2,920.0	2,920.0	2,935.0	2,945.0	2,950.0	170	2,103.03	2,945.0	2.55	5.00	Zone - 2920

Apex Master Plan Revisions 2012

Active Scenario: Backbone Hyd PEAK Demands

FlexTable: Junction Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Demand (gpm)	Pressure (psi)	Hydraulic Grade (ft)	Zone	Is Active?
J-SID01	2,240.0	124.81	131.7	2,544.5	Zone - 2545	True
J-SID02	2,255.0	124.81	125.3	2,544.6	Zone - 2670	True
J-SID03	2,260.0	124.81	123.2	2,544.8	Zone - 2670	True
J-SID04	2,305.0	124.81	155.8	2,665.0	Zone - 2670	True
J-SID05	2,320.0	124.81	149.3	2,665.0	Zone - 2670	True
J-SID06	2,330.0	124.81	145.0	2,665.0	Zone - 2670	True
J-SID07	2,360.0	124.81	132.1	2,665.3	Zone - 2670	True
J-SID08	2,370.0	124.81	128.2	2,666.2	Zone - 2670	True
J-SID09	2,380.0	124.81	124.1	2,666.9	Zone - 2670	True
J-SID10	2,425.0	124.81	105.2	2,668.2	Zone - 2670	True
J-SID11	2,450.0	124.81	95.2	2,670.0	Zone - 2670	True
J-SID12	2,350.0	52.84	190.2	2,789.6	Zone - 2670	True
J-SID13	2,475.0	52.84	136.1	2,789.6	Zone - 2795	True
J-SID29	2,210.0	0.00	95.2	2,430.0	Zone - 2430	True
J-SID30	2,266.0	0.00	70.9	2,430.0	Zone - 2430	True
J-SID31	2,300.0	0.00	56.2	2,430.0	Zone - 2430	True
J-SID32	2,336.0	216.32	40.7	2,430.0	Zone - 2430	True
J-SID33	2,275.0	215.90	67.0	2,429.8	Zone - 2430	True
J-SID34	2,408.0	77.12	113.4	2,670.1	Zone - 2430	True
J-SID35	2,575.0	56.39	93.0	2,789.9	Zone - 2795	True
J-SID36	2,500.0	375.53	125.3	2,789.6	Zone - 2795	True
J-SID38	2,260.0	0.00	123.4	2,545.2	Zone - 2545	True
J-SID39	2,190.0	56.53	153.7	2,545.2	Zone - 2545	True
J-SID40	2,165.0	56.53	121.2	2,445.2	Zone - 2445	True
J-SID41	2,170.0	0.00	119.1	2,445.2	Zone - 2445	True
J-SID43	2,230.0	360.52	136.1	2,544.5	Zone - 2545	True
J-SID44	2,230.0	124.81	136.1	2,544.5	Zone - 2545	True
J-SID46	2,445.0	711.44	149.1	2,789.6	Zone - 2795	True
J-SID48	2,675.0	109.22	116.7	2,944.8	Zone - 2920	True
J-SID49	2,535.0	0.00	176.3	2,942.5	Zone - 2920	True
J-SID51	2,623.0	291.30	139.2	2,944.7	Zone - 2795	True
J-SID52	2,520.0	0.00	118.8	2,794.5	Zone - 2795	True
J-SID53	2,515.0	114.74	121.2	2,795.1	Zone - 2795	True
J-SID55	2,400.0	0.00	168.7	2,790.0	Zone - 2795	True
J-SID56	2,580.0	0.00	90.8	2,789.9	Zone - 2795	True
J-SID57	2,580.0	0.00	157.8	2,944.7	Zone - 2795	True
J-SID59	2,650.0	114.74	126.3	2,941.8	Zone - 2920	True
J-SID60	2,440.0	67.09	99.5	2,670.1	Zone - 2670	True
J-SID61	2,425.0	77.12	157.9	2,789.9	Zone - 2670	True
J-SID62	2,600.0	52.84	148.9	2,944.2	Zone - 2920	True
J-SID74	2,225.0	124.81	138.2	2,544.5	Zone - 2545	True
J-SID75	2,491.0	192.70	131.5	2,794.9	Zone - 2795	True
J-SID81	2,690.0	0.00	110.3	2,944.9	Zone - 2920	True

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Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd PEAK Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID02	J-SID01	J-SID02	1,946	16	Ductile Iron	130.0	1.690	0.47	-296.45	0.13	Zone - 2545
P-SID09	J-SID02	J-SID03	1,356	16	Ductile Iron	130.0	1.690	0.67	-421.27	0.18	Zone - 2670
P-SID12	J-SID06	J-SID07	898	16	Ductile Iron	130.0	0.960	1.06	-666.67	0.28	Zone - 2670
P-SID13	J-SID07	J-SID08	2,112	16	Ductile Iron	130.0	1.960	1.26	-791.49	0.90	Zone - 2670
P-SID14	J-SID08	J-SID09	1,090	16	Ductile Iron	130.0	1.960	1.46	-916.30	0.64	Zone - 2670
P-SID15	J-SID09	J-SID10	1,871	16	Ductile Iron	130.0	0.960	1.66	-1,041.11	1.30	Zone - 2670
P-SID16	J-SID10	J-SID11	2,206	16	Ductile Iron	130.0	0.960	1.86	-1,165.93	1.88	Zone - 2670
P-SID39	J-SID57	J-SID51	3,462	24	Ductile Iron	130.0	0.600	0.00	-0.01	0.00	Zone - 2795
P-SID41	J-SID55	T-SID3	5,187	24	Ductile Iron	130.0	0.250	0.11	-154.25	0.01	Zone - 2795
P-SID44	J-SID44	J-SID43	1,387	16	Ductile Iron	130.0	1.690	0.12	-77.99	0.01	Zone - 2545
P-SID50	PMP-B1A	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID51	J-SID40	J-SID41	3,772	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID57	J-SID53	J-SID52	3,295	16	Ductile Iron	130.0	1.690	0.81	505.61	0.60	Zone - 2795
P-SID58	J-SID38	J-SID39	5,926	30	Ductile Iron	130.0	0.500	0.05	113.07	0.00	Zone - 2445
P-SID63	J-SID35	J-SID36	8,958	24	Ductile Iron	130.0	0.500	0.42	594.27	0.30	Zone - 2795
P-SID64	T-SID3	J-SID35	4,531	36	Ductile Iron	130.0	0.250	0.43	1,362.10	0.10	Zone - 2795
P-SID65	PRV-SID07	J-SID60	3,972	16	Ductile Iron	130.0	1.690	0.70	-438.52	0.55	Zone - 2670
P-SID69	T-SID2	J-SID33	4,302	16	Ductile Iron	130.0	1.690	0.34	215.90	0.16	Zone - 2430
P-SID70	J-SID32	T-SID2	2,303	24	Ductile Iron	130.0	0.500	0.15	-216.32	0.01	Zone - 2430
P-SID71	J-SID31	J-SID32	3,237	24	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID72	J-SID30	J-SID31	5,555	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID73	J-SID29	J-SID30	1,841	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID77	PMP-B1C	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID80	J-SID43	PRV-SID07	4,919	16	Ductile Iron	130.0	1.690	0.70	-438.52	0.68	Zone - 2545

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd PEAK Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID81	PMP-B2B	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID84	J-SID56	PMP-B2B	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID85	J-SID49	J-SID59	13,461	24	Ductile Iron	130.0	1.690	0.52	735.09	0.67	Zone - 2920
P-SID86	PMP-B2C	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID87	J-SID56	PMP-B2C	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID88	PRV-SID08	J-SID52	960	16	Ductile Iron	130.0	1.690	0.81	-505.61	0.19	Zone - 2795
P-SID89	J-SID51	J-SID48	8,137	24	Ductile Iron	130.0	0.600	0.21	-291.31	0.07	Zone - 2795
P-SID90	PMP-B1B	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID91	J-SID56	PMP-B2A	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID94	J-SID35	J-SID46	6,307	24	Ductile Iron	130.0	1.690	0.50	711.44	0.30	Zone - 2795
P-SID97	PMP-B2A	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID99	J-SID36	J-SID13	1,169	24	Ductile Iron	130.0	0.500	0.16	218.74	0.01	Zone - 2795
P-SID114	J-SID49	PRV-SID05	149	24	Ductile Iron	130.0	0.960	1.05	1,483.44	0.04	Zone - 2920
P-SID115	J-SID75	PRV-SID15	1,533	24	Ductile Iron	130.0	0.960	0.92	1,290.74	0.23	Zone - 2795
P-SID121	J-SID13	J-SID12	3,415	24	Ductile Iron	130.0	0.250	0.12	165.90	0.01	Zone - 2795
P-SID122	T-SID2	PMP-B1C	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID123	T-SID2	PMP-B1B	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID124	T-SID2	PMP-B1A	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID129	J-SID43	PRV-SID10	747	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2545
P-SID130	PRV-SID10	J-SID41	3,377	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID131	J-SID38	PRV-SID11	2,293	30	Ductile Iron	130.0	0.500	0.05	-113.07	0.00	Zone - 2670
P-SID132	PRV-SID11	J-SID12	327	30	Ductile Iron	130.0	0.500	0.05	-113.07	0.00	Zone - 2670
P-SID150	J-SID04	J-SID05	748	24	Ductile Iron	130.0	0.960	0.30	-417.04	0.01	Zone - 2670
P-SID153	T-SID1	J-SID04	4,087	30	Ductile Iron	130.0	0.960	0.12	253.86	0.01	Zone - 2670

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd PEAK Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID154	J-SID62	J-SID49	4,256	24	Ductile Iron	130.0	0.960	1.57	2,218.53	1.65	Zone - 2920
P-SID157	J-SID59	PRV-SID12	2,038	24	Ductile Iron	130.0	0.980	0.44	620.35	0.08	Zone - 2920
P-SID158	J-SID48	J-SID81	6,506	24	Ductile Iron	130.0	0.600	0.28	-400.53	0.10	Zone - 2920
P-SID159	PRV-SID12	J-SID53	1,807	24	Ductile Iron	130.0	0.980	0.44	620.35	0.07	Zone - 2795
P-SID160	J-SID05	J-SID06	908	24	Ductile Iron	130.0	0.960	0.38	-541.86	0.03	Zone - 2670
P-SID164	R-1	PMP-A	296	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID165	PMP-A	J-SID29	2,377	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID166	J-SID81	J-SID62	1,823	24	Ductile Iron	130.0	0.000	1.61	2,271.37	0.72	<None>
P-SID170	J-SID04	PRV-SID14	146	16	Ductile Iron	130.0	1.690	0.87	546.08	0.05	Zone - 2670
P-SID171	PRV-SID14	J-SID03	1,443	16	Ductile Iron	130.0	1.690	0.87	546.08	0.31	Zone - 2670
P-SID175	PRV-SID05	J-SID75	1,437	24	Ductile Iron	130.0	0.960	1.05	1,483.44	0.27	Zone - 2795
P-SID176	PRV-SID09	J-SID40	1,782	30	Ductile Iron	130.0	0.500	0.03	56.53	0.00	Zone - 2445
P-SID178	PRV-SID15	J-SID11	175	24	Ductile Iron	130.0	0.960	0.92	1,290.74	0.04	Zone - 2670
P-SID180	J-SID60	PRV-SID08	781	16	Ductile Iron	130.0	1.690	0.81	-505.61	0.16	Zone - 2670
P-SID186	J-SID01	J-SID74	660	16	Ductile Iron	130.0	1.690	0.27	171.64	0.02	Zone - 2545
P-SID187	J-SID74	J-SID44	2,003	16	Ductile Iron	130.0	1.690	0.07	46.82	0.00	Zone - 2545
P-SID189	J-SID61	PRV-SID16	2,700	16	Ductile Iron	130.0	0.000	0.12	77.12	0.01	Zone - 2670
P-SID190	J-SID55	J-SID61	3,051	16	Ductile Iron	130.0	0.000	0.25	154.24	0.06	Zone - 2795
P-SID191	PRV-SID16	J-SID34	681	16	Ductile Iron	130.0	0.000	0.12	77.12	0.00	Zone - 2430
P-SID192	J-SID39	PRV-SID09	214	30	Ductile Iron	130.0	0.500	0.03	56.53	0.00	Zone - 2445
P-SID194	J-SID35	J-SID56	560	42	Ductile Iron	130.0	0.000	0.00	0.00	0.00	Zone - 2795
P-SID196	T-SID4	J-SID81	218	24	Ductile Iron	130.0	0.000	1.89	2,671.90	0.12	Zone - 2920

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd PEAK Demands
FlexTable: PRV Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Diameter (Valve) (in)	Hydraulic Grade Setting (Initial) (ft)	Pressure Setting (Initial) (psi)	Flow (gpm)	Pressure (From) (psi)	Pressure (To) (psi)	Downstream Pipe	Zone
PRV-SID05	2,535.0	24	2,795.1	112.6	1,483.44	176.3	112.6	P-SID175	Zone - 2920
PRV-SID07	2,335.0	16	2,545.0	90.9	438.52	144.7	90.9	P-SID80	Zone - 2670
PRV-SID08	2,435.0	16	2,670.0	101.7	505.61	155.5	101.8	P-SID180	Zone - 2795
PRV-SID09	2,185.0	30	2,445.0	112.6	56.53	155.8	112.6	P-SID176	Zone - 2545
PRV-SID10	2,200.0	16	2,445.1	106.1	0.00	149.0	106.1	P-SID130	Zone - 2445
PRV-SID11	2,325.0	30	2,545.0	95.2	113.07	201.0	95.3	P-SID131	Zone - 2670
PRV-SID12	2,575.0	24	2,795.0	95.2	620.35	158.7	95.3	P-SID159	Zone - 2920
PRV-SID14	2,300.0	16	2,545.1	106.1	546.08	157.9	106.1	P-SID171	Zone - 2670
PRV-SID15	2,452.0	24	2,670.0	94.4	1,290.74	148.3	94.4	P-SID178	Zone - 2795
PRV-SID16	2,450.0	16	2,670.0	95.2	77.12	147.1	95.2	P-SID191	Zone - 2670

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd PEAK Demands
FlexTable: Pump Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Pump Definition	Status (Initial)	Intake Grade (ft)	Discharge Grade (ft)	Discharge (gpm)	Pump Head (ft)	Zone
PMP-A	2,210.0	PMP A	Off	2,220.0	2,430.0	0.00	0.00	Zone - 2430
PMP-B1A	2,400.0	B1A	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1B	2,400.0	B1B	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1C	2,400.0	B1C	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B2A	2,580.0	B2A	Off	2,789.9	2,944.7	0.00	0.00	Zone - 2795
PMP-B2B	2,580.0	B2B	Off	2,789.9	2,944.7	0.00	0.00	Zone - 2795
PMP-B2C	2,580.0	B2C	Off	2,789.9	2,944.7	0.00	0.00	Zone - 2795

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd PEAK Demands
FlexTable: Simulated Connection Point Reservoir - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Flow (In net) (gpm)	Flow (Out net) (gpm)	Zone
R-1	2,220.0	0.00	0.00	Zone - 2430

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd PEAK Demands
FlexTable: Tank Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Elevation (Base) (ft)	Elevation (Minimum) (ft)	Elevation (Initial) (ft)	Elevation (Maximum) (ft)	Diameter (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)
T-SID1	2,640.0	2,640.0	2,655.0	2,665.0	2,670.0	170	253.86	2,665.0
T-SID2	2,400.0	2,400.0	2,420.0	2,430.0	2,430.0	170	432.21	2,430.0
T-SID3	2,765.0	2,765.0	2,780.0	2,790.0	2,795.0	240	1,516.34	2,790.0
T-SID4	2,920.0	2,920.0	2,935.0	2,945.0	2,950.0	170	2,671.90	2,945.0

Volume Full (Calculated) (MG)	Volume Full (Input) (MG)	Zone
2.55	5.00	Zone - 2670
1.70	5.00	Zone - 2430
5.08	10.00	Zone - 2795
2.55	5.00	Zone - 2920

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Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Junction Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Demand (gpm)	Pressure (psi)	Hydraulic Grade (ft)	Zone	Is Active?
J-SID01	2,240.0	59.72	132.0	2,545.0	Zone - 2545	True
J-SID02	2,255.0	59.72	125.5	2,545.0	Zone - 2670	True
J-SID03	2,260.0	59.72	123.3	2,545.1	Zone - 2670	True
J-SID04	2,305.0	59.72	155.8	2,665.0	Zone - 2670	True
J-SID05	2,320.0	59.72	149.3	2,665.1	Zone - 2670	True
J-SID06	2,330.0	59.72	145.0	2,665.1	Zone - 2670	True
J-SID07	2,360.0	59.72	132.2	2,665.5	Zone - 2670	True
J-SID08	2,370.0	59.72	128.3	2,666.6	Zone - 2670	True
J-SID09	2,380.0	59.72	124.3	2,667.3	Zone - 2670	True
J-SID10	2,425.0	59.72	105.3	2,668.5	Zone - 2670	True
J-SID11	2,450.0	59.72	95.2	2,670.1	Zone - 2670	True
J-SID12	2,350.0	25.28	187.5	2,783.4	Zone - 2670	True
J-SID13	2,475.0	25.28	133.4	2,783.4	Zone - 2795	True
J-SID29	2,210.0	0.00	134.1	2,520.0	Zone - 2430	True
J-SID30	2,266.0	0.00	109.9	2,520.0	Zone - 2430	True
J-SID31	2,300.0	0.00	95.2	2,520.0	Zone - 2430	True
J-SID32	2,336.0	103.50	79.6	2,520.0	Zone - 2430	True
J-SID33	2,275.0	103.30	67.0	2,430.0	Zone - 2430	True
J-SID34	2,408.0	36.90	113.4	2,670.1	Zone - 2430	True
J-SID35	2,575.0	26.98	90.2	2,783.5	Zone - 2795	True
J-SID36	2,500.0	179.68	122.6	2,783.4	Zone - 2795	True
J-SID38	2,260.0	0.00	123.4	2,545.2	Zone - 2545	True
J-SID39	2,190.0	27.05	153.7	2,545.2	Zone - 2545	True
J-SID40	2,165.0	27.05	121.2	2,445.2	Zone - 2445	True
J-SID41	2,170.0	0.00	119.1	2,445.2	Zone - 2445	True
J-SID43	2,230.0	172.50	136.3	2,545.0	Zone - 2545	True
J-SID44	2,230.0	59.72	136.3	2,545.0	Zone - 2545	True
J-SID46	2,445.0	340.40	146.4	2,783.4	Zone - 2795	True
J-SID48	2,675.0	52.26	143.4	3,006.4	Zone - 2920	True
J-SID49	2,535.0	0.00	177.5	2,945.3	Zone - 2920	True
J-SID51	2,623.0	139.38	198.5	3,081.7	Zone - 2795	True
J-SID52	2,520.0	0.00	119.0	2,795.0	Zone - 2795	True
J-SID53	2,515.0	54.90	121.2	2,795.2	Zone - 2795	True
J-SID55	2,400.0	0.00	194.7	2,850.1	Zone - 2795	True
J-SID56	2,580.0	0.00	87.9	2,783.1	Zone - 2795	True
J-SID57	2,580.0	0.00	231.4	3,114.9	Zone - 2795	True
J-SID59	2,650.0	54.90	127.7	2,945.1	Zone - 2920	True
J-SID60	2,440.0	32.10	99.6	2,670.2	Zone - 2670	True
J-SID61	2,425.0	36.90	183.9	2,850.1	Zone - 2670	True
J-SID62	2,600.0	25.28	149.8	2,946.2	Zone - 2920	True
J-SID74	2,225.0	59.72	138.4	2,545.0	Zone - 2545	True
J-SID75	2,491.0	92.20	131.5	2,795.0	Zone - 2795	True
J-SID81	2,690.0	0.00	111.0	2,946.5	Zone - 2920	True

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID02	J-SID01	J-SID02	1,946	16	Ductile Iron	130.0	1.690	0.21	-133.86	0.03	Zone - 2545
P-SID09	J-SID02	J-SID03	1,356	16	Ductile Iron	130.0	1.690	0.31	-193.58	0.04	Zone - 2670
P-SID12	J-SID06	J-SID07	898	16	Ductile Iron	130.0	0.960	1.30	-817.50	0.41	Zone - 2670
P-SID13	J-SID07	J-SID08	2,112	16	Ductile Iron	130.0	1.960	1.40	-877.22	1.09	Zone - 2670
P-SID14	J-SID08	J-SID09	1,090	16	Ductile Iron	130.0	1.960	1.50	-936.94	0.67	Zone - 2670
P-SID15	J-SID09	J-SID10	1,871	16	Ductile Iron	130.0	0.960	1.59	-996.66	1.20	Zone - 2670
P-SID16	J-SID10	J-SID11	2,206	16	Ductile Iron	130.0	0.960	1.69	-1,056.38	1.57	Zone - 2670
P-SID39	J-SID57	J-SID51	3,462	24	Ductile Iron	130.0	0.600	8.89	12,532.86	33.13	Zone - 2795
P-SID41	J-SID55	T-SID3	5,187	24	Ductile Iron	130.0	0.250	9.94	14,020.42	60.13	Zone - 2795
P-SID44	J-SID44	J-SID43	1,387	16	Ductile Iron	130.0	1.690	0.07	-45.30	0.00	Zone - 2545
P-SID50	PMP-B1A	J-SID55	50	24	Ductile Iron	130.0	0.250	6.11	8,615.77	0.38	Zone - 2795
P-SID51	J-SID40	J-SID41	3,772	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID57	J-SID53	J-SID52	3,295	16	Ductile Iron	130.0	1.690	0.40	249.91	0.16	Zone - 2795
P-SID58	J-SID38	J-SID39	5,926	30	Ductile Iron	130.0	0.500	0.02	54.10	0.00	Zone - 2445
P-SID63	J-SID35	J-SID36	8,958	24	Ductile Iron	130.0	0.500	0.20	284.34	0.08	Zone - 2795
P-SID64	T-SID3	J-SID35	4,531	36	Ductile Iron	130.0	0.250	4.16	13,184.58	6.53	Zone - 2795
P-SID65	PRV-SID07	J-SID60	3,972	16	Ductile Iron	130.0	1.690	0.35	-217.81	0.15	Zone - 2670
P-SID69	T-SID2	J-SID33	4,302	16	Ductile Iron	130.0	1.690	0.16	103.30	0.04	Zone - 2430
P-SID70	J-SID32	T-SID2	2,303	24	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID71	J-SID31	J-SID32	3,237	24	Ductile Iron	130.0	0.500	0.07	103.50	0.00	Zone - 2430
P-SID72	J-SID30	J-SID31	5,555	30	Ductile Iron	130.0	0.500	0.05	103.50	0.00	Zone - 2430
P-SID73	J-SID29	J-SID30	1,841	30	Ductile Iron	130.0	0.500	0.05	103.50	0.00	Zone - 2430
P-SID77	PMP-B1C	J-SID55	50	24	Ductile Iron	130.0	0.250	1.94	2,739.22	0.04	Zone - 2795
P-SID80	J-SID43	PRV-SID07	4,919	16	Ductile Iron	130.0	1.690	0.35	-217.81	0.19	Zone - 2545

Apex Master Plan Revisions 2012

Active Scenario: Backbone Hyd AVG Day Demands

FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID81	PMP-B2B	J-SID57	50	24	Ductile Iron	130.0	0.600	1.52	2,143.97	0.04	Zone - 2795
P-SID84	J-SID56	PMP-B2B	50	24	Ductile Iron	130.0	0.950	1.52	2,143.97	0.05	Zone - 2795
P-SID85	J-SID49	J-SID59	13,461	24	Ductile Iron	130.0	1.690	0.26	359.71	0.18	Zone - 2920
P-SID86	PMP-B2C	J-SID57	50	24	Ductile Iron	130.0	0.600	1.54	2,165.32	0.04	Zone - 2795
P-SID87	J-SID56	PMP-B2C	50	24	Ductile Iron	130.0	0.950	1.54	2,165.32	0.05	Zone - 2795
P-SID88	PRV-SID08	J-SID52	960	16	Ductile Iron	130.0	1.690	0.40	-249.91	0.05	Zone - 2795
P-SID89	J-SID51	J-SID48	8,137	24	Ductile Iron	130.0	0.600	8.79	12,393.48	75.30	Zone - 2795
P-SID90	PMP-B1B	J-SID55	50	24	Ductile Iron	130.0	0.250	1.94	2,739.22	0.04	Zone - 2795
P-SID91	J-SID56	PMP-B2A	50	24	Ductile Iron	130.0	0.950	5.83	8,223.56	0.72	Zone - 2795
P-SID94	J-SID35	J-SID46	6,307	24	Ductile Iron	130.0	1.690	0.24	340.40	0.08	Zone - 2795
P-SID97	PMP-B2A	J-SID57	50	24	Ductile Iron	130.0	0.600	5.83	8,223.56	0.53	Zone - 2795
P-SID99	J-SID36	J-SID13	1,169	24	Ductile Iron	130.0	0.500	0.07	104.66	0.00	Zone - 2795
P-SID114	J-SID49	PRV-SID05	149	24	Ductile Iron	130.0	0.960	0.86	1,208.30	0.03	Zone - 2920
P-SID115	J-SID75	PRV-SID15	1,533	24	Ductile Iron	130.0	0.960	0.79	1,116.10	0.17	Zone - 2795
P-SID121	J-SID13	J-SID12	3,415	24	Ductile Iron	130.0	0.250	0.06	79.38	0.00	Zone - 2795
P-SID122	T-SID2	PMP-B1C	50	30	Ductile Iron	130.0	0.160	1.24	2,739.22	0.01	Zone - 2430
P-SID123	T-SID2	PMP-B1B	50	30	Ductile Iron	130.0	0.160	1.24	2,739.22	0.01	Zone - 2430
P-SID124	T-SID2	PMP-B1A	50	30	Ductile Iron	130.0	0.160	3.91	8,615.77	0.12	Zone - 2430
P-SID129	J-SID43	PRV-SID10	747	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2545
P-SID130	PRV-SID10	J-SID41	3,377	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID131	J-SID38	PRV-SID11	2,293	30	Ductile Iron	130.0	0.500	0.02	-54.10	0.00	Zone - 2670
P-SID132	PRV-SID11	J-SID12	327	30	Ductile Iron	130.0	0.500	0.02	-54.10	0.00	Zone - 2670
P-SID150	J-SID04	J-SID05	748	24	Ductile Iron	130.0	0.960	0.50	-698.06	0.04	Zone - 2670
P-SID153	T-SID1	J-SID04	4,087	30	Ductile Iron	130.0	0.960	0.17	-385.04	0.02	Zone - 2670

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID154	J-SID62	J-SID49	4,256	24	Ductile Iron	130.0	0.960	1.11	1,568.01	0.87	Zone - 2920
P-SID157	J-SID59	PRV-SID12	2,038	24	Ductile Iron	130.0	0.980	0.22	304.81	0.02	Zone - 2920
P-SID158	J-SID48	J-SID81	6,506	24	Ductile Iron	130.0	0.600	8.75	12,341.22	59.88	Zone - 2920
P-SID159	PRV-SID12	J-SID53	1,807	24	Ductile Iron	130.0	0.980	0.22	304.81	0.02	Zone - 2795
P-SID160	J-SID05	J-SID06	908	24	Ductile Iron	130.0	0.960	0.54	-757.78	0.05	Zone - 2670
P-SID164	R-1	PMP-A	296	30	Ductile Iron	130.0	0.250	0.05	103.50	0.00	Zone - 2430
P-SID165	PMP-A	J-SID29	2,377	30	Ductile Iron	130.0	0.250	0.05	103.50	0.00	Zone - 2430
P-SID166	J-SID81	J-SID62	1,823	24	Ductile Iron	130.0	0.000	1.13	1,593.29	0.37	<None>
P-SID170	J-SID04	PRV-SID14	146	16	Ductile Iron	130.0	1.690	0.40	253.30	0.01	Zone - 2670
P-SID171	PRV-SID14	J-SID03	1,443	16	Ductile Iron	130.0	1.690	0.40	253.30	0.08	Zone - 2670
P-SID175	PRV-SID05	J-SID75	1,437	24	Ductile Iron	130.0	0.960	0.86	1,208.30	0.19	Zone - 2795
P-SID176	PRV-SID09	J-SID40	1,782	30	Ductile Iron	130.0	0.500	0.01	27.05	0.00	Zone - 2445
P-SID178	PRV-SID15	J-SID11	175	24	Ductile Iron	130.0	0.960	0.79	1,116.10	0.03	Zone - 2670
P-SID180	J-SID60	PRV-SID08	781	16	Ductile Iron	130.0	1.690	0.40	-249.91	0.04	Zone - 2670
P-SID186	J-SID01	J-SID74	660	16	Ductile Iron	130.0	1.690	0.12	74.14	0.00	Zone - 2545
P-SID187	J-SID74	J-SID44	2,003	16	Ductile Iron	130.0	1.690	0.02	14.42	0.00	Zone - 2545
P-SID189	J-SID61	PRV-SID16	2,700	16	Ductile Iron	130.0	0.000	0.06	36.90	0.00	Zone - 2670
P-SID190	J-SID55	J-SID61	3,051	16	Ductile Iron	130.0	0.000	0.12	73.80	0.02	Zone - 2795
P-SID191	PRV-SID16	J-SID34	681	16	Ductile Iron	130.0	0.000	0.06	36.90	0.00	Zone - 2430
P-SID192	J-SID39	PRV-SID09	214	30	Ductile Iron	130.0	0.500	0.01	27.05	0.00	Zone - 2445
P-SID194	J-SID35	J-SID56	560	42	Ductile Iron	130.0	0.000	2.90	12,532.86	0.34	Zone - 2795
P-SID196	T-SID4	J-SID81	218	24	Ductile Iron	130.0	0.000	7.62	-10,747.93	1.53	Zone - 2920

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Apex Master Plan Revisions 2012

Active Scenario: Backbone Hyd AVG Day Demands

FlexTable: PRV Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Diameter (Valve) (in)	Hydraulic Grade Setting (Initial) (ft)	Pressure Setting (Initial) (psi)	Flow (gpm)	Pressure (From) (psi)	Pressure (To) (psi)	Downstream Pipe	Zone
PRV-SID05	2,535.0	24	2,795.1	112.6	1,208.30	177.5	112.6	P-SID175	Zone - 2920
PRV-SID07	2,335.0	16	2,545.0	90.9	217.81	144.9	90.9	P-SID80	Zone - 2670
PRV-SID08	2,435.0	16	2,670.0	101.7	249.91	155.7	101.8	P-SID180	Zone - 2795
PRV-SID09	2,185.0	30	2,445.0	112.6	27.05	155.8	112.6	P-SID176	Zone - 2545
PRV-SID10	2,200.0	16	2,445.1	106.1	0.00	149.3	106.1	P-SID130	Zone - 2445
PRV-SID11	2,325.0	30	2,545.0	95.2	54.10	198.3	95.3	P-SID131	Zone - 2670
PRV-SID12	2,575.0	24	2,795.0	95.2	304.81	160.1	95.3	P-SID159	Zone - 2920
PRV-SID14	2,300.0	16	2,545.1	106.1	253.30	157.9	106.1	P-SID171	Zone - 2670
PRV-SID15	2,452.0	24	2,670.0	94.4	1,116.10	148.3	94.4	P-SID178	Zone - 2795
PRV-SID16	2,450.0	16	2,670.0	95.2	36.90	173.1	95.2	P-SID191	Zone - 2670

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Pump Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Pump Definition	Status (Initial)	Intake Grade (ft)	Discharge Grade (ft)	Discharge (gpm)	Pump Head (ft)	Zone
PMP-A	2,210.0	PMP A	On	2,220.0	2,520.0	103.50	300.00	Zone - 2430
PMP-B1A	2,400.0	B1A	On	2,429.9	2,850.5	8,615.77	420.62	Zone - 2430
PMP-B1B	2,400.0	B1B	On	2,430.0	2,850.2	2,739.22	420.19	Zone - 2430
PMP-B1C	2,400.0	B1C	On	2,430.0	2,850.2	2,739.22	420.19	Zone - 2430
PMP-B2A	2,580.0	B2A	On	2,782.4	3,115.4	8,223.56	332.97	Zone - 2795
PMP-B2B	2,580.0	B2B	On	2,783.1	3,114.9	2,143.97	331.82	Zone - 2795
PMP-B2C	2,580.0	B2C	On	2,783.1	3,114.9	2,165.32	331.82	Zone - 2795

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
Reservoir FlexTable: Table - 1 (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Flow (In net) (gpm)	Flow (Out net) (gpm)	Zone
R-1	2,220.0	-103.50	103.50	Zone - 2430

Apex Master Plan Revisions 2012
Active Scenario: Backbone Hyd AVG Day Demands
FlexTable: Tank Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Elevation (Base) (ft)	Elevation (Minimum) (ft)	Elevation (Initial) (ft)	Elevation (Maximum) (ft)	Diameter (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)	Volume Full (Calculated) (MG)	Volume Full (Input) (MG)	Zone
T-SID1	2,640.0	2,640.0	2,655.0	2,665.0	2,670.0	170	-385.04	2,665.0	2.55	5.00	Zone - 2670
T-SID2	2,400.0	2,400.0	2,420.0	2,430.0	2,430.0	170	14,197.52	2,430.0	1.70	5.00	Zone - 2430
T-SID3	2,765.0	2,765.0	2,780.0	2,790.0	2,795.0	240	-835.84	2,790.0	5.08	10.00	Zone - 2795
T-SID4	2,920.0	2,920.0	2,935.0	2,945.0	2,950.0	170	-10,747.93	2,945.0	2.55	5.00	Zone - 2920

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Apex Master Plan Revisions 2012

Active Scenario: Backbone Fire Flow PEAK Demands

Junction FlexTable: Fire Flow Node Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Satisfies Fire Flow Constraints?	Demand (gpm)	Fire Flow (Needed) (gpm)	Fire Flow (Available) (gpm)	Pressure (psi)	Pressure (Calculated System Lower Limit) (psi)	Pressure (System Lower Limit) (psi)	Is Fire Flow Run Balanced?	Zone
J-SID01	True	124.81	6,000.00	6,001.00	131.7	40.7	20.0	True	Zone - 2545
J-SID02	True	124.81	6,000.00	6,001.00	125.3	40.7	20.0	True	Zone - 2670
J-SID03	True	124.81	6,000.00	6,001.00	123.2	40.7	20.0	True	Zone - 2670
J-SID04	True	124.81	6,000.00	6,001.00	155.8	40.7	20.0	True	Zone - 2670
J-SID05	True	124.81	6,000.00	6,001.00	149.3	40.7	20.0	True	Zone - 2670
J-SID06	True	124.81	6,000.00	6,001.00	145.0	40.7	20.0	True	Zone - 2670
J-SID07	True	124.81	6,000.00	6,001.00	132.1	40.7	20.0	True	Zone - 2670
J-SID08	True	124.81	6,000.00	6,001.00	128.2	40.7	20.0	True	Zone - 2670
J-SID09	True	124.81	6,000.00	6,001.00	124.1	40.7	20.0	True	Zone - 2670
J-SID10	True	124.81	6,000.00	6,001.00	105.2	40.7	20.0	True	Zone - 2670
J-SID11	True	124.81	6,000.00	6,001.00	95.2	40.7	20.0	True	Zone - 2670
J-SID12	True	52.84	6,000.00	6,001.00	190.2	40.7	20.0	True	Zone - 2670
J-SID13	True	52.84	6,000.00	6,001.00	136.1	40.7	20.0	True	Zone - 2795
J-SID29	True	0.00	6,000.00	6,001.00	95.2	38.1	20.0	True	Zone - 2430
J-SID30	True	0.00	6,000.00	6,001.00	70.9	38.1	20.0	True	Zone - 2430
J-SID31	True	0.00	6,000.00	6,001.00	56.2	38.1	20.0	True	Zone - 2430
J-SID32	True	216.32	6,000.00	6,001.00	40.7	53.6	20.0	True	Zone - 2430
J-SID33	True	215.90	6,000.00	6,001.00	67.0	40.7	20.0	True	Zone - 2430
J-SID34	True	77.12	6,000.00	6,001.00	113.4	40.7	20.0	True	Zone - 2430
J-SID35	True	56.39	6,000.00	6,001.00	93.0	40.7	20.0	True	Zone - 2795
J-SID36	True	375.53	6,000.00	6,001.00	125.3	40.7	20.0	True	Zone - 2795
J-SID38	True	0.00	6,000.00	6,001.00	123.4	40.7	20.0	True	Zone - 2545
J-SID39	True	56.53	6,000.00	6,001.00	153.7	40.7	20.0	True	Zone - 2545
J-SID40	True	56.53	6,000.00	6,001.00	121.2	40.7	20.0	True	Zone - 2445
J-SID41	True	0.00	6,000.00	6,001.00	119.1	40.7	20.0	True	Zone - 2445
J-SID43	True	360.52	6,000.00	6,001.00	136.1	40.7	20.0	True	Zone - 2545
J-SID44	True	124.81	6,000.00	6,001.00	136.1	40.7	20.0	True	Zone - 2545
J-SID46	True	711.44	6,000.00	6,001.00	149.1	40.7	20.0	True	Zone - 2795
J-SID48	True	109.22	6,000.00	6,001.00	116.7	40.7	20.0	True	Zone - 2920
J-SID49	True	0.00	6,000.00	6,001.00	176.3	40.7	20.0	True	Zone - 2920
J-SID51	True	291.30	6,000.00	6,001.00	139.2	40.7	20.0	True	Zone - 2795
J-SID52	True	0.00	6,000.00	6,001.00	118.8	40.7	20.0	True	Zone - 2795
J-SID53	True	114.74	6,000.00	6,001.00	121.2	40.7	20.0	True	Zone - 2795
J-SID55	True	0.00	6,000.00	6,001.00	168.7	40.7	20.0	True	Zone - 2795
J-SID56	True	0.00	6,000.00	6,001.00	90.8	40.7	20.0	True	Zone - 2795
J-SID57	True	0.00	6,000.00	6,001.00	157.8	40.7	20.0	True	Zone - 2795
J-SID59	True	114.74	6,000.00	6,001.00	126.3	40.7	20.0	True	Zone - 2920
J-SID60	True	67.09	6,000.00	6,001.00	99.5	40.7	20.0	True	Zone - 2670
J-SID61	True	77.12	6,000.00	6,001.00	157.9	40.7	20.0	True	Zone - 2670
J-SID62	True	52.84	6,000.00	6,001.00	148.9	40.7	20.0	True	Zone - 2920
J-SID74	True	124.81	6,000.00	6,001.00	138.2	40.7	20.0	True	Zone - 2545
J-SID75	True	192.70	6,000.00	6,001.00	131.5	40.7	20.0	True	Zone - 2795
J-SID81	True	0.00	6,000.00	6,001.00	110.3	40.7	20.0	True	Zone - 2920

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow PEAK Demands
FlexTable: Junction Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Demand (gpm)	Pressure (psi)	Hydraulic Grade (ft)	Zone	Is Active?
J-SID01	2,240.0	124.81	131.7	2,544.5	Zone - 2545	True
J-SID02	2,255.0	124.81	125.3	2,544.6	Zone - 2670	True
J-SID03	2,260.0	124.81	123.2	2,544.8	Zone - 2670	True
J-SID04	2,305.0	124.81	155.8	2,665.0	Zone - 2670	True
J-SID05	2,320.0	124.81	149.3	2,665.0	Zone - 2670	True
J-SID06	2,330.0	124.81	145.0	2,665.0	Zone - 2670	True
J-SID07	2,360.0	124.81	132.1	2,665.3	Zone - 2670	True
J-SID08	2,370.0	124.81	128.2	2,666.2	Zone - 2670	True
J-SID09	2,380.0	124.81	124.1	2,666.9	Zone - 2670	True
J-SID10	2,425.0	124.81	105.2	2,668.2	Zone - 2670	True
J-SID11	2,450.0	124.81	95.2	2,670.0	Zone - 2670	True
J-SID12	2,350.0	52.84	190.2	2,789.6	Zone - 2670	True
J-SID13	2,475.0	52.84	136.1	2,789.6	Zone - 2795	True
J-SID29	2,210.0	0.00	95.2	2,430.0	Zone - 2430	True
J-SID30	2,266.0	0.00	70.9	2,430.0	Zone - 2430	True
J-SID31	2,300.0	0.00	56.2	2,430.0	Zone - 2430	True
J-SID32	2,336.0	216.32	40.7	2,430.0	Zone - 2430	True
J-SID33	2,275.0	215.90	67.0	2,429.8	Zone - 2430	True
J-SID34	2,408.0	77.12	113.4	2,670.1	Zone - 2430	True
J-SID35	2,575.0	56.39	93.0	2,789.9	Zone - 2795	True
J-SID36	2,500.0	375.53	125.3	2,789.6	Zone - 2795	True
J-SID38	2,260.0	0.00	123.4	2,545.2	Zone - 2545	True
J-SID39	2,190.0	56.53	153.7	2,545.2	Zone - 2545	True
J-SID40	2,165.0	56.53	121.2	2,445.2	Zone - 2445	True
J-SID41	2,170.0	0.00	119.1	2,445.2	Zone - 2445	True
J-SID43	2,230.0	360.52	136.1	2,544.5	Zone - 2545	True
J-SID44	2,230.0	124.81	136.1	2,544.5	Zone - 2545	True
J-SID46	2,445.0	711.44	149.1	2,789.6	Zone - 2795	True
J-SID48	2,675.0	109.22	116.7	2,944.8	Zone - 2920	True
J-SID49	2,535.0	0.00	176.3	2,942.5	Zone - 2920	True
J-SID51	2,623.0	291.30	139.2	2,944.7	Zone - 2795	True
J-SID52	2,520.0	0.00	118.8	2,794.5	Zone - 2795	True
J-SID53	2,515.0	114.74	121.2	2,795.1	Zone - 2795	True
J-SID55	2,400.0	0.00	168.7	2,790.0	Zone - 2795	True
J-SID56	2,580.0	0.00	90.8	2,789.9	Zone - 2795	True
J-SID57	2,580.0	0.00	157.8	2,944.7	Zone - 2795	True
J-SID59	2,650.0	114.74	126.3	2,941.8	Zone - 2920	True
J-SID60	2,440.0	67.09	99.5	2,670.1	Zone - 2670	True
J-SID61	2,425.0	77.12	157.9	2,789.9	Zone - 2670	True
J-SID62	2,600.0	52.84	148.9	2,944.2	Zone - 2920	True
J-SID74	2,225.0	124.81	138.2	2,544.5	Zone - 2545	True
J-SID75	2,491.0	192.70	131.5	2,794.9	Zone - 2795	True
J-SID81	2,690.0	0.00	110.3	2,944.9	Zone - 2920	True

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Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow PEAK Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID02	J-SID01	J-SID02	1,946	16	Ductile Iron	130.0	1.690	0.47	-296.45	0.13	Zone - 2545
P-SID09	J-SID02	J-SID03	1,356	16	Ductile Iron	130.0	1.690	0.67	-421.27	0.18	Zone - 2670
P-SID12	J-SID06	J-SID07	898	16	Ductile Iron	130.0	0.960	1.06	-666.67	0.28	Zone - 2670
P-SID13	J-SID07	J-SID08	2,112	16	Ductile Iron	130.0	1.960	1.26	-791.49	0.90	Zone - 2670
P-SID14	J-SID08	J-SID09	1,090	16	Ductile Iron	130.0	1.960	1.46	-916.30	0.64	Zone - 2670
P-SID15	J-SID09	J-SID10	1,871	16	Ductile Iron	130.0	0.960	1.66	-1,041.11	1.30	Zone - 2670
P-SID16	J-SID10	J-SID11	2,206	16	Ductile Iron	130.0	0.960	1.86	-1,165.93	1.88	Zone - 2670
P-SID39	J-SID57	J-SID51	3,462	24	Ductile Iron	130.0	0.600	0.00	-0.01	0.00	Zone - 2795
P-SID41	J-SID55	T-SID3	5,187	24	Ductile Iron	130.0	0.250	0.11	-154.25	0.01	Zone - 2795
P-SID44	J-SID44	J-SID43	1,387	16	Ductile Iron	130.0	1.690	0.12	-77.99	0.01	Zone - 2545
P-SID50	PMP-B1A	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID51	J-SID40	J-SID41	3,772	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID57	J-SID53	J-SID52	3,295	16	Ductile Iron	130.0	1.690	0.81	505.61	0.60	Zone - 2795
P-SID58	J-SID38	J-SID39	5,926	30	Ductile Iron	130.0	0.500	0.05	113.07	0.00	Zone - 2445
P-SID63	J-SID35	J-SID36	8,958	24	Ductile Iron	130.0	0.500	0.42	594.27	0.30	Zone - 2795
P-SID64	T-SID3	J-SID35	4,531	36	Ductile Iron	130.0	0.250	0.43	1,362.10	0.10	Zone - 2795
P-SID65	PRV-SID07	J-SID60	3,972	16	Ductile Iron	130.0	1.690	0.70	-438.52	0.55	Zone - 2670
P-SID69	T-SID2	J-SID33	4,302	16	Ductile Iron	130.0	1.690	0.34	215.90	0.16	Zone - 2430
P-SID70	J-SID32	T-SID2	2,303	24	Ductile Iron	130.0	0.500	0.15	-216.32	0.01	Zone - 2430
P-SID71	J-SID31	J-SID32	3,237	24	Ductile Iron	130.0	0.500	0.00	-0.01	0.00	Zone - 2430
P-SID72	J-SID30	J-SID31	5,555	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID73	J-SID29	J-SID30	1,841	30	Ductile Iron	130.0	0.500	0.00	0.00	0.00	Zone - 2430
P-SID77	PMP-B1C	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID80	J-SID43	PRV-SID07	4,919	16	Ductile Iron	130.0	1.690	0.70	-438.52	0.68	Zone - 2545

Apex Master Plan Revisions 2012

Active Scenario: Backbone Fire Flow PEAK Demands

FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID81	PMP-B2B	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID84	J-SID56	PMP-B2B	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID85	J-SID49	J-SID59	13,461	24	Ductile Iron	130.0	1.690	0.52	735.09	0.67	Zone - 2920
P-SID86	PMP-B2C	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID87	J-SID56	PMP-B2C	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID88	PRV-SID08	J-SID52	960	16	Ductile Iron	130.0	1.690	0.81	-505.61	0.19	Zone - 2795
P-SID89	J-SID51	J-SID48	8,137	24	Ductile Iron	130.0	0.600	0.21	-291.31	0.07	Zone - 2795
P-SID90	PMP-B1B	J-SID55	50	24	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2795
P-SID91	J-SID56	PMP-B2A	50	24	Ductile Iron	130.0	0.950	0.00	0.00	0.00	Zone - 2795
P-SID94	J-SID35	J-SID46	6,307	24	Ductile Iron	130.0	1.690	0.50	711.44	0.30	Zone - 2795
P-SID97	PMP-B2A	J-SID57	50	24	Ductile Iron	130.0	0.600	0.00	0.00	0.00	Zone - 2795
P-SID99	J-SID36	J-SID13	1,169	24	Ductile Iron	130.0	0.500	0.16	218.74	0.01	Zone - 2795
P-SID114	J-SID49	PRV-SID05	149	24	Ductile Iron	130.0	0.960	1.05	1,483.44	0.04	Zone - 2920
P-SID115	J-SID75	PRV-SID15	1,533	24	Ductile Iron	130.0	0.960	0.92	1,290.74	0.23	Zone - 2795
P-SID121	J-SID13	J-SID12	3,415	24	Ductile Iron	130.0	0.250	0.12	165.90	0.01	Zone - 2795
P-SID122	T-SID2	PMP-B1C	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID123	T-SID2	PMP-B1B	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID124	T-SID2	PMP-B1A	50	30	Ductile Iron	130.0	0.160	0.00	0.00	0.00	Zone - 2430
P-SID129	J-SID43	PRV-SID10	747	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2545
P-SID130	PRV-SID10	J-SID41	3,377	16	Ductile Iron	130.0	1.690	0.00	0.00	0.00	Zone - 2445
P-SID131	J-SID38	PRV-SID11	2,293	30	Ductile Iron	130.0	0.500	0.05	-113.07	0.00	Zone - 2670
P-SID132	PRV-SID11	J-SID12	327	30	Ductile Iron	130.0	0.500	0.05	-113.07	0.00	Zone - 2670
P-SID150	J-SID04	J-SID05	748	24	Ductile Iron	130.0	0.960	0.30	-417.04	0.01	Zone - 2670
P-SID153	T-SID1	J-SID04	4,087	30	Ductile Iron	130.0	0.960	0.12	253.86	0.01	Zone - 2670
P-SID154	J-SID62	J-SID49	4,256	24	Ductile Iron	130.0	0.960	1.57	2,218.53	1.65	Zone - 2920

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow PEAK Demands
FlexTable: Pipe Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Start Node	Stop Node	Length (ft)	Diameter (in)	Material	Hazen-Williams C	Minor Loss Coefficient (Local)	Velocity (ft/s)	Flow (gpm)	Headloss (ft)	Zone
P-SID157	J-SID59	PRV-SID12	2,038	24	Ductile Iron	130.0	0.980	0.44	620.35	0.08	Zone - 2920
P-SID158	J-SID48	J-SID81	6,506	24	Ductile Iron	130.0	0.600	0.28	-400.53	0.10	Zone - 2920
P-SID159	PRV-SID12	J-SID53	1,807	24	Ductile Iron	130.0	0.980	0.44	620.35	0.07	Zone - 2795
P-SID160	J-SID05	J-SID06	908	24	Ductile Iron	130.0	0.960	0.38	-541.86	0.03	Zone - 2670
P-SID164	R-1	PMP-A	296	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID165	PMP-A	J-SID29	2,377	30	Ductile Iron	130.0	0.250	0.00	0.00	0.00	Zone - 2430
P-SID166	J-SID81	J-SID62	1,823	24	Ductile Iron	130.0	0.000	1.61	2,271.37	0.72	<None>
P-SID170	J-SID04	PRV-SID14	146	16	Ductile Iron	130.0	1.690	0.87	546.08	0.05	Zone - 2670
P-SID171	PRV-SID14	J-SID03	1,443	16	Ductile Iron	130.0	1.690	0.87	546.08	0.31	Zone - 2670
P-SID175	PRV-SID05	J-SID75	1,437	24	Ductile Iron	130.0	0.960	1.05	1,483.44	0.27	Zone - 2795
P-SID176	PRV-SID09	J-SID40	1,782	30	Ductile Iron	130.0	0.500	0.03	56.53	0.00	Zone - 2445
P-SID178	PRV-SID15	J-SID11	175	24	Ductile Iron	130.0	0.960	0.92	1,290.74	0.04	Zone - 2670
P-SID180	J-SID60	PRV-SID08	781	16	Ductile Iron	130.0	1.690	0.81	-505.61	0.16	Zone - 2670
P-SID186	J-SID01	J-SID74	660	16	Ductile Iron	130.0	1.690	0.27	171.64	0.02	Zone - 2545
P-SID187	J-SID74	J-SID44	2,003	16	Ductile Iron	130.0	1.690	0.07	46.82	0.00	Zone - 2545
P-SID189	J-SID61	PRV-SID16	2,700	16	Ductile Iron	130.0	0.000	0.12	77.12	0.01	Zone - 2670
P-SID190	J-SID55	J-SID61	3,051	16	Ductile Iron	130.0	0.000	0.25	154.24	0.06	Zone - 2795
P-SID191	PRV-SID16	J-SID34	681	16	Ductile Iron	130.0	0.000	0.12	77.12	0.00	Zone - 2430
P-SID192	J-SID39	PRV-SID09	214	30	Ductile Iron	130.0	0.500	0.03	56.53	0.00	Zone - 2445
P-SID194	J-SID35	J-SID56	560	42	Ductile Iron	130.0	0.000	0.00	0.00	0.00	Zone - 2795
P-SID196	T-SID4	J-SID81	218	24	Ductile Iron	130.0	0.000	1.89	2,671.90	0.12	Zone - 2920

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Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow PEAK Demands
FlexTable: PRV Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Diameter (Valve) (in)	Hydraulic Grade Setting (Initial) (ft)	Pressure Setting (Initial) (psi)	Flow (gpm)	Pressure (From) (psi)	Pressure (To) (psi)	Downstream Pipe	Zone
PRV-SID05	2,535.0	24	2,795.1	112.6	1,483.44	176.3	112.6	P-SID175	Zone - 2920
PRV-SID07	2,335.0	16	2,545.0	90.9	438.52	144.7	90.9	P-SID80	Zone - 2670
PRV-SID08	2,435.0	16	2,670.0	101.7	505.61	155.5	101.8	P-SID180	Zone - 2795
PRV-SID09	2,185.0	30	2,445.0	112.6	56.53	155.8	112.6	P-SID176	Zone - 2545
PRV-SID10	2,200.0	16	2,445.1	106.1	0.00	149.0	106.1	P-SID130	Zone - 2445
PRV-SID11	2,325.0	30	2,545.0	95.2	113.07	201.0	95.3	P-SID131	Zone - 2670
PRV-SID12	2,575.0	24	2,795.0	95.2	620.35	158.7	95.3	P-SID159	Zone - 2920
PRV-SID14	2,300.0	16	2,545.1	106.1	546.08	157.9	106.1	P-SID171	Zone - 2670
PRV-SID15	2,452.0	24	2,670.0	94.4	1,290.74	148.3	94.4	P-SID178	Zone - 2795
PRV-SID16	2,450.0	16	2,670.0	95.2	77.12	147.1	95.2	P-SID191	Zone - 2670

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow PEAK Demands
FlexTable: Pump Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Pump Definition	Status (Initial)	Intake Grade (ft)	Discharge Grade (ft)	Discharge (gpm)	Pump Head (ft)	Zone
PMP-A	2,210.0	PMP A	Off	2,220.0	2,430.0	0.00	0.00	Zone - 2430
PMP-B1A	2,400.0	B1A	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1B	2,400.0	B1B	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B1C	2,400.0	B1C	Off	2,430.0	2,790.0	0.00	0.00	Zone - 2430
PMP-B2A	2,580.0	B2A	Off	2,789.9	2,944.7	0.00	0.00	Zone - 2795
PMP-B2B	2,580.0	B2B	Off	2,789.9	2,944.7	0.00	0.00	Zone - 2795
PMP-B2C	2,580.0	B2C	Off	2,789.9	2,944.7	0.00	0.00	Zone - 2795

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow PEAK Demands
FlexTable: Simulated Connection Point Reservoir - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Flow (In net) (gpm)	Flow (Out net) (gpm)	Zone
R-1	2,220.0	0.00	0.00	Zone - 2430

Apex Master Plan Revisions 2012
Active Scenario: Backbone Fire Flow PEAK Demands
FlexTable: Tank Table - APEX (APEX 10 2012 rev1.wtg)

Current Time: 0.000 hours

Label	Elevation (ft)	Elevation (Base) (ft)	Elevation (Minimum) (ft)	Elevation (Initial) (ft)	Elevation (Maximum) (ft)	Diameter (ft)	Flow (Out net) (gpm)	Hydraulic Grade (ft)	Volume Full (Calculated) (MG)	Volume Full (Input) (MG)	Zone
T-SID1	2,640.0	2,640.0	2,655.0	2,665.0	2,670.0	170	253.86	2,665.0	2.55	5.00	Zone - 2670
T-SID2	2,400.0	2,400.0	2,420.0	2,430.0	2,430.0	170	432.21	2,430.0	1.70	5.00	Zone - 2430
T-SID3	2,765.0	2,765.0	2,780.0	2,790.0	2,795.0	240	1,516.35	2,790.0	5.08	10.00	Zone - 2795
T-SID4	2,920.0	2,920.0	2,935.0	2,945.0	2,950.0	170	2,671.90	2,945.0	2.55	5.00	Zone - 2920

APPENDIX D

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D1 - Wastewater Design Flow Calculations

This sheet presents calculations for establishing the wastewater design flow rate for the Apex Industrial Park. The design flow rate is determined using CNLV municipal code section 13.24.070 and Design and Construction Standards for Wastewater Collection Systems Section 2.2.1

Average Wastewater Flow Rate per Acre

Average Flow Rate Per Fixture Unit

0.45	ERU/fixture unit	Office/warehouse value per CNLV Code Section 13.24.070

Design Building Structure

208	Fixture Units	Number of fixture units per design building
23	Acres	Number of acres per design building

Standard ERU Flow Rate

250	gpm/ERU	Assumed typical value

Average Flow Rate

0.707	gpm/acre	Average wastewater flow rate per acre of development

Peak Wastewater Flow Rate per Acre

7670	Acres	Total Apex Industrial Park developable acreage

Flow Rate

12.1	cfs	Average wastewater flow at Apex Industrial Park buildout

Peak Factor

2.2	unitless	From DCSWCS Table C

Peak Flow Rate

1.55	gpm/acre	Peak wastewater flow rate per acre of development

Design Wastewater Flow Rate per Acre

Wet Weather Allowance

1.55	gpm/acre	Peak wastewater flow rate per acre
0.25	unitless	Wet weather allowance factor
0.389	gpm/acre	Wet Weather Allowance

Design Flow Rate

Design Flow Rate = Peak Flow Rate + Wet Weather Allowance

1.94	gpm/acre	Design wastewater flow rate per acre of development

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D2 - Sewershed Acreages and Design Flows

Sewershed Number	Acreage	Design Flow (gpm)
K1	311	603
K2	285	553
K3	358	695
K4	425	825
K5	401	778
K6	247	479
K7	42	81
K7A	223	433
K8	148	287
K9	59	114
12	315	611
13	316	613
14	195	378
15	103	200
16	225	437
17	176	341
18	182	353
19	19	37
20	157	305
21	9	17
22	7	14
23	69	134
24	238	462
25	184	357
26	444	861
27	139	270
28	126	244
29	92	178
30	155	301
31	12	23
32	233	452
33	98	190
34	133	258
35	181	351
36	12	23
37	25	49
38	252	489
39	5	10
40	101	196
41	5	10
42	238	462
43	131	254
44	59	114
45	127	246
46	35	68
47	39	76
48	295	572
49	39	76
	7670	**14880**

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D3 - Wastewater Collection System Pipeline Design Point Tributary Acreages

Design Point No.	Tributary Area Numbers	Tributary Areas Acres	Total Acreage for Design Point	Design Flow Rate (gpm)
1	12	315	315	611
2	K1	311	311	603
3	12	315	911	1767
	K1	311		
	K2	285		
4	12	315	1336	2592
	K1	311		
	K2	285		
	K4	425		
5	K3	358	358	695
6	K3	358	759	1472
	K5	401		
7	K7A	223	223	433
8	K3	358	1024	1987
	K5	401		
	K7A	223		
	K7	42		
9	12	315	1583	3071
	K1	311		
	K2	285		
	K4	425		
	K6	247		
10	12	315	2607	5058
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
11	16	225	225	437
12	12	315	3147	6105
	16	225		
	12	315		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
13	14	195	195	378
14	13	316	511	991
	14	195		
15	13	316	614	1191
	14	195		
	15	103		

Item D3 - Wastewater Collection System Pipeline Design Point Tributary Acreages

Design Point No.	Tributary Area Numbers	Tributary Areas Acres	Total Acreage for Design Point	Design Flow Rate (gpm)
16	12	315	3446	6685
	13	316		
	14	195		
	15	103		
	16	225		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
17	17	176	176	341
18	12	315	3622	7027
	13	316		
	14	195		
	15	103		
	16	225		
	17	176		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
19	18	182	201	390
	19	19		
20	12	315	3823	7417
	13	316		
	14	195		
	15	103		
	16	225		
	17	176		
	18	182		
	19	19		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
21	20	157	173	336
	21	9		
	22	7		

Item D3 - Wastewater Collection System Pipeline Design Point Tributary Acreages

Design Point No.	Tributary Area Numbers	Tributary Areas Acres	Total Acreage for Design Point	Design Flow Rate (gpm)
22	12	315	3996	7752
	13	316		
	14	195		
	15	103		
	16	225		
	17	176		
	18	182		
	19	19		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
	20	157		
	21	9		
	22	7		
23	38	252	252	489
24	38	252	618	1199
	32	233		
	34	133		
25	38	252	716	1389
	32	233		
	34	133		
	33	98		
26	38	252	897	1740
	32	233		
	34	133		
	33	98		
	35	181		
27	38	252	897	1740
	32	233		
	34	133		
	33	98		
	35	181		
28	36	12	250	485
	24	238		
29	23	69	69	134
30	38	252	1216	2359
	32	233		
	34	133		
	33	98		
	35	181		
	23	69		
	24	238		
	36	12		

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D3 - Wastewater Collection System Pipeline Design Point Tributary Acreages

Design Point No.	Tributary Area Numbers	Tributary Areas Acres	Total Acreage for Design Point	Design Flow Rate (gpm)
31	38	252	1400	2716
	32	233		
	34	133		
	33	98		
	35	181		
	23	69		
	24	238		
	36	12		
	25	184		
32	28	126	126	244
33	27	139	139	270
34	29	92	92	178
35	30	155	155	301
36	29	92	247	479
	30	155		
37	27	139	512	993
	28	126		
	29	92		
	30	155		
38	26	444	225	437
39	26	444	1270	2464
	27	139		
	28	126		
	29	92		
	30	155		
	34	133		
	35	181		
40	Not Used	Not Used	Not Used	Not Used
41	12	315	4127	8006
	13	316		
	14	195		
	15	103		
	16	225		
	17	176		
	18	182		
	19	19		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
	20	157		
	21	9		
	22	7		
	43	131		

Item D3 - Wastewater Collection System Pipeline Design Point Tributary Acreages

Design Point No.	Tributary Area Numbers	Tributary Areas Acres	Total Acreage for Design Point	Design Flow Rate (gpm)
42	12	315	6488	12587
	13	316		
	14	195		
	15	103		
	16	225		
	17	176		
	18	182		
	19	19		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
	20	157		
	21	9		
	22	7		
	43	131		
	26	444		
	27	139		
	28	126		
	29	92		
	30	155		
	34	133		
	35	181		
	36	12		
	38	252		
	41	5		
	32	233		
	33	98		
	23	69		
	24	238		
	25	184		

Design Point No.	Tributary Area Numbers	Tributary Areas Acres	Total Acreage for Design Point	Design Flow Rate (gpm)
43	12	315	6614	12831
	13	316		
	14	195		
	15	103		
	16	225		
	17	176		
	18	182		
	19	19		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
	20	157		
	21	9		
	22	7		
	43	131		
	26	444		
	27	139		
	28	126		
	29	92		
	30	155		
	34	133		
	35	181		
	36	12		
	38	252		
	32	233		
	33	98		
	23	69		
	24	238		
	25	184		
	37	25		
	39	5		
	40	101		
44	45	127	127	246

Design Point No.	Tributary Area Numbers	Tributary Areas Acres	Total Acreage for Design Point	Design Flow Rate (gpm)
45	12	315	6741	13078
	13	316		
	14	195		
	15	103		
	16	225		
	17	176		
	18	182		
	19	19		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
	20	157		
	21	9		
	22	7		
	43	131		
	26	444		
	27	139		
	28	126		
	29	92		
	30	155		
	34	133		
	35	181		
	36	12		
	38	252		
	32	233		
	33	98		
	23	69		
	24	238		
	25	184		
	37	25		
	39	5		
	40	101		
	45	127		

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D3 - Wastewater Collection System Pipeline Design Point Tributary Acreages

Design Point No.	Tributary Area Numbers	Tributary Areas Acres	Total Acreage for Design Point	Design Flow Rate (gpm)
46	12	315	6741	13078
	13	316		
	14	195		
	15	103		
	16	225		
	17	176		
	18	182		
	19	19		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
	20	157		
	21	9		
	22	7		
	43	131		
	26	444		
	27	139		
	28	126		
	29	92		
	30	155		
	34	133		
	35	181		
	36	12		
	38	252		
	32	233		
	33	98		
	23	69		
	24	238		
	25	184		
	37	25		
	39	5		
	40	101		
	45	127		
47	42	238	238	462

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D3 - Wastewater Collection System Pipeline Design Point Tributary Acreages

Design Point No.	Tributary Area Numbers	Tributary Areas Acres	Total Acreage for Design Point	Design Flow Rate (gpm)
48	12	315	7274	14112
	13	316		
	14	195		
	15	103		
	16	225		
	17	176		
	18	182		
	19	19		
	K1	311		
	K2	285		
	K4	425		
	K6	247		
	K3	358		
	K5	401		
	K7A	223		
	K7	42		
	20	157		
	21	9		
	22	7		
	43	131		
	26	444		
	27	139		
	28	126		
	29	92		
	30	155		
	34	133		
	35	181		
	36	12		
	38	252		
	32	233		
	33	98		
	23	69		
	24	238		
	25	184		
	37	25		
	39	5		
	40	101		
	45	127		
	42	238		
	48	295		
49	37	25	131	254
	39	5		
	40	101		
50	41	5	5	10

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D4 - Wastewater Collection System Gravity Pipeline Sizes

This spreadsheet/table presents wastewater pipe sizing and provides flow capacity at minimum pipe slope. The flow capacity is compared to the design flow rate for each design point. If the flow capacity exceeds the design flow the pipe size indicated is adequate for the corresponding design point. The d/D and Manning's n values are as shown. Calculations are based on Manning's formula and minimum pipe slopes per DCSWCS Table "D" and 0.08% for pipes of 24-inch diameter and greater.

d/D = 0.75
n = 0.013

DESIGN POINT No.	TRIBUTARY AREA (acres)	(S_m) MINIMUM PIPE SLOPE (%)	(D) PIPE DIAMETER (inches)	(Q_d) DESIGN FLOW (cfs)	(d) DEPTH OF FLOW (feet)	(A) FLOW CROSS SECTIONAL AREA (sqft)	(P) WETTED PERIMETER (feet)	(R_h) HYDRAULIC RADIUS (feet)	(V) FLOW VELOCITY (feet/sec)	Q_c FLOW CAPACITY (cfs)	FLOW CAPACITY EXCEED DESIGN FLOW? (Y/N)
1	315	0.20%	12	1.36	0.75	0.63	2.09	0.30	2.29	1.45	Y
2	311	0.20%	12	1.34	0.75	0.63	2.09	0.30	2.29	1.45	Y
3	911	0.10%	21	3.93	1.31	1.94	3.67	0.53	2.36	4.56	Y
4	1,336	0.08%	24	5.76	1.50	2.53	4.19	0.60	2.30	5.82	Y
5	358	0.15%	15	1.54	0.94	0.99	2.62	0.38	2.30	2.27	Y
6	759	0.12%	18	3.27	1.13	1.42	3.14	0.45	2.33	3.31	Y
7	223	0.25%	10	0.96	0.63	0.44	1.75	0.25	2.27	0.99	Y
8	1,024	0.10%	21	4.42	1.31	1.94	3.67	0.53	2.36	4.56	Y
9	1,583	0.08%	27	6.83	1.69	3.20	4.71	0.68	2.49	7.98	Y
10	2,607	0.08%	36	11.25	2.25	5.69	6.28	0.91	3.02	17.20	Y
11	225	0.25%	10	0.97	0.63	0.44	1.75	0.25	2.27	0.99	Y
12	3,147	0.08%	36	13.57	2.25	5.69	6.28	0.91	3.02	17.20	Y
13	195	0.25%	10	0.84	0.63	0.44	1.75	0.25	2.27	0.99	Y
14	511	0.15%	15	2.20	0.94	0.99	2.62	0.38	2.30	2.27	Y
15	614	0.12%	18	2.65	1.13	1.42	3.14	0.45	2.33	3.31	Y
16	3,446	0.08%	36	14.86	2.25	5.69	6.28	0.91	3.02	17.20	Y
17	176	0.25%	10	0.76	0.63	0.44	1.75	0.25	2.27	0.99	Y
18	3,622	0.08%	36	15.62	2.25	5.69	6.28	0.91	3.02	17.20	Y
19	201	0.25%	10	0.87	0.63	0.44	1.75	0.25	2.27	0.99	Y
20	3,823	0.08%	36	16.49	2.25	5.69	6.28	0.91	3.02	17.20	Y
21	173	0.25%	10	0.75	0.63	0.44	1.75	0.25	2.27	0.99	Y
22	Force Main										
23	252	0.20%	12	1.09	0.75	0.63	2.09	0.30	2.29	1.45	Y
24	618	0.12%	18	2.67	1.13	1.42	3.14	0.45	2.33	3.31	Y
25	716	0.12%	18	3.09	1.13	1.42	3.14	0.45	2.33	3.31	Y
26	897	0.10%	21	3.87	1.31	1.94	3.67	0.53	2.36	4.56	Y
27	897	0.10%	21	3.87	1.31	1.94	3.67	0.53	2.36	4.56	Y
28	250	0.20%	12	1.08	0.75	0.63	2.09	0.30	2.29	1.45	Y
29	69	0.33%	8	0.30	0.50	0.28	1.40	0.20	2.24	0.63	Y
30	1,216	0.08%	24	5.25	1.50	2.53	4.19	0.60	2.30	5.82	Y
31	1,400	0.08%	27	6.04	1.69	3.20	4.71	0.68	2.49	7.98	Y
32	126	0.33%	8	0.54	0.50	0.28	1.40	0.20	2.24	0.63	Y
33	139	0.33%	8	0.60	0.50	0.28	1.40	0.20	2.24	0.63	Y
34	92	0.33%	8	0.40	0.50	0.28	1.40	0.20	2.24	0.63	Y
35	155	0.25%	10	0.67	0.63	0.44	1.75	0.25	2.27	0.99	Y

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D4 - Wastewater Collection System Gravity Pipeline Sizes

This spreadsheet/table presents wastewater pipe sizing and provides flow capacity at minimum pipe slope. The flow capacity is compared to the design flow rate for each design point. If the flow capacity exceeds the design flow the pipe size indicated is adequate for the corresponding design point. The d/D and Manning's n values are as shown. Calculations are based on Manning's formula and minimum pipe slopes per DCSWCS Table "D" and 0.08% for pipes of 24-inch diameter and greater.

d/D = 0.75
n = 0.013

DESIGN POINT No.	TRIBUTARY AREA (acres)	(S_m) MINIMUM PIPE SLOPE (%)	(D) PIPE DIAMETER (inches)	(Q_d) DESIGN FLOW (cfs)	(d) DEPTH OF FLOW (feet)	(A) FLOW CROSS SECTIONAL AREA (sqft)	(P) WETTED PERIMETER (feet)	(R_h) HYDRAULIC RADIUS (feet)	(V) FLOW VELOCITY (feet/sec)	Q_c FLOW CAPACITY (cfs)	FLOW CAPACITY EXCEED DESIGN FLOW? (Y/N)
36	247	0.20%	12	1.07	0.75	0.63	2.09	0.30	2.29	1.45	Y
37	512	0.15%	15	2.21	0.94	0.99	2.62	0.38	2.30	2.27	Y
38	225	0.20%	12	0.97	0.75	0.63	2.09	0.30	2.29	1.45	Y
39	1,270	0.08%	24	5.48	1.50	2.53	4.19	0.60	2.30	5.82	Y
40	Not Used										
41	Force Main										
42	Force Main										
43	6,614	0.08%	48	28.53	3.00	10.11	8.38	1.21	3.67	37.07	Y
44	127	0.33%	8	0.55	0.50	0.28	1.40	0.20	2.24	0.63	Y
45	6,741	0.08%	48	29.08	3.00	10.11	8.38	1.21	3.67	37.07	Y
46	6,741	0.08%	48	29.08	3.00	10.11	8.38	1.21	3.67	37.07	Y
47	238	0.20%	12	1.03	0.75	0.63	2.09	0.30	2.29	1.45	Y
48	7,274	0.08%	48	31.38	3.00	10.11	8.38	1.21	3.67	37.07	Y
49	131	0.33%	8	0.57	0.50	0.28	1.40	0.20	2.24	0.63	Y
50	5	0.33%	8	0.02	0.50	0.28	1.40	0.20	2.24	0.63	Y

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D

Item D5 - Maximum Velocity Met Calculations

This spreadsheet/table was prepared to meet the requirement 2.2.3.a of the ***Design and Construction Standards for Wastewater Collection Systems***
of meeting the maximum velocity requirement of 10 feet per second for gravity sewer pipes flowing 3/4 full conveying peak wet weather flow.
The calculations involve the use of Manning's formula with an "n" value of 0.013 and the maximum slope as provided in Table D of the DCSWCS.
for pipelines 24-inch and diameter. Maximum slopes for pipelines greater than 24-inch in diameter are as shown.
The spreadsheet provides the maximum installation slope for the pipeline corresponding to each design point.

DESIGN POINT	SEWERSHED BASIN AREA (ACRES)	MAXIMUM SLOPE TO LIMIT VELOCITY TO 10 FPS AT PIPE 75% Full (%)	DESIGN FLOW (GPM)	DESIGN FLOW (MGD)	DESIGN FLOW (CFS)	PIPE DIAMETER (INCHES)	PIPE RADIUS (FEET)	FLOW AREA @ 3/4 FULL PIPE (SQFT)	WETTED PERIMETER (FEET)	HYDRAULIC RADIUS (FEET)	PIPE FLOW MAXIMUM VELOCITY @ MAXIMUM SLOPE FLOWING 75% FULL (FPS)
1	315	3.76%	610	0.88	1.36	12	0.500	0.6319	2.09	0.30	9.96
2	311	3.76%	602	0.87	1.34	12	0.500	0.6319	2.09	0.30	9.96
3	911	1.78%	1,764	2.54	3.93	21	0.875	1.9353	3.67	0.53	9.97
4	1,336	1.49%	2,586	3.72	5.76	24	1.000	2.5277	4.19	0.60	9.97
5	358	2.79%	693	1.00	1.54	15	0.625	0.9874	2.62	0.38	9.96
6	759	2.19%	1,469	2.12	3.27	18	0.750	1.4218	3.14	0.45	9.97
7	223	4.79%	432	0.62	0.96	10	0.417	0.4388	1.75	0.25	9.95
8	1,024	1.78%	1,982	2.85	4.42	21	0.875	1.9353	3.67	0.53	9.97
9	1,583	1.27%	3,065	4.41	6.83	27	1.125	3.1991	4.71	0.68	9.96
10	2,607	0.86%	5,047	7.27	11.25	36	1.500	5.6873	6.28	0.91	9.94
11	225	4.79%	436	0.63	0.97	10	0.417	0.4388	1.75	0.25	9.95
12	3,147	0.86%	6,093	8.77	13.58	36	1.500	5.6873	6.28	0.91	9.94
13	195	4.79%	378	0.54	0.84	10	0.417	0.4388	1.75	0.25	9.95
14	511	2.79%	989	1.42	2.20	15	0.625	0.9874	2.62	0.38	9.96
15	614	2.19%	1,189	1.71	2.65	18	0.750	1.4218	3.14	0.45	9.97
16	3,446	0.86%	6,671	9.61	14.87	36	1.500	5.6873	6.28	0.91	9.94
17	176	4.79%	341	0.49	0.76	10	0.417	0.4388	1.75	0.25	9.95
18	3,622	0.86%	7,012	10.10	15.62	36	1.500	5.6873	6.28	0.91	9.94
19	201	4.79%	389	0.56	0.87	10	0.417	0.4388	1.75	0.25	9.95
20	3,883	0.86%	7,517	10.83	16.75	36	1.500	5.6873	6.28	0.91	9.94
21	173	4.79%	336	0.48	0.75	10	0.417	0.4388	1.75	0.25	9.95
22	FORCE MAIN										
23	252	3.76%	488	0.70	1.09	12	0.500	0.6319	2.09	0.30	9.96
24	618	2.19%	1,196	1.72	2.67	18	0.750	1.4218	3.14	0.45	9.97
25	716	2.19%	1,386	2.00	3.09	18	0.750	1.4218	3.14	0.45	9.97
26	897	1.78%	1,737	2.50	3.87	21	0.875	1.9353	3.67	0.53	9.97
27	897	1.78%	1,737	2.50	3.87	21	0.875	1.9353	3.67	0.53	9.97
28	250	3.76%	484	0.70	1.08	12	0.500	0.6319	2.09	0.30	9.96

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D5 - Maximum Velocity Met Calculations

DESIGN POINT	SEWERSHED BASIN AREA (ACRES)	MAXIMUM SLOPE TO LIMIT VELOCITY TO 10 FPS AT PIPE 75% Full (%)	DESIGN FLOW (GPM)	DESIGN FLOW (MGD)	DESIGN FLOW (CFS)	PIPE DIAMETER (INCHES)	PIPE RADIUS (FEET)	FLOW AREA @ 3/4 FULL PIPE (SQFT)	WETTED PERIMETER (FEET)	HYDRAULIC RADIUS (FEET)	PIPE FLOW MAXIMUM VELOCITY @ MAXIMUM SLOPE FLOWING 75% FULL (FPS)
29	69	6.46%	134	0.19	0.30	8	0.333	0.2809	1.40	0.20	9.95
30 NOTE (1)	1,216	1.49%	2,354	3.39	5.25	24	1.000	2.5277	4.19	0.60	9.97
31	1,400	1.27%	2,710	3.90	6.04	27	1.125	3.1991	4.71	0.68	9.96
32	126	6.46%	244	0.35	0.54	8	0.333	0.2809	1.40	0.20	9.95
33	139	6.46%	269	0.39	0.60	8	0.333	0.2809	1.40	0.20	9.95
34	92	6.46%	178	0.26	0.40	8	0.333	0.2809	1.40	0.20	9.95
35	155	4.79%	300	0.43	0.67	10	0.417	0.4388	1.75	0.25	9.95
36	247	3.76%	478	0.69	1.07	12	0.500	0.6319	2.09	0.30	9.96
37	512	2.79%	991	1.43	2.21	15	0.625	0.9874	2.62	0.38	9.96
38 NOTE (2)	225	3.76%	436	0.63	0.97	12	0.500	0.6319	2.09	0.30	9.96
39	1,270	1.49%	2,459	3.54	5.48	24	1.000	2.5277	4.19	0.60	9.97
40	NOT USED										
41	FORCE MAIN										
42	FORCE MAIN										
43	6,614	0.59%	12,381	17.83	27.59	48	2.000	10.1108	8.38	1.21	9.99
44	127	6.46%	246	0.35	0.55	8	0.333	0.2809	1.40	0.20	9.95
45	6,741	0.59%	13,051	18.79	29.08	48	2.000	10.1108	8.38	1.21	9.99
46	6,741	0.59%	13,051	18.79	29.08	48	2.000	10.1108	8.38	1.21	9.99
47	238	3.76%	461	0.66	1.03	12	0.500	0.6319	2.09	0.30	9.96
48	7,274	0.59%	14,082	20.28	31.38	48	2.000	10.1108	8.38	1.21	9.99
49	131	6.46%	254	0.37	0.57	8	0.333	0.2809	1.40	0.20	9.95
50	5	6.46%	10	0.01	0.02	8	0.333	0.2809	1.40	0.20	9.95

Notes:
(1) Design point 30 is for both gravity collection for Central and the force main for Lift Station 2
(2) Design point 38 is for both gravity collection for Black Mountain and the force main for Lift Station 3

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D6 - Minimum Velocity Met Calculations

This spreadsheet/table was prepared to meet the requirement 2.2.3.a of the ***Design and Construction Standards for Wastewater Collection Systems*** of meeting the minimum velocity requirement of 2 feet per second for gravity sewer pipes flowing half full conveying peak wet weather flow.
The calculations involve the use of Manning's formula with an "n" value of 0.013 and the minimum pipeline slopes as provided in Table D of the DCSWCS for pipelines 24-inch diameter and less. Minimum slopes for pipelines greater than 24-inch diameter are as shown.
The spreadsheet provides the minimum installation slope for the pipeline corresponding to each design point.

DESIGN POINT	BASIN AREA (ACRES)	MINIMUM SLOPE TO ACHIEVE A 50% FULL PIPE AT MINIMUM SLOPE (%)	DESIGN FLOW (GPM)	DESIGN FLOW (MGD)	DESIGN FLOW (CFS)	PIPE DIAMETER (INCHES)	PIPE RADIUS (FEET)	FLOW AREA @HALF FULL PIPE (SQFT)	WETTED PERIMETER (FEET)	HYDRAULIC RADIUS (FEET)	PIPE FLOW VELOCITY @ MINIMUM SLOPE FLOWING 50% FULL (FPS)
1	315	0.20%	610	0.88	1.36	12	0.500	0.39	1.57	0.25	2.02
2	311	0.20%	602	0.87	1.34	12	0.500	0.39	1.57	0.25	2.02
3	911	0.10%	1,764	2.54	3.93	21	0.875	1.20	2.75	0.44	2.08
4	1,336	0.08%	2,586	3.72	5.76	24	1.000	1.57	3.14	0.50	2.04
5	358	0.15%	693	1.00	1.54	15	0.625	0.61	1.96	0.31	2.04
6	759	0.12%	1,469	2.12	3.27	18	0.750	0.88	2.36	0.37	2.06
7	223	0.25%	432	0.62	0.96	10	0.417	0.27	1.31	0.21	2.00
8	1,024	0.10%	1,982	2.85	4.42	21	0.875	1.20	2.75	0.44	2.08
9	1,583	0.07%	3,065	4.41	6.83	27	1.125	1.99	3.53	0.56	2.06
10	2,607	0.05%	5,047	7.27	11.25	36	1.500	3.53	4.71	0.75	2.11
11	225	0.25%	436	0.63	0.97	10	0.417	0.27	1.31	0.21	2.00
12	3,147	0.05%	6,093	8.77	13.58	36	1.500	3.53	4.71	0.75	2.11
13	195	0.25%	378	0.54	0.84	10	0.417	0.27	1.31	0.21	2.00
14	511	0.15%	989	1.42	2.20	15	0.625	0.61	1.96	0.31	2.04
15	614	0.12%	1,189	1.71	2.65	18	0.750	0.88	2.36	0.37	2.06
16	3,446	0.05%	6,671	9.61	14.87	36	1.500	3.53	4.71	0.75	2.11
17	176	0.25%	341	0.49	0.76	10	0.417	0.27	1.31	0.21	2.00
18	3,622	0.05%	7,012	10.10	15.62	36	1.500	3.53	4.71	0.75	2.11
19	201	0.25%	389	0.56	0.87	10	0.417	0.27	1.31	0.21	2.00
20	3,823	0.05%	7,401	10.66	16.49	36	1.500	3.53	4.71	0.75	2.11
21	173	0.25%	335	0.48	0.75	10	0.417	0.27	1.31	0.21	2.00
22	FORCE MAIN										
23	252	0.20%	488	0.70	1.09	12	0.500	0.39	1.57	0.25	2.02
24	618	0.12%	1,196	1.72	2.67	18	0.750	0.88	2.36	0.37	2.06
25	716	0.12%	1,386	2.00	3.09	18	0.750	0.88	2.36	0.37	2.06
26	897	0.10%	1,737	2.50	3.87	21	0.875	1.20	2.75	0.44	2.08
27	897	0.10%	1,737	2.50	3.87	21	0.875	1.20	2.75	0.44	2.08
28	250	0.20%	484	0.70	1.08	12	0.500	0.39	1.57	0.25	2.02

DESIGN POINT	BASIN AREA (ACRES)	MINIMUM SLOPE TO ACHIEVE A 50% FULL PIPE AT MINIMUM SLOPE (%)	DESIGN FLOW (GPM)	DESIGN FLOW (MGD)	DESIGN FLOW (CFS)	PIPE DIAMETER (INCHES)	PIPE RADIUS (FEET)	FLOW AREA @HALF FULL PIPE (SQFT)	WETTED PERIMETER (FEET)	HYDRAULIC RADIUS (FEET)	PIPE FLOW VELOCITY @ MINIMUM SLOPE FLOWING 50% FULL (FPS)
29	69	0.35%	134	0.19	0.30	8	0.333	0.17	1.05	0.17	2.04
30 NOTE (1)	1,216	0.08%	2,354	3.39	5.25	24	1.000	1.57	3.14	0.50	2.04
31	1,400	0.07%	2,710	3.90	6.04	27	1.125	1.99	3.53	0.56	2.06
32	126	0.35%	244	0.35	0.54	8	0.333	0.17	1.05	0.17	2.04
33	139	0.35%	269	0.39	0.60	8	0.333	0.17	1.05	0.17	2.04
34	92	0.35%	178	0.26	0.40	8	0.333	0.17	1.05	0.17	2.04
35	155	0.25%	300	0.43	0.67	10	0.417	0.27	1.31	0.21	2.00
36	247	0.20%	478	0.69	1.07	12	0.500	0.39	1.57	0.25	2.02
37	512	0.15%	991	1.43	2.21	15	0.625	0.61	1.96	0.31	2.04
38 NOTE (2)	225	0.20%	436	0.63	0.97	12	0.500	0.39	1.57	0.25	2.02
39	1,270	0.08%	2,459	3.54	5.48	24	1.000	1.57	3.14	0.50	2.04
40	NOT USED										
41	FORCE MAIN										
42	FORCE MAIN										
43	6,614	0.031%	12,831	18.48	28.59	48	2.000	6.28	6.28	1.00	2.02
44	127	0.35%	246	0.35	0.55	8	0.333	0.17	1.05	0.17	2.04
45	6,741	0.031%	13,051	18.79	29.08	48	2.000	6.28	6.28	1.00	2.02
46	6,741	0.031%	13,051	18.79	29.08	48	2.000	6.28	6.28	1.00	2.02
47	238	0.25%	461	0.66	1.03	12	0.500	0.39	1.57	0.25	2.26
48	7,274	0.031%	14,082	20.28	31.38	48	2.000	6.28	6.28	1.00	2.02
49	131	0.35%	254	0.37	0.57	8	0.333	0.17	1.05	0.17	2.04
50	5	0.35%	10	0.01	0.02	8	0.333	0.17	1.05	0.17	2.04

Notes:
(1) Design point 30 is for both gravity flow for Central and the force main for Lift Station 2
(2) Design point 38 is for both gravity flow for Black Mountain and the force main for Lift Station 3

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D7 - Force Main Sizing

Lift Station	Design Point No.	Design Flow (gpm)	Design Flow (cfs)	Force Main Cross Sectional Area @ V=6 ft/sec (sq. inches)	Force Main Diameter @ V=6 ft/sec (sq. inches)	Selected Force Main Diameter (inches)	Selected Force Main Cross Sectional Area (sq. feet)	Flow Velocity at Selected Force Main Diameter (feet/sec)
1A	DP-22	7752	17.3	414.5	23.0	24	3.14	5.50
1B	DP-41	8006	17.8	428.1	23.3	24	3.14	5.68
1C	DP-42	12587	28.0	673.1	29.3	30	4.91	5.71
2	DP-30	2359	5.3	126.1	12.7	14	1.07	4.92
3	DP-39	2468	5.5	132.0	13.0	14	1.07	5.14

Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D8 - Lift Station Discharge Head Calculation

Lift Station	Lift Station Elevation (feet)	Lift Station Discharge Elevation (feet)	Static Lift (feet)	Suction Lift	Force Main Diameter (inches)	Flow Rate (gpm)	Force Main Length (feet)	Force Main Material of Construction	Total Discharge Head (feet)	Total Discharge Head (psi)
1A	2160	2335	175	20	24	7752	13529	PVC	235	101.8
1B	2335	2450	115	20	24	8006	9720	PVC	165	71.4
1C	2450	2550	100	20	30	12587	5071	PVC	132	57.2
2	2428	2500	72	20	14	2359	6145	PVC	120	52.0
3	2380	2500	120	20	14	2468	9870	PVC	188	81.4

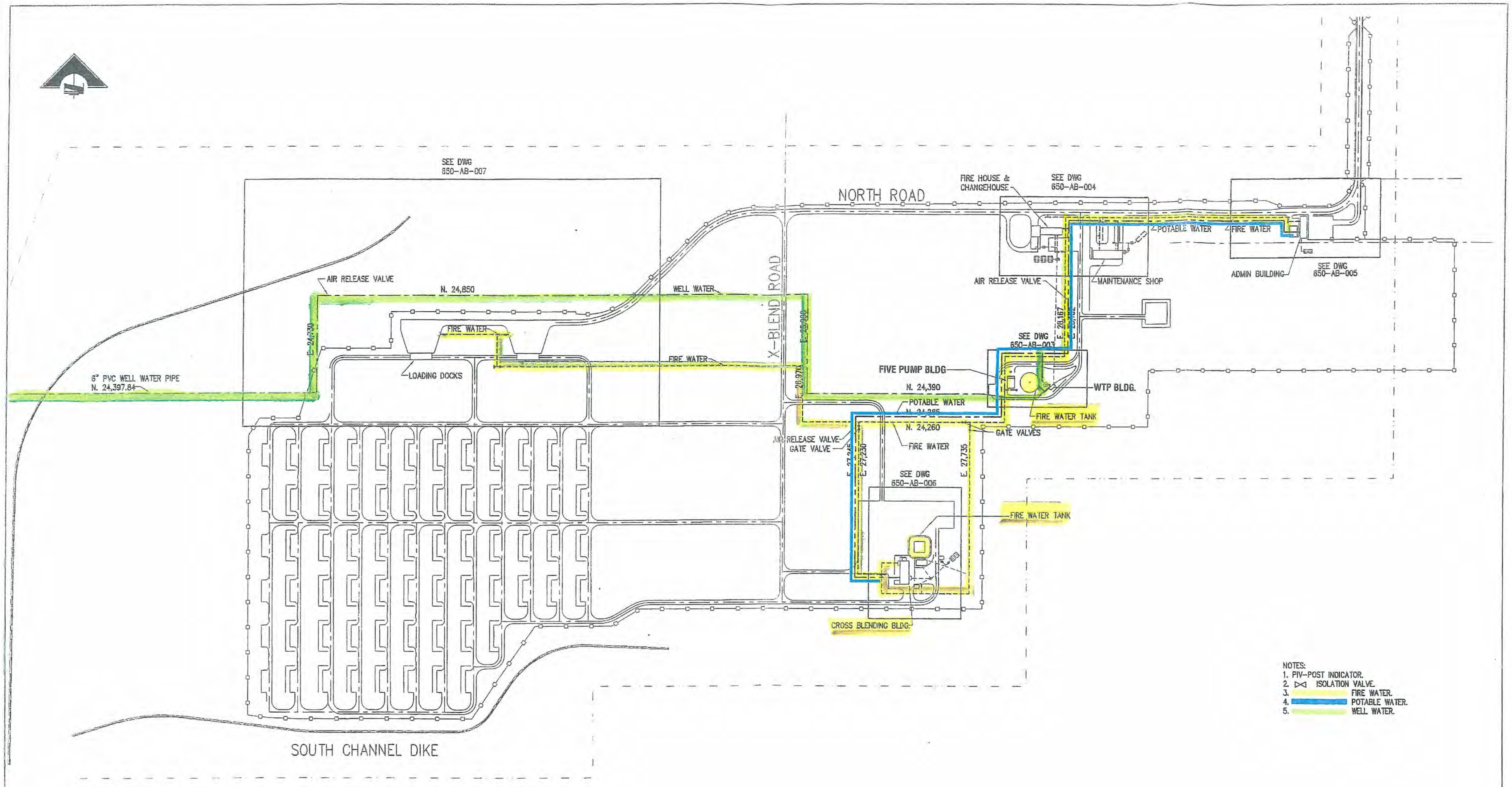
Apex Industrial Park
Water and Wastewater Master Plan - December 28, 2012
Appendix D
Item D9 - Water Demands and Required Water Storage Tank Volume

Park	Developable Acreage	Average Day Water Demand (gpm)	Average Day Water Demand (MGD)	Maximum Day Water Demand (gpm)	Maximum Day Water Demand (MGD)	Peak Hour Water Demand (gpm)	Peak Hour Water Demand (MGD)	Subpark ERU Count	Required Tank Operating Storage (MG)	Required Tank Emergency Reserve Storage
Black Mountain	444.2	137.7	0.198	187.3	0.270	287.8	0.414	899	0.629	0.472
Central	492.6	152.7	0.220	207.7	0.299	319.2	0.460	997	0.698	0.523
Commercial Center North	174.5	54.1	0.078	73.6	0.106	113.1	0.163	353	0.247	0.185
Commercial Center South	333.9	103.5	0.149	140.8	0.203	216.3	0.312	676	0.473	0.355
Foothills	326.1	101.1	0.146	137.5	0.198	211.3	0.304	660	0.462	0.346
Industrial Rail	131.1	40.6	0.059	55.3	0.080	84.9	0.122	265	0.186	0.139
Kapex	2,504.2	776.3	1.118	1055.8	1.520	1622.5	2.336	5068	3.547	2.661
Miners Mesa	238.1	73.8	0.106	100.4	0.145	154.3	0.222	482	0.337	0.253
Northern Apex	354.3	109.8	0.158	149.4	0.215	229.6	0.331	717	0.502	0.376
Northern Flats	556.3	172.5	0.248	234.5	0.338	360.4	0.519	1126	0.788	0.591
Northern Flats West	103.4	32.1	0.046	43.6	0.063	67.0	0.096	209	0.146	0.110
Northern Highlands	362.7	112.4	0.162	152.9	0.220	235.0	0.338	734	0.514	0.385
North Hills	333.3	103.3	0.149	140.5	0.202	215.9	0.311	674	0.472	0.354
Pinnacle	297.5	92.2	0.133	125.4	0.181	192.8	0.278	602	0.421	0.316
Solo Mountain	348.0	107.9	0.155	146.7	0.211	225.5	0.325	704	0.493	0.370
Vegas Vista	523.0	162.1	0.233	220.5	0.318	338.9	0.488	1058	0.741	0.556
Total	**7,523.2**	**2332**	**3.358**	**3172**	**4.567**	**4874.3**	**7.019**	**15225**	**10.657**	**7.993**

Notes:

(1) Average Day water demand is based on 0.5 acre feet per acre per year which equals 0.31 gpm/acre.
(2) CNLV standards utilize 1.1 gpm/acre as average day water demand for and Industrial Park
(3) Maximum day water demand factor is 1.36 (developed from CNLV standards for industrial park 1.5/1.1=1.36)
(4) The peak hour demand factor is 2.09 (developed form CNLV standards for industrial parks, 2.3/1.1=2.09
(5) Subpark ERU count is based on 300 gallons per day per ERU (an assumed ERU demand)
(6) Tank operating storage is based on 700 gpm/ERU
(7) Tank emergency reservoir storage is 75% of required operating storage
(8) Fire storage is based on 6000 gpm for 4 hour duration = 1.44 MG
(9) Total Tank Storage = Operating Storage + Emergency Reserve + Fire Storage = 10.7MG + 8.0MG + 1.44MG = 20.14 MG say 20 MG total storage required

APPENDIX E



PRELIMINARY
NOT FOR CONSTRUCTION

DWG. NO.	REFERENCES TITLE	DWG. NO.	REFERENCES TITLE	REV.	REVISIONS DESCRIPTION	BY	APP'D	DATE	REV.	REVISIONS DESCRIPTION	BY	APP'D	DATE
									P1	FOR CLIENT REVIEW	RP		5/04

	DATE
DESIGNED BY: RP	MAY 04
DRAWN BY: BJS	MAY 04
CHECKED BY: DM	JUN 04
M3 PROJ. MGR.: DM	JUN 04
USA PROJ. MGR.:	
SCALE: 1"=200'	

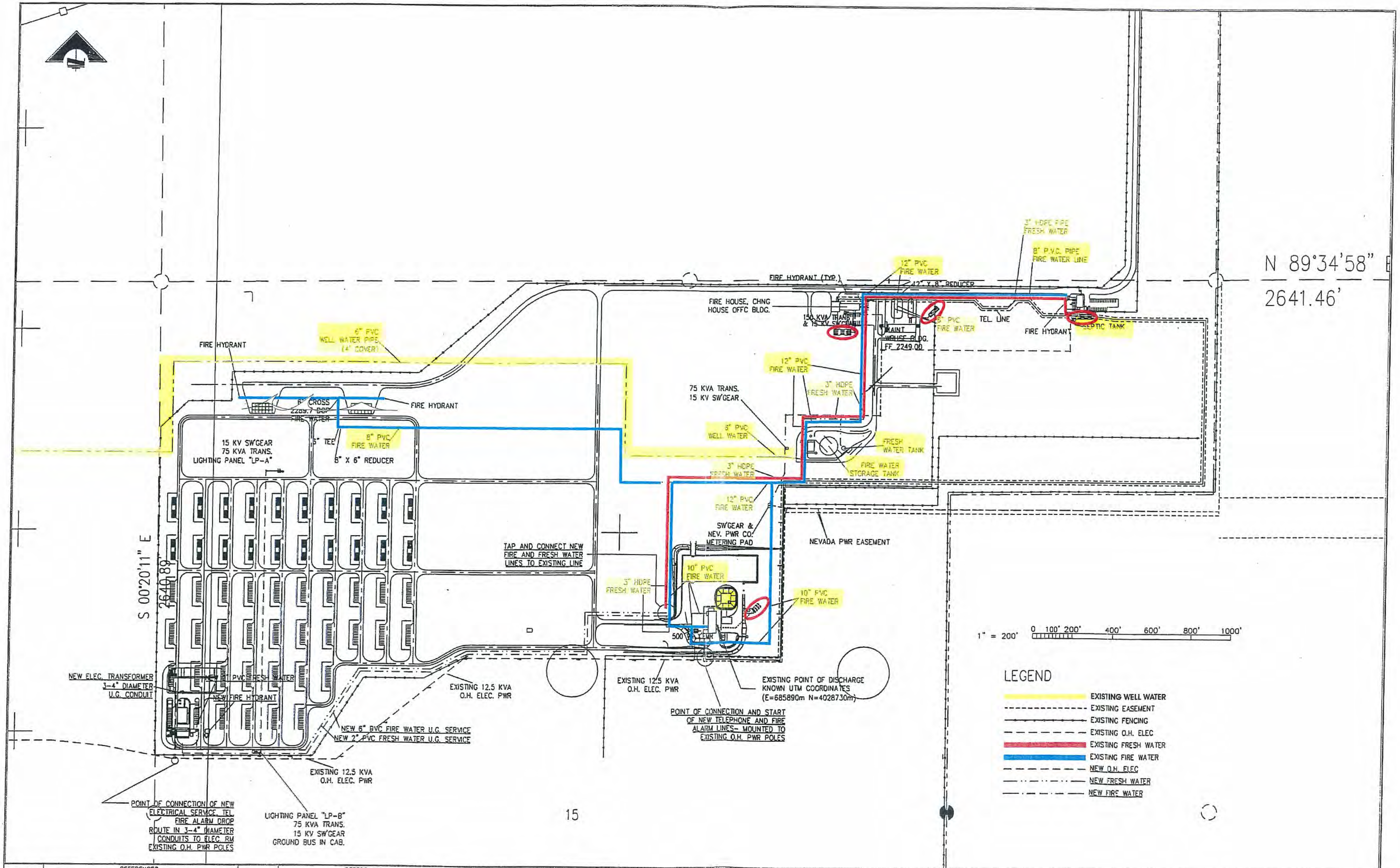
M3 Engineering & Technology Corp.
Tucson, Arizona
Chandler, Arizona
Hermosillo, Sonora Mexico

AVESTOR

APEX NEVADA PLANT
WATER SYSTEM
SITE PLAN

JOB NO. M3-PN 03219.04
DWG. NO.
650-AB-002
REV. P1
DATE 5/27/04

NAME: P:\2003\03219.04\Mech\650AB002.dwg LAST REV: P1 LAST UPDATE: JUN 09, 2004 TIME: 10:22 AM BY: rp117 PLOT SCALE: 1:1



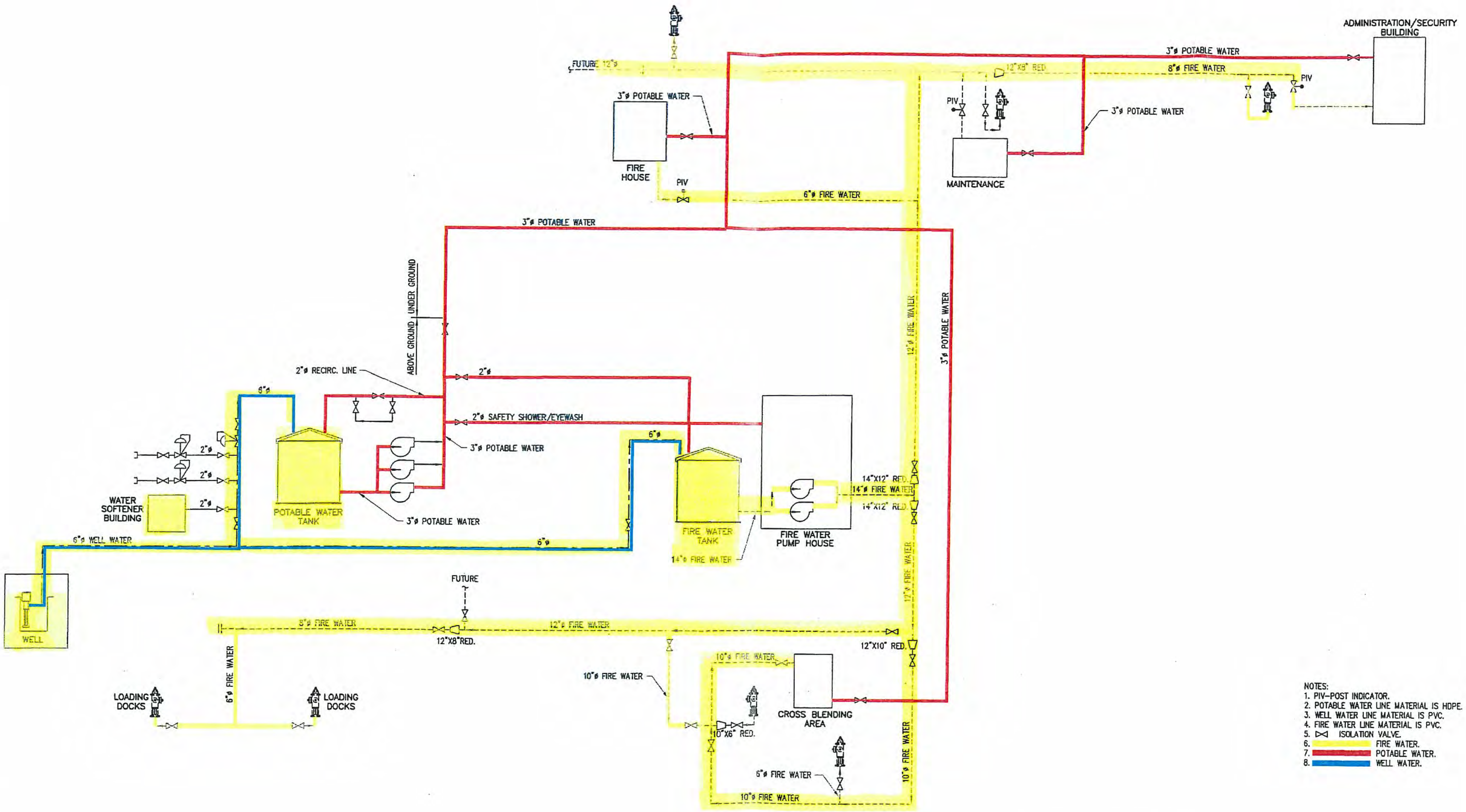
DWG. NO.	REFERENCES TITLE	DWG. NO.	REFERENCES TITLE	REV.	REVISIONS DESCRIPTION	BY	APP'D	DATE	REV.	REVISIONS DESCRIPTION	BY	APP'D	DATE

	DATE
DESIGNED BY: D.M.M	01/04
DRAWN BY: JDL	01/04
CHECKED BY:	
MJ PROJ. MGR. D.M.M.	
USA PROJ. MGR.: DMP	4/04
SCALE: 1"=200'	

AVESTOR

APEX NEVADA PLANT
BATTERY TESTING CENTER
CIVIL
SITE UTILIES PLAN

JOB NO. MJ-PN 03219.02
DWG. NO. 650-CI-005
REV. P1
DATE 4/13/04



NOTES:
1. PIV-POST INDICATOR.
2. POTABLE WATER LINE MATERIAL IS HDPE.
3. WELL WATER LINE MATERIAL IS PVC.
4. FIRE WATER LINE MATERIAL IS PVC.
5. ⋈ ISOLATION VALVE.
6. 🟨 FIRE WATER.
7. 🟥 POTABLE WATER.
8. 🟦 WELL WATER.

PRELIMINARY
NOT FOR CONSTRUCTION

REFERENCES DWG. NO.	REFERENCES TITLE	REFERENCES DWG. NO.	REFERENCES TITLE	REV.	REVISIONS DESCRIPTION	BY	APP'D	DATE	REV.	REVISIONS DESCRIPTION	BY	APP'D	DATE
									P1	FOR CLIENT REVIEW	RP		5/04

		DATE
DESIGNED BY:	RP	MAY 04
DRAWN BY:	BJS	MAY 04
CHECKED BY:	DM	JUN 04
M3 PROJ. MGR.:	DM	JUN 04
USA PROJ. MGR.:		
SCALE:	NONE	

M3 Engineering & Technology Corp.
Tucson, Arizona
Chandler, Arizona
Hermosillo, Sonora Mexico

AVESTOR

APEX NEVADA PLANT
WATER SYSTEM
DIAGRAM

JOB NO. M3-PN 03219.04
DWG. NO.
650-AB-001
REV. ~~P1~~ DATE ~~5/27/04~~

NAME: P:\2003\03219.04\Mech\650AB001.dwg LAST REV: P1 LAST UPDATE: JUN 09, 2004 TIME: 10:27 AM BY: rp117 PLOT SCALE: 1:1

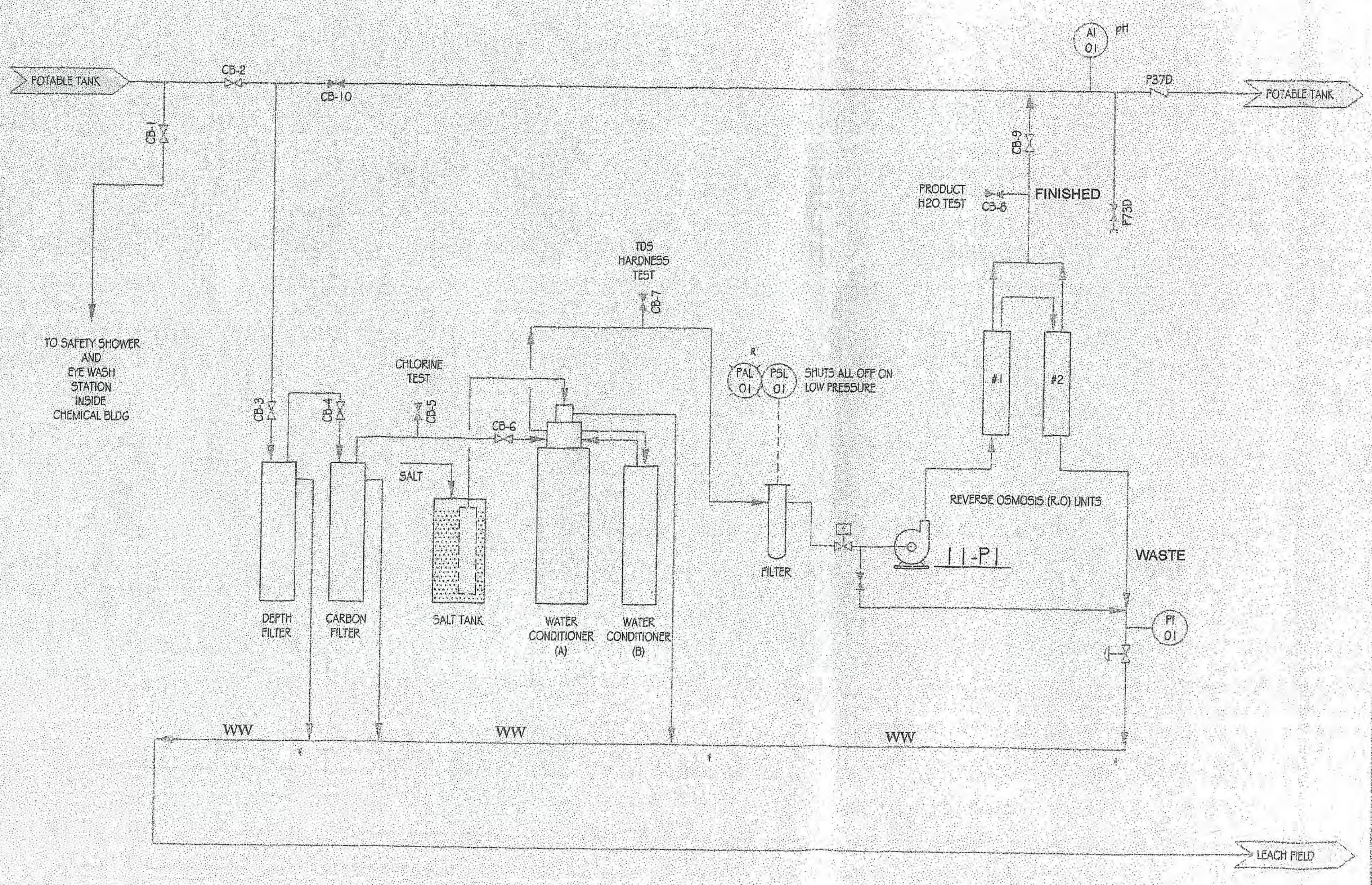
DRAWN BY: GM BUCO
SCALE: NONE
DATE: 11-15-95

JOB NO.
A.F.E.
ENGR: R. SALDIVAR

KERR-McGEE CHEMICAL CORP.
HENDERSON, NEVADA

AMMONIUM PERCHLORATE (APEX)
WATER PURIFICATION, CHEMICAL BDLG.

DRAWING NO.
D-1-1-1



WHITE—DIVISION OF WATER RESOURCES
CANARY—CLIENT'S COPY
PINK—WELL DRILLER'S COPY

STATE OF NEVADA
DIVISION OF WATER RESOURCES

WELL DRILLER'S REPORT

Please complete this form in its entirety

1,800

OFFICE USE ONLY
Log No. 33206
Permit No. ~~54232~~ 55674
Basin 13-216

PRINT OR TYPE ONLY

NOTICE OF INTENT NO. 5984

1. OWNER KERR-MC GEE CHEMICAL CORP.
MAILING ADDRESS P.O. BOX 25861
OKLAHOMA CITY, OK 73125

ADDRESS AT WELL LOCATION KERR-MC GEE CHEM. CORP.
APEX FACILITY, HIGHWAY 93 N
APEX, NEVADA

2. LOCATION NW ¼ NW ¼ Sec. 16 T. 18 N [✓ S] R. 63 E CLARK County
PERMIT NO. 54232 Issued by Water Resources | Parcel No. | Subdivision Name

3. TYPE OF WORK
New Well ☒ Recondition ☐
Deepen ☐ Other ☐

4. PROPOSED USE
Domestic ☐ Irrigation ☐ Test ☐
Municipal ☐ Industrial ☒ Stock ☐

5. TYPE WELL
Cable ☐ Rotary ☒
Other ☐

6. LITHOLOGIC LOG

Material	Water Strata	From	To	Thickness
Silty sand		0	5	5'
Conglomerate with pebbles of limestone chert and sandstone plus clay streaks		5	285	280'
Hard calcareous silt and sandstone with limestone and chert		285	375	90'
Limestone with chert streaks	640-45 675-95	375	795	420'
Dolomite with limestone and chert streaks	850 880	795	900	105'
Limestone with chert streaks	965 985	900	985	85'
Limestone with chert and sand streaks	1010 1025	985	1030	45'
Limestone with chert streaks		1030	1145	115'

RECEIVED
FEB 15 1990
Div. of Water Resources
Branch Office–Las Vegas

Date started January 2, 1990
Date completed February 7, 1990

7. WELL TEST DATA

Pump RPM	G.P.M.	Draw Down	After Hours Pump
3300	200	21	48

BAILER TEST
G.P.M. ______ Draw down ______ feet ______ hours
G.P.M. ______ Draw down ______ feet ______ hours
G.P.M. ______ Draw down ______ feet ______ hours

8. WELL CONSTRUCTION

Diameter 12 1/4 inches Total depth 1145 feet
9 7/8 inches 75' to 1005'
8 3/4 inches 1005' to 1145'
Casing record
Weight per foot 16.94 lb. Thickness .188

Diameter	From	To
8 5/8 inches	+2 feet	1,000 feet
6 5/8 inches	1,000 feet	1,145 feet
inches	feet	feet
inches	feet	feet
inches	feet	feet
inches	feet	feet

Surface seal: Yes ☒ No ☐ Type Cement
Depth of seal 75 feet
Gravel packed: Yes ☐ No ☒
Gravel packed from ______ feet to ______ feet

Perforations: 8" is 16 row 6" is 6 row
Type perforation Mill Slot
Size perforation 1/8 X 3 X 6" Centers
From 700 feet to 1,000 feet
From 1,000 feet to 1,145 feet
From ______ feet to ______ feet
From ______ feet to ______ feet
From ______ feet to ______ feet

9. WATER LEVEL

Static water level 578 feet below land surface
Flow ______ G.P.M. ______ P.S.I.
Water temperature 81 °F Quality ______

10. DRILLER'S CERTIFICATION

This well was drilled under my supervision and the report is true to the best of my knowledge.

Name Water Well SErvices (Contractor) 89130
Address 4545 N. Rancho, Las Vegas, NV (Contractor)

Nevada contractor's license number issued by the State Contractor's Board 0022311
Nevada contractor's driller's number issued by the Division of Water Resources 694
Nevada driller's license number issued by the Division of Water Resources, the on-site driller 1426
Signed ______ By driller performing actual drilling on site or contractor
Date February 14, 1990

(1)

(Rev. 11-83)

USE ADDITIONAL SHEETS IF NECESSARY

(0)-427

WHITE—DIVISION OF WATER RESOURCES
CANARY—CLIENT'S COPY
PINK—WELL DRILLER'S COPY

PRINT OR TYPE ONLY
DO NOT WRITE ON BACK

STATE OF NEVADA
DIVISION OF WATER RESOURCES
WELL DRILLER'S REPORT
Please complete this form in its entirety in accordance with NRS 534.170 and NAC 534.340

OFFICE USE ONLY
Log No. 8377
Permit No. 66784
Basin 216

NOTICE OF INTENT NO. 22211

1. OWNER Dry Lake Water
MAILING ADDRESS 2701 N Tenaya Way St 200
Las Vegas, Nevada

ADDRESS AT WELL LOCATION I-15 & Apex Frontage Rd Exit 58

2. LOCATION NE ¼ NE ¼ Sec. 27 T 18 /18S N [✓ S] R 63 E Clark County
PERMIT NO. 66784 (Issued by Water Resources) 122-05-010-004 (Parcel No.) Subdivision Name

3. WORK PERFORMED
☒ New Well ☐ Replace ☐ Recondition
☐ Deepen ☐ Abandon ☐ Other

4. PROPOSED USE
☐ Domestic ☐ Irrigation ☐ Test
☒ Municipal/Industrial ☐ Monitor ☐ Stock

5. WELL TYPE
☐ Cable ☒ Rotary ☐ RVC
☒ Air ☐ Other

6. LITHOLOGIC LOG

Material	Water Strata	From	To	Thickness
Overburden		0	3'	3'
Limestone	620'	3'	1232'	1229'
intermintent Frac				

Central

Date started 6-28-01, 19
Date completed 7-19-01, 19

7. WELL TEST DATA

TEST METHOD: ☐ Bailer ☐ Pump ☒ Air Lift

	G.P.M.	Draw Down (Feet Below Static)	Time (Hours)
200 PSI	100	NO DATA	24

8. WELL CONSTRUCTION
Depth Drilled 1232 Feet Depth Cased 1232 Feet

HOLE DIAMETER (BIT SIZE)

	From	To
28 Inches	0 Feet	52 Feet
17½ Inches	52 Feet	1232 Feet
Inches	Feet	Feet

CASING SCHEDULE

Size O.D. (Inches)	Weight/Ft. (Pounds)	Wall Thickness (Inches)	From (Feet)	To (Feet)
20	78.60	.375	0	52
10	40.48	.365	-1	1232

Perforations:
Type perforation Louvered (Roscoe Moss)
Size perforation 100 Slot
From 852 feet to 992 feet
From 1072 feet to 1232 feet
From feet to feet
From feet to feet
From feet to feet

Surface Seal: ☒ Yes ☐ No
Depth of Seal 52'
Placement Method: ☒ Pumped ☐ Poured

Seal Type:
☐ Neat Cement
☒ Cement Grout
☐ Concrete Grout

Gravel Packed: ☐ Yes ☒ No
From feet to feet

9. WATER LEVEL
Static water level 620 feet below land surface
Artesian flow G.P.M. P.S.I.
Water temperature 61 °F Quality

10. DRILLER'S CERTIFICATION
This well was drilled under my supervision and the report is true to the best of my knowledge.

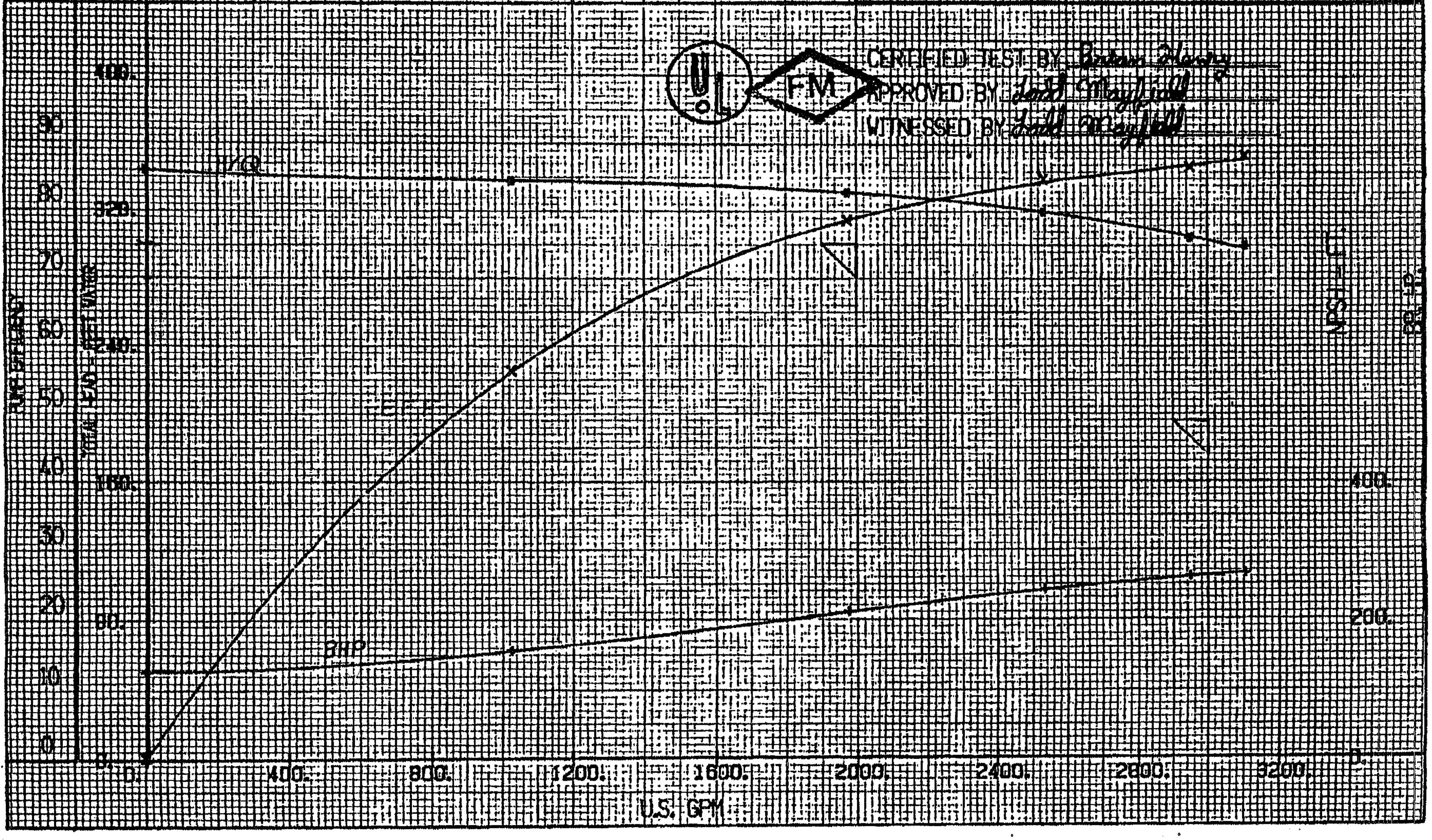
Name Layne Christensen Co. (Contractor)
Address 12030 E Riggs Rd (Contractor)
Chandler, Arizona 85249
Nevada contractor's license number issued by the State Contractor's Board 19101
Nevada driller's license number issued by the Division of Water Resources, the on-site driller 1882
Signed Lowell Stephen Clow (By driller performing actual drilling on site or contractor)
Date 7-19-01

(Rev. 3-91) USE ADDITIONAL SHEETS IF NECESSARY (0)-627

PATTERSON PUMP COMPANY
A SUBSIDIARY OF THE GORMAN-RUPP CO.

SOLD TO: J.E. MERIT CONSTRUCTORS		SERIAL NO.: 89PT-14043-L8	
JOB DRIVER 266 HP	GPM 2000	IMP. PATT. C-4070	PUMP TYPE M
TEST DRIVER 250 HP MARATHON	FT. HD. 300.0	IMP. DIA. 17.375 1/2 TIP	SIZE 10x8
MOTOR EFF'Y 93% TEST SPEED 1787	RATED SPEED 1750	NO. STAGES 1 TEST NO. 1	DATE 5-24-00

CERTIFIED TEST BY Brian Henry
APPROVED BY Todd Mayfield
WITNESSED BY Todd Mayfield



EXISTING FIRE PUMPS

SE ROA 34923

JA_7452

GESCO NV.

244 Hyssop Court
Henderson, NV 99015
Cell: (702)375-3275
Fax: (702) 564-8985

PROPERTY OF Mountain View Industrial (Pump Left)		PMI FILE #	START UP#
ADDRESS	TESTED BY Brian Swett		TIME 8:00 AM
CITY LV	STATE Nevada	DATE TESTED 1/30/08	
SUBJECT Annual	WITH Simplex Grinnell	FAX Yes	TO: / TO:

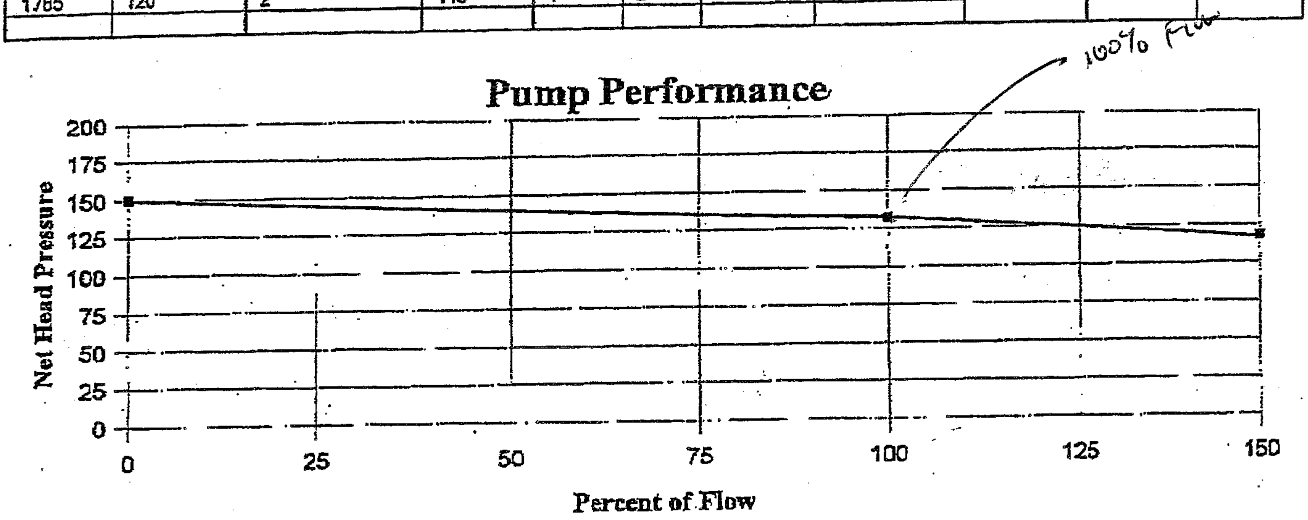
PUMP DATA	SHAFT HSC	MANUFACTURER Patterson	APPROVED yes	SHOP OR SERIAL # 89PT-14042	MODEL OR TYPE 10x8M	
	RATED GPM 2000	RATED HEAD-FT (PSI) 130	RATED RPM 1750	SUCTION FROM: Tank	IF TANK, TANK SIZE 50,000	TANK HEIGHT 40 ft
DRIVER	MANUFACTURER CAT	APPROVED Yes	SHOP OR SERIAL # 91B02823	MODEL OR TYPE 3306BDITA	RATED H.P. 266	RATED RPM 1750

	DIESEL MOTOR X	ELECTRIC MOTOR	RATED VOLT	OPER. VOLT	RATED FL AMPS	AMPS @ 150%	PHASE	CYCLES	SERVICE FACTOR

CONTROLLER	MANUFACTURER Firetrol	APPROVED Yes	START 80 ☒ AUTO ☒ PRESSURE DROP	STOP 90 ☒ MANUAL	JOCKEY PUMP ☒ YES ON psi 100 OFF psi 110
	SHOP OR SERIAL NO 48931	MODEL OR TYPE FTA-1100			

SPEED RPM	DISCHARGE PRESSURE PSI	SUCTION PRESSURE PSI	NET HEAD PSI	STREAMS			GALLONS PER MINUTE	PERCENT OF RATED CAPACITY	VOLTS	AMPS
				NO	SIZE	PITOT PRESSURE				
1855	155	5	150	0	0	0	0	0		
1803	134	2	132	4	2.5	10	2000	100		
1785	120	2	118	4	2.5	20	3000	150		

Pump Performance



COMMENTS:
Change out check valve and gate valve in cooling water discharge line. Enine runs hot due to a bad valve in cooling water line.

GESCO NV.

244 Hyssop Court
Henderson, NV 99015
Cell: (702)375-3275
Fax: (702) 564-8985

PROPERTY OF Mountain View Industrial (Pump Right)				PMI FILE #	START UP #
ADDRESS				TESTED BY Brian Swett	TIME 8:00 AM
CITY LV	STATE Nevada			DATE TESTED 1/30/08	
SUBJECT Annual	WITH Simplex Grinnell	FAX Yes	TO:	TO:	

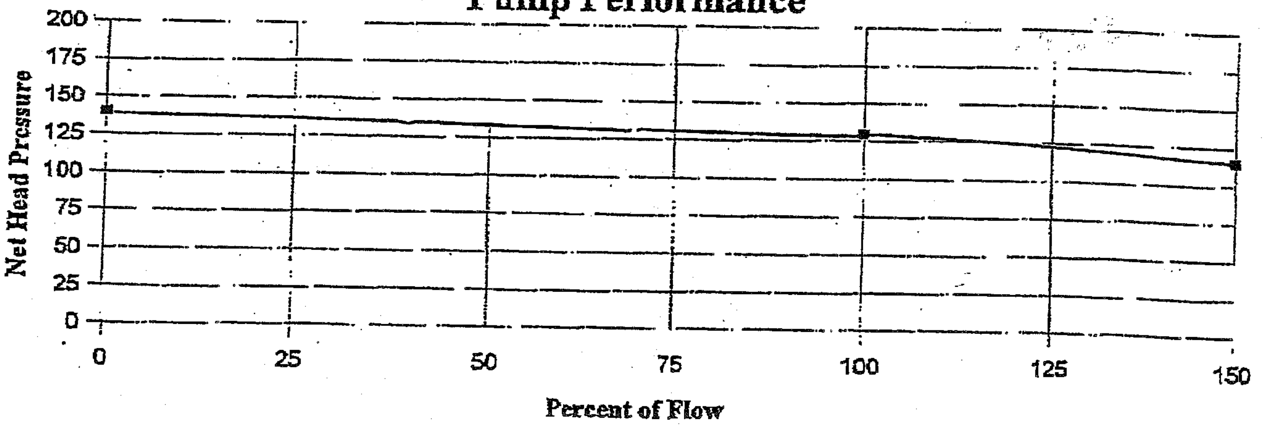
PUMP DATA	SHAFT HSC	MANUFACTURER Patterson	APPROVED yes	SHOP OR SERIAL # 89PT-14042-43LB	MODEL OR TYPE 10x8M
	RATED GPM 2000	RATED HEAD-FT (PSI) 130	RATED RPM 1750	SUCTION FROM: Tank	IF TANK, TANK SIZE 50,000
					TANK HEIGHT 40 ft
DRIVER	MANUFACTURER CAT	APPROVED Yes	SHOP OR SERIAL # 91B02823	MODEL OR TYPE 3306BDITA	RATED H.P. 266
					RATED RPM 1750

DIESEL MOTOR X	ELECTRIC MOTOR	RATED VOLT	OPER VOLT	RATED FL AMPS	AMPS @ 150%	PHASE	CYCLES	SERVICE FACTOR

CONTROLLER	MANUFACTURER Firetrol	APPROVED Yes	START 90 ☒ AUTO ☒ PRESSURE DROP	STOP 100 ☒ MANUAL	JOCKEY PUMP ☒ YES ON psi 100 OFF psi 110
	SHOP OR SERIAL NO 48931	MODEL OR TYPE FTA-1100			

SPEED RPM	DISCHARGE PRESSURE PSI	SUCTION PRESSURE PSI	NET HEAD PSI	STREAMS			GALLONS PER MINUTE	PERCENT OF RATED CAPACITY	VOLTS	AMPS
				NO	SIZE	PITOT PRESSURE				
1808	145	5	140	0	0	0	0	0		
1783	135	5	130	4	2.5	10	2000	100		
1744	120	5	115	4	2.5	20	3000	150		

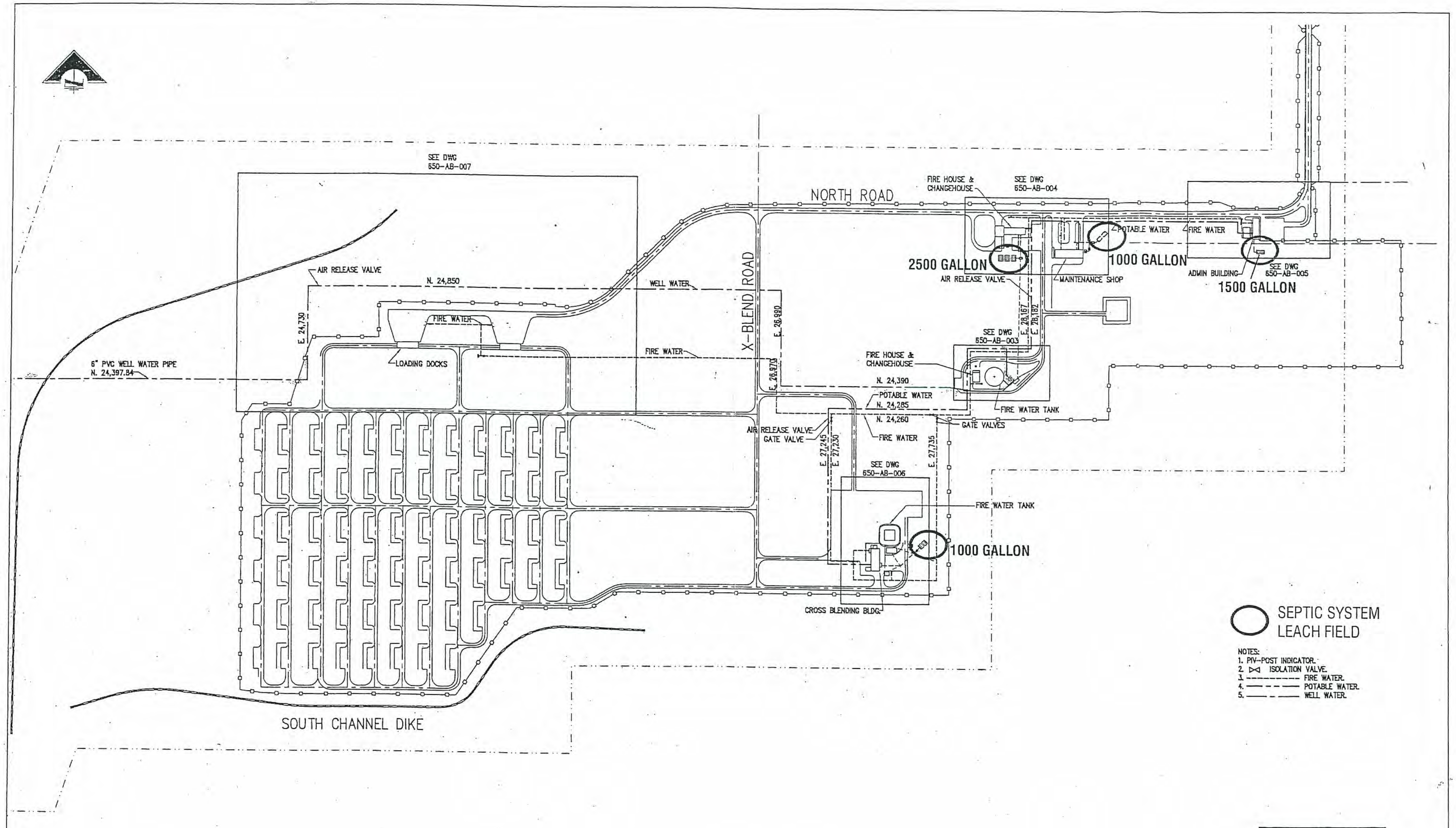
Pump Performance



COMMENTS:

Change out check valve on discharge line of pump. Pressure will not hold. Change out both Main Relief Valves.

APPENDIX F



PRELIMINARY
NOT FOR CONSTRUCTION

REV.	REVISIONS DESCRIPTION	BY	APP'D	DATE
P1	FOR CLIENT REVIEW	RP		5/04

	DATE
DESIGNED BY: RP	MAY 04
DRAWN BY: BJS	MAY 04
CHECKED BY: DM	JUN 04
M3 PROJ. MGR.: DM	JUN 04
USA PROJ. MGR.:	
SCALE: 1"=200'	

M3 Engineering & Technology Corp.
Tucson, Arizona
Chandler, Arizona
Hermosillo, Sonora Mexico

AVESTOR

APEX NEVADA PLANT
WATER SYSTEM
SITE PLAN

JOB NO. M3-PN 03219.04
DWG. NO.
650-AB-002

NAME: P:\2003\03219.04\Mech\650AB002.dwg LAST REV: P1 LAST UPDATE: JUN 08, 2004 TIME: 10:22 AM BY: rp117 PLOT SCALE: 1:1

USGS
science for a changing world

U.S. Department of the Interior
U.S. Geological Survey

Prepared in cooperation with the
Bureau of Land Management

Introduction

The U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM) initiated a cooperative study through the Southern Nevada Public Land Management Act (Bureau of Land Management, 1998) to install six wells in the carbonate-rock and basin-fill aquifers of Clark County, Nevada, in areas of sparse groundwater data. This map uses water levels from these new wells, water levels from existing wells, and altitudes of spring discharge points to update a regional potentiometric map of the carbonate-rock aquifer and provide evidence to interpret the direction of regional groundwater flow. This potentiometric surface map is accompanied by drilling and borehole geophysical logs, well-construction information, lithology, water chemistry, and water levels from the newly drilled wells.

Carbonate-Rock Aquifer and Regional Groundwater Flow

The carbonate-rock aquifer in Clark County consists of thick sequences of Paleozoic-age limestone and dolomite with thinner beds of shale, sandstone, and quartzite that are deformed and extended. Mountain blocks of carbonate rock, separated by intermountain basins, thicken westward from the Muddy Mountains toward the Las Vegas and Sheep Ranges (Dettinger and others, 1995; Prudic and others, 1995; Harrill and Prudic, 1998; Heilweil and Brooks, 2011). Groundwater in the aquifer flows through fractures and faults associated with regional deformation and through small-scale brittle fractures.

The aquifer is primarily recharged through fractures in high-precipitation areas that are in high-altitude mountain ranges near groundwater divides. Regional discharge is from springs and riparian areas at low altitudes in major drainage basins. Discharge from springs at the regional scale is generally constant and less transient than from springs discharging from more localized flow systems (Toth, 1963). Active groundwater withdrawals (or pumping) can affect local spring discharge, producing fluctuations not characteristic of discharge from natural regional springs.

Parts of three groundwater flow systems compose the carbonate-rock aquifer in Clark County: (1) the Colorado System, (2) Death Valley System, and (3) Mesquite Valley System (Harrill and others, 1988). In Clark County, groundwater flow in the Colorado System is principally to the southeast, discharging at the headwaters to the Muddy River. Flow in the Death Valley System is principally to the west, discharging to springs in Amargosa Valley and Death Valley (Faunt and others, 2010). Localized flow in the Mesquite Valley System discharges by evapotranspiration from phreatophytes and evaporation on the valley playa (Glancy, 1968).

Groundwater flow directions and gradients are presented on potentiometric maps by Bedinger and Harrill (2010) and Brooks and others (2014). Both studies used available groundwater levels, spring altitudes, and discharge data to classify groundwater and springs as regional or local. Bedinger and Harrill (2010) generalized hydrogeologic and geologic characteristics as proxy data to define regional hydraulic heads, which are described as water levels that are (1) lower than the water table in areas of recharge, (2) above the altitude of intermediate and regional discharge areas, and (3) below the altitude of non-discharging dry playas.

Brooks and others (2014) developed a regional-scale numerical groundwater flow model to evaluate groundwater availability in the Great Basin. The published potentiometric contours, representative of the carbonate-rock aquifer, were based on water-level observations from wells completed in basin fill and carbonate rock. These studies were conducted at a regional scale and included relatively few direct observations from wells in Clark County, which are completed in carbonate rock.

Selected Existing Hydrogeologic Data

Water levels, water chemistry, lithology, and construction data from monitoring wells were compiled from the USGS National Water Information System (NWIS) database (U.S. Geological Survey, 2016) and from Thomas and others (1996), and compared to information obtained from the six new wells. Sites near production wells were excluded from this selection because of the potential for pumping related drawdown to affect water levels, and monitoring wells were excluded if screened across multiple intervals. Wells were selected if they were screened in the carbonate-rock aquifer or in the basin-fill aquifer at depths greater than 500 feet. It is assumed that basin-fill wells at this depth are in hydraulic connection with the carbonate-rock aquifer (Prudic and others, 1995). In Clark County, 24 wells completed in carbonate rock, 28 wells completed in deep basin-fill deposits, and 5 springs were selected from the USGS NWIS database (table 1) and included in this report.

Table 1. Existing monitoring wells representative of the carbonate-rock and basin-fill aquifers in Clark County, Nevada.

[ID, identifier; USGS, U.S. Geological Survey; NWIS, National Water Information System; mm/dd/yyyy, month/day/year; NGVD 29, National Geodetic Vertical Datum of 1929; CR, carbonate rock; BF, basin fill; —, no data]

Map ID	USGS site ID	USGS NWIS site name	Site type	Well depth (feet)	Hole depth (feet)	Contributing aquifer	Date of water-level measurement (mm/dd/yyyy)	Water level, in feet below land surface	Water-level altitude, in feet above mean sea level (NGVD 29)
1	361816115241301	212 S19 E59 18AAC 1	Well	542	542	CR	09/01/1964	417.00	3,484
2	363500115400001	161 S16 E56 16 1 Indian Springs Sewage Co	Well	550	590	CR	06/01/1963	54.00	3,146
3	362846114495501	216 S17 E64 09DDCD1 CRYSTAL 2	Well	565	565	CR	08/21/2000	254.94	1,815
4	364741114532801	210 S13 E63 26AAAA1 USGS-MX CE-DT-5	Well	628	628	CR	08/13/1999	349.81	1,820
5	360016115361501	163 S22 E57 29DABC1 USBLM NDOT 01	Well	660	660	CR	09/07/2010	306.15	3,917
6	364743114533101	210 S13 E63 23DDDC1 USGS-MX CE-DT-4	Well	669	669	CR	10/15/2015	356.27	1,819
7	363212115240301	212 S16 E58 23DDD 1 USFWS SBH-1	Well	720	720	CR	05/28/2015	575.20	2,891
8	362531114524201	216 S18 E64 07BB 1 WELL (REPORT R50)	Well	793	793	CR	11/29/1956	226.40	1,819
9	355829115150601	212 S23 E60 03DBCB1 TORTOISE CENTER	Well	800	800	CR	03/19/1990	555.00	2,150
10	361736114531601	215 S19 E63 13DCAA1 EBM-3	Well	900	1,241	CR	02/20/2004	578.73	1,810
11	363308114553001	217 S16 E63 09DDAB1 USBLM SHV-1	Well	920	920	CR	10/01/2015	833.69	1,815
12	363332115244001	212 S16 E58 14A 1 USFWS DR-1	Well	930	960	CR	05/28/2015	813.40	2,760
13	364604114471301	219 S13 E64 35DCAD1 USGS-MX CE-DT-6	Well	937	937	CR	11/01/2002	456.00	1,819
14	364830115512601	160 S13 E55 19 1 TW- 3	Well	1,127	1,860	CR	08/25/2015	1,103.00	2,381
15	363407115215301	212 S16 E59 08 2 USGS - Cow Camp	Well	1,403	1,403	CR	07/29/2015	1,330.30	2,856
16	362507114572701	216 S18 E63 05AADB1	Well	1,979	2,007	CR	03/01/2002	755.00	1,811
17	360946115421401	162 S20 E56 33CCAA1 TROUT CANYON 01	Well	718.5	720	CR	01/05/2015	467.30	4,794
18	364451114585001	210 S14 E62 01ADBD1 CSVM-5	Well	1,780	1,783	CR	09/20/2011	1,081.20	2,048
19	362700114564401	216 S17 E63 21DCCC1 HV-1	Well	2,480	2,480	CR	06/20/2000	882.00	1,820
20	361811115404401	212 S19 E56 15ABBD1	Well	660	660	CR	01/26/1981	214.40	8,500
21	364738114534001	210 S13 E63 26AABD1 CSV-RW-2	Well	710	720	CR	09/14/2011	383.40	1,819
22	364728114531001	210 S13 E63 25BDBB1 CSVM-1	Well	1,040	1,060	CR	09/21/2011	341.90	1,819
23	364529114492401	219 S13HE64 33DBBC1 UMVM-1	Well	1,200	1,200	CR	04/22/2003	247.00	1,831
24	363943114552301	210 S15 E63 03BBCC1 CSVM-2	Well	1,400	1,425	CR	09/20/2011	750.70	1,822
25	360201115204701	212 S22 E59 15DAAB1	Well	532	532	BF	03/14/1990	267.21	2,823
26	363201115333801	211 S16 E57 28B 1 Hwy95 Cons 1	Well	550	550	BF	04/22/1963	98.00	3,083
27	360247115224401	212 S22 E59 09CBDB1 HUMANE	Well	570	570	BF	01/21/2009	354.80	2,898
28	363452115405101	161 S16 E56 08BAAC1 USAF Well 3	Well	600	600	BF	07/29/2015	68.00	3,062
29	363447115404601	161 S16 E56 08BAAD1 USAF Well 106-2	Well	604	604	BF	07/29/2015	63.15	3,067
30	363255115515801	161 S16 E54 24BCBA1 Army 2	Well	627	658	BF	08/17/2015	495.20	3,318
31	355015115102601	166 S24 E61 20DDAC1 HIDDEN VALLEY	Well	640	640	BF	12/03/1956	605.00	2,423
32	354454115205401	164A S25 E59 27AACA1 JAIRPORT	Well	650	650	BF	12/11/2008	280.90	2,499
33	361136115101401	212 S23 E61 03BCC 1 Sky Harbor Airport	Well	650	650	BF	04/18/2011	215.36	2,160
34	360941115104801	212 S20 E61 32CDC 1	Well	665	665	BF	04/18/2011	18.47	2,077
35	355923115174201	212 S22 E60 32CB 1	Well	700	700	BF	08/06/1979	460.00	2,420
36	360826115020001	212 S21 E62 10ACAA1 Nevada Power Company	Well	715	715	BF	04/20/2011	21.94	1,683
37	364601114514301	210 S13 E64 31DADA1 USGS CSV-1	Well	765	765	BF	07/31/2009	346.91	1,813
38	361939115154801	212 S19 E60 04DAB 2 NV Division of Forestry	Well	780	780	BF	04/21/2011	77.51	2,376
39	364127114553001	210 S14 E63 28AACD1 USGS CSV-3	Well	780	780	BF	09/20/2011	594.00	1,820
40	355947115163501	212 S22 E60 33BB 1	Well	785	785	BF	12/10/1976	585.00	2,120
41	360931115083802	212 S21 E61 03ABB 2	Well	807	807	BF	04/18/2011	9.08	2,005
42	361843115161001	212 S19 E60 09BCC 1	Well	830	830	BF	04/28/2011	155.76	2,354
43	361233115021501	212 S20 E62 15BBAB1 USAF Nellis 12 (C)	Well	1,000	1,000	BF	04/27/2011	124.71	1,691
44	361346115115901	212 S20 E61 06CBDD1 CNLV Desert Aire	Well	1,000	1,000	BF	04/27/2011	60.72	2,150
45	361400115040901	212 S20 E62 05CAAA1 CNLV Wilshire	Well	1,000	1,000	BF	10/01/2015	62.56	1,806
46	361303115140301	212 S20 E60 11CAAA1 LVVWD W028	Well	1,003	1,003	BF	01/18/2007	202.05	2,085
47	361232115061001	212 S20 E61 13ABDB1 CNLV Diana Terrace	Well	1,230	1,230	BF	10/01/2015	11.83	1,845
48	361626115090701	212 S19 E61 21DDB 1 CNLV Regional Park 1	Well	1,300	1,300	BF	09/01/2015	40.72	2,119
49	360809115252601	212 S21 E58 12DDDD1 RED ROCK WASH	Well	503	503	BF	11/07/2008	400.54	3,288
50	364014114315301	220 S14 E67 31DACD1	Well	387	620	BF	03/19/1987	116.00	1,574
51	364912114041201	222 S13 E71 09BDCA1 PS27	Well	1,450	1,493	BF	07/08/1994	84.00	1,573
52	364044114165201	222 S14 E69 33ABC 1 D & HA	Well	880	880	BF	03/10/1985	37.26	1,341
53	362239114263501	215 S18 E67 12DDAD1 ROGERS SPRING	Spring	—	—	CR	—	—	1,576
54	362321114252601	215 S18 E68 07ABBA1 BLUE POINT SPRING	Spring	—	—	CR	—	—	1,562
55	09419625	CORN CK SPGS AT NATIONAL FISH & WILDLIFE HDQRS, NV	Spring	—	—	CR	—	—	2,930
56	09415910	PEDERSON SPGS NR MOAPA, NV	Spring	—	—	CR	—	—	1,811
57	362450115442001	161 S18 E55 01DACC1 COLD CREEK SPRING	Spring	—	—	CR	—	—	6,324

Drilling, Borehole Geophysical Logs, Lithology, and Well Construction

Groundwater monitoring wells were installed at six locations in Clark County. Criteria for selecting drill sites included (1) the carbonate-rock aquifer was relatively close to the surface, (2) there were no nearby groundwater withdrawals, and (3) access for drilling equipment was possible on existing roads.

Drilling techniques were dependent upon borehole advancement rate and lithology. Mud rotary drilling was predominantly used when drilling through unconsolidated material consisting mostly of sand, gravel, and cobbles. At all sites, the drill penetration rate through unconsolidated material was relatively consistent and progressed rapidly with this technique. When penetration rate slowed in denser rock units, air-hammer drilling was used. A change in drilling method allowed for consistent downward progress and limited drill time and cost.

Spontaneous potential (SP), natural gamma, caliper, and resistivity (borehole, 16- and 64-inch normal) wireline geophysical logs were obtained at each newly drilled borehole. The SP logs measure the voltage between the borehole and an electrode at the surface and are used to identify permeability changes and boundaries between formations at depth. Natural gamma logs show formation radiation intensity, which is generally higher for clay-rich rocks and sediments that tend to emit elevated levels of radiation from natural decay of uranium and thorium to potassium-40. Caliper logs measure borehole diameter and can indicate the presence of fractures along the borehole wall. Resistivity logs record the electrical resistivity of the formation and can indicate higher-porosity transmissive zones. These logs are used together to provide information on the subsurface geology.

Drill cuttings (chips of broken geologic material brought to the surface by drilling fluids) were washed and analyzed. These cuttings, borehole geophysical data, and observations made during drilling provide an indication of the subsurface geologic characteristics at each new drill site. Borehole geophysical logs, drill penetration rate, and subsurface lithology are presented with the study area map.

Wells were constructed of steel or polyvinyl chloride (PVC) well casing ranging from 4.5 to 6.625 inches in diameter. Vertically slotted screens were installed in water-bearing zones interpreted from borehole geophysics. A summary of well-construction information for each of the newly drilled wells is shown in table 2.

Table 2. Summary of well construction information for newly drilled wells in Clark County, Nevada.

[USGS, U.S. Geological Survey; NWIS, National Water Information System; ID, identifier; NDWR, Nevada Division of Water Resources; OD, outside dimension; DCR, depth to consolidated rock; WP, water production; gpm, amount of water pumped from well in gallons per minute; SCH, schedule; PVC, polyvinyl chloride; CR, carbonate rock; BF, basin fill; MR, mud rotary; AH, air hammer; >, greater than; —, no data; NA, not applicable]

Well name	USGS NWIS site ID	Map ID	NDWR log ID	Hole depth (feet)	Well depth (feet)	Diameter of casing (OD), in inches	Screened interval depth		Casing material	DCR (feet)	Aquifer completion	Drilling method	Well test data	
							From (feet)	To (feet)					WP (gpm)	Time (hours)
BW-01	364204114454501	A	109838	1,928	1,926	4.500	1,786	1,926	SCH 80 PVC	595	CR	MR/ AH	3 to 5	24
LSC-01	362454115270201	B	112697	905	890	6.625	336 808	417 889	SCH 40 steel	65	CR	MR	150	6
	(nested)		—	—	210	2.250	190	210	SCH 80 PVC	—	BF	MR	0 (dry)	0 (dry)
RB-01	362135114285401	C	113526	975	973	6.000	810	952	SCH 40 steel	755	CR	MR/ AH	>150	3
BUFPKTS-01	362352114414501	D	114409	1,200	1,198	4.500	988	1,198	SCH 40 steel	221	CR	MR	20	10
IVPH-01	354849115225001	E	115275	1,295	1,290	4.500	1,065	1,275	SCH 40 steel	38	CR	MR/ AH	30	10
JM-01	362901115220001	F	121811	1,103	1,080	4.500	200 780	300 1,080	SCH 40 steel SCH 40 steel	NA	BF	MR	50 to 75	50

Table 3. Total dissolved solids and concentrations of major ions in water samples collected from new wells in Clark County, Nevada.

[mm/dd/yyyy, month/day/year; mg/L, milligrams per liter; <, less than; CR, carbonate rock; BF, basin fill]

Well name	Date (mm/dd/yyyy)	Total dissolved solids (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Principal contributing aquifer
BW-01	04/30/2010	616	60.8	24.4	101	11.0	56.3	195	< 1.0	264	CR
LSC-01	06/14/2012	249	45.1	28.2	5.0	1.46	2.90	21.4	< 1.0	246	CR
RB-01	04/09/2014	2,980	399	135	272	18.5	312	1,570	< 1.0	145	CR
BUFPKTS-01	04/10/2014	234	7.6	4.8	72.4	5.68	17.9	20.6	8.4	166	CR
IVPH-01	04/11/2014	499	67.1	38.2	53.9	3.33	105	86.4	< 1.0	210	CR
JM-01	03/14/2013	283	35.7	28.5	33.4	1.82	5.85	19.0	< 1.0	299	BF

Water Chemistry

Water-quality samples for major-ion chemistry and the stable isotopes of water (deuterium, δ^2H, and oxygen, δ^{18}O) were collected at each new well site, and results of analysis were compared to existing values from springs and wells near the drill sites. Total dissolved solids (TDS) and concentrations of calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), sulfate (SO_4), carbonate (CO_3), and bicarbonate (HCO_3) were measured by the USGS National Water Quality Laboratory (NWQL), in Denver, Colorado (table 3). Deuterium (δ^2H) and oxygen (δ^{18}O) isotopes were analyzed by the USGS Radiogenic Isotope Facility in Denver, Colorado (table 4).

Standard three-well-casing volumes were purged from each well, and water samples were collected with a submersible pump except at two sites (wells IVPH–01 and BUFPKTS–01) where samples were obtained through bailing. A 20-foot-long bailer was used to purge water from the well and collect a representative water sample.

Table 4. Isotopic ratios of deuterium (δ^2H) and oxygen (δ^{18}O) in water samples collected from new wells drilled in Clark County, Nevada.

[δ^2H, deuterium (^{2}H) to protium (^{1}H) isotopic ratio relative to VSMOW; δ^{18}O, oxygen-18 to oxygen-16 isotopic ratio relative to VSMOW; VSMOW, Vienna Standard Mean Ocean Water; ‰, per mil (parts per thousand)]

Well name	δ^2H (‰)	δ^{18}O (‰)
BW-01	–97.49	–12.89
LSC-01	–103.00	–13.98
RB-01	–91.70	–12.38
BUFPKTS-01	–82.50	–11.26
IVPH-01	–92.30	–12.71
JM-01	–95.67	–13.01

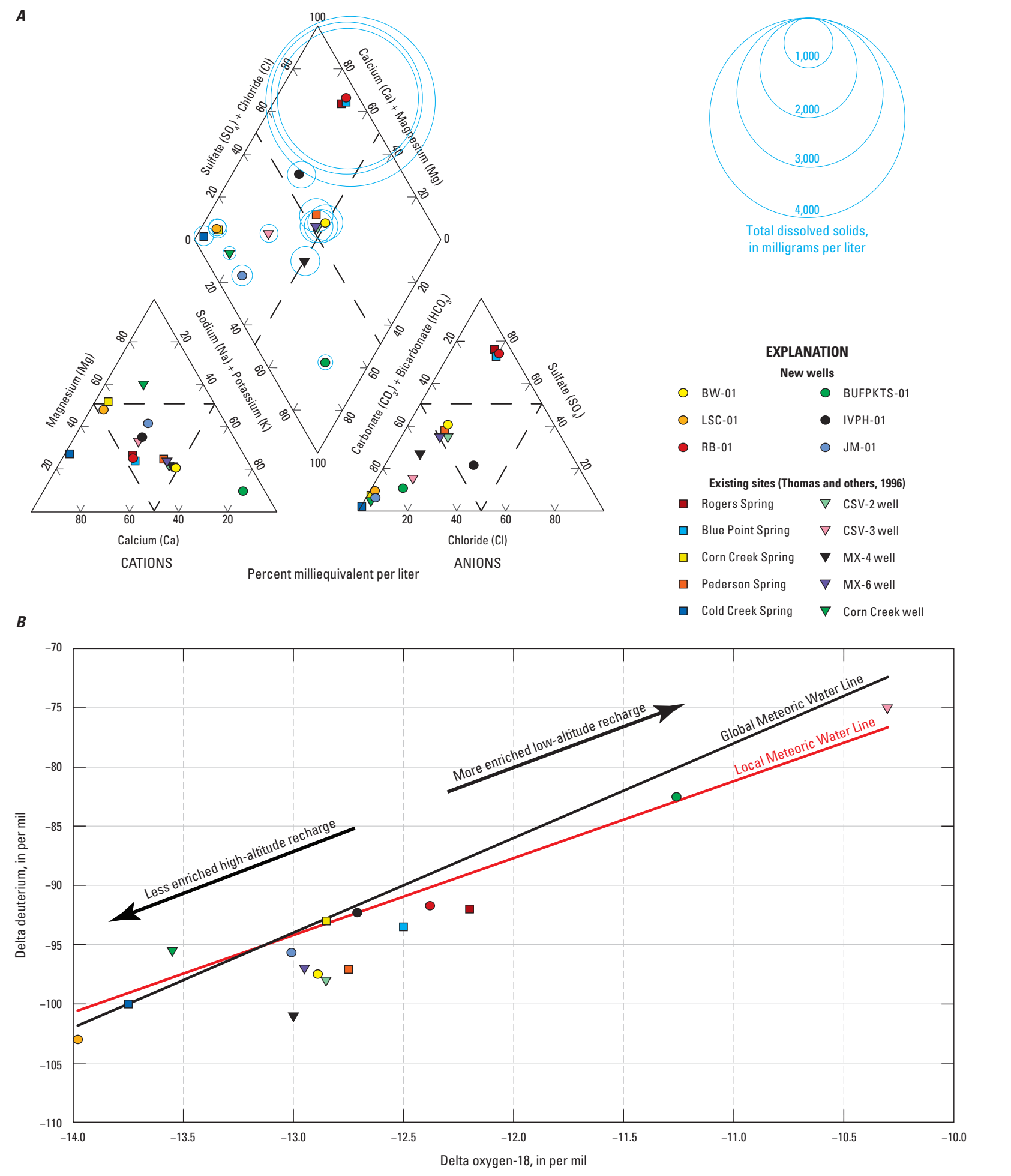


Figure 1. *A*, Total dissolved solids and major-ion concentrations in water samples collected from wells and springs associated with regional groundwater flow, and *B*, isotopic ratios of delta deuterium (δ^2H) and delta oxygen-18 (δ^{18}O) in samples collected from new and reference wells and springs in Clark County, Nevada (Global Meteoric Water Line [$\delta^2H = 8\times\delta^{18}O + 10$; Craig, 1961], and Local Meteoric Water Line [$\delta^2H = 6.5\times\delta^{18}O - 9.7$; Friedman and others, 1992]).

Major-ion chemistry is important to an understanding of the migration of water through a groundwater flow system. A Piper diagram (fig. 1*A*) can be used to evaluate the chemical characteristics of groundwater and the effects of chemical processes occurring between minerals and water. Groundwater samples from newly drilled wells show similar major-ion chemistry to previously sampled wells and springs (Thomas and others, 1996) that are assumed to represent groundwater from the regional carbonate-rock aquifer.

Isotopic ratios of δ^2H and δ^{18}O in water samples collected from wells drilled for this study and in samples previously collected from wells and springs, are compared to the Global Meteoric Water Line (GMWL) and a Local Meteoric Water Line (LMWL) on figure 1*B*. This plot provides a comparison of recharge from low-altitude and high-altitude precipitation sources to waters from previously published data (Thomas and others, 1996).

Water-Level Information

Water levels from newly drilled wells were measured periodically from 2009 to 2015 and stored in the USGS NWIS database (https://waterdata.usgs.gov/nwis). These data were quality assured, which included evaluating measurements for temporal irregularity and adjustments due to known borehole deviation. Water levels were relatively stable throughout the duration of this project except for well BW-01, which experienced a decline of approximately 3 feet from January 2010 to May 2013, and a subsequent recovery of approximately 1 foot from June 2013 to June 2014.

Variations in borehole direction during drilling (drift) are common and can require corrections to water-level measurements. Borehole drift was monitored, and deviation was measured where drift was detected during the drilling of all new wells. The borehole at well BUFPKTS–01 was the only site that needed correction because borehole drift occurred above the depth of the static water level. The water level for this well was corrected using the equation from Elliott and Fenelon (2010):

$$V_d = \left(M_d - M_{top}\right) \times \left(\frac{\Delta V_{int}}{\Delta M_{int}}\right) + V_{top} \quad (1)$$

$$V_d = M_d \times 0.993 - 3.45 \quad (2)$$

where

V_d	is the corrected vertical depth,
M_d	is the measured depth,
M_{top}	is the measured depth to the top of the correction interval,
ΔV_{int}	is the difference in the true vertical depth between the top and bottom of the correction interval,
ΔM_{int}	is the difference in the measured top and bottom of the correction interval, and
V_{top}	is the corrected vertical depth to the top of the interval over which the correction applies.

Regional Potentiometric Surface

Groundwater levels from the six wells drilled for this project and wells fitting the criteria described in the section "Selected Existing Hydrogeologic Data," were compiled and used to construct a groundwater-level map representing the regional potentiometric surface of the upper carbonate-rock aquifer in Clark County, Nevada, in 2009–2015. Data used to construct the potentiometric surface are published separately as a USGS data release (Wilson, 2019). This map is similar to the regional potentiometric surface shown on previous maps by Bedinger and Harrill (2010) and Brooks and others (2014). In general, the potentiometric surface on this map follows the overlying land-surface topography. Higher topographic altitudes typically have higher groundwater altitudes, hydraulic gradients generally are steep near mountain ranges and low (flatten) in basins, and water-level contours parallel and intersect surface-water features.

Area on map	Description
A	In the Las Vegas and Sheep Ranges, and the Spring Mountains, mountain block recharge contributes to and directs regional groundwater flow in Clark County.
B	Water-level contours generally indicate groundwater flow to the east, terminating at discharge points along the Las Vegas Wash in Las Vegas Valley, and the Muddy River near Moapa Valley.
C	A low water-level gradient near Moapa Valley indicates slow groundwater movement toward the Muddy River and Lake Mead.
D	A low water-level gradient in northeast Clark County indicates that groundwater in this area flows toward the Virgin River.

Summary and Conclusions

During 2009 and 2015, the U.S. Geological Survey in cooperation with the Bureau of Land Management installed six new wells in Clark County, Nevada. The wells were installed to address the spatial gaps of wells completed in the carbonate-rock aquifer. This map describes new and existing water-level and hydrologic data used to (1) develop a potentiometric map, and (2) provide additional supporting evidence for the direction of regional groundwater flow in the upper carbonate-rock aquifer in Clark County. Results from this study indicate that the Spring Mountains and the Las Vegas and Sheep Ranges provide primary recharge to the groundwater system in western Clark County. Additionally, potentiometric contours indicate eastward groundwater flow in much of Clark County that terminates at springs along Las Vegas Wash, the Muddy River, and the Virgin River. Previous maps by Bedinger and Harrill (2010) and Brooks and others (2014) show similar water-surface altitudes and gradients. This study introduces new water-level measurement sites that cover data gaps and support previous regional water-surface interpretations. Additionally, comparison of lithologic descriptions, geophysical logs, and groundwater chemistry from the six wells drilled during this study to existing data, substantiates that water levels in the new wells represent the regional carbonate-rock aquifer.

References Cited

Bedinger, M.S., and Harrill, J.R., 2010, Appendix 1: Regional potential for interbasin flow of groundwater, *in* Belcher, W.R., and Sweetkind, D.S., eds., Death Valley regional groundwater flow system, Nevada and California—Hydrogeologic framework and transient groundwater flow model: U.S. Geological Survey Professional Paper 1711, p. 345–364, https://pubs.usgs.gov/pp/1711/.

Brooks, L.E., Masbruch, M.D., Sweetkind, D.S., and Buto, S.G., 2014, Steady-state numerical groundwater flow model of the Great Basin carbonate and alluvial aquifer system: U.S. Geological Survey Scientific Investigations Report 2014–5213, 124 p., https://pubs.usgs.gov/sir/2014/5213/.

Bureau of Land Management, 1998, Southern Nevada Public Land Management Act of 1998—Public Law 105–263: Bureau of Land Management, https://www.gpo.gov/fdsys/pkg/PLAW-105publ263/pdf/PLAW-105publ263.pdf.

Craig, H., 1961, Isotopic variations in meteoric waters: Science, v. 133, no. 3465, p. 1702–1703, http://www.jstor.org/stable/1708089?origin=JSTOR-pdf.

Dettinger, M.D., Harrill, J.R., Schmidt, D.L., and Hess, J.W., 1995, Distribution of carbonate-rock aquifers and the potential for their development, southern Nevada and adjacent parts of California, Arizona, and Utah: U.S. Geological Survey Water-Resources Investigations Report 91–4146, 100 p., 2 pl., https://pubs.er.usgs.gov/publication/wri914146.

Elliott, P.E., and Fenelon, J.M., 2010, Database of groundwater levels and hydrograph descriptions for the Nevada Test Site area, Nye County, Nevada (ver. 9.0, February 2019): U.S. Geological Survey Data Series 533, 13 p., https://doi.org/10.3133/ds533.

Faunt, C.C., D'Agnese, F.A., and O'Brien, G.M., 2010, Hydrology, chap. D *in* Belcher, W.R., and Sweetkind, D.S., eds., Death Valley regional groundwater flow system, Nevada and California—Hydrogeologic framework and transient groundwater flow model: U.S. Geological Survey Professional Paper 1711, p. 133–159, https://pubs.usgs.gov/pp/1711/.

Friedman, I., Smith, G.I., Gleason, J.D., Warden, A., and Harris, J.M., 1992, Stable isotope composition of waters in southeastern California—1. Modern precipitation: Journal of Geophysical Research—Atmospheres, v. 97, no. D5, p. 5795–5812, https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/92JD00184.

Glancy, P.A., 1968, Water-resources appraisal of Mesquite–Ivanpah Valley area, Nevada and California: Nevada Department of Conservation and Natural Resources, Groundwater Resources Reconnaissance Series Report 46, 57 p.

Harrill, J.R., Gates, J.S., and Thomas, J.M., 1988, Major ground-water flow systems in the Great Basin region of Nevada, Utah, and adjacent states: U.S. Geological Survey Hydrologic Investigations Atlas HA-694-C, 2 sheets, scale 1:1,000,000, https://doi.org/10.3133/ha694C.

Harrill, J.R., and Prudic, D.E., 1998, Aquifer systems in the Great Basin region of Nevada, Utah, and adjacent states—Summary report: U.S. Geological Survey Professional Paper 1409–A, 66 p., https://pubs.usgs.gov/pp/1409a/report.pdf.

Heilweil, V.M., and Brooks, L.E., eds., 2011, Conceptual model of the Great Basin carbonate and alluvial aquifer system: U.S. Geological Survey Scientific Investigations Report 2010–5193, 191 p., https://pubs.usgs.gov/sir/2010/5193/.

Prudic, D.E., Harrill, J.R., and Burbey, T.J., 1995, Conceptual evaluation of regional ground-water flow in the carbonate-rock province of the Great Basin, Nevada, Utah, and adjacent states: U.S. Geological Survey Professional Paper 1409–D, 102 p., https://pubs.er.usgs.gov/publication/pp1409D.

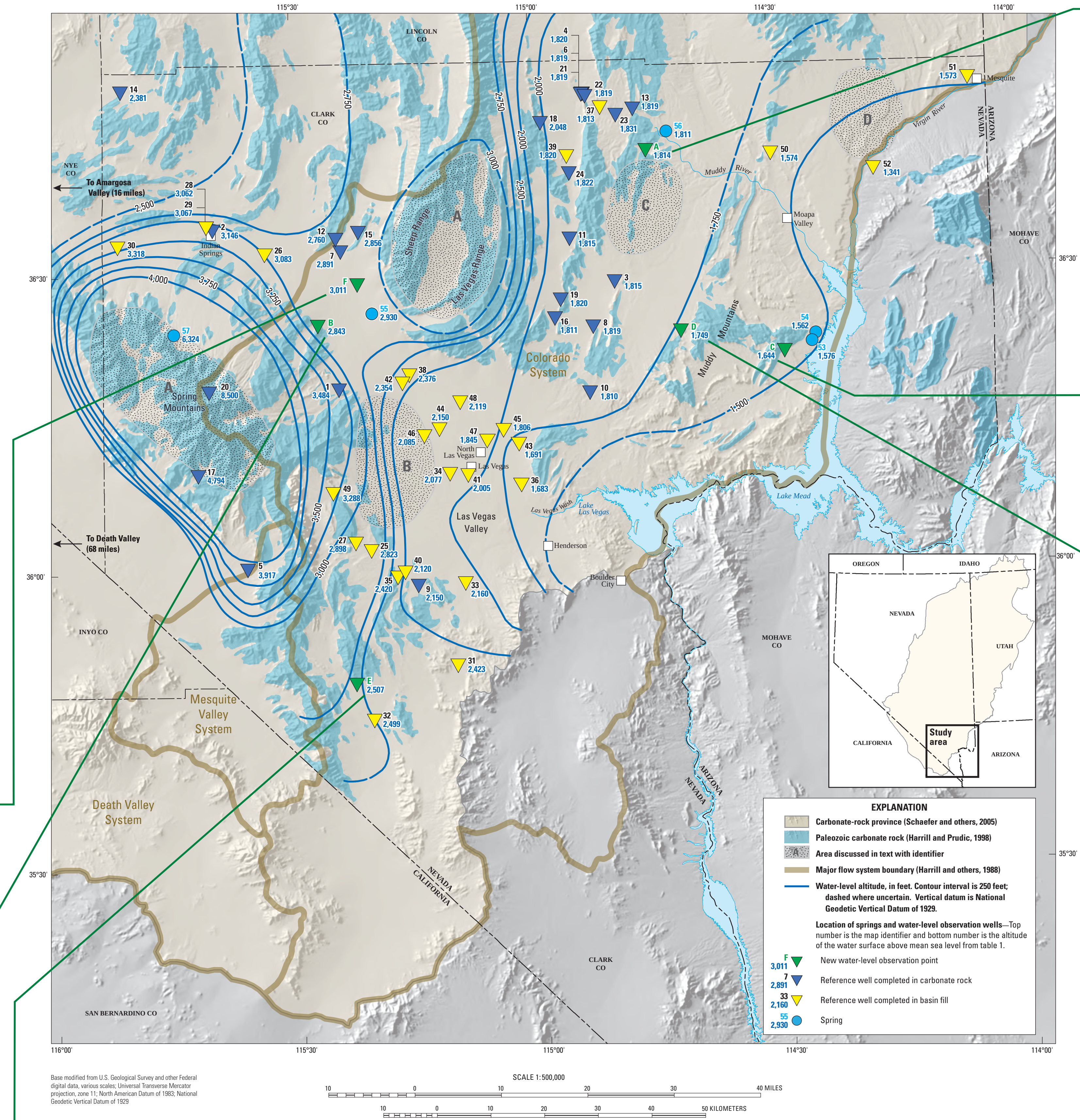
Schaefer, D.H., Thiros, S.A., and Rosen, M.R., 2005, Ground-water quality in the carbonate-rock aquifer of the Great Basin, Nevada and Utah, 2003: U.S. Geological Survey Scientific Investigations Report 2005–5232, 41 p., https://pubs.usgs.gov/sir/2005/5232/.

Thomas, J.M., Welch, A.H., and Dettinger, M.D., 1996, Geochemistry and isotope hydrology of representative aquifers in the Great Basin region of Nevada, Utah, and adjacent states: U.S. Geological Survey Professional Paper 1409–C, 100 p., https://pubs.er.usgs.gov/publication/pp1409C.

Toth, J., 1963, A theoretical analysis of groundwater flow in small drainage basins: Journal of Geophysical Research, v. 68, no. 16, p. 4795–4812, https://agupubs.onlinelibrary.wiley.com/doi/10.1029/JZ068i016p04795.

U.S. Geological Survey (USGS), 2016, USGS water data for the Nation: U.S. Geological Survey National Water Information System database, accessed January 2016, at https://doi.org/10.5066/F7P55KJN.

Wilson, J.W., 2019, Supplemental data for drilling, construction, water chemistry, water levels, and regional potentiometric surface of the upper carbonate-rock aquifer in Clark County, Nevada, 2009–2015: U.S. Geological Survey data release, https://doi.org/10.5066/P9K73T7Q.



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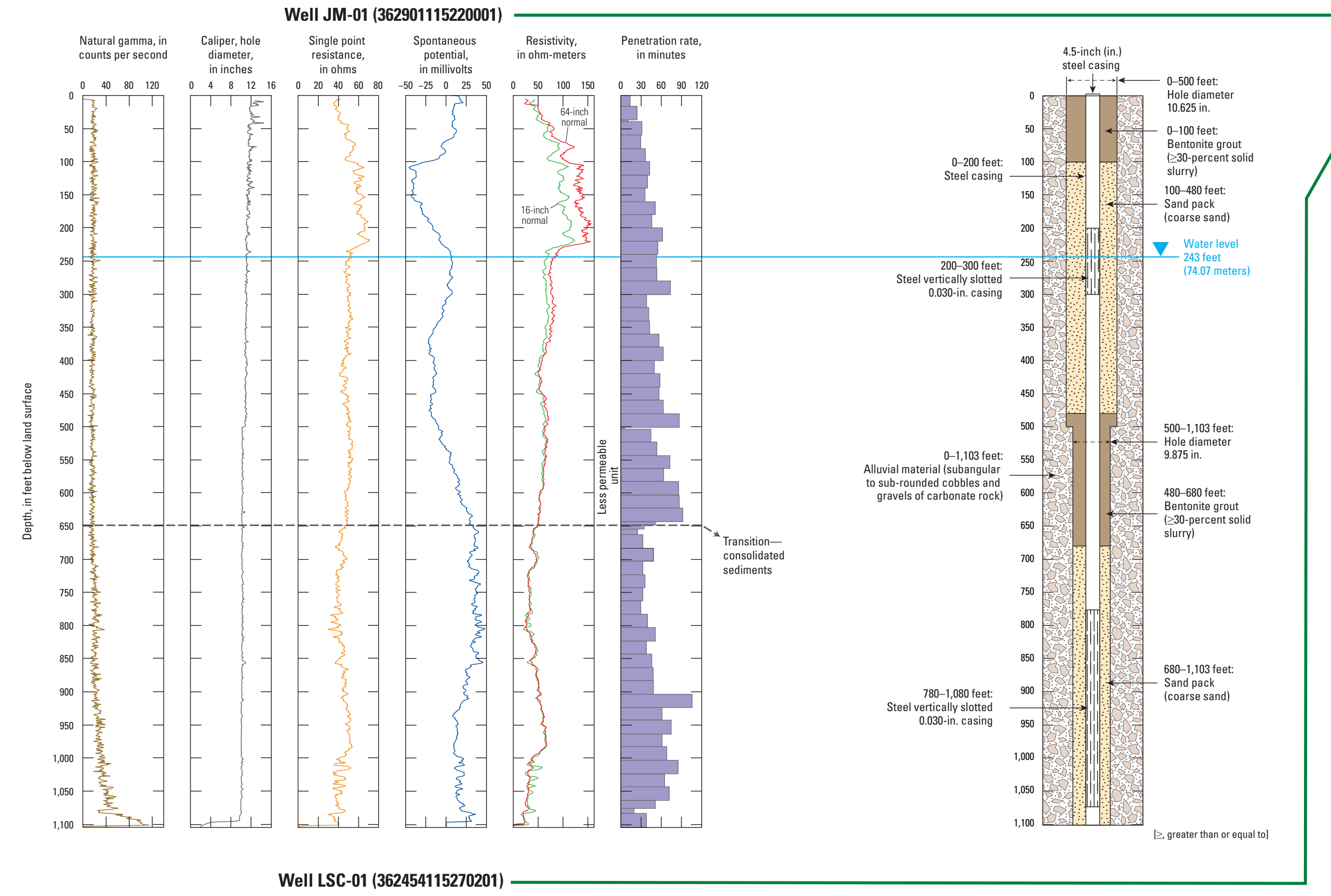

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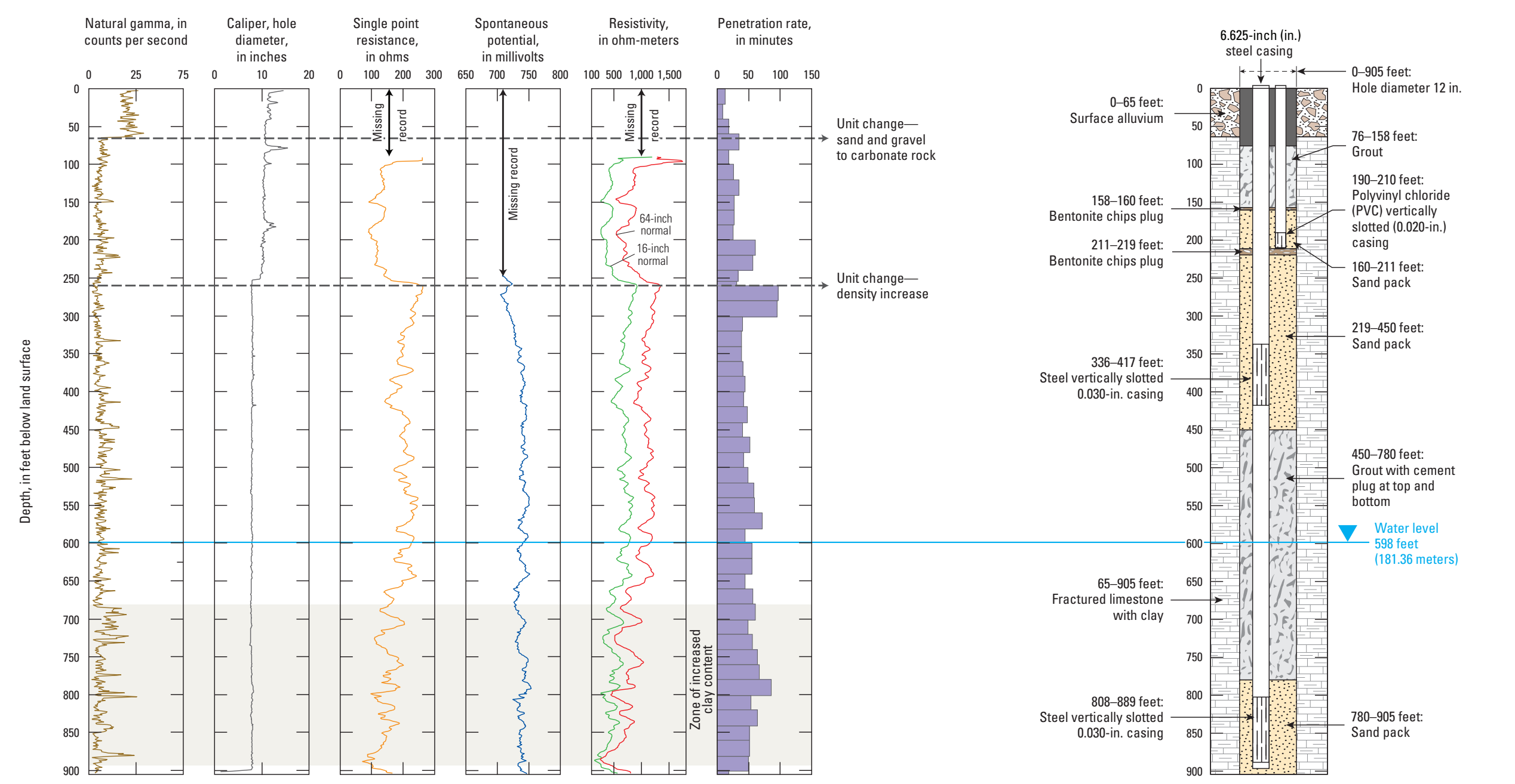

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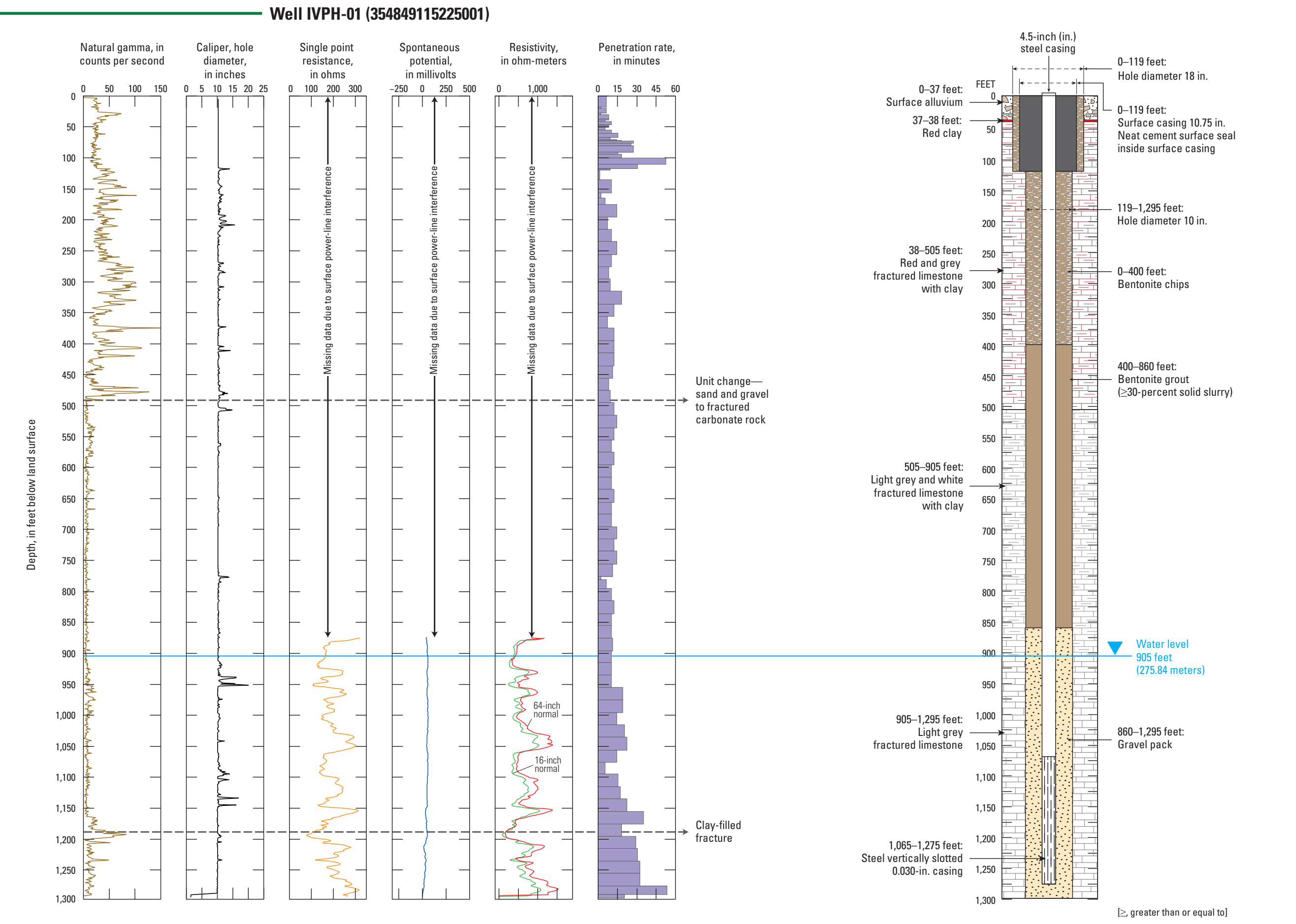

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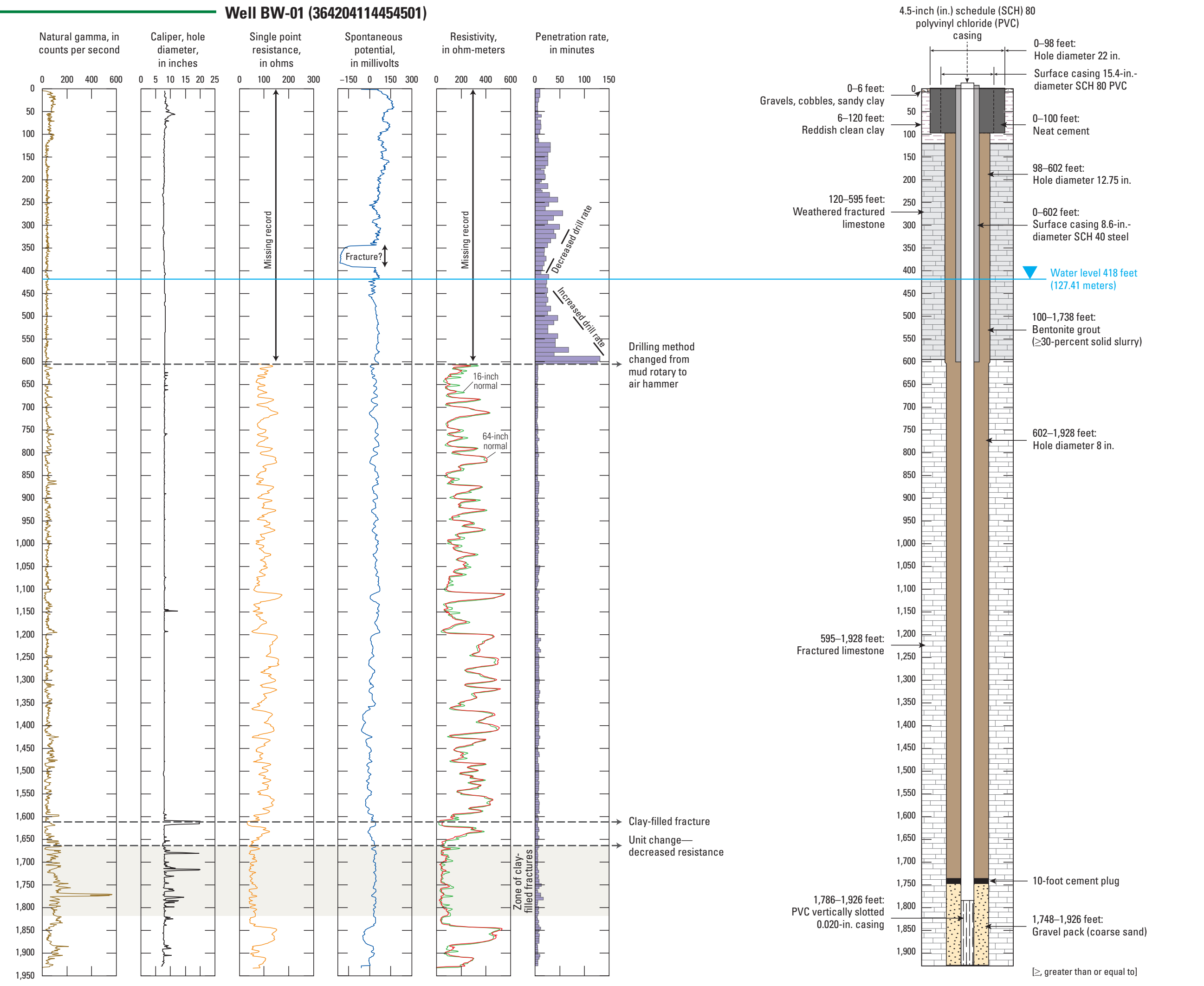

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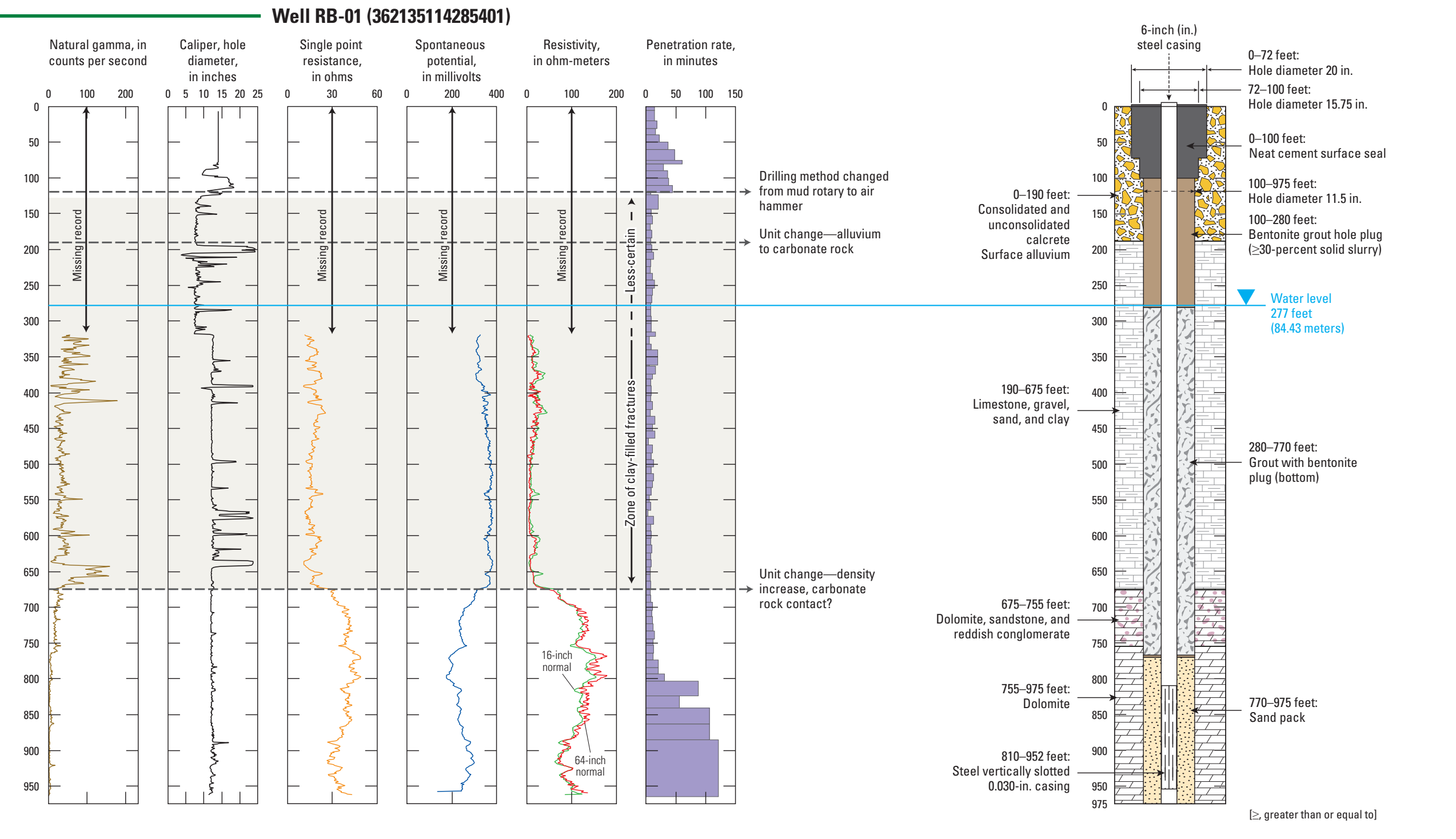

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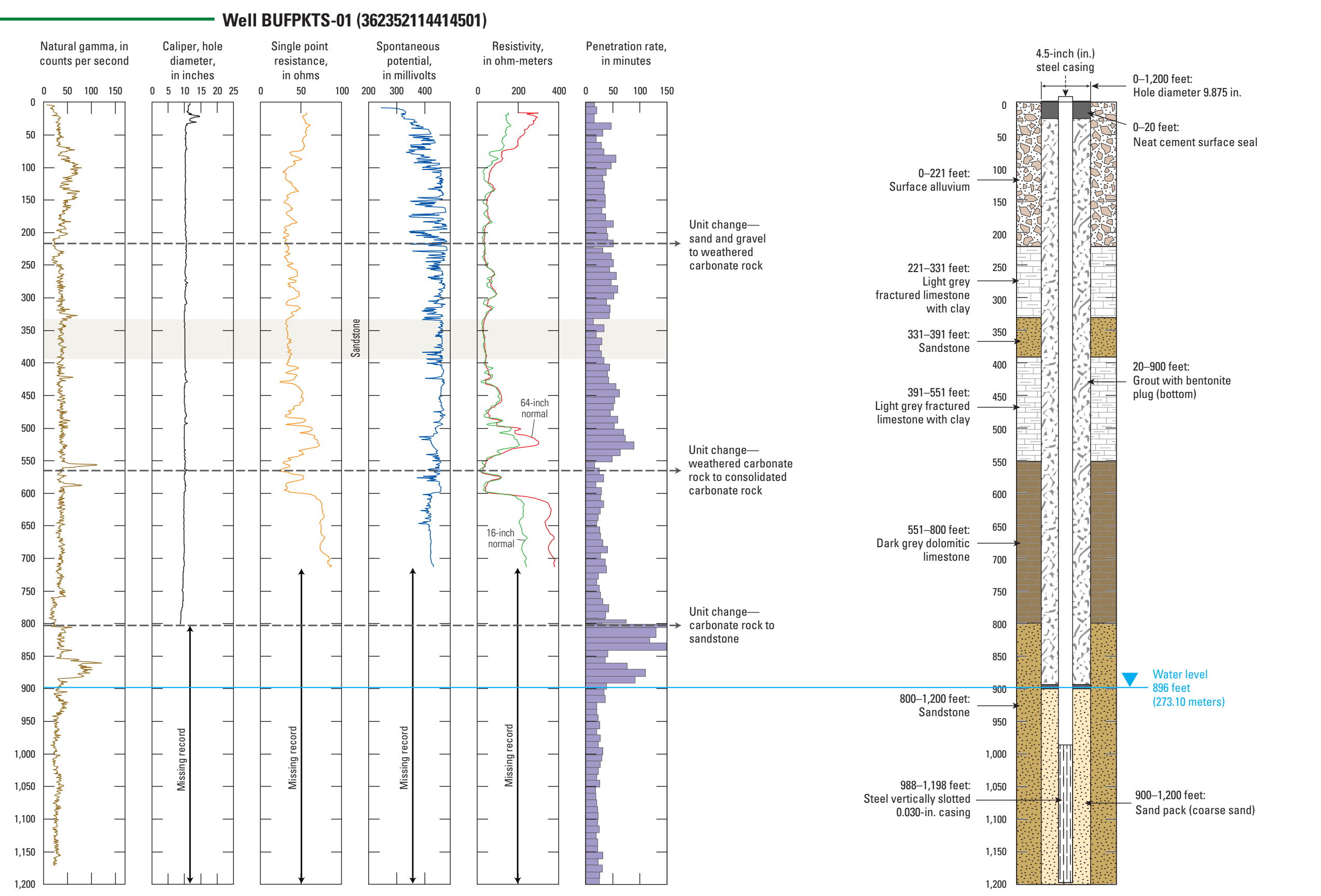

Well BUFPKTS-01 (362352114414501)

Drilling, Construction, Water Chemistry, Water Levels, and Regional Potentiometric Surface of the Upper Carbonate-Rock Aquifer in Clark County, Nevada, 2009–2015

By
Jon W. Wilson
2019

ISSN 2329-132X (online)
https://doi.org/10.3133/sim3434

Digital files available at https://doi.org/10.3133/sim3434 or https://pubs.usgs.gov/sim/3434/.

Suggested citation: Wilson, J.W., 2019, Drilling, construction, water chemistry, water levels, and regional potentiometric surface of the upper carbonate-rock aquifer in Clark County, Nevada, 2009–2015: U.S. Geological Survey Scientific Investigations Map 3434, scale 1:500,000, https://doi.org/10.3133/sim3434.

SOUTHERN NEVADA WATER AUTHORITY
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(702) 862-3400 • snwa.com

June 13, 2013

Mr. Bill Van Liew
National Park Service
Water Resources Division
1201 Oak Ridge Drive, Suite 250
Fort Collins, Colorado 80525-5596

Dear Mr. Van Liew:

SUBJECT: TRANSMITTAL OF SNWA COMMENTS ON THE NUMERICAL GROUNDWATER FLOW MODEL OF SELECTED BASINS WITHIN THE COLORADO REGIONAL GROUNDWATER FLOW SYSTEM, SOUTHEASTERN NEVADA, VERSION 1.0

Per our conversation at the 2013 Nevada Water Resources Annual Conference, please find enclosed a report containing technical review comments prepared by the Southern Nevada Water Authority (SNWA) regarding the *Numerical Groundwater Flow Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southeastern Nevada, Version 1.0* prepared by Tetra Tech, Inc. for the National Park Service, U.S. Fish and Wildlife Service, and Bureau of Land Management (September 28, 2012). A technical review of the following products was performed:

- Report titled *Development of a Numerical Groundwater Flow Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southeastern Nevada - Version 1.0*
- Report titled *Predictions of the Effects of Groundwater Pumping in the Colorado Regional Groundwater Flow System Southeastern Nevada*
- Modeling files provided in electronic form in folder named *Modeling Datasets.*

It is apparent from these products that significant efforts were expended to develop the subject model and, given the complexity of the area, the work accomplished by the authors thus far is recognized. However, given the broad purpose of the model ("…to evaluate the cumulative effects of pumping…and to estimate the magnitude and timing of changes that will occur as a result of use of the groundwater"), SNWA has serious doubts that the model can accomplish this goal. After review, it is apparent that the documentation of the conceptual and numerical models is incomplete and the calibration of the numerical model is inadequate. For example, the steady-state model (pre-pumping) simulates flow in the Muddy River at about 20,000 acre-feet per year (afy). This simulated flow is a poor match to the Tetra Tech calibration target of 32,000 afy or the 33,700 afy reported by Eakin (1964)[1]. Without a good calibration to predevelopment conditions, the model is not ready for transient calibration or to be used to predict the "magnitude and timing of changes" due to future groundwater pumping. Deficiencies in the conceptualization and representation in the numerical model of springs and evapotranspiration are the main causes of the inadequate model calibration. These deficiencies, coupled with many others described in the enclosed report, yield a model that, in its current state, is unusable for its intended purpose.

SNWA appreciates the opportunity to provide these comments and recommends appropriate corrections to the model and documentation. If you have any questions regarding the enclosed report, please contact Andrew Burns at (702) 862-3772 or me at (702) 862-3713.

Sincerely,

Zane Marshall, Director
Water and Environmental Resources Department

ZM:AB:clw

Enclosure

c: Rick Felling, NDWR

---

[1] Eakin, T.E., 1964, Ground-water appraisal of Coyote Spring and Kane Spring Valleys and Muddy River Springs area, Lincoln and Clark Counties, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources Reconnaissance Series, Report 25, 40 p.

SOUTHERN NEVADA
WATER AUTHORITY

Water and Environmental Resources Department
Water Resources Division

Technical Review of Numerical Groundwater Flow Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southeastern Nevada, Version 1.0 - A Model Prepared by Tetra Tech for the National Park Service, U.S. Fish and Wildlife Service and Bureau of Land Management

June 2013

Suggested citation: Southern Nevada Water Authority, 2013, Technical Review of Numerical Groundwater Flow Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southeastern Nevada, Version 1.0 - A Model Prepared by Tetra Tech for the National Park Service, U.S. Fish and Wildlife Service and Bureau of Land Management: Southern Nevada Water Authority, Las Vegas, NV, Doc. No. WRD-ED-0020, 30 p.

CONTENTS

FIGURES

TABLES

ACRONYMS

COV	Coefficient of variation
CCRP	Central Carbonate-Rock Province
DRN	Drain Package (MODFLOW)
DRT	Drain Return Package (MODFLOW)
ET	Evapotranspiration
HGU	Hydrogeologic Unit
HUF	Hydrogeologic Unit Flow Package (MODFLOW)
K	Hydraulic conductivity
LVVWD	Las Vegas Valley Water District
NPS	National Park Service
PC4	Paleozoic carbonate unit 4
PRISM	Parameter-elevation Regressions on Independent Slopes Model
SFR2	Streamflow Routing Package 2 (MODFLOW)
SNWA	Southern Nevada Water Authority
T	Transmissivity
U.S.	United States
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator

ABBREVIATIONS

afy	acre-feet per year
cfs	cubic feet per second
ft/yr	feet per year
ft^2/d	square feet per day

INTRODUCTION

This document contains a technical review of a numerical groundwater flow model of selected basins of the Colorado Regional Groundwater Flow System, located in southeastern Nevada. The model was developed by Tetra Tech for the National Park Service, U.S. Fish and Wildlife Service, and Bureau of Land Management, collectively referred to as the Department of Interior Bureaus. This review covers the following products dated September 28, 2012:

- Report titled “Development of a Numerical Groundwater Flow Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southeastern Nevada - Version 1.0” (referred to herein as the "Model Development Report")
- Report titled “Predictions of the Effects of Groundwater Pumping in the Colorado Regional Groundwater Flow System Southeastern Nevada” (referred to herein as the "Model Prediction Report")
- Modeling files provided in electronic form in folder named “*Modeling Datasets*”

It is apparent from these products that significant efforts were expended to develop the subject model and, given the complexity of the area, the work accomplished by the authors thus far is recognized. As stated on page 63 of the Model Development Report, the purpose of the model is "…to evaluate the cumulative effects of pumping in different areas within the model, and to estimate the magnitude and timing of changes that will occur as a result of use of the groundwater." However, as explained in this document, both the model and the corresponding reports have a number of serious defects that render the model unusable for its intended purpose. This review focusses on the predevelopment model, which represents the system under natural conditions before significant development by man, and is modeled in the first 2 stress periods in the "pre-production" simulation of the Tetra Tech model. Only a limited review of the transient and predictive simulations was performed because the defects that render the predevelopment model unusable, as it does not represent the natural system, also render all subsequent model simulations unreliable and therefore unusable too.

Extensive revisions to the model and associated reports are necessary to resolve the defects identified in this review. These revisions would need to be performed prior to using the model for any predictive simulations and are described in the following text:

1. Preparation of a complete and well-documented conceptual model based on all available and relevant old and new information. This conceptual model would preferably be documented and peer-reviewed prior to the development of the numerical model.
2. Revision of the construction of the numerical model so that important features such as faults, springs, evapotranspiration, and boundary conditions are represented as accurately as possible.

3. Refinement of the model construction through calibration of the revised numerical model to more accurately represent the natural conditions of the system being modeled (approximate predevelopment conditions).

4. Calibration of the numerical model to transient conditions, using all available and relevant hydraulic head, spring discharge, and stream flow data.

5. Preparation of a complete and well-documented numerical model report that would include a detailed analysis of the model fit, including comparisons of simulated targets to actual observations; and a robust comparison between the final calibrated parameters and the observed ranges. This report should also be peer reviewed prior to its use for predictive simulations.

GENERAL COMMENTS - PREDEVELOPMENT MODEL

This section contains descriptions of the major issues identified in the predevelopment model. Remedies are suggested where possible.

Predevelopment Model Calibration

The main issue is that the numerical model is not properly calibrated for predevelopment conditions under natural conditions (stress periods 1 and 2), as exhibited by (1) large residuals for major discharge calibration targets (e.g. Muddy springs discharge); (2) the large magnitude and inappropriate distributions of the head residuals; and (3) hydraulic parameter estimates well outside of the observed ranges, particularly the hydraulic conductivity (K) and transmissivity (T) of the Paleozoic Carbonate unit 4 (PC4). Without a good calibration to predevelopment conditions, the model is not yet ready for the transient calibration or predictive runs.

Discharge Calibration Targets

As reported by the authors of the Tetra Tech model, the measured stream flow in the Muddy River at the Moapa gage is about 32,000 afy under pre-development conditions [Eakin (1964) reports 33,700 afy]. The Tetra Tech model only simulates a flow of about 20,000 afy, or only 63 percent of the assumed value (32,000 afy). This target represents the largest and most reliable of all targets in the White River Flow System portion of the model domain. SNWA (2009a) assumed that the predevelopment stream flow at the Muddy River near Moapa gage to be equal to the average annual flow of 33,700 afy (adjusted for precipitation runoff events), estimated by Eakin (1964). SNWA (2009a) derived an estimate of the variability of this estimate from the historical record up to 1962. The coefficient of variation (COV) of stream flow at that location prior to 1962 was about 0.13 for the raw record (unadjusted) and about 0.02 for the adjusted record, not including suspect measurements. Therefore, stream base flow at this location is known within 4 percent (2 standard deviations). Allowing for model error in addition to the observation error, one should be able to match this target to within 5 or even 10 percent maximum of the observed value.

The authors did not report the simulated flows at other gages located downstream from the Moapa gage on the Muddy River but an examination of the model files reveals that these are also not well matched (Table 1). For example, the simulated streamflow in the Muddy River at Lake Mead is more than 40,000 afy. This is at least 4 times larger than ever reported. SNWA (2009a) estimated a base flow of 7,000 afy based on unadjusted measurements taken in 1914 at the St. Thomas gaging station. The St Thomas gage was located on the Muddy River at its confluence with the Colorado River and was destroyed when Lake Mead was created. Rush (1968) in Reconnaissance Report No. 50, reports an estimate of 10,000 afy based on data collected in 1967.

Table 1
Comparison of Simulated and Observed Streamflow Rates at Gages Located along the Muddy River, under Predevelopment Conditions

Gage	Simulated Value (afy)	Observed		
		Observed Value (afy)	Time Observed	Source
Moapa	20,300	33,700	1914 to 1962	Eakin (1964)
Glendale	48,000	33,600	1951 to 1960	LVVWD (2001)
St Thomas (Lake Mead)	46,600	7,000	1914	SNWA (2009a) based on Wells (1954)

LVVWD: Las Vegas Valley Water District
SNWA: Southern Nevada Water Authority

Head Residuals

In theory and in a well-calibrated model, residuals should vary randomly about a mean value of zero. Table 2 lists the statistics for the head residuals (calculated as simulated minus observed values) at the end of stress period 2. These statistics indicate that the probability distribution of the heads is not normal and has a large mean value of -49 feet. Furthermore, a plot of the same head residuals versus the observed values (Figure 1) confirms that the distribution of the residual is biased. At head elevations lower than about 3,000 ft amsl, most points fall above the zero line, whereas most points at head elevations larger than 3,000 ft fall below the zero line. Figure 6.2-2 of the Tetra Tech report also shows that the spatial distribution of the head residuals is biased. Residuals are mostly positive in the southern part of the model area, and negative in the northern part. These are indications that the model solution is not a good fit to the real system and additional work on the conceptual model and calibration are required.

Hydraulic Parameter Estimates

The values of transmissivity derived by Tetra Tech are inconsistent with the existing data (provided in Table 3-1 of Tetra Tech's report) and with preliminary estimates derived by SNWA based on the Order-1169 aquifer test. The spatial distribution of the total transmissivity is shown in Figure 2 for reference.

Table 2
Pre Production Model, Stress Period 2
Head Residual Statistics

Statistic	Value
Mean	-49
Standard Error	43
Median	6
Standard Deviation	266
Sample Variance	70,747
Kurtosis	5
Skewness	-2
Range	1,526
Minimum	-963
Maximum	562
Sum	-1870
Count	38

In the Tetra Tech model, the total transmissivity in the Muddy River Springs area and a portion of Coyote Springs Valley exceeds 1,000,000 ft^2/day, whereas the highest reported for aquifer test values as summarized in the Tetra Tech Table 3-1 are 530,000 ft^2/day for Well RW-1 in Coyote Spring Valley, and 92,940 to 360,000 ft^2/day for wells proximal to the Muddy River Springs. Within the immediate vicinity of the Muddy River Springs, simulated transmissivities exceed 9,000,000 ft^2/d (Figure 2). These values are significantly greater than those reported in the current literature. One possible solution would be to analyze the Order-1169 aquifer test data and constrain the model by those results.

The large hydraulic conductivity values derived by PEST for the PC4 unit in the Muddy River Springs Area are likely caused by the faulty model representation of the springs (seeps) that occur between the main springs and the Moapa gage. In an attempt to match the streamflow in the Muddy River at Moapa, PEST is forced to calculate extremely large Ks for the PC4 unit in that area.

The issue is likely the result of the plumbing depths of these springs (seeps) being too shallow. Also, as a result of this issue, the water is by-passing the Moapa gage, discharging into the Muddy River downgradient from the Moapa gage, as exhibited by the over-simulated amount of streamflow at gages located below Moapa. This issue is further discussed in a later comment.

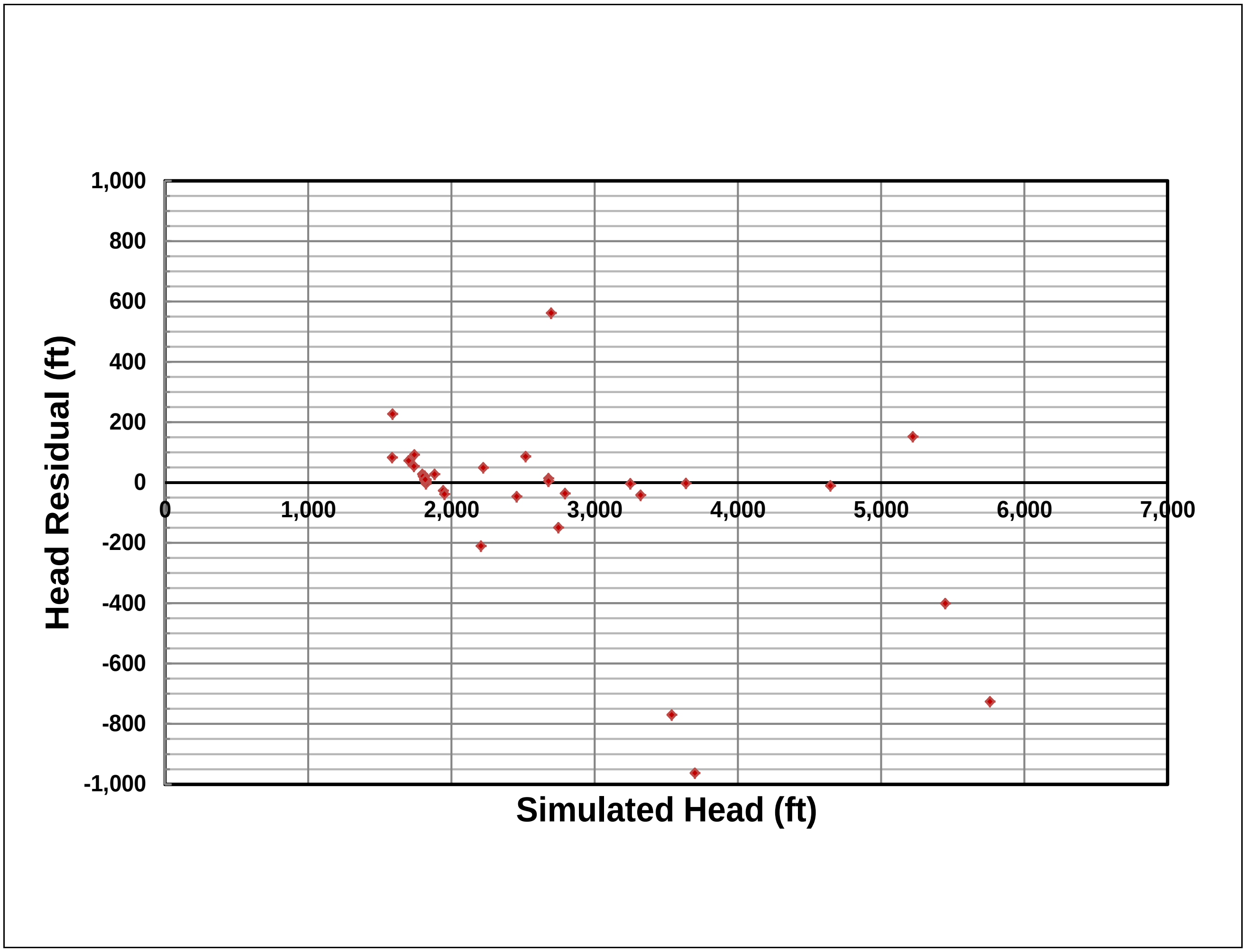


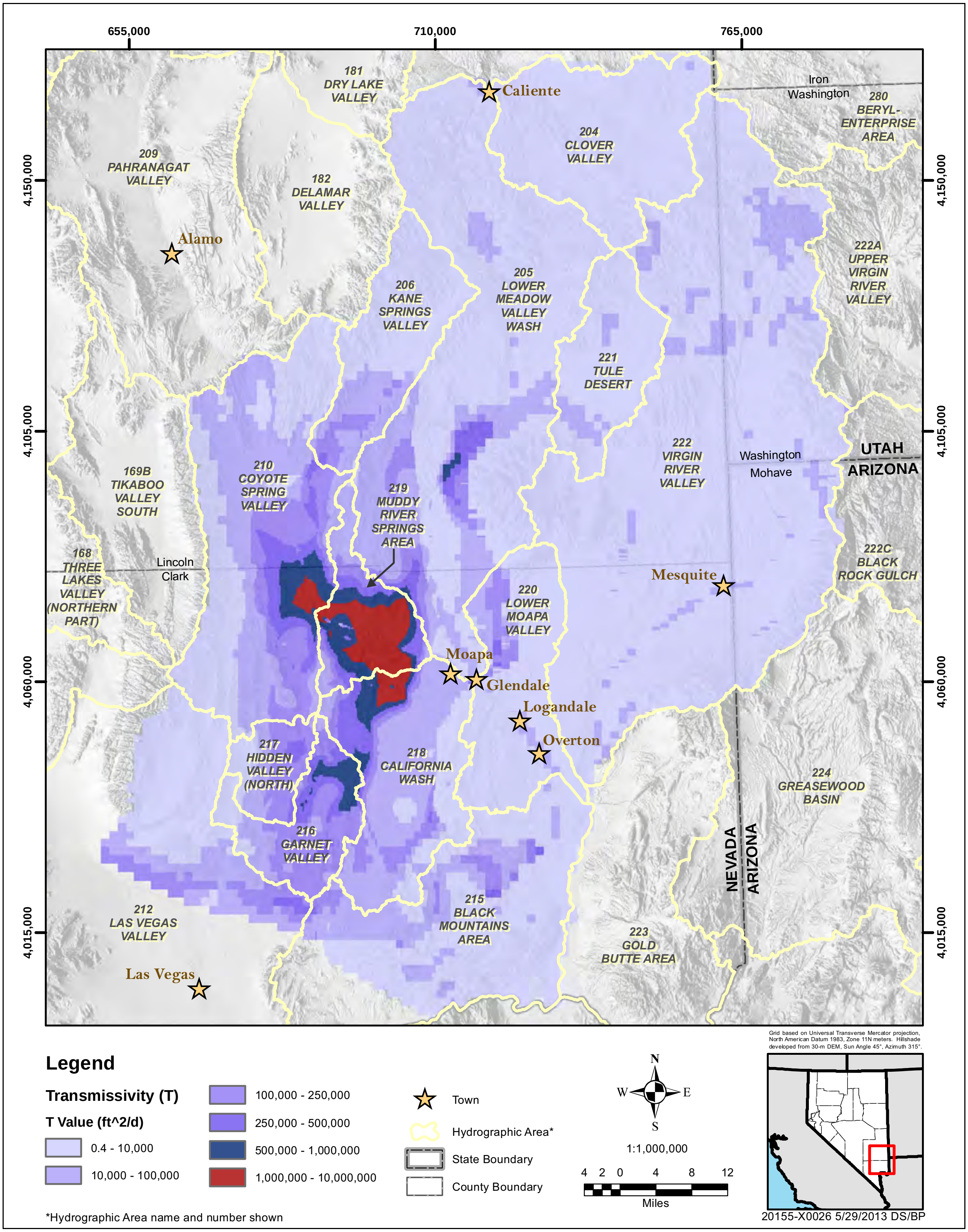
Figure 1
Head Residuals versus Simulated Heads for Predevelopment Conditions, Stress Period 2

Conceptual Model

Missing Faults in the Hydrogeologic Framework

Some major structures have been identified in the basins comprising the Tetra Tech model area, based on photogeologic interpretations and field work (Page et al., 2005; Scheirer et al., 2006; Scheirer and Andreasen, 2008). These structures which include faults located along the Muddy River from Coyote Spring Valley all the way to Lake Mead are not included in the Tetra Tech model. Two SNWA reports (SNWA, 2009a and b) describe how these structures were included into the conceptual and numerical model developed by SNWA. The omission of these faults acting as conduits, leads to simulated subsurface flow to Lake Mead that may be underestimated, for example.

The following is an excerpt from SNWA (2009a, page 4-4) describing these faults; for more details and maps, see SNWA (2009a and b):



Grid based on Universal Transverse Mercator projection, North American Datum 1983, Zone 11N meters. Hillshade developed from 30-m DEM, Sun Angle 45°, Azimuth 315°.

*Hydrographic Area name and number shown

20155-X0026 5/29/2013 DS/BP

Figure 2
Total Transmissivity Distribution in the Tetra Tech Model

> "Recent photogeologic interpretations and limited field work (Page et al., 2005; Scheirer et al., 2006; Scheirer and Andreasen, 2008) have provided insight into the hydrogeology of the southern part of the area. Based on this work, selected structural features were reinterpreted as significant to groundwater flow in the southern part of the study area. These features consist of middle Miocene to Holocene basin-range faults of north, east, and northwest trends. These faults are interpreted to be connected and to form a path for groundwater flow from southern Coyote Spring Valley to the Muddy River Springs Area and eventually to Lake Mead. These faults are also interpreted to have hydraulic conductivities large enough to move groundwater through this area as evidenced by the spring and stream flow in the Muddy River Springs Area. These faults constitute a structural zone from Coyote Spring Valley to Lake Mead (Scheirer and Andreasen, 2008). These faults were directly added to the simplified hydrogeologic model that is discussed in Sections 4.3 and 4.4."

See the following documents for further information on the missing faults.

Scheirer, D.S., Page, W.R., and Miller, J.J., 2006, Geophysical studies based on gravity and seismic data of Tule Desert, Meadow Valley Wash, and California Wash basins, southern Nevada. U.S. Geological Survey Open-File Report 2006-1396, 44 p.

Scheirer, D.S., and Andreasen, A.D., 2008, Results of gravity fieldwork conducted in March 2008 in the Moapa Valley region of Clark County, Nevada: U.S. Geological Survey Open-File Report 2008-1300, 40 p.

Southern Nevada Water Authority, 2009a, Conceptual model of groundwater flow for the Central Carbonate-Rock Province-Clark, Lincoln, and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Vegas, Nevada, 416 p.

Southern Nevada Water Authority, 2009b, Transient numerical model of groundwater flow for the Central Carbonate-Rock Province-Clark, Lincoln, and White Pine Counties Groundwater Development Project: Prepared in cooperation with the Bureau of Land Management. Southern Nevada Water Authority, Las Vegas, Nevada, 394 p.

Missing Analytical Solutions Based on Order-1169 Test

The Order-1169 aquifer test data should have been analyzed (at least for some portions of the test) to derive estimates of aquifer properties for the carbonate aquifer in that area, before using the information in the numerical model. Such analysis would have provided mean values and ranges of aquifer properties, in addition to the ones you list in Table 3-1 on page 11 of the Tetra Tech report. The Order-1169 test provides more reliable initial estimates and ranges of hydraulic properties, particularly for the PC4 unit, for use during model calibration. SNWA conducted preliminary analyses of the Order-1169 data and derived ranges of hydraulic conductivities for the PC4 unit that are much lower than the ones used in this model.

Hydraulic Properties by Hydrogeologic Unit

Aquifer-property data are provided in Table 3-1 of the Tetra Tech model report, but the authors did not analyze these data to clearly identify observed mean values and ranges of hydraulic properties for the hydrogeologic units composing the framework of the aquifer system. The mean values serve as the initial estimates of the parameters and the ranges may serve as constraints during model calibration and/or provide comparative measures for the calibrated values to evaluate their appropriateness and gage the model's representativeness of the real system. This information is also critical to the modeler whether the calibration is done by trial and error or using automatic techniques such as PEST. The PEST information and files are lacking from the report and the modeling files. Providing the PEST files would have at least revealed the ranges used in the model, if the modeler chose to include them in the input PEST file. Although it is clear that constraints on hydraulic conductivity were not used during the PEST optimization process, as some of the pilot point values are well outside of the observed ranges. A summary table of aquifer-property data containing means and ranges derived from all available data should be developed, used by the modeler(s) during model development, and included in the report. The PEST files should be included along with the MODFLOW files in future publications of the model.

Springs

Springs that are located within the model domain should be properly identified, their characteristics including their source depth listed, and classified as to whether they should or should not be included in the numerical model. The spring sources or plumbing depths of regional and sub-regional springs are particularly important because they identify which layers of the numerical model should supply their discharge water. References containing important information to help identify the depth of the spring sources based on water chemistry (Pohlmann et al., 1998) and relationships between spring water temperatures and the geothermal gradient such as Mifflin (1968), must be considered. For example, using water temperature data and Mifflin's (1968) relationship, SNWA (2009a) estimated the plumbing depth of the Muddy springs to be between 2,500 and 3,100 feet below ground surface. Since this information was not considered in the Tetra Tech model, the source of water to the Muddy River springs was placed at a much shallower depth. As a result, the vertical hydraulic gradient in the numerical model was too small and as a consequence simulated discharge does not match the observed total spring discharge as observed at the Moapa gage on the Muddy River. More information may be found in the following reports:

Mifflin, M.D., 1968, Delineation of ground-water flow systems in Nevada: Desert Research Institute, Water Resources Center, Technical Report Series H-W, Publication No. 4, 115 p.

Pohlmann, K.F., Campagna, D.J., Chapman, J.B., and Earman, S., 1998, Investigation of the origin of springs in the Lake Mead National Recreation Area: Desert Research Institute, Water Resources Center, Publication No. 41161, 94 p.

Recharge

Initial recharge estimates are based on the Maxey-Eakin (ME) method and 800-meter normal Parameter-elevation Regressions on Independent Slopes Model (PRISM) of precipitation. The ME efficiencies were adjusted during model calibration. As concluded by the Nevada State Engineer (NSE, 2007, p. 12 and 13), the standard Maxey-Eakin recharge efficiencies should only be applied to the Hardman precipitation maps (Hardman, 1936). Also, the standard Maxey-Eakin recharge efficiencies only apply to the 13 basins and the estimates of groundwater discharge estimates that Maxey and Eakin (1949) used at that time. If new recharge estimates are to be derived based on updated precipitation maps and/or updated groundwater discharge estimates, as is the case for the Tetra Tech model, the appropriate recharge efficiencies should be recalculated using the groundwater-balance method.

Estimates of recharge efficiencies could be derived by balancing recharge to estimates of discharge, prior to input in the model to reduce the number of calibration parameters and present a complete conceptual model prior to numerical model construction and calibration.

Discharge

The omission of existing and available information on groundwater discharge and streamflow under predevelopment conditions may have led to fatal flaws in the conceptual model, which were then represented in the numerical model. Estimates of predevelopment groundwater discharge from springs and especially by evapotranspiration (ET) in some basins are incorrect. For groundwater ET, recent measurements (DeMeo et al., 2008) that are not representative of predevelopment conditions were used in the model. The authors should have considered older reports giving information of what conditions were before significant development started (Glancy and Van Denburgh, 1969; Rush, 1968; LVVWD, 1992), and fully utilized references that are included in their report (Eakin, 1964 and Rush, 1964).

The underestimation of the value of predevelopment ET in Lower Moapa, in particular, causes major problems during model calibration. Predevelopment conditions were much different than when DeMeo et al. (2008) conducted his study. Although the estimates in DeMeo et al. (2008) are reasonable for the time they represent, they are not appropriate for predevelopment conditions everywhere in the model domain. For instance, while SNWA (2009) and reconnaissance estimates for groundwater ET in Lower Moapa Valley are 25,000 and 24,000 afy, respectively, DeMeo et al. (2008) report only 11,500 afy. The difference of 13,000 to 14,000 afy of unaccounted for groundwater loss manifests itself as extra flow in the Muddy River (see Overton target). This also contributes to an outflow from the Muddy River to Lake Mead of more than 40,000 afy, a flow that is at least 4 times larger than historical measurements and estimates indicate. SNWA (2009) estimated 7,000 afy of base flow at the St Thomas gage based on gage records available for Water Years (WY) 1913 through 1916 (Wells, 1954), while Eakin (1968b) estimated flow to Lake Mead to be about 10,000 afy. See excerpt from SNWA (2009a, Section 7.3.1.1.3 , page 7-46) below:

> "The Muddy River near the St. Thomas gaging station was located just upstream from the confluence of the Muddy and Virgin rivers (Figure 7-9). This gaging station was flooded and destroyed when Lake Mead was created. Because of its early record and

> location with respect to the Colorado River, the gage records for this station were most representative of predevelopment conditions of flow from the Muddy River to the Colorado River. Gage records are available for Water Years (WY) 1913 through 1916 (Wells, 1954).
>
> The gage records began in June of WY 1913 and ended in September of WY 1916, during which time there was a 7-month period of missing records from June of WY 1915 to December of WY 1916 (Wells, 1954). The mean annual flow for the only complete year (WY 1914) was 19.3 cfs, or about 14,000 afy (Wells, 1954). This measurement includes contributions from both groundwater and storm runoff. The period of record mean annual flow was calculated to be 19.6 cfs based on the mean monthly values; however, this value reflects large flood events during February of WY 1914 (136 cfs). Given the limitations of the available records, it is impossible to determine the magnitude of the groundwater component. Rush (1968b) estimated this flow to be 10,000 afy but qualified the estimate as a rough approximation based on few data gathered in 1967. This flow most likely represented agricultural return flows.
>
> For this analysis, it is estimated that about half of the stream flow measured in WY 1914 was groundwater discharge, or 7,000 afy. Furthermore, this value is assumed to represent the portion of stream flow of groundwater origin reaching the Colorado River (pre-lake) or Lake Mead under predevelopment conditions. No data are available to derive COVs for this gage; however, they can be assumed to be at least as large as the COV estimated for the other two gages. Considering the lack of information, they are probably larger.
>
> Stream flow in the Muddy River between the Glendale gage and the St. Thomas gage (Figure 7-9) decreases from 31,500 afy to 7,000 afy, or a difference of about 24,500 afy. This amount is very close to the annual volume of groundwater ET estimated by Method 1 for Lower Moapa Valley. This amount, when reduced by the amount of ET located above the gage near Glendale (2,200 afy), is equal to about 23,100 afy. Therefore, stream flow between the two gages is most probably infiltrating into the groundwater flow system and sustaining the riparian vegetation located along the banks of the Muddy River in Lower Moapa Valley."

For more information spring and stream discharge before significant development by man, see the following documents:

Glancy, P.A. and A.S. Van Denburgh, 1969, Water-resources appraisal of the Lower Virgin River Valley Area, Nevada, Arizona, and Utah: Nevada Department of Conservation and Natural Resources, Water Resources Reconnaissance Series Report 51, 94 p.

Rush, F.E., 1968, Water-resources appraisal of the Lower Moapa-Lake Mead area, Clark County, Nevada: Nevada Department of Conservation and Natural Resources, Water Resources Reconnaissance Series Report 50, 75 p.

LVVWD and the MARK Group, 1992, Hydrology and Interactive Computer Modeling of Ground and Surface-Water in the Lower Virgin River Valley, Primarily in Clark County, Nevada, Cooperative Water Project - Water for Nevada's Future- Hydrologic Report. Las Vegas Valley Water District, Las Vegas. NV

Eakin, T.E., 1964, Ground-water appraisal of Coyote Spring and Kane Spring Valleys and Muddy River Springs area, Lincoln and Clark Counties, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources Reconnaissance Series, Report 25, 40 p.

Maxey, G.B., and Eakin, T.E., 1949, Ground water in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada: Nevada State Engineer, Water Resources Bulletin 8, 59 p.

Rush, E.F., 1964, Ground-water appraisal of the Meadow Valley area, Lincoln and Clark Counties, Nevada: Nevada Department of Conservation and Natural Resources, Groundwater resources - Reconnaissance Report 27, 43 p.

Numerical Model

Spring Representation

Major springs in the Muddy River Spring Area forming the head waters of the Muddy River are not properly represented in the numerical model. The Muddy River Springs are represented in the model using the Stream Flow Routing (SFR2) package of MODFLOW in which the discharge from the springs originates only from the uppermost layers of the model. This representation is conceptually at odds with the physical reality of the spring complex. As discussed in a previous comment, the Muddy River Springs derive their flow from deeper portions of the flow system, rather than from the shallow model layers. Springflow discharges in the stream which loses water to the alluvium where a portion of the water is consumed by ET.

This physical process can be represented in MODFLOW in several manners. To preserve the dynamics of deep sourced spring discharge supplying water to the river, a preferred option would be to use the DRT (Drain Return) package in MODFLOW to represent the springs forming the headwaters of the river and keeping the SFR2 package to represent the river. An alternative option would be to keep using the SFR2 package only but adding vertical "stream" reaches at the location of the springs with their first segment located in the layer corresponding to the deepest part of the aquifer system supplying water to the spring. For an example of this setup, see the Central Carbonate-Rock Province (CCRP) numerical model report prepared by SNWA (2009b). This option was utilized in the CCRP model to represent the Muddy River Springs and other springs. These alternative solutions may help you achieve a better match to discharge using more realistic values of hydraulic conductivity.

Evapotranspiration Representation

The ET process is represented using the well package and seasonal changes in ET are simulated in the model. It does not make sense to calibrate the model to seasonal variations of ET when the objective of the model is to serve as a predictive tool for effects of potential pumping in the long term. Also ET, which is a head-dependent process, is simulated using the WELL package, which only allows specified fluxes as inputs. It is extremely inappropriate to use the well package to represent groundwater ET in a transient model, particularly in the predictive simulations far into the future with potentially significant withdrawals of groundwater. As groundwater is pumped, heads in the ET areas may decrease, thereby decreasing the ET rates. This is a major issue for the predictive runs. The ET process should be simulated using the ET package or the Drain Package (DRN) package so that calibrated estimates of the parameters controlling the ET process can be derived and used in the transient simulations. This is an absolute necessity if the model is meant to be a tool to predict what may happen to ET if and when potential future pumping is imposed on the system and the water table is lowered. The observed ET rates and/or volumes should be used as targets during model calibration.

Calibration Targets

The observation weights are not explicitly provided in the report. Whether calibration is performed by trial and error or automatically, the observations used as targets, their measurement errors, and their ranges need to be clearly identified in the description of the conceptual model and all modeling files containing the related information included in the review package.

From the MODFLOW observation process file, it appears that all head values were assigned weights of 1 and the Rogers and Blue Point spring discharge was assigned a weight of 3, but no explanation is provided as to how or why such weights were used. The weights used in the PEST input file are unknown as the PEST files were not part of the model documentation.

Observation weights should be based on data accuracy and dependent on the errors associated with the observations. In addition, if several types of observations are used, relative weighing is required as to not favor one type of measurement over another. Such information is not presented in detail in the report. From the MODFLOW files, it appears that observation weights for all observations other than the gages are equal to 1. However, on p. 34, the report states: "As a result, the simulated streamflow at Lewis Avenue was many-fold larger than measured, and a low weighting factor was applied at the Lewis Gage to minimize the impact on the PEST estimation process." No PEST files were provided to check the weights used in the PEST input file.

Calibration Process

The following are recommendations to help resolve some of issues identified in the model calibration process:

It is not apparent from the reports that a systematic approach for developing numerical groundwater flow models was followed. Model calibrations could benefit from following standards such as the 14 guidelines for effective model calibration documented by Hill (1998) and later updated by Hill and Tiedeman (2007), cited as follows:

Hill, M.C., 1998, Methods and guidelines for effective model calibration: U.S. Geological Survey Water-Resources Investigations Report 98-4005, 90 p.

Hill, M.C., and Tiedeman, C.R., 2007, Effective groundwater model calibration-With analysis of data, sensitivities, predictions, and uncertainty: Hoboken, New Jersey, John Wiley and Sons, Inc.

The initial recharge distribution should be estimated independent of the numerical model and adjusted, if necessary, during model calibration.

Evapotranspiration should be simulated as a head-dependent boundary condition as described earlier, and the observed discharge rates/volumes should be used as calibration targets. The model should be calibrated to mean annual observations rather than seasonal values. The principal of parsimony should be applied here as the seasonal values only add additional complexity that is not required for the stated purpose of the model.

The time discretization should be changed. Typically, if sufficient historical data are available, the historical period may be subdivided into sequential periods for purposes of steady-state and transient calibration and verification/validation. The heads simulated at the end of each time period are used as initial conditions for the next time period. In this case, model calibration is performed using 2 disconnected time periods: prior to 1949 (predevelopment) to 1987 and 2008 to 2011. The verification/validation (called confirmation here) period spans the whole historical period, from 1949 to 2011.

The initial heads used in the Order 1169 model, which covers a time period ranging from 2008 to 2011, are those simulated for the end of the predevelopment model i.e. 1987. According to Figure 3.6-2 in the Model Development Report, significant pumping occurred within the model domain between 1987 and 2008. This means that the heads in 2008 must not be the same as in 1987. It is, therefore, wrong to use the 1987 heads as initial heads in the Order 1169 model. Changing the time discretization to properly cover the entire period of record would resolve this issue and improve your calibration.

Information Presentation

Report

In addition to the defects identified in the model, another major weakness in this effort is in the documentation. In its current state, the model is provided without presenting a separate and comprehensive description of the conceptual model including the details of the available data, the data analyses, and interpretations. The available information should be based on a comprehensive literature review of past studies, including field and modeling studies.

It is extremely important to formulate a conceptual model of the aquifer system being modeled before constructing the numerical model. An adequate description of the conceptual model has many advantages. It allows the modeler to clearly formulate and perhaps deepen his or her understanding of the system based on the available information. It allows others to review the conceptual model before even starting the construction of the numerical model and provide valuable feedback to the modeling team.

Standard methods could be used to develop the conceptual model. Even the most seasoned modeler could benefit from following standard methods because such methods provide a systematic roadmap to complete the task and ensure that all components have been accounted for. In addition, standard methods, when properly applied, give more credence to the work. Examples of standards for groundwater flow modeling include those designed by the American Society for Testing and Materials (ASTM, 1996) and by the Environmental Protection Agency in a manual titled "Guidance on the Development, Evaluation, and Application of Environmental Models" (EPA, 2009). Note that the modeling process used for environmental models is applicable to hydrologic models as the latter are a subset of the former.

The model construction and calibration process should also be documented in detail. Detailed cross sections of the model represented framework should be prepared so that the Hydrogeologic Unit Flow Package (HUF) assignments may be reviewed in relation to the hydrogeologic framework model. All parameters, their initial values, and their ranges should be listed. Estimates of hydraulic properties by hydrogeologic unit (HGU) should be provided. All targets, their mean values, their error measures and their range of values should be listed, including their weights and how they were derived.

The documentation of the Tetra Tech model results is inadequate. As described by Halford (2013), "a groundwater-flow model must be comprehensible in order to assure stakeholders that the model approximates reality and can be used to accurately assess the effects of groundwater development." In order to achieve this goal, clear documentation with simple maps are required to allow comparisons between model simulations and observed conditions. This includes the development of maps and tables of transmissivity and storage-coefficient distributions as it is generally not possible to reject alternative conceptual models with just water-level and drawdown observations (Halford, 2013).

More specifically, a comprehensive evaluation of the model results should also be provided, including model fit and evaluation of parameters. The following lists several of the items required to accomplish this task:

- Figure 6.2-3 should show the observed and simulation values relative to the 1:1 line, rather than the correlation between the two.

- Graphs or tables of simulated and observed stream flow at gages along the Muddy and Virgin rivers should be provided.

- Simulated water budget component estimates should be provided by hydrographic area (use ZONEBUD), as these components are generally published by hydrographic area. This will allow comparison of calibration results to reported values.

- The estimated parameters should be compared to literature ranges using graphs or tables.

- An evaluation of whether the residuals are normally distributed and uncorrelated should be provided.

For a comprehensive description of model result evaluation methods, see Hill and Tiedeman (2007) described in an earlier comment.

Electronic Files and Documentation

The model documentation is also insufficient. It is apparent that changes were made to the source code used for this model. However, the exact changes to the source code are not documented. These modifications should be provided by listing the portions of changed code (original code and new code) in some form, even if the modified source code is not included in the submittal. Not all modeling files are provided, for example the PEST files were not provided. Providing this information would assist the reviewers in performing a more thorough and complete review of the model and allow them to make better recommendations for improvements.

GENERAL COMMENTS - PREDICTIONS REPORT

Given the issues identified in the review of the numerical model and the fact that the model is not calibrated, this review of the predictive simulations and associated report is limited. As stated in the review of the numerical model, some of the identified issues render the numerical model unusable as a predictive tool in its current state. Once the issues identified in the numerical model are addressed, predictive simulations can be performed. Such simulations should, however, take the following comments into account.

- Simulations 3-7 contain pumping of water rights that are still in application status. These scenarios were not conceived with any thought as to what portion of the pumping in each valley may actually be permitted but are rather done by year of the application. Therefore, they are all very unrealistic. More realistic scenarios are necessary.

- The simulations assume pumping 24 hours per day, 7 days per week, 365 days per year for 1,000 years without regards to well-maintenance down time or management strategies involving alternative pumping distributions, or cessation of pumping by any user. While this is typical of models, this limitation needs to be presented to the reader. The simulations do not account for triggers that have been established that would limit drawdowns or changes in discharge at specific locations. This assumption must be explicitly stated in the descriptions of the scenarios and their limitations.

- ET in the simulations is represented as wells pumping at the annual ET rate of the area. As such, there is no reduction in ET throughout the simulation as would be the case if the ET were captured by pumping. As a result, drawdowns would be over-simulated in these areas. A switch to the MODFLOW ET package for a better representation of ET is necessary, as already stated in the review comments on the numerical model.

- In the simulations, there is a substantial amount of time between when the upper springs in the Muddy River System are impacted by pumping and those that are lower. If this were the case, the upper springs would provide significant advanced warning to allow for the management or curtailment of pumping that would avoid the effects to the lower springs and the Muddy River.

- There were no attempts to perform any management scenarios such as the cessation of pumping to determine how quickly the system might recover. Given the triggers that are established, this sort of run on a well-calibrated model, may be very informative.

- The model documentation is very poor. However it does contain some caveats including that the model may be useful if improved with the addition of future pumping and monitoring data. Additional work on the model construction and calibration would also vastly improve the model.

SPECIFIC COMMENTS - MODEL DEVELOPMENT REPORT

Page 1, Section 1.0, 2nd paragraph: In this paragraph, a previous model built by GeoTrans for the study area is described, but no references to documents describing this model are provided. Please refer to and provide appropriate documentation.

Section 1.2, 1st paragraph, last sentence: The stated objective is to improve the previous model in terms of predictive capabilities. Although this new model covers a larger area, apparently has a better representation of the hydrogeologic framework, and uses more sophisticated analysis tools, it does not fulfill this objective, at least not yet given the model's current state of calibration.

Section 1.3: Given that (1) the previous versions of this model were not documented in detail (GeoTrans 2001 and 2003); (2) this new model covers a larger area; and (3) a significant period of time has elapsed since the last model revision in 2003; the approach should include all steps needed to develop this model. This would include:

A clear statement of the modeling objectives.

A three-dimensional conceptual model for the aquifer system of the study area, based on a comprehensive literature review of old and new information and including detailed descriptions of:

- The hydrogeologic framework and how it was simplified into HGUs
- Aquifer-property data and how they were summarized by HGU
- Hydrologic features
- Water budget

The estimates of the water-budget components (recharge, ET, interbasin flow, springflow and streamflow) should be provided for predevelopment conditions and times for which information is available for transient conditions. Summary water budget tables should be included.

A numerical model for the flow systems of the study area, including:

- Construction of the numerical model based on the conceptual model

- Identification of all parameters and calibration targets
- Calibration of the numerical model to predevelopment conditions
- Calibration of the numerical model to transient conditions
- Verification of the numerical model using transient data, if such data are sufficiently available

Page 3, Section 1.3-Item no. 3: New data are great but careful consideration of the time the data were collected versus the time they are represented in the model is necessary. For example, ET rates measured recently may be similar to those prevailing under predevelopment conditions, but the ET areas may be different.

Page 5, Section 2.2, 1st paragraph: The sources of information cited for spring and stream locations and flows are incomplete. Older reports such as the Reconnaissance reports should be added to your list, as they provide the best information of approximate predevelopment conditions.

Page 5, Section 2.2, 2nd paragraph: When selecting small springs from topographic maps and/or Google Earth, was consideration given as to whether these springs discharge from the regional aquifer system that is being simulated? Is it possible that some of these springs are perched? What were the spring selection criteria for inclusion in the model?

Page 5, Section 2.3: It is stated that the spatial and temporal distributions of ET were based on recent studies by DeMeo et al. (2008). The estimates derived by DeMeo et al. (2008) do not represent the mean pre-development ET for all basins in the study area. In particular, the DeMeo et al. (2008) estimate of ET for Lower Moapa Valley (11,500 afy) is less than half of what ET was when Rush (1968) conducted his reconnaissance study (24,000 afy). The difference in the annual volumes is mostly due to a change in the phreatophyte and irrigation acreages. See Table 3 for details. In addition, estimates made by LVVWD (2001) and SNWA (2009a), using different methods, also yielded average annual ET volumes of 26,500 afy and 25,000 afy, respectively, for Lower Moapa, or more than twice the estimate derived by DeMeo et al. (2008). Thus, in addition to the new studies, other references describing and/or estimating historical conditions including predevelopment conditions should have been considered. Please consult all relevant Reconnaissance Reports, LVVWD and SNWA reports, Cole and Katzer (2000); Dixon and Katzer (2002), etc...

Table 3
Comparison of Evapotranspiration Estimates for Lower Moapa Valley

Source	ET Type	Acreage	ET Rate (ft/yr)	ET Volume (afy)
De Meo et al. (2008)	Phreatophytes	3,550	2.2	7,880
Rush (1968)	Phreatophytes	5,600	2.0	11,200
De Meo et al. (2008)	Agriculture	700	5.2	3,640
Rush (1968)	Agriculture	3,400	3.9	13,200

Page 10: After the stratigraphy and the structural features are described, it would be useful to add a Section 3.1.3 titled "hydrogelogic framework" or "hydrogeologic units" and describe how the stratigraphic units were grouped into hydrogeologic units (HGUs). Relevant information from Section 3.1.1 could be moved into this new subsection.

Page 11, Section 3.2 Aquifer Parameters, Table 3-1: First, many more data are available for the study area and should be included in this table or in an appendix. Second, the numerical model requires hydraulic conductivity (K) as the input, not transmissivity. The data in this table are missing information about the tested aquifer interval to derive hydraulic conductivity (K) values. As stated previously, the final model calibrated values should be compared to these ranges at some point to ensure they are reasonable.

Page 12: If the HGUs in the previous section are defined as recommended above, the hydraulic properties could be defined for each of them at the end of Section 3.2 (Aquifer Parameters), after the available data are presented. This aquifer property table by HGU should include means and ranges for hydraulic conductivity and storage coefficients. Later this information can be used to derive initial estimates and constraints for the HGUs K and S parameters.

Page 12, Section 3.3, 1st paragraph., 1st sentence: Considering that Harrill (2007) is an unpublished report, the methods by which Harrill (2007) derived the estimates of inflow and outflow along the boundary of the study area should be summarized; or the report provided in the appendix. Second, it states that the Harrill (2007) estimates were modified. An explanation is needed as to how the estimates were modified, and why. Also, a comparison of the Harrill (2007) estimates to those derived by others should be provided since there is uncertainty in all estimates of interbasin flow.

Page 12, Section 3.3, 1st paragraph., 3rd sentence: It states that "There is a net inflow into the area, most water coming into Coyote Spring Valley from Tikapoo Valley on the west side of the Sheep Range (CSV-2) and from Pahranagat Valley (CSV-3)". This sentence is misleading, it is true that most water comes from Pahranagat Valley but not from Tikapoo Valley. At least list Pahranagat Valley first in the sentence.

Page 13, Table 3-2: The comments provided in this table hint that the authors of this report, rather than Harrill (2007) estimated some of the boundary fluxes. Details on how this was accomplished should be provided in the report or its appendix. Table 3-2 should also include estimates by others for comparison.

Page 13, Section 3.4: The method used to derive estimates of recharge for the model area is incomplete. The recharge efficiencies were not adjusted so that recharge balances discharge. Although the efficiencies (referred to as “Maxey-Eakin coefficients” in report) were adjusted to estimates of discharge later during model calibration, a complete and balanced initial estimate of the recharge distribution should have been derived first, at least for the long-term average recharge you use to represent predevelopment natural conditions (steady-state model). This would help define the water budget for a complete conceptual model, prior to the numerical model construction. Furthermore, recharge and all other water budget components by basin should have been provided to enable comparisons with previous estimates of others. Note that resultant recharge efficiencies should not be called Maxey-Eakin efficiencies as they are substantively different by their method of derivation and magnitude.

Page 14, Section 3.5.1: This section does not include any references to spring discharge data, temperatures, or other information to identify the plumbing depths of the modeled springs.

Page 14, Section 3.5.1, 1st paragraph, 4th sentence: The total predevelopment discharge from the Muddy River springs, as measured at the Moapa gage, was correctly cited (34,000 afy), yet a smaller value (32,000 afy) was used in the numerical model. Why?

Page 15, 3rd paragraph: Perched springs should not be represented in the numerical model. Yet Section 5.2.2 (Springs) states:"Numerous small springs in the Clover and Delamar Mountains were also simulated using a DRAIN cell only in layer 1."

Page 15, Section 3.5.2, 1st paragraph, sentences 1 and 2: The general definition of ET is correct but the statement that "ET, for the purposes of this model, includes evaporation from open water and soils, and transpiration from plants," is not. The numerical model only simulates ET from groundwater and surface-water sourced by groundwater, i.e. phreatophyte transpiration, evaporation from shallow groundwater, and evaporation from open water fed by groundwater. Transpiration of plants sustained by soil moisture from precipitation, evaporation from soils and open water fed by precipitation cannot be simulated by MODFLOW.

Page 15, Section 3.5.2, 1st paragraph, 3rd sentence: Specify that the National Park Service (NPS) funded the USGS to delineate the distribution of and to quantify the amount of annual discharge of ET *from groundwater and surface water,* as the the report prepared by DeMeo et al. (2008) indicates. Although De Meo et al. (2008) had to measure total ET rates in the field, their estimates of ET from each basin did not include ET from precipitation (see previous comment).

Page 15, Section 3.5.2, Table 3-4: Specify when these measurements were made, because the groundwater ET value in Lower Moapa Valley reported by DeMeo et al. (2008) is less than half of previously reported estimates (see general comments). Although the ET rates used by DeMeo et al. (2008) may represent averages over time, the ET areas were delineated using satellite imagery from a single year, 2003. Section 3.5.1, end of 1st paragraph, states that "with development, pumping had decreased the discharge [of the Muddy River springs] to approximately 22,000 afy in 2004. Furthermore, Figure 3.6-2 shows that pumping in the Muddy River Springs Area was maintained at relatively high rates starting in 1987 and pumping rates were similar in 2003 and 2004. The Muddy River flow at Moapa decreased by about 12,000 afy, from 34,000 afy in 1967 (approximate predevelopment conditions) to 22,000 afy in 2004. Thus, the difference in the estimate of ET in Lower Moapa Valley between 24,000 afy (Rush, 1968) and 11,500 afy (DeMeo et al., 2008) is partially due to the reduction in river flow upstream of Lower Moapa Valley. The reduction in river flow is due to pumping and stream water diversions. Other factors contributing to the difference between the estimates of ET include changes in land use along the Muddy River and estimates of ET rates.

Page 20, Section 4.1 and 4.2: The approach seems reasonable and appears to yield a hydrogeologic framework that is consistent with the conceptual rendition as exhibited by the cross-section comparisons. However, as described in the general comments, there are additional faults that may act as conduits for flow in this area (see SNWA 2009a and b).

Page 27, paragraph 2 (Section 5.1.4): The depth-decay equation is missing a parenthesis.

Page 30, 1st paragraph, 3rd complete sentence: These "numerous" springs located on the mountains should not be simulated in this MODFLOW-based model.

Page 30, Section 5.2.3: In the previous model (Geo Trans 2001 and 2003, ET was simulated using the ET package. This version of the model uses the well package. The use of the ET package is superior because it allows ET to be represented as a head-dependent discharge process (which it is), use of ET estimates as targets to adjust the parameters, and how the ET rates may change under the various scenarios to be simulated. This is obviously important given the differences in predevelopment ET estimates and those developed by DeMeo et al. (2008).

Page 32, Section 5.3, 1st paragraph: The description of model calibration is lacking essential elements. The description should include a list of the model parameters, their initial estimates and constraints.

Page 32, Section 5.3, second paragraph: The discussion on model uncertainty is better suited in the discussion of the results. This discussion should be replaced with estimates of the measurement errors on the observed values. Such errors could be used to define weights for the targets and gage whether the calibration is reasonable or not.

Page 32, Section 5.3.1 Calibration Approach: This section would be clearer if each model was discussed separately: steady-state model first, then transient, etc..

Page 33, Section 5.3.2, 1st paragraph: Simply listing how many targets were used is inadequate; the data and the analysis of the data including the statistical analyses should also be presented. Measurement errors should be used to derive variances which can form the basis of weights for the targets. Adjusting the weights of targets based on the magnitudes of their values should be considered.

Page 34, 1st paragraph: The steady-state data set and the source data from which it was derived should be described. How were the original data processed and reduced?

Page 34, last paragraph, 1st sentence: Some information exists, a complete literature review should be performed (see general comments).

Page 35, last paragraph: The use of the pilot points and automatic calibration is not warranted at this point, considering the model may still have some construction issues and is poorly calibrated. As long as a connection between the deep carbonate aquifer and the Muddy River above or at Moapa is not represented in the model, and the river flows downgradient from Moapa under predevelopment conditions do not match, this automatic calibration or any transient calibration will not substantively improve the model.

Page 36, 2nd paragraph, 1st sentence: The potentiometric heads simulated for the end of the pre-production model, i.e. 1987, should not be used as the initial heads for the Order 1169 model, which starts in 2008. Stresses that occurred between 1987 and 2008 must certainly have altered the heads to some degree.

Page 37, Section 6.0: The presentation of the calibrated model does not appropriately describe the fit of the model to the observed data and does not demonstrate that the estimated parameters fall within observed, reasonable, and/or reported ranges.

Page 39, Table 6-2: As discussed under the general comments, the estimates of K in the Muddy River Springs Area are far outside the observed range of values. This is likely a result of an unconstrained PEST attempting to match flow to the Muddy Springs.

Page 40, Table 6-4: The estimates of storage parameters provided in this table fall within the range of observed values. The authors, however, should (1) document the observed values as a part of the description of the conceptual model, (2) present the initial parameter values used in the model, and (3) compare the final estimates to reported ranges.

Page 47, 2nd and 3rd full paragraphs: The mismatches described are not due to uncertainty in pumping and diversion information. They are due to faulty model construction and usage of transient observations to represent predevelopment conditions (ET for Lower Moapa Valley for example). Please see earlier comments.

Page 49, Table 6-5: Streamflow in the Muddy River at Lake Mead is simulated at more than 40,000 afy. This is at least 4 times larger than ever reported. SNWA (2009a) estimated a base flow of 7,000 afy based on unadjusted measurements taken in 1914 at the St. Thomas gaging station. Rush (1968) in Recon Report 50, reports an estimate of 10,000 afy based on data collected in 1967.

Page 64, Section 8.0: Among others, references to the previous GeoTrans model are missing.

GeoTrans, Inc. 2001. Groundwater modeling of the Muddy River Area and surrounding basins with an emphasis on evaluating pending groundwater applications in Coyote Spring Valley. A Report prepared by GeoTrans, Inc. for the U. S. Fish and Wildlife Service, Portland, OR.

GeoTrans, Inc. 2003. Addendum to groundwater modeling of the Muddy River Area and surrounding basins with an emphasis on evaluating pending groundwater applications in Coyote Spring Valley. A Report prepared by GeoTrans, Inc. for the U. S. Fish and Wildlife Service, Portland, OR.

REFERENCES

American Society for Testing and Materials, 1996, Standard guide for conceptualization and characterization of ground-water systems, ASTM D-5979-96, American Society for Testing and Materials, West Conshohocken, PA, 7 p.

Cole, E., and T. Katzer. 2000. Analysis of gains and losses in Virgin River flow between Bloomington, Utah, and Littlefield, Arizona: Southern Nevada Water Authority, Las Vegas, Nevada, 57 p.

DeMeo, G.A., Smith, J.L., Damar, N.A., and J. Darnell, 2008, Quantifying ground-water and surface-water discharge from evapotranspiration processes in 12 Hydrographic Areas of the Colorado Regional Ground-Water Flow System, Nevada, Utah, and Arizona, U.S. Geologic Survey, Scientific Investigations Report 2008-5116, 23 p.

Dixon, G.L., and T.L. Katzer. 2002. Geology and hydrology of the Lower Virgin River Valley in Nevada, Arizona, and Utah: Mesquite, Nevada, Virgin Valley Water District. Virgin Valley Water District Report, Report VVWD-01, 127 p.

Eakin, T.E., 1964, Ground-water appraisal of Coyote Spring and Kane Spring Valleys and Muddy River Springs area, Lincoln and Clark Counties, Nevada: Nevada Department of Conservation and Natural Resources, Ground-Water Resources Reconnaissance Series, Report 25, 40 p.

EPA (U.S. Environmental Protection Agency), 2009, Guidance on the development, evaluation, and application of environmental models, EPA/100/K-09/003, Office of Environmental Information.

GeoTrans, Inc,. 2001. Groundwater modeling of the Muddy River Area and surrounding basins with an emphasis on evaluating pending groundwater applications in Coyote Spring Valley. A Report prepared by GeoTrans, Inc. for the U. S. Fish and Wildlife Service, Portland ,OR.

GeoTrans, Inc., 2003. Addendum to groundwater modeling of the Muddy River Area and surrounding basins with an emphasis on evaluating pending groundwater applications in Coyote Spring Valley. A Report prepared by GeoTrans, Inc. for the U. S. Fish and Wildlife Service, Portland, OR.

Glancy, P.A. and A.S. Van Denburgh, 1969, Water-resources appraisal of the Lower Virgin River Valley Area, Nevada, Arizona, and Utah: Nevada Department of Conservation and Natural Resources, Water Resources Reconnaissance Series Report 51, 94 p.

Halford, K.J., 2013, Reporting flow model results for groundwater development. A presentation at the Nevada Water Resources Association 2013 Annual Conference. Abstract retrieved from http://www.nvwra.org/storage/2013/2013Conf_Program.pdf.

Hardman, G., 1936, Nevada precipitation and acreages of land by rainfall zones: University of Nevada, Reno, Agricultural Experiment Station, mimeographed report, 10 p.

Harrill, J.R., 2007, Evaluation of boundary fluxes for the ground-water flow model being prepared as part of the SNPLMA-5 project: unpublished consultant report, December 2007, 17 p.

Hill, M.C., 1998, Methods and guidelines for effective model calibration: U.S. Geological Survey Water-Resources Investigations Report 98-4005, 90 p.

Hill, M.C., and Tiedeman, C.R., 2007, Effective groundwater model calibration-With analysis of data, sensitivities, predictions, and uncertainty: Hoboken, New Jersey, John Wiley and Sons, Inc.

Las Vegas Valley Water District, 2001, Water resources and ground-water modeling in the White River and Meadow Valley flow systems, Clark, Lincoln, Nye, and White Pine counties, Nevada: Las Vegas Valley Water District, Las Vegas, Nevada, 285 p.

LVVWD and the MARK Group, 1992, Hydrology and interactive computer modeling of ground and surface-water in the Lower Virgin River Valley, primarily in Clark County, Nevada, Cooperative Water Project - Water for Nevada's Future- Hydrologic Report. Las Vegas Valley Water District, Las Vegas. NV

Maxey, G.B., and Eakin, T.E., 1949, Ground water in the White River Valley, White Pine, Nye, and Lincoln counties, Nevada: State of Nevada, Office of the State Engineer, Water Resources Bulletin No. 8, 59 p.

Maxey, G.B., and Eakin, T.E., 1949, Ground water in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada: Nevada State Engineer, Water Resources Bulletin 8, 59 p.

Mifflin, M.D., 1968, Delineation of ground-water flow systems in Nevada: Desert Research Institute, Water Resources Center, Technical Report Series H-W, Publication No. 4, 115 p.

Nevada State Engineer (The office of the State Engineer of The State Nevada), 2007, The ruling (#5712) In the matter of applications 72218, 72219, 72220 and 72221 filed to appropriate the underground waters of the Kane Springs Valley hydrographic basin (206), Lincoln County, Nevada.

Page, W.R., Dixon, G.L., Rowley, P.D., and Brickey, D.W., 2005, Geologic map of parts of the Colorado, White River, and Death Valley groundwater flow systems-Nevada, Utah, and Arizona: Nevada Bureau of Mines and Geology Map 150, scale 1:250,000.

Pohlmann, K.F., Campagna, D.J., Chapman, J.B., and Earman, S., 1998, Investigation of the origin of springs in the Lake Mead National Recreation Area: Desert Research Institute, Water Resources Center, Publication No. 41161, 94 p.

Rush, E.F., 1964, Ground-water appraisal of the Meadow Valley area, Lincoln and Clark Counties, Nevada: Nevada Department of Conservation and Natural Resources, Groundwater resources - Reconnaissance Report 27, 43 p.

Rush, F.E., 1968, Water-resources appraisal of the Lower Moapa-Lake Mead area, Clark County, Nevada: Nevada Department of Conservation and Natural Resources, Water Resources Reconnaissance Series Report 50, 75 p.

Scheirer, D.S., Page, W.R., and Miller, J.J., 2006, Geophysical studies based on gravity and seismic data of Tule Desert, Meadow Valley Wash, and California Wash basins, southern Nevada. U.S. Geological Survey Open-File Report 2006-1396, 44 p.

Scheirer, D.S., and Andreasen, A.D., 2008, Results of gravity fieldwork conducted in March 2008 in the Moapa Valley region of Clark County, Nevada: U.S. Geological Survey Open-File Report 2008-1300, 40 p.

Southern Nevada Water Authority, 2009a, Conceptual model of groundwater flow for the Central Carbonate-Rock Province-Clark, Lincoln, and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Vegas, Nevada, 416 p.

Southern Nevada Water Authority, 2009b, Transient numerical model of groundwater flow for the Central Carbonate-Rock Province-Clark, Lincoln, and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Vegas, Nevada, 394 p.

Wells, J.V.B., 1954, Compilation of records of surface waters of the United States through September 1950-Part 9, Colorado River Basin: U.S. Geological Survey Water-Supply Paper 1313, 749 p.

Permit No. 83490

THE STATE OF NEVADA

PERMIT TO CHANGE THE PUBLIC WATERS OF THE STATE OF NEVADA HERETOFORE APPROPRIATED

Name of Permittee:	LAS VEGAS VALLEY WATER DISTRICT
Source:	UNDERGROUND
Basin:	GARNET VALLEY
Manner of Use:	MUNICIPAL AND DOMESTIC
Period of Use:	JANUARY 1ST THROUGH DECEMBER 31ST
Priority Date:	10/17/1989

****

APPROVAL OF STATE ENGINEER

This is to certify that I have examined the foregoing application, and do hereby grant the same, subject to the following limitations and conditions:

This permit, to change the point of diversion of a portion of the waters of an underground source as heretofore granted under Permit 54073, is issued subject to the terms and conditions imposed in said Permit 54073 and with the understanding that no other rights on the source will be affected by the change proposed herein. This well shall be equipped with a two (2) inch opening for measuring depth to water. A totalizing meter must be installed and maintained in the discharge pipeline near the point of diversion and accurate measurements must be kept of water placed to beneficial use. The totalizing meter must be installed before any use of the water begins or before the proof of completion of work is filed. If the well is flowing, a valve must be installed and maintained to prevent waste. This source is located within an area designated by the State Engineer pursuant to NRS 534.030. The State retains the right to regulate the use of the water herein granted at any and all times.

This permit does not extend the permittee the right of ingress and egress on public, private or corporate lands.

The total combined duty of water under Permits 77745 and 83490, having the same point of diversion, shall not exceed 310.02 acre-feet annually.

The total combined duty of water under Permits 54073, 54074, 68822, 74399, 79001, 79002, 79003, 79004, 79005, 79006, 79007, 79008, 79009, 79010 and 83490, being fully supplemental, shall not exceed 2,274.57 acre-feet annually.

The issuance of this permit does not waive the requirements that the permit holder obtain other permits from State, Federal and local agencies.

If any water under this permit is cancelled or any water is not put to beneficial use, it will revert to the groundwater source and not back to the base water right.

This permit is issued for use by the City of North Las Vegas for municipal and domestic purposes in Garnet Valley within the Apex Area.

(Continued on Page 2)

The well authorized under this permit must be drilled into and only draw water from the carbonate system. The demonstration of such construction must be submitted to the State Engineer prior to putting any water to beneficial use.

All provisions of the monitoring plan submitted to the State Engineer for approval under base right Permits 54073, 54074 and 68822, shall remain in force, and will apply to all subsequent change applications and new diversion-only appropriations. If information from the monitoring plan or other studies demonstrates an adverse impact on existing rights, mitigation will be required to the satisfaction of the State Engineer.

The point of diversion and place of use are as described on the submitted application to support this permit.

The amount of water to be appropriated shall be limited to the amount which can be applied to beneficial use, **and not to exceed 0.68 cubic feet per second or 300.0 acre-feet annually.**

Work must be prosecuted with reasonable diligence and proof of completion of work shall be filed on or before: **Filed Under 77745 on August 02, 2010**

Water must be placed to beneficial use and proof of the application of water to beneficial use shall be filed on or before: **August** 22 **2019**

Map in support of proof of beneficial use shall be filed on or before: **N/A**

IN TESTIMONY WHEREOF, I, JASON KING, P.E.,

State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 22nd day of **August, 2014**

for State Engineer

Application No. 83490

APPLICATION FOR PERMISSION TO CHANGE POINT OF DIVERSION, MANNER OF USE AND PLACE OF USE OF THE PUBLIC WATERS OF THE STATE OF NEVADA HERETOFORE APPROPRIATED

THIS SPACE FOR OFFICE USE ONLY

Date of filing in State Engineer's Office JAN 31 2014

Returned to applicant for correction

Corrected application filed

Map filed Jan 9 2009 under 77745

The applicant Las Vegas Valley Water District
1001 S. Valley View Blvd. of Las Vegas
Street Address or PO Box City or Town
Nevada, 89153 hereby make(s) application for permission to change the
State and ZIP Code

☑ Point of diversion ☐ Place of use ☐ Manner of use ☑ of a portion

of water heretofore appropriated under (Identify existing rights by Permit, Certificate, Proof or Claim Nos. If Decreed, give title of Decree and identify right in Decree.)
Permit 54073

----

1. The source of water is Underground
Name of stream, lake, underground, spring or other sources.

2. The amount of water to be changed 300.00 acre-feet annually
Second feet, acre-feet. One second foot equals 448.83 gallons per minute.

3. The water to be used for Municipal and domestic
Irrigation, power, mining, commercial, etc. If for stock, state number and kind of animals. Must limit to one major use

4. The water heretofore used for Municipal and domestic
If for stock, state number and kind of animals.

5. The water is to be diverted at the following point (Describe as being within a 40-acre subdivision of public survey and by course and distance to a found section corner. If on unsurveyed land, it should be stated.)
NW 1/4 NW 1/4 Section 16, T. 18S., R.63E., MDB&M, or at a point from which the NE corner of said Section 16 bears N. 78°18'25" E. a distance of 4,154.~~34~~ feet. Please see map filed for Permit 77745.
.45

PLO
2/5/14

6. The existing point of diversion is located within (If point of diversion is not changed, do not answer.)
Lot 1 (SW 1/4 SW 1/4) Section 32, T.17S., R.63E., MDB&M, or at a point from which the southwest corner of said Section 32 bears S. 39°06"46" W., a distance of 465 feet.

2/6-CL
Garnet Valley
(Dry Lake Valley)

7. Proposed place of use (Describe by legal subdivisions. If for irrigation, state number of acres to be irrigated.)
Unchanged (within Clark, Lincoln, Nye and White Pine Counties).

8. Existing place of use (Describe by legal subdivisions. If changing place of use and/or manner of use of irrigation permit, describe acreage to be removed from irrigation.)
Within Clark, Lincoln, Nye and White Pine Counties.

9. Proposed use will be from January 1 (Month and Day) to December 31 (Month and Day) of each year.

10. Existing use permitted from January 1 (Month and Day) to December 31 (Month and Day) of each year.

11. Description of proposed works. (Under the provision of NRS 535.010 you may be required to submit plans and specifications of your diversion or storage works.) (State manner in which water is to be diverted, i.e., diversion structure, ditches, pipes and flumes or drilled well, pump and motor, etc.)
Existing well identified by log number 33206.

12. Estimated cost of works Already complete.

13. Estimated time required to construct works Already complete. See well log number 33206.
If well completed, describe well.

14. Estimated time required to complete the application of water to beneficial use five years.

15. Provide a detailed description of the proposed project and its water usage (use attachments if necessary): (Failure to provide a detailed description may cause a delay in processing.)
Water will be used by the City of North Las Vegas for municipal and domestic purposes in Garnet Valley within the Apex area.

16. Miscellaneous remarks:

John J. Entsminger
Type or print name clearly

Signature, applicant or agent

Las Vegas Valley Water District
Company Name

1001 S. Valley View Blvd.
Street Address or PO Box

Las Vegas, NV 89153
City, State, ZIP Code

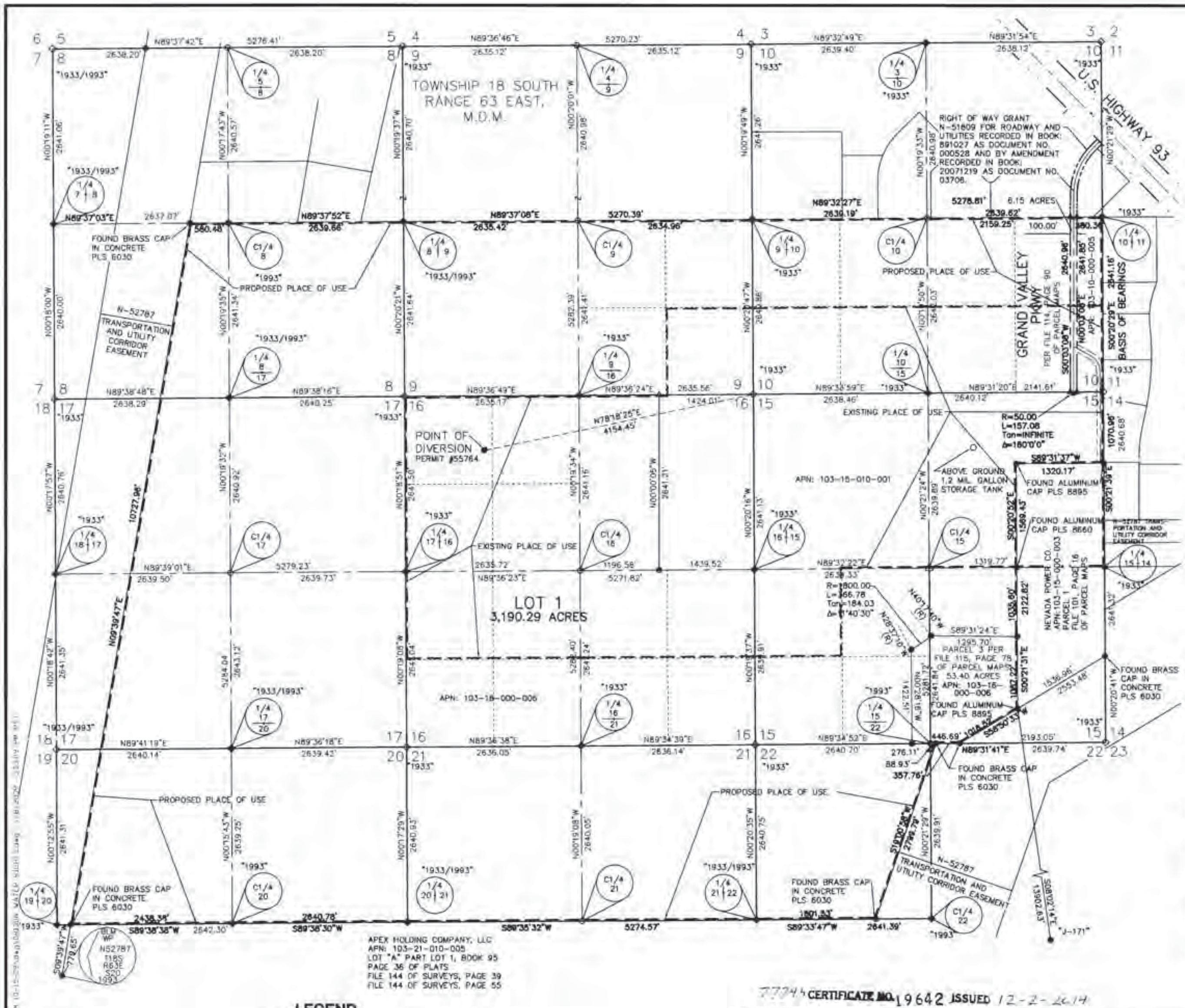
john.entsminger@snwa.com
E-mail Address

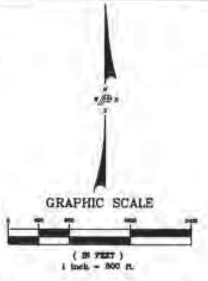
(702) 875-7080
Phone No. Ext.

APPLICATION MUST BE SIGNED
BY THE APPLICANT OR AGENT

Revised 07/13 $240 FILING FEE AND SUPPORTING MAP MUST ACCOMPANY APPLICATION

SHEET NO. 1 OF 1 SHEETS





WATER RIGHTS SURVEYOR'S AFFIDAVIT

STATE OF NEVADA } SS
COUNTY OF CLARK }

I, MARK D. HERZIG, BEING FIRST DULY SWORN, DEPOSE AND SAY THAT THIS MAP CONSISTING OF ONE (1) SHEET, NUMBERED FROM 1 TO 1, INCLUSIVE, HAS BEEN CORRECTLY DRAWN TO THE DESIGNATED SCALE FROM FIELD NOTES MADE BY ME, OR UNDER MY SUPERVISION AND DIRECTION ON THE 23th DAY OF DECEMBER, 2008; THAT IT TRULY AND CORRECTLY REPRESENTS THE PROPOSED LOCATION AND EXTENT OF THE WORKS USED TO DIVERT WATER FROM THE GARNET VALLEY BASIN IN CLARK COUNTY BY KAPEX, LLC, A NEVADA LIMITED LIABILITY COMPANY, FOR COMMERCIAL PURPOSES. THAT THE PROPOSED POINT OF DIVERSION AND THE BOUNDARY OF ALL LANDS ARE FULLY AND CORRECTLY THEREON.

Mark D. Herzig

MARK D. HERZIG, P.L.S. 18982
STATE WATER RIGHTS SURVEYOR, CERTIFICATE NO. 1220

MARK D. HERZIG Exp. 6-30-11 No. 18982

1-08-09

SUBSCRIBED AND SWORN TO BEFORE ME, KIM M. WEBB, THIS 8th DAY OF JANUARY, 2009.

Kim M. Webb

KIM M. WEBB, NOTARY PUBLIC IN AND FOR SAID CLARK COUNTY, NEVADA

MY APPOINTMENT EXPIRES ON THE 12th DAY OF APRIL, 2009.

BASIS OF BEARINGS:

NORTH 00°20'29" EAST, BEING THE THE EAST LINE OF THE SOUTHEAST QUARTER (SE1/4) OF SECTION 10, TOWNSHIP 18 SOUTH, RANGE 63 EAST, M.D.M., CITY OF NORTH LAS VEGAS, CLARK COUNTY, NEVADA, AS SHOWN ON THAT CERTAIN MAP RECORDED IN FILE 114, PAGE 90 OF PARCEL MAPS, CLARK COUNTY RECORDER'S OFFICE, CLARK COUNTY, NEVADA.

NOTES:

1) ALL DISTANCES SHOWN ARE GROUND VALUES

2) THE EXISTING PLACE OF USE CONTAINS 1,039.42 ACRES
THE PROPOSED PLACE OF USE CONTAINS 3,243.69 ACRES

LEGEND

— — — — — = EXISTING OR PROPOSED PLACE OF USE
———————— = SECTION LINE
——— - ——— - ——— = QUARTER SECTION LINE
———————— = BOUNDARY LINE
——-·-——-·-—— = RIGHT-OF-WAY
B.L.M. = BUREAU OF LAND MANAGEMENT
U.S.G.L.O. = UNITED STATES GOVERNMENT LAND OFFICE
(R) = RADIAL BEARING

◆◇ FOUND UNITED STATES GENERAL LAND OFFICE MONUMENT AS NOTED
△ FOUND 5/8" REBAR WITH ALUMINUM CAP STAMPED "F.W. ORBAN PLS 4541" PER FILE 114, PAGE 90 OF PARCEL MAPS
⊖ FOUND NAIL AND BRASS TAG "PLS 4541"
○ NO POINT FOUND OR SET
■ FOUND REBAR AND ALUMINUM CAP AS NOTED
● FOUND 5/8" REBAR WITH ALUMINUM CAP STAMPED "M.D. HERZIG PLS 18982" PER FILE 115, PAGE 78 OF PARCEL MAPS
APN ASSESSOR'S PARCEL NUMBER

77745 CERTIFICATE NO. 19642 ISSUED 12-2-2014

STATE ENGINEER'S USE

REV:
1-9-2009
The label on the POD should be 55674 not 55764

FILED
JAN 09 2009

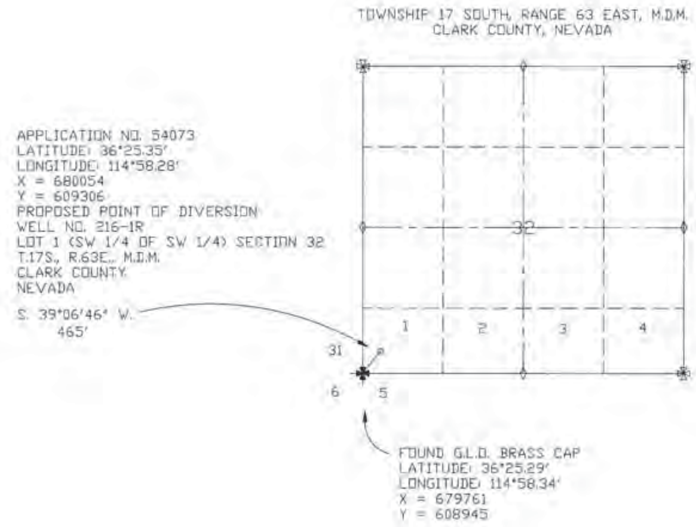
Ⓢ

MAP TO ACCOMPANY AN APPLICATION TO
CHANGE THE PLACE OF USE
UNDER PERMIT NO. 55674
CERTIFICATE NO. 16705

FOR: COMMERCIAL PURPOSES
BY: KAPEX, LLC
FROM: AN UNDERGROUND SOURCE
IN: CLARK COUNTY, NEVADA

97169T 83490 77745

TOWNSHIP 17 SOUTH, RANGE 63 EAST, M.D.M.
CLARK COUNTY, NEVADA



APPLICATION NO. 54073
LATITUDE: 36°25.35'
LONGITUDE: 114°58.28'
X = 680054
Y = 609306
PROPOSED POINT OF DIVERSION
WELL NO. 216-1R
LOT 1 (SW 1/4 OF SW 1/4) SECTION 32
T.17S., R.63E., M.D.M.
CLARK COUNTY,
NEVADA

S. 39°06'46" W.
465'

FOUND G.L.O. BRASS CAP
LATITUDE: 36°25.29'
LONGITUDE: 114°58.34'
X = 679761
Y = 608945

SURVEYOR'S CERTIFICATE

STATE OF NEVADA)
) S.S.
COUNTY OF WASHOE)

I, MICHAEL D. BUSCHELMAN, being first duly sworn, depose and say that this map, consisting of one sheet, has been correctly drawn to the designated scale from field notes of a survey made under my supervision and direction on or before February 15, 1990 That it correctly represents the location of the proposed point of diversion from an underground source in Clark County, Nevada, by the Las Vegas Valley Water District for municipal and domestic use. I further state that the proposed point of diversion shown on this map was furnished by the Las Vegas Valley Water District under the signature of Alan F. Walter, Chief Engineer and Water Rights Surveyor. The position of the reference corner shown on this map was derived from Loran-C navigation equipment with adjustments to conform with the 1927 North American Datum as utilized by U.S.G.S. quad maps and transformed to Nevada State Plane Coordinates, East Zone. The position of the section lines shown on this map were established by transforming B.L.M. survey plats to State Plane Coordinates.

Michael D Buschelman
STATE WATER RIGHT SURVEYOR NO. 792

Subscribed and sworn to before me this 15 day of MARCH, 1990

Nancy A. Mark
Notary Public in and for said County and State

My appointment expires on Oct 26, 1992

BASIS OF BEARINGS:

NEVADA STATE PLANE COORDINATE SYSTEM, EAST ZONE AS DERIVED FROM LATITUDE AND LONGITUDE READINGS FROM LORAN-C NAVIGATION EQUIPMENT AND WITH ADJUSTMENTS TO CONFORM WITH U.S.G.S. QUAD MAPS

1000 0 1000 2000 3000 4000
SCALE 1"=1000'

LEGEND:

FILED
MAR 22 1990
STATE ENGINEER'S OFFICE

✚	FOUND SECTION CORNER AS NOTED
♦	FOUND 1/4 SECTION CORNER AS NOTED
⊠	COMPUTED SECTION CORNER
◊	COMPUTED 1/4 SECTION CORNER
○	PROPOSED POINT OF DIVERSION

MAP TO ACCOMPANY APPLICATION FOR PERMIT TO APPROPRIATE THE PUBLIC WATERS OF THE STATE OF NEVADA, FROM AN UNDERGROUND SOURCE IN GARNET (DRY LAKE) VALLEY GROUND WATER BASIN, CLARK COUNTY, NEVADA

APPLICATION NO. 54073

APPLICANT: LAS VEGAS VALLEY WATER DISTRICT
PLACE OF USE: CLARK, LINCOLN, NYE, AND WHITE PINE COUNTIES.
MANNER OF USE: MUNICIPAL AND DOMESTIC

SHEET 1
OF 1

86467T
83490
79354
78954T
77643T
77642T

73151 73150 73149 72798 72799T 71521 T 68837T 68822 68784 T 68161 T 68056T 67650 67595T 54073

STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

DIVISION OF WATER RESOURCES

BEFORE MELISSA FLATLEY, HEARING OFFICER

IN THE MATTER OF THE
ADMINISTRATION AND
MANAGEMENT OF THE LOWER
WHITE RIVER FLOW SYSTEM
WITHIN COYOTE SPRING
VALLEY HYDROGRAPHIC BASIN
(210(, A PORTION OF BLACK
MOUNTAINS AREA
HYDROGRAPHIC BASIN (215),
GARNET VALLEY
HYDROGRAPHIC BASIN (216),
HIDDEN VALLEY
HYDROGRAPHIC BASIN (217),
CALIFORNIA WASH
HYDROGRAPHIC BASIN (218),
AND MUDDY RIVER SPRINGS
AREA (AKA UPPER MOAPA
VALLEY HYDROGRAPHIC BASIN
(219)

INTERIM ORDER 1303

<u>COYOTE SPRINGS INVESTMENT, LLC'S DISCLOSURE OF WITNESSES AND EXHIBITS</u>

RECEIVED
2019 SEP -6 PM 3:17
STATE ENGINEERS OFFICE

Pursuant to the August 26, 2019 Amended Notice of Hearing in this matter, Coyote Springs Investment, LLC ("CSI") submits the following as and for its disclosure of witnesses and exhibits for the September 23, 2019 evidentiary hearing ("Hearing").

A. Witness List and Summary of Testimony

CSI designates the following as witnesses it will or may call during the September 23, 2019 Administrative Hearing.

1. Stephen B. Reich, P.E., P.G.
   Principal
   Stetson Engineers, Inc.
   785 Grand Avenue Suite 202
   Carlsbad, CA 92008

Mr. Reich will testify to the analysis, evaluation, findings and conclusions set forth in the July 3, 2019 Evaluation of Basin Hydrogeology and Assessment of Sustainable Yield in the Lower White River Flow System, Southeastern Nevada ("CSI Order 1303 Report"). Mr. Reich will also present testimony concerning his analysis, evaluation, findings and conclusions as set forth in the August 16, 2019 Rebuttal To Order 1303 Reports Submitted to The Nevada State Engineer ("CSI Rebuttal Report"). In addition, Mr. Reich will testify concerning the deficiencies, shortcomings, flaws, and inaccuracies of the July 3, 2019 reports submitted to the State Engineer by the other reporting Stakeholders.

Mr. Reich will testify regarding the geological and hydrogeological characteristics of the southeastern Nevada regional carbonate aquifer system based on groundwater levels, pumping data, and geological investigations performed during the preparation of the CSI Order 1303 Report and CSI Rebuttal Report. A conceptual model of the LWRFS will be presented that addresses recharge and discharge fluxes that affect the occurrence and flow of groundwater. Mr. Reich will also highlight sustainable management techniques that may be applied to the LWRFS based on his principles identified in his October 4, 2018 Concept Paper "Framework for Sustainable Groundwater Management in the Lower White River Flow System" ("CSI October 2018 Concept Paper").

Mr. Reich has been previously qualified as an expert witness on behalf of the Confederated Tribes of the Goshute Reservation in Nevada State Engineer proceedings regarding Spring Valley (2017). Additionally, Mr. Reich acted as an expert consultant for the Long Now Foundation regarding Spring Valley hearing in 2011. Mr. Reich previously testified in Federal Court as an expert in water rights and hydrology on behalf of the United States Department of Justice regarding Water Rights of the Humboldt River; and in Superior Court of Arizona regarding the General Adjudication of all Rights to Use Water in the Gila River System. Mr. Reich has also testified in California Superior Court regarding civil engineering as it relates to hydraulics and hydrology (A.D.

Seeno Construction Company v. Contra Costa Water District). Mr. Reich acted as an expert consultant for the United States Department of Justice on behalf of the United States Marine Corps Base Camp Pendleton in Federal Court regarding water rights and hydrology in U.S. v. Eastern Municipal Water District. Attached hereto as **Attachment 1** is Mr. Reich's Curriculum Vitae.

2. Jean M. Moran, P.G., Ch.G.
Senior Hydrogeologist
Stetson Engineers, Inc.
785 Grand Avenue Suite 202
Carlsbad, CA 92008

Ms. Moran will testify concerning certain findings, conclusions, opinions, evaluations, and contents of the CSI Order 1303 Report. Ms. Moran will also testify about certain portions of the CSI's Rebuttal Report. Ms. Moran will offer testimony and opinions concerning the deficiencies, errors, and shortcomings of other parties' July 3, 2019 reports to the State Engineer and will further testify to the shortcoming, deficiencies, and errors set forth in other parties' August 16, 2019 rebuttal reports. Additionally, Ms. Moran will be available to testify regarding sustainable management practices in support of the Concept Paper.

Ms. Moran will testify to her analysis and preparation of Theis analysis as it pertains to groundwater level impacts from drawdown in a pumping well. Additionally, Ms. Moran is directly involved in sustainable management criteria and contributed to preparation of the Concept Paper. Ms. Moran has performed a field inspection of the Muddy River Springs Area and Coyote Spring Valley and has participated in the development of a conceptual model for groundwater flow in the LWRFS.

Ms. Moran has testified as an expert in Superior Court of Arizona regarding the General Adjudication of all Rights to Use Water in the Gila River System on behalf of the United States Department of Justice. Additionally, Ms. Moran is an expert for the United States Department of Justice in Texas v. New Mexico. Ms. Moran has not previously been qualified as an expert witness in proceedings before the Nevada State

Engineer. Attached as **Attachment 2** is Ms. Moran's Curriculum Vitae.

3. Molly R. Palmer, P.E.
Senior Engineer
Stetson Engineering, Inc.
2171, Francisco Blvd East, Suite K
San Rafael, CA 94901

Ms. Palmer will testify concerning certain aspects of the CSI Order 1303 Report and the CSI Rebuttal Report. Ms. Palmer will also address certain deficiencies, defects and shortcomings of other parties' initial expert reports and rebuttal expert reports.

Ms. Palmer prepared hydrologic analysis of climate in southeastern Nevada and prepared an analysis of local recharge to Coyote Spring Valley from the Sheep Range. Ms. Palmer will be available to discuss previous estimates of recharge by Maxey-Eakin and current estimates based on current raster-based precipitation PRISM datasets.

Ms. Palmer has not previously been qualified as an expert witness in proceedings before the Nevada State Engineer. Attached as **Attachment 3** is Ms. Palmer's Curriculum Vitae.

4. Norm Carlson
Chief Geophysicist
Zonge International, Inc.
3322 E. Fort Lowell Road
Tucson, AZ 85716

Mr. Carlson will testify about the April 2019 CSAMT field work that was performed in the Coyote Springs Valley on behalf of CSI, as documented in Appendix C to the CSI Rebuttal Report. His testimony will address the CSAMT geophysical method, data acquisition, instrumentation, processing, and interpretation of the April 2019 geophysical fieldwork for CSI. Mr. Carlson will be available to address the geophysical properties of basin fill and carbonate aquifers and response observed from the survey performed in the Coyote Spring Valley.

Mr. Carlson was qualified as an expert in geophysics by the Nevada State Engineer to represent in Water Rights Application Hearing of Lincoln County and Vidler Water Company, Nos 64592 and 64693, May 2002 and January 2008. Mr. Carlson has also qualified as an expert in geophysics before the Second Judicial District Court, State of New Mexico, No. D-202-CV-2014-07209, March 2018. Attached as **Attachment 4** is Mr. Carlson's Curriculum Vitae.

5. Timothy J. Durbin, P.E.
Timothy J. Durbin, Inc.
5330 Primrose Drive, Suite 228
Fair Oaks, CA 95628

Mr. Durbin will testify concerning the ground water hydrology and drainage flows in the Coyote Springs Valley and will rebut findings, assertions and conclusions expressed in the July 3, 2019 reports submitted by Southern Nevada Water Authority and as expressed in the August 16, 2019 Rebuttal Report submitted by Southern Nevada Water Authority.

Mr. Durbin has analyzed water-related impacts of groundwater development within the relevant region, which included development of a groundwater model. His work in eastern Nevada is supported by his experience with the United States Geological Survey as District Chief for the Water Resources Division, Nevada District, which included hydrogeologic and geophysical investigations and groundwater modeling.

Mr. Durbin has been qualified as an expert in hearings before the State Engineer. Mr. Durbin's Curriculum Vitae is attached hereto as **Attachment 5**.

6. Other Experts

CSI reserves the right to call as expert witnesses any or all of the experts who have been, or may subsequently be, designated by any of the parties to this proceeding.

CSI reserves the right, pursuant to Nevada law, as well as any other constitutional, statutory and/or common law rights it may have, to later name other experts before the Hearing or call to testify at the Hearing experts not named, whose testimony may be utilized to rebut the contentions and testimony of the parties, the parties' witnesses or other persons or witnesses that may testify.

CSI reserves the right to call supplemental witnesses, rebuttal witnesses and experts to address issues raised by the State Engineer or by other parties at the Hearing. CSI also reserves the right to supplement this designation.

B. Exhibit List

CSI designates the following exhibits it will or may introduce during the September 23, 2019 Administrative Hearing:

1. *CSI Ex. No. 1 - CSI July 3, 2019 Order 1303 Report;*

2. *CSI Ex. No. 2 - CSI August 16, 2019 Rebuttal Report;*

3. *CSI Ex. No. 3 - CSI October 2018 Concept Paper;*

4. *CSI Ex. No 4 - CSI June 13, 2019 Submittal of May 31, 2019 Technical Report and Large Lot Coyote Springs – Village A Map;*

5. *CSI Ex. No. 5 – NCDC 2019 Nevada Division 3 south-central climate data;*

6. *CSI Ex. No. 6 – NCDC 2019. Nevada Division 4 extreme-south climate data;*

7a. *CSI Ex. No. 7a – CSI-1 water level vs CSI-1 pumping and CSV pumping;*

7b. *CSI Ex. No. 7b – CSI-1 water level vs CSI-1 pumping and MRSA pumping;*

8a. *CSI Ex. No. 8a – CSI-2 water level vs CSI-2 pumping and CSV pumping;*

8b. *CSI Ex. No. 8b – CSI-2 water level vs CSI-2 pumping and MRSA pumping;*

9a. *CSI Ex. No. 9a – CSI-3 water level vs CSI-3 pumping and CSV pumping;*

9b. *CSI Ex. No. 9b – CSI-3 water level vs CSI-3 pumping and MRSA pumping;*

10a. *CSI Ex. No. 10a – CSI-4 water level vs CSI-4 pumping and CSV pumping;*

10b. *CSI Ex. No. 10b – CSI-4 water level vs CSI-4 pumping and MRSA pumping;*

11a. *CSI Ex. No. 11a – MX-5 water level vs MX-5 pumping and CSV pumping;*

11b. *CSI Ex. No. 11b – MX-5 water level vs MX-5 pumping and MRSA* *pumping;*

12. *CSI Ex. No. 12 – Groundwater Level and Pumping versus Monthly Precipitation in Basin 210;*

13. *CSI Ex. No. 13 – Map showing Pumping and Monitoring wells in Basins 210 and portions of 219 with Fault locations identified from April 2019 CSAMT Survey;*

14. *CSI Ex. No. 14 – Rowley, P.D., Dixon, G. L., Mankinen, E.A., Pari, K.T., McPhee D. K., et al., 2017. Geology and Geophysics of White Pine and Lincoln Counties, Nevada, and Adjacent Parts of Nevada and Utah: The Geologic Framework of Regional Groundwater Flow Systems. Nevada Bureau of Mines and Geology Report 56;*

15. *CSI Ex. No. 15 – Memorandum of Agreement and Amendments thereto; and*

16. *CSI Ex. No. 16 – CSI recorded Affidavits to Relinquish Water Rights for Moapa Dace.*

C. Additional Exhibits

In addition to the designated exhibits, CSI intends to rely on various portions of the expert witness reports and rebuttal reports submitted by other participants including, but not limited to, those documents and the reports submitted by Southern Nevada Water Authority that include or make reference to Muddy River Intentionally Created Surplus Reports for calendar years 2008-2018.

Dated this 6th day of September, 2019.

Kent R. Robison

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LIST OF ATTACHMENTS

Attachment No.	Description
1	Stephen B. Reich, P.E., P.G.'s Curriculum Vitae
2	Jean M. Moran, P.G., Ch.G.'s Curriculum Vitae
3	Molly R. Palmer, P.E.'s Curriculum Vitae
4	Norm Carlson's Curriculum Vitae
5	Timothy J. Durbin, P.E.'s Curriculum Vitae

ATTACHMENT 1

Curriculum Vitae

STEPHEN B. REICH, PE, PG

Principal, Stetson Engineers Inc.

EDUCATION:	M.S. Geophysical Engineering, Colorado School of Mines, 1989 B.S. Geophysical Engineering, Colorado School of Mines, 1985
CREDENTIALS:	Registered Professional Civil Engineer No. 58713, California Registered Professional Geologist No. 9712, California
PROFESSIONAL EXPERIENCE:	29 years

OVERVIEW

Mr. Reich provides technical and administrative expertise required to manage multi-faceted water resource projects that require in-depth knowledge of water rights, environmental requirements, regulatory issues, and civil engineering solutions. Mr. Reich has led technical teams for both litigation and settlement purposes for issues related to water supply, water quality, wastewater, and water rights disputes. His responsibilities have included developing basin management plans for groundwater and surface water resources in legally and environmentally constrained basins. Mr. Reich is currently involved in developing groundwater sustainability plans for clients in California to meet the State's requirement under the Sustainability Groundwater Management Act.

Mr. Reich developed a comprehensive adaptive management plan that met the requirements of the project proponents, the United States Fish and Wildlife Service, the National Marine Fisheries Service, and other state and local regulators. The plan was developed through extensive consultation with various organizations through the NEPA and ESA Section 7 consultation process over a period of 3 years. Quantitative threshold values were established for various triggers so pre-established mitigation measures would be implemented, if necessary. The result of his effort is a geographical web-based system that provides database management and decision-making processes tied to meeting physical, environmental, and legal constraints. Monthly reports are currently being assimilated into annual reports to assure constraints identified in two Biological Opinions for the project are met, as well as meeting state water rights reporting requirements. Similarly, in 2015 and 2016, Mr. Reich led the City of San Juan Capistrano in developing a Groundwater Management Plan to balance the use of their surface and groundwater resources while meeting environmental and physical constraints. Results from his efforts are used to meet state regulatory requirements for monitoring and reporting.

As sole arbitrator between LADWP and Inyo County, regarding groundwater pumping in Owens Valley, Mr. Reich balanced legal, physical, and environmental requirements to settle a pumping dispute between Inyo County and Los Angeles Department of Water and Power. Mr. Reich currently leading a team of engineers and biologists to assess in-stream flow requirements for southern Steelhead in southern California; the result which is being used as a basis of for operating a federally funded diversion project. His expertise in hydrology, water quality, geomorphology, civil engineering, economics, state and federal water supply issues, and environmental concerns provides a wide range of experience for the successful completion of both small- and large-scale water development projects.

Mr. Reich has extensive knowledge of developing and managing large water projects in California and the southwestern U.S. Working with federal and local water agencies, he has participated in developing large water supply projects. Mr. Reich also brings experience in working with regulators and federal agencies in developing water supply projects that satisfy U.S. Fish and Wildlife, National Marines Fisheries Service, Army Corps of Engineers, the U.S. Environmental Protection Agency, and RWQCB basin management requirements.

COURT AND EXPERT WITNESS EXPERIENCE:

Review of Spring Valley, Nevada Monitoring, Management, and Mitigation Plan

As lead consultant to the Confederated Tribes of the Goshute Reservation, Mr. Reich reviewed and provided an expert report regarding Southern Nevada Water Agency's (SNWA) Monitoring, Management, and Mitigation Plan (MMM Plan) for Spring, Cave, Dry Lake, and Delamar Valleys, Nevada. Mr. Reich reviewed the applicant's proposed MMM Plan, prepared in response to the Seventh Judicial District Court of Nevada's remand to the State Engineer, to establish standards for mitigation in the event of a conflict with existing water rights or unreasonable effects to the environment or the public interest. Mr. Reich and his team assessed monitoring requirements and quantitative measures necessary to identify unreasonable effects that could potentially occur due to the applicant's proposed project. The recommendations provided in his expert report addressed adaptive management techniques and processes for long-term management that included early-time triggers for constraints, comprehensive reporting, and stakeholder involvement.

As lead consulting expert to the Long Now Foundation, Mr. Reich oversaw the development of a soils report and presented soil experts to the Nevada State Engineer in the 2011 Spring, Cave, Dry Lake, and Delamar water rights hearings (SNWA applicant). Mr. Reich has also acted as lead consulting expert for the Untied States Department of Justice for water rights, groundwater, water quality, and civil engineering issues in the Murrieta-Temecula groundwater basin, California *(United States v. Eastern Municipal Water District and Rancho California Water District)*. Mr. Reich's responsibilities for the United States included the coordination and development of expert reports regarding the occurrence and movement of water and civil engineering.

Mr. Reich has also presented testimony on behalf of the United States Department of Justice regarding water rights and water supply in Nevada (*Nevada State Engineer v. South Fork Band of Te-Moak Tribe*) and in Arizona (General Adjudication of all Rights to Use Water in the Gila River System and Source; In re San Pedro Subflow). Mr. Reich's responsibilities included assessment of water rights, diversion works, hydrogeology, geophysics, and geology as they relate to the availability and use of surface and groundwater.

Mr. Reich has testified in California Superior Court regarding AB1600 development fees associated with providing water and wastewater services to new development. Mr. Reich's responsibilities included assessing the actual cost of services provided to new development compared to improvements provided to existing customers. Expert testimony of civil engineering analysis included facilities analysis, capacity requirements, and construction costs.

Santa Margarita River Conjunctive Use Project (U.S. v. Fallbrook PUD)

As lead engineer, designer, and project manager for a $52 million project, Mr. Reich developed a conjunctive use project, based on MODFLOW groundwater model, which utilizes surface flow during winter-time rainfall events to recharge a groundwater aquifer for subsequent extraction during peak summer demand months. Mr. Reich was responsible for the design of the diversion facility, conveyance systems, and recharge facilities to divert water from the Santa Margarita River. Mr. Reich oversaw the development of field investigations, including the construction of monitoring and production wells, to support the creation of a numerical groundwater model. Working with the Bureau of Reclamation and the United States Navy, Mr. Reich played a key role in the development of legislative approval of the project passed by the United States congress in public law PL 111-11 to support settlement of *U.S. v Fallbrook PUD et al.*

- Lead technical expert during water rights negotiations that led to two settlement agreements in *U.S. v. Fallbrook PUD et at.*
- Author and project manager of the Santa Margarita River Conjunctive Use Project (CUP)
- Lead Designer and Project Manager of diversion facilities
- Lead author of the Santa Margarita River CUP Adaptive Management Plan
- Construct and manage groundwater model

Indian Wells Valley Groundwater Sustainability Plan (DWR-SGMA)

Mr. Reich provides technical guidance and oversight for the development of a Groundwater Sustainability Plan (GSP) for a critically overdrafted basin in the desert region of California. The GSP relies on a multi-faceted approach that includes groundwater modeling and subsequent monitoring of groundwater resources to assure long-term groundwater sustainability for stakeholders in Indian Wells Valley, including the China Lake Naval Air Weapons Station.

- Peer-reviewed numerical regional watershed model developed by Dessert Research Institute for China Lake Naval Air Weapon Station to evaluate the model's suitability for supporting the development, implementation, and performance of the Groundwater Sustainability Plan for the Indian Wells Valley Groundwater Authority.
- Worked with Technical Advisory Committee discussions in a public meeting forum, and model ad hoc committee review for a 'Critically Overdrafted Basin'. Development of management model scenarios for developing a sustainable management plan with criteria and measurable objectives based on California's Sustainable Management Act (SGMA).
- Developed groundwater monitoring program and database for DWR, SGMA approval.

San Pedro River Subflow Delineation, Arizona (Gila River Adjudication)

Mr. Reich is the lead technical consultant for the Department of Justice for assessing groundwater-surface water interaction in the Gila River Adjudication. Mr. Reich has performed geological and geophysical investigations along the San Pedro River to delineate the subflow zone that supports streamflow. His involvement has included expert witness testimony regarding groundwater and geologic issues. Currently, Mr. Reich is assessing groundwater modeling methodologies required to support the court's adjudication of wells that impact the subflow zone; including cone of depletion tests and quantification of stream depletion.

- Retained by DOJ-ENRD for expert review of cone of influence methodologies developed by Arizona Department of Water Resources, including both numerical and analytical models.
- Review of USGS *Ground-Water Flow Model of the Sierra Vista Subwatershed and Sonoran Portions of the Upper San Pedro Basin, Southeastern Arizona, United States, and Northern Sonora, Mexico* for application of determining subflow zone depletion from the San Pedro River.
- Provided professional review, comments, and discussion of court documents submitted by Arizona Department of Water Resources; and review of affidavits from other lawyers and consultants for the Department of Justice. Developed supporting maps and summary tables to quantify subflow extents differences.

Napa Valley Vineyard, California

As lead hydrologist and project manager, Mr. Reich let a team to evaluate spring flow and groundwater supply for a vineyard development in the Napa Valley. Tasks included geologic mapping, groundwater-surface water interaction, monitoring protocols, and impact analysis related to groundwater development.

- Evaluate spring flow as water supply for vineyard development. Study geologic units, faulting, and watershed contribution to water supply at spring boxes. Establish monitoring protocols for perennial and seasonal surface spring flow, storage pond capacity, and water supply needs.

AREAS OF EXPERIENCE AND EXPERTISE:

Water Rights Studies

As a member of the Stetson technical team consulting the Pyramid Lake Paiute Tribe, prepared documents on irrigation and land use status using aerial photographs and historic documents. Additionally, involved with a cooperative effort between the Tribe, the U.S. Department of Justice, and the U.S. Bureau of Reclamation in identifying the transfer of water rights. Coordinated GIS data and other databases with relevance to legal and illegal irrigated lands.

(Pyramid Lake Paiute Tribe, Pyramid Lake Land Use Study, 1992 - present).

Basin Management

Mr. Reich has developed and implemented basin management and adaptive management programs for multiple basins located throughout California and the southwest U.S. His responsibilities included working with various federal and non-federal stakeholders to establish goals and project constraints. Between 2010 and 2015, Mr. Reich developed a sustainable yield model for the Temecula Groundwater Basin that met streamflow and groundwater constraints. Mr. Reich has performed sustainable yield studies in the Santa Margarita Basin to meet operational, legal, and environmental requirements for various clients so operating criteria can be established. His duties included establishing pumping schedules, identifying monitoring requirements, developing web-based databases, and producing monthly and annual reports to meet environmental and legal requirements.

Water Rights Negotiations

Technical lead for the United States and the Marine Corps Camp Pendleton in the settlement of one of the longest running (90+ years) water rights disputes in California. Using technical studies prepared by experts in numerous fields, developed the technical portion of a settlement agreement that allowed for the restoration of streamflow to satisfy both ecological demands and municipal demands. A MODFLOW ground-water model, a hydrologic model, and the classification of the riparian and biological habitat were just a few of the numerous studies that were used to establish the basis for settlement of a complex river system. The negotiated agreement acknowledges the beneficial use of water for human consumption and ecological demands.

Water Treatment

Mr. Reich was responsible for the design, construction, and operation of a 1,000 gallon per minute Liquid Granular Activated Carbon (LGAC) treatment facility to remove volatile organic carbon compounds from groundwater. The purpose of the facility was to test for the removal of VOCs in the presence of high total organic carbons that could reduce the efficacy of the treatment process. The results of the LGAC facility have been used to establish long-term management goals for the continued use of groundwater from wells in a VOC contaminated aquifer.

Groundwater Development Along Coastal Zones

Mr. Reich has led investigations regarding the development of groundwater from aquifers adjacent to the Pacific Ocean. Using numerical groundwater models and hydrogeologic principles, Mr. Reich has designed barriers to saltwater intrusion through the use of injecting reclaimed wastewater. These projects have allowed for an increase in the sustainable yield of groundwater aquifers located along coastal zones.

Reclaimed Wastewater

Mr. Reich has performed numerous investigations to develop projects that use highly treated wastewater effluent. A 36-acre constructed treatment wetland in southern California was designed to "polish" wastewater for disposal through groundwater recharge. Mr. Reich also investigated the use of existing injection wells near Las Pulgas, California and the designed new injection wells near Oceanside to dispose of reclaimed wastewater in the transition zone that exists in aquifers between the fresh water and saltwater barrier.

Environmental and Fisheries

Mr. Reich recently completed a study in 2016 that identified minimum streamflow requirements for migration passage of southern steelhead trout in a southern California river. Working jointly with fisheries biologists, Mr. Reich and his team conducted in-stream surveys, performed hydraulic analysis, calculated hydrologic requirements, and developed management scenarios to support fish passage. Riparian and estuarine habitat requirements that supported fish passage were also investigated as part of the study.

Municipal Water Systems Analysis

Participating as a member of a Technical Committee, Mr. Reich worked directly with private developers and the Contra Costa Water District in analyzing AB1600 buy-in charges for new customers. As an expert witness, Mr. Reich has testified on the use and division of raw and treated water infrastructure by new and existing customers, including pipe network systems, reservoir, pumping plant, and canal structures. He has coordinated data acquisition of available documents and maps in order to perform hydraulic, civil, and economic analyses to support cost allocation of facilities.

Mr. Reich has authored Urban Water Management, Capital Improvement, Water Supply Plans and other supporting documents to support various water districts throughout California. Responsibilities have included supervising pipe network models, economic rate models, water rights, and water supply tasks that support the development of these plans. Additional responsibilities have included participation in presentations to water/wastewater boards and technical involvement in negotiation discussions.

Water Wells/Drilling Expertise

- Supervised mud rotary, reverse rotary, air drilling, and sonic drilling of numerous monitoring and production wells throughout California, Utah, and Arizona. Designed and developed nested wells for monitoring vertical groundwater gradients from multiple aquifers.
- Responsible for the drilling and completion of a 1,300-foot water well on the Pechanga Indian Reservation, CA including the geological and geophysical logging of the well, determination of the screened interval, and pump testing of the well.
  (U.S. Department of Justice, Pechanga Reservation Ground-water Study).
- Responsible for the design, acquisition and interpretation of a seismic refraction survey to determine the suitability of a shallow ground-water supply on the Shivwitz Indian Reservation in Southwestern Utah. Additionally, five shallow boreholes were drilled and incorporated in the interpretation of the final results.
  (U.S. Department of Justice, Shivwitz Reservation Ground-Water Study).
- Designed and implemented both geophysical and hydrogeologic studies for the Southern California Water Company (SCWC). Working directly with their chief hydrogeologist, coordinated both field and office studies concerned with the design and location of new water wells within numerous ground-water basins throughout California. Additionally, analyzed some of SCWC's existing water wells in Edna Valley and Barstow for the determination of surface water influences and their pertinence to drinking water standards.
  (SCWC Water Well Studies)

ATTACHMENT 2

Curriculum Vitae

JEAN M. MORAN, PG, CHG

Senior Hydrogeologist, Supervisor I

Ms. Moran's area of expertise includes the design, construction, and application of numerical hydrogeologic models to characterize the occurrence and movement of water in groundwater basins, including; delineation of groundwater aquifers; assessment of sustainable yield under varying hydrologic conditions; and, quantification of the surface water – groundwater interaction. Ms. Moran has developed models that have been used to design successful surface water-groundwater conjunctive use projects, reclaimed water aquifer storage and reuse projects, and long-term sustainable yield assessments. An integral part of these evaluations has included evaluation of groundwater quality impacts from surface water recharge, quantifying the effect of pumping on riparian evapotranspiration, and impacts to natural habitats and stream systems.

In addition to numerical modeling, Ms. Moran has developed and implemented investigations for subsurface characterization of groundwater aquifers for complex hydrogeological sites. She has supervised the design and installation of production and monitoring wells, performed aquifer performance tests, and conducted shallow groundwater field investigations. Ms. Moran's field experience and application of analytical models has supported her professional focus on characterizing and quantifying the groundwater-surface water interaction process of southwestern United States' streams and rivers.

EDUCATION:	M.S. Hydrogeology, University of California, Berkeley, 1997 B.S. Geology, University of Wisconsin, Madison, 1994
CREDENTIALS:	Registered Geologist No. 7162, California Certified Hydrogeologist No. 755, California
PROFESSIONAL COMMUNITY INVOLVEMENT	California Groundwater Resources Association San Diego Association of Geologists Northern California Geological Society National Ground Water Association
PROFESSIONAL EXPERIENCE:	22 years

EXPERT WITNESS CASE:

- In re the General Adjudication of all Rights to Use Water in the Gila River System and Source; In re San Pedro Subflow Technical Report. Contested Case No. W1-103 in the Superior Court of the State of Arizona in and for the County of Maricopa. Deposed (January 23, 2018) and testified (March 7-8, 2018) as expert for the United States Department of Justice, Environmental & Natural Resources Division.

SELECTED PROJECTS AND MODELING EXPERIENCE:

Indian Wells Valley Groundwater Sustainability Plan (DWR-SGMA)

- Peer-reviewed numerical regional watershed MODFLOW model developed by Dessert Research Institute for China Lake Naval Air Weapon Station to evaluate the model's suitability for supporting the development, implementation, and performance of the Groundwater Sustainability Plan for the Indian Wells Valley Groundwater Authority.
- Managed Technical Advisory Committee discussions in a public meeting forum, and model ad hoc committee review for a 'Critically Overdrafted Basin'. Development of management model scenarios for developing a sustainabile management plan with criteria and measurable objectives based on California's Sustainable Management Act (SGMA).
- Developed modeling and GIS analysis for assessing impacts to domestic and other shallow wells from a lowering groundwater table caused by regional pumping greater than natural recharge. Developed data gap analysis, and field work plan to validate model assumptions and contribute to future model updates.

San Pedro River Subflow Delineation, Arizona (Gila River Adjudication)

- Retained by DOJ-ENRD for expert review, deposition, and testimony cone of influence methodologies developed by Arizona Department of Water Resources, including both numerical and analytical models.
- Review of MODFLOW model developed by the USGS (*Ground-Water Flow Model of the Sierra Vista Subwatershed and Sonoran Portions of the Upper San Pedro Basin, Southeastern Arizona, United States, and Northern Sonora, Mexico)* for application of determining subflow zone depletion from the San Pedro River. Conducted model runs to assess calibration, stream-aquifer interaction, and cone of depressions developed from pumping wells.
- Provided professional review, comments, and discussion of court documents submitted by Arizona Department of Water Resources; and review of affidavits from other lawyers and consultants for the Department of Justice. Developed supporting maps and summary tables to quantify subflow extents differences.

Santa Margarita River Basin; Recharge/Recovery Enhancement Program, California

- Designed a watershed groundwater and surface water MODFLOW model for an alluvial river valley. The monthly model was constructed over a 50-year balanced hydrologic period that has been actively updated with new data since 2001 as an investigative, predictive, and design tool for Camp Pendleton to study potential hydrogeologic and environmental impacts from which to make drought, normal, and wet year water basin management decisions for analysis.
- Completed a MODFLOW and MODPATH analysis to evaluate groundwater under the direct influence of surface water (GWUDI) for drinking water wells in riparian floodplain alluvium. Conducted field verification program for model results.
- Characterized groundwater flow patterns and movement using MODPATH to assess minimum aquifer storage requirements for recycled water for a Direct Potable Reuse project.
- Developed MT3D transport model to evaluate salt and nutrient management within the basin.
- Implemented a recharge rate and mounding study at a series of off-river percolation basins to determine seasonal infiltration rates for estimating overall project yield.

- Evaluated salt water intrusion into the near-coast aquifer and potential impacts from upstream wastewater treatment wetlands. Used vegetation coverage and groundwater model to estimate TDS dilution and loading, changes in storage and streamflow that will occur under future development plans.

San Onofre and San Mateo Basins, California

- Developed a MODFLOW model with the stream package to assess long-term sustainable yield in a riparian coastal basin in southern California. The model was coupled with MODPATH and MT3D to evaluated salt water intrusion, and salt loading within the basin.

Las Pulgas Basin, California

- Developed a MODFLOW model for a riparian coastal basin in southern California to evaluate basin perennial yield. Determined placement of groundwater production wells to limit exposure to naturally occurring chromium in the subsurface aquifers.

Cahuilla Groundwater Basin, California

- Member of Technical Advisory Committee for determining sustainable yield of aquifer. Developed MODFLOW model to evaluate water resources and water rights within the Anza Terwilliger Basins. Evaluation of USGS study for aquifer thickness from gravity surveys. Development of a hydrologic budget during a balanced period.

Coachella Valley Groundwater Basin, California

- Reviewed the groundwater flow model of Coachella Valley developed by Graham Fogg, UC-Davis. Assess CVWD's application of the model to evaluate salt loading for a Salt and Nutrient Management Plan, and groundwater impacts from recharging Colorado River water, agricultural return flow, and other land use, for the Agua Caliente Band of Cahuilla Indians.
- Hydrogeologic analysis of regional pumping effects on the changes of groundwater in storage.

Underground Waters of the Gila River; Safford Valley, Arizona (Globe Equity No. 59)

- Reviewed Holocene floodplain alluvial sediments based on Arizona Geological Survey mapping and field recognizance to define the subflow zone along the Gila River near Safford AZ and to evaluate if wells are capturing subflow to the Gila River.
- Researched, collected data, organized, and constructed a water use inventory encompassing a 36-year balanced hydrologic period (1955-1990) for a 135,600-acre watershed. Developed a monthly accounting for municipal, mining, and 36,000 acres of irrigated water use, melding USGS streamflow and groundwater use data, Gila River Water Commissioner Reports surface water diversion data, Arizona DWR well location data, and GIS land use coverages

Napa Valley Vineyard, California

- Evaluate spring flow as water supply for vineyard development. Study geologic units, faulting, and watershed contribution to water supply at spring boxes. Establish monitoring protocols for perennial and seasonal surface spring flow, storage pond capacity, and water supply needs.

Rezoning Industrial Site to Housing, Napa, California

- Setup, performed, and analyzed aquifer performance testing to measure hydraulic properties throughout multiple aquifer units. Aquifer testing included monitoring pumping influences on streamflow in a tidally influenced reach of the Napa River. Boundary conditions included faulting, interference from nearby pumping wells, and contributions from recharge zones. Groundwater and surface water quality sampling was conducted at set intervals throughout the step, constant rate pumping, and recovery tests,

Ranch on Silver Creek Hydrogeologic Assessment, California

- Developed water balance study for 660-acre site. Researched local and regional regulations and compiled surface and groundwater information from existing information, maps, and field data (using GIS) to compare pre- and post development impact analysis from changes to watershed management and use of reclaimed irrigation water.

Fallbrook Public Utility District Conjunctive Use Project, California

- Worked with public utility district on water supply and waste water reuse in their water basin plan. Evaluated recharge basins, seasonal timing of reservoir releases, off stream storage locations, summer releases to enhance endangered species habitat, and well production management programs using an established groundwater model.

Staff Hydrogeologist with Groundwater Technologies Inc. and Fluor Daniel GTI

- Managed compliance with Regional Water Board/regulatory orders and permits, including the writing of feasibility studies, work plans, and quarterly/annual summary reports; conducted presentations for clients and regulators, managed technical support staff; coordinated field work and subcontractors; analyzed data and used groundwater flow and transport modeling for hydraulic characterization of aquifers. Projects included the following:

Groundwater Contaminant Study in Support of Site Remediation Efforts, Former Food Production Facility, California.

- Performed hydraulic aquifer testing to determine potential change in permeability from addition of permanganate. Managed permanganate injection pilot study and waste discharge permit compliance. Prepared computer model for groundwater flow and transport for 3-D visualization of VOC contaminant plume. Performed design and monitoring of source zone rededication using KMO4 to oxidize TCE.

Groundwater Contaminant Study to assist location of optional additional pumping well for modified treatment system, Former Computer Chip Manufacturing Facility, CA.

- Managed monitoring program and compliance with existing Regional Water Board order. Managed and coordinated field efforts and data analysis for full-scale source zone treatment with permanganate. Prepared groundwater modeling for former manufacturing site with VOC impacts to groundwater. Prepared evaluation of historical contaminant migration to fingerprint plume migration across time.

Geological Litigation Support, Semiconductor Design and Fabrication Facility, CA.

- Managed database of data and maps that were generated by approximately 10 potentially responsible parties held liable for remediating a site impacted by a commingled VOC plume. Performed contaminant finger printing to support these efforts.

Groundwater modeling, Lignite Mine, TX.

- Prepared SWIFT groundwater flow model to support client in determining appropriate dewatering efforts of lignite mines before initiating mining operations to support permitting application process. Model was prepared to extend from 1995 to 2009.

Aquifer testing, Tidal Study for Power Plant and Chemical Manufacturing Plant, CA.

- Designed and conducted passive monitoring, analyzed data, and reported on tidal influences on groundwater flow and transport with respect to site-specific contaminants.

Permanganate Pilot Studies at Two Sites with TCE Impacted Groundwater, CA.

- Prepared injection work plan, including extensive monitoring plan; worked with field crew and wrote summary report. First time permanganate was used for San Francisco and Central Valley Region CRWQCBS.

Sampling and Monitoring Protocol, CA.

- Low flow sampling techniques, including equipment setup and calibration. Vadoze zone water samples. lysimeter installation and sampling procedures.

Other Related

- Developed a spreadsheet model to estimate air emissions and co-authored Wisconsin's Greenhouse Gas Study for the Wisconsin Department of Natural Resources as an air management specialist.
- Research and groundwater model development with TN Narasimhan at the University of California, Berkeley. Presented findings at USGS, Menlo Park, CA.
- Conducted laboratory analysis of water samples for the Environmental Engineering laboratory at the University of Wisconsin, Madison.

ATTACHMENT 3

Curriculum Vitae

MOLLY R. PALMER, PE

Senior Water Resources Engineer

Ms. Palmer is a licensed California Civil Engineer specializing in hydrology, water rights, water supply planning, and modeling studies. She has worked in western states to analyze water rights compliance, water use, and water supply development. She has overseen modeling studies of surface water systems, including hydrologic models such as HSPF, and hydraulic models such as HEC-RAS (2D and 3D), H2OMap, and InfoWater.

Much of her work has focused on analysis of surface water within groundwater-dominated systems. She has prepared surface water studies to be used as inputs for MODFLOW numerical groundwater models, and regularly works with hydrogeologists to understand surface and groundwater interactions. Ms. Palmer has prepared rainfall-runoff models of complex watersheds and has worked to characterize recharge into aquifers. She also has expertise performing hydrologic and hydraulic analyses necessary to quantify instream flow requirements for species.

EDUCATION:	M.S. Civil & Environmental Engineering, MIT, 2003 B.S. Civil & Environmental Engineering, Georgia Tech, 2001
CREDENTIALS:	California Civil Engineer, No. 71788
PROFESSIONAL EXPERIENCE:	15 years

SELECTED PROJECTS AND EXPERIENCE:

Indian Wells Valley Groundwater Sustainability Plan (DWR-SGMA)

- Developed hydrology and climate data to characterize precipitation, runoff, and streamflow in Indian Wells Valley
- Peer-reviewed recharge estimates for a numerical MODFLOW model developed for China Lake Naval Air Weapon Station to evaluate the model's suitability for supporting the development, implementation, and performance of the Groundwater Sustainability Plan for the Indian Wells Valley Groundwater Authority.

North Coast Instream Flow Policy (California State Water Resources Control Board)

- Volume Depletion Approach Study: Lead engineer and hydrologist for volume depletion approach study. Designed and conducted field study at 17 stream locations. Prepared rainfall-runoff models (HSPF) of three watersheds and used them to analyze diversions on headwaters streams and their impact on instream flow and fisheries habitat. Worked with fisheries biologists to understand habitat criteria and develop hydrologic and hydraulic criteria.

- Policy Development: Prepared hydrologic records to assess instream flow policy for anadromous salmonids. Prepared rainfall-runoff models (HSPF) in north coast policy area and simulated impacts of policy under varying hydrologic conditions. Reviewed CEQA impacts of policy on regional water supply.

Irrigation District in Tulare County, California

- Performed water supply analysis for conjunctive use of water from surface storage and groundwater storage. Prepared application to appropriate water, including hydrologic technical analysis.

Santa Margarita River Basin; Recharge/Recovery Enhancement Program, California

- Designed surface water and hydrologic models for an alluvial river valley. Simulated precipitation, runoff, and recharge in a daily, 50-year model. Integrated hydrology data with reservoir and project operations model. Prepared surface water data to be integrated into a MODFLOW numerical model which has been used as a an investigative, predictive, and design tool for Camp Pendleton to study potential hydrogeologic and environmental impacts from which to make drought, normal, and wet year water basin management decisions for analysis.
- Instream flow analysis: conducted field work, modeling and analysis to determine timing and frequency of steelhead passage opportunities. Worked with hydraulic engineers and biologists to design alternatives for fish passage structures.
- Evaluated long-term impacts of climate change on future conditions. Downscaled global climate data and applied to existing models to bracket potential changes in temperature, precipitation, and evaporation and impacts on water supply.
- Maintained accounting model for flow augmentation program on river. Reviewed gage and meter data and prepared daily spreadsheet model of flows, augmentation, and credits for the two parties of the agreement. Provide support for watershed monitoring program.

Natural Flow Analysis, Fort Belknap Reservation, Montana

- Prepared hydrologic analysis of Peoples Creek and Milk River streamflow to evaluate natural flow available on the streams. Prepared regression-based models to compute streamflow at several key locations.

Tonto Apache Tribe Water Supply, Arizona

- Prepared a water budget and water supply plan for Tonto Apache Tribe. Developed land use plan, crop water requirements, and diversion requirements for Reservation.

Mendota Wildlife Area, Water Supply Conveyance Alternatives, California

- Performed engineering and hydrologic analyses to support design of alternative conveyances of water under the Central Valley Project Improvement Act.

Reservoir and Diversion Operations, San Diego Creek Watershed, California

- Performed analysis of reservoir and diversion operations for two dams. Performed hydrologic analysis of marsh operations and water availability. Submitted documentation to the Division of Water Rights to substantiate water use and water rights.

Dam Failure Inundation Mapping, California

- Oversaw modeling and mapping for eight inundation mapping studies of dams. Supervised preparation of three-dimensional hydraulic models in HEC-RAS. Evaluated flood corridors and prepared emergency action plans (EAPs).

San Onofre and San Mateo Basins, California

- Prepared climate and hydrology data as inputs to a MODFLOW model to assess long-term sustainable yield in a riparian coastal basin in southern California.

South Coast Conduit Hydrologic Study, Santa Barbara County, California

- Conducted hydrologic study to estimate runoff at dozens of stream crossings and key locations on coastal streams in Santa Barbara County. Processed gage data and performed regression analysis to estimate streamflow.

Comprehensive Water Rights Claim, Umatilla Indian Reservation, Oregon

- Completed surface water supply calculations for consumptive use and instream flow claims; Worked with fisheries team to develop flows for Tennant Method; Compiled memoranda on consumptive use and instream flows and produced comprehensive claim report.

Sonoma County Vineyard, California

- Evaluated surface water supply for a vineyard. Installed water measurement equipment and tracked water availability and usage. Prepared application to appropriate water.

Water Supply Planning, Contra Costa and Solano Counties, California

- Provided peer review of water system master plans. Reviewed hydraulic pipe network models and evaluated system operations. Prepared feasibility analysis of water supply for planned projects. Assessed cost allocations for capital improvement plans and facility reserve charges.

Other Related

- Laboratory research at the Parsons Lab at MIT on wetland hydrodynamics. Published findings in *Limnology and Oceanography*.

Selected Publications and Work Products

- Stetson Engineers Inc. and R2 Resource Consultants. March 2014. North Coast Instream Flow Volume Depletion Approach Study. Prepared by Stetson Engineers and R2 Resource Consultants. Prepared for California State Water Resources Control Board Division of Water Rights.
  http://www.swrcb.ca.gov/waterrights/water_issues/programs/instream_flows/vdas/

- Stetson Engineers Inc. April 2012. Southern California Steelhead Passage Assessment, Lower Santa Margarita River, California and CUP Surface Water Availability Analysis (TM 1.1). Prepared by Stetson Engineers. Prepared for United States Bureau of Reclamation, Fallbrook Public Utilities District, and United States Marine Corps Base Camp Pendleton. https://www.usbr.gov/lc/socal/reports/SMCUPFallbrook/Steelhead/SteelheadPassageAssessment.pdf
- R2 Resources Consultants, Inc. and Stetson Engineers Inc. March 2008. North Coast Instream Flow Policy: Scientific Basis and Development of Alternatives Protecting Anadromous Salmonids. Prepared by R2 Resource Consultants and Stetson Engineers. Prepared for California State Water Resources Control Board Division of Water Rights http://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/docs/draft_policy_2008/05_task3rpt_admindraftfinal_03142008.pdf
- Palmer, M.R., H.M. Nepf, T.J.R. Pettersson, and J.D. Ackerman. 2004. Observations of particle capture on a cylindrical collector: Implications for particle accumulation and removal in aquatic systems. *Limnology and Oceanography*, 49(1): 76-85. https://aslopubs.onlinelibrary.wiley.com/doi/epdf/10.4319/lo.2004.49.1.0076

ATTACHMENT 4

Zonge International, Inc
3322 E. Fort Lowell Rd
Tucson, AZ 85716
Office: (520)327-5501
Fax: (520) 325-1588
www.zonge.com

Norman R. Carlson, Chief Geophysicist
Zonge International, Inc.
Tucson, Arizona

Registered Professional Geoscientist (Geophysics) Texas License # 4703

44 Years Employment Experience

1979 - Present: ***Chief Geophysicist, Zonge Engineering & Research Organization (including field work in California, Nevada, Arizona, Oregon, Washington, Idaho, Wyoming, Texas, Oklahoma, New Mexico, Nebraska, Colorado, Hawaii, Mexico, and Brazil)***
Currently specializing in the application of electrical geophysics to environmental, groundwater, and geotechnical engineering concerns. Responsibilities include geophysical project design and quality control, field crew supervision, development of new applications, data processing, and interpretation. Current research efforts are focused on development of high resolution electrical and electromagnetic methods for shallow delineation. Responsible for technical presentations of case-histories, methods, and current research directions at numerous annual technical meetings, and for public relations involving the explanation of geophysical methods and results for public high-profile environmental and groundwater projects.

1977 - 1979: ***Party Chief, Western Geophysical Company, Houston, Texas (including field work in California, Utah, Colorado, Arizona, and the Beaufort Sea, north of Alaska)***
Supervised a 30-person Vibroseis seismic crew on numerous projects in the western US and served as assistant party chief on an air-gun winter ice seismic crew on the Beaufort Sea.

1975 – 1977: ***Quality Control Seismologist, United Geophysical Company, Pasadena, California (including field work in Michigan and southwestern desert of Iran)***
Responsible for seismic data quality on a remote camp-out seismic field crew in the southwestern Iranian desert; during extended personnel breaks, also performed duties of the blaster, expediter, and party chief.

Education **University of Arizona (1971-1975)** B.S. Geophysics

Expert Witness Testimony

Qualifed to give expert witness testimony in geophysics before the Nevada State Engineer in the Water Rights Application Hearing of Lincoln County and Vidler Water Company, Nos. 64692 and 64693, May, 2002.

Qualifed to give expert witness testimony in geophysics before the Nevada State Engineer in the Water Rights Application Hearing of Lincoln County and Vidler Water Company, Nos. 64692 and 64693, January, 2008.

Qualified to give expert witness testimony in geophysics before the Second Judicial District Court, State of New Mexico, No. D-202-CV-2014-07209, Aquifer Science LLC v Scott Verhines, New Mexico State Engineer, March, 2018.

Professional Society Memberships and Participation

\# \# **Society of Exploration Geophysicists**: elected District Representative for six western states, 1992 – 1998.
Environmental & Engineering Geophysical Society: elected President, 2003 (voting member of Board of Directors 2003-2005 as President-Elect, President, and Past President).
Environmental & Engineering Geophysical Society: elected Secretary/Treasurer, 2001-2002.
Environmental & Engineering Geophysical Society: appointed Editor **of FastTIMES**, a quarterly publication of EEGS, 2002.
Arizona Hydrological Society, member

Training and Instructor Experience

Instructor: Mine Safety and Health Administration (MSHA), Metal and non-metal surface
Provided Geophysical Field and Equipment Training in the following countries:
Japan (three times, Metal Mining Agency of Japan, Kakioka Magnetic Observatory
People's Republic of China (four times, for government ministries of Petroleum Industry, Coal Industry, Nuclear Industry, and Mining and Metallurgy Industry)
Korea (for Korean Institute of Energy Resources)
Yugoslavia (for Nafta Gas)
Jordan (twice, for Natural Resources Authority of Jordan, funded by USGS)
Mexico (for various mining industry companies)
Turkey (for government agency Maden Teknik ve Arama)
Indonesia (for Department of Volcanology, a government agency)

Groundwater Publications and Presentations

Carlson, N.R., Bushner, G., Wold, C., and Blandford, N, 2018, "Geophysical CSAMT Survey Results and Groundwater Modeling in a Groundwater Appropriation Trial", Ground Water Week, National Ground Water Association, December 3-6, 2018, Las Vegas, NV.

Carlson, N.R., 2016, "The CSAMT and TEM Methods", in Surface Geophysical Methods for Hydrological Assessment Workshop, Arizona Hydological Society Annual Meeting, September, 2016, Tucson, AZ.

Carlson, N. R., Feast, C.F., Bushner, G.L., and Hoerth, R. 2011, "The Use of CSAMT and NSAMT in siting groundwater production wells: Two Case Histories", the International Workshop on Gravity, Electrical and Magnetic Methods and Their Applications, Chinese Geophysical Society and the Society of Exploration Geophysicists, October 10-13, 2011, Beijing, China.

Carlson, N. R., Monk, E.T., and Alderete, J.P., 2011, "Groundwater exploration in the Edgewood, New Mexico Area using CSAMT", Arizona Hydrological Society Annual Conference, September 18-20, 2011, Flagstaff, Arizona.

Carlson, N. R., Feast, C.F., Bushner, G.L., and Hoerth, R. 2011, "What to drill: red or blue? Using CSAMT and NSAMT in siting groundwater production wells in southeastern Nevada", Proceedings of the 43rd Symposium on Engineering Geology and Geotechnical Engineering (EGGE), Las Vegas, NV.

Carlson, N., Lesan, H., Morris, L., 2009, "Applications of Mineral Exploration Geophysical Methods to Leak Detection and Monitoring at Nuclear Power Plants", Proceedings: 2009 Electric Power Research Institute Groundwater Protection Workshop, Charleston, SC.

Conway, Clay M., Carlson, Norman R., Condrat, George, Robison, Lori, Stevenson, Gene M., McMullin, Garrett, 2009, Investigation and successful development of the N-aquifer near Blanding, Utah, 61st Annual Meeting, Rocky Mountain Section, The Geological Society of America, May 11-13, 2009, Orem, UT.

Carlson, N.R., Paski, P.M., and Pellatz, R., 2009, Deep ground-water exploration in the Flagstaff, Arizona area using CSAMT, Annual Meeting of the Arizona Hydrological Society and the American Institute of Hydrology, Scottsdale, Arizona.

Carlson, N.R., Ivancie, P., Sirles, P.C., 2007, Correlating surface geophysics, geology, and borehole information: a case history, presentation at the Groundwater Summit 2007, National Groundwater Association, April 29-May 3, 2007, Albuquerque, New Mexico.

Carlson, N.R., and Urquhart, S.A., 2006, A sewer sinkhole study using TEM, ***The Leading Edge***, Society of Exploration Geophysicists, March, 2006, Vol. 25, No. 3, pp. 348-350.

Carlson, N.R., and Paski, P.M., 2006, Deep fault and fracture delineation using the CSAMT method, presentation at the Groundwater Summit 2006, National Groundwater Association, April 22-27, 2006, San Antonio, Texas.

Carlson, N.R., Paski, P.M., and Urquhart, S.A., 2005, Applications of controlled source and natural source audio-frequency magnetotellurics to groundwater exploration, Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), Environmental and Engineering Geophysical Society, April, 2005, Atlanta, Georgia.

Hughes, L.H., and Carlson, N.R., 2003, Mapping structural pathways for DNAPL transport in karst using induced polarization, Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), Environmental and Engineering Geophysical Society, April, 2003, San Antonio, Texas.

Carlson, N.R., K.L. Zonge, G. Ring and M. Rex, 2000, "Fluid-flow mapping at a copper leaching operation in Arizona," ***The Leading Edge***, pp. 752 – 755.

ATTACHMENT 5

Timothy Durbin, P.E., Timothy J. Durbin, Inc.

Professional Registration

Professional Civil Engineer, 1972
California No. 20651

Education

M.S., Civil Engineering, 1971
Stanford University, California

B.S., Civil Engineering, 1967
Stanford University, California

Professional Affiliations

American Society of Civil Engineers

American Geophysical Union

International Association of Hydrogeologist

National Groundwater Association

Publications

Durbin, T.J., 1974, Digital simulation of the effects of urbanization on runoff in the upper Santa Ana Valley, California: U.S. Geological Survey Water-Resources Investigations 41-73, 44 p.

Durbin, T.J., and Hardt, W.F., 1974, Hydrologic analysis of the Mojave River, California, using a mathematical model: U.S. Geological Survey Water-Resources Investigation 17-74, 50 p.

Durbin, T.J., 1975, Selected effects of suburban development on runoff in south-coastal California: in Proceedings of Second National Symposium on Urban Hydrology and Sediment Control, Lexington, Kentucky, p. 209-217.

Durbin, T.J., 1975, Ground-water hydrology of Garner Valley, San Jacinto Mountains, California – a mathematical analysis of recharge and discharge: U.S. Geological Survey Open-File Report 75-305, 40 p.

Durbin, T.J., 1978a, Application of Gauss algorithm and Monte Carlo simulation to the identification of aquifer parameters: in Proceedings of 26th Annual American Society of

Tim Durbin has over 40 years of engineering experience and directs projects relating to groundwater and surface-water hydrology. Areas of expertise include design of multidisciplinary investigations, design of large-scale programs for the collection and interpretation of hydrologic data, and application of mathematical modeling to the analysis of problems in groundwater and surface-water hydrology. Tim Durbin's early professional career was with the U. S. Geological Survey, first as a research hydrologist, later as director of that agency's water-resource activities successively in Nevada and California.

Project Experience

Guideline for Groundwater Modeling. Preparing guidelines for groundwater models submitted to the California Department of Water Resources regarding streamflow depletions due to groundwater-substitution transfers of surface water. The guidelines address developing a hydrogeologic conceptual model and translating and translating the conceptual model into a numerical groundwater model. The guidelines will address the model geographic extent, grid/mesh design, boundary conditions, initial conditions, aquifer-parameter estimates, and calibration. *California Department of Water resources, California.*

Sacramento Valley Groundwater Basin, California. Serving as senior advisor to California Department of Water Resources regarding development of a groundwater model of the Sacramento Valley groundwater basin. The model will be used by the Department for assessing streamflow depletions due to groundwater-substitution transfers of surface water. *California Department of Water Resources, California.*

Antelope Valley Groundwater Basin, California. The Antelope Valley groundwater basin is being adjudicated to address the overdraft within the basin. Developed criteria for defining the geographic extent of the groundwater. Developed estimate of natural recharge within adjudicated area. Work was done in support of litigation related to the adjudication. *City of Los Angeles, California.*

Seaside Groundwater Basin, California. The Seaside groundwater basin was adjudicated to balance the threat of seawater intrusion against the need for groundwater production to supply water to communities overlying the basin and within the Monterey Peninsula area. Developed a groundwater model to assess the relation between groundwater production and seawater intrusion. Work was done in support of litigation related to the adjudication. *California American Water, Monterey, California.*

Heavenly Valley, California. Analyzed the hydrologic impacts of the proposed use of groundwater for snow-making within the Heavenly Valley ski resort. The proposal was to pump groundwater from an alpine valley within which the groundwater and surface-water system were hydrologically connected. The analysis involved collecting field data, constructing a linked groundwater/surface-water model, and using the model to predict the impact of the proposed pumping on both groundwater levels and streamflow. Work was done in support of a permit to pump additional groundwater for snow-making. *Vail Resorts, South Lake Tahoe, California.*

Carbonate Aquifer System, Eastern Nevada. Analyzed the water-related impacts of groundwater development within the regional Carbonate Aquifer System that underlies central and eastern Nevada. The Southern Nevada Water Authority, which delivers water to Las Vegas and neighboring communities, is considering a project to import of groundwater from the Carbonate Aquifer. The analysis is focused on the possible impacts of the project on springs and phreatophytes. The work includes developing a groundwater model of the

Civil Engineers Hydraulic Division Specialty Conference, College Park, Maryland, p. 101-111.

Durbin, T.J., 1978b, Calibration of a mathematical model of the Antelope Valley ground-water basin, California: U.S. Geological Survey Water-Supply Paper 2046, 51 p.

Durbin, T.J., and Morgan, C.O., 1978, Well-response model of the confined area, Bunker Hill ground-water basin, San Bernardino County, California: U.S. Geological Survey Water-Resources Investigation 77-129, 39 p.

Arteaga, F.E., and Durbin, T.J., 1978, Development of a relation for steady-state pumping rate from Eagle Valley ground-water basin, Nevada: U.S. Geological Survey Open-File Report 79-261, 44 p.

Durbin, T.J., Kapple, G.W., and Freckleton, J.R., 1978, Two-dimensional and three-dimensional digital flow models of the Salinas Valley ground-water basin, California: U.S. Geological Survey Water-Resources Investigation 78-113, 134 p.

Van Denburgh, A.S., Seitz, H.R., Durbin, T.J., and Harrell, J.R., 1982, Proposed monitoring network for ground-water quality, Las Vegas Valley, Nevada: U.S. Geological Survey Open-File Report 80-1286, 25 p.

Durbin, T.J., 1983, Application of Gauss algorithm and Monte Carlo simulation to the identification of aquifer parameters: U.S. Geological Survey Open-File Report 81-688, 26 p.

Katzer, T., Durbin, T.J., and Maurer, D.K., 1984, Water-resources appraisal of the Galena Creek basin, Washoe County, Nevada: U.S. Geological Survey Open-File Report 84-433, 59 p.

Kapple, G.W., Mitten, H.T., Durbin, T.J., and Johnson, M.J., 1984, Analysis of Carmel Valley alluvial ground-water basin, California, using digital flow model

Carbonate Aquifer System. The model extends over an area covering 20,000 square miles. The work was done in support of hearings before the Nevada State Engineer on water-right applications by the Authority. *Southern Nevada Water Authority, Las Vegas, Nevada and subsequently U. S. Department of the Interior.*

North Platte River, Wyoming and Nebraska. Analyzed the impacts of water-resource development and reservoir operations on water supply, streamflows, regional economics, and wildlife resources within the North Platte River Basin, Nebraska and Wyoming. Designed and directed a multi-disciplinary investigation involving agricultural engineers, groundwater hydrologists, surface-water hydrologists, agricultural economists, and environmental scientists in six different consulting firms. Work was done in support of litigation before the U.S. Supreme Court between the states of Nebraska and Wyoming. *Attorney General, Lincoln, Nebraska.*

Santa Monica Groundwater Basin, California. Analyzed the occurrence of MTBE in the Santa Monica groundwater basin, California. MTBE contamination from multiple sites has resulted in abandonment of public-supply wells. An analysis of the sources and fate of MTBE within the Santa Monica groundwater basin is being conducted. Work was done within the context of State and Federal regulatory proceedings and litigation. *ConocoPhillips, Houston, Texas.*

Special Master, California. Assigned as Special Master in a technical dispute between City of San Bernardino, California and the Regional Water Quality Control Board. The issue is the cause of a wastewater discharge to the Santa Ana River. The work was being done within the context of a State regulatory proceeding. *Regional Water Quality Control Board, Santa Ana, California.*

Bookman-Edmonston Engineering, Inc., Sacramento, California. Vice President (May 1998 – January 1999)

Directed projects related to groundwater and surface-water hydrology. Directed a staff of about 30 engineers, hydrologists, biologists, and geologists. Examples of such projects include:

Flooding, Arizona. Analyzed the causes of flooding near Phoenix, Arizona. Residential and commercial areas were flooded during a summer storm. The analysis involved assessing the effect of irrigation ditches and other facilities on the depth of flooding. The work was done in support of litigation.

Pipeline Break, California. Analyzed the impact of floodflows on the failure of a stream pipeline crossing within Thousand Oaks, California. A large sewer line failed owing to channel erosion during an extreme flood event. The recurrence interval of the erosion event was analyzed. The work was done within the context of a State regulatory proceeding.

Hydrologic Consultants, Inc., Sacramento, California. President (March 1989 – May 1998)

Directed projects related to groundwater and surface-water hydrology. Directed a staff of about 10 hydrologists, geologists, and engineers. Examples of such projects include:

Lake Tahoe, California and Nevada. Analyzed the impacts of urban development on the water quality of Lake Tahoe, California. Work involved the analysis of sediment and nutrient transport in streams tributary to the lake and nutrient cycling within the lake. Work was done for litigation.

Streamflow Temperature, California. Analyzed streamflow temperature within the Owens River, Owens Valley, California. Work was done to evaluate the hydrologic feasibility of reestablishing a fishery within the Owens River.

Groundwater Salinity, California. Analyzed the source and management of surface-water and groundwater salinity within the Lompoc groundwater basin.

techniques: U.S. Geological Survey Water-Resources Investigation 83-4280, 45 p.

Hromadka, T.V., and Durbin, T.J., 1984, Adjusting the nodal point distribution in domain ground-water flow numerical models: in Proceedings of Fifth International Conference on Finite Elements in Water Resources, p. 265-284.

Durbin, T.J., and Berenbrock, C., 1985, Three-dimensional simulation of free-surface aquifers by the finite-element method: U.S. Geological Survey Water-Supply Paper 2270, p. 51-67.

Mitten, H.T., Lines, G.C., Berenbrock, C., and Durbin, T.J., 1988, Water resources of Borrego Valley and vicinity, San Diego County, California: Phase 2, Development of ground-water flow model: Water Resources Investigations 87-4199.

Martin, P., and Durbin, T.J., 1990, Identification of net-flux rates for ground-water models: U.S. Geological Survey Water-Supply Paper, 2340, pp. 119-130.

Hromadka, T.V., and Durbin, T.J., 1986, Two-dimensional dam-break analysis for Orange County Reservoir: Water Resources Bulletin, v. 22, n. 2, p. 249-256.

Hromadka, T.V., and Durbin, T.J., 1986, Modeling steady-state advective transport by the CVBEM: Engineering Analysis, v. 3, n. 1, p. 9-15.

Durbin, T.J., 1988, Two-dimensional simulation of ground-water flow by finite-element method: Microsoftware for Engineers, v. 2, n. 1, p. 40-48.

Azrag, E.A., Durbin, T.J., and Nour El-Din, N.N., 1986, Two-dimensional simulation of solute transport by finite-element method: Microsoftware for Engineers, v. 2, n. 3, p. 171-180.

Work involved developing groundwater and surface-water models of the Santa Ynez River basin, including salinity models. Work was done in support of litigation.

Agricultural Drainage, California. Analyzed the causes and management of drainage water discharges from the Firebaugh and Central California Water District to natural watercourses and the San Joaquin River. Work was done in support of litigation.

FERC Re-licensing, California. Developed a model for the optimal use of ground water and surface water within the Turlock and Modesto Irrigation Districts for the benefit of water supply and environmental resources. Work was done in support of the FERC re-licensing of New Don Pedro Reservoir.

Seawater Intrusion, California. Analyzed seawater intrusion in the Salinas Valley. Analyzed the impacts of groundwater pumping on seawater intrusion. Analyzed the impacts of reservoir operations on streamflow recharge and seawater intrusion. Work was done in support of litigation.

Petroleum Contamination, California. Analyzed the source of soil and groundwater contamination by petroleum hydrocarbons at Santa Barbara, California. Work was done in support of litigation. Analyzed the source of soil and groundwater contamination by petroleum hydrocarbons at Oxnard, California. Work was done in support of litigation.

San Bernardino Groundwater Basin, California. Analyzed the occurrence of high groundwater levels in the San Bernardino Valley, California using surface-water and groundwater models. High groundwater levels resulted from excess artificial recharge and other factors. Work was done in support of litigation.

Arkansas River, Colorado and Kansas. Analyzed the effects of groundwater pumping and other factors in the depletion of streamflow in the Arkansas River at the Colorado-Kansas state line using surface-water, groundwater, and institutional models. Work was done in support of litigation in the U.S. Supreme Court between the states of Kansas and Colorado.

Geothermal Development, California. Analyzed the effects of geothermal development on thermal-spring discharges in the Mammoth Lakes area, California using groundwater and heat-transport models. Work was done in support of litigation.

S.S. Papadopulos & Associates, Inc., Davis, California. Vice President and Manager of Davis office (October 1985 – March 1989)

Directed and conducted investigations of numerous aspects of groundwater hydrology. Examples of such projects include:

Love Canal, New York. Analyzed the migration of groundwater contaminants at the Love Canal hazardous waste site in Niagara Falls, New York using a groundwater model. The Love Canal site is a Superfund Site. Work was done in support of litigation.

Groundwater Contamination, New Jersey. Analyzed the migration of groundwater contaminants at the Lone Pine landfill near Freehold, New Jersey. The Lone Pine landfill is a Superfund site. Work was done as part of a remedial investigation.

Modeling Code. Developed a computer program for the simulation of soil-water movement within and near a land-disposal facility. Work was done for the U.S. Environmental Protection Agency in support of the preparation regulations relating to the design of cover, liner, and leak-detection systems for land-disposal facilities.

Sediment Transport, California. Analyzed the impacts of urban development on flooding and sediment transport for streams in Orange County, California. Work

Atkinson, L.C., Durbin, T.J., and Azrag, E.A., 1992, Estimating the effects of non-Darcian flow on inflow to a pit and slope stability: Society for Mining, Metallurgy, and Exploration 1992 Annual Meeting, Paper 92-156, 4 p.

Durbin, T.J., and Atkinson, L.C., 1993, Optimizing the design of mine dewatering systems: Society for Mining, Metallurgy, and Exploration 1993 Annual Meeting, Paper 93-103, 5 p.

Avon, L., and Durbin, T.J., 1994, Evaluation of the Maxey-Eakin method for estimating recharge to ground-water basins in Nevada: Water Resources Bulletin, v. 30, n. 1, pp. 99-112.

Durbin, T.J., Bond, L.D., 1997, FEMFLOW3D: A finite-element program for the simulation of three-dimensional aquifers, Version 1.0: U.S. Geological Survey Open-File Report 97-810, 338 p.

Hromadka, T. V., Durbin, T.J., 2000, Estimating changes in sediment transport trends due to catchment changes: in Proceedings of Floodplain Management Association Conference on Non-Structural Solutions to Floodplain Management, San Diego, Calif.

Rajagopal-Durbin, A., and Durbin, T. J., 2008, Wells are not always water follies: Sustainable groundwater policies for the American West: Water Policy, v. 10, n. 2, p. 145-164.

Durbin, T. J., and Delemos, D. W., 2007, Adaptive under relaxation of Picard iterations in ground-water models: Ground Water, v. 45, n. 5, p. 648-651..

Durbin, T. J., Delemos, D. W., and Rajagopal-Durbin, A., 2008, Application of superposition to non-linear ground-water models: Ground Water, v. 46, n. 2, p. 251-258.

Bredehoeft, J., and Durbin, T., 2009 Groundwater development - the time to full capture problem: Groundwater, v. 47, n. 1, pp. 2-9.

supported the permitting of a large residential and commercial development project.

Williamson and Schmid, Hydrotec Division, Davis, California. Manager of Davis office (July 1984 – October 1985)

Directed and conducted investigations for evaluation of groundwater resources, management of regional groundwater systems, and evaluation of hazardous waste sites. Studies involved identification of essential hydrologic issues, collection of hydrologic data, and application of quantitative methods to evaluate alternatives and to select an optimal solution. Examples of such projects include:

Groundwater Contamination, California. Developed a three-dimensional groundwater model of a physical barrier at a hazardous waste landfill in order to evaluate performance of the existing barrier and proposed modifications. Work was done for regulatory compliance.

Isotope Geochemistry, California. Analyzed a hazardous waste site using isotope geochemistry and groundwater models as investigative tools. Work was done for regulatory compliance.

Groundwater Salinity, Nevada. Analyzed the utilization of fresh water body overlying saline water using surface geophysical techniques and a density-dependent groundwater flow model.

U.S. Geological Survey, Water Resources Division, California District. District Chief (August 1982 – July 1984)

Managed California District (350 persons in 14 offices) with annual budget of $25 million (in 1995 dollars) for hydrologic investigations. Responsible for developing plans for hydrologic investigations and ensuring plans were implemented. Provided organizational and technical input to development of large scale, multi-agency investigations. Examples of such projects include:

Agricultural Drainage, California. Investigation of water quality related to agricultural drainage from the west side of San Joaquin Valley, California.

San Francisco Bay, California. Investigation of hydrodynamics of San Francisco Bay and Sacramento-San Joaquin, California Delta hydrologic systems.

Groundwater Exports, California. Investigation of the effects of exporting water from Owens Valley groundwater basin, California, including both hydrologic and biological impacts.

Central Valley Groundwater, California. Assessment of the groundwater resources of the Central Valley, California. Work was part of the Central Valley Regional Aquifer System Analysis (RASA).

Modeling Code. Development of numerical finite element codes (now used within the U.S. Geological Survey) for simulation of two- and three-dimensional groundwater flow and solute transport.

U.S. Geological Survey, Water Resources Division, Nevada District. District Chief (January 1980 – August 1982) and Assistant District Chief (July 1977 – August 1982)

Managed Nevada District (80 persons in three offices) with annual budget of $10 million (in 1995 dollars) for hydrologic investigations. Projects included:

Truckee River, Nevada. Design and organization of Truckee-Carson River Quality Assessment and Great Basin Regional Aquifer System Analysis (RASA).

Groundwater Management, Nevada. Development of groundwater and solute transport models for Washoe Valley, Galena Creek, Eagle Valley, and Carson Valley groundwater basins in Nevada.

Geothermal Development, Nevada. Design and organization of regional

Books

Hromadka, T.V., Durbin, T.J., and DeVries, J.J., 1984, Computer methods in water resources: Lighthouse Publications, Mission Viejo (California), 344 p.

Hromadka, T.V., McCuen, R.H., Devries, J.J., and Durbin, T.J., 1993, Computer methods in environmental and water resources engineering: Lighthouse Publications, Mission Viejo (California), 590 p.

geothermal investigations of areas throughout Nevada including Dixie Valley, Ruby Valley, Black Rock Desert, and Carson Desert.

U.S. Geological Survey, Water Resources Division, California District. Hydrologist (December 1975 – July 1977), Hydrologist (October 1974 – December 1975), Hydrologist (September 1973 – October 1974), and Hydrologist (July 1972 – July 1977)

Served as Project Chief for numerous groundwater projects involving hydrogeologic and geophysical investigations and groundwater modeling. Conducted research in development of finite-element models for simulation of groundwater flow and mass transport. Applied results of research to solution of management problems and provided assistance to hydrologists within USGS and other public agencies in use of these models.

CERTIFICATE OF SERVICE

I certify that I am an employee of ROBISON, SHARP, SULLIVAN & BRUST, and that on this date I caused a true copy of **COYOTE SPRINGS INVESTMENT, LLC'S DISCLOSURE OF WITNESSES AND EXHIBITS** to be served on all parties to this action by emailing an attached Adobe Acrobat PDF version of the document to the email addresses below:

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Dated this 6th day of September, 2019.

V. Jayne Ferretto

V. JAYNE FERRETTO
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Order 1303 Report

Evaluation of Basin Hydrogeology and Assessment of Sustainable Yield in the Lower White River Flow System, Southeastern Nevada

July 3, 2019

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TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

APPENDICES

A. GENERAL GROUPING OF GEOLOGIC LAYERS

B. HYDROGEOLOGIC AND PHYSICAL PROPERTIES OF ROCKS

C. ESTIMATES OF RECHARGE, EVAPOTRANSPIRATION, AND GROUNDWATER FLOW IN THE LWRFS

D. SUPPORTING CALCULATIONS FOR COYOTE SPRING VALLEY RECHARGE ESTIMATES

E. SUPPORTING GROUNDWATER LEVEL, STREAMFLOW, AND PUMPING GRAPHS

TABLE OF ACRONYMS

AFY	Acre-feet per year
amsl	Above mean sea level
CBD	Center for Biological Diversity
CCRFCD	Clark County Regional Flood Control District
CDM	Cumulative departure from mean
COOP	National Weather Service Cooperative
CSAMT	Controlled Source Audio-frequency Magnetotellurics
CS Nevada	Coyote Springs Nevada, LLC
CSI	Coyote Springs Investment, LLC
CY	Calendar Year
CSV	Coyote Spring Valley
DOI	U.S. Department of the Interior
DRI	Desert Research Institute
ET	Evapotranspiration
GBWN	Great Basin Water Network
GIS	Geographic Information System
gpm	Gallons per minute
LWRFS	Lower White River Flow System
MBOP	Moapa Band of Paiute Indians
MRSA	Muddy River Springs Area
MVWD	Moapa Valley Water District
mya	Million years ago
NHD	National Hydrography Dataset
NRCS	National Resources Conservation Service
NSE	Nevada State Engineer
Ωm	Ohm-meters
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RAWS	Remote Automated Weather Station
SNOTEL	Snow Telemetry
SNWA	Southern Nevada Water Authority
USGS	United States Geological Survey
WRCC	Western Regional Climate Center

1.0 INTRODUCTION

The purpose of this report is to address the Nevada State Engineer's (NSE) request in Interim Order 1303 (Order 1303) to provide a report regarding the water resources in the Coyote Spring Valley, Muddy River Springs Area, California Wash, Hidden Valley, Garnet Valley, and a portion of the Black Mountains Area (alternatively, The Joint Administrative Unit). Specifically, Order 1303 requests that interested stakeholders address:

a. The geographic boundary of the hydrologically connected groundwater and surface water systems comprising of the Lower White River Flow System;

b. The information obtained from the Order 1169 aquifer test, subsequent to the aquifer test, and from Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test;

c. The long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, including the relationships between the location of pumping on discharge to the Muddy River Springs and the capture of Muddy River flow:

d. The effects of movement of water rights between alluvial wells and carbonate wells on deliveries to senior decreed rights on the Muddy River; and,

e. Any other matter believed to be relevant to the State Engineer's analysis.

The following report addresses the issues raised in Order 1303 and provides recommendations on how to provide long-term management for sustainability in the Lower White River Flow System (LWRFS).

2.0 ORDER 1169 AQUIFER TEST AND POST-TEST RESPONSE

After reviewing aquifer test reports resulting from Order 1169 (March 8, 2002) and Order 1169A (December 21, 2012), the NSE issued Ruling #6255 on January 29, 2014. NSE's Order 1169 placed new applications for appropriation of water from Coyote Spring Valley, Black Mountains Area, Garnet Valley, Hidden Valley, Muddy River Springs Area, and Lower Moapa Valley (collectively termed Order 1169 Basins) in abeyance until the aquifer test was completed. NSE Order 1169A stated that the aquifer test was completed as of December 31, 2012, and the parties had until June 28, 2013 to file reports based on the test data.[1] Subsequently, aquifer test reports were submitted by Southern Nevada Water Authority (SNWA), Coyote Springs Investment, LLC (CSI), U.S. Department of Interior (DOI), Moapa Band of Paiute Indians (MBOP), Moapa Valley Water District (MVWD), Great Basin Water Network (GBWN), and the Center for Biological Diversity (CBD).

The NSE issued Ruling 6255, which upheld the protests to applications for new appropriations in Order 1169 Basins, denying new applications based on the grounds that there is no unappropriated water, and that new appropriations would conflict with existing water rights. Ruling 6255 also addressed perennial yield and found that the scientific literature supported that the Coyote Spring Valley, Muddy River Springs Area, Hidden Valley, Garnet Valley and California Wash basins should be jointly managed.[2] Ruling 6255 did not determine the perennial yield of Coyote Spring Valley, but instead indicated that the total supply to the Order 1169 Basins is likely less than 50,000 acre-feet per year (AFY).[3]

2.1 SUMMARY ASSESSMENT OF ORDER 1169 TEST REPORTS

The information contained in the Order 1169 aquifer test reports by SNWA, CSI, DOI, MBOP, MVWD, GBWN, and CBD did not adequately present all the existing information to allow for the NSE to make an informed decision regarding the availability and sufficiency of water in what would become the Joint Administrative Unit. These reports were not unanimous in whether water was captured from storage or recharge, the effects of climate, or the impacts of geologic structure, among other differences.

The SNWA Study Report (SNWA, 2013) observed that there is a lack of pumping responses north of the Kane Springs Fault, in an area north of the MX-5 pumping site. Observations by SNWA in their June 2013 Order 1169 Test Report also noted the presence of flow barriers in the Coyote

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[1] Order 1169A also rescinded provision 8 of Order 1169 that required an update to Exhibit No. 54 from the July 2001 hearing.

[2] Ruling 6255, para V, page 26.

[3] Ibid.

Spring Valley: "Monitor wells CSVM-3 and CSVM-5 do not show any response due to pumping from the MX-5 and CSI 1-4 wells, strongly suggesting the presence of flow barriers between these wells and MX-5 rather than a delayed response."[4] SNWA's analysis of Muddy River streamflow at the Moapa gage also found that "nearby carbonate pumping" was not influencing senior Muddy River surface-water rights.[5]

The MBOP Order 1169 Study (MBOP, 2013) observed that declines in groundwater levels during the test period were affected by local and regional climate, atmospheric pressure, tides, and crustal loading phenomena. Additionally, the MBOP Study concluded that the pumping response from groundwater pumped at MX-5 is dominated by boundary conditions, not groundwater storage.[6]

The DOI Study (DOI, 2013) observed that water captured during the test was likely from groundwater storage, and only a fraction was from natural discharge,[7] but their conclusion was based on an average 1.4-foot decline over the entire study area due to pumping without consideration of climate variability. The DOI report specifically stated: "Likewise, no corrections have been made for longer-term (regional) trends in groundwater levels given continued uncertainties concerning the availability of a 'reference' well that can be used to make such corrections."[8] Contrary to their assumption, the records[9] indicate that long-term seasonal variations due to recharge and anthropogenic impacts, including those from local carbonate and alluvial pumping, affect surface water resources of the Muddy River.

The GBWN Study (GBWN, 2013) observed that "groundwater levels for all wells have been decreasing since the mid-1990s with some recovery due to wet conditions from 2004 to 2005. During the 2010 to 2012 pump test period the rate of decline in carbonate wells increased."[10] Data provided in their report indicates that groundwater levels in the carbonate aquifer[11] and spring discharge at the Pederson Spring Complex[12] increased following the 2005 wet year event. While the GBWN Study notes that "After 2005 the region primarily returned to drought conditions. The late 1990s were among the wettest years since 1980,"[13] it does not differentiate the impacts caused by Order 1169 pumping, other pumping in the five-basin area, and climatic conditions. Additional

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[4] SNWA June 2013 Order 1169 Report, page 36.
[5] Ibid, Page 45.
[6] MBOP Order 1169 Study, page 32.
[7] DOI Order 1169 Study, Page 31.
[8] Ibid, page 9.
[9] As presented and explained in this report.
[10] GBWN, 2013. Section: Muddy River Springs Area
[11] Ibid, Figure 13
[12] Ibid, Figure 17
[13] Ibid, Section: Discussion of Pumpage, Groundwater Levels and Spring Discharges.

groundwater, spring, and climatic data would be required to assess how the carbonate aquifer and springs respond to prolonged wet and dry cycles.

Important factors that affect the availability of water in the Joint Administrative Unit area, which have become apparent since the submission of the Order 1169 Aquifer Test Reports in June of 2013, include: (1) the impact of long-term climatic cycles on regional groundwater levels; (2) regional geology and groundwater flow; (3) local structural and sedimentary geology; and (4) the effect of nearby pumping on springs in the Muddy River Springs Area. These factors, as well as others, affect the determination of available water, as well as the availability of water to meet the demands of decreed Muddy River water rights and the Moapa dace.

2.2 HYDROLOGIC VARIABILITY AND CLIMATE

The sustainable yield of a basin can be described as "the maximum quantity of water, calculated over a base period representative of long-term conditions in the basin and including any temporary surplus, that can be withdrawn annually from the groundwater supply without causing an undesirable result."[14] The long-term conditions of a basin can be described by the regional climate that affects the recharge, and by groundwater conditions within that basin. The regional climate of the LWRFS is best described by multiple precipitation stations that reflect conditions of both the mountain blocks and valley floors.

Two precipitation records were reviewed to establish the long-term climatic conditions in the LWRFS. A longer 123-year record summarizing the Extreme Southern region of Nevada for the period 1895 to 2017[15] was available from the Western Regional Climate Center (WRCC) (Figure 1, top graph). A shorter 52-year period precipitation record from 1966 to 2017 was available for the Pahranagat Wildlife Refuge (National Weather Service Cooperative station number 265880), located up-gradient from the LWRFS (Figure 1, bottom graph). Wet and dry cycles in the LWRFS may be identified from cumulative departure from mean (CDM) curves that show long-term precipitation trends referenced to average conditions.

The CDM curve for the Extreme Southern region of Nevada shows that relative wet periods occurred from the early-1900s to the early-1920s, the mid-1930s to the early-1940s, and the mid- to late-1970s to the early-1980s. An extended dry period occurred from the mid-1940s to mid- to late-1970s, and a shorter dry period occurred from the mid-2000s to the present. The CDM curve for precipitation at the Pahranagat Wildlife Refuge shows similar patterns of wet and dry cycles over the 1966 to 2017 period. A wet period occurred in early 1980s, from 2004 to 2005, and again from 2013

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[14] California Code of Regulations §10721

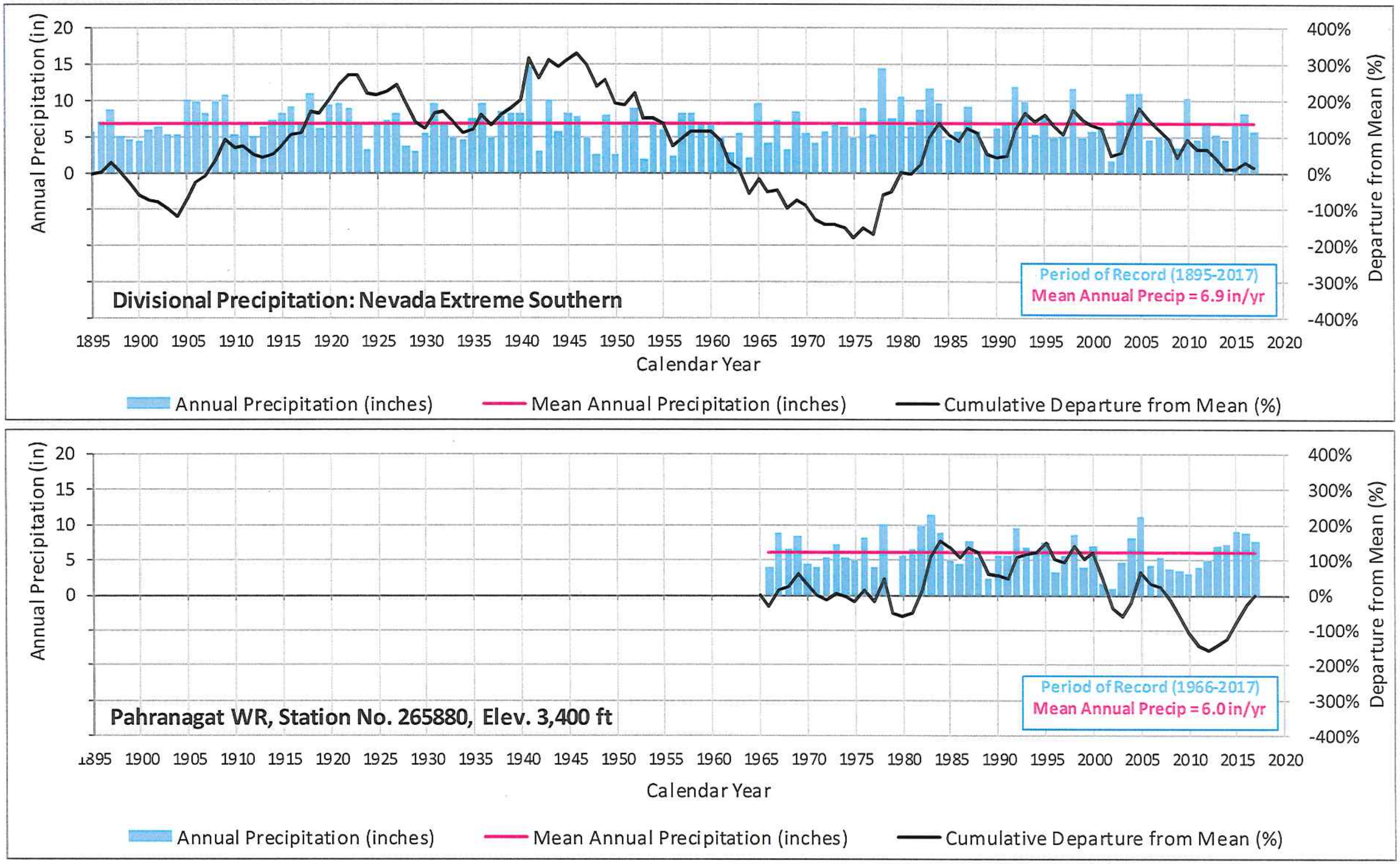
[15] WRCC https://wrcc.dri.edu/cgi-bin/divplot2_form.pl?2604

to 2017. Beginning in 2000, an extended dry period occurred through 2012, except for above average rainfall in 2004 and 2005. The end of the extended dry period in 2012 corresponds with the end of the Order 1169 aquifer test.

A CDM curve may also be used to describe a balanced hydrologic cycle, which occurs when the beginning and end of the cycle show a similar value for cumulative departure. For example, the 36-year period from 1982 through 2017, at both rainfall records, begins and ends on the zero value for cumulative departure, indicating that this 36-year period has the same conditions, on average, as the longer-term periods on each graph. 1982 through 2017 reflects a balanced hydrologic cycle, containing wet periods in the early 1980s and mid-2000s, an average period from 1992 through 2000, and a dry period from 2006 through 2012. For short-term planning, a 14-year balanced hydrologic period may be identified from 2003 through 2016. The data for the Extreme Southern region of Nevada shows a wetting cycle in 2004-2005 and an extended dry period from 2006 through 2017. The Pahranagat Wildlife Refuge precipitation record for 14-year period is characterized by the 2004-2005 wet cycle and a dry cycle from 2006 through 2012.

Investigation and analysis of long-term hydrologic cycles that include extended wet and dry periods are required to assess the occurrence, movement, and availability of groundwater in the LWRFS. Wet hydrologic conditions reset the balance of available groundwater and allow managers to meet targets based on varying demands over the multiple year periods based on a balanced hydrologic period. The Order 1169 aquifer test that was conducted in 2011 and 2012 occurred at the end of an extended dry period when all water resources throughout the LWRFS were negatively affected.

FIGURE 1



PRECIPITATION DATA FOR THE LOWER WHITE RIVER FLOW SYSTEM

2.3 REVIEW OF 2013 SERIESSEE ANALYSIS

Order 1303 relies on Ruling 6254, which cited modeling analysis by the DOI that identified a regional-wide carbonate aquifer water-level decline, estimated to be 1 to 1.6 feet in 1,100 square miles of the LWRFS[16] during the Order 1169 aquifer test. Ruling 6254 cited the DOI's Order 1169 Aquifer Test report (DOI, 2013), which used SeriesSEE modeling to discern and partition the effects of pumping at MX-5 on other locations. Review of the DOI Order 1169 Report and attached appendices show that it does not represent an adequate basis for establishing an "Administrative Unit" for the entire LWRFS. The documented SeriesSEE modeling does not include local and regional recharge, changes in the alluvial aquifer, climatic variability, or boundary effects that could affect the model's conclusions when the full dynamics are accounted for in the LWRFS.

The DOI report relied upon by the State Engineer in Order 1303 is based on modeling results that support a region-wide drawdown based on a simple Theis solution. The calibration process, hydrogeologic parameters used for modeling, and supporting pump test data are not documented and do not allow for third-party verification. Both regional and local recharge that affect the availability of water is not accounted for in DOI's evaluation. Furthermore, available data from 2013 through 2017 have not been used to verify the results of the 2013 model. Based on the lack of documentation and third-party repeatability, the DOI report should not be the primary document relied upon to support region-wide water level drawdown and the need for Order 1303.

In order to evaluate the results from the 2013 DOI model, a Theis solution was utilized to assess relative impacts to the Pederson Spring Complex from pumping in both the Coyote Spring Valley and Muddy River Springs Area. Previously published data[17] was relied upon to analytically model groundwater level drawdown in the Muddy River Springs Area from two pumping centers located at MX-5 and Arrow Canyon wells. The analytical model AquiferWin32© was used to simulate drawdown caused by pumping at the two locations. All pumping in the Coyote Spring Valley was simulated as occurring at the MX-5 well location in the eastern portion of Coyote Spring Valley. Since MX-5 is the closest well to the Pederson Spring area (compared to other production wells in Coyote Spring Valley), this provides a more conservative assumption for the analysis. The MX-5 location is approximately 11.5 miles west of the Pederson Spring location at a heading of 300°. A single pumping rate of 5,217 AFY, or 3,232 gallons per minute (gpm), was selected to represent pumping at this location. This is the average of calendar year (CY) 2011 and CY 2013 production rates, as reported in SNWA (2013).

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[16] Order 1303, Page 4.

[17] Reported transmissivity by SNWA (2007, Table E-1) averages 279,249 ft^2/day for Coyote Spring Valley and Muddy River Springs Area wells. Measured transmissivity at CSI-4 of 130,000 ft^2/day based on 670 feet of saturated aquifer completed in a fractured zone of the carbonate aquifer.

A midpoint location between the two Arrow Canyon wells was used to simulate carbonate pumping in the Muddy River Springs Area. This location is 2.5 miles from the Pederson Spring location, at a heading of approximately 320°. The volume of pumping was estimated to be 3,000 AFY, or 1,859 gpm. This is similar to an estimate of historical pumping shown in some of the figures in SNWA (2013) for the Muddy River Springs Area. Simulated drawdown due to (1) pumping in Coyote Spring Valley, (2) pumping in Arrow Canyon, and (3) pumping from both well locations are shown in Figure 2.

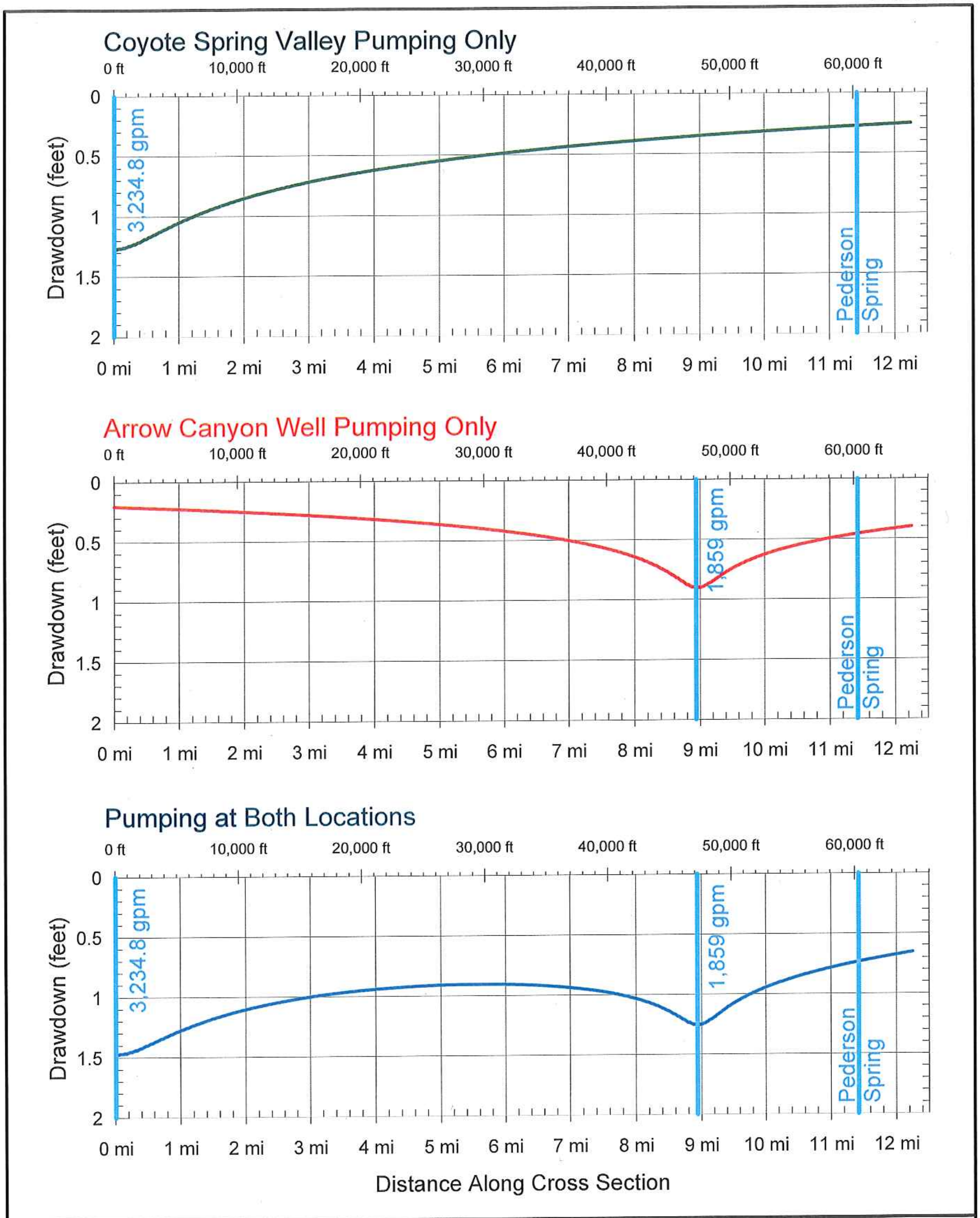
Simulated groundwater level drawdown at the Pederson Spring Complex due to pumping 5,217 AFY in Coyote Spring Valley is estimated to be 0.28 feet (see green line in upper graph of Figure 2) after two years. Simulated groundwater level drawdown at the Pederson Spring Complex due to pumping 3,000 AFY at the Arrow Canyon Wells is estimated to be 0.46 feet (see red line in middle graph of Figure 2) after two years. Finally, simulated groundwater level drawdown at the Pederson Spring Complex due to pumping a combined 8,217 AFY at the Coyote Spring Valley and Arrow Canyon Wells is estimated to be 0.74 feet (see blue line in lower graph of Figure 2) after two years. Results of this analysis indicate that pumping in Coyote Spring Valley during the Order 1169 Aquifer Test has a 38% impact on groundwater level decline at the Pederson Spring Complex after two years when climate and other diversions in the LWRFS are ignored.

The results of this analysis provide an example of the difference in impacts to groundwater levels at the Pederson Spring Complex due to pumping in Coyote Spring Valley versus Arrow Canyon. The analysis was based on Theis equation analytical model that assumed:

1. Groundwater pumping occurs at a constant average rate through the year based upon historical groundwater production;
2. Groundwater pumping is generalized to occur at two locations;
3. An existing general flow gradient of a 1 foot drop every 2 miles;
4. A homogeneous aquifer;
5. The aquifer was assumed to be of infinite extent, and no additional influences to the resulting cone of depression were considered beyond the specified gradient. This includes no recharge or surface inflows from precipitation, agriculture return flows, streamflow, or other sources;
6. No boundary effects.

This evaluation was performed to develop a relative impact analysis of pumping in Coyote Spring Valley and MRSA to groundwater levels at the Pederson Spring Complex. The results are different than those presented in the 2013 DOI report. Our results show a greater influence on monitoring well EH-4 water levels from pumping at Arrow Canyon wells, which are closer to the spring complex, than from pumping at MX-5 in Coyote Spring Valley, which is farther from the springs. The DOI SeriesSEE model simulates the greatest impact at EH-4 from pumping in Coyote Spring Valley.

FIGURE 2



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**SIMULATED DRAWDOWN
AT PEDERSON SPRING COMPLEX
DUE TO PUMPING IN COYOTE SPRING VALLEY,
ARROW CANYON, AND BOTH LOCATIONS.**

AquiferWin WinFlow
Time = 730 days
T = 279,259 ft^2/day
S = 0.03

2.4 Calculated Drawdown at an Observation Point using the Theis Solution

The Theis solution was used to estimate the impact of two pumping wells on drawdown at an observation point based on varying values of transmissivity. While the solution does not account for recharge, groundwater gradients, or boundary effects, it provides an analysis of relative impact to drawdown at an observation point from two pumping wells located at different distances from the observation point. The location of the pumping wells and observation point are consistent with MX-5, Arrow Canyon wells, and the Pederson Spring Complex shown in Figure 2. The pumping rate at the well 11.5 miles from the observation point was 3,232 gpm, while the pumping rate at the second well located 2.5 miles from the observation well was 1,859 gpm. Each well pumped continuously for three years so drawdown at the observation point could be assessed based on both transmissivity and time. The values of transmissivity that were investigated spanned three orders of magnitude, including 28,000 ft^2/day (209,440 gpd/ft), 280,000 ft^2/day (2,094,400 gpd/ft), and 2,800,000 ft^2/day (20,944,000 gpd/ft). The storage coefficient (storativity) was held constant at 0.03 (dimensionless).

Given a transmissivity value of 28,000 ft^2/day, drawdown at the observation point after 1 year is 1.65 feet due to the well pumping 2.5 miles away and 0.03 feet due to the well 11.5 miles away (Table 1). When transmissivity is increased by an order of magnitude, to 280,000 ft^2/day, drawdown at the observation point after 1 year is 0.46 feet due to the well pumping 2.5 miles away and 0.28 feet from the well 11.5 miles away. Finally, when transmissivity is increased to 2,800,000 ft2/day, drawdown at the observation point is 0.07 feet from the nearby well and 0.07 feet from the distal well.

Table 1. Theis Solution for Drawdown at an Observation Point due to Two Pumping Wells

	Drawdown (feet) at Observation Point After:		
Transmissivity	1-Year of Pumping	2-Years of Pumping	3-Years of Pumping
11.5 miles from Pederson Spring (Q=3,232 gpm)			
28,000 ft^2/day	0.03	0.22	0.46
280,000 ft^2/day	0.17	0.28	0.34
2,800,000 ft^2/day	0.05	0.07	0.07
2.5 miles from Pederson Spring (Q=1,859 gpm)			
28,000 ft^2/day	1.65	2.29	2.68
280,000 ft^2/day	0.39	0.46	0.50
2,800,000 ft^2/day	0.06	0.07	0.07

The Theis solution also shows the impact to drawdown due to pumping over time. Generally, the cone of depression expands at a faster rate given a lower value of transmissivity. The increase in drawdown at the observation point due to constant pumping for three years at the nearby well is 62% (1.65 feet to 2.68 feet) when transmissivity is 28,000 ft^2/day and 16% (0.06 feet to 0.07 feet) when transmissivity is 2,800,000 ft^2/day. Similarly, the increase in drawdown at the observation point due to constant pumping for three years at the distal well is 14300% (0.03 feet to 0.46 feet) when transmissivity is 28,000 ft^2/day and 40% (0.05 feet to 0.07 feet) when transmissivity is 2,800,000 ft^2/day. The Theis solution shows that the cone of depression propagates at a slower rate when transmissivity is high, and at a faster rate when transmissivity is low.

The Theis solution provides insight to the post-Order 1169 aquifer test data collected in the Muddy River Springs Area. The bulk transmissivity value between Coyote Spring Valley and Muddy River Springs Area is at least 280,000 ft^2/day, and possibly much greater. Transmissivity in the carbonate aquifer in Muddy River Springs Area and Coyote Spring Valley was reported to be 312,040 ft^2/day (Arrow Canyon), 365,840 ft^2/day (EH-4), 321,310 ft^2/day (MX-5), and 117,847 ft^2/day (MX-4) by SNWA (2007, Table E-1). A value that would be appropriate to estimate the impact of pumping in Coyote Spring Valley to groundwater levels in Muddy River Springs Area would be the average of reported transmissivity for these four wells of 279,259 ft^2/day. Additionally, a simple solution of Darcy's flow equation based on the groundwater level elevation difference between monitoring wells UMVM-1 and EH-5b, a flow corridor 1.6 miles wide and 4,000 feet deep, and a flow of 37,000 AFY would result in a transmissivity value greater than 279,259 ft^2/day.

The calculated drawdown at an observation point located 11.5 miles from a well pumping 5,217 AFY (3,232 gpm) for two years, based on the average transmissivity of 279,259 ft^2/day and a storativity value of 0.03, is 0.28 feet. While this analysis does not account for groundwater gradients, recharge, and boundary effects,[18] it provides a relative impact analysis for a well pumping in Coyote Spring Valley on an observation point in the Muddy River Springs Area.

Based on the above analysis, it is unlikely that impacts at the Pederson Spring Complex due to pumping in Coyote Spring Valley occurred immediately after Order 1169 pumping began, as previously indicated in the June 2013 Order 1169 aquifer test reports.[19] The groundwater level in EH-4 provides an appropriate representation of the groundwater-level at the Pederson Spring Complex since only flow is measured at the springs. The 1.51-foot decline in EH-4 groundwater level, from 1,816.57 ft above mean sea level (amsl) in May 2006 to 1,815.06 ft amsl in April 2011,[20] is likely attributable to climate, total diversions in Muddy River Springs Area ( ), and other

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[18] The Theis solution assumes isotropic and homogeneous conditions.

[19] See DOI (2013) page 3.

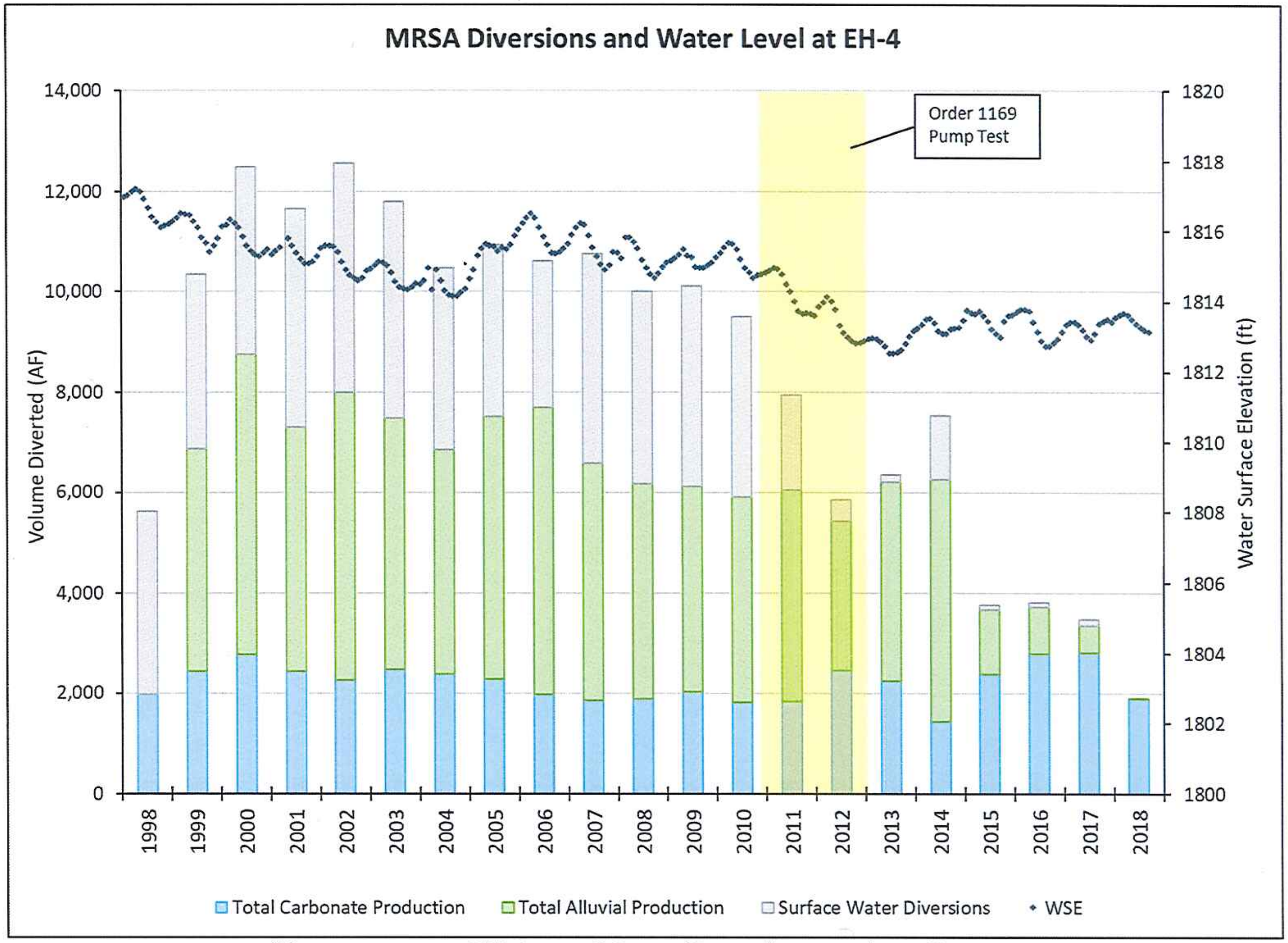
[20] Spring-time groundwater levels in EH-4 reflect annual maximum values and are used for comparison.

nearby pumping prior to the Order 1169 aquifer test. The continued 2.05-foot decline from April 2011 to April 2013 reflects the combined impact from climate and other pumping during the Order 1169 aquifer test on carbonate groundwater levels in the Muddy River Springs Area. The explanation provided by SNWA (2018) is more plausible explanation of observed impacts near the springs, indicating that Muddy River Springs Area alluvial and carbonate pumping impacts the Muddy River streamflow, alluvial aquifer, and springs.

Total alluvial pumping, carbonate pumping, and surface water diversions in the Muddy River Springs Area are compared to groundwater levels at EH-4 in . As depicted by the EH-4 hydrograph, groundwater levels have not recovered to pre-Order 1169 levels, which could be due to local Muddy River Springs Area production and climatic variability. Because alluvial and carbonate pumping in the Muddy River Springs Area has a direct impact on senior decreed rights on the Muddy River, the relationship between total diversions in the Muddy River Springs Area and surface flow is an important concept to include in sustainable management.

The recovery of carbonate aquifer groundwater levels in EH-4 due to increased recharge is most pronounced in 2005, following the wet years of 2004 and 2005. Following these wet years, the region experienced a long-term dry condition beginning in 2006 and lasting though the end of the Order 1169 aquifer test in 2012. The dry hydrologic conditions during this period are reflected in the decline in EH-4 groundwater-levels from 2006 through 2013. Likely due to slightly above normal rainfall at the Pahranagat Wildlife Refuge from 2013 through 2017, EH-4 groundwater levels only showed a modest recovery of 0.77 feet by April 2018. The most pronounced impact to EH-4 groundwater levels is due to the reduction in total diversions from the Muddy River Springs Area. The long decline in EH-4 groundwater levels from 1998 through 2004 and from 2006 through 2013 can likely be attributed to total diversions in the Muddy River Springs Area. When total diversions are reduced in 2014, groundwater levels cease to decline.

FIGURE 3



HYDROGRAPH OF EH-4 WITH MUDDY RIVER SPRINGS AREA DIVERSIONS

The Theis analysis and review of water levels and production in the Muddy River Springs Area indicate that factors other than pumping in Coyote Spring Valley are affecting spring discharge at the Pederson Spring Complex. First, the rate of interbasin groundwater flow between Coyote Spring Valley and Muddy River Springs Area dictates that transmissivity must be at least 280,000 ft^2/day in order to achieve to achieve a rate of 37,000 AFY.[21] The high value of transmissivity results in a minimal impact to EH-4 groundwater levels due to Order 1169 pumping as shown by the results in Table 1.

Second, the Theis solution indicates that drawdown in the Muddy River Springs Area due to pumping in Coyote Spring Valley would expand in magnitude over a period of two years. The Theis analysis and post-Order 1169 data show that groundwater levels in the Muddy River Springs Area are more responsive to changes in local production and hydrologic conditions, than they are pumping impacts from Coyote Spring Valley.

Third, the impact from nearby carbonate pumping at the Arrow Canyon wells would be much greater than the impact from Coyote Spring Valley pumping over a short two-year period. Therefore, factors such as Muddy River Springs Area stream diversions, alluvial pumping, carbonate pumping, and regional climate have a greater impact on spring flow in the Muddy River Springs Area than does pumping in Coyote Spring Valley.

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[21] See Section 5. Thomas et al. (2001).

3.0 GEOGRAPHIC BOUNDARY OF THE LOWER WHITE RIVER FLOW SYSTEM

The purpose of this section is to describe the regional and local carbonate rock aquifer that contains developable water resources in eastern Nevada and western Utah. In general, groundwater moves parallel to faults, in a north-to-south direction, from the Upper White River Basin south toward Lake Mead. Local recharge from rainfall and snowmelt supports water development in each basin and may contribute to regional groundwater flow. Discharge from the aquifer occurs as a result of groundwater production, discharge to streams and springs, interbasin groundwater flow, and loss to evapotranspiration (ET). The mechanisms that control groundwater flow throughout the entire carbonate rock province include structural geologic features, hydrogeologic properties, and natural and anthropogenic stresses.

3.1 LWRFS BOUNDARY

The boundary of the LWRFS includes Coyote Spring Valley, Muddy River Springs Area, California Wash, Hidden Valley, Garnet Valley, and a portion of the Black Mountains Area as defined in Order 1303 (Figure 4). The upper boundary of the LWRFS is consistent with the boundary identified in Order 1303. Specifically, the Pahranagat, Delamar, and Kane Springs Valleys are not included since these areas are tributary to the LWRFS and are distinctly separated by fault and structural boundaries.[22] The Lower Meadow Valley Wash is also tributary to the LWRFS, and is not included due to the depth to the carbonate aquifer and lack of existing or planned development. The water resources in these four basins can be administered individually, or in combination with other tributary basins.

Regional groundwater flow in the southeastern Nevada is generally in a north-to-south direction along normal faults and fractures within the carbonate aquifer. Although watershed and basin boundaries topographically define drainage patterns, they do not necessarily[23] impact the regional groundwater flow pattern. Faults and structural features are the first step in assessing groundwater resources in the carbonate rock aquifer (Rowley et al., 2017). Although water resources in the LWRFS are largely controlled by regional flow patterns, the boundary of the LWRFS, as identified by Order 1303, may be used for administration and sustainability planning.

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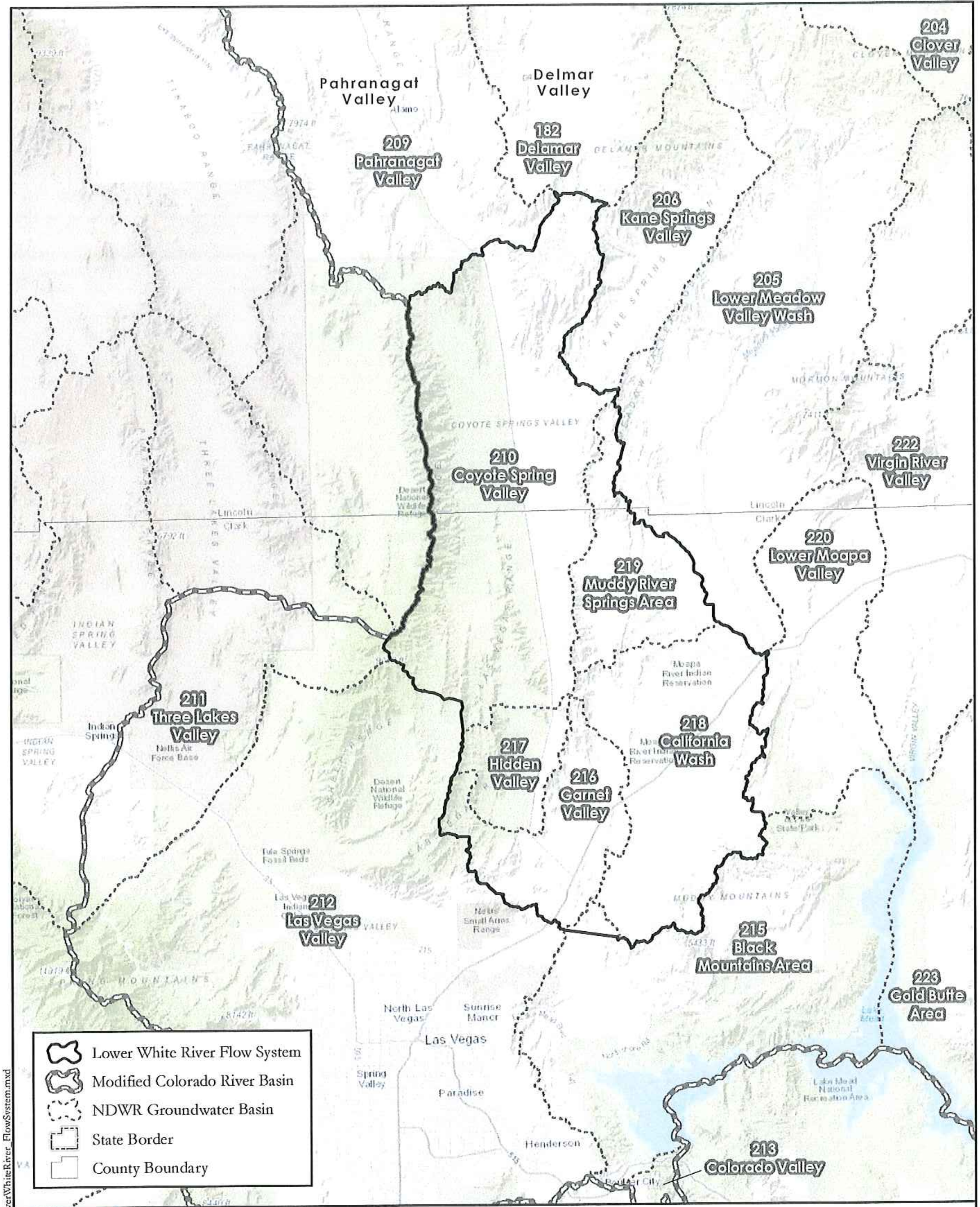
[22] See Order 1169 Aquifer Test Reports.

[23] Basins defined by structural geologic boundaries or local lithology may affect regional groundwater flow.

FIGURE 4



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MODIFIED LOWER WHITE RIVER FLOW SYSTEM

Source: Modified from Rowley, et al; 2017

N

0 6.5 13 Miles

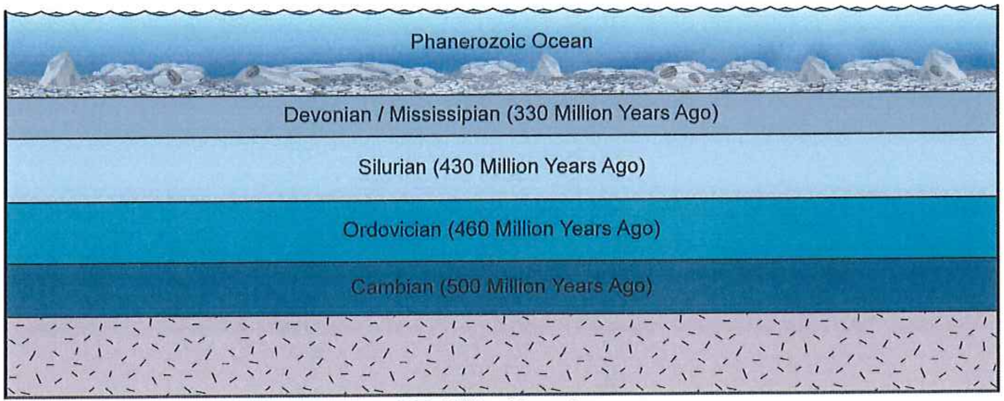
3.2 GEOLOGIC HISTORY

The geologic history of the eastern part of Nevada is characterized by rocks ranging from Precambrian sedimentary rocks to widespread Quaternary alluvial deposits (United States Geological Survey (USGS), 2007). The geologic evolution of the study area since the end of Precambrian (650 million year ago (mya)) time may be subdivided into three general phases: (1) marine sediments deposited along a passive continental margin; (2) late Devonian to Eocene compressive deformation; and (3) middle to late Cenozoic extension, faulting, volcanism, and continental sedimentation (Levy and Christie-Blick, 1989). This sequence of sedimentation, compressive deformation, and extensional faulting establish the geologic framework that controls groundwater flow throughout eastern Nevada. Thus, any water-resource assessment of the area must consider the complex geologic structure and geologic history, as well as the distribution of the diverse rock types and geologic environments.

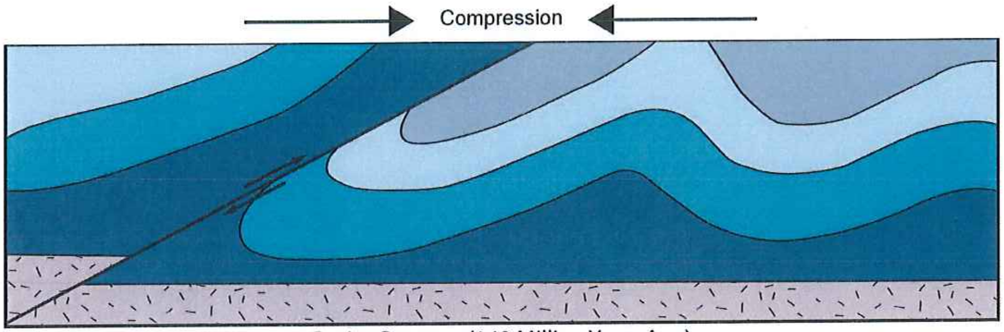
Many studies have been performed by USGS, Desert Research Institute (DRI), SNWA, and others that describe the geologic history and framework in detail. The purpose of this section is to illustrate that the historical sequence of deposition and tectonic activity shows how geologic units and structure control the occurrence and movement of groundwater. The marine sediments that were deposited between 540 mya and 250 mya generally include carbonates, shales, and quartzites that form the aquifers which are the subject of this report. The formation of these sediments represents the transgression and regression of the sea over a broad continental shelf and is depicted in the upper cross-section of Figure 5.

Beginning at the end of the Devonian period (400 mya), compressional forces associated with the Antler Orogeny began to affect the northwest portion of eastern Nevada (Rowley et al., 2017). Later, around the Jurassic to early tertiary period (200 mya – 60 mya), structural compression associated with the Sevier Orogeny resulted in north- to north-northeast striking folds and thrust faults that are evident today throughout eastern and southeastern Nevada (Rowley et al., 2017). Finally, Basin and Range extension beginning about 20 mya formed the north striking basins and mountain ranges that characterize the Basin and Range province. The cross-sections shown in Figure 5 provide a generalized depiction of deposition, compressional folding, extensional faulting, and mountain building occurring from about 500 mya to the present.

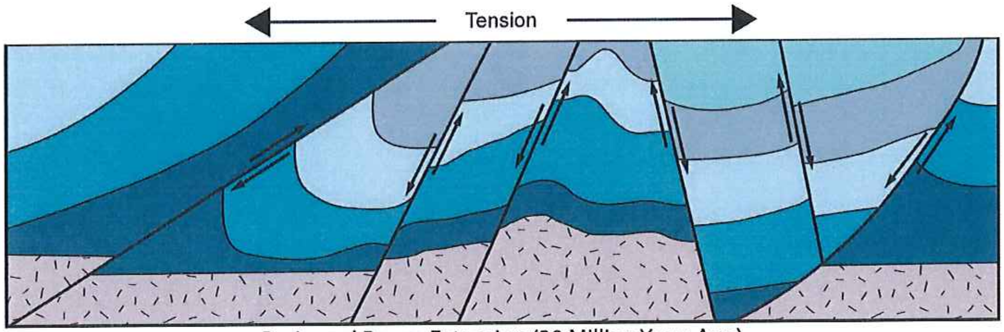
FIGURE 5



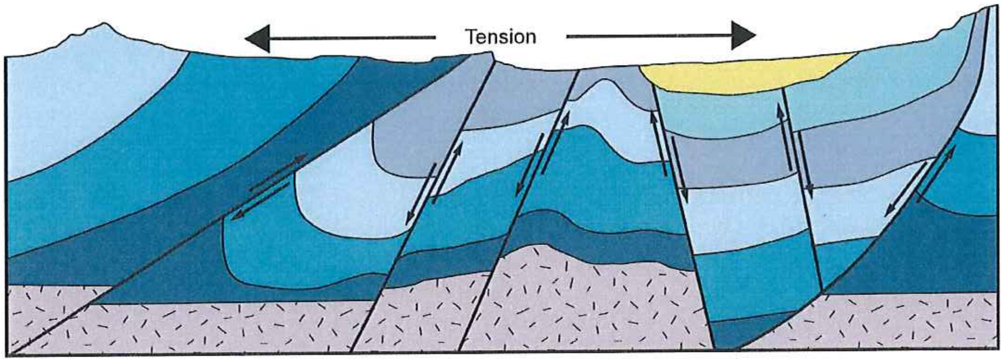
500 Million Years Ago



Sevier Orogeny (140 Million Years Ago)



Basin and Range Extension (20 Million Years Ago)



Basin and Range Extension (10 Million Years Ago)

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Conceptual Formation of Carbonate Aquifer in the Lower White River Flow System

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The Sheep Range mountains, which are composed of carbonate rocks, form the western edge of the Coyote Spring Valley. This range represents the leading edge of the Gass Peak thrust fault that was associated with the Sevier Orogeny (200 mya – 60 mya) (Rowley et al., 2017). The eastern boundary of Coyote Spring Valley is bounded by the Arrow Canyon Range to the south and the Meadow Valley Range to the north, both of which were formed due to normal faulting associated with Basin and Range extension. Additional normal faults associated with Basin and Range extension are present between the two ranges (Rowley et al., 2017). A generalized geologic depiction of Coyote Spring Valley based on Rowley et al. (2017) is shown in Figure 6. The prominent geologic features of Coyote Spring Valley include the north- to north-northeast trending faults and the thick sequence of carbonate rocks.

3.3 IMPACT OF STRUCTURAL FEATURES AND FAULTS ON GROUNDWATER FLOW

Based on the most recent study by Rowley et al., (2017), "Basin and Range extension controls groundwater flow," and groundwater flow generally occurs along rock fractures associated with normal faults (extensional), while flow across faults is retarded. Rowley et al. (2017) further explain that extensional faulting is more important to groundwater flow, since these types of faults tend to stay open compared to compressional faults (i.e. Gass Peak Thrust), which do not result in open fractures for groundwater flow. Thus, identifying the locations of normal faults is a primary target for describing groundwater flow in the carbonate rock province.

There are numerous north- to north-northeast trending extensional normal faults within Coyote Spring Valley and the entire LWRFS that act to control the occurrence and movement of groundwater. While some of these faults tend to convey groundwater parallel to the fault, they also act to impede water flow perpendicular to the strike of the fault. The impact of these faults is described in the various sections below, which detail the relative connection between pumping wells, observation wells, and springs throughout the study area.

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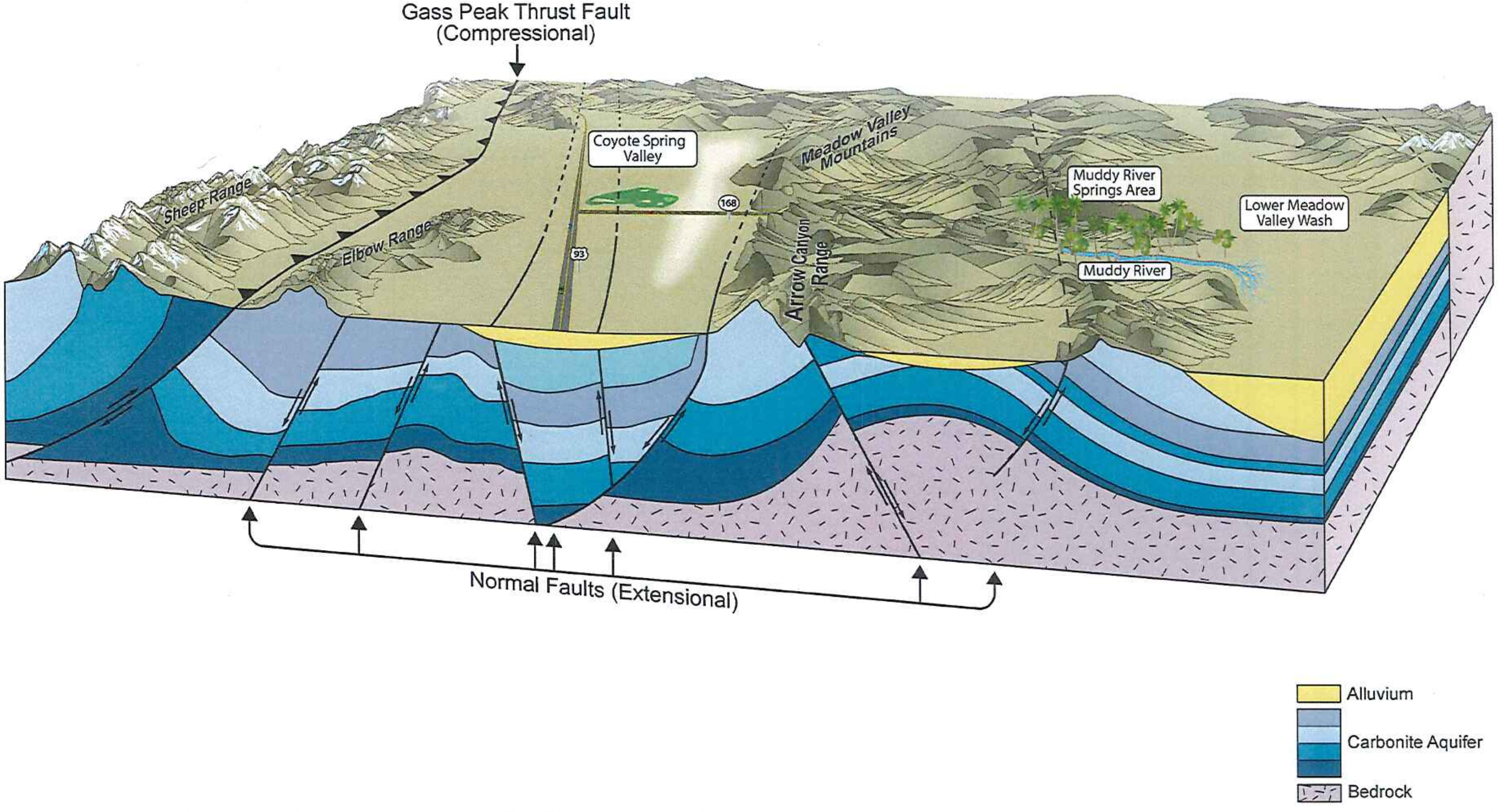
FIGURE 6



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Conceptual Geologic Cross-Section of Coyote Spring Valley and Muddy River Springs Area

3.4 MODIFIED NSE COLORADO RIVER BASIN SYSTEM

The NSE's Designated Groundwater Basins of Nevada Map (Nevada Division of Water Resources, 2017) identifies 27 basins in southeastern Nevada as the Colorado River Basin (Basins 198 to 224). Included in these 27 basins are the six basins of the proposed LWRFS, including: Coyote Spring Valley (210), Black Mountain Area (215), Garnet Valley (216), Hidden Valley (217), California Wash (218), and Muddy River Springs Area (219). However, Cave Valley, (180), Dry Lake Valley (181), and Delamar Valley (182) are not included in the NSE's designation of the Colorado River Basin, although they contribute to interbasin groundwater flow into the LWRFS and the larger Colorado River Basin. Based on deuterium and oxygen-18 data analyses, Thomas and Mihevc (2011) suggest that interbasin groundwater flow occurs from Cave Valley into southeastern White River Valley (207) and northeastern Pahroc Valley (208). Furthermore, Thomas and Mihevc (2011) also suggest that interbasin groundwater flow occurs from Dry Lake Valley into Delamar Valley, eventually discharging into Coyote Spring Valley.[24] Thus, based on this prior analysis, and for purposes of this report, the Colorado River Basin boundary referenced in this report has been modified from the NSE's boundary to include Cave Valley, Dry Lake Valley, and Delamar Valley.

3.5 REGIONAL AND LOCAL GEOLOGIC MAPS

The most recent geologic map of eastern Nevada developed by Rowley et. al (2017) is presented in Figure 7. The extent of the map reaches southern Elko, eastern Nye, White Pine, Lincoln, and Clark Counties. Generalized geologic maps of the Colorado River Basin system and the LWRFS are shown in Figure 8 and Figure 9, respectively. The drainage basins included in the modified Colorado River Basin system have been adjusted from the NSE's inventory of basins for this area to account for interbasin groundwater flow from basins outside the NSE's surface boundary delineation, as discussed in Section 3.4. Additionally, individual geologic units have been generalized into basement, carbonate, volcanic, or basin fill units in order to better depict the aquifers that are the subject of this investigation (see Appendix A).

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[24] Thomas and Mihevc (2011) indicate that a portion of the interbasin flow from Delamar may flow to Pahranagat Valley.

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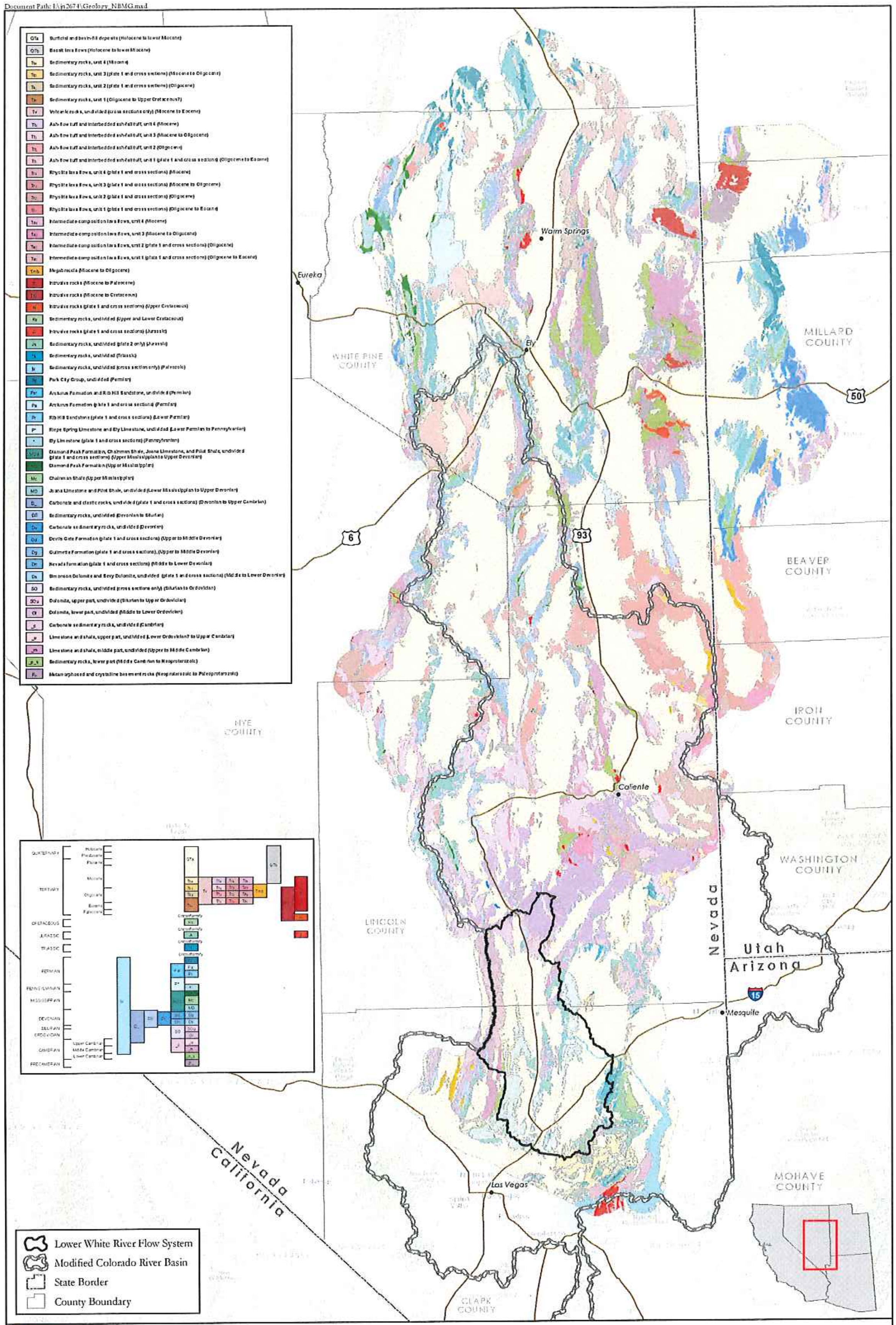

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REGIONAL GEOLOGIC MAP
COLORADO RIVER BASIN, NEVADA

Source: Modified from Rowley, et al; 2017

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Miles

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FIGURE 7

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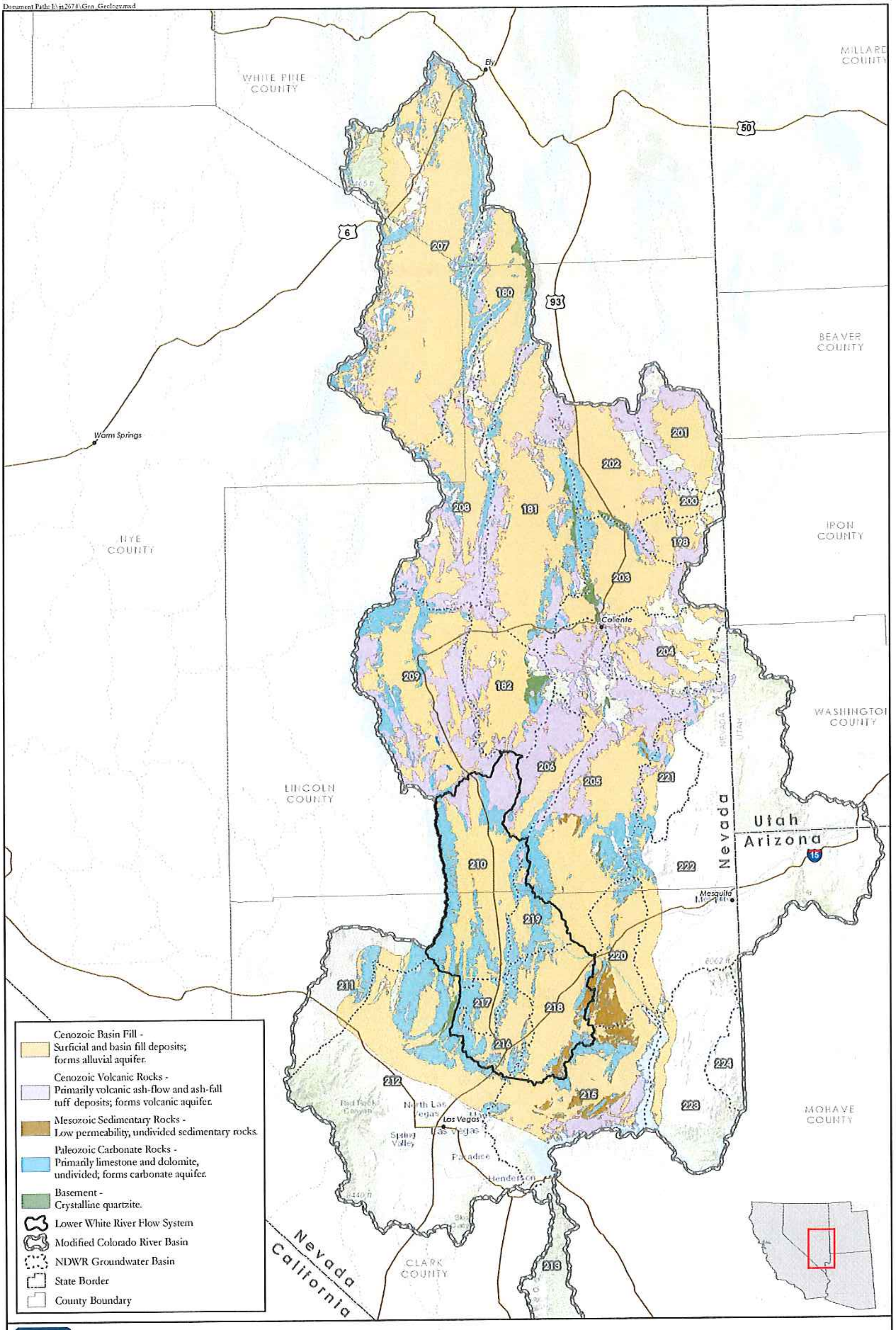

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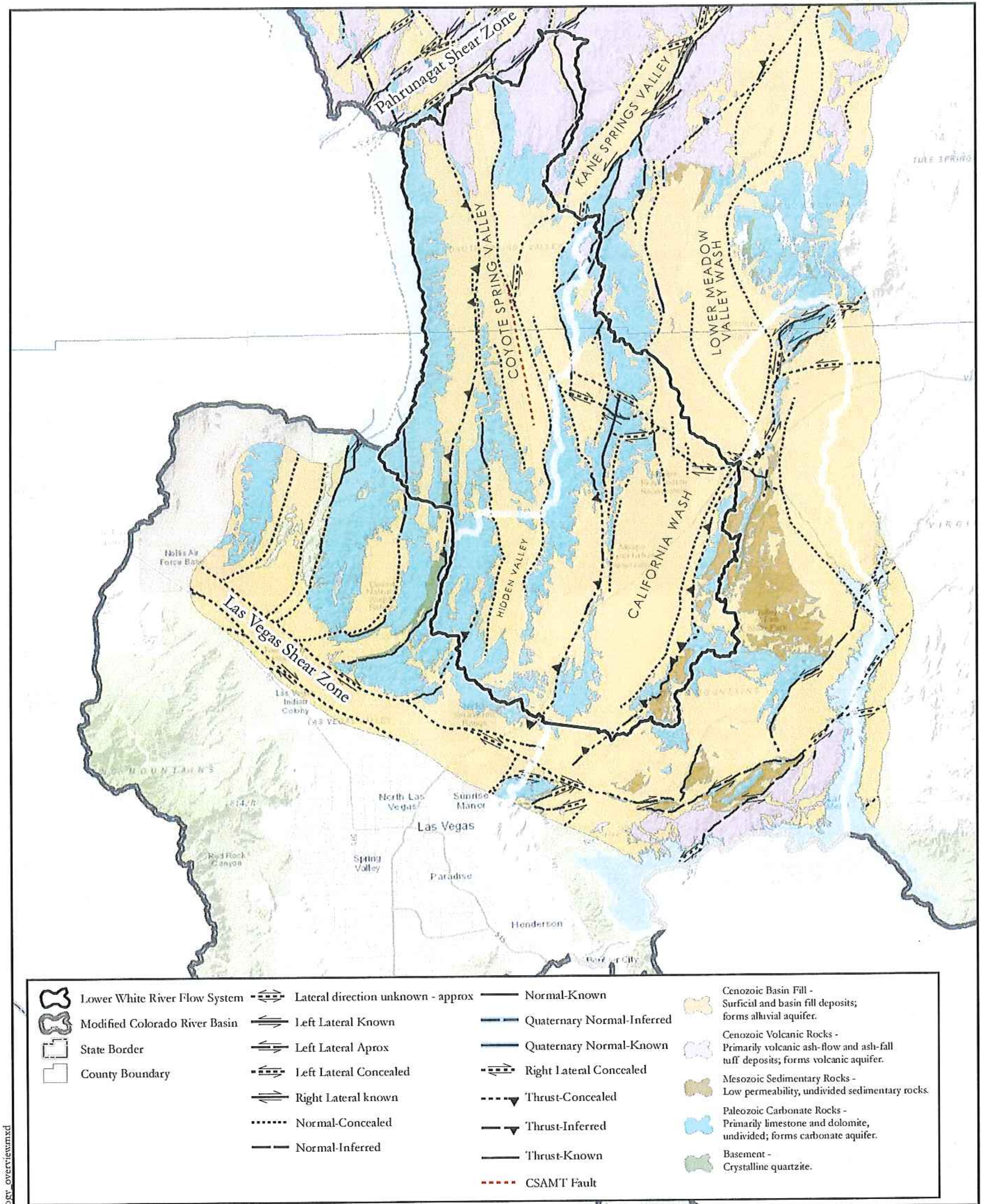
GENERALIZED REGIONAL GEOLOGIC MAP
COLORADO RIVER BASIN, NEVADA

Source: Modified from Rowley, et al; 2017

FIGURE 8



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REGIONAL GEOLOGY
COYOTE SPRING VALLEY

Source: Modified from Rowley, et al; 2017

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3.6 APRIL 2019 GEOPHYSICAL INVESTIGATION

Major faults within Coyote Spring Valley are based on Rowley et al. (2017) and a Controlled Source Audio-frequency Magnetotellurics (CSAMT) survey performed at the request of Coyote Springs Nevada, LLC (CS Nevada) during April 2019. A CSAMT survey transmits electrical signals into the ground through a 3,000- to 5,000-foot-long wire, grounded at each end to control the electrical source. Electrical responses are then gathered at a receiver site located up to six miles away from the transmitter. These signals are then processed to determine the electrical resistivity of the geologic formations below the receiver site. By making measurements at numerous receiving stations along a line, a cross section of the earth's electrical resistivity properties can be produced, providing information about subsurface faults, fractures, geologic structures, mineralization, and groundwater. CS Nevada employed the CSAMT technique to assess the locations of normal (extensional) faults and structural blocks in Coyote Spring Valley to assess the preferred paths of groundwater flow. The location of the April 2019 CSAMT cross-section survey Lines A, B, and C are shown in Figure 10.

Review of the April 2019 CSAMT cross-section Lines A and B (Figure 11 and Figure 12, respectively) shows a prominent carbonate block (blue color), bounded on either side by normal (extensional) faults. The carbonate block occurs between stations 8,900 and 11,500 on Line A, and between stations 9,000 and 12,000 on Line B. While these normal faults were mapped by Rowley et al. (2017), their location and relationship to the carbonate outcrop in Coyote Spring Valley provides evidence that there are two separate north-south flow paths. One flow path on the west side supports regional groundwater flow toward Hidden Valley, while the eastern flow path supports regional groundwater flow toward Muddy River Springs Area and California Wash.

The resistivity of unsaturated limestone to range from 50 ohm-meters (Ωm) to 10^7 Ωm and unsaturated dolomite to range from 350 Ωm to 5,000 Ωm (Telford et. al, 1976, Appendix B). Saturated limestone is reported to be 600 Ωm with 11% water content; and saturated dolomite is reported to be 530 Ωm with 2% water content[25]. Unsaturated alluvium and sands are reported to range from 10 Ωm to 800 Ωm. The green color at the surface (approximately 100 Ωm) of Lines A and B likely represents unsaturated alluvium and sands; while the deeper layers immediately below the unsaturated alluvium, shown as brown to yellow (8 Ωm to 20 Ωm), likely represent saturated alluvium. The darker red colors ranging from 1 Ωm to 5 Ωm represent saturated basin fill and carbonate rocks. The dark blue color (600 Ωm to 10,000 Ωm) in Lines A and B represent unsaturated limestone that was confirmed by surface mapping, while the lighter blues and greens within the solid blue carbonate block may likely represent areas of saturated fractured limestone within the carbonate block.

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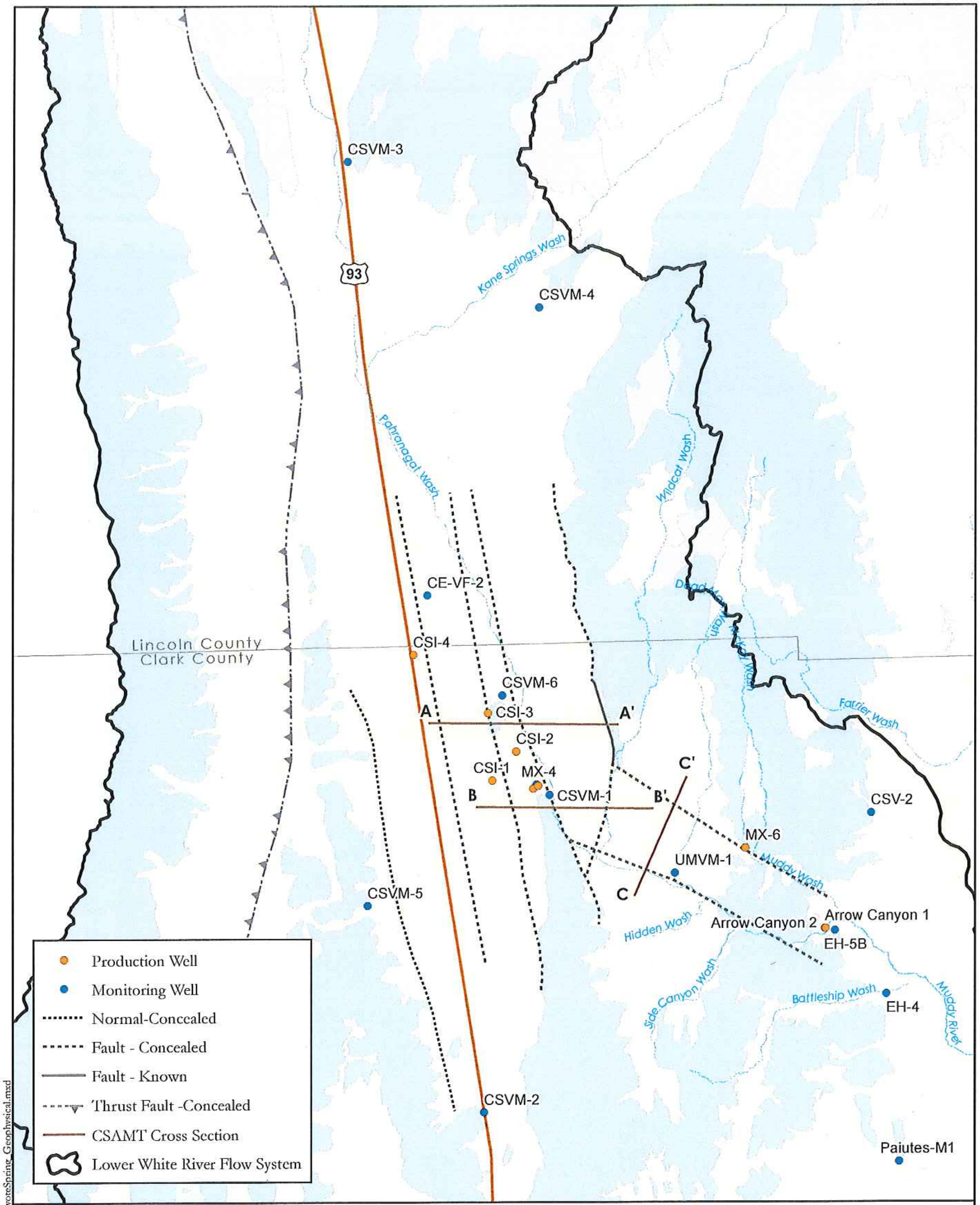
[25] The actual resistivity of these sediments in Coyote Spring Valley will vary from reported book values due to temperature and chemical composition of the water.

FIGURE 10



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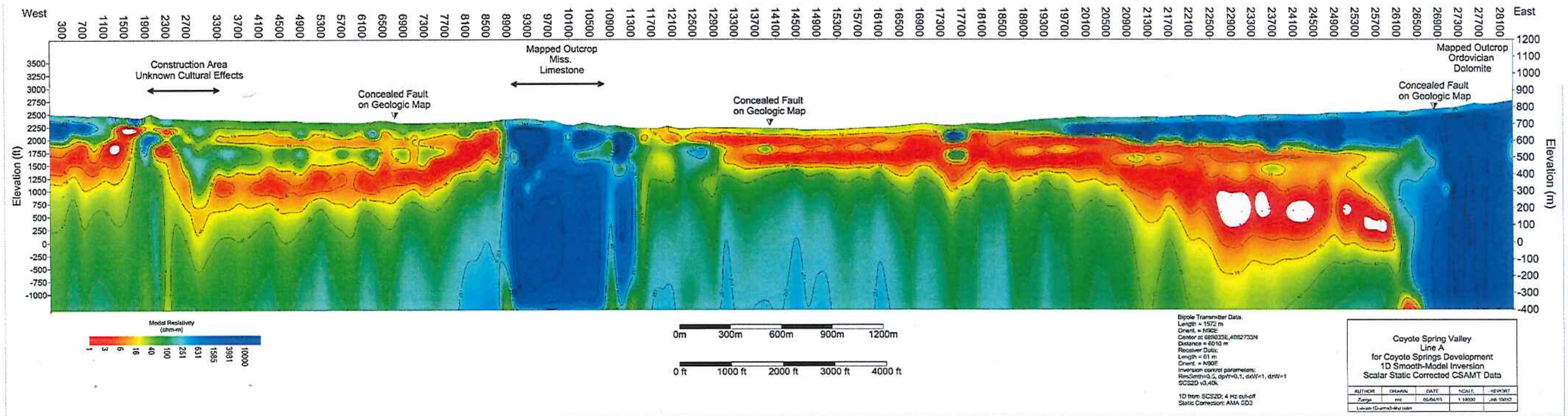
FAULTS LOCATED BY APRIL 2019 CSAMT SURVEY
COYOTE SPRING VALLEY, NEVADA

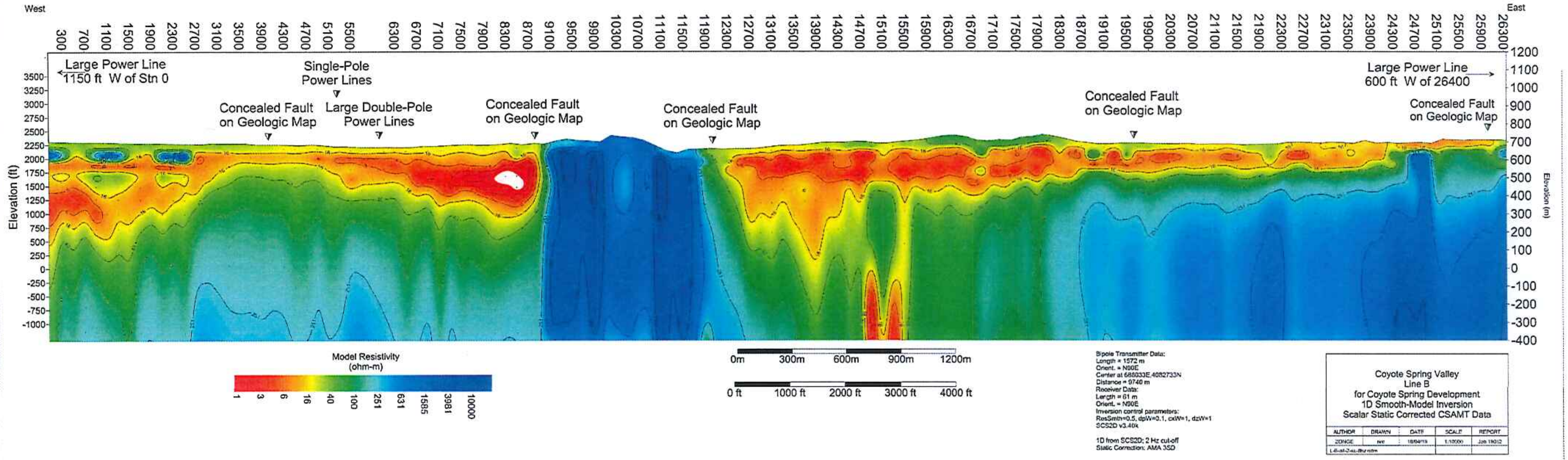
Source: Modified from Rowley, et al; 2017
(See previous figure for geology legend)

FIGURE 11



APRIL 2019 CSAMT RESULTS
RESISTIVITY CROSS-SECTION LINE A

FIGURE 12



APRIL 2019 CSAMT RESULTS
RESISTIVITY CROSS-SECTION LINE B

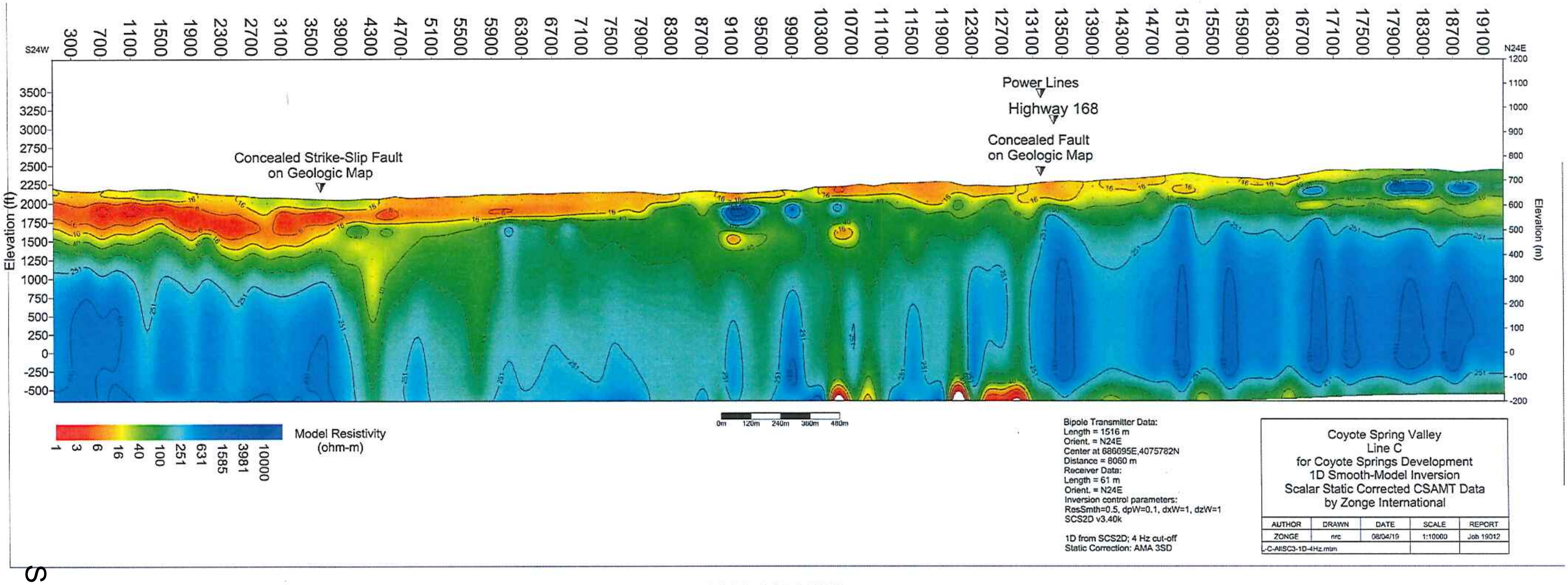
Production wells MX-5 and CSI-2 are located on the eastern side of the carbonate block, while production wells CSI-1, -3, and -4 are located on the western side of the block. The carbonate block effectively isolates the groundwater production wells on the east side of the carbonate block from those on the west side of the carbonate block. The carbonate block also results in a division of groundwater inflow to Coyote Spring Valley from Pahranagat, Delamar, and Kane Springs Valley. Interbasin groundwater outflow from Coyote Spring Valley is to both the Muddy River Springs Area and Hidden and Garnet Valleys. Furthermore, the carbonate block and normal faults isolate local recharge from the Sheep Range to the zone west of the carbonate block, such that it eliminates or limits contributions of local recharge to interbasin groundwater flow to the Muddy River Springs Area.

A previously unmapped fault (shown in red in Figure 9), located at station 1900, is evident at the western end of Line A by the offset in low resistivity (red color) values. The presence of this fault is further supported by the transmissivity values measured at CSI-4 to be 130,000 ft^2/day in a well that penetrated 670 feet of carbonate aquifer (Johnson, 2006). The transmissivity at this well was an order of magnitude higher than values measured in CSI-1, -2, and -3, indicating that CSI-4 was likely located in or near highly fractured carbonate associated with extensional faulting.

Results from Line C (Figure 13), located immediately southeast of CSVM-1, identify the previously mapped sub-parallel faults between Coyote Spring Valley and the Muddy River Springs Area. The geophysical data suggest that the area between the faults is highly fractured, supporting the previous interpretation of an area of high transmissivity.

The preliminary results of combining the generalized geologic map, known faults, and faults identified through the April 2019 CSAMT survey are shown in Figure 9. While the locations of faults mapped by Rowley et al. (2017) have not been adjusted based on the April 2019 CSAMT survey, the new fault mapped at the west end of Line A has been added. As previously discussed, groundwater generally moves parallel to normal (extensional) faults in the north-to-south direction. Groundwater flow in the west-to-east direction is impeded by the normal faults, except in areas where cross faults create a preferred pathway for groundwater flow. The Pahranagat Wash from Coyote Spring Valley to Muddy River Springs Area represents one of these areas where faulting between the two basins has resulted an area of high transmissivity for groundwater flow, thus creating a preferred flow path from the east side of Coyote Spring Valley to the Muddy River Springs Area.

FIGURE 13



Bipole Transmitter Data:
Length = 1516 m
Orient. = N24E
Center at 686695E,4075782N
Distance = 8060 m
Receiver Data:
Length = 61 m
Orient. = N24E
Inversion control parameters:
ResSmth=0.5, dpW=0.1, dxW=1, dzW=1
SCS2D v3.40k

1D from SCS2D; 4 Hz cut-off
Static Correction: AMA 3SD

Coyote Spring Valley
Line C
for Coyote Springs Development
1D Smooth-Model Inversion
Scalar Static Corrected CSAMT Data
by Zonge International

AUTHOR	DRAWN	DATE	SCALE	REPORT
ZONGE	nrc	08/04/19	1:10000	Job 19012
L-C-AllSC3-1D-4Hz.mtm				

APRIL 2019 CSAMT RESULTS
RESISTIVITY CROSS-SECTION LINE C

4.0 LWRFS AND COYOTE SPRING VALLEY WATER BUDGETS

Groundwater flow through the carbonate aquifer in the LWRFS originates from both regional and local recharge sources. The regional source of groundwater flow is interbasin flow that originates approximately 200 miles to the north, at the head of the White River Flow System (Eakin, 1966). Additional precipitation and recharge falling in Nevada's central eastern mountains recharges the regional carbonate aquifer that flows north-to-south, towards Las Vegas and Lake Mead. Local recharge occurs within many of the individual basins, along the bounding mountain ranges that define each basin's geographic boundary. Local recharge contributes to and supports groundwater production and evapotranspiration within a basin, as well as regional interbasin groundwater flow between adjacent basins.

4.1 LOCAL RECHARGE FROM THE SHEEP RANGE

Local recharge to Coyote Spring Valley from the Sheep Range, which has been estimated in literature to range from 1,900 AFY to 14,000 AFY[26], may be considered the perennial yield of Coyote Spring Valley. Eakin (1964) estimated recharge in Coyote Spring and Kane Springs Valleys to be a combined 2,600 AFY. An isotopic study by the USGS (Thomas et al., 1996) estimated the Sheep Range's contribution to local recharge of 14,000 AFY. Thomas et al. (2001) assessed local and regional flow in southeastern Nevada using a deuterium mass-balanced model and estimated local recharge in Coyote Spring Valley to be 4,000 AFY. Lopes and Evetts (2004) reported 2,100 AFY of natural recharge in Coyote Spring Valley. The reported values demonstrate that there is some uncertainty in the volume of recharge to Coyote Spring Valley. Published estimates of local recharge from the Arrow Canyon Range and Meadow Valley Mountains on the eastern side of Coyote Spring Valley are not available.

Several recharge models may be used to estimate recharge in Nevada groundwater basins. The recharge models are described below, and were applied to recharge zones in the Sheep Range using geographic information system (GIS) techniques and several data sources.

4.1.1 Description of Recharge Models in Nevada

Recharge to groundwater basins in Nevada is often estimated using a recharge model developed by Maxey and Eakin (1949). The method applies a series of recharge coefficients to corresponding precipitation zones. Each defined precipitation zone, with a particular range of average annual precipitation, is assumed to yield the percentage of that precipitation which reaches

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[26] Studies estimating recharge to Coyote Spring Valley include: 1,900 AFY by Nevada Division of Water Resources (1971); 5,000 to 6,000 AFY by Kirk and Campana (1990); 4,000 AFY by Thomas et al. (2001); and 14,000 AFY by Thomas et al. (1996).

the groundwater aquifer. Table 2 gives the precipitation bands and coefficients for the Maxey-Eakin method.

TABLE 2. PRECIPITATION ZONES AND RECHARGE COEFFICIENTS FROM MAXEY AND EAKIN (1949)

Precipitation Zone (in/year)	Recharge Coefficient
< 8	0.00
8-12	0.03
12-15	0.07
15-20	0.15
> 20	0.25

The Maxey-Eakin method was originally applied using a precipitation map of Nevada prepared by Hardman (1936). The exact methods used to prepare the Hardman precipitation map are not known, but the delineation of precipitation zones likely relied upon altitude data and precipitation measurements collected at weather stations in Nevada. Precipitation is highly dependent upon altitude.

Eakin (1964, 1966) later studied the White River Area, including Coyote Spring Valley, using these methods. As described in these studies, altitude-precipitation relationships were defined, wherein particular altitudes were associated with a range of precipitation values. Table 3 gives the altitude zones and corresponding precipitation and recharge coefficients.

TABLE 3. PRECIPITATION ZONES, ALTITUDE ZONES, AND RECHARGE COEFFICIENTS FROM EAKIN (1966)

Precipitation Zone (in/year)	Altitude Zone (ft)	Assumed Average Annual Precipitation (in)	Recharge Coefficient
< 8	below 6,000	variable	0.00
8-12	6,000 to 7,000	10	0.03
12-15	7,000 to 8,000	13.5	0.07
15-20	8,000 to 9,000	17.5	0.15
> 20	more than 9,000	25	0.25

The Maxey-Eakin method has been evaluated in several studies (Watson et al. 1976; Dettinger, 1989; Avon and Durbin, 1994; and others). Similar models have been proposed in recent years: Nichols (2000) developed a set of recharge coefficients based on estimates of groundwater evapotranspiration in 15 valleys in eastern Nevada. Similar to the Maxey-Eakin method, the Nichols recharge coefficients were developed for several precipitation zones. Epstein (2004) evaluated both the Maxey-Eakin method and Nichols method and developed a new model using algorithmic optimization (Epstein, 2004; Epstein et al. 2010). The precipitation zones and coefficients developed by Nichols (2000) and Epstein (2004) are given in Table 4 and Table 5, respectively.

TABLE 4. PRECIPITATION ZONES AND RECHARGE COEFFICIENTS FROM NICHOLS (2000)

Precipitation Zone (in/year)	Recharge Coefficient
less than 8	0.000
8 to less than 12	0.008
12 to less than 16	0.130
16 to less than 20	0.144
20 to less than 34	0.158
equal or greater than 34	0.626

TABLE 5. PRECIPITATION ZONES AND RECHARGE COEFFICIENTS FROM EPSTEIN (2004)

Precipitation Zone (in)	Recharge Coefficient
0 to less than 10	0.019
10 to less than 20	0.049
20 to less than 30	0.195
greater than 30	0.629

The Nichols method uses similar precipitation bands to the Maxey-Eakin method, with the exception that a division is defined at 16 inches per year rather than 15 inches per year. Nichols also added a precipitation zone for annual precipitation greater than 20 inches per year. The Epstein method uses only four precipitation zones, with divisions at 10, 20, and 30 inches per year. The lower bound for occurrence of recharge is 0 inches per year, in contrast to 8 inches per year in the Maxey-Eakin and Nichols methods.

All of the recharge models described above are dependent upon the spatial distribution of precipitation. Until the 1990s, the only statewide precipitation map of Nevada was the Hardman map, a hand-drawn map originally prepared in 1936 and updated through the 1960s (e.g. Hardman, 1962 as cited in Lamke and Moore, 1965). In the 1990s, a research group at Oregon State University began producing computer-generated maps of average annual precipitation for the United States (Daly et al., 1994; Daly et al., 1997, Daly et al., 2001). These maps use a method called Parameter-elevation Regressions on Independent Slopes Model (PRISM) to estimate average annual precipitation on a spatial grid. The first two PRISM data sets were produced based on climate normals for 1961-1990 and 1971-2000 with a resolution of 4 kilometers. The third and most recent PRISM data set (PRISM Climate Group, 2015) is based on climate normals for 1981-2010 and has 800-meter resolution. The 30-year climate normal period from 1981-2010 has similar average annual precipitation to the long-term record in southern Nevada,[27] indicating that the recent PRISM data set is representative of long-term averages in this region.

4.1.2. Application of Recharge Models to Coyote Spring Valley

The recharge models described above were applied to the Sheep Range along the west side of Coyote Spring Valley. The contiguous area that drains to Hidden Valley to the south of Coyote Spring Valley was also included for completeness. Recharge zones for Kane Springs Valley, the Arrow Canyon Range and Meadow Valley were not included in this study. Historical estimates of recharge are not available for the Arrow Canyon Range and Meadow Valley, and it is not known whether they contribute significant recharge.

Fifteen general recharge zones were delineated (Figure 14); zones 1 through 12 are part of Coyote Spring Valley (Nevada hydrographic area No. 210) and Zones 13 through 15 are part of Hidden Valley (Nevada hydrographic area No. 217). GIS tools were used to delineate the recharge zones based on hydrography and elevation. The recharge zones were delineated from the ridge of the Sheep Range, which has elevations as high as 9,653 ft amsl, east toward the toe of the mountain slopes, at approximately 2,700 feet amsl. The recharge zones were based upon the sub-basin delineations that are part of the National Hydrography Dataset (NHD) (USGS, 2016). The total area delineated in Figure 14 is 409 square miles. The area and range of elevations within each recharge zone is given in Table 6.

Several recharge models were applied to the recharge zones shown in Figure 14 to understand the range of values for recharge in Coyote Spring Valley and Hidden Valley. All of the recharge models used here are dependent upon the spatial distribution of precipitation. The spatial distribution of precipitation rates may be defined based on altitude (e.g. Eakin, 1964; Eakin, 1966; SNWA, 2006), or the spatial distribution may be taken directly from a precipitation map. Both of these approaches are used here and compared.

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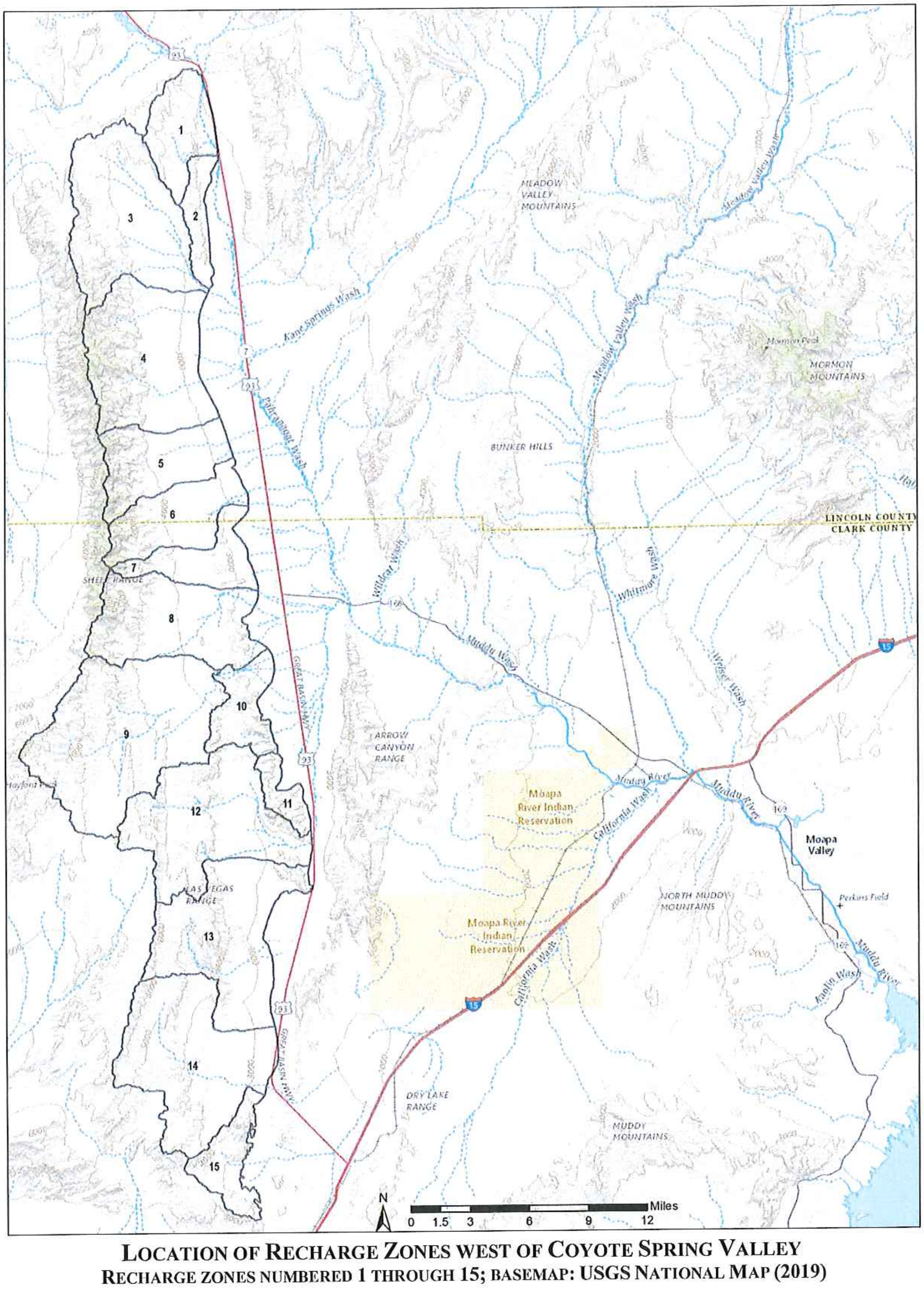
[27] Long-term average annual precipitation for Nevada Extreme Southern Division 04 is 6.9 inches per year for 1895-2018 and 6.9 inches per year for 1981-2010. Data from: https://www.esrl.noaa.gov/psd/data/timeseries/

FIGURE 14



LOCATION OF RECHARGE ZONES WEST OF COYOTE SPRING VALLEY
RECHARGE ZONES NUMBERED 1 THROUGH 15; BASEMAP: USGS NATIONAL MAP (2019)

TABLE 6. AREA AND ELEVATION FOR RECHARGE ZONES

Hydrographic Area	Recharge Zone & Name		Area		Elevation[a] (ft)		
			(sq mi)	(acres)	Min	Avg	Max
COYOTE SPRING VALLEY (210)	1	Evergreen Flat	15.4	9,841	2,802	3,568	5,093
	2	Pahranagat Wash A	7.1	4,575	2,752	3,070	3,981
	3	Coyote Spring Valley A	42.0	26,901	2,793	4,178	7,487
	4	Coyote Spring Valley B	41.3	26,416	2,762	4,156	7,663
	5	Cherry Spring	20.5	13,137	2,761	4,287	7,728
	6	Grapevine Spring	19.5	12,500	2,760	4,121	8,293
	7	Pahranagat Wash B	13.4	8,565	2,761	3,630	8,127
	8	Perkins Spring	32.6	20,840	2,735	4,496	8,337
	9	Sawmill Wash	59.0	37,770	3,509	5,904	9,653
	10	Las Vegas Range A	11.7	7,504	2,711	3,367	4,609
	11	Las Vegas Range B	5.5	3,530	2,681	3,229	4,653
	12	Wamp Spring	42.8	27,385	2,782	4,242	7,298
HIDDEN VALLEY (217)	13	Hidden Valley A	40.7	26,030	2,763	3,944	7,081
	14	Hidden Valley B	45.9	29,389	2,778	4,248	7,127
	15	Dry Lake	11.3	7,219	2,725	3,280	4,696
		Total	408.8	261,601			

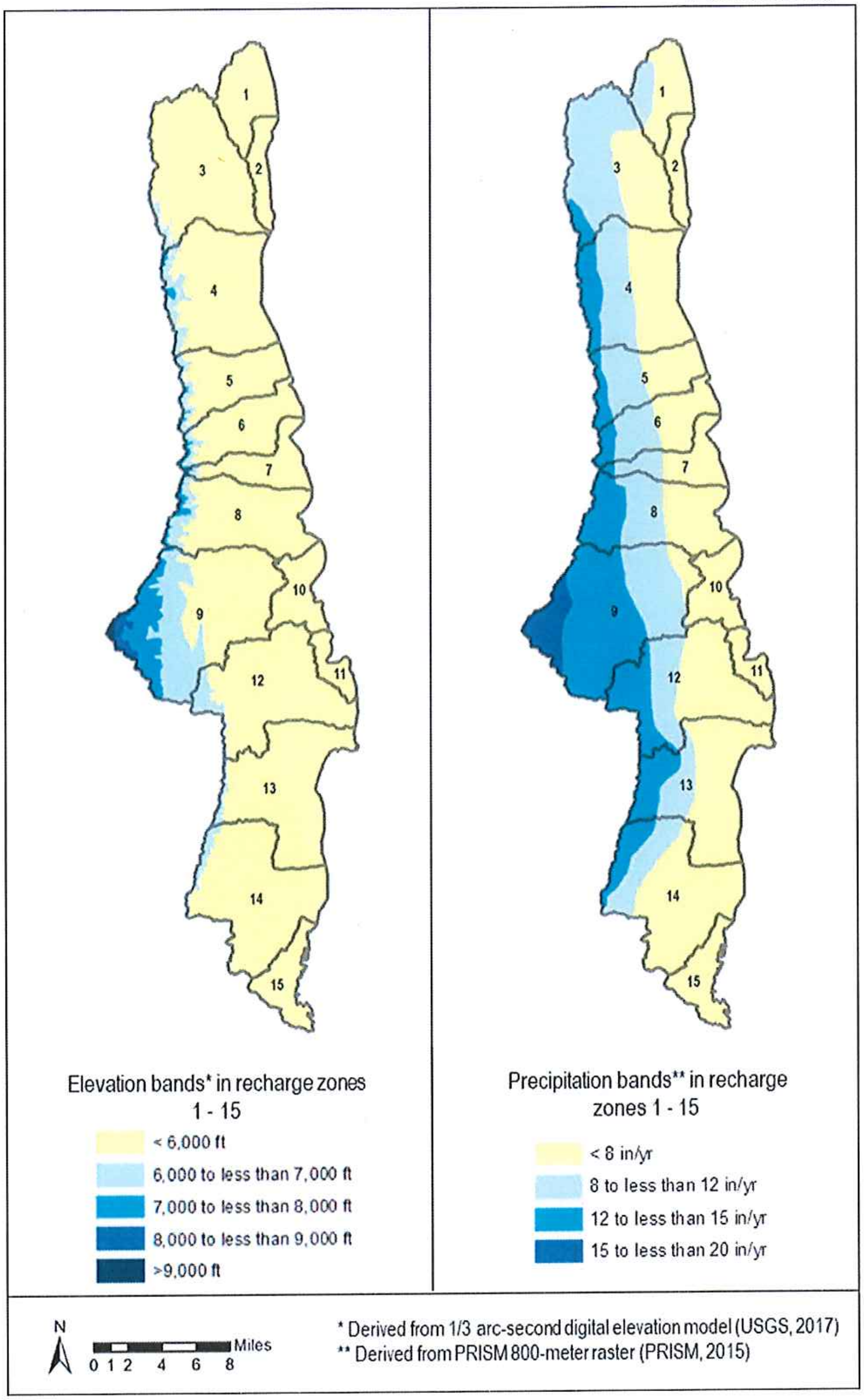
Notes.

a. Elevation estimated from one-third arc-second digital elevation model (USGS, 2017)

The recharge areas were first divided into elevation bands using the altitude divisions defined by Eakin (1966) and given in Table 3. A digital elevation model from the USGS (2017) was used to delineate each elevation band. The delineated elevation bands are shown in the left panel of Figure 15. In this recharge model, only areas at greater than 6,000 ft amsl contribute to recharge. The blue bands in each panel represent areas of recharge, whereas the yellow bands represent areas of no recharge.

The recharge areas were also divided into precipitation bands using the 800-meter-resolution raster of average annual precipitation from PRISM (2015). As shown on the right panel of Figure 15, the PRISM raster shows that the Sheep Range has many areas where the elevation is less than 6,000 ft amsl but precipitation averages more than 8 inches per year. The two panels in Figure 15 show the importance of accurately understanding the spatial distribution of precipitation: the model assumptions on the right panel (precipitation-based bands) include a larger contributing area for recharge compared to the model assumptions on the left (elevation bands).

FIGURE 15



* Derived from 1/3 arc-second digital elevation model (USGS, 2017)

** Derived from PRISM 800-meter raster (PRISM, 2015)

ELEVATION AND PRECIPITATION BANDS USED TO ESTIMATE RECHARGE

Recharge was estimated using the elevation-based and precipitation-based bands. The elevation-based bands in the left panel of Figure 15 were used with the altitude relationships and Maxey-Eakin coefficients given in Table 3. For this calculation, the average annual precipitation was taken from the assumed value presented by Eakin (1966), rather than from a precipitation map. The total recharge for zones 1 through 15 estimated using this method is 1,600 AFY. Appendix Table D-1 gives detailed calculations for this method. The value of 1,600 AFY computed here is less than the value of 2,600 AFY previously computed by Eakin (1964). This is expected since Eakin included Kane Springs Valley and this analysis excludes it. Moreover, because Eakin and this analysis use different sources for elevation, there are also differences in the area for each elevation band.[28]

Precipitation bands were delineated using the PRISM raster and the appropriate precipitation divisions for the Maxey-Eakin, Nichols, or Epstein methods. In all of these methods, the average annual precipitation was computed for each recharge zone and each precipitation band using the PRISM raster data in GIS software. The annual recharge volumes using each of those methods are 6,700 AFY, 8,600 AFY, and 6,400 AFY, respectively. A summary of the recharge calculations is shown in Table 7; Appendix Tables D-2 through D-4 contain detailed calculations. Recharge estimates that rely upon the PRISM precipitation data are higher than those computed with elevation. The PRISM data set used here is the third version and has been refined and become more scientifically sophisticated over time. The PRISM model accounts for different facets of topography, not just elevation, and can therefore provide precipitation estimates for the windward and leeward slopes of a range. In this way, using the PRISM data set offers a potentially improved way to estimate recharge contributions. However, the PRISM data set has not been specifically evaluated for accuracy within the Sheep Range.

Precipitation data in the Sheep Range, especially above 6,000 ft amsl, are limited. Stetson reviewed precipitation data from the National Weather Service Cooperative (COOP), Remote Automated Weather Station (RAWS), Snow Telemetry (SNOTEL), Natural Resources Conservation Service (NRCS), and Clark County Regional Flood Control District (CCRFCD) weather networks. Only two stations, the Wamp Springs RAWS station (6,027 ft amsl) and Hayford Peak NRCS station (9,870 ft amsl), are in or near the Sheep Range at an elevation above 6,000 ft. However, both of these stations are located to the west of the Sheep Range ridge, west of the recharge areas in Figure 14. Data at these stations may not be directly representative of precipitation in areas east of the ridge which contribute recharge to Coyote Spring Valley. Other stations, such as the Elbow Canyon

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[28] The "Area by Elevation Band" values computed in Table D-1 are less than the zone areas reported in Table 5 of Eakin (1964); some of this difference is certainly due to the inclusion of Kane Springs Valley in Eakin's analysis, and some of the difference appears to be due to differences in source topography.

CCRFCD station, and the Pahranagat and Desert Wildlife Refuge COOP stations, are at elevations less than 4,000 ft amsl and are not in close proximity to the mountain recharge areas.

TABLE 7. SUMMARY OF RECHARGE CALCULATIONS FOR THE SHEEP RANGE

	Delineation of bands from:	**Elevation (USGS, 2017)**	**Precipitation Raster (PRISM, 2015)**		
	Precipitation rate/volume from:	**Eakin (1966)**	**Precipitation Raster (PRISM, 2015)**		
	Source of Runoff Coefficients:	**Maxey & Eakin (1949)**[/a]	**Maxey & Eakin (1949)**[/b]	**Nichols (2001)**[/c]	**Epstein (2004)**[/d]
Hydro-graphic Area	**Recharge Zone and Name**	**Estimated Recharge (AFY)**			
COYOTE SPRING VALLEY (210)	1 Evergreen Flat	0	60	10	110
	2 Pahranagat Wash A	0	0	0	40
	3 Coyote Spring Valley A	30	480	300	590
	4 Coyote Spring Valley B	100	550	650	630
	5 Cherry Spring	60	280	310	340
	6 Grapevine Spring	50	230	250	290
	7 Pahranagat Wash B	10	80	60	140
	8 Perkins Spring	120	610	880	600
	9 Sawmill Wash	1,170	2,830	3,920	1,760
	10 Las Vegas Range A	0	0	0	80
	11 Las Vegas Range B	0	0	0	30
	12 Wamp Spring	50	660	980	680
HIDDEN VALLEY (217)	13 Hidden Valley A	20	470	690	520
	14 Hidden Valley B	30	400	530	540
	15 Dry Lake	0	0	0	60
	Total	1,640	6,700	8,600	6,400
	Range of Estimates:	1,600 AFY to 8,600 AFY			

Notes.
a. See supporting calculations in Appendix Table F-1
b. See supporting calculations in Appendix Table F-2
c. See supporting calculations in Appendix Table F-3
d. See supporting calculations in Appendix Table F-4

The range of annual recharge to Coyote Spring and Hidden Valleys computed in this analysis is 1,640 AFY to 8,600 AFY. This falls within the range of values reported in literature (see Appendix C values for Coyote Spring Valley and Hidden Valley). While previous testimony[29] in front of the NSE has identified that the "Maxey-Eakin recharge coefficients are married to the Hardman map and cannot be used otherwise," they have been included in our analysis to show the

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[29] Ruling 5712, page 11.

difference in recharge estimates due to the application of 1962 rainfall rates used in the Hardman map (1,640 AFY) and the raster precipitation data (PRISIM, 2015) (6,400 to 8,600 AFY).

The results of our analysis indicate that recharge to Coyote Spring Valley ranged from 1,590 AFY to 7,380 AFY when contributions to Hidden Valley were excluded. If the Maxey-Eakin related methods investigated in our analysis are ignored since they rely on older precipitation maps and use runoff coefficients that should not be applied to newer rainfall maps, then the range of recharge to Coyote Spring Valley is between 5,280 AFY and 7,380 AFY. We suggest that the lower value of 5,280 AFY should be used for sustainability planning until additional rainfall data is collected to support a higher value.

The range of values presented here highlights the need for direct precipitation measurements within the Sheep Range recharge areas. High-altitude stations would help to better understand the spatial patterns of precipitation and the applicability of the recharge models and methods described here. However, in lieu of better local precipitation data, which may take many years to collect, the recharge calculations here demonstrate that a value of 5,280 AFY, as used in the groundwater budget in Section 4.3, is an appropriate estimate for recharge to Coyote Spring Valley from the Sheep Range.

4.2 LWRFS BOUNDARY WATER BUDGET

Numerous studies have been performed to assess the quantity of local and regional groundwater flow in each of Nevada's basins. SNWA (2007) assessed local and regional flow in southeastern Nevada and found regional inflow to Coyote Spring Valley was 50,700 AFY, of which Pahranagat Valley contributes 22,440 AFY, Delamar Valley contributes 24,070 AFY,[30] and Kane Springs Valley contributes 4,190 AFY. Interbasin groundwater recharge from Lower Meadow Valley Wash into the LWRFS was estimated by SNWA (2007) to be 9,200 AFY. Local recharge into the LWRFS was estimated to be 2,310 AFY, with 2,130 AFY from the Sheep Range into Coyote Spring Valley, 40 AFY into Muddy River Springs Area, 40 AFY into Hidden Valley, 100 AFY into Garnet Valley, and 0 AFY into both California Wash and Black Mountains Area. These local recharge estimates are low in comparison to other estimates for the area.[31] Total recharge to the LWRFS boundary based on SNWA (2007) is estimated to be 62,210 AFY (Table 8).

Pre-development outflow from the LWRFS was estimated based on reported values by SNWA (2007). Groundwater flow out of California Wash to Lower Moapa Valley and Black

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[30] Thomas and Mihevc (2011), estimated outflow from Delamar Valley to be 24,900 AFY.

[31] Thomas et al. (2001) estimated total local recharge in the LWRFS to be 6,800 AFY based on a deuterium mass-balance model. See Appendix C for range of estimates from literature review. Local Recharge from Coyote Spring Valley was estimated in Section 4.1 to be 5,280 AFY.

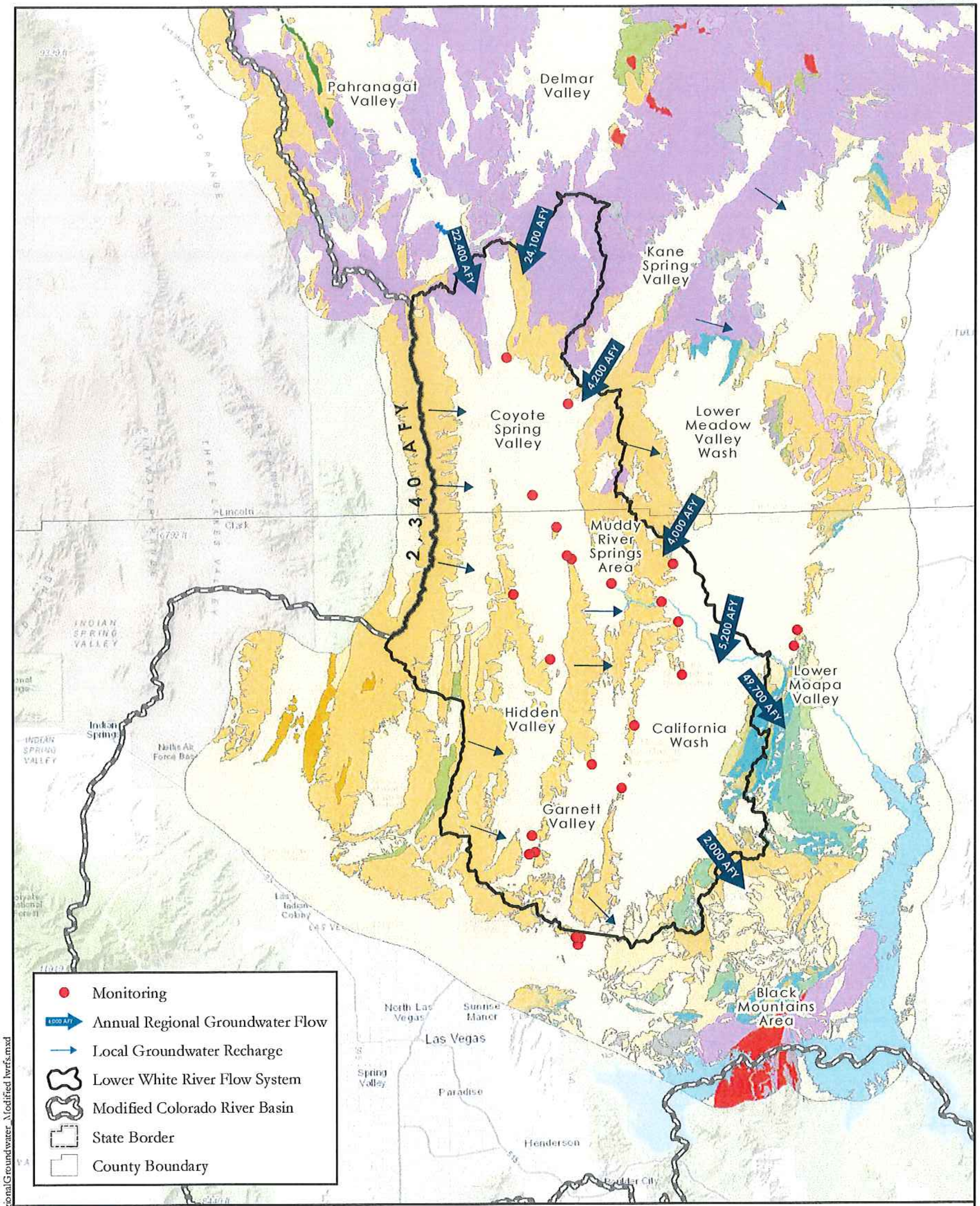
Mountains Area was estimated to be 51,700 AFY, of which 2,000 AF flows toward the Black Mountains Area. Evapotranspiration from California Wash, Black Mountains Area, Muddy River Springs Area, and Coyote Spring Valley was estimated to be 11,930 AFY. Surface flow from spring discharge to the Muddy River and other springs in the LWRFS is included in the groundwater outflow estimates. Based on groundwater outflow, evapotranspiration, and surface flow, the discharge from the LWRFS is estimated to be 63,630 AFY. The water budget for the LWRFS based on SNWA (2007) is shown graphically in Figure 16.

TABLE 8. PRE-DEVELOPMENT WATER BUDGET FOR THE LWRFS BASED ON SNWA (2007) CAVE, DRY LAKE, AND DELAMAR HYDROGEOLOGIC REPORT

Flux Term	Annual Flux (AFY)
Inflow	
Groundwater	
Pahranagat Valley	22,400
Delamar Valley	24,100
Kane Springs Valley	4,200
L. Meadow Valley Wash to MRSA	4,000
L. Meadow Valley Wash to Cal. Wash	5,200
Local Recharge[(a)]	2,310
Total Inflow	62,210
Outflow	
Groundwater	
Cal Wash to Lower Moapa Valley[(b)]	49,700
Black Mountain Area toward Lake Mead	2,000
Evapotranspiration	
California Wash	4,510
Muddy River Springs Area	5,990
Black Mountains Area	1,430
Surface Water[(b)]	Incl.
Total Outflow	63,630

Notes: (a) 2,130 AFY (CSV) + 40 AFY (MRSA) + 40 AF (Hidden) + 100 AFY (Garnet) + 30 AFY (Lower Moapa)

(b) California Wash to Lower Moapa Valley occurs as spring discharge from MRSA springs and subsurface outflow.



Document Path: I:\jn2674\RegionalGroundwater_Modified lwrfs.mxd

STETSON ENGINEERS INC.

REGIONAL GROUNDWATER FLOW AND LOCAL RECHARGE IN THE LWRFS

Source: SNWA, 2007

N

0 6.5 13 Miles

The term "Pre-Development" has been used in this report to establish a water budget that does not account for existing alluvial and carbonate groundwater pumping or surface diversions. Thomas et al. (2001, 2011) based the deuterium mixing model on "pre-development" ET rates and relied on water samples collected over many decades in eastern Nevada. While samples may be impacted by pumping, the intent of the water budget analysis is to show recharge and discharge estimates based on the best available data. It is acknowledged that pumping and water development in eastern Nevada prior to the collection of water samples may influence the water budget.

The flux values developed by SNWA (2007) produce a non-unique solution, since a "proportionate decrease or increase in both recharge and ET rates, or a different combination of groundwater sources and mixing, can produce the same results" (Thomas et al., 2001). Therefore, a literature review of available recharge and discharge estimates was performed to assess the reasonableness of the terms, and is provided in Appendix C. Groundwater inflow to the LWRFS ranged from a minimum of 20,400 AFY to 85,500 AFY, averaging 51,923 AFY. NSE Ruling 6255[32] estimated a total of 47,000 AFY to the LWRFS that included: 39,000 AFY from Pahranagat, Delamar, and Kane Springs Valleys; and 8,000 AFY from Lower Meadow Valley Wash to Muddy River Springs Area. Local recharge in the LWRFS ranged from a minimum of 1,996 AFY to 17,818 AFY, averaging 5,475 AFY. Groundwater outflow ranged from 0 AFY to 53,711 AFY, averaging 24,852 AFY. Evapotranspiration from the LWRFS ranged from 1,000 AFY to 15,080 AFY, averaging 10,652 AFY.

The water budget provided in Table 8 and shown in Figure 16 presents an initial budget that may be used for groundwater sustainability in the LWRFS. The proposed budget accounts for local recharge, surface water flow, and groundwater flow that supports senior decreed water rights on the Muddy River in Muddy River Springs Area, California Wash, and Lower Moapa Valley. Ruling 6254 states that the perennial yield of a groundwater basin is defined as the maximum amount of groundwater that can be withdrawn each year over the long-term without depleting the groundwater reservoir and that it is ultimately limited to the maximum amount of natural discharge that can be used for beneficial use. While the perennial yield may be limited to the natural recharge to a groundwater basin, it is typically less in order to prevent adverse conditions such as water quality degradation, storage depletion, diminishing yield of wells, increased pumping costs, and land subsidence.

The amount of water available for appropriation from Nevada's basins has previously been based on the capture of evapotranspiration and groundwater outflow. Under sustainable management conditions for the Lower White River Flow System, factors such as climate, geology,

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[32] NSE 6255, page 25.

and point of diversion will affect the total quantity that can be pumped based on an acceptable level of impact to resources. This report recommends and supports that an initial estimate of groundwater available for appropriation should be based on capturing all evapotranspiration and groundwater outflow from the LWRFS. The SNWA (2007) estimate of 51,700 AFY of subsurface outflow includes discharge from the springs in the Muddy River Springs Area. Therefore, for the purpose of estimating subsurface outflow from California Wash, 32,000 AFY of surface discharge is subtracted from the 51,700 AFY to yield 19,700 AFY of subsurface outflow. Additionally, the amount of evapotranspiration for the LWRFS is estimated to be 11,930 AFY; resulting in the total evapotranspiration and groundwater outflow of 30,630 AFY. Operating under sustainable management techniques that include monitoring, management, and mitigation will allow existing water rights holders to exercise their rights in priority and assess impacts over time and allow the NSE and stakeholders to assess and protect resources as pumping increases toward the maximum value of 30,630 AFY. Because existing production in the LWRFS is much less than 30,630 AFY, resources of the Muddy River will be protected as a reasonable lowering of the groundwater table occurs.[33]

4.3 COYOTE SPRING VALLEY WATER BUDGET

Numerous studies have been performed to assess the quantity of local and regional groundwater flow in each of Nevada's basins. Reported estimates of local recharge to Coyote Spring Valley from the west bounding Sheep Range ranges from 1,900 AFY to 14,000 AFY. SNWA (2007) assessed local and regional flow in southeastern Nevada and found regional inflow to Coyote Spring Valley was 50,700 AFY, of which Pahranagat Valley contributes 22,440 AFY, Delamar Valley contributes 24,070 AFY,[34] and Kane Springs Valley contributes 4,190 AFY. SNWA (2007) estimated local recharge to be 2,130 AFY. A comparison with other estimates reveals that this value may be low. A local recharge of 5,280 AFY, as estimated in Section 4.1, is more reasonable based on recent studies and updated rainfall patterns (PRISM, 2015). Published estimates of additional recharge that may occur on the east side of Coyote Spring Valley from the Arrow Canyon Range and Meadow Valley Mountains are not available.

Pre-development outflow from Coyote Spring Valley was estimated based SNWA (2007). Groundwater flow out of Coyote Spring Valley was split between 37,800 AFY of flow to Muddy River Springs Area, and 17,180 AFY of flow to Hidden and Garnet Valleys. Estimated evapotranspiration in Coyote Spring Valley is 1,000 AFY, based on Thomas et al. (2001). Groundwater flow to the Muddy River Springs Area was also supported by 32,000 AFY of flow from Lower Meadow Valley Wash to Lower Moapa. Groundwater flow out of Hidden and Garnet

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[33] NRS 534.110(4)

[34] Thomas and Mihevc (2011), estimated outflow from Delamar Valley to be 24,900 AFY.

Valleys was toward the Black Mountains Area (Thomas et al., 2001). The regional groundwater flow and local recharge in the vicinity of Coyote Spring Valley is shown graphically in Figure 17 and described in Table 9.

Groundwater outflow from Coyote Spring Valley towards Hidden and Garnet Valleys eventually discharges toward the Black Mountains Area and the Las Vegas Shear Zone, the latter of which is a prominent northwest-southeast trending feature that marks the end of the regional carbonate aquifer. In addition to local recharge and groundwater flow from California Wash, groundwater discharge from the Black Mountains Area may occur as evapotranspiration, spring discharge, or seepage along the northern boundary of Lake Mead and Las Vegas.

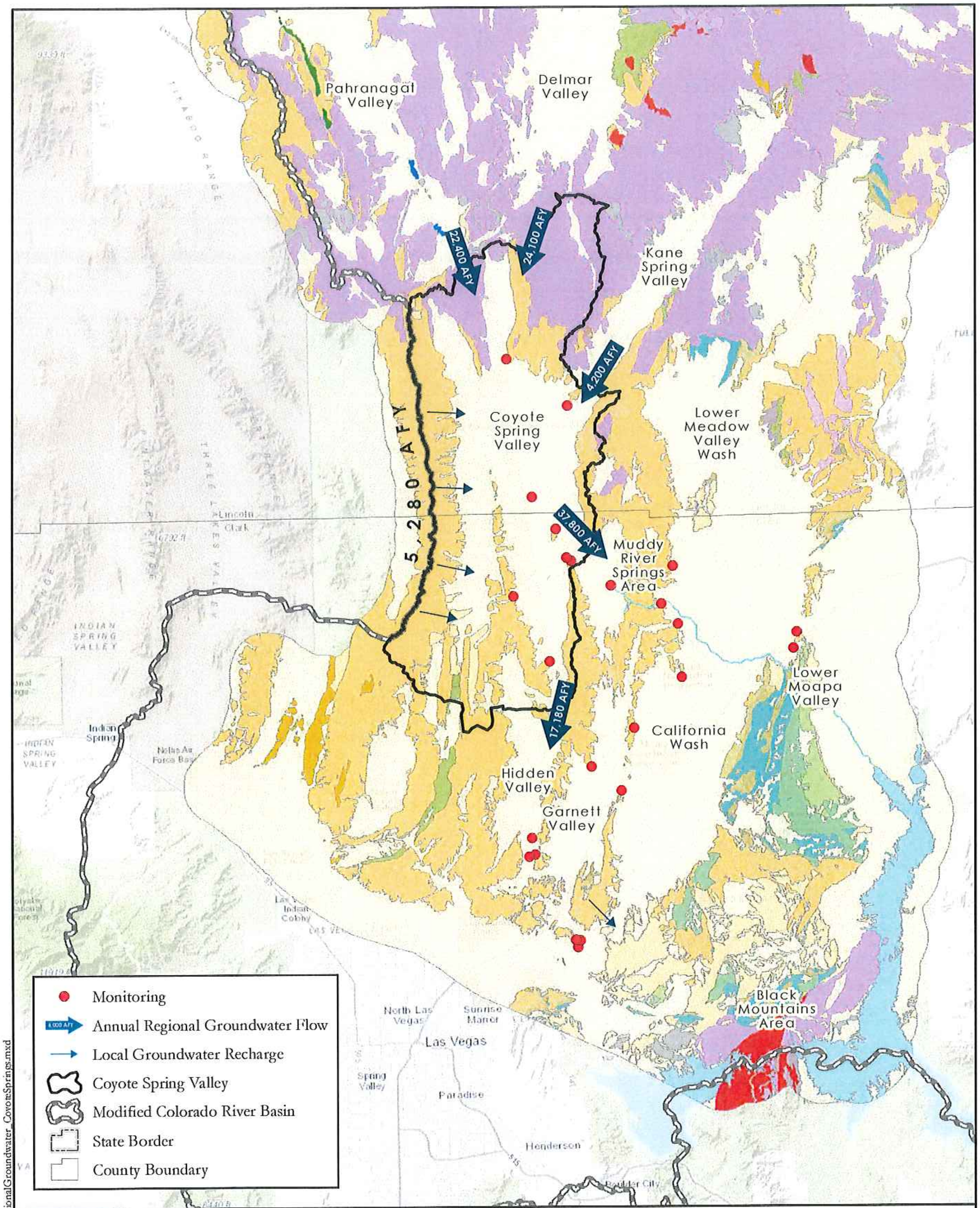
TABLE 9. PRE-DEVELOPMENT WATER BUDGET FOR THE COYOTE SPRING VALLEY BASED ON DEUTERIUM MASS-BALANCED MODEL (MODIFIED FROM SNWA, 2007)

Flux Term	Annual Flux (AFY)
Inflow	
Pahranagat Valley	22,400
Delamar Valley	24,100
Kane Springs Valley	4,200
Local Recharge from Sheep Range[a]	5,280
Local Recharge from east side of CSV[b]	Unknown
Total Inflow	55,980
Outflow	
Muddy River Springs Area(a)	37,800
Hidden/Garnet Valley	17,180
Evapotranspiration	1,000
Total Outflow	55,980

Notes: a) Local recharge has been modified from SNWA (2007) to include the updated recharge estimate from the Sheep Range based on 2015 PRISM data. Additional recharge from the Sheep Range flows toward Hidden and Garnet Valleys.

b) Published estimates of local recharge to Coyote Spring Valley that may occur from Arrow Canyon Range and Meadow Valley Mountains are not available.

FIGURE 17



Document Path: I:\jn2674\RegionalGroundwater_CoyoteSprings.mxd

STETSON ENGINEERS INC.

REGIONAL GROUNDWATER FLOW AND LOCAL RECHARGE IN THE COYOTE SPRING VALLEY

Source: Modified from SNWA, 2007

N

0 6.5 13 Miles

5.0 GROUNDWATER-LEVEL RESPONSES

This section of the report provides observations of groundwater and surface water level responses in the Coyote Spring Valley and Muddy River Springs Area due to pumping and natural climatic variability.

5.1 GROUNDWATER LEVEL RESPONSES

Groundwater-levels in the carbonate aquifer respond to changes in recharge and discharge fluxes that are due to long-term and short-term natural climatic variability and anthropogenic stresses. Long-term time periods characterized by wetter than normal climatic conditions will result in an increase in groundwater levels if discharge rates remain constant. When discharge rates from the aquifer vary and recharge remains constant, groundwater levels will increase when discharge is reduced and decrease when discharge increases. Short-term annual groundwater pumping is also reflected in the groundwater levels; as pumping rates increase during high summer demand, groundwater levels decrease. Review of groundwater level responses in monitoring wells located in both Muddy River Springs Area and the Coyote Spring Valley can be analyzed for impacts due to both long-term climatic variability and short-term changes in pumping rates.

Groundwater levels in the Muddy River Springs Area monitoring well EH-4 show a seasonal response to Muddy River Springs Area carbonate groundwater pumping; minimum groundwater levels occur in summer when pumping is at a maximum, while maximum levels occur in the winter/spring when pumping is curtailed (bottom pane, Figure 18). When groundwater levels in EH-4 are compared to carbonate pumping in Coyote Spring Valley (top pane, Figure 18), there is no variation in the seasonal response pre-2005 and post-2005, when pumping in Coyote Spring Valley was initiated. What is most evident from the water level graph is the long-term climatic impact of drying from 1998 through 2004, wetting in 2004 and 2005, drying from 2006 through 2013, and stable water levels from 2013 through 2018.

Monitoring wells CSVM-1 (Figure 19), CSVM-6, and MX-4 (Appendix E)[35] show a response during the Order 1169 aquifer test (upper pane, Figure 19), as well as a response to pumping in Muddy River Springs Area (lower pane, Figure 19). Similar to groundwater level responses in EH-4, a pumping signature from carbonate pumping in Muddy River Springs Area appears in CSVM-1, CSVM-6, and MX-4 prior to 2005 when groundwater pumping in Coyote Spring Valley began. The groundwater level data suggest hydraulic communication between Muddy River Springs Area and the eastern portion of Coyote Spring Valley. Also similar to EH-4, the long-

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[35] See Appendix E supporting groundwater level graphs for: CE-VF-2, CSVM-1, CSVM-2, CSVM-3, CSVM-4, CSVM-5, CSVM-6, MX-4, EH-4, EH-5B, UMVM-1, and CSV-2.

term climatic variability from 1998 through 2018 results in increase and decreases in long-term trends of the groundwater level.

Coyote Spring Valley monitoring wells CSVM-2, -3, -4, -5 (Figure 20), and CE-VF-2 (Appendix E) do not show a response to pumping that occurred in either Muddy River Springs Area or the eastern portion of Coyote Spring Valley. There was no response in these monitoring wells from pumping at MX-5 during the Order 1169 aquifer test due to barriers to flow created by normal (extensional) faults that impede groundwater flow in the east-west direction, discussed in the above sections of this report. These monitoring wells are isolated from the eastern portion of Coyote Spring Valley by the normal faults and a structural carbonate block that act as barriers to flow, as evidenced by the lack of water level response. The April 2019 CSAMT survey provides evidence to groundwater flow barriers and substantiates the observations made by SNWA in 2013. Normal faulting associated with the carbonate structural block act as a barrier to groundwater flow in the west to east direction.

Based on these observations, pumping in the western portion of Coyote Spring Valley would not impact groundwater levels on the eastern side of the valley.[36] Production wells CSI-1, -3, and -4, which are on the same side of the structural block as CSVM-2, -3, -4, -5, and CE-VF-2 monitoring wells, are effectively isolated from groundwater resources in the eastern portion of Coyote Spring Valley. Therefore, groundwater pumping in CSI-1, -3, and -4 will not likely cause impact to groundwater resources in the Muddy River Springs Area. Normal faults, as suggested by Rowley et al. (2017) and identified by the April 2019 CSAMT survey, act as barriers to groundwater flow in the west to east direction across the structural carbonate block bounded by the normal faults.

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[36] Information provided by MBOP at the April 22, 2019 pre-HRT meeting in Las Vegas discussed lack of water level response in CSI-3 during Order 1169 pumping.

Basin 219 - Muddy River Springs Area

EH-4

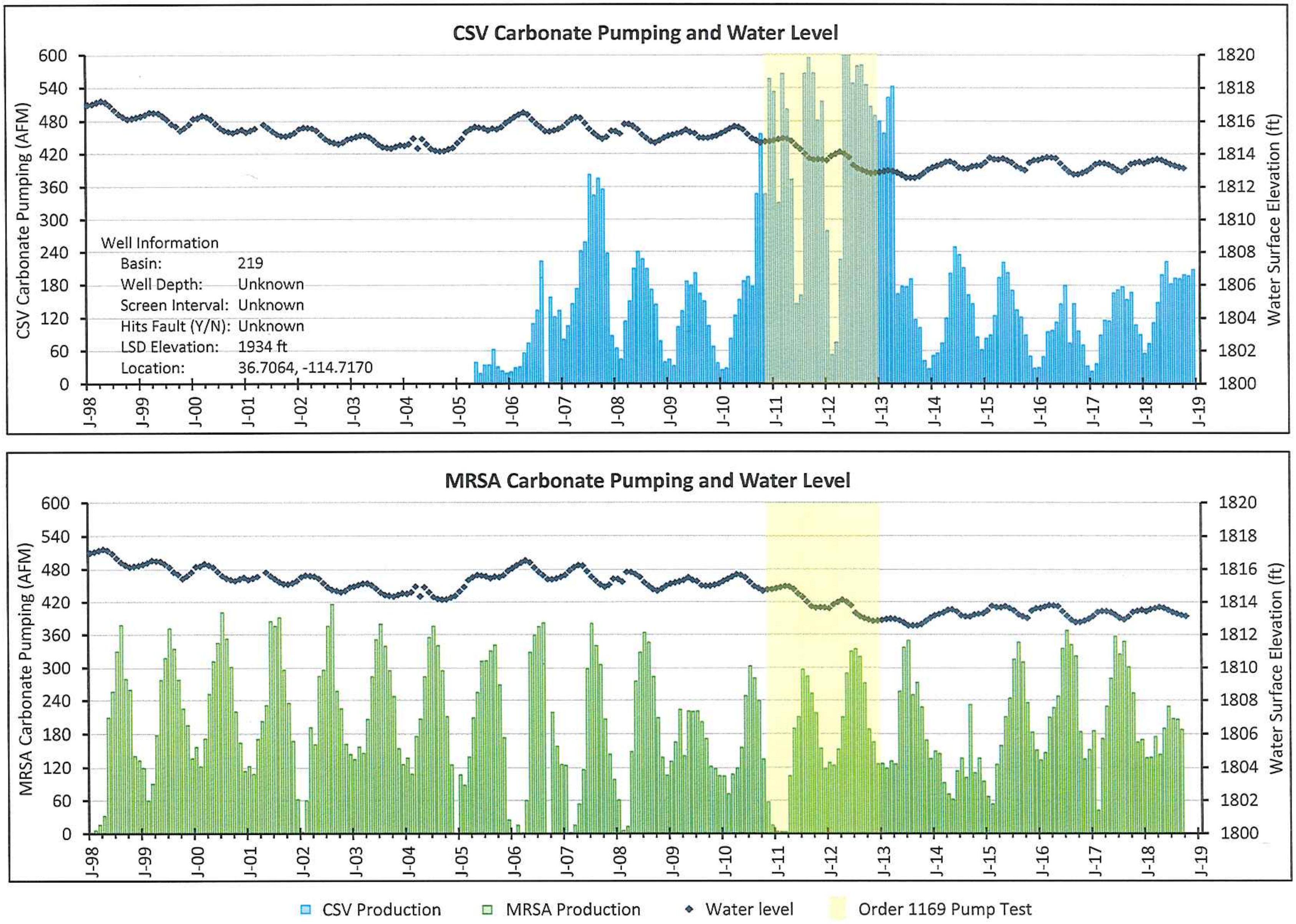
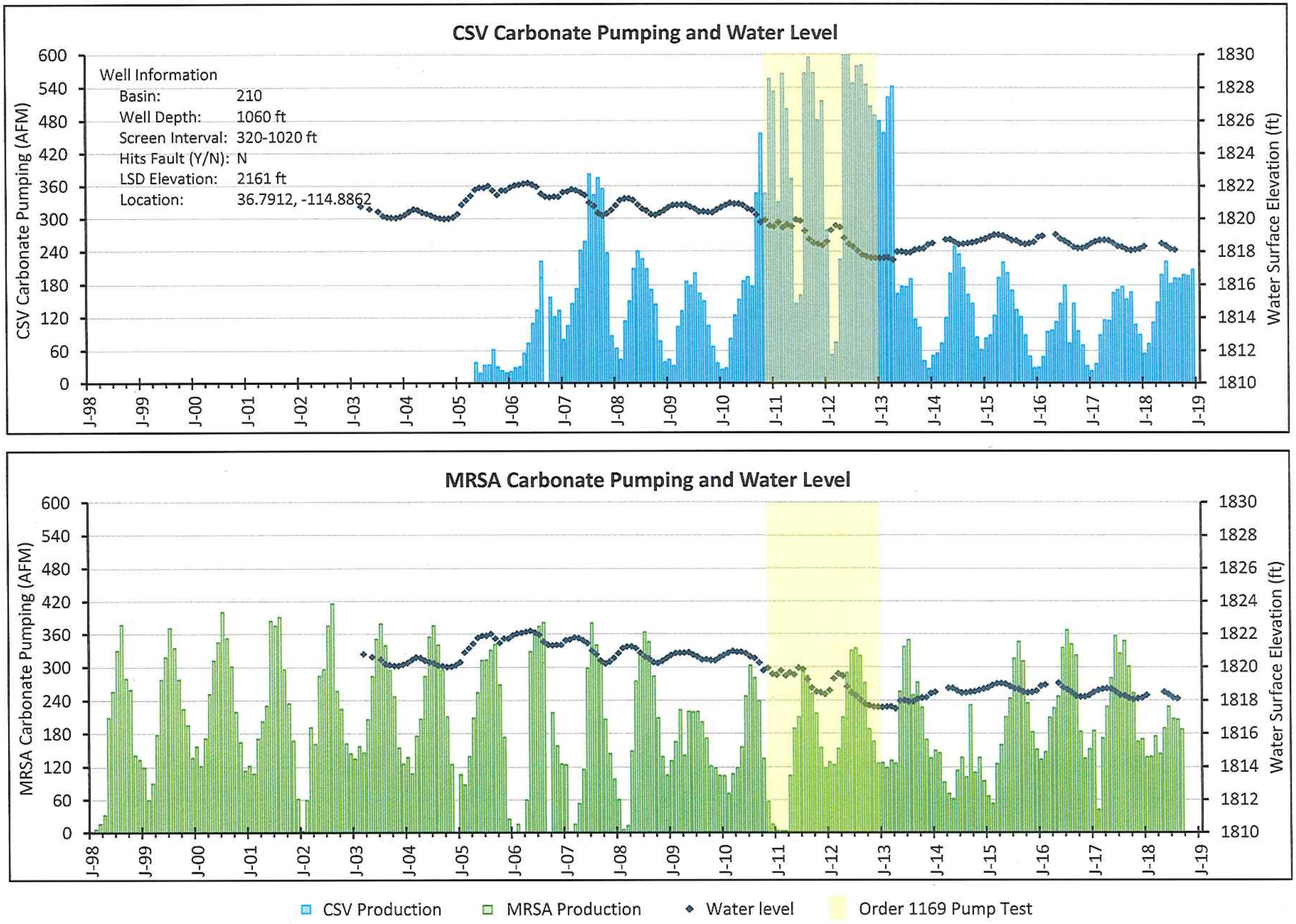


FIGURE 18

Basin 210 - Coyote Spring Valley

CSVM-1



Well Information
Basin: 210
Well Depth: 1060 ft
Screen Interval: 320-1020 ft
Hits Fault (Y/N): N
LSD Elevation: 2161 ft
Location: 36.7912, -114.8862

FIGURE 19

Basin 210 - Coyote Spring Valley

CSVM-5

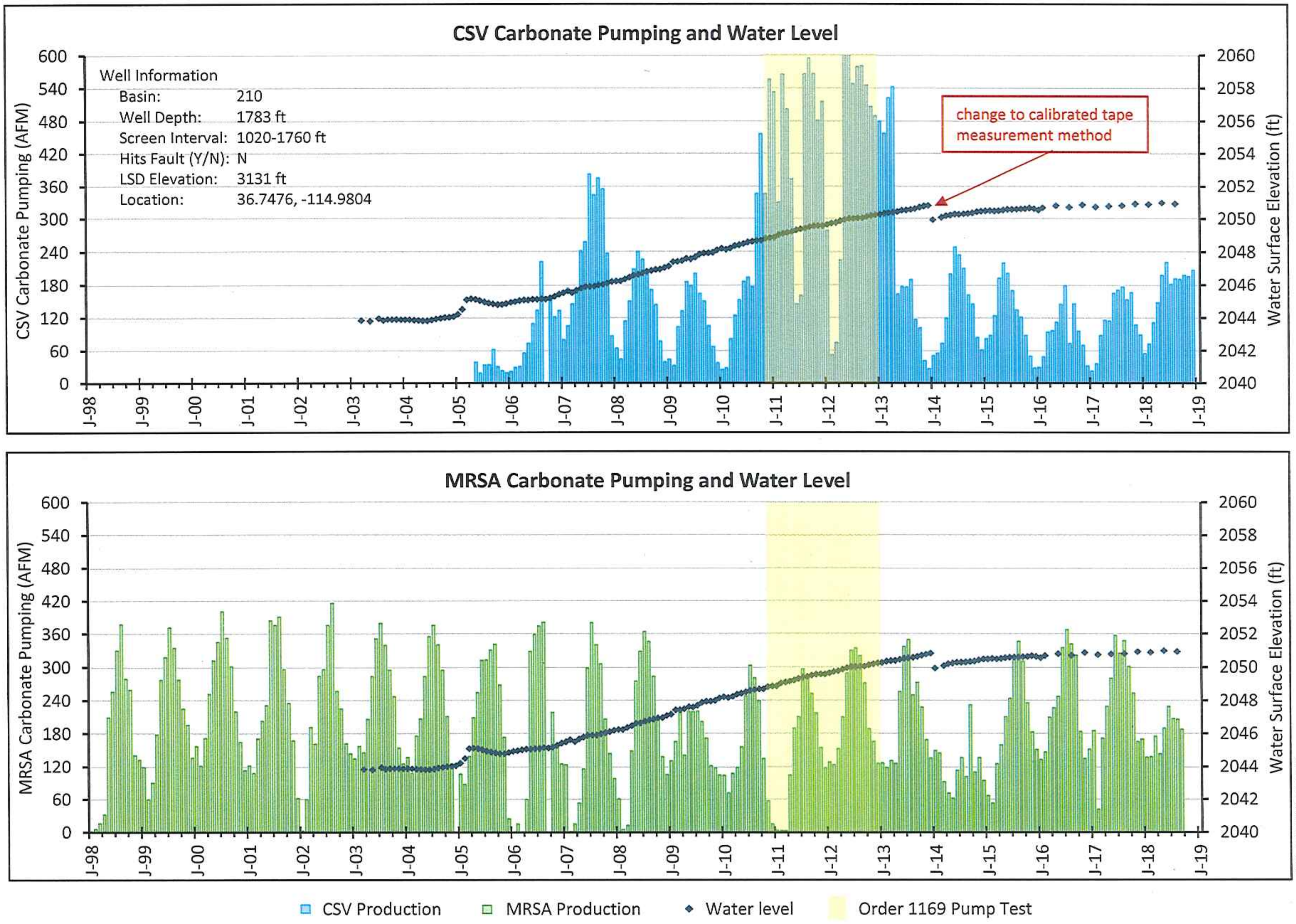


FIGURE 20

5.2 SURFACE WATER FLOW RESPONSE

Observations of surface flow records at Warm Spring West near Moapa gage (USGS # 09415920) in the Muddy River Springs Area show that the gage reflects carbonate groundwater levels in EH-4 (Figure 21). Surface flow responds to both wet climatic conditions and extended dry periods as exhibited by the declining surface flow during the 2006-2013 extended dry period following the 2004/2005 wet years. The seasonal signature between highs during winter and spring and lows during summer and fall is also evident in this hydrograph. Further evidence that pumping in Coyote Spring Valley has little, if any, impact on carbonate groundwater levels in the Muddy River Springs Area is shown by the comparison of surface flow to records of groundwater pumping from CSI-2. Located on the eastern side of the carbonate block in Coyote Spring Valley, CSI-2 pumped an equivalent annual rate 2,200 AFY during the last three quarters of 2018. The flow at Warm Springs West continued to show its seasonal variation with no upward or downward trend in surface flow during this period.

Other records of surface flow are compared to groundwater pumping in both Coyote Spring Valley and Muddy River Springs Area in Appendix E. The Muddy River near Moapa gage (USGS # 09416000) shows that surface flow has been increasing steadily since 2001, coincident with a reduction in total diversions from the Muddy River Springs Area as previously shown in . Additionally, surface flow at this gage did not subside or decline during the Order 1169 aquifer test, suggesting that factors other than pumping in Coyote Spring Valley have a larger effect on total streamflow originating from the Muddy River Springs Area. The flow data at the Muddy River near Moapa gage show that senior decreed water rights, resources that support the survival of the Moapa dace,[37] and groundwater resources for appropriation can be managed in a sustainable manner.

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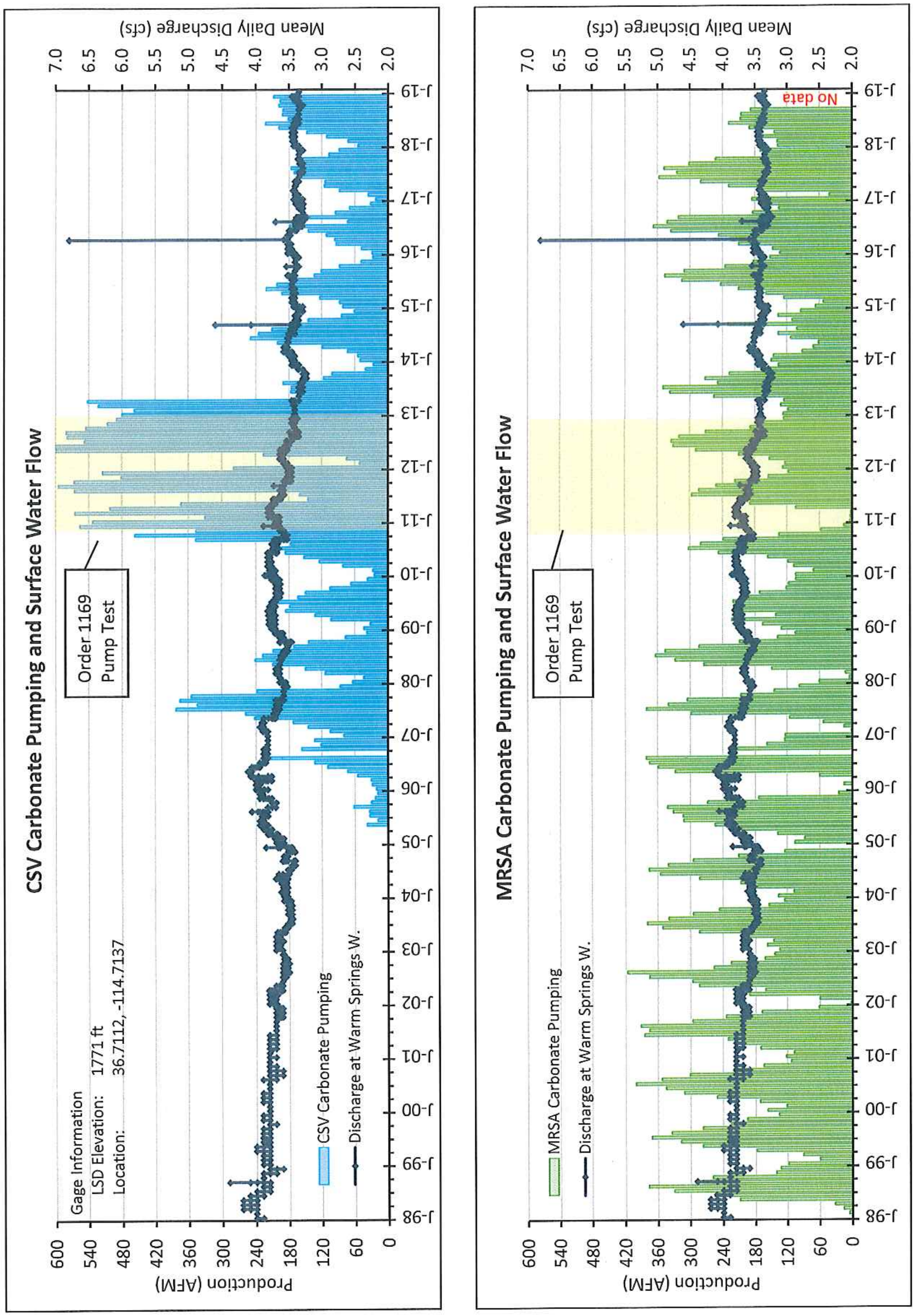
[37] The population of Moapa dace increased from low of 462 in August 2008 and February 2009, to a high of 2,182 in August 2015. Data show February 2005 count as 1,296 and the August 2017 count to be 1,533. https://www.fws.gov/uploadedFiles/MoapaDace2017%20508%20checked.pdf

FIGURE 21


Warm Springs West (USGS 09415920)
CSV Carbonate Pumping and Surface Water Flow
Gage Information
LSD Elevation: 1771 ft
Location: 36.7112, -114.7137
CSV Carbonate Pumping
Discharge at Warm Springs W.
Order 1169 Pump Test
Production (AFM)
Mean Daily Discharge (cfs)
0
60
120
180
240
300
360
420
480
540
600
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
J-98
J-99
J-00
J-01
J-02
J-03
J-04
J-05
J-06
J-07
J-08
J-09
J-10
J-11
J-12
J-13
J-14
J-15
J-16
J-17
J-18
J-19
MRSA Carbonate Pumping and Surface Water Flow
MRSA Carbonate Pumping
Discharge at Warm Springs W.
Order 1169 Pump Test
No data

6.0 SUMMARY AND CONCLUSIONS

The occurrence and movement of water in the LWRFS cannot be explained by an arbitrary boundary based on surface drainage divides. Interbasin groundwater flow into the LWRFS occurs from Pahranagat Valley, Delamar Valley, Kane Springs Valley, and the Lower Meadow Valley Wash. Interbasin groundwater outflow from California Wash into the Lower Moapa Valley occurs due to interbasin groundwater inflow and local recharge within the LWRFS. Together, these sources of local and regional groundwater flow support streams, springs, and evapotranspiration in Muddy River Springs Area, California Wash, and the Black Mountains Area basins. Assessment of impacts to decreed rights on the Muddy River, spring flow, and Moapa dace habitat must account for inflow from the entire carbonate rock aquifer and not just the portion within Coyote Spring Valley. Based on the importance of assessing the impacts of groundwater pumping on senior rights of the Muddy River and springs in the Muddy River Springs Area, the water budget presented in this report for the LWRFS should be adopted by the NSE for determining long-term sustainability in the region.

6.1 WATER AVAILABLE FOR SUSTAINABLE DEVELOPMENT

The role of the NSE is to develop a water budget and inventory of all water in each basin that is available for appropriation to beneficial use in the public's interest.[38] Typically, the amount of water available for appropriation could be calculated based on capture of evapotranspiration and groundwater outflow. The purpose of this section of the report is to establish an estimate for quantifying the amount of groundwater and surface water that may be put to a beneficial use in a sustainable manner.

SNWA (2007) suggests that approximately 11,930 AFY of evapotranspiration occurs within the LWRFS and an additional 51,700 AFY of subsurface outflow, spring flow, and surface flow occurs toward the Lower Moapa Valley and Black Mountains Area. The proposed water budget of the LWRFS further indicates that regional groundwater inflow and local recharge within the LWRFS boundary totals 62,240 AFY. These sources of the interbasin groundwater flow and local recharge supports springs and rising groundwater in the Muddy River Springs Area and California Wash, which in turn supports senior decreed water rights along the Muddy River. After accounting for 32,000 AFY of surface flow of the Muddy River, the total evapotranspiration and groundwater outflow from the LWRFS is 30,630 AFY.

The flow patterns of regional and local groundwater in the LWRFS boundary are neither simple nor straightforward. The April 2019 CSAMT data indicate that regional groundwater recharge to Coyote Spring Valley flows in a north-to-south direction along preferred western and

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[38] See NRS 532.167 and NRS 534.020

eastern flow paths, separated by a relatively impermeable carbonate block. Outflow from Coyote Spring Valley to Hidden Valley, Garnett Valley, and the Black Mountains Area eventually discharges toward the Las Vegas Shear Zone and California Wash. Interbasin groundwater flow from Lower Meadow Valley Wash support springs, evapotranspiration, and surface flows in both the Muddy River Springs Area, California Wash, and eventually the Lower Moapa Valley.

Estimated drawdown using the Theis solution indicates that impacts from carbonate wells pumping in the Muddy River Springs Area has a greater impact on groundwater levels in EH-4 than pumping in Coyote Spring Valley. Furthermore, SNWA (2018) suggests that groundwater production from the Muddy River Springs Area alluvial aquifer depletes Muddy River streamflow on a 1:1 basis; and that Muddy River Springs Area carbonate production wells capture water that would otherwise replenish the alluvial aquifer. Review of groundwater levels (EH-4) and Muddy River Springs Area total surface and groundwater production supports SNWA's conclusion since a reduction in total diversions since 2013 have resulted in stable carbonate groundwater levels and an increase in Muddy River flows.

Hydrologic conditions for the extreme southern Nevada have been in a below normal trend since 2006, while hydrologic conditions in Pahranagat Valley have been slightly above normal since 2013. Based on the below normal hydrologic conditions in extreme southern Nevada, groundwater levels in EH-4 may have continued to decrease without a reduction in Muddy River Springs Area diversions and groundwater production. The degree of impact from slightly wetter than normal hydrologic conditions in Pahranagat Valley to groundwater levels in the Muddy River Springs Area require further investigation. Because regional interbasin groundwater recharge occurs from the upgradient basins, climate variability in these basins may largely dictate groundwater levels in the LWRFS.

6.2 ORDER 1303 ISSUES

The purpose of this report is to address the NSE's request in Order 1303 to address water resources in the Coyote Spring Valley, Muddy River Springs Area, California Wash, Hidden Valley, Garnet Valley, and a portion of the Black Mountains Area (Joint Administrative Unit). Based on the data and analyses provided in this report, this section addresses specific issues.

Order 1303 Issue 1: The geographic boundary of the hydrologically connected groundwater and surface water systems comprising of the Lower White River Flow System

The LWRFS should be used by the NSE to sustainably manage the surface and groundwater resources. Interbasin groundwater recharge from Pahranagat Valley, Delamar Valley, Kane Springs Valley, and Lower Meadow Valley Wash add to and support regional groundwater flow within the

LWRFS boundary. Although these four basins contribute to the resources within the LWRFS, each of them should be administered separately and not be included in the LWRFS due to geologic characteristics that separate them from the proposed Administrative Unit. The total pre-development inflow to LWRFS is estimated to be 62,210 AFY, while the total predevelopment outflow is estimated to be 63,630 AFY.

Order 1303 Issue 2: The information obtained from the Order 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test.

Hydrologic data for extreme southern Nevada indicates that the area has been in long-term below normal hydrologic condition since 2006. Rainfall data from Pahranagat Valley indicates below normal hydrologic conditions existed from 2006 through the end of 2012, but the upgradient basin has been experiencing above normal hydrologic conditions from 2013 through 2017. The hydrologic conditions play an important role in sustainably managing resources in the LWRFS. The period 1982 through 2017 reflects a balanced hydrologic cycle, containing wet periods in the early 1980s and mid-2000s, an average period from 1992 through 2000, and a dry period from 2006 through 2012 (Stetson, 2018). Because interbasin groundwater inflow to the LWRFS impacts groundwater levels in the LWRFS, the Pahranagat Wildlife Refuge rainfall data could be used to describe relative wet and dry cycled. The precipitation and groundwater level data for both extremen southern Nevada and the Pahranagat Wildlife Refuge show that the Order 1169 aquifer test occurred during a prolonged dry period that began in 2006.

A simple Theis solution to estimate impacts to groundwater levels in Muddy River Springs Area, due to pumping in Coyote Spring Valley, may not provide an absolute solution of groundwater level drawdown, but it does provide a relative comparison. Pumping from the carbonate aquifer in Coyote Spring Valley has less impact on groundwater levels in EH-4 than nearby carbonate pumping in the Muddy River Springs Area. The impact to groundwater levels is constrained by the value of transmissivity used to estimate drawdown; smaller values of transmissivity has a greater impact on drawdown when compared to higher values. In order to solve Darcy's equation for total flux from Coyote Spring Valley to Muddy River Springs Area, high values of hydraulic permeability are required to solve the equation. High values of hydraulic permeability result in high values of transmissivity (greater than 280,000 ft^2/day). Therefore, while there is a hydraulic connection between Muddy River Springs Area and Coyote Spring Valley, the high value of transmissivity minimizes the impact of the distal pumping on carbonate groundwater levels.

Pumping from carbonate wells in the Muddy River Springs Area affects the amount of recharge from the carbonate aquifer to the alluvial aquifer (SNWA, 2018). Pumping from the alluvial fill aquifer and surface diversions in the Muddy River Springs Area affects the flow of the Muddy River. Therefore, surface diversions, carbonate pumping, and alluvial pumping in the Muddy River Springs Area affects springs and surface flow that support the Moapa dace and senior decreed water rights. Future goals and objectives for sustainable management should consider location and geologic structure as key factors when establishing triggers and thresholds.

Varying hydrologic conditions, interbasin groundwater inflow from Coyote Spring Valley and Lower Meadow Valley Wash, surface water diversions, and groundwater pumping in the Muddy River Springs area impacts spring and surface water flow along the Muddy River. The data collected since the end of 2012 at EH-4 do not show a continued decline in carbonate groundwater levels that would likely be expected to occur following a two-year prolonged pump test at MX-5. Rather, the data show that as total diversions in the Muddy River Springs Area have declined, groundwater levels have remained stable. As the region experiences future wet cycle comparable to 2004/2005 or the mid-1980s, carbonate groundwater levels at EH-4 will likely show recovery if recent Muddy River Springs Area surface and groundwater production remain constant.

<u>Order 1303 Issue 3: The long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, including the relationships between the location of pumping on discharge to the Muddy River Springs and the capture of Muddy River flow.</u>

As previously stated above, the amount of water available for appropriation can be calculated based on capture of evapotranspiration and groundwater outflow. The water budget for the LWRFS indicates that pre-development evapotranspiration is 11,930 AFY and outflow toward the Lower Moapa Valley is 51,700 AFY. These values provide a basis for initiating long-term sustainable management in the region. Subsurface outflow from California Wash is estimated by subtracting 32,000 AFY of surface discharge from the 51,700 AFY to yield 19,700 AFY. The amount of evapotranspiration for the LWRFS is estimated to be 11,930 AFY; resulting in the total evapotranspiration and groundwater outflow of 30,630 AFY. Operating under sustainable management techniques that include monitoring, management, and mitigation will allow existing water rights holders to exercise their rights in priority and assess impacts over time and allow the NSE and stakeholders to assess and protect resources as pumping increases toward the maximum value of 30,630 AFY. This initial estimate of sustainable yield allows for senior rights along the Muddy River to be exercised.

Spring flow and surface flow in the Muddy River Springs Area is affected by groundwater and surface water development based on its relative upgradient or downgradient location, local recharge, regional recharge, and boundary conditions. The April 2019 CSAMT survey and groundwater level responses in Coyote Spring Valley show that pumping on the west side of Coyote Spring Valley has no measurable impact on flow to the Muddy River Springs Area. The results from the Theis solution and observations of flow in the Warm Spring West gage since 2013 also show minimal or no impact in the Muddy River Springs Area due to pumping on the eastern side of Coyote Spring Valley. While there is no direct measurement of outflow or evapotranspiration from Coyote Spring Valley, the balanced water budget shown in Table 9 indicates up to 5,280 AFY can be produced from the western side of Coyote Spring Valley without impact to the Muddy River Springs Area.

Order 1303 Issue 4: The effects of movement of water rights between alluvial wells and carbonate wells on deliveries to senior decreed rights to the Muddy River.

Groundwater pumping from the carbonate aquifer affects the flow from the carbonate aquifer to the alluvial basin, which then affects the flow from the alluvial basin to the Muddy River. All groundwater pumping, regardless of which aquifer it is pumped from, will eventually affect the flow of the Muddy River or subflow out of the LWRFS. Two factors that must be addressed are the well's location and the delay between pumping and impact.

The location of the well with respect to the entire Muddy River, not just the portion of the river in the Muddy River Springs Area, should be addressed when considering impacts to senior decreed water rights. Regional groundwater flow from California Wash and Lower Meadow Valley Wash supports Muddy River streamflow, not just discharge in the Muddy River Springs Area. The Muddy River may act as both a losing and gaining river as it flows from Moapa through Glendale and eventually toward Overton and Lake Mead. Extractions may have a 1:1 impact on streamflow or they may act to reduce subsurface groundwater flow out of the LWRFS boundary.

Groundwater pumping from the carbonate aquifer will have a delayed response on surface flow of the Muddy River depending on its location. Groundwater pumping from the alluvial aquifer will likely have a relatively immediate impact on streamflow, when compared to carbonate aquifer pumping. Under sustainable management conditions, future adaptive techniques may be available to affect short-term changes such that a reduction in alluvial pumping may immediately impact available water supplies. But, in order to manage the LWRFS over a long-term sustainable period, groundwater pumping from the alluvial and carbonate aquifers should be considered equally. The movement of water rights between alluvial wells and carbonate wells will only serve to shift the timing and location of impacts and not the amount of the impact.

6.3 SUMMARY OF CONCLUSIONS

Groundwater in the carbonate aquifer of southeastern Nevada generally follows a north-south direction along normal faults and structural boundaries. Basin and Range aged related fault zones create preferred pathways for groundwater flow since they formed through extensional faulting creating open spaces and fractures for groundwater flow. Within the LWRFS, these normal faults extend north-to-south through Coyote Spring Valley from Pahranagat and Delamar Valleys toward the Hidden Valley. Recent April 2019 CSAMT survey data show preferred pathways for groundwater flow occur through Coyote Spring Valley toward Hidden Valley and the Muddy River Springs Area through a sub-parallel fault system. The LWRFS contains a series of parallel and sub-parallel north-south trending faults that is bounded in the north west by the Pahranagat Shear Zone and the south by the Las Vegas Shear Zone and Lake Mead. The following results and conclusions provide the basis for structuring any final order arising from Order 1303:

a. Groundwater flow in the carbonate rock aquifer cannot be defined by topographic boundaries that control the flow of surface water. The LWRFS should account for inflow from Lower Meadow Valley Wash to sustainably manage the resources.

b. The carbonate aquifer beneath the entire modified Colorado River Flow System boundary, not just that portion below Coyote Spring Valley, contributes to groundwater resources in Hidden Valley, Garnett Valley, Muddy River Springs Area, California Wash, and the Black Mountains Area. Contributions from Lower Meadow Valley Wash must be accounted for when assessing water resources in the LWRFS.

c. Identification of faults and structural features are the first step in assessing groundwater resources in the carbonate rock aquifer.

d. Normal (extensional) faults create preferred pathways for groundwater flow, in a direction parallel to the fault, throughout the regional carbonate aquifer. They also can act as a barrier to flow in the perpendicular direction to the strike of the fault.

e. The April 2019 CSAMT survey identified normal (extensional) faults in Coyote Spring Valley the control the movement of groundwater. Interbasin groundwater flow occurs toward both Muddy River Springs Area and Hidden and Garnet Valleys.

f. Normal (extensional) faults in the Coyote Spring Valley define a carbonate structural carbonate block that creates preferred flow paths that separate groundwater flow to Muddy River Springs Area from flow towards Hidden and Garnet Valleys.

g. Regional and local groundwater recharge to LWRFS is estimated to be 62,240 AFY. Total outflow, including subsurface outflow and evapotranspiration is 63,630 AFY.

h. Regional interbasin groundwater recharge to Coyote Spring Valley is estimated to be 50,700 AFY. Total groundwater flow is approximately 55,980 AFY, including 5,280 AFY local recharge.

i. Regional groundwater outflow from Coyote Spring Valley to Muddy River Springs Area and Hidden and Garnet Valleys under pre-development conditions is estimated to be 55,980 AFY,

j. Groundwater levels in monitoring wells located west of the structural block in Coyote Spring Valley are not affected by groundwater pumping in Muddy River Springs Area or pumping from MX-5 and CSI-2.

k. Development of locally derived groundwater from wells on the west side of the structural block in the Coyote Spring Valley will not affect decreed water rights on the Muddy River, springs in the Muddy River Springs Area, or habitat that supports the Moapa dace

l. Local recharge in Coyote Spring Valley from the Sheep Range is contained west of a structural carbonate block that limits its contribution to the Muddy River Springs Area.

m. An initial long-term *adequate and sustainable* supply of groundwater in the LWRFS is 30,630 AFY, based the total estimated evapotranspiration and subsurface outflow. Because existing groundwater pumping is much less than the initial estimate, adaptive management techniques can be used to adjust this value in the future based on hydrologic conditions and groundwater development.

n. Up to 5,280 AFY of local recharge may be pumped from the Coyote Spring Valley each year over the long-term without directly affecting the regional groundwater discharge in the Muddy River Springs Area.

7.0 REFERENCES

Avon, L. and Durbin, T.J., 1994. Evaluation of the Maxey-Eakin method for estimating recharge to ground-water basins in Nevada. *Journal of the American Water Resources Association, 30*(1), pp.99-111.

Daly, C., R.P. Neilson, and D.L. Phillips. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. *J. Appl. Meteor.*, 33, 140-158.

Daly, C., G. Taylor, and W. Gibson. 1997. The PRISM approach to mapping precipitation and temperature. *10th AMS Conf. on Applied Climatology*, Reno, NV, 10-12.

Daly, C., G.H. Taylor, W. P. Gibson, T.W. Parzybok, G. L. Johnson, P. Pasteris. 2001. High-quality spatial climate data sets for the United States and beyond. *Transactions of the American Society of Agricultural Engineers*, 43: 1957-1962.

Dettinger, Michael D, 1989. Reconnaissance estimates of natural recharge to desert basins in Nevada, USA, by using chloride balance calculations. *Journal of Hydrology*, 106 (1989) 55-78.

Eakin, T.E., 1964. Ground-water appraisal of Coyote Spring and Kane Spring Valleys and Muddy River Springs Area: Lincoln and Clark Counties, Nevada. Department of Conservation and Natural Resources.

Eakin, T.E., 1966. A Regional Interbasin Ground-water System in the White River Areas, southeastern Nevada. Water Resources Research, *Water Resources Research,* 2: 251-271.

Epstein, Brian Jeffery, 2004. Development and uncertainty analysis of empirical recharge prediction models for Nevada's desert basins. University of Nevada, Reno thesis dissertation.

Epstein, Brian Jeffery, et. al., 2010. Development and uncertainty analysis of empirical recharge prediction models for Nevada's desert basins. *Journal of the Nevada Water Resources Association*, 1 (2010) 1-22.

Great Basin Water Network, 2013, Technical Memorandum Comments on Carbonate Order 1169 Pump Test Data and the Groundwater Flow System in Coyote Spring and Muddy River Springs Valley, Nevada. Prepared by Tom Myers, Ph.D., June 12, 2013.

Hardman, G., 1936. Nevada precipitation and acreages of land by rainfall zones. University of Nevada Experimental Station, Reno, Nevada.

Hardman, George, 1962. Precipitation map of Nevada. Nevada Department of Conservation and Natural Resources.

Johnson, M.E., 2006. Drilling and Development of CSI Well No. 4 for Coyote Springs Investment LLC, Coyote Spring Valley, Clark County, Nevada.

Kirk, S.T. and Campana, M.E., 1990. A Deuterium-calibrated groundwater flow model of a regional carbonate-alluvial system: Desert Research Institue, Reno, Nevada. *Journal of Hydrology v. 119.* pp. 357-388.

Lamke, Robert D., Moore, Donald O., 1965. Interim inventory of surface water resources of Nevada. Water Resources Bulletin No. 30.

Levy M, Christie-Blick N., 1989. Pre-Mesozoic Palinspastic Reconstruction of the Eastern Great Basin (Western United States). Science 1989 Sep 29;245(4925):1454-62.

Lopes, T.J. and Evetts, D.M., 2004. Ground-water pumpage and artificial recharge estimates for calendar year 2000 and average annual natural recharge and interbasin flow by hydrographic area, Nevada. US Department of the Interior, US Geological Survey.

Maxey, G.B. and Eakin, T.E., 1949. Ground water in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada. Water Resources Bulletin No. 8.

Moapa Band of Paiutes, June 2013. Summary of Order 1169 Testing Impacts, per Order 1169A. Prepared by Cady Johnson and Martin Mifflin.

Nevada Division of Water Resources, 2017. Designated Groundwater Basins of Nevada: Office of the State Engineer, Carson City, Nevada. Map.

Nevada Division of Water Resources, 1971. Nevada's Water Resources, prepared by Nevada State Engineer. Water for Nevada Report No. 3.

Nichols, W.D., 2000. Regional ground-water evapotranspiration and ground-water budgets, Great Basin, Nevada. U.S. Geological Survey Professional Paper No. 1628.

PRISM Climate Group, Oregon State University. 2015. 30-year normal precipitation: Annual; Period: 1981-2010. Resolution: 800 meters. http://prism.oregonstate.edu

Rowley, P.D., Dixon, G. L., Mankinen, E.A., Pari, K.T., Mcphee D. K., et al., 2017. Geology and Geophysics of White Pine and Lincoln Counties, Nevada, and Adjacent Parts of Nevada and

Utah: The Geologic Framework of Regional Groundwater Flow Systems. Nevada Bureau of Mines and Geology Report 56.

Southern Nevada Water Authority, 2018. Assessment of Water Resource Conditions in the Lower White River Flow System: Southern Nevada Water Authority, Las Vegas, Nevada, Doc. No. WRD-ED-0051, 116 p.

Southern Nevada Water Authority, June 2013. Nevada State Engineer Order 1169 and 1169A Study Report.

Southern Nevada Water Authority, June 2007. Water-Resources Assessment and Hydrogeologic Report for Cave, Dry Lake, and Delamar Valleys. Presentation to the Office of the Nevada State Engineer.

Southern Nevada Water Authority, June 2006. Derivation of a spatial distribution of areal recharge from estimates based on estimates reported in reconnaissance investigation reports for the Spring Valley Area. Presentation to the Office of the Nevada State Engineer Volume 2.

Stetson Engineers, December 13, 2018. Technical Memorandum to Nevada State Engineer from Stetson Engineers

Telford, W.M, Geldart, L.P., Sheriff, R.E., Keys, D.A., 1976. Applied Geophysics. Cambridge University Press.

Thomas, J.M., Welch, A.H. and Dettinger, M.D., 1996. Geochemistry and isotope hydrology of representative aquifers in the Great Basin region of Nevada, Utah, and adjacent states. U.S. Geological Survey Professional Paper 1409-C.

Thomas, J.M., Calhoun, S.C., Apambire, W.B., May 2001. A deuterium Mass-balance Interpretation of Groundwater Sources and Flows in Southern Nevada. DRI, Publication No. 41169.

Thomas, J.M., Mihevc., T.M, 2011. Evaluation of Groundwater Origins, Flow Paths, and Ages in East-Central and Southeastern Nevada. DRI, Publication No. 41253

U.S. Department of the Interior (DOI), June 2013. Test Impacts and Availability of Water Pursuant to Applications Pending Under Order 1169, U.S. Fish and Wildlife

U.S. Geological Survey, 2019. USGS National Map Data Collection: U.S. Geological Survey. https://viewer.nationalmap.gov/basic/

U.S. Geological Survey, 2017. 1/3rd arc-second digital elevation models (DEMs) - USGS National Map 3DEP Downloadable Data Collection: U.S. Geological Survey. https://viewer.nationalmap.gov/basic/

U.S. Geological Survey, 2016. Watershed boundary data Set for HUC 15010012 - USGS National Map. Downloadable Data Collection: U.S. Geological Survey. https://viewer.nationalmap.gov/basic/

U.S. Geological Survey, 2007. Water Resources of the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and adjacent Areas in Nevada and Utah. Scientific Investigations Report 2007–5261

U.S. Geological Survey, 1989. Basic Ground-Water Hydrology. U.S. Geological Survey Water Supply Page 2220.

Watson, P., Sinclair, P. and Waggoner, R., 1976. Quantitative evaluation of a method for estimating recharge to the desert basins of Nevada. *Journal of Hydrology*, 31(3-4), pp.335-357.

Appendix A

General Grouping of Geologic Layers

STETSON
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DRAFT NOTE TO FILE

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Phone: (760) 730-0701 FAX: (415) 457-1638 Web site: www.stetsonengineers.com

TO:	File	DATE:	April 26, 2019
FROM:	Nichole Weedman	JOB NO:	2674-002
RE:	Grouping of Geologic Units in the Lower White River Flow System, Nevada.		

1.0. GEOLOGIC UNITS

Rawley et al. (2017) mapped twenty-two geologic units within the Lower White River Flow System (LWRFS). These units range in age from Cambrian to Quaternary, and compose the three aquifers observed in the Lower White River Flow System: the carbonate aquifer (oldest), the volcanic aquifer and the alluvial aquifer (youngest). Due to density of individual geologic units, units were grouped based on water-bearing properties, rock type, and age. Description of units grouped can be found in Table 1.

2.0. PALEOZOIC BASEMENT AND CARBONATE ROCKS

Paleozoic rock units found in the LWRFS were grouped as 1) Basement or 2) Paleozoic Carbonate Rocks based largely on rock type and presence within the carbonate rock aquifer.

Middle Cambrian to late Proterozoic (CpCs)

- This rock unit was grouped as Paleozoic Basement Rock. CpCs is composed largely of metamorphic quartzite with minor limestone and shale. Based upon rock type and Rowley, et al.'s (2017) definition of the lower aquifer, it can be inferred that this geologic unit is not part of the carbonate rock aquifer. CpCs was classified as Paleozoic Basement.

Upper to Middle Cambrian (Cm)

- Cm was grouped with the Paleozoic Carbonate Rock unit. Rowley, et al. (2017) defined this unit as "a thick limestone sequence that marks the base of the lower carbonate rock aquifer." Inclusion within the carbonate rock aquifer was the reason this unit was grouped as Paleozoic Carbonate Rock.

TABLE 1. LOWER WHITE RIVER FLOW SYSTEM

Era	NV Bureau of Mines Units (Rowley, et al., 2017)	Grouped Units[1]
Cenozoic	QTa	Basin Fill
	QTB	Volcanic
	Ts4	Basin Fill
	Tt4	Volcanic
	Tt3	Volcanic
	Tt2	Volcanic
	Ta5	Volcanic
	Ti	Volcanic
Mesozoic	Ks	Sedimentary
	Js	Sedimentary
	^s	Sedimentary
Paleozoic	Pp	Carbonate
	Par	Carbonate
	P*	Carbonate
	MD	Carbonate
	Du	Carbonate
	Ds	Carbonate
	Ol	Carbonate
	Cc	Carbonate
	Cu	Carbonate
	Cm	Carbonate
	CpCs	Basement

---

[1] Units were grouped as of Paleozoic Basement, Paleozoic Carbonate Rocks, Mesozoic Sedimentary Rocks, Cenozoic Volcanic Rocks, or Cenozoic Basin Fill

Lower Ordovician? to Upper Cambrian (Cu)

- This unit was grouped as Paleozoic Carbonate Rock based on rock type (undivided limestone and shale) and map contacts. Cu was in contact with numerous other rock units grouped as Paleozoic Carbonate Rocks, and was observed in the surrounding ranges.

Cambrian (Cc)

- Cc was grouped as Paleozoic Carbonate Rock based on the rock type (undivided carbonate sedimentary rock).

Middle to Lower Ordovician (Ol)

- Ol was grouped as Paleozoic Carbonate Rock. Although this unit is composed largely of quartzite, two dolomite formations (Laketown and Ely Springs) are present in the LWRFS allowing this unit to be grouped with the Paleozoic Carbonate Rock unit.

Middle to Lower Devonian (Ds)

- Ds was grouped as Paleozoic Carbonate Rock due to rock type (undivided dolomite).

Devonian (Du)

- Like Ds, this geologic unit was grouped as Paleozoic Carbonate Rock based on its rock type (undivided carbonate sedimentary rocks).

Lower Mississippian to Upper Devonian (MD)

- This unit was grouped as Paleozoic Carbonate Rock based on rock type. In the LWRFS MD is composed primarily of limestone.

Lower Permian to Pennsylvanian (P*)

- P* was grouped with Paleozoic Carbonate Rock based on rock type (limestone).

Lower Permian (Par)

- Par was included with Paleozoic Carbonate Rock although it is not carbonate. Par is an undivided sandstone unit within the carbonate rock aquifer (Rowley, et al., 2017). Due to its inclusion within the carbonate aquifer, Par was grouped with carbonate rocks.

Upper and Lower Permian (Pp)

- This unit was included with Paleozoic Carbonate Rock based on rock type as well as the unit's water-bearing properties. This unit is composed of limestone and marks the top of the carbonate aquifer (Rowley et al., 2017).

3.0. MESOZOIC SEDIMENTARY ROCKS

Mesozoic sedimentary rocks found in the LWRFS were grouped as a separate unit. This decision was made based on the unit's age and low-permeability. Mesozoic Sedimentary Rocks found in the LWRFS include Triassic (TRs), Jurassic (Ji), and Upper and Lower Cretaceous (Ks). These units are composed of clastic, fluvial deposits.

4.0. CENOZOIC VOLCANIC AND BASIN FILL ROCK UNITS

Cenozoic rock units observed in the LWRFS were grouped as Cenozoic Volcanic Rocks or Cenozoic Basin Fill. The grouping of units was based on rock type as well as water-bearing properties. Volcanic Rocks observed in the LWRFS are the result of surrounding caldera complexes and compose the volcanic rock aquifer. The remaining basin fill observed in the LWRFS formed as a result of fluvial deposits, and compose the alluvial aquifer.

Miocene to Paleocene (Ti)

- Ti was grouped as Cenozoic Volcanic Rock based on rock type and map contacts. Ti is an intrusive pluton formed from the intrusion of magma into another rock body. This rock unit was grouped with Cenozoic Volcanic Rocks because plutonic and volcanic rocks form through similar processes, however plutonic rocks cool underground whereas volcanic rocks cool above ground.

Miocene (Ta4)

- Ta4 was grouped as Cenozoic Volcanic Rock based on rock type. This unit is composed of lava flows.

Oligocene (Tt2), Miocene to Oligocene (Tt3), and Miocene (Tt4)

- Tt2, Tt3, and Tt4 were grouped as Cenozoic Volcanic Rock based on rock type. All three units are poorly to densely welded ash-flow tuffs with interbedded ash-fall tuffs.

Miocene (Ts4)

- Ts4 was grouped a Cenozoic Basin Fill based on Rowley, et al.'s (2017) definition of Ts4 as "a basal basin-fill sedimentary unit."

Holocene to lower Miocene (QTb)

- QTb is the final unit observed in the LWRFS grouped as Cenozoic Volcanic Rock. Rowley, et al. (2017) stated QTb is "The mafic end of the bimodal volcanic sequence."

Holocene to lower Miocene (QTa)

- QTa was grouped as the final Cenozoic Basin Fill unit observed in the LWRFS. This unit was formed through fluvial processes and forms the alluvial aquifer.

5.0. REFERENCES

Rowley, P.D., Dixon, G.L., Mankinen, E.A., Pari, K.T., McPhee, D.K., McKee, E.H., Burns, A.G., Watrus, J.M., Ekren, E.B., Patrick, W.G., and Brandt, J.M., 2017, Geology and geophysics of White Pine and Lincoln Counties, Nevada, and adjacent parts of Nevada and Utah: The geologic framework of regional groundwater flow systems: Nevada Bureau of Mines and Geology Report 56.

Appendix B

Hydrologic and Physical Properties of Rocks

Telford, W.M, Geldart, L.P., Sheriff, R.E., Keys, D.A., 1976. Applied Geophysics. Cambridge University Press. pp 454-455.

Ore	Other minerals	Gangue	$\rho(\Omega m)$
Graphitic slate			0·13
Graphite, massive			10^{-4}–5×10^{-3}
MoS_2			2×10^{2}–4×10^{3}
MnO_2 colloidal ore			1·6
Cu_2S			3×10^{-2}
$CuFeS_2$			10^{-4}–1
$CuFeS_2$ 80%	10% FeS	10%	0·66
$CuFeS_2$ 90%	2% FeS	8% SiO_2	0·65
$FeCr_2O_4$			10^{3}
$FeCr_2O_4$ 95%		5% Serp.	$1{\cdot}2 \times 10^{4}$

Tables 5.4 and 5.5 list typical values for rocks and unconsolidated formations. The ranges here are quite similar to water, which obviously is the controlling factor in many rocks.

Table 5.4. *Resistivities of igneous and metamorphic rocks*

Rock type	Resistivity range (Ωm)
Granite	3×10^{2}–10^{6}
Granite porphyry	$4{\cdot}5 \times 10^{3}$ (wet)–$1{\cdot}3 \times 10^{6}$ (dry)
Feldspar porphyry	4×10^{3} (wet)
Albite	3×10^{2} (wet)–$3{\cdot}3 \times 10^{3}$ (dry)
Syenite	10^{2}–10^{6}
Diorite	10^{4}–10^{5}
Diorite porphyry	$1{\cdot}9 \times 10^{3}$ (wet)–$2{\cdot}8 \times 10^{4}$ (dry)
Porphyrite	10–5×10^{4} (wet)–$3{\cdot}3 \times 10^{3}$ (dry)
Carbonatized porphyry	$2{\cdot}5 \times 10^{3}$ (wet)–6×10^{4} (dry)
Quartz porphyry	3×10^{2}–9×10^{5}
Quartz diorite	2×10^{4}–2×10^{6} (wet)–$1{\cdot}8 \times 10^{5}$ (dry)
Porphyry (various)	60–10^{4}
Dacite	2×10^{4} (wet)
Andesite	$4{\cdot}5 \times 10^{4}$ (wet)–$1{\cdot}7 \times 10^{2}$ (dry)
Diabase porphyry	10^{3} (wet)–$1{\cdot}7 \times 10^{5}$ (dry)
Diabase (various)	20–5×10^{7}
Lavas	10^{2}–5×10^{4}
Gabbro	10^{3}–10^{6}
Basalt	10–$1{\cdot}3 \times 10^{7}$ (dry)
Olivine norite	10^{3}–6×10^{4} (wet)
Peridotite	3×10^{3} (wet)–$6{\cdot}5 \times 10^{3}$ (dry)
Hornfels	8×10^{3} (wet)–6×10^{7} (dry)
Schists (calcareous and mica)	20–10^{4}
Tuffs	2×10^{3} (wet)–10^{5} (dry)
Graphite schist	10–10^{2}
Slates (various)	6×10^{2}–4×10^{7}
Gneiss (various)	$6{\cdot}8 \times 10^{4}$ (wet)–3×10^{6} (dry)
Marble	10^{2}–$2{\cdot}5 \times 10^{8}$ (dry)
Skarn	$2{\cdot}5 \times 10^{2}$ (wet)–$2{\cdot}5 \times 10^{8}$ (dry)
Quartzites (various)	10–2×10^{8}

Table 5.5. *Resistivities of sediments*

Rock type	Resistivity range (Ωm)
Consolidated shales	20–2×10^{3}
Argillites	10–8×10^{2}
Conglomerates	2×10^{3}–10^{4}
Sandstones	1–$6{\cdot}4 \times 10^{8}$
Limestones	50–10^{7}
Dolomite	$3{\cdot}5 \times 10^{2}$–5×10^{3}
Unconsolidated wet clay	20
Marls	3–70
Clays	1–100
Alluvium and sands	10–800
Oil sands	4–800

Very roughly, igneous rocks have the highest resistivity, sediments the lowest, with metamorphic rocks intermediate. However, there is considerable overlapping, as in other physical properties. In addition, the resistivities of particular rock types vary directly with age and lithology, since the porosity of the rock and salinity of the contained water are affected by both. For example, the resistivity range of Precambrian volcanics is 200–5000 Ωm, while for Quaternary rocks of the same kind it is 10–200 Ωm.

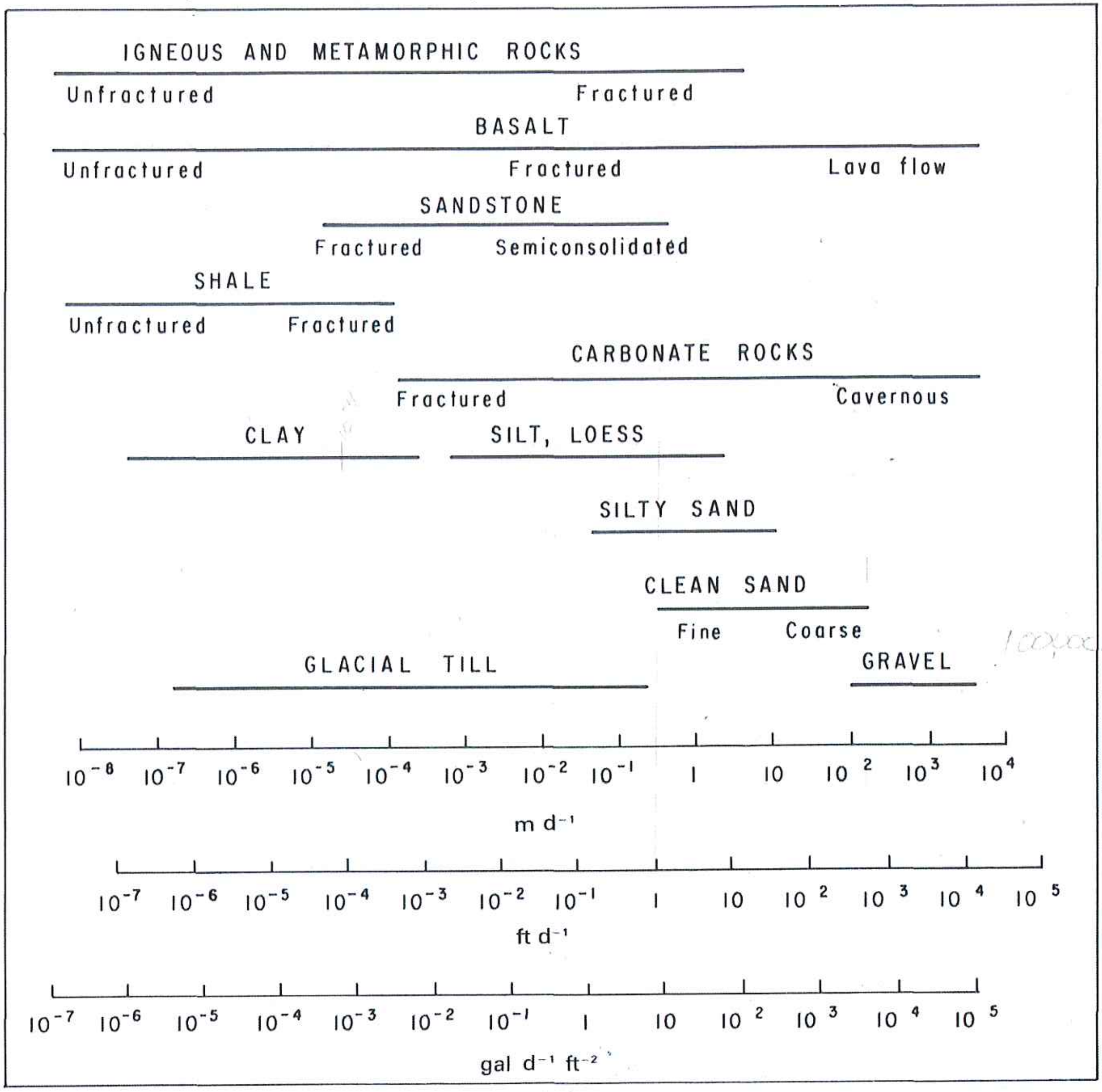
The effect of water content on the bulk resistivity of rocks has been frequently mentioned and is evident from table 5.4. Further data are listed in table 5.6, where samples with variable amounts of water are shown. In all cases a small change in the percentage of water effects the resistivity enormously.

Table 5.6. *Variation of rock resistivity with water content*

Rock	% H_2O	$\rho(\Omega m)$	Rock	% H_2O	$\rho(\Omega m)$
Siltstone	0·54	$1{\cdot}5 \times 10^{4}$	Pyrophyllite	0·76	6×10^{6}
Siltstone	0·44	$8{\cdot}4 \times 10^{6}$	Pyrophyllite	0·72	5×10^{7}
Siltstone	0·38	$5{\cdot}6 \times 10^{8}$	Pyrophyllite	0·7	2×10^{8}
Coarse grain SS	0·39	$9{\cdot}6 \times 10^{5}$	Pyrophyllite	0	10^{11}
Coarse grain SS	0·18	10^{8}	Granite	0·31	$4{\cdot}4 \times 10^{3}$
Medium grain SS	1·0	$4{\cdot}2 \times 10^{3}$	Granite	0·19	$1{\cdot}8 \times 10^{6}$
Medium grain SS	1·67	$3{\cdot}2 \times 10^{6}$	Granite	0·06	$1{\cdot}3 \times 10^{8}$
Medium grain SS	0·1	$1{\cdot}4 \times 10^{8}$	Granite	0	10^{10}
Graywacke SS	1·16	$4{\cdot}7 \times 10^{3}$	Diorite	0·02	$5{\cdot}8 \times 10^{5}$
Graywacke SS	0·45	$5{\cdot}8 \times 10^{4}$	Diorite	0	6×10^{6}
Arkosic SS	1·26	10^{3}	Basalt	0·95	4×10^{4}
Arkosic SS	1·0	$1{\cdot}4 \times 10^{3}$	Basalt	0·49	9×10^{5}
Organic limestone	11	$0{\cdot}6 \times 10^{3}$	Basalt	0·26	3×10^{7}
Dolomite	2	$5{\cdot}3 \times 10^{3}$	Basalt	0	$1{\cdot}3 \times 10^{8}$
Dolomite	1·3	6×10^{3}	Olivine-pyrox.	0·028	2×10^{4}
Dolomite	0·96	8×10^{3}	Olivine-pyrox.	0·014	4×10^{5}
Peridotite	0·1	3×10^{3}	Olivine-pyrox.	0	$5{\cdot}6 \times 10^{7}$
Peridotite	0·03	2×10^{4}			
Peridotite	0·016	10^{6}			
Peridotite	0	$1{\cdot}8 \times 10^{7}$			

U.S. Geological Survey, 1989. Basic Ground-Water Hydrology. U.S. Geological Survey Water Supply Page 2220. pp. 13, 36, 37.

Hydraulic Conductivity of Selected Rocks



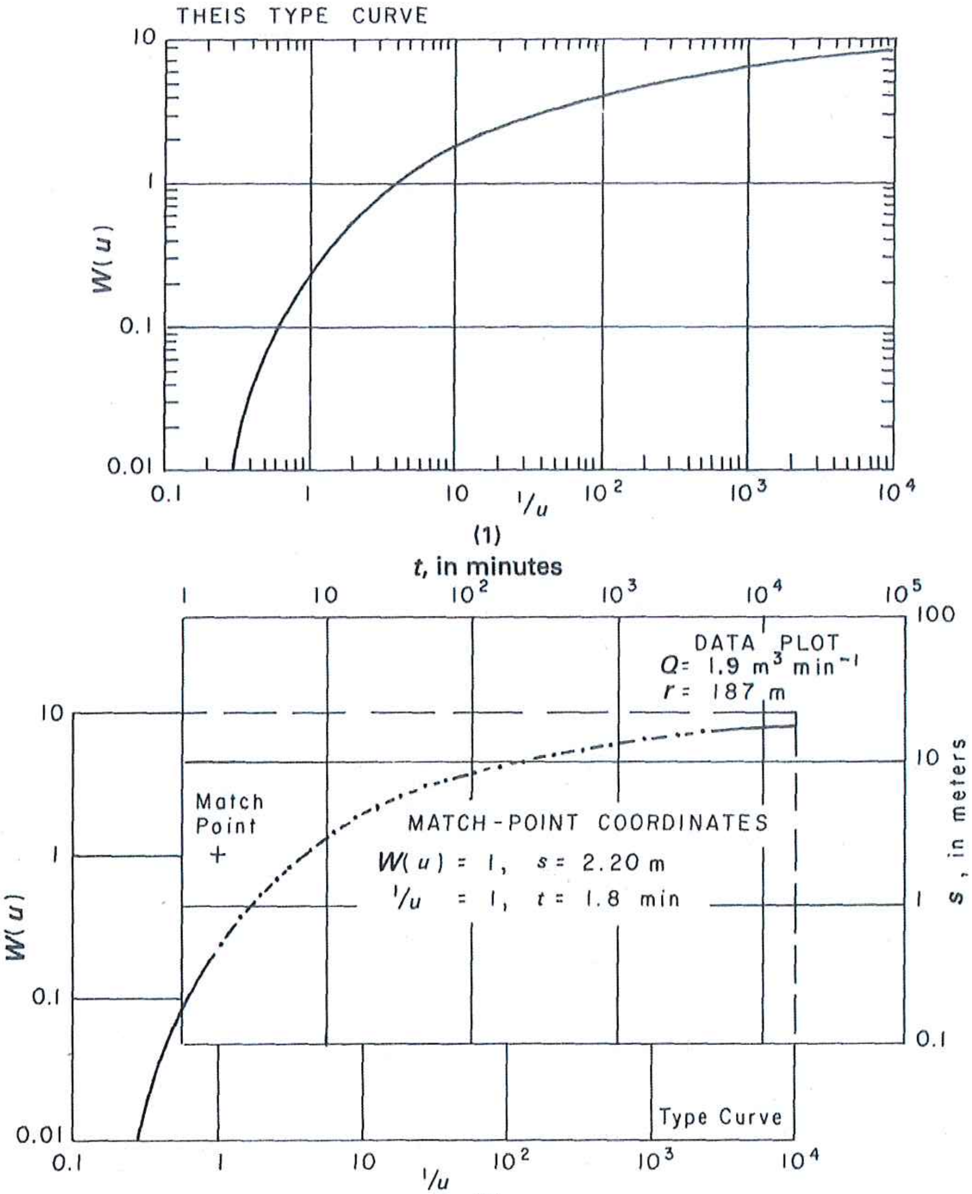
(2)

that area is said to be *homogeneous*. If, on the other hand, the hydraulic conductivity differs from one part of the area to another, the aquifer is said to be *heterogeneous*.

Hydraulic conductivity may also be different in different directions at any place in an aquifer. If the hydraulic conductivity is essentially the same in all directions, the aquifer is said to be *isotropic*. If it is different in different directions, the aquifer is said to be *anisotropic*.

Although it is convenient in many mathematical analyses of ground-water flow to assume that aquifers are both homogeneous and isotropic, such aquifers are rare, if they exist at all. The condition most commonly encountered is for hydraulic conductivity in most rocks and especially in unconsolidated deposits and in flat-lying consolidated sedimentary rocks to be larger in the horizontal direction than it is in the vertical direction.

ANALYSIS OF AQUIFER-TEST DATA



(1)

(2)

In 1935, C. V. Theis of the New Mexico Water Resources District of the U.S. Geological Survey developed the first equation to include time of pumping as a factor that could be used to analyze the effect of withdrawals from a well. Thus, the *Theis equation* permitted, for the first time, determination of the hydraulic characteristics of an aquifer before the development of new steady-state conditions resulting from pumping. The importance of this capability may be realized from the fact that, under most conditions, a new steady state cannot be developed or that, if it can, many months or years may be required.

Theis assumed in the development of the equation that:

1. The transmissivity of the aquifer tapped by the pumping well is constant during the test to the limits of the cone of depression.
2. The water withdrawn from the aquifer is derived entirely from storage and is discharged instantaneously with the decline in head.
3. The discharging well penetrates the entire thickness of the aquifer, and its diameter is small in comparison with the pumping rate, so that storage in the well is negligible.

These assumptions are most nearly met by confined aquifers at sites remote from their boundaries. However, if certain precautions are observed, the equation can also be used to analyze tests of unconfined aquifers.

The forms of the Theis equation used to determine the transmissivity and storage coefficient are

$$T = \frac{Q\,W(u)}{4\pi s} \tag{1}$$

$$S = \frac{4Ttu}{r^2} \tag{2}$$

where T is transmissivity, S is the storage coefficient, Q is the pumping rate, s is drawdown, t is time, r is the distance from the pumping well to the observation well, $W(u)$ is the well function of u, which equals

$$-0.577216 - \log_e u + u - \frac{u^2}{2\times 2!} + \frac{u^3}{3\times 3!} - \frac{u^4}{4\times 4!} + \ldots$$

and $u = (r^2S)/(4Tt)$.

The form of the Theis equation is such that it cannot be solved directly. To overcome this problem, Theis devised a convenient graphic method of solution that involves the use of a *type curve* (1). To apply this method, a data plot of drawdown versus time (or drawdown versus t/r^2) is matched to the type curve of $W(u)$ versus $1/u$ (2). At some convenient point on the overlapping part of the sheets containing the data plot and type curve, values of s, t (or t/r^2), $W(u)$, and $1/u$ are noted (2). These values are then substituted in equations 1 and 2, which are solved for T and S, respectively.

A Theis type curve of $W(u)$ versus $1/u$ can be prepared from the values given in the table contained in the preceding section, "Aquifer Tests." The data points are plotted on logarithmic graph paper—that is, graph paper having logarithmic divisions in both the x and y directions.

The dimensional units of transmissivity (T) are L^2t^{-1}, where L is length and t is time in days. Thus, if Q in equation 1 is in cubic meters per day and s is in meters, T will be in square meters per day. Similarly, if, in equation 2, T is in square meters per day, t is in days, and r is in meters, S will be dimensionless.

Traditionally, in the United States, T has been expressed in units of gallons per day per foot. The common practice now is to report transmissivity in units of square meters per day or square feet per day. If Q is measured in gallons per minute, as is still normally the case, and drawdown is measured in feet, as is also normally the case, equation 1 is modified to obtain T in square feet per day as follows:

$$T = \frac{Q\,W(u)}{4\pi s} = \frac{\text{gal}}{\text{min}} \times \frac{1{,}440\ \text{min}}{\text{d}} \times \frac{\text{ft}^3}{7.48\ \text{gal}} \times \frac{1}{\text{ft}} \times \frac{W(u)}{4\pi}$$

or

$$T(\text{in ft}^2\ \text{d}^{-1}) = \frac{15.3Q\,W(u)}{s}$$

(when Q is in gallons per minute and s is in feet). To convert square feet per day to square meters per day, divide by 10.76.

The storage coefficient is dimensionless. Therefore, if T is in square feet per day, t is in minutes, and r is in feet, then, by equation 2,

$$S = \frac{4Ttu}{r^2} = \frac{4}{1} \times \frac{\text{ft}^2}{\text{d}} \times \frac{\text{min}}{\text{ft}^2} \times \frac{\text{d}}{1{,}440\ \text{min}}$$

or

$$S = \frac{Ttu}{360\,r^2}$$

(when T is in square feet per day, t is in minutes, and r is in feet).

Analysis of aquifer-test data using the Theis equation involves plotting both the type curve and the test data on logarithmic graph paper. If the aquifer and the conditions of the test satisfy Theis's assumptions, the type curve has the same shape as the cone of depression along any line radiating away from the pumping well and the drawdown graph at any point in the cone of depression.

Use of the Theis equation for unconfined aquifers involves two considerations. First, if the aquifer is relatively fine grained, water is released slowly over a period of hours or days, not instantaneously with the decline in head. Therefore, the value of S determined from a short-period test may be too small.

Second, if the pumping rate is large and the observation well is near the pumping well, dewatering of the aquifer may be significant, and the assumption that the transmissivity of the aquifer is constant is not satisfied. The effect of dewatering of the aquifer can be eliminated with the following equation:

$$s' = s - \left(\frac{s^2}{2b}\right) \tag{3}$$

where s is the observed drawdown in the unconfined aquifer, b is the aquifer thickness, and s' is the drawdown that would have occurred if the aquifer had been confined (that is, if no dewatering had occurred).

To determine the transmissivity and storage coefficient of an unconfined aquifer, a data plot consisting of s' versus t (or t/r^2) is matched with the Theis type curve of $W(u)$ versus $1/u$. Both s and b in equation 3 must be in the same units, either feet or meters.

As noted above, Theis assumed in the development of his equation that the discharging well penetrates the entire thickness of the aquifer. However, because it is not always possible, or necessarily desirable, to design a well that fully penetrates the aquifer under development, most discharging wells are open to only a part of the aquifer that they draw from. Such *partial penetration* creates vertical flow in the vicinity of the discharging well that may affect drawdowns in observation wells located relatively close to the discharging well. Drawdowns in observation wells that are open to the same zone as the discharging well will be larger than the drawdowns in wells at the same distance from the discharging well but open to other zones. The possible effect of partial penetration on drawdowns must be considered in the analysis of aquifer-test data. If aquifer-boundary and other conditions permit, the problem can be avoided by locating observation wells beyond the zone in which vertical flow exists.

Appendix C

Estimates of Recharge, Evapotranspiration, and Groundwater Flow in the LWRFS

Appendix C - Estimates of Recharge, ET, and GW Outflow in the LWRFS

LWRFS Local Recharge (AFY)

	Basin						
Source	CSV	MRSA	HV	GV	CW	BMA	**Total[g]**
Recon	2,000	0	400	400	100	100	**2,900**
Eakin 1966[a]	2,600	0	400	400	100	100	**3,500**
NDWR 1971	1,900	100	400	400	100	100	**2,900**
Kirk 1990[b]	5,014	NE	NE	NE	NE	NE	**5,014**
Kirk 1990[c]	6,012	NE	NE	NE	NE	NE	**6,012**
USGS 1996	14,000	NE	NE	NE	NE	NE	**14,000**
DRI 2001	4,000	300	300	400	300	500	**5,300**
LVVWD 2001	4,000	237	339	393	311	438	**5,280**
BCM 2004[d]	5,184	12	188	294	23	54	**5,701**
BCM 2004[e]	5,951	207	571	1,000	652	1,470	**8,381**
Epstein 2004[f]	5,815	509	521	976	1,738	3,178	**9,559**
USGS 2004	2,100	NE	400	400	60	70	**2,960**
DRI 2007	2,300	0	0	100	0	0	**2,400**
SNWA 2007	2,128	38	42	96	0	0	**2,304**
SNWA 2009	2,215	41	45	101	0	0	**2,402**
Min	*1,900*	*0*	*0*	*96*	*0*	*0*	***1,996***
Max	*14,000*	*509*	*571*	*1,000*	*1,738*	*3,178*	***17,818***
Mean	*4,348*	*131*	*301*	*413*	*282*	*501*	***5,475***

Notes:

(a) Eakin (1966) includes KSV in the local recharge estimate for CSV. This is not acknowledged in several studies which cite the 2,600 AF value.

(b) Results of Scenarios 1 and 3

(c) Results of Scenario 2

(d) Mean value of Basin Characterization Model

(e) Time series result of Basin Characterization Model

(f) Based on Bootstrap Brute-Force Model

(g) Total does not include BMA, as most of the area is not included in the LWRFS. BMA values included in table for reference.

Abbreviations:

CSV	Coyote Spring Valley	LMV	Lower Moapa Valley
MRSA	Muddy River Springs Area	PV	Pahranagat Valley
HV	Hidden Valley	DV	Delamar Valley
GV	Garnet Valley	KSV	Kane Springs Valley
CW	California Wash	LMVW	Lower Meadow Valley Wash
BMA	Black Mountains Area	NE	Not estimated

Appendix C - Estimates of Recharge, ET, and GW Outflow in the LWRFS

LWRFS GW Inflow (AFY)

Source	Basin PV to CSV	DV to CSV	KSV to CSV	LMVW to MRSA	LMVW to CW	LMVW to LMV	**Total[a]**
Recon	37,300	0	600	0	12,700	0	**50,600**
NDWR 1971	35,000	0	0	0	7,000	0	**42,000**
DRI 2001	28,000	16,000	6,000	0	0	32,000	**50,000**
LVVWD 2001	28,000	16,000	6,000	0	0	32,000	**50,000**
USGS 2004	NE	900	NE	0	7,000	0	**7,900**
DRI 2007	20,400	25,500	4,500	4,000	5,200	0	**59,600**
SNWA 2007	22,443	24,068	4,189	4,000	5,200	0	**59,900**
SNWA 2011	NE	24,800	NE	NE	NE	NE	**24,800**
Min	*20,400*	*0*	*0*	*0*	*0*	*0*	***20,400***
Max	*37,300*	*25,500*	*6,000*	*4,000*	*12,700*	*32,000*	***85,500***
Mean	*28,524*	*13,409*	*3,548*	*1,143*	*5,300*	*9,143*	***51,923***

Note:

(a) Total does not include inflow to LMV as it is not part of the LWRFS. LMV to Lake Mead values included for reference.

LWRFS ET (AFY)

Source	Basin CSV	MRSA	HV	GV	CW	BMA	**Total[a]**
Recon	500	0	0	0	1,000	0	**1,500**
NDWR 1971	NE	NE	0	0	1,700	1,200	**2,900**
DRI 2001	1,000	5,000	0	0	5,000	2,000	**13,000**
LVVWD 2001	1,000	5,080	0	0	5,760	2,000	**13,840**
DRI 2007	0	6,000	0	0	4,500	1,400	**11,900**
SNWA 2007	0	5,989	0	0	4,505	1,432	**11,926**
DeMeo 2008	NE	4,090	NE	NE	6,080	1,952	**12,122**
SNWA 2009	NE	5,998	NE	NE	4,506	1,432	**11,936**
Min	*0*	*0*	*0*	*0*	*1,000*	*0*	***1,000***
Max	*1,000*	*6,000*	*0*	*0*	*6,080*	*2,000*	***15,080***
Mean	*500*	*4,594*	*0*	*0*	*4,131*	*1,427*	***10,652***

Abbreviations:

CSV	Coyote Spring Valley	LMV	Lower Moapa Valley
MRSA	Muddy River Springs Area	PV	Pahranagat Valley
HV	Hidden Valley	DV	Delamar Valley
GV	Garnet Valley	KSV	Kane Springs Valley
CW	California Wash	LMVW	Lower Meadow Valley Wash
BMA	Black Mountains Area	NE	Not estimated

Appendix C - Estimates of Recharge, ET, and GW Outflow in the LWRFS

LWRFS GW Outflow (AFY)

	Basin				
Source	CW to BMA	CW to LMV	MRSA to LMV	LMV to Lake Mead	**Total**[a]
Recon	0	21,300	0	21,100	**21,300**
NDWR 1971	0	0	0	1,100	**0**
DRI 2001	4,000	8,000	0	26,000	**12,000**
LVVWD 2001	2,300	41,000	0	48,000	**43,300**
USGS 2004	NE	NE	NE	1,100	**0**
DRI 2007	2,000	18,800	0	17,200	**20,800**
SNWA 2007	2,000	49,711	0	24,432	**51,711**
SNWA 2009	NE	NE	NE	10,808	**0**
Min	*0*	*0*	*0*	*1,100*	***0***
Max	*4,000*	*49,711*	*0*	*48,000*	***53,711***
Mean	*1,717*	*23,135*	*0*	*18,718*	***24,852***

Note:

(a) Total does not include outflow from LMV as it is not part of the LWRFS. LMV to Lake Mead values included for reference.

Abbreviations:

CSV	Coyote Spring Valley	LMV	Lower Moapa Valley
MRSA	Muddy River Springs Area	PV	Pahranagat Valley
HV	Hidden Valley	DV	Delamar Valley
GV	Garnet Valley	KSV	Kane Springs Valley
CW	California Wash	LMVW	Lower Meadow Valley Wash
BMA	Black Mountains Area	NE	Not estimated

Appendix C - Estimates of Recharge, ET, and GW Outflow in the LWRFS

Sources

Eakin 1966	Eakin, T. E., 1966, A regional interbasin ground-water system in the White River area, southeastern Nevada: U. S. Geological Survey Water Resources Research, Vol. 2, No. 2, pp 251-271.
NDWR 1971	Nevada Division of Water Resources, 1971. Nevada's Water Resources, prepared by: Nevada State Engineer, Water for Nevada Report No. 3, 97 p.
Kirk 1990	Kirk, S. T., and M. E. Campana, 1990. A deuterium-calibrated groundwater flow model of a regional carbonate-alluvial system: Journal of Hydrology 119, pp 337-388.
USGS 1996	Thomas, J. M., A. H. Welch, and M. D. Dettinger, 1996. Geochemistry and isotope hydrology of representative aquifers in the Great Basin Region of Nevada, Utah, and adjacent states: U. S. Geological Survey Professional Paper 1409-C, 110 p.
DRI 2001	Thomas, J. M., S. C. Calhoun, and W. B. Apambire, 2001, A Deuterium mass-balance interpretation of groundwater sources and flows in southeastern Nevada: prepared for Las Vegas Valley Water District. Desert Research Institute, Nevada, Publication No. 41169, 52 p.
LVVWD 2001	Las Vegas Valley Water District, 2001, Water resources and ground-water modeling in the White River and Meadow Valley Flow Systems, Clark, Lincoln, Nye, and White Pine Counties, Nevada: Las Vegas Valley Water District, Las Vegas, Nevada, 250 p.
BCM 2004	Flint, A. L., L. E. Flint. J. A. Hevesi, and J. M. Blainey, 2004, Fundamental concepts of recharge in the Desert Southwest – A regional modeling perspective: pp.159-184 in Hogan, J. F., Phillips, F. M., and Scanlon, B. R., eds. Ground-water recharge in a desert environment – The southwestern United States: American Geophysical Union, Water and Science Applications Series Vol. 9 294 p.
Epstein 2004	Epstein, B. J., 2004, Development of Uncertainty Analysis of Empirical Recharge Prediction Models for Nevada's Desert Basins, University of Nevada Reno M. S. Thesis, 204p.
USGS 2004	Lopes, T. J., and D. M. Evetts, 2004, Ground-water pumpage and artificial recharge estimates for calendar year 2000 and average annual natural recharge and interbasin flow by hydrographic area, Nevada: U.S. Geological Survey Investigations Report 2004-5239, Carson City, Nevada, 87 p.
DRI 2007	Thomas J. M.and T. M. Mihevic, 2007, Stable Isotope Evaluation of Water Budgets for the White River and Meadow Valley Wash Regional Groundwater Flow Systems in East-Central and Southeastern Nevada, Letter Report, 189 p.
SNWA 2007	Southern Nevada Water Authority, 2007, Water Resources Assessment and Hydrogeologic Report for Cave, Dry Lake and Delamar Valleys, Presentation to the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada, 352 p.
SNWA 2009	Southern Nevada Water Authority, 2009, Conceptual model of groundwater flow for the Central Carbonate Rock Province: Clark, Lincoln, and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Veegas, Nevada, 416 p.
DeMeo 2008	DeMeo, G.A., Smith, J.L., Damar, N.A., and Darnell, J., 2008, Quantifying ground-water and surface-water discharge from evapotranspiration processes in 12 hydrographic areas of the Colorado Regional Ground-Water Flow System, Nevada, Utah, and Arizona: U.S. Geological Survey Scientific Investigations Report 2008-5116, 34 p.
SNWA 2011	Burns A.G. and W. Drici, 2011. Hydrology and water resources of Spring, Cave, Dry Lake, and Delamar valleys, Nevada and vicinity: Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada, 313 p.
Recon*	Estimates from the reconnaissance series reports; Cited from secondary source; DRI 2007 (Figure 14)

Appendix D

Supporting Calculations for Coyote Spring Valley Recharge Estimates

Table D-1. Estimate of Recharge using Elevation Bands and Precipitation-Elevation relationship from Eakin, 1966

	Recharge Zone and Name	Area by Elevation Band (acres)					Average Precipitation by Band (in/yr)					Precipitation Volume (ac-ft)					Recharge by Band (ac-ft/yr)					Estimated Annual Recharge (ac-ft)	
							Precipitation (in/yr) by band (Eakin, 1964):										Recharge coefficients from Maxey-Eakin (1949):						
							varies	10	13.5	17.5	21						0	0.03	0.07	0.15	0.25		
							Source: Eakin, 1966																
		< 6000 ft	6000-7000 ft	7000-8000 ft	8000-9000 ft	>9000 ft	< 6000 ft	6000-7000 ft	7000-8000 ft	8000-9000 ft	>9000 ft	< 6000 ft	6000-7000 ft	7000-8000 ft	8000-9000 ft	>9000 ft	< 6000 ft	6000-7000 ft	7000-8000 ft	8000-9000 ft	>9000 ft	Total	Rounded
1	Evergreen Flat	9,841	0	0	0	0	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	0	0
2	Pahranagat Wash A	4,575	0	0	0	0	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	0	0
3	Coyote Spring Valley A	25,874	973	54	0	0	–	10.0	13.5	–	–	–	808	61	–	–	0	24	4	–	–	28	30
4	Coyote Spring Valley B	23,429	2,456	531	0	0	–	10.0	13.5	–	–	–	2,039	597	–	–	0	61	42	–	–	103	100
5	Cherry Spring	11,522	1,291	325	0	0	–	10.0	13.5	–	–	–	1,071	366	–	–	0	32	26	–	–	58	60
6	Grapevine Spring	11,370	771	329	30	0	–	10.0	13.5	17.5	–	–	640	370	44	–	0	19	26	7	–	52	50
7	Pahranagat Wash B	8,292	215	57	2	0	–	10.0	13.5	17.5	–	–	178	64	3	–	0	5	4	0	–	10	10
8	Perkins Spring	17,977	2,034	797	32	0	–	10.0	13.5	17.5	–	–	1,688	897	46	–	0	51	63	7	–	120	120
9	Sawmill Wash	19,146	10,576	6,405	1,465	177	–	10.0	13.5	17.5	21.0	–	8,778	7,206	2,139	310	0	263	504	321	77	1,166	1,170
10	Las Vegas Range A	7,504	0	0	0	0	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	0	0
11	Las Vegas Range B	3,530	0	0	0	0	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	0	0
12	Wamp Spring	25,253	2,132	0	0	0	–	10.0	–	–	–	–	1,769	–	–	–	0	53	–	–	–	53	50
13	Hidden Valley A	25,198	832	0	0	0	–	10.0	–	–	–	–	691	–	–	–	0	21	–	–	–	21	20
14	Hidden Valley B	28,009	1,381	0	0	0	–	10.0	–	–	–	–	1,146	–	–	–	0	34	–	–	–	34	30
15	Dry Lake	7,219	0	0	0	0	–	–	–	–	–	–	–	–	–	–	0	–	–	–	–	0	0
	Subtotal by zone	228,737	22,661	8,498	1,529	177						0	18,808	9,560	2,232	310	0	564	669	335	77	1,646	1,640
	Total			total, acres		261,601								total, ac-ft		30,910							
				total, sq mi		409																	

Table D-2. Estimate of Recharge using Precipitation Bands and Recharge Coefficients from Maxey and Eakin (1949)

														Recharge coefficients from Maxey-Eakin (1949):					
						Source: PRISM, 2015								0	0.03	0.07	0.15	Estimated Annual	
		Area by Precip Band (acres)				Average Precipitation by Band (in/yr)				Precipitation Volume (ac-ft)				Recharge by Band (ac-ft/yr)				Recharge (ac-ft/yr)	
Recharge Zone and Name		< 8"	8-12"	12-15"	15-20"	< 8"	8-12"	12-15"	15-20"	< 8"	8-12"	12-15"	15-20"	< 8"	8-12"	12-15"	15-20"	Total	Rounded
1	Evergreen Flat	7,317	2,523	0	0	6.6	8.7	--	--	4,000	1,836	--	--	0	55	--	--	55	60
2	Pahranagat Wash A	4,575	0	0	0	6.1	--	--	--	2,331	--	--	--	0.0	--	--	--	0	0
3	Coyote Spring Valley A	10,099	15,326	1,476	0	7.0	9.7	12.5	--	5,865	12,443	1,543	--	0.0	373	108	--	481	480
4	Coyote Spring Valley B	13,033	9,150	4,232	0	6.6	10.0	12.8	--	7,183	7,643	4,522	--	0.0	229	317	--	546	550
5	Cherry Spring	5,922	5,238	1,977	0	6.7	10.4	12.6	--	3,293	4,520	2,072	--	0.0	136	145	--	281	280
6	Grapevine Spring	6,629	4,391	1,480	0	6.6	10.2	13.9	--	3,663	3,721	1,717	--	0.0	112	120	--	232	230
7	Pahranagat Wash B	6,122	2,137	306	0	6.3	9.8	14.2	--	3,202	1,743	362	--	0.0	52	25	--	78	80
8	Perkins Spring	8,860	6,209	5,771	0	6.6	9.9	13.4	--	4,853	5,144	6,448	--	0.0	154	451	--	606	610
9	Sawmill Wash	2,211	9,768	20,761	5,029	7.5	10.0	13.3	15.6	1,382	8,165	22,939	6,558	0.0	245	1606	984	2,834	2,830
10	Las Vegas Range A	7,426	78	0	0	6.3	8.3	--	--	3,921	54	--	--	0.0	2	--	--	2	0
11	Las Vegas Range B	3,530	0	0	0	5.7	--	--	--	1,690	--	--	--	0.0	--	--	--	0	0
12	Wamp Spring	14,325	6,463	6,597	0	6.2	9.9	13.1	--	7,422	5,319	7,176	--	0.0	160	502	--	662	660
13	Hidden Valley A	16,975	4,441	4,614	0	5.9	9.9	13.3	--	8,343	3,649	5,102	--	0.0	109	357	--	467	470
14	Hidden Valley B	20,253	5,681	3,456	0	6.6	9.2	13.3	--	11,137	4,355	3,843	--	0.0	131	269	--	400	400
15	Dry Lake	7,219	0	0	0	5.4	--	--	--	3,259	--	--	--	0.0	--	--	--	0	0
	Subtotal by zone	134,495	71,406	50,670	5,029					71,546	58,593	55,724	6,558	0	1,758	3,901	984	6,642	6,650
	Total			total, acres	261,601							total, ac-ft	192,421						
				total, sq mi	409							avg, in/yr:	8.8						

Table D-3. Estimate of Recharge using Precipitation Bands and Recharge Coefficients from Nichols (2001)

					Source: PRISM, 2015								Recharge coefficients from Nichols (2000): 0	0.008	0.13	0.144	Estimated Annual	
	Area by Precip Band (acres)				Average Precipitation by Band (in/yr)				Precipitation Volume (ac-ft)				Recharge by Band (ac-ft/yr)				Recharge (ac-ft)	
Recharge Zone and Name	< 8"	8-12"	12-16"	16-20"	< 8"	8-12"	12-16"	16-20"	< 8"	8-12"	12-16"	16-20"	< 8"	8-12"	12-16"	16-20"	Total	Rounded
1 Evergreen Flat	7,317	2,523	0	0	6.6	8.7	--	--	4,000	1,836	--	--	0	15	--	--	15	10
2 Pahranagat Wash A	4,575	0	0	0	6.1	--	--	--	2,331	--	--	--	0	--	--	--	0	0
3 Coyote Spring Valley A	10,099	15,326	1,476	0	7.0	9.7	12.5	--	5,865	12,443	1,543	--	0	100	201	--	300	300
4 Coyote Spring Valley B	13,033	9,150	4,232	0	6.6	10.0	12.8	--	7,183	7,643	4,522	--	0	61	588	--	649	650
5 Cherry Spring	5,922	5,238	1,977	0	6.7	10.4	12.6	--	3,293	4,520	2,072	--	0	36	269	--	306	310
6 Grapevine Spring	6,629	4,391	1,480	0	6.6	10.2	13.9	--	3,663	3,721	1,717	--	0	30	223	--	253	250
7 Pahranagat Wash B	6,122	2,137	306	0	6.3	9.8	14.2	--	3,202	1,743	362	--	0	14	47	--	61	60
8 Perkins Spring	8,860	6,209	5,771	0	6.6	9.9	13.4	--	4,853	5,144	6,448	--	0	41	838	--	879	880
9 Sawmill Wash	2,211	9,768	24,708	1,083	7.5	10.0	13.6	16.2	1,382	8,165	28,040	1,459	0	65	3,645	210	3,921	3,920
10 Las Vegas Range A	7,426	78	0	0	6.3	8.3	--	--	3,921	54	--	--	0	0	--	--	0	0
11 Las Vegas Range B	3,530	0	0	0	5.7	--	--	--	1,690	--	--	--	0	--	--	--	0	0
12 Wamp Spring	14,325	6,463	6,597	0	6.2	9.9	13.1	--	7,422	5,319	7,176	--	0	43	933	--	975	980
13 Hidden Valley A	16,975	4,441	4,614	0	5.9	9.9	13.3	--	8,343	3,649	5,102	--	0	29	663	--	692	690
14 Hidden Valley B	20,253	5,681	3,456	0	6.6	9.2	13.3	--	11,137	4,355	3,843	--	0	35	500	--	534	530
15 Dry Lake	7,219	0	0	0	5.4	--	--	--	3,259	--	--	--	0	--	--	--	0	0
Subtotal by zone	134,495	71,406	54,617	1,083					71,546	58,593	60,825	1,459	0	469	7,907	210	8,586	8,580
Total			total, acres	261,601							total, ac-ft	192,424						
			total, sq mi	409							avg, in/yr:	8.8						

Table D-4. Estimate of Recharge using Precipitation Bands and Recharge Coefficients from Epstein (2004)

			Source: PRISM, 2015				Recharge coefficients from Epstein (2004):			
							0.019	0.049	Estimated Annual	
	Area by Precip Band (acres)		Average Precipitation by Band (in/yr)		Precipitation Volume (ac-ft)		Recharge by Band (ac-ft/yr)		Recharge (ac-ft)	
Recharge Zone and Name	< 10"	10-20"	< 10"	10-20"	< 10"	10-20"	< 10"	10-20"	Total	Rounded
1 Evergreen Flat	9,841	0	7.2	--	5,866	--	111	--	111	110
2 Pahranagat Wash A	4,575	0	6.1	--	2,331	--	44	--	44	40
3 Coyote Spring Valley A	19,418	7,483	7.9	11.3	12,836	7,059	244	346	590	590
4 Coyote Spring Valley B	17,582	8,834	7.3	11.8	10,663	8,694	203	426	629	630
5 Cherry Spring	7,940	5,198	7.1	11.7	4,728	5,049	90	247	337	340
6 Grapevine Spring	8,495	4,005	7.1	11.9	5,023	3,974	95	195	290	290
7 Pahranagat Wash B	7,211	1,354	6.6	11.6	3,994	1,304	76	64	140	140
8 Perkins Spring	11,658	9,182	7.0	12.5	6,820	9,530	130	467	597	600
9 Sawmill Wash	7,088	30,681	8.5	13.3	5,012	33,938	95	1,663	1,758	1,760
10 Las Vegas Range A	7,504	0	6.3	--	3,962	--	75	--	75	80
11 Las Vegas Range B	3,530	0	5.7	--	1,690	--	32	--	32	30
12 Wamp Spring	17,846	9,540	6.8	12.5	10,095	9,939	192	487	679	680
13 Hidden Valley A	19,524	6,505	6.2	12.5	10,159	6,753	193	331	524	520
14 Hidden Valley B	24,181	5,209	7.0	12.7	14,005	5,532	266	271	537	540
15 Dry Lake	7,219	0	5.4	--	3,259	--	62	--	62	60
Subtotal by zone	173,610	87,991			100,444	91,773	1,908	4,497	6,405	6,410
Total		total, acres 261,601				total, ac-ft 192,217				
		total, sq mi 409				avg, in/yr: 8.8				

Appendix E

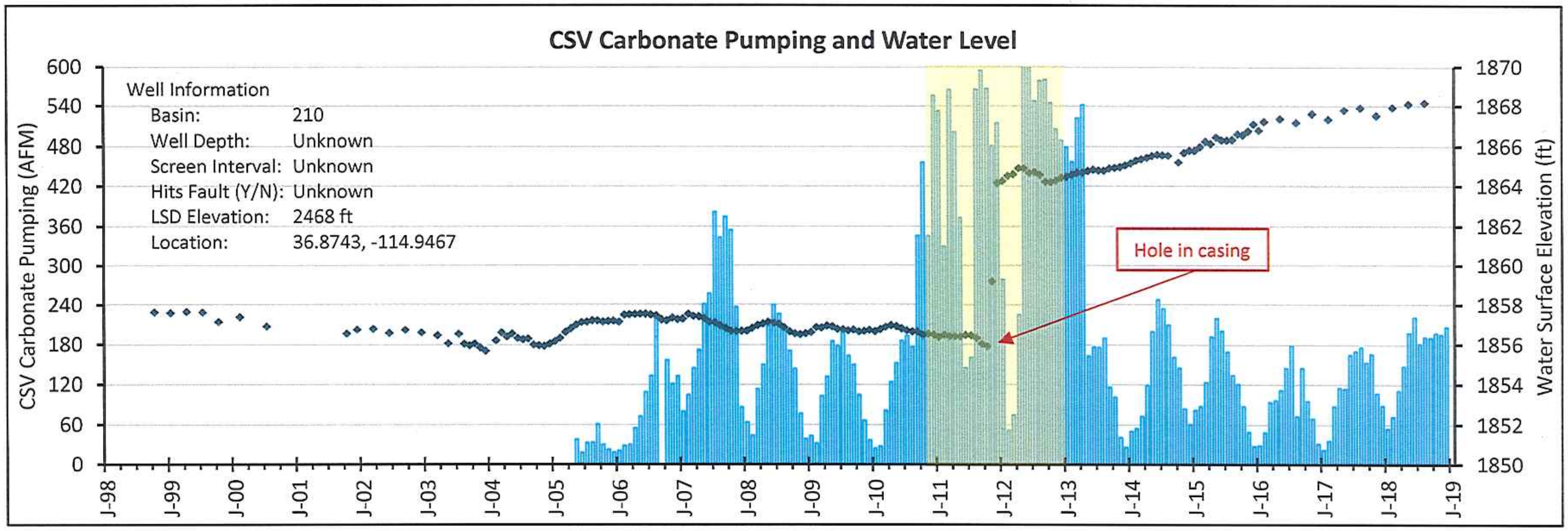
Supporting Groundwater Level and Pumping Graphs

Carbonate Aquifer Monitoring Wells
Coyote Spring Valley and Muddy River Springs Area

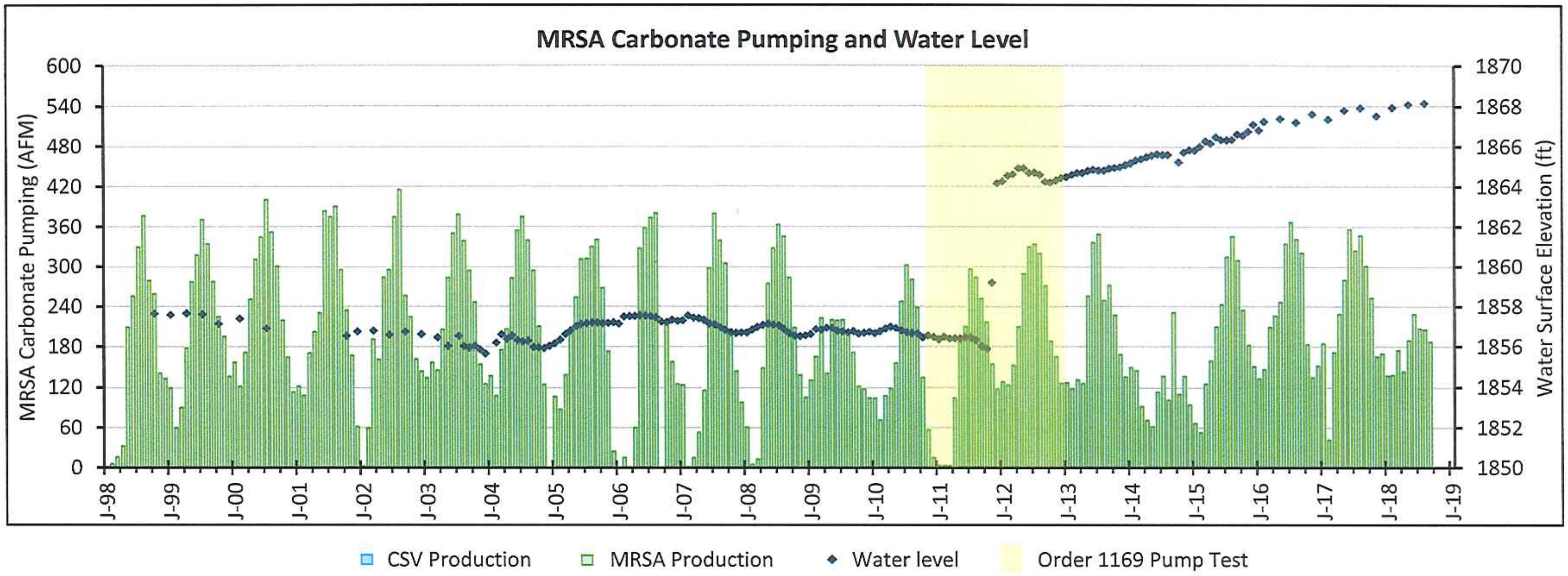
				Screened Interval		Hits Fault		Location	
No.	Well Name	Basin	Well Depth	Start Depth	End Depth	(Y/N)	LSD Elevation	Lat	Long
1	CE-VF-2	210					2468 ft	36.8743	-114.9467
2	CSVM-1	210	1060 ft	320 ft	1020 ft	N	2161 ft	36.7912	-114.8862
3A 3B	CSVM-2	210	1425 ft	720 ft	1380 ft	N	2573 ft	36.6618	-114.9231
4	CSVM-3	210	1230 ft	380 ft	1180 ft	N	2651 ft	37.0525	-114.9834
5	CSVM-4	210	1605 ft	800 ft	1580 ft	N	2842 ft	36.9911	-114.8865
6	CSVM-5	210	1783 ft	1020 ft	1760 ft	N	3131 ft	36.7476	-114.9804
7A 7B	CSVM-6	210	1200 ft	420 ft	1160 ft	N	2252 ft	36.8325	-114.9092
8	MX-4	210	669 ft			N	2177 ft	36.7957	-114.8928
9	EH-4	219					1934 ft	36.7064	-114.7170
10	EH-5B	219					1845 ft	36.7329	-114.7426
11	UMVM-1	219	1785 ft	960 ft	1760 ft	N	1785 ft	36.7581	-114.8232
12	CSV-2	219	478 ft				2186 ft	36.7807	-114.7227

Basin 210 - Coyote Spring Valley

CE-VF-2



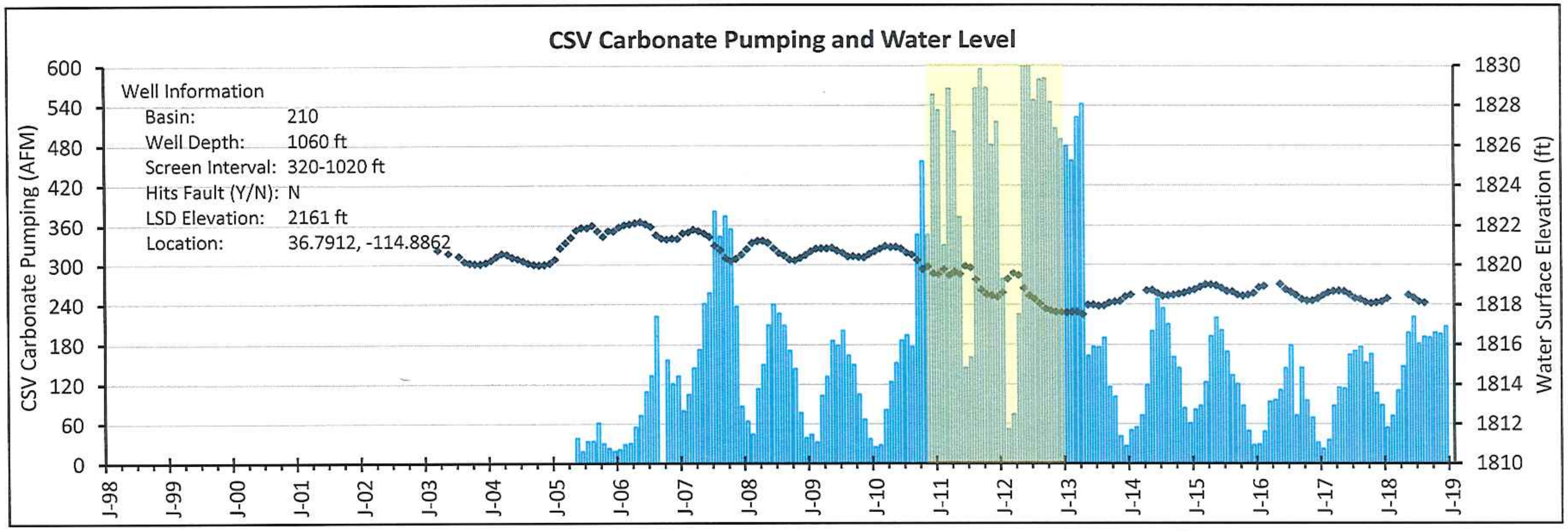
CSV Carbonate Pumping and Water Level



MRSA Carbonate Pumping and Water Level

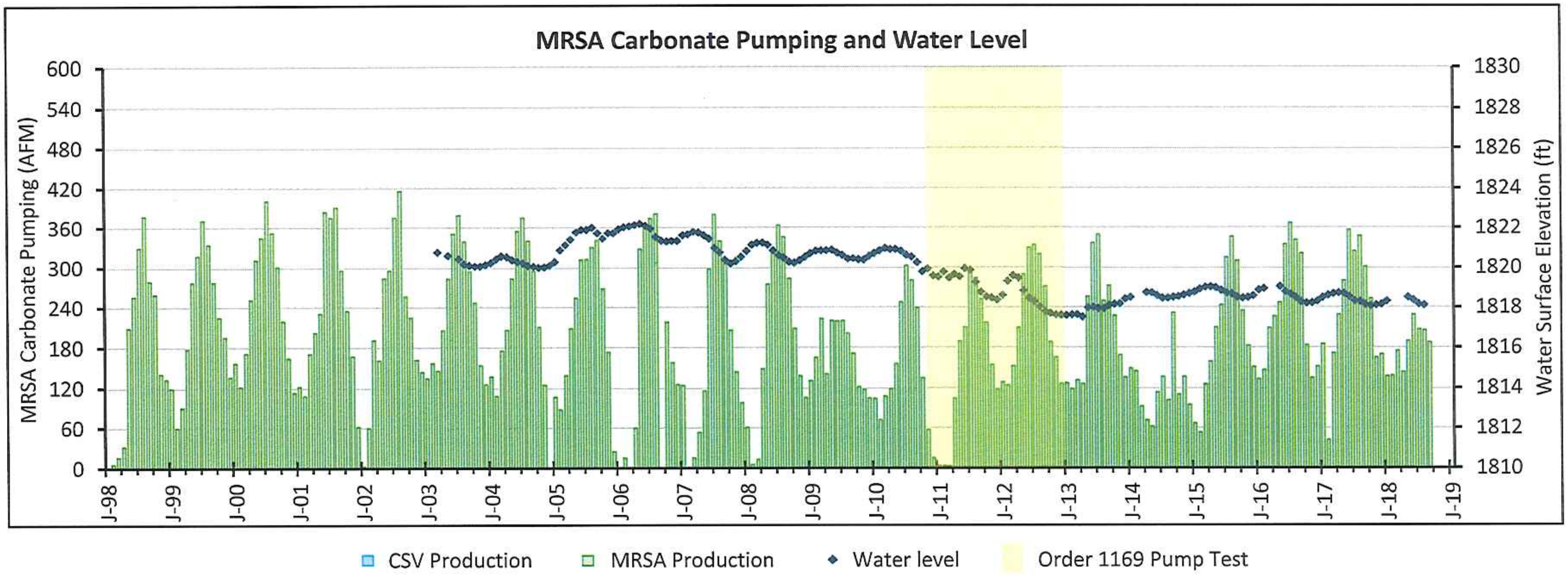
Basin 210 - Coyote Spring Valley

CSVM-1



CSV Carbonate Pumping and Water Level

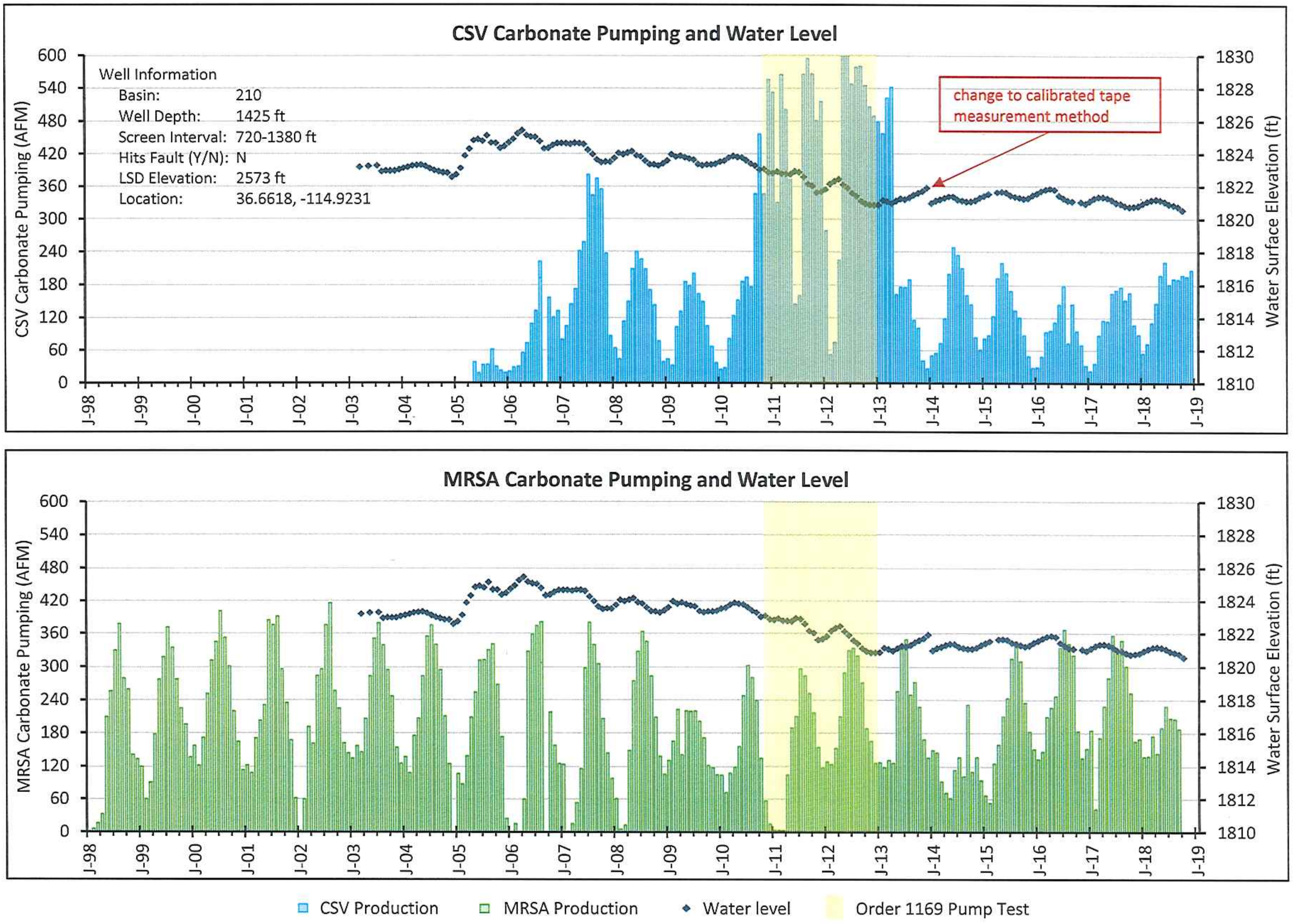
Well Information
Basin: 210
Well Depth: 1060 ft
Screen Interval: 320-1020 ft
Hits Fault (Y/N): N
LSD Elevation: 2161 ft
Location: 36.7912, -114.8862



MRSA Carbonate Pumping and Water Level

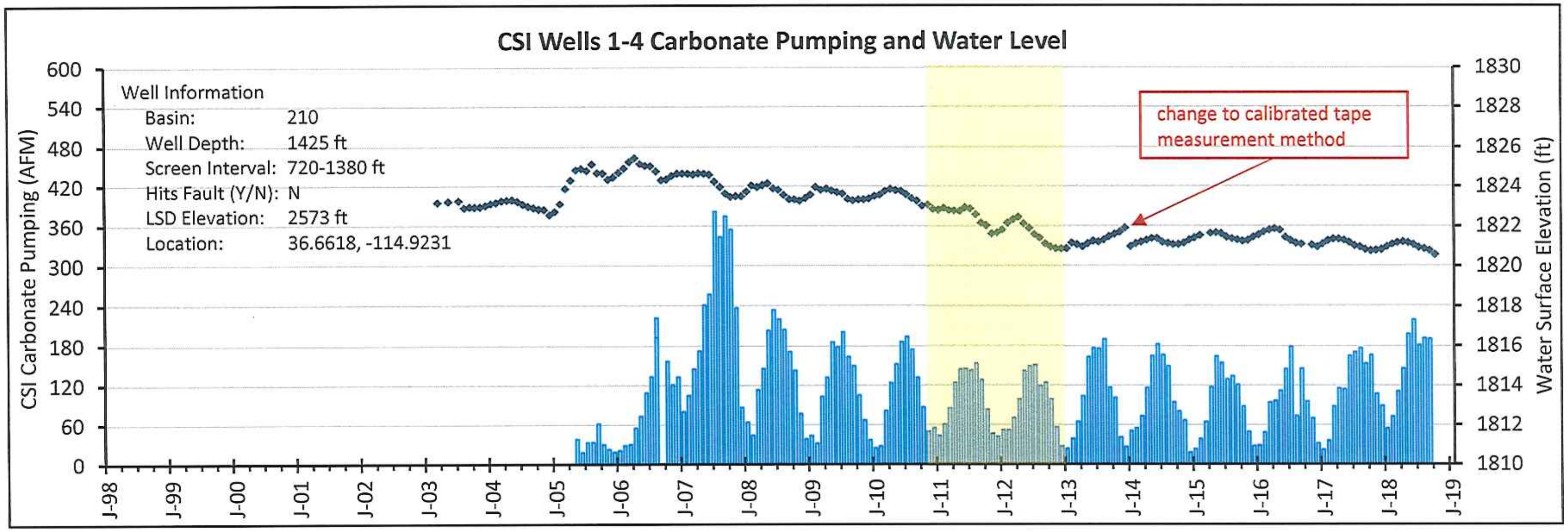
Basin 210 - Coyote Spring Valley

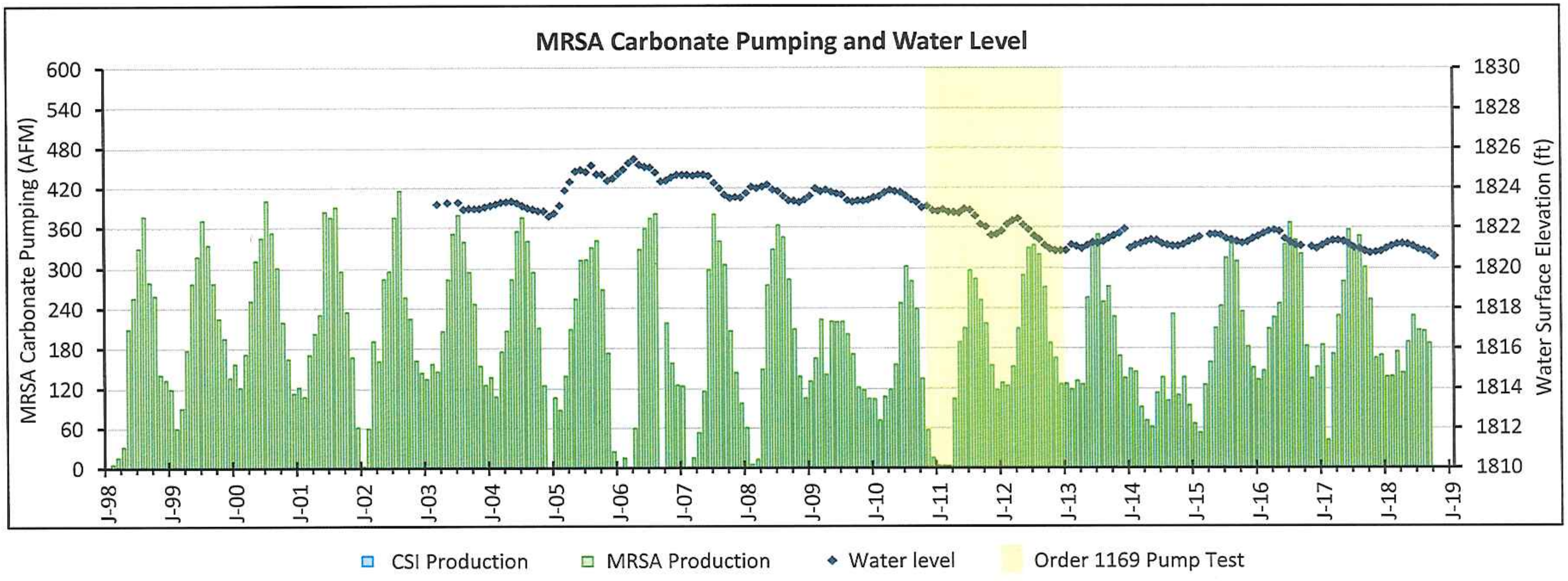
CSVM-2



Basin 210 - Coyote Spring Valley

CSVM-2

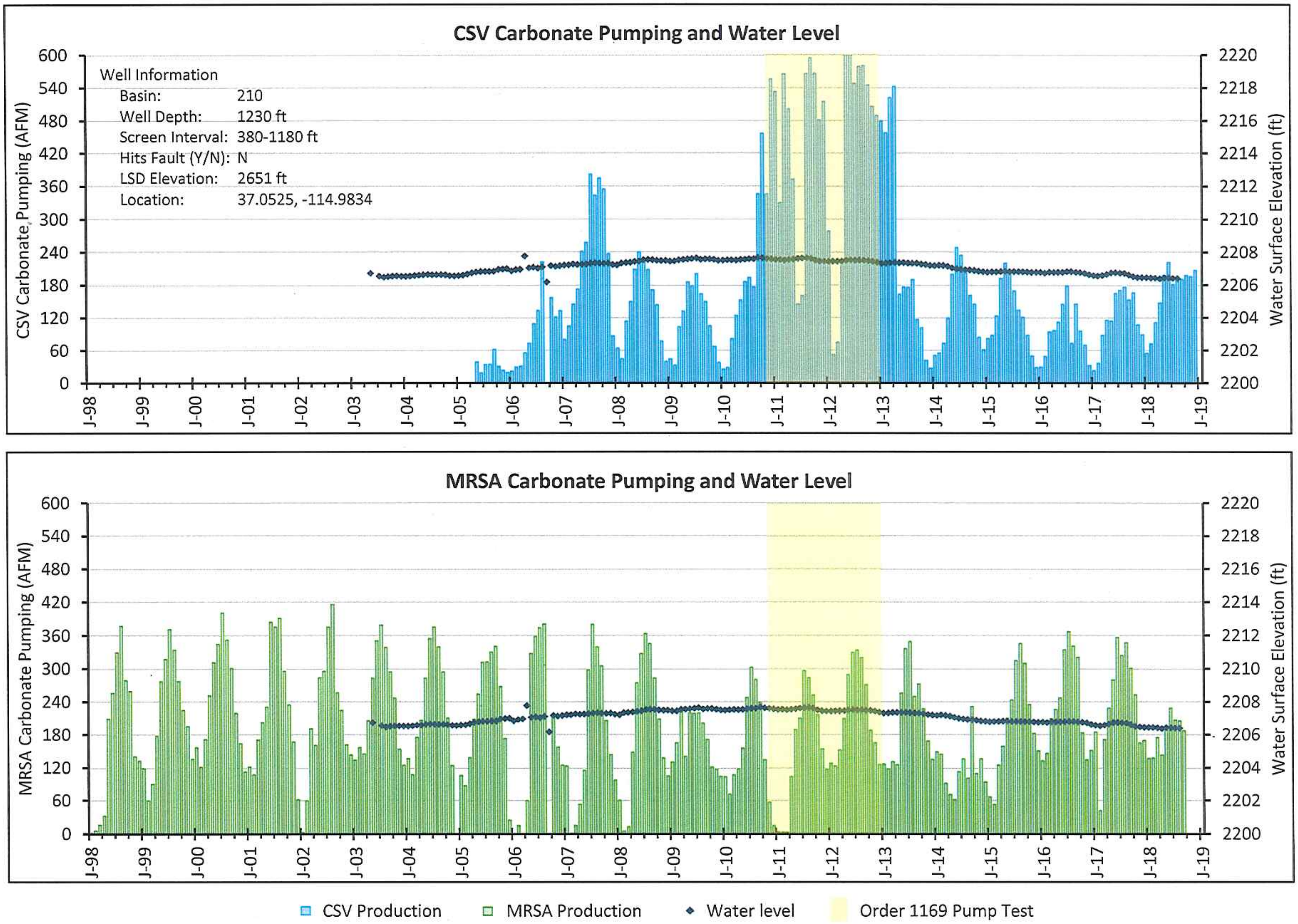

CSI Wells 1-4 Carbonate Pumping and Water Level


MRSA Carbonate Pumping and Water Level

3B

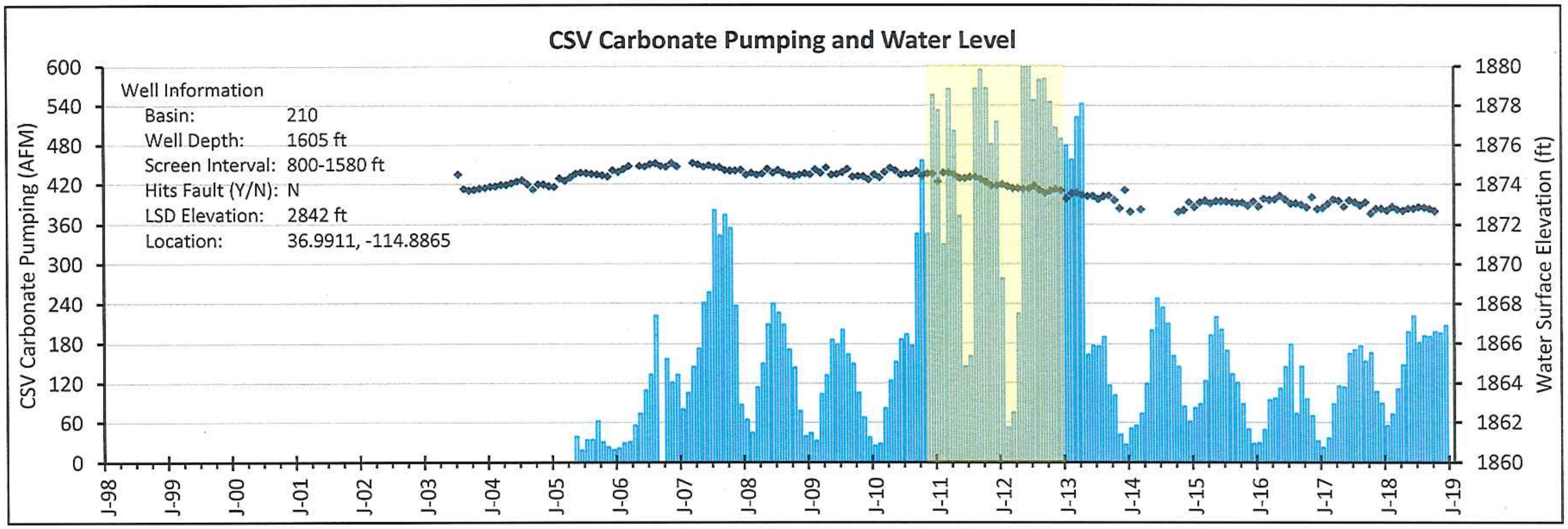
Basin 210 - Coyote Spring Valley

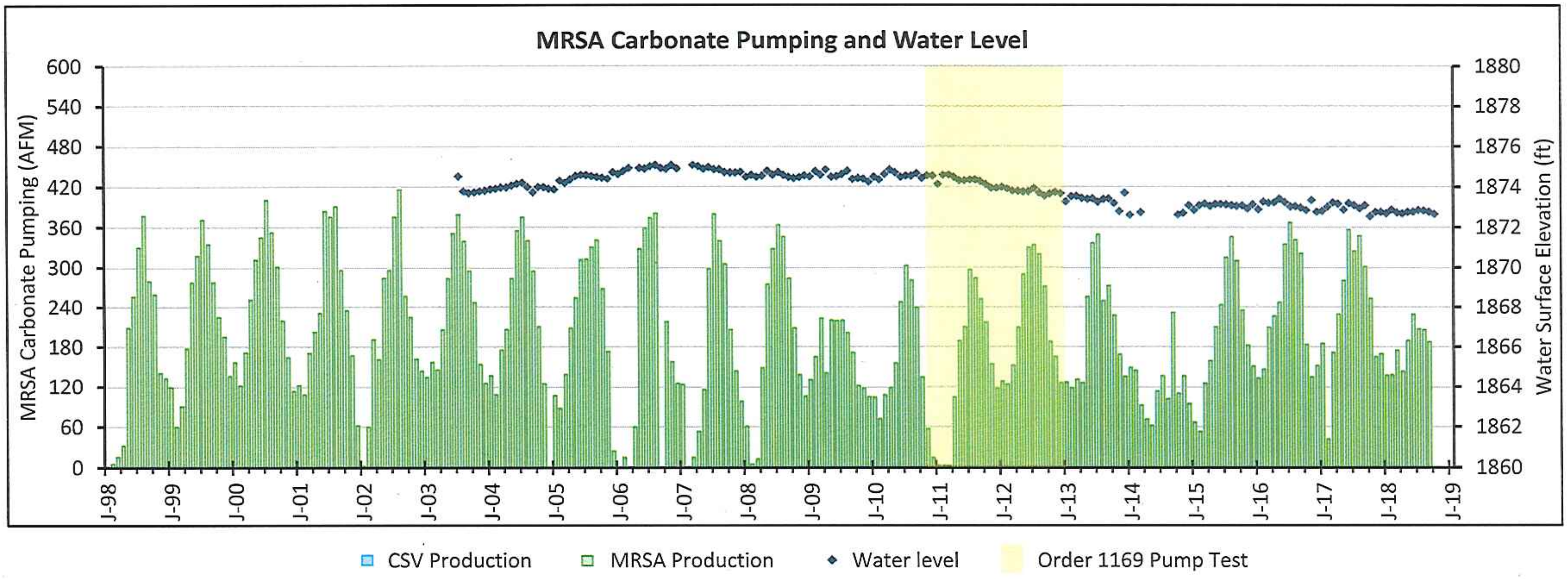
CSVM-3



Basin 210 - Coyote Spring Valley

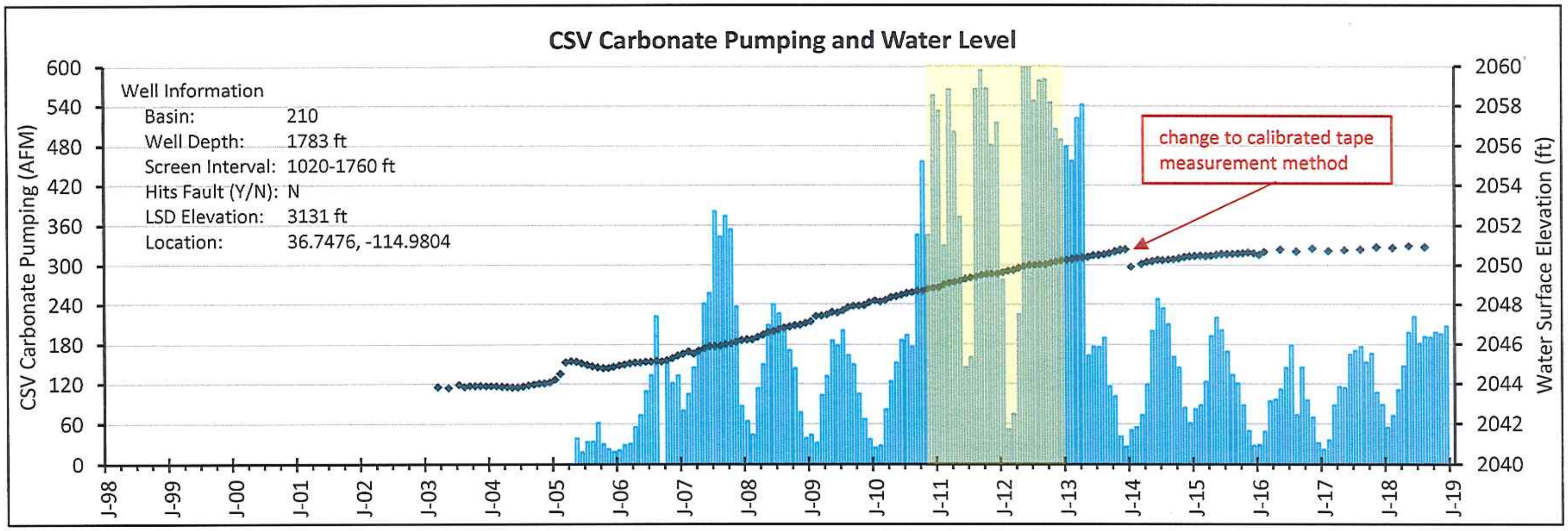
CSVM-4

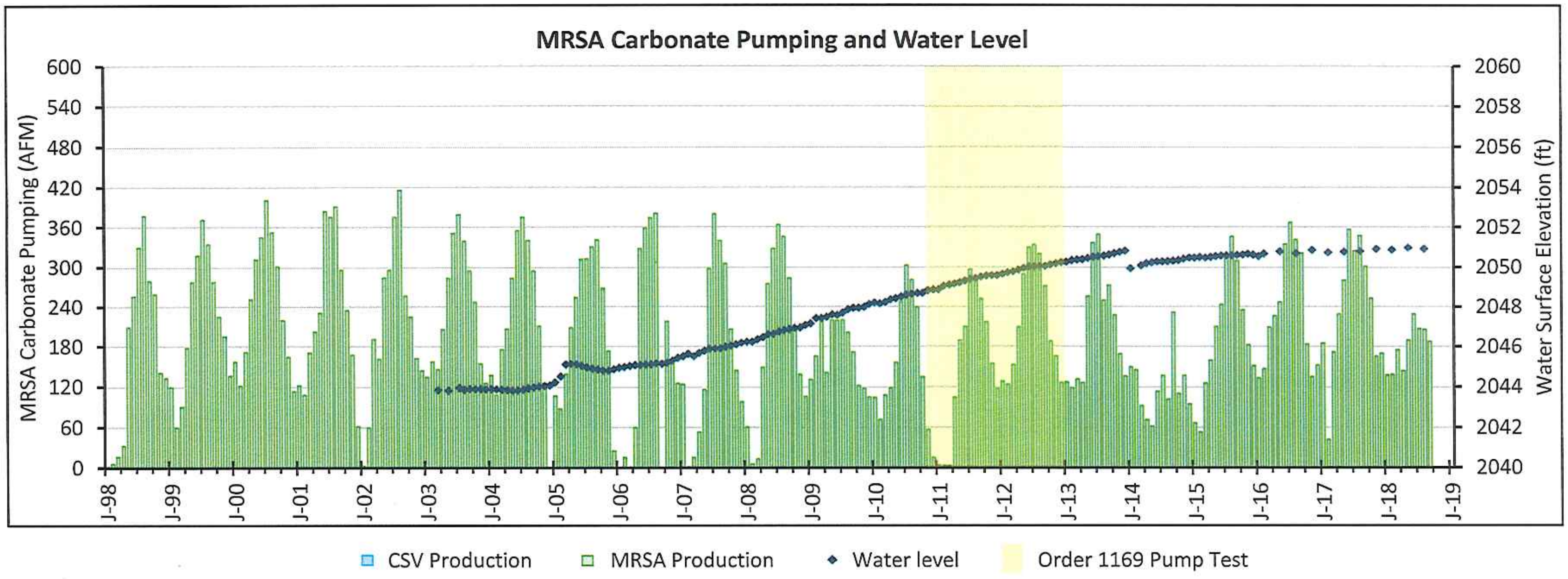




Basin 210 - Coyote Spring Valley

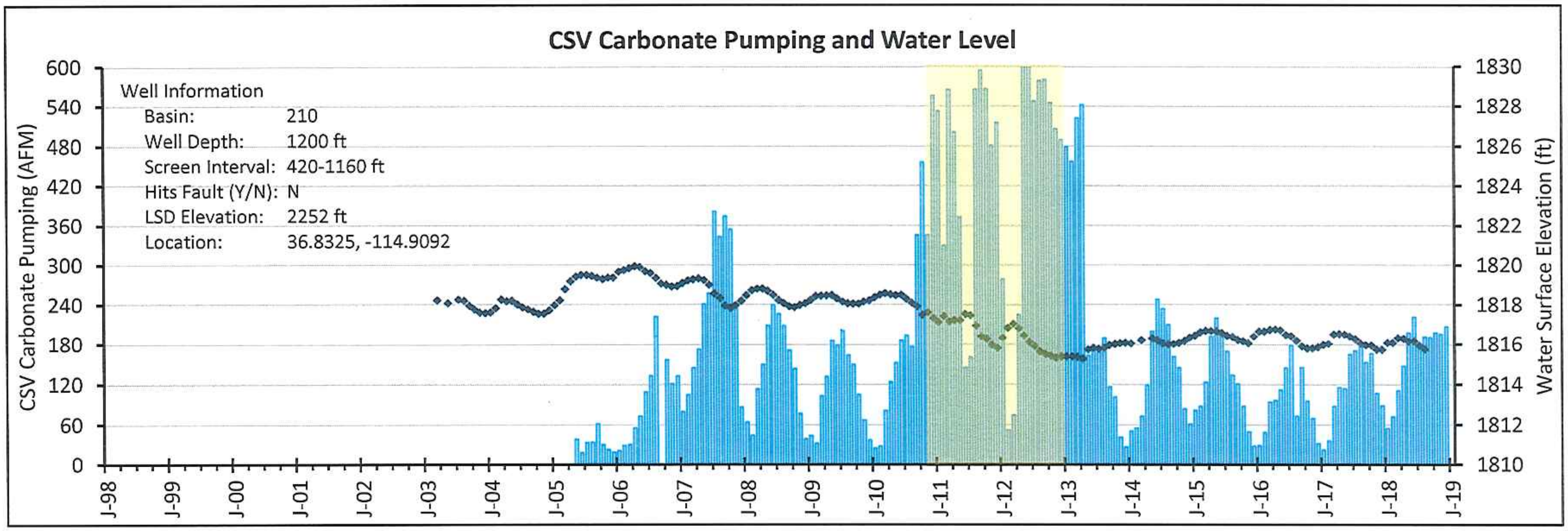
CSVM-5

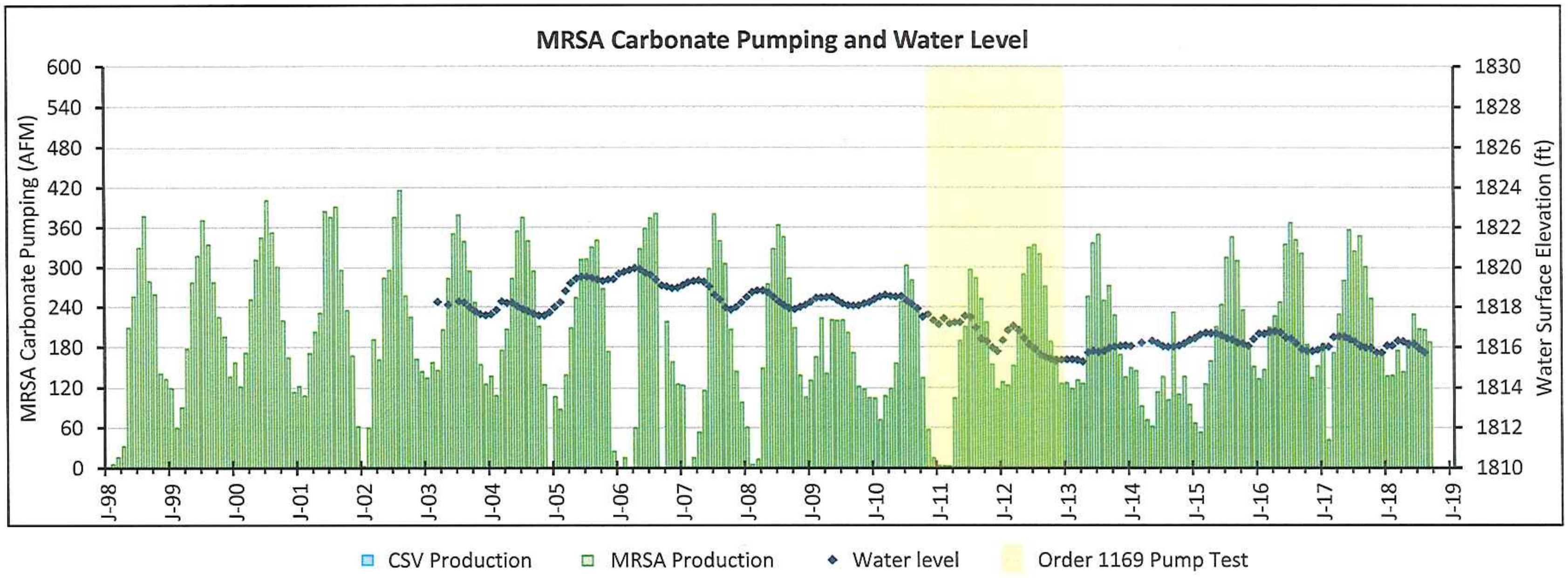

CSV Carbonate Pumping and Water Level


MRSA Carbonate Pumping and Water Level

Basin 210 - Coyote Spring Valley

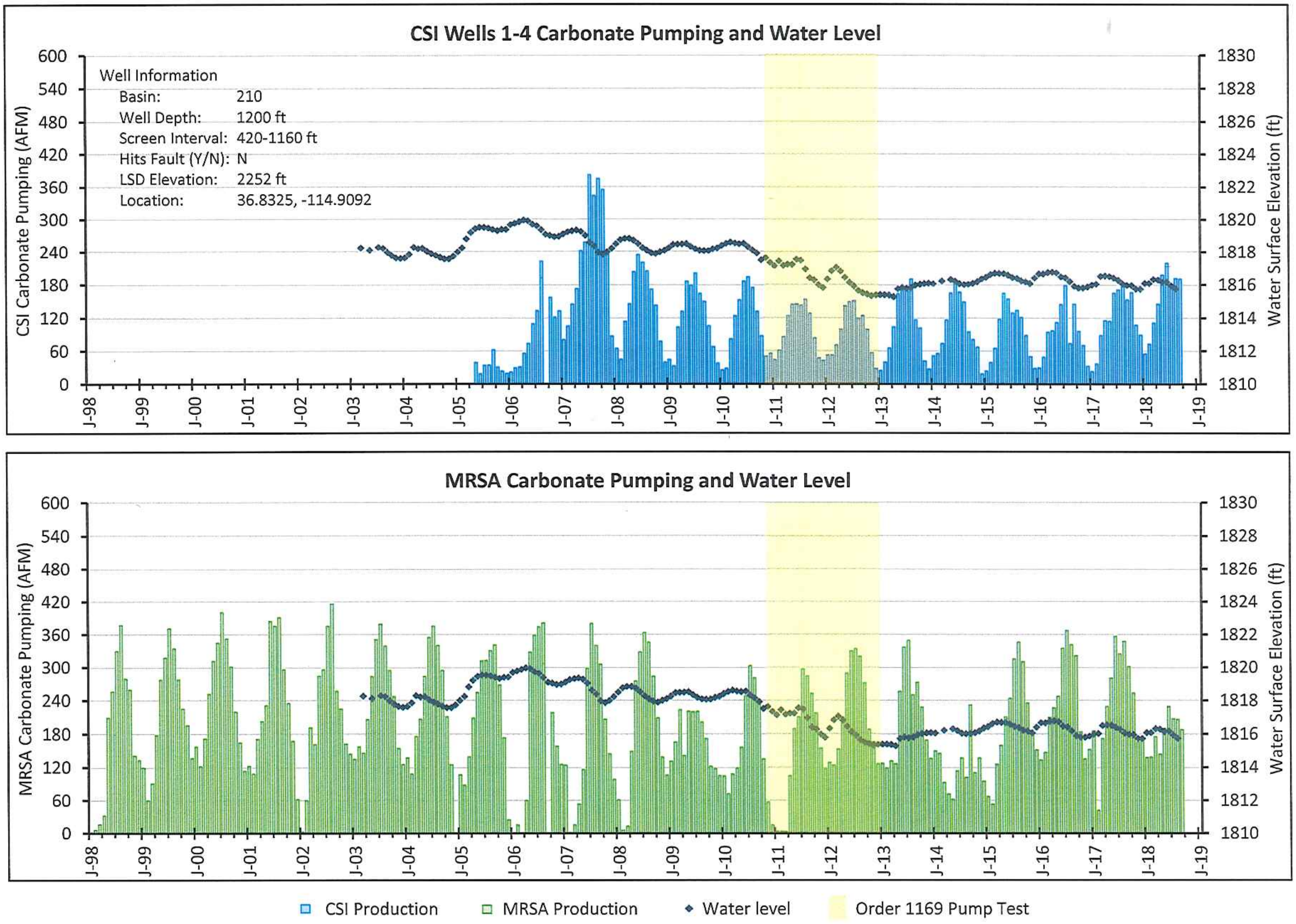
CSVM-6


CSV Carbonate Pumping and Water Level


MRSA Carbonate Pumping and Water Level

Basin 210 - Coyote Spring Valley

CSVM-6

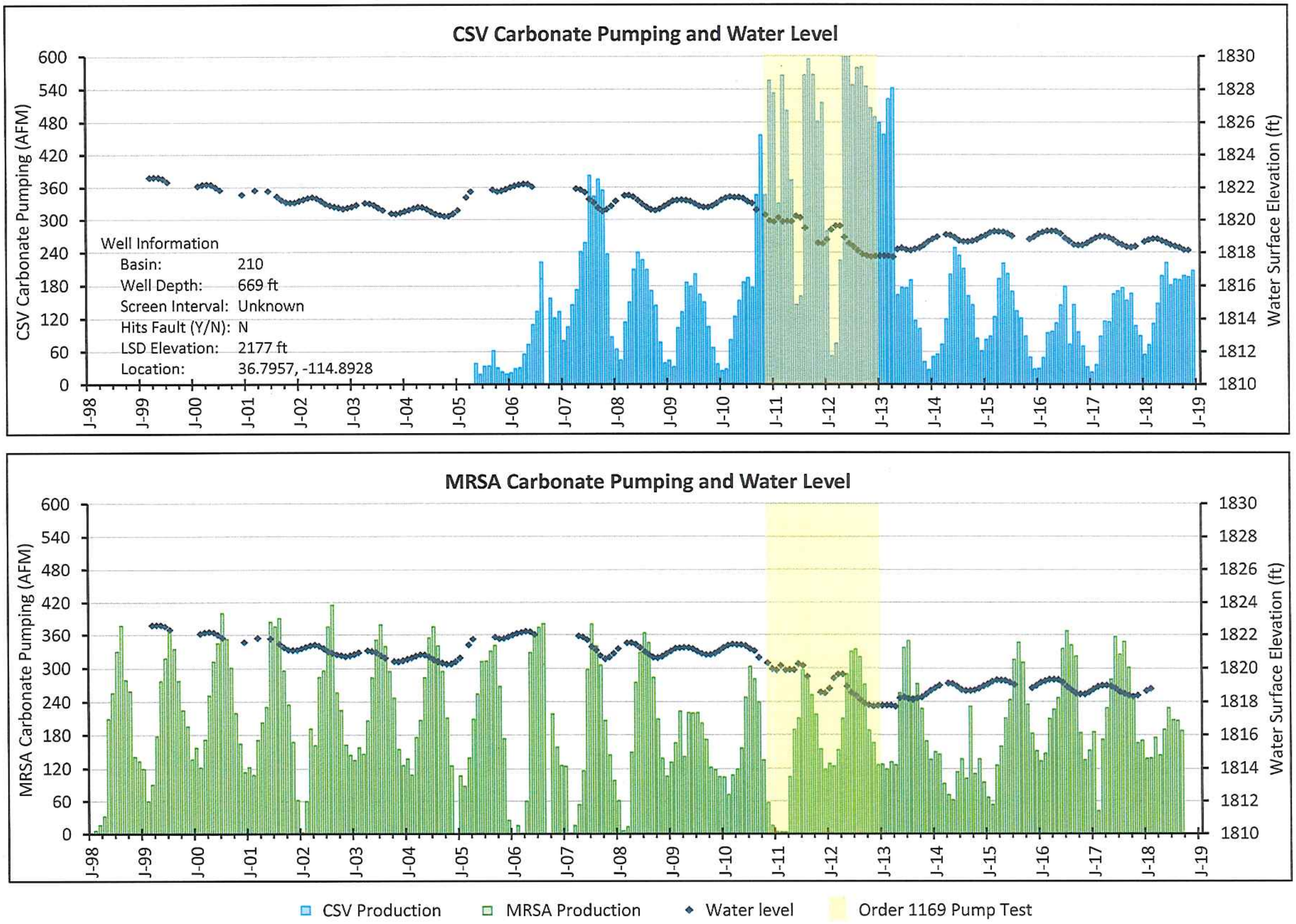

CSI Wells 1-4 Carbonate Pumping and Water Level

MRSA Carbonate Pumping and Water Level

7B

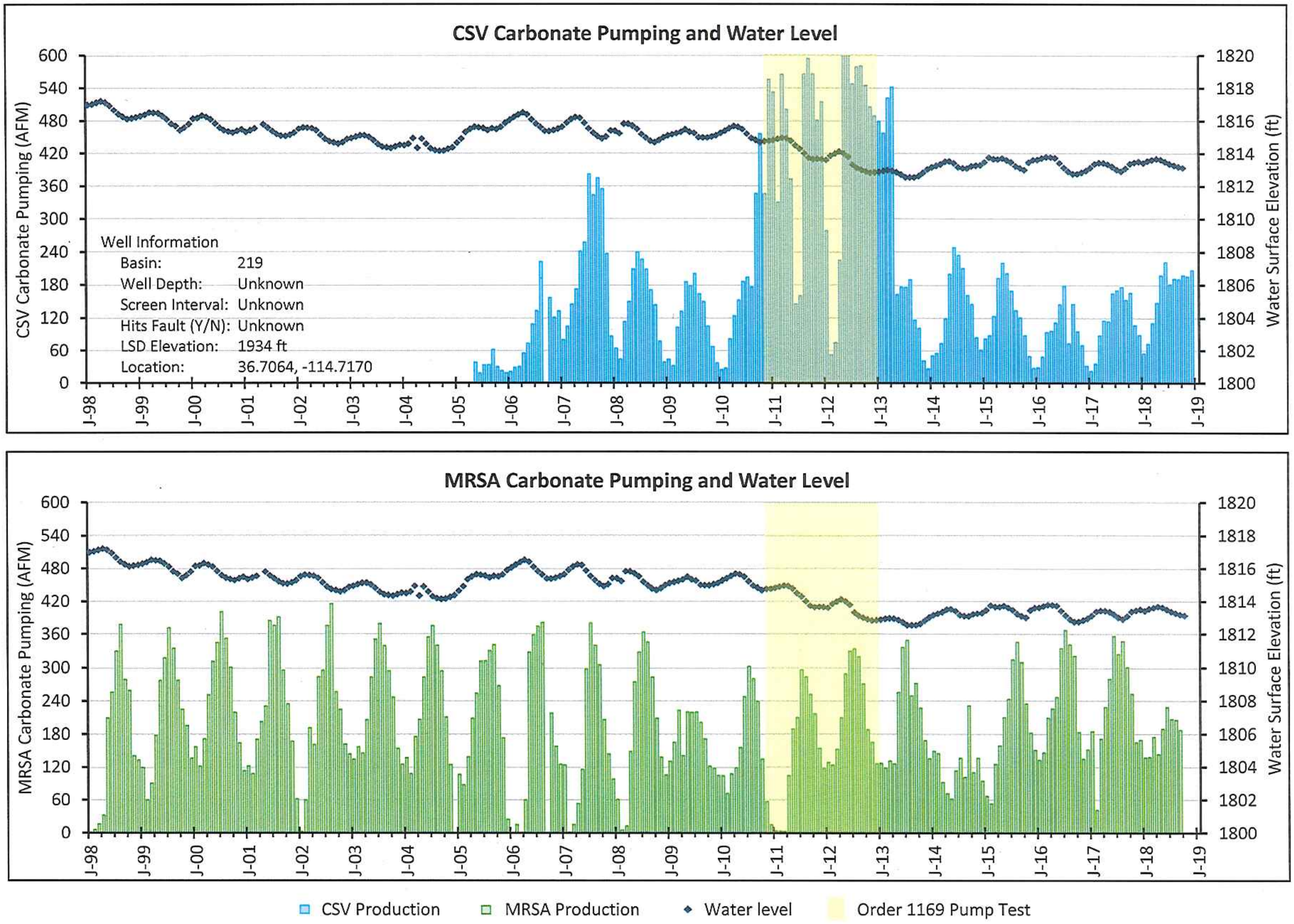
Basin 210 - Coyote Spring Valley

MX-4



Basin 219 - Muddy River Springs Area

EH-4

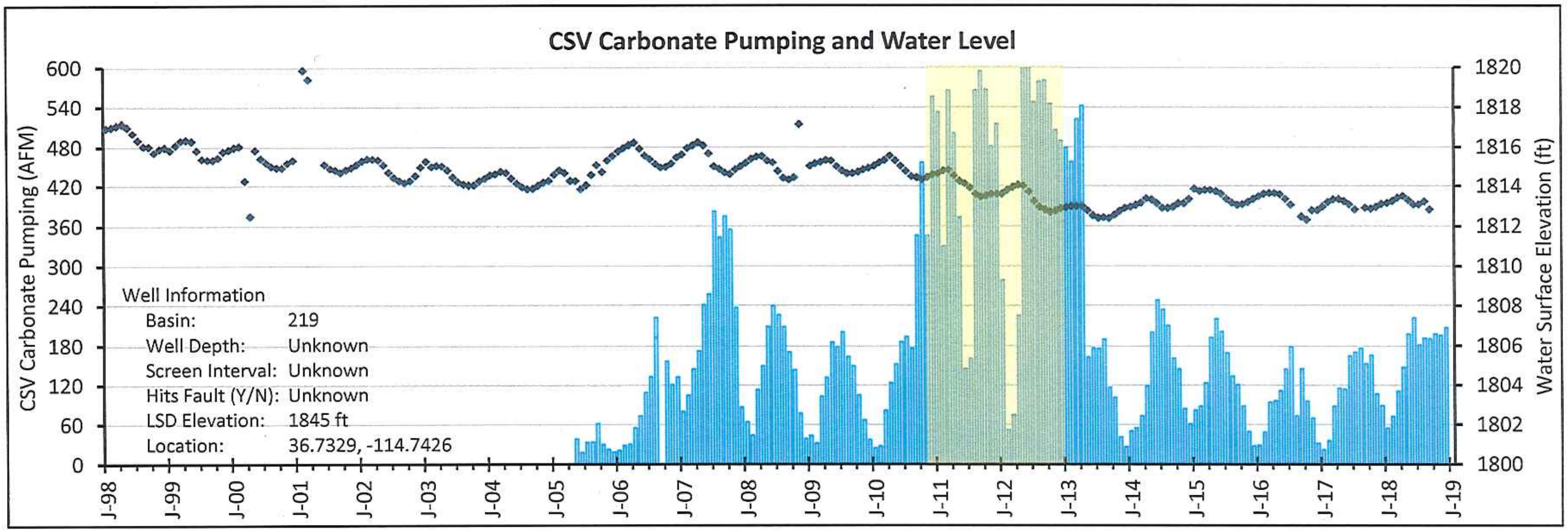


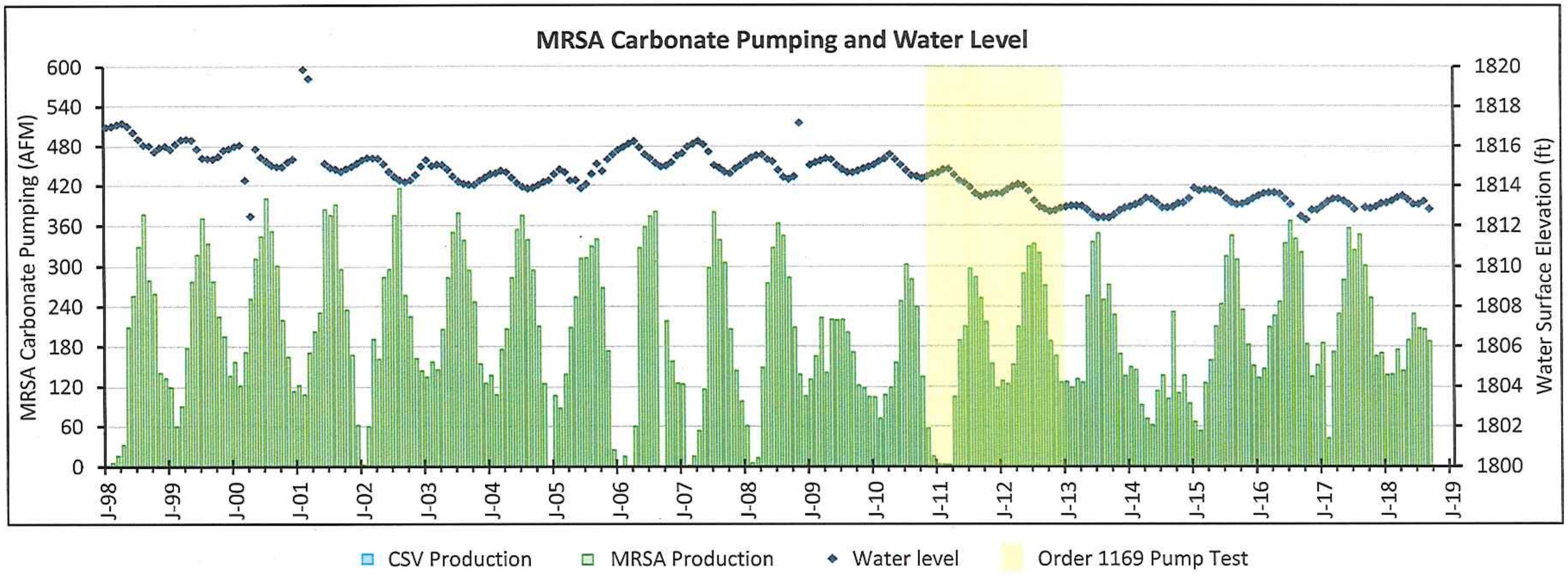
Well Information

Basin:	219
Well Depth:	Unknown
Screen Interval:	Unknown
Hits Fault (Y/N):	Unknown
LSD Elevation:	1934 ft
Location:	36.7064, -114.7170

Basin 219 - Muddy River Springs Area

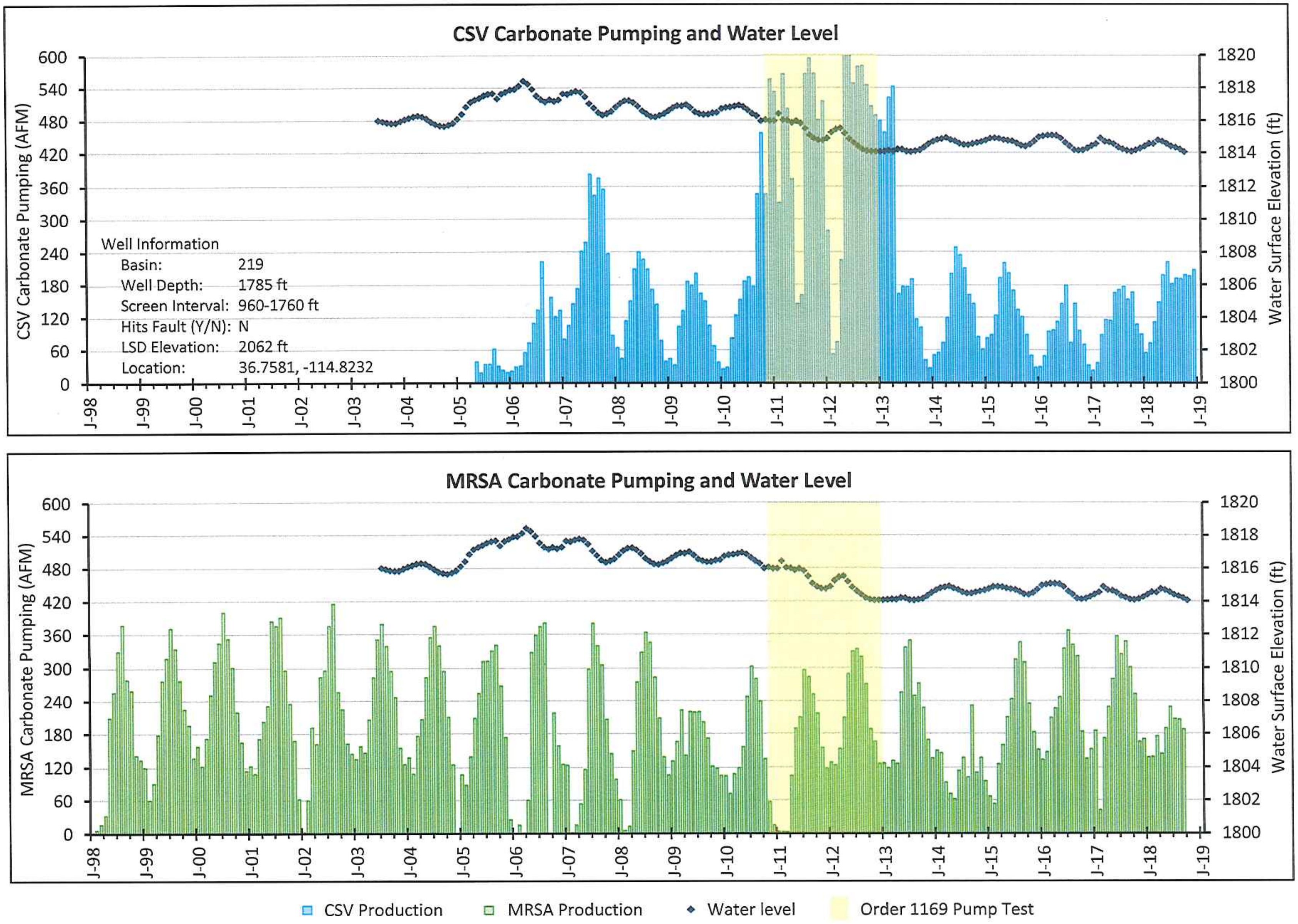
EH-5B





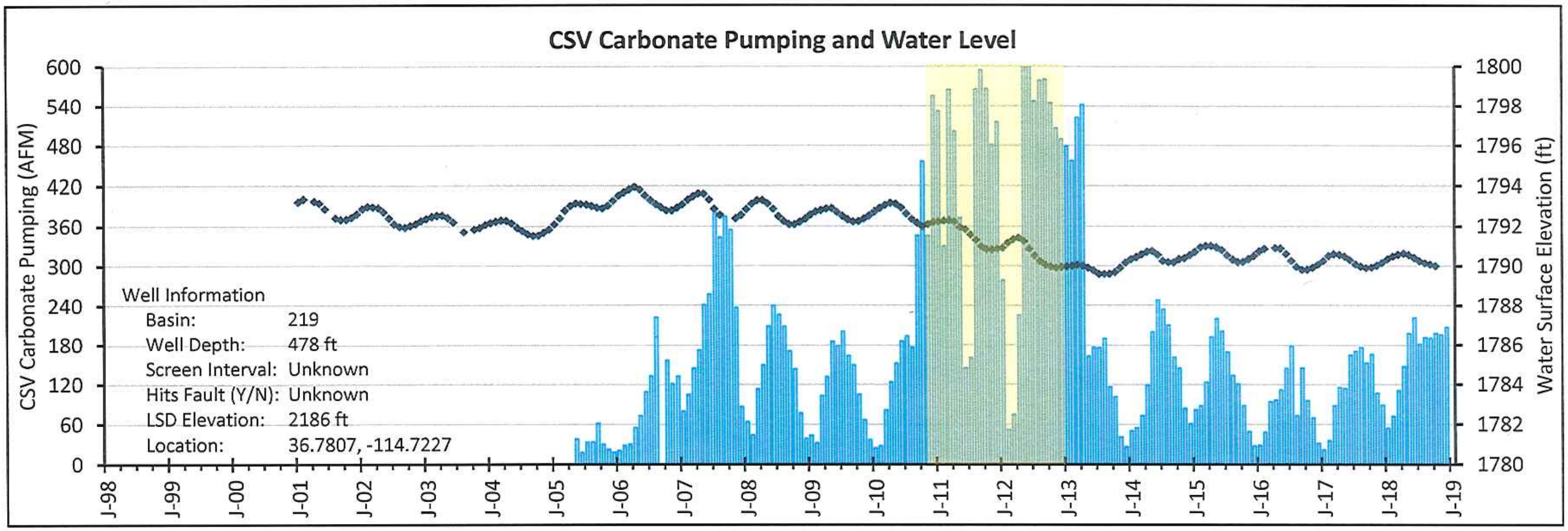
Basin 219 - Muddy River Springs Area

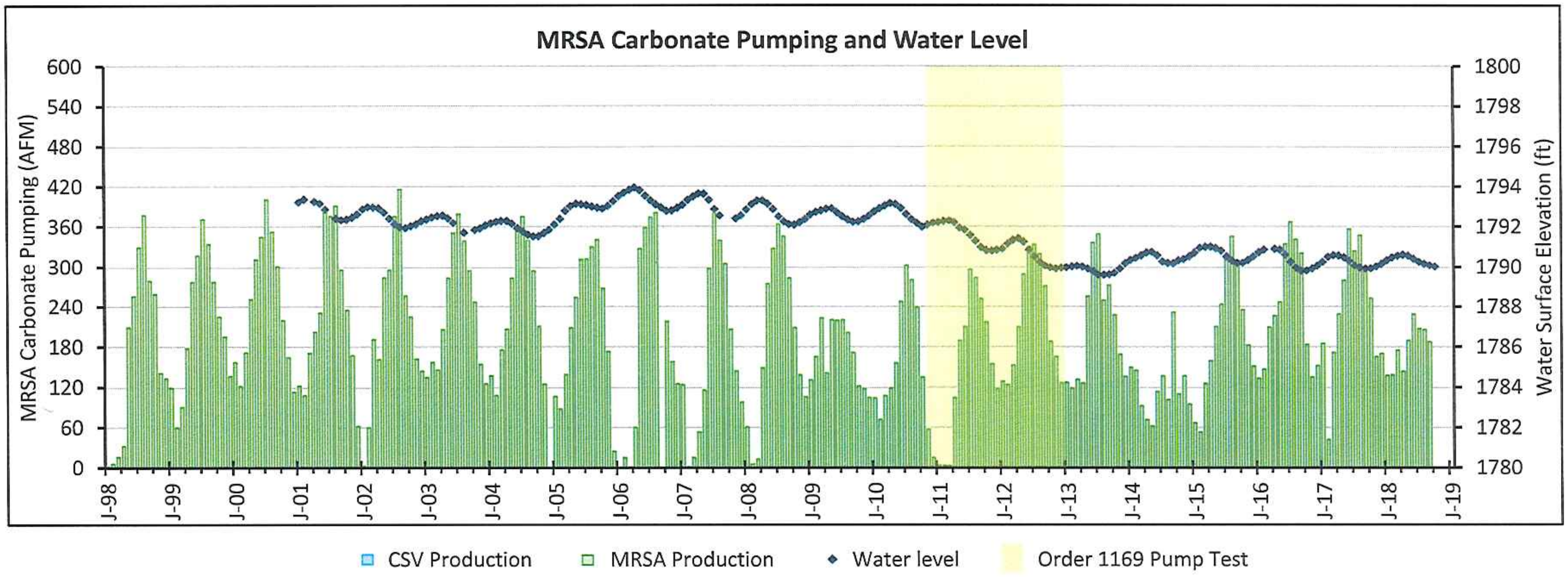
UMVM-1



Basin 219 - Muddy River Springs Area

CSV-2

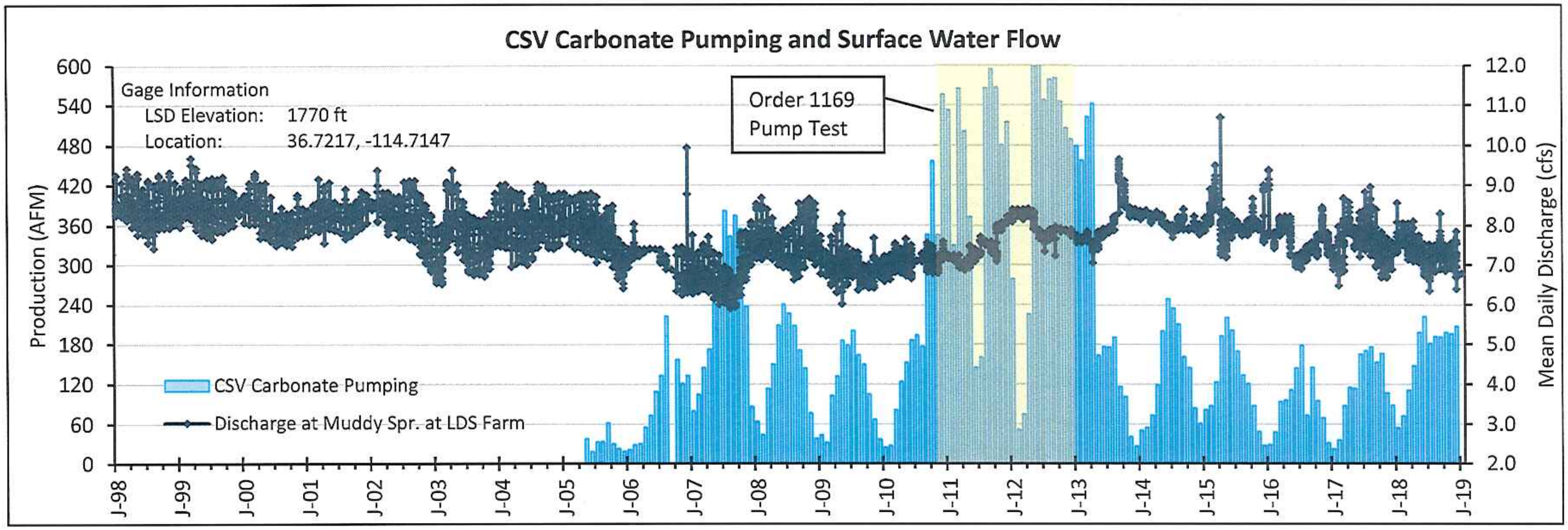




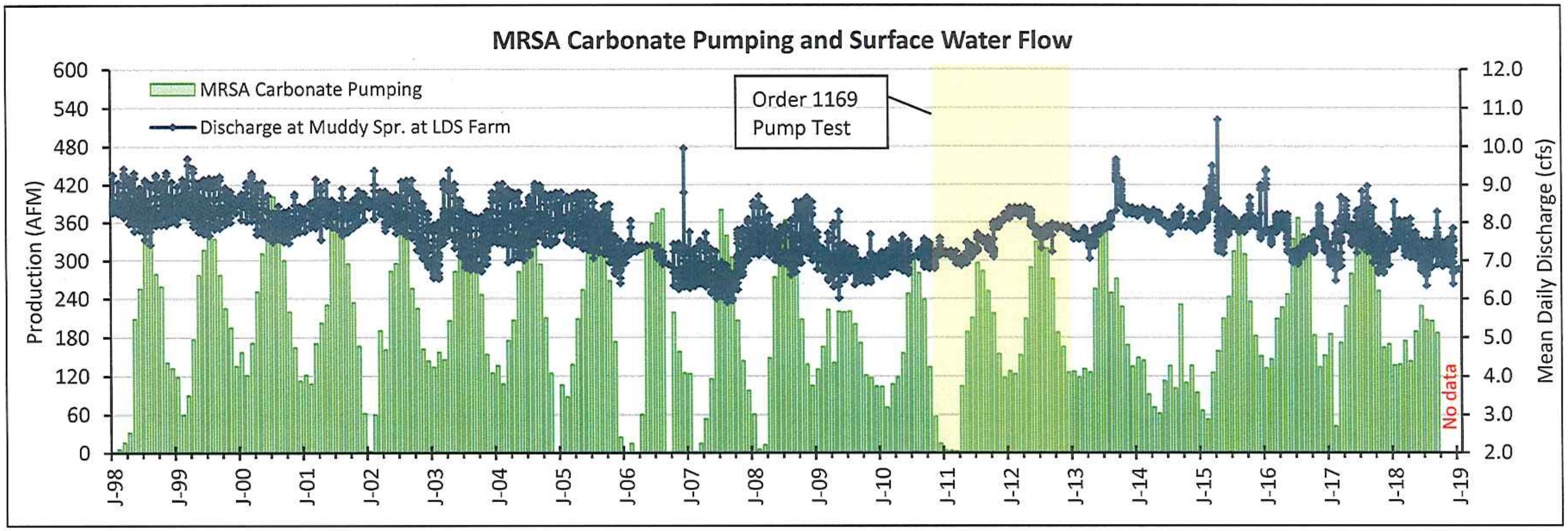
Surface Water Monitoring in Muddy River Springs Area

				Location	
No.	Surface Water Site	USGS Station No.	LSD Elevation	Lat	Long
1	Muddy River Springs at LDS Farm	09415900	1770 ft	36.7217	-114.7147
2	Warm Springs West	09415920	1771 ft	36.7112	-114.7137
3	Pederson Spring	09415910	1811 ft	36.7096	-114.7160
4	Pederson Spring East	09415908	1808 ft	36.7094	-114.7157
5	Muddy River Near Moapa	09416000	1710 ft	36.7111	-114.6944
6	Muddy River Near Glendale	09419000	1460 ft	36.6431	-114.5389

Muddy River Springs at LDS Farm (USGS 09415900)

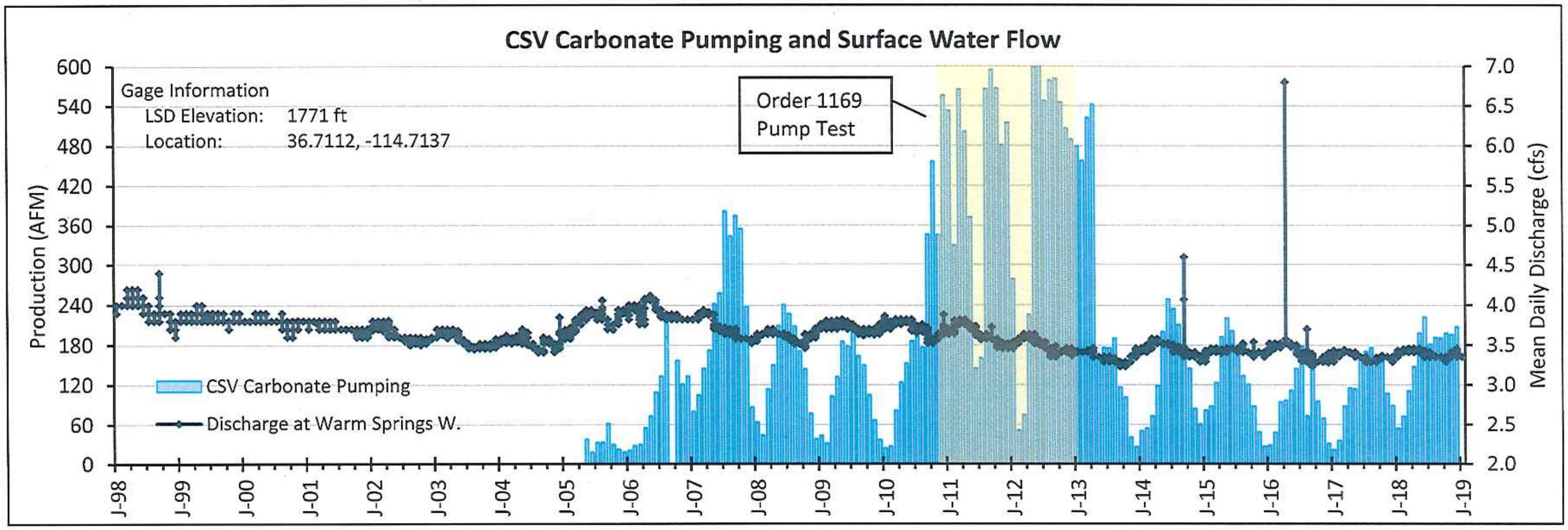


CSV Carbonate Pumping and Surface Water Flow

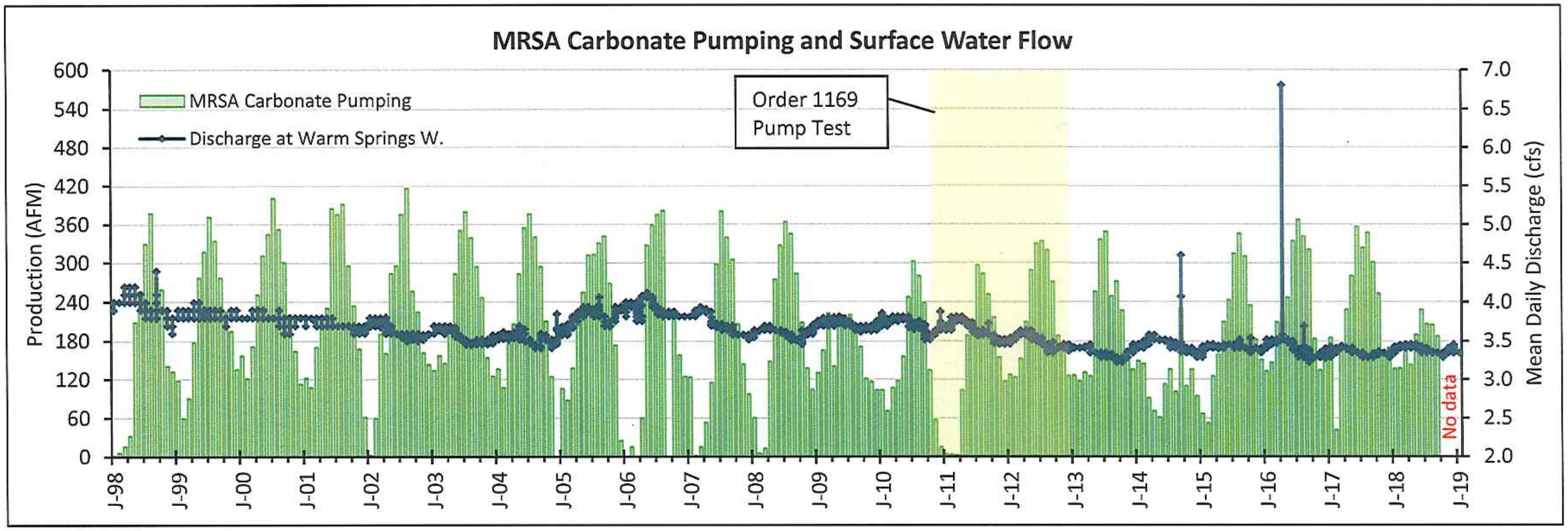


MRSA Carbonate Pumping and Surface Water Flow

Warm Springs West (USGS 09415920)

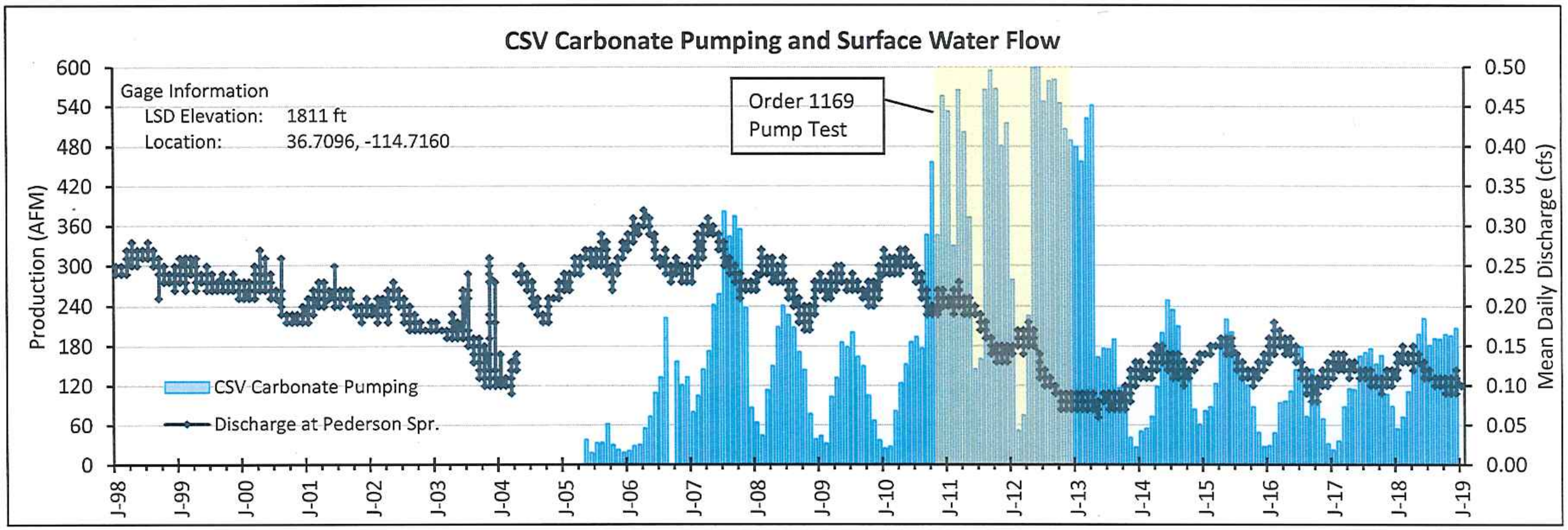


CSV Carbonate Pumping and Surface Water Flow

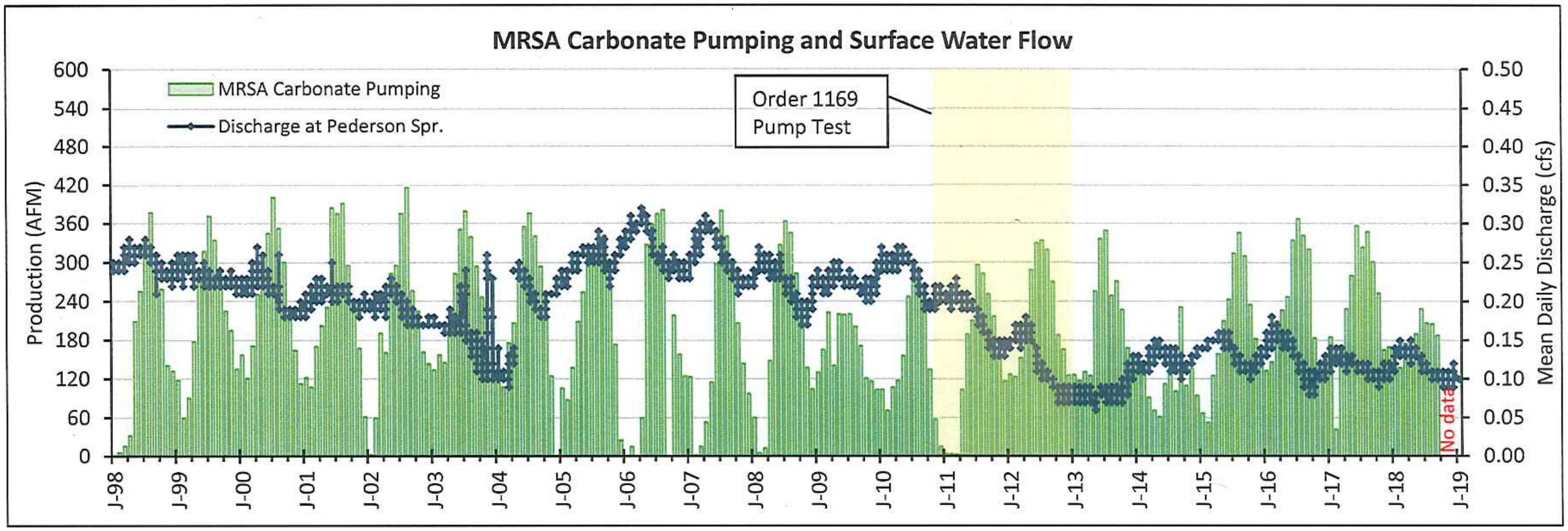


MRSA Carbonate Pumping and Surface Water Flow

Pederson Spring (USGS 09415910)

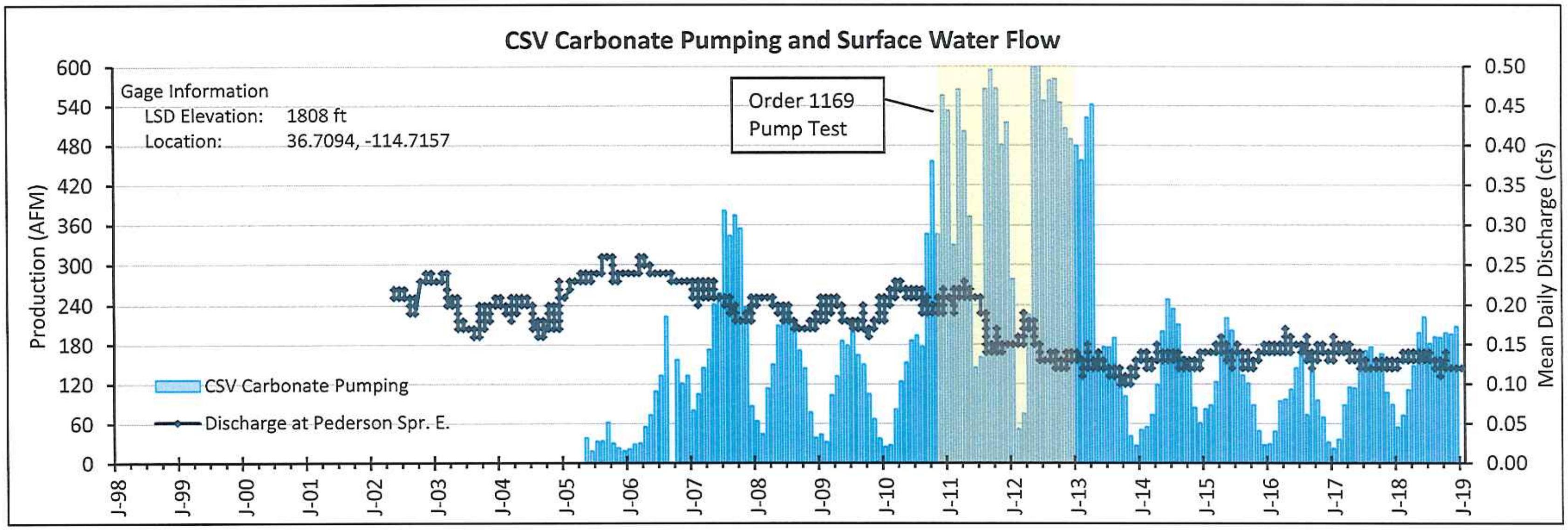


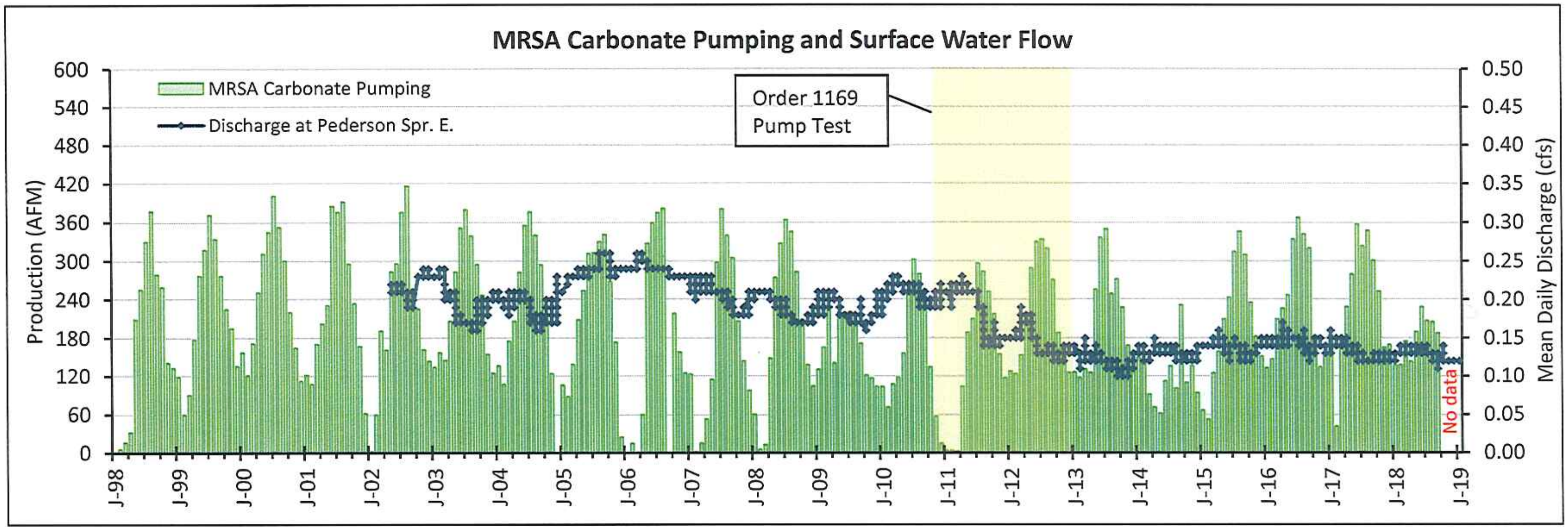
CSV Carbonate Pumping and Surface Water Flow



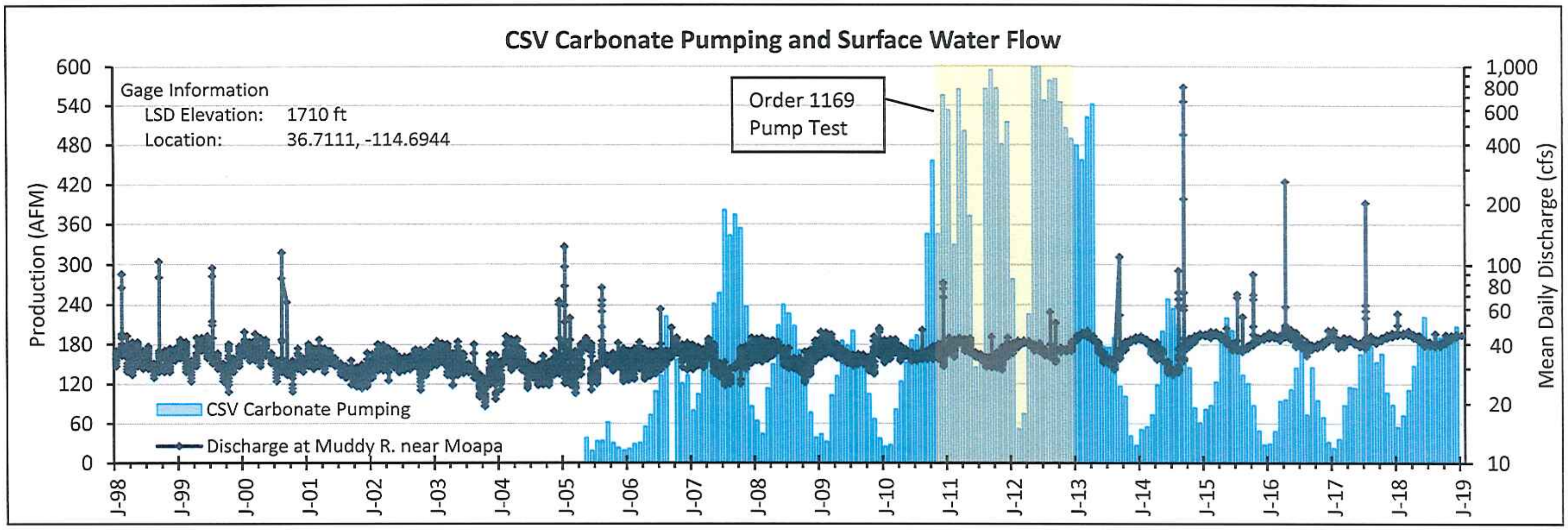
MRSA Carbonate Pumping and Surface Water Flow

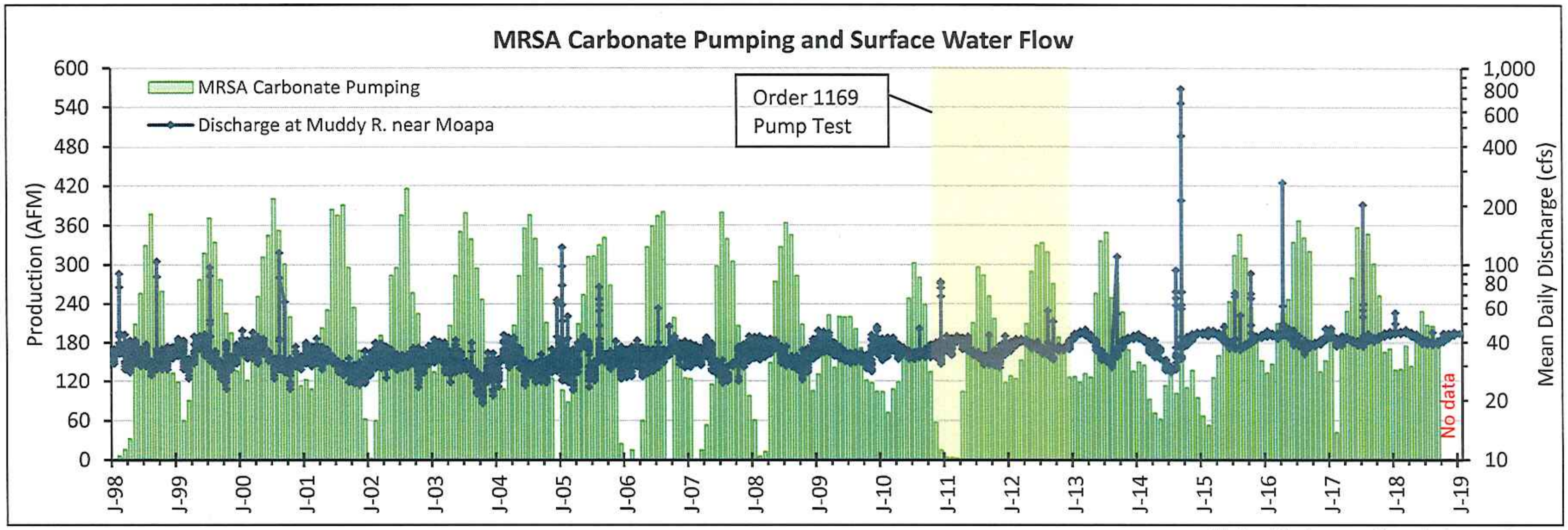
Pederson Spring East (USGS 09415908)


CSV Carbonate Pumping and Surface Water Flow


MRSA Carbonate Pumping and Surface Water Flow

Muddy River near Moapa (USGS 09416000)

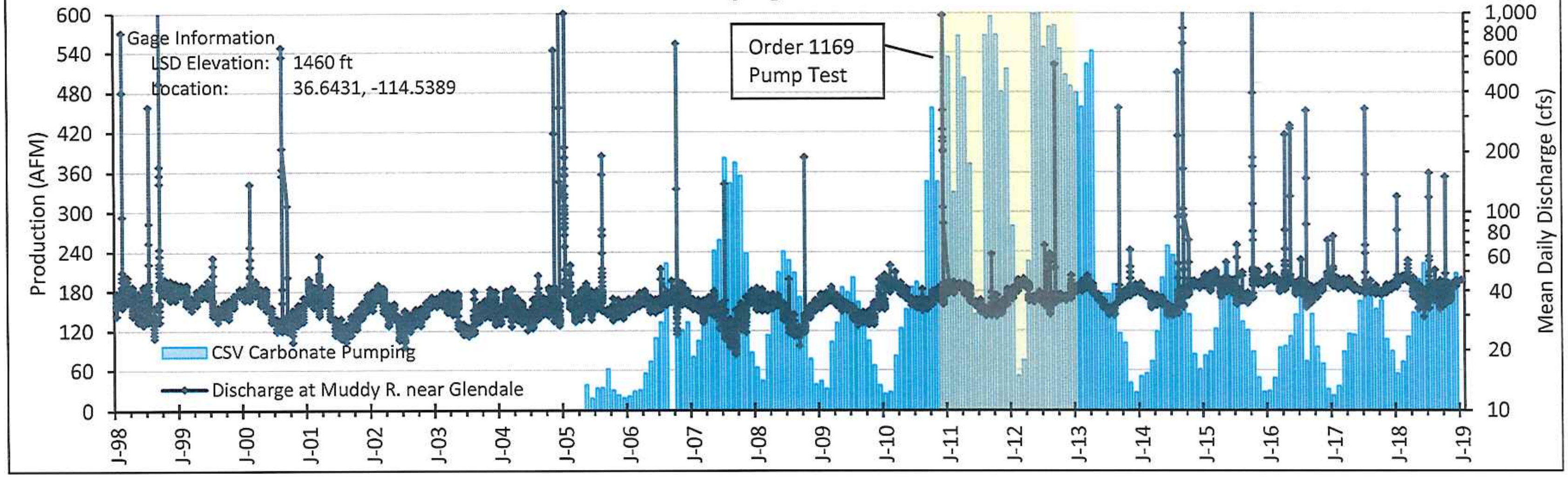

CSV Carbonate Pumping and Surface Water Flow


MRSA Carbonate Pumping and Surface Water Flow

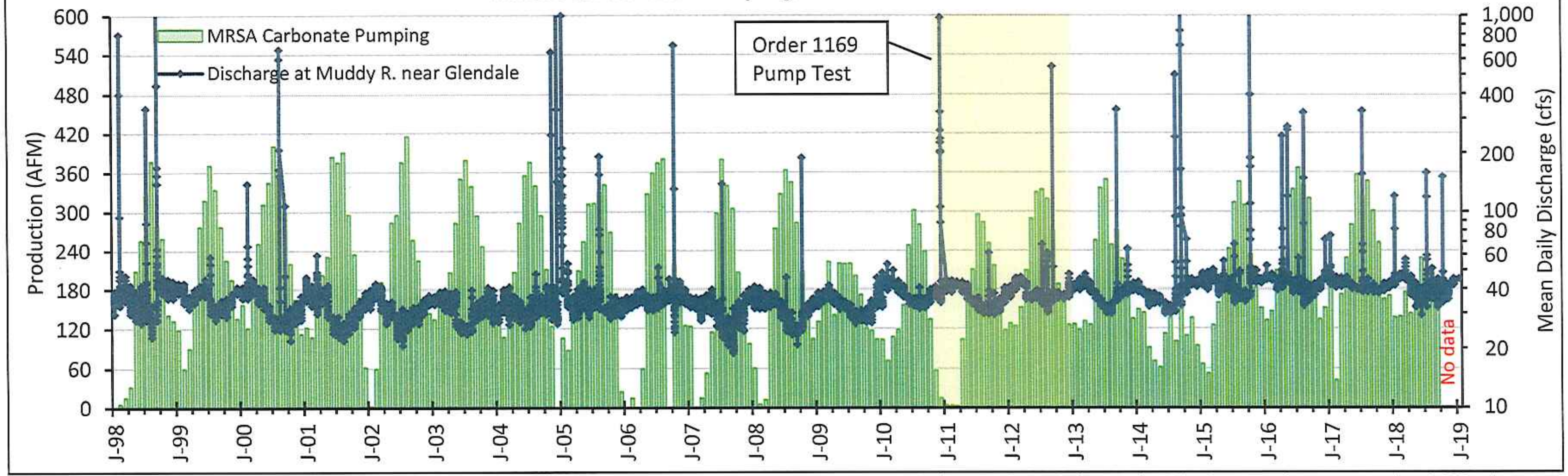
Note: Discharge given in log scale.

Muddy River near Glendale (USGS 09419000)

CSV Carbonate Pumping and Surface Water Flow



MRSA Carbonate Pumping and Surface Water Flow



Note: Discharge given in log scale. Discharge axis truncated at 1000 cfs.