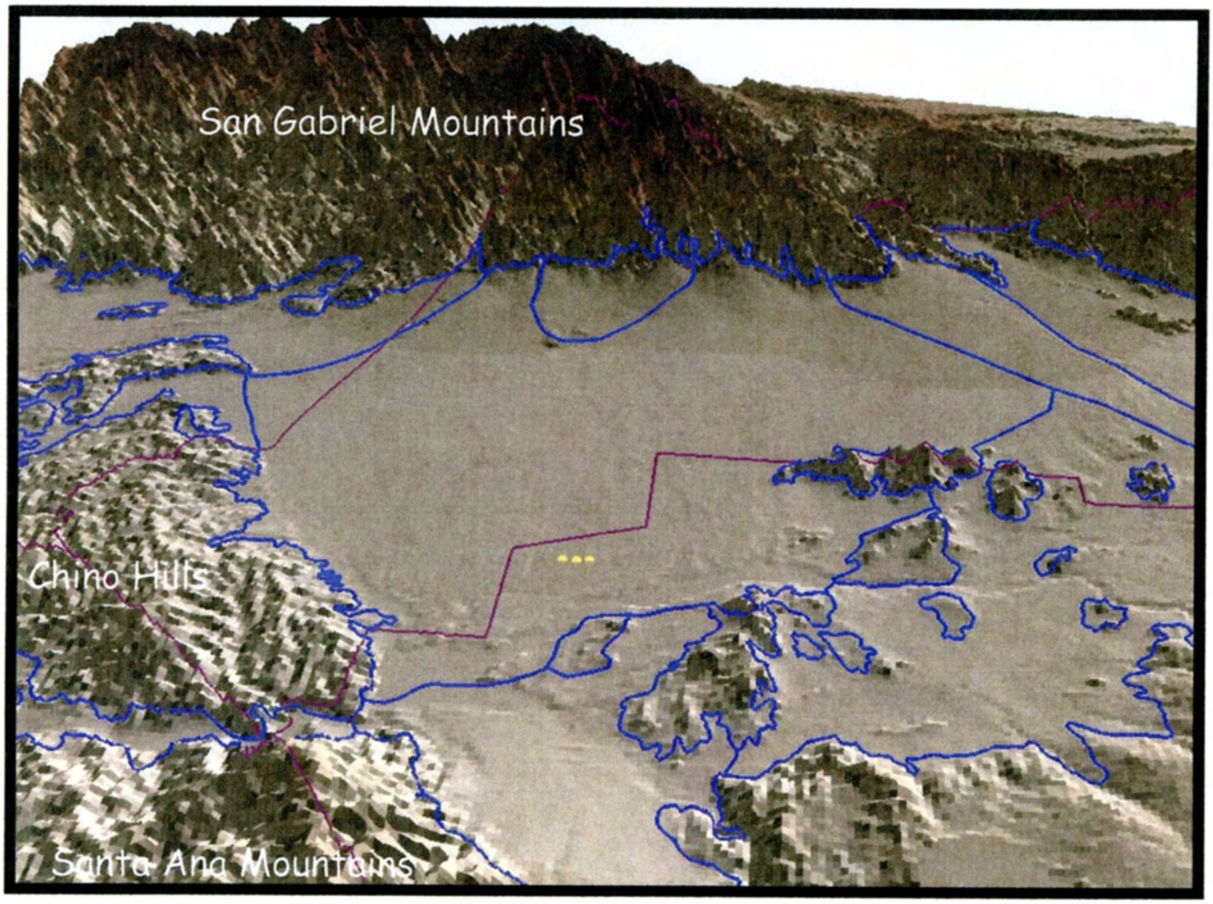
Aquifer Characteristics of the Southern Chino Groundwater Basin with Emphasis on Drilling, Construction, and Testing of Three Municipal Water Supply Wells



Christopher Horsley
Department of Geological Sciences
California State Polytechnic University, Pomona
2004

Aquifer Characteristics of the Southern Chino Groundwater Basin with Emphasis on Drilling, Construction, and Testing of Three Municipal Water Supply Wells

CONTENTS

TABLES

No. **Description**

Aquifer Characteristics of the Southern Chino Groundwater Basin with Emphasis on Drilling, Construction, and Testing of Three Municipal Water Supply Wells

1.0 INTRODUCTION

Three new municipal water supply wells were recently completed in Riverside County, California (Figure 1) for the Chino Desalter Authority (CDA). The purpose of these three wells (Well I-13, I-14, and I-15) is to supply untreated water from the Southern Chino Groundwater Basin to the Chino I and Chino II Desalter Plants for purification by Reverse Osmosis (RO) and subsequent delivery to contracted water users. The three new water supply wells are located in northwestern Riverside County, west of the I-15 and south of the I-60 freeways. More directly Well I-13 is located 0.4 miles southeast of the intersection between Cloverdale Ave. and Archibald Ave. Well I-14 is located 1.25 miles south of Cloverdale Ave. and west of Harrison Street. Well I-15 is located on the northwest corner of Cedar Creek and 65th Street. This area of former agricultural land (dairy farms) is rapidly undergoing conversion to suburban tract housing.

The goal of this project is to extract the high nitrate groundwater from the Southern Chino Groundwater Basin, treat it through a Reverse Osmosis treatment facility, and return it to the contracted users for municipal use. The groundwater in the Southern Chino Groundwater Basin is extremely high in nitrate concentration due to the heavy agricultural use of the land for many decades. Because of the increasing urbanization of this area, the present water supply for the water supply in the region while cleaning up high nitrate groundwater from previous land use. Construction of the three wells will provide valuable insights into the hydrogeological characteristics of the area as well as the vertical extent of the nitrate contamination.

Several questions were answered as a result of this project. For instance, due to the shallow depth of the private agricultural wells in the area, the depth to bedrock and the bedrock type is not known. Although bedrock contour maps of the area have been produced, the CDA wells helped provide the precise bedrock depth and bedrock type in this area. Detailed subsurface stratigraphy of the project area was obtained through the use of lithologic samples from the drilling and from geophysical logs performed on the boreholes. Isolated aquifer zone tests were performed at several zones of varying depths at the three well sites. These zone tests provided information regarding the vertical extent of the nitrate contamination in the Project Area. Also from the zone tests and from pumping tests performed on the completed wells, specific aquifer characteristics were acquired such as transmissivity.

2.0 HYDROGEOLOGIC SETTING

2.1 Chino Groundwater Basin Geology

The Chino Groundwater Basin (Figure 1) is one of the largest groundwater basins in Southern California and provides municipalities and private entities a critical source of much needed water for a rapidly expanding population. The basin encompasses an area of approximately 71 square miles beneath the southern Pomona Valley of northwest Riverside and southwestern San Bernardino Counties. It is bounded to the north by the San Gabriel Mountains and the Red Hill Fault, to the east by the Jurupa Mountains and the Rialto-Colton Fault, to the south by the Santa Ana River and the La Sierra Hills, and to the west by the Chino Hills and the Puente Hills.

The San Gabriel Mountains (Figure 1) are part of the Transverse Range physiographic province of southern California. This rugged mountain range (peak elevations >10,000 ft) is actively forming by transpression within the "big bend" of the San Andreas Fault. Rapid uplift and erosion expose primarily granitic and metamorphic rocks of Proterozoic-Mesozoic age (Ehlig, 1975; Nourse, 2002). This mountain block is bounded along its southern margin by a series of frontal thrust faults within the Cucamonga Fault Zone (Morton and Matti, 1987). These north dipping faults disrupt a series of mountain front alluvial fans and form impermeable groundwater barriers. The Red Hill Fault (Eckis, 1928) forms the northern boundary of the Chino Groundwater Basin.

The Jurupa Mountains to the east and the La Sierra Hills to the south are composed mainly of granitic and metasedimentary rocks (CDMG, 1986). The northwest trending Rialto-Colton Fault north of the Jurupa Mountains is characterized by both right-lateral strike-slip and normal fault motion. This fault forms the eastern boundary of the Chino Groundwater Basin.

The Santa Ana River, which flows along the southern edge of the Chino Groundwater Basin begins in the San Bernardino Mountains to the east and meanders down-gradient to the Pacific Ocean at Huntington Beach. Much of the sedimentary section that makes up the southern Chino aquifer consists of Quaternary fluvial deposits of the Santa Ana River.

The Chino and Puente Hills to the west are both composed of the Topanga Formation and the Puente Formation (Woodford et al. 1946; Shelton, 1955). The early Miocene Topanga Formation consists of sandstones and conglomerates that are in excess of 480 meters thick near the Puente Hills area (Yerkes, 1972). The overlying Miocene to early Pliocene Puente Formation is characterized by marine sandstones, siltstones, and shales (Eldrige, 1907), but is over 4,000 meters thick (Yerkes, 1972).

The weathering and erosion of the hills and mountains neighboring the Chino Basin has resulted in the subsequent filling of the basin with late Cenozoic alluvial sediments (Figure 2). These sediments consist of aquifer forming sands and gravels with interbedded layers of silt and clay. Aquifers are formed in the basin where these alluvial sediments are saturated with groundwater. The depth of the alluvial sediments varies throughout the basin, but in the southern section near the Santa Ana River (Project Area), the alluvial sediments were previously thought to be less than 500 feet thick. The drilling of the three municipal water supply wells confirmed this notion for the depth to bedrock in this area.

The alluvial sediments of the Chino Groundwater Basin (Figure 2) can be further classified as Older Alluvium and Recent Alluvium (Mendenhall, 1908; Eckis, 1934; DWR, 1970). The older alluvium consists of Pleistocene terrace and fan deposits derived from the erosion of bedrock in the Santa Ana Mountains to the southwest and the Puente Hills to the west (Durham and Yerkes, 1964). These materials include sands and gravels with interbedded layers of silt and clay. The older alluvial unit is located stratigraphically above the underlying bedrock and below the overlying younger alluvium. The contact between the older alluvial unit and the underlying bedrock is a nonconformity in which the underlying bedrock was exposed to erosion before the subsequent filling of the basin.

The younger alluvium in the Southern Chino Basin (i.e. Project Area) is predominately from paleo-channel and floodplain deposits of the Santa Ana River and its tributaries. These sediments consist of sands, gravels, and interbedded layers of silt and clay that come from the San Gabriel Mountains, the Chino and Puente Hills, and the San Bernardino Mountains (Figure 1). Sediments from the Santa Ana Mountains are not found in the younger (recent) alluvium due to the evolution of the Santa Ana River drainage system, which has incised into the older alluvial sediments in the Project Area. The Santa Ana River flows between the Project

Area and the Santa Ana Mountains and acts as a barrier to sediments from the Santa Ana Mountains from being deposited within the Project Area.

Two significant faults are located within the Chino Groundwater Basin (Figure 1). The active Chino Fault along the base of the Chino Hills to the west is a northern extension of the Elsinore fault zone (DWR, 1970). The Central Ave. Fault, located east of the Chino Hills, has been mapped based on groundwater level differences on either side of the fault, although no surface expression of the fault has been identified (Geoscience, 2001).

2.2 Chino Groundwater Basin Topography

The Project Area is located at an elevation between 620 and 720 feet above mean sea level in an area of low topographic relief (Figure 1). The floor of the Chino Basin slopes gently to the south from the San Gabriel Mountains towards the Santa Ana River. The lowest point in the basin is the Prado Flood Control Basin to the southwest with an elevation of 475 feet above mean sea level. CDA Well I-13 is located at an elevation of 627 feet above ground surface whereas CDA Well I-14 is located at an elevation of 630 feet above ground surface. CDA Well I-15 is located at an elevation of 633 feet above ground surface.

2.3 Chino Groundwater Basin Aquifer Systems

There are two distinct aquifer systems found in the Chino Groundwater Basin, the upper and the lower systems (Geoscience, 2001). The upper aquifer system can be defined as an unconfined to unconfined to semi-confined system that is present across the entire Chino Basin. The lower aquifer system is generally classified as a confined aquifer bounded by low-permeability fine-grained sediments. This lower aquifer is present in the northern portion of the groundwater basin and is generally thought to be absent in the Project Area. Furthermore, the upper aquifer system in the Project Area was thought to be characterized by high percentages of sands and gravels relative to the silts and clays. The source for the high percentages of sands and gravels in the Project Area are deposits from the Santa Ana River. The upper unconfined aquifer in the Project Area is open to infiltration of nitrate bearing surface water from agricultural lands, leading to high levels of nitrate contamination in the aquifer (Figure 4). Data collected during the drilling program was aimed at verifying this.

3.0 TESTING PROTOCOL – Well Installation Process

3.1 Introduction

Drilling for the Chino Desalter Authority Wells I-13, I-14, and I-15 (Figure 2) began in October 2002 and was contracted out to Bakersfield Well & Pump of Bakersfield, California. Geoscience Support Services Inc. of Claremont, California oversaw the drilling program and designed the wells. The boreholes were drilled and the wells designed around the lithology encountered during the drilling process. The wells were designed to extract high nitrate groundwater from the local aquifers in the Southern Chino Groundwater Basin.

3.2 Conductor Borehole and Conductor Casing Installation

To begin the well installation process, drillers installed the conductor borehole. The conductor borehole serves two purposes for the well installation process. The borehole acts as a sanitary seal for the well and stabilizes the drill rig. A 48-inch diameter conductor borehole was drilled to a depth of 50 feet using a bucket auger drill rig (Appendix A – picture 1). Once the hole was completed, a 36-inch outside diameter surface conductor casing (ASTM A139 Grade B Steel) (Appendix A – pictures 2, 3, & 4) was installed within the 50 foot hole and was then cemented in place from the ground surface to the completed depth of 50 feet.

3.3 Pilot Borehole Drilling Process

Once the conductor casing was cemented in place and allowed to cure, the pilot borehole was then drilled. The pilot borehole was drilled using the reverse circulation drilling method with a 17½-inch diameter tri-cone mill-tooth bit (Appendix A – picture 5). Its purpose is to provide the geologist with lithologic samples for evaluation, to create an access for the geophysical logging tools, and to act as a guide for the reaming bit. Due to its relatively inexpensive cost, the reverse circulation drilling method is the method of choice when large diameter, high capacity water wells are constructed. Before the drilling process began, the conductor casing was filled with water to ground surface through a water line (approximately 12-inches in diameter) welded to the side of the casing. This water line was connected from the conductor casing to the storage tank where the water needed for drilling is stored.

The reverse circulation drilling method uses compressed air to retrieve the drill cuttings from the bottom of the borehole. The compressed air is forced through a 2-inch diameter airline located within the drill pipe. The compressed air reduces the density of the drilling fluid causing the fluid and the cuttings to rise through the drill pipe for collection. The water and drill cuttings are then discharged into the settling tank (mud pit). The cuttings were sampled at regular intervals and the water was recycled for continued use during the drilling process. The water used for the drilling process first enters the pilot borehole through the annular space between the walls of the borehole and the drill pipe. As it passes down the borehole and past the drill bit, the water picks up the drill cuttings and transports them through the drill bit and up the central drill pipe to the mud pit.

Additional water must continuously be added to the borehole because of the increasing depth of the borehole and the fact that some of the water used for drilling is lost through permeable strata encountered during drilling. Quite often, fine particles produced from the drilling are suspended in the water and will adhere to the borehole wall, forming a “mud cake” that decreases the amount of water lost to the surrounding formation. The volume of water required at the drilling site for loss into the formation is as little as 20 gpm, though when drilling through highly permeable formations such as dry, coarse sands and gravels, as much as 1,000 gpm may be required (Driscoll, 1986).

Caving and collapse of the borehole was prevented by maintaining adequate water pressure during the drilling process. This was accomplished by keeping the water level in the borehole at the ground surface and by keeping the flow velocity of the borehole water at a minimum. The flow velocity of the borehole water is quite low due to the fact that the water in the borehole is stable and additional water is slowly added as the drilling progresses.

3.4 Well Design Process

3.4.1 Lithology

Lithologic samples were collected from the drill rig at 10 foot depth intervals and logged according to the Universal Soil Classification System (USCS). The characteristics of the drill cuttings noted in the logs included sediment grain size, sorting, cementation and roundness, as well as wet soil color (based on Munsell color charts). The lithologic samples were collected and placed in one gallon Ziploc® freezer bags and labeled with the well name, date of sample, and the depth interval at which the sample was collected. The lithologic samples were later arranged in chip trays allowing for the client and geologist to view the continuous borehole section (Appendix A – picture 6).

The lithology encountered in the three CDA wells consisted primarily of interbedded layers of sands and gravels and silts and clays. The predominate lithology noted in the three wells was fine to coarse grained sand with traces of gravel, silt, and clay.

3.4.2 Geophysical Logs

Once the pilot borehole for the well was completed the geophysical logging began. The geophysical logging process consisted of placing a variety of logging tools (Appendix A – pictures 7 & 8) down the pilot borehole to provide information about the surrounding lithology. The geophysical logs were used in conjunction with the drill cuttings to select zones for testing and to determine the most favorable intervals for the placement of the well screen (sand and gravel layers) and the blank well casing (silt and clay layers). Several geophysical logging tools were used in this process. For the CDA wells the following geophysical logs were run:

- Short / Long Normal Resistivity
- Gamma Ray
- Temperature
- Guard
- Sonic

A full suite of geophysical logs is required for the borehole because quality data are not always obtained from each individual log. By employing several different logging tests, viable information regarding the borehole lithology can be obtained.

The logging tools (also known as "sondes") were run down the open borehole which was filled with drilling fluid (water, formation water, and possibly drilling mud). The tools are connected to the logging van by cables and wires which carry the information from the sonde to the logging computer. When the open borehole is logged, several factors must be considered when reading the data output. These include the mud resistivity, the fluid temperature, the resistivity of the natural groundwater, and the depth of fluid penetration into the surrounding formation (Welenco, 1996).

Short / Long Normal Resistivity Logs

Short and long normal resistivity logs are used in the well design process because they can distinguish differing lithologic layers within the borehole. The short normal resistivity tool reads the resistivity of the lithology very close to the borehole and the long normal resistivity tool records the resistivity of the lithology deeper into the formation, but has a lower bed resolution (Driscoll, 1986). The resistivity tool consists of a string of electrodes placed 16-inches and 64-inches apart. The depth at which the tool reads into the formation is 2 times the distance between the electrodes. The electrodes on the short normal resistivity tool are located 16-inches apart and the electrodes for the long normal resistivity tool are spaced 64-inches apart. The results of these logs distinguish between materials of different grain size based on differences in resistivity. For example, coarse material (sands and gravels) are highly resistant, while fine grained materials (silts and clays) have a very low resistivity (i.e., they have a higher conductivity).

Gamma Ray Log

Natural gamma radiation logs are the most commonly utilized nuclear logs in the field of hydrogeology (Fetter, 2001). The gamma ray log measures the emission of radiation of Potassium 40 (K 40), Thorium 232 (Th 232), Uranium 235 (U 235), and Uranium 238 (U 238). Of these four elements, Potassium 40 is the most abundant. Potassium 40 is found throughout rock strata in minerals such as biotite, orthoclase, potassium feldspar, and the clay minerals (Welenco, 1996). Clay-rich formations have a considerably higher natural gamma activity than that of quartz sands (Todd, 1980) and thus, the gamma ray log shows an increasing detection strength from sands and gravels, to silts and clays.

Temperature Log

The temperature log provides hydrogeologists with information regarding the changing temperature of the groundwater within the borehole. The temperature sensor is located on the tip of the temperature probe, so that as the probe is lowered down the borehole, there is no disturbance of the groundwater resulting in false temperature readings. The temperature log is useful because it can alert hydrogeologists of boundaries between aquifers based on contrasts in groundwater temperature. The temperature of the groundwater is expected to increase steadily with depth, but lower temperatures encountered at depth can result from natural surface recharge (Todd, 1980).

Guard Log

Unlike the short and long normal resistivity logs where spheres of electrical current are used to read into the borehole wall, the guard log uses a disk-shaped electrical field to evaluate the lithology of the borehole. This is accomplished by using two guard electrodes to concentrate the current into a disk shape within the surrounding lithology. The advantage of this disk shape is that it penetrates three times deeper into the formation than one guard electrode and is able to read the lithology to within the length of the current electrode. Therefore, if the length of the current electrode is 4-inches and the guard electrode is three feet, then the guard log can interpret the beds to within 4-inches and can penetrate into the formation with a radius of 9 feet (Figure 5) (Welenco 1996).

The guard log demonstrates its usefulness in alluvial settings where the inter-layering of lithologic beds is highly prominent. The short and long normal resistivity logs will average the grain sizes of a gravel bed that has inter-layered silts and sands, whereas the guard log will define these thinner beds allowing for a more distinct lithologic profile.

Sonic Log

The purpose of the sonic log is to differentiate between the lithologic units by measuring the amount of time it takes a compressional sound wave to travel one foot (measured in μs/foot). The sonic tool is lowered down the open borehole and pulses of sound are transmitted at a frequency of approximately 23,000 Hz. The compressional sound waves are detected by a receiver which is located on the sonde at a distance of several feet from the transmitter. This receiver picks up the sound pulses and the computer calculates the amount of time it takes the sound to travel from the transmitter, through the drilling fluid into the borehole wall, down the formation, and back through the drilling fluid to the receiver (Welenco, 1996). Sound waves travel faster through denser material (i.e. bedrock) and slower through less dense material (i.e. sands, gravels, silts, and clays). Therefore, a longer travel time indicates a lower density material which equates, in general, to a higher porosity. From a graph of sound velocity vs. depth the hydrogeologic properties of the lithology can be interpreted.

3.4.3 Isolated Aquifer Zone Testing

Upon completion of the geophysical logs the results were reviewed by a hydrogeologist and were compared with the lithologic samples obtained from the drilling process. This verifies that the outcome from the geophysical logs is consistent with the actual lithologic samples. The hydrogeologists then used both the geophysical logs and the lithologic samples to select particular regions from the borehole to be tested in detail for hydrogeologic characteristics. These tests are referred to as "zone tests".

Before the zone testing began, artificial fill (backfill material) was placed down the borehole until it approached 10 feet below the lowermost zone. A 10 foot bentonite seal was then placed on top of the fill sealing off the aquifers below the zone. A 20 foot long, 8-inch diameter section of well screen was lowered down the borehole until it reached the bentonite seal. A filter pack consisting of coarse sand and gravel was then placed within the annular space between the well screen and the borehole wall. This material was added until it reached the top of the well screen. The objective of the filter pack is to keep fine sands, silts, and clays from the surrounding formation from entering the pump and potentially damaging it. Another 10 foot bentonite seal was placed above the well screen and filter pack to separate the upper aquifers from the test zone (Figure 6).

The 20 foot long test zone was then air lifted until the discharge water from the zone was clean. Airlifting is a process by which compressed air is forced through holes cut into a 2-inch diameter pipe. The pipe is placed within the well and as the compressed air rises, sediment suspended within the water is carried up to the surface. Once the water was clean, the test zone was then pumped with a submersible pump for roughly 4-6 hours at a recommended rate of 200 gpm (ASCE, 2004). During the pumping, drawdown of the water table and the discharge rate of the pumped water were measured to obtain data regarding the aquifer yield. Water quality samples were taken at the end of the test and were later analyzed for specific contaminants. Tri-linear (Piper) Diagrams showing the results of the water quality analysis are shown in Figures 7a -7c.

When the zone test was completed, the well screen was taken out of the well and cleaned. The borehole was then backfilled with gravel to the bottom of the next zone. The wells screen was placed back into the borehole at the specified depth and the process repeated itself. With the information from the zone tests performed on the borehole, essential data was obtained regarding variations in aquifer yield and the vertical extent of contaminants within the aquifer. These data were then used in designing the final well.

Three zones were chosen for each of the CDA wells at varying depths. The following table shows these zones and the level of nitrate contaminant within the zone.

Summary of Nitrate Concentration - Aquifer Zone Testing

CDA Well No.	Zone	Depth Interval (ft bgs)	Static Water Level (ft bgs)	Pumping Water Level (ft bgs)	Average Discharge Rate (gpm)	Nitrate Concentration (mg/L)
I-13	1	295-315	73.8	111.2	153	15
	2	186-206	74.0	106.5	157	140
	3	136-156	74.0	86.5	155	480
I-14	1	350-370	74.4	138.2	73	3.6
	2	190-210	73.3	95.2	166	106
	3	110-130	73.6	89.2	173	314
I-15	1	273-293	74.5	86.0	161	8.3
	2	173-193	74.6	91.3	157	74
	3	113-133	76.0	89.9	161	230

3.4.4 Sieve Analysis

Sieve analyses were performed on particular intervals of the borehole based on review of the lithologic samples and the geophysical logs. These intervals were chosen based on their presumed potential to yield water. The samples were dried and sieved using standard U.S. sieves whose weights are known and recorded. The sieve sizes were selected to separate the samples into various grain sizes while retaining no more than 20 percent of the sample (Driscoll, 1986). The sieves used and their corresponding opening sizes are shown in the following table.

Summary of U.S. Standard Sieves Used for Analysis

U.S. Standard Sieve No.	Sieve Opening [in.]	Sieve Opening [mm]
1/4	0.25	6.3
3/8	0.375	9.53
4	0.187	4.75
8	0.094	2.38
12	0.066	1.68
16	0.047	1.19
20	0.033	0.84
30 *	0.023	0.58
40	0.017	0.43
50	0.012	0.3
100	0.006	0.15
200	0.0029	0.075

* The 30 sieve was used instead of the 40 sieve on CDA I-15

The percent of material passing through each sieve was then plotted on a graph opposite its corresponding opening size in mm. The graph results in a grain-size distribution curve, also known as an S-shaped curve (Figure 8). The shape of the curves of each of the intervals sampled allows for an appropriate filter pack to be designed for that particular well. The slot size of the well screen was also determined by the shape of the grain-size distribution curve. This value is plotted on the graph and shows how much of the designed filter pack will pass through the well screen. For a well to perform efficiently, the filter pack must be designed to prevent the formation material from entering the well (Figure 8).

3.4.5 Well Design Criteria

The final well design incorporates the data obtained from the lithologic log, geophysical logs, isolated aquifer zone testing, and sieve analyses. Potential aquifers were first identified from the lithologic log and geophysical logs. Aquifers are typically characterized by sediment layers consisting primarily of sand and/or sand gravel mixtures. These layers show up on the resistivity logs as zones of high resistivity. These data, along with confirmation of yield and water quality from the isolated aquifer zone testing, confirm the interval of the well to be perforated. Sieve analyses of aquifer material collected during drilling dictate the gradation of the filter pack and the slot size of the perforations.

3.5 Well Construction

3.5.1 Pilot Borehole Reaming

The 17½-inch diameter pilot borehole was enlarged to a final diameter of 26-inches to allow for the 16-inch diameter well casing to be placed in the borehole. The reaming process began after the geophysical logs were run and while the well was being designed by the hydrogeologists. This process involved attaching a 26-inch diameter bit about 2 feet above the top of the original 17½-inch diameter bit (Appendix A – picture 9). During this process, no lithologic samples were taken.

3.5.2 Casing Installation

The well casing was installed once the borehole was reamed to its final diameter. When the casing arrives on site it must be checked by the hydrogeologist to make sure that the right footage of blank casing and screened casing is on site. The well casing was installed in order in 40 foot sections and each subsequent section was welded onto the next as the casing was lowered down the borehole. Steel centralizers were welded onto the casing every 120 feet to make sure that the casing was centered throughout the borehole and kept away from the borehole wall. Once all of the casing was lowered into the borehole the next step in the well construction began.

3.5.3 Filter Pack Installation

The filter pack for the well was installed using a tremie pipe. The tremie pipe is a 2-inch diameter pipe that is placed down the annular space between the well casing and the borehole wall. The selected filter pack was then fed through this tremie pipe filling up the annular space. As the filter pack filled up the annular space, the tremie pipe was raised to allow for more filter pack to be placed around the well casing. The annular space was filled with the filter pack from the bottom of the borehole to the ground surface. A cross section of the wells can be seen in figure 9.

3.5.4 Well Development

When the wells were installed and the filter pack placed in the annular space between the casing and the borehole wall, the wells were then developed. The CDA wells were initially developed using a combination airlifting and swabbing tool (Appendix A – picture 10). The purpose of the initial development is to consolidate the filter pack after placement and to remove colloidal and fine-grained sediments from within the well, filter pack, and near-well zone. The wells were developed in ten foot intervals and were swabbed and airlifted simultaneously until the discharged water appeared relatively clean.

Final development on the three wells was conducted using a vertical turbine test pump. This final well development consisted of pumping the wells at a steady discharge rate until the sand concentration reached a minimum threshold of less than 5 parts per million (ppm). The discharge rates of the wells were measured using an in-line propeller meter.

3.5.5 Pumping Tests

Two separate pumping tests were performed on the CDA wells once the well development had been completed. First, a step drawdown test was run in which the wells were pumped at three discharge rates increasing from the initial step to the final step. The wells were pumped at the discharge rates until the drawdown within the well began to stabilize. Upon completion of the step drawdown test, a 24-hour constant rate test was performed to determine aquifer transmissivity.

The purpose of these two pumping tests is to obtain data which, when input into equations, yield information regarding specific well and aquifer parameters. Certain assumptions have been made when deriving the equations and these assumptions must be accounted for during the tests. The assumptions made include the following:

- The aquifer material is assumed to consist of porous media, with flow velocities being laminar and obeying Darcy's law.

- The aquifer is considered to be homogeneous, isotropic, of infinite aerial extent, and of constant thickness throughout.

- Water is released from (or added to) internal aquifer storage instantaneously upon change in water level.

- No storage occurs in the semi-confining layers of leaky aquifers.

- The storage in the well is negligible.

- The pumping well penetrates the entire aquifer and receives water from the entire thickness by horizontal flow.

- The slope of the water table or piezometric surface is assumed to be flat during the test with no natural (or other) recharge occurring, which would affect test results.

- The pumping rate is assumed constant during the entire time period of pumping during the constant-rate test, and constant during each discharge step in the step drawdown test.

The most common equation used for evaluating pumping test data is Jacob's equation (Jacob, 1950);

$$s(r,t) = \frac{264Q}{T}\log\left(\frac{0.3\,Tt}{r^2 S}\right).$$

Jacob's equation is valid for use for most hydrogeologic problems of practical interest, is easier to use than the Theis equation, and involves a simple graphical procedure to calculate transmissivity.

These pumping tests enable estimates of aquifer transmissivity and hydraulic conductivity. Transmissivity is defined as, the rate at which water is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient. It is a function of properties of the liquid, the porous media, and the thickness of the porous media (Fetter, 2001). Transmissivity (T, in gpd/ft) can be calculated as:

$$T = \frac{264Q}{\Delta s}$$

where:

Q = Pumping rate, [gpm]

Δs = Change in drawdown over one log cycle of time, [ft] Hydraulic conductivity is defined as a coefficient of proportionality describing the rate at which water can move through a permeable medium (Fetter, 2001). Hydraulic conductivity (K, in gpd/ft^2) can be calculated as:

$$K = \frac{\text{(Transmissivity)(well efficiency)}}{\text{aquifer thickness}}$$

The data obtained from the step drawdown and constant rate pumping tests were then graphed and are shown in figures 10 & 11 respectively.

4.0 FINDINGS

4.1 Lithology – Bedrock Intercepts

The depth to bedrock and bedrock type were not previously known in the Project Area. As a result of the CDA wells, the depth and type of bedrock at three locations were obtained. The bedrock intercept values were determined through the evaluation of the resistivity logs and the drilling rate. Bedrock is easily identified on the resistivity logs by a sharp and steady "kick" on the log to the right (higher resistivity). Furthermore, as the drill bit encounters bedrock, the penetration rate of the drill decreases noticeably and the entire rig begins to clatter.

Bedrock was encountered in the westernmost well (I-13) at approximately 365 feet bgs (Figure 3 and Appendix B). The lithologic samples obtained from this depth interval reveal fine to medium-grained sand. This is to be expected as the uppermost portion of the bedrock encountered will be weathered. Also, as the drilling continues through the bedrock, the drill bit will break up the rock into smaller pieces.

In Well I-14, traces of bedrock were intercepted at roughly 521 feet bgs (Figure 3 and Appendix B). At this depth the lithologic log shows a lithology of clayey to silty sand. The sand in the sample is fine to coarse-grained. Green, sandy clay balls up to 35 mm are found in the sample along with granitic fragments. Due to the extreme depth of this well and the green clay balls found in the sample, it can be inferred that there may be a fault through this region of the basin. This is unfounded and if the fault exists it is not a groundwater barrier.

Bedrock was detected in Well I-15 (the easternmost well) at approximately 316 feet bgs (Figure 3 and Appendix B). This value and the value obtained from Well I-13 (~365 feet bgs) are striking in contrast to the depth to bedrock in Well I-14 (~521 feet bgs) which further supports the notion for a fault and/or paleo-channel in the region.

The bedrock type encountered in the Project Area was granitic in composition, though through this type of drilling process, accurate samples can not be procured to ensure exact identification of the bedrock. Alluvial sediments encountered during the drilling process include fine grained gravels, fine to coarse grained sand, and interbedded layers of silts and clays.

4.2 Aquifer Characteristics

Based on pumping test data, the aquifer transmissivity in the vicinity of the wells ranges from 260,000 gpd/ft to 370,000 gpd/ft. Hydraulic conductivities of the aquifer range from 980 gpd/ft^2 to 1,140 gpd/ft^2. These results show that the sediments associated with alluvial deposition along the Santa Ana River are very permeable and yield abundant water to wells.

4.3 Groundwater Quality

Water samples were collected upon completion of the 24-hour constant rate test and were submitted to the laboratory for Title 22 analysis (Figure 12). The samples were analyzed for several constituents including pH, Nitrate (as NO_3), Total Dissolved Solids (TDS), Total Cations, Total Anions, and Organic Chemicals. All constituents were recorded and noted but the two constituents of most interest were Nitrate (as NO_3) and TDS.

The California Department of Health Services has established a maximum contaminant level (MCL) for Nitrate (as NO_3) of 45.0 mg/L. The nitrate concentrations in the CDA wells were well above this level. Well I-13 had a nitrate concentration of 93 mg/L, over twice the concentration of nitrate allowed for primary drinking water standards. The level of nitrate detected in Well I-14 was 130 mg/L, nearly three times the allowable limit. A nitrate concentration of 120 mg/L was received from Well I-15.

The TDS concentrations in Wells I-13, I-14 and I-15 were 460 mg/L, 670 mg/L, and 660 mg/L respectively.

The high Nitrate and TDS concentrations were anticipated and support the need for water treatment through a Reverse Osmosis plant. The Nitrate and TDS concentrations are highest in the shallow aquifer zones and are consistent with the surface source of Nitrate and TDS. The results of the isolated aquifer zone testing indicated that the lowest concentrations of Nitrate and TDS are found at depth.

5.0 Summary

In summary, data obtained during the drilling of the Chino Desalter Authority wells indicates:

- Bedrock consists of granite and occurs at depths ranging from ~316 feet bgs to ~521 feet bgs indicating the bedrock surface is undulating in the Project Area.
- Overlying aquifer sediments consist primarily of fine to coarse grained sand, fine grained gravel, and interbedded layers of silt and clay. These deposits are associated with the Santa Ana River.
- Aquifer sediments are very permeable and yield abundant water to wells. Transmissivity values range from 260,000 gpd/ft to 370,000 gpd/ft, and hydraulic conductivity values range from 980 gpd/ft^2 to 1,140 gpd/ft^2.
- Groundwater quality has been degraded through agricultural land use resulting in high concentrations of Nitrate and TDS with the highest concentrations in the shallow aquifer zones. The contaminated water will be treated by Reverse Osmosis yielding drinking quality water for municipal use.

6.0 Acknowledgements

I would like to thank Russ Kyle, Terry Watkins, Ailco Wolf, David Bauer, Patti Praznik, and all of the staff at Geoscience Support Services, Inc. for their assistance, encouragement, and support, Mr. Tom O'Neill of the Chino Basin Desalter Authority for allowing me to use the data from the CDA wells to produce this thesis, and my parents, Mike and Karen, for their unremitting support throughout my college years. I would also like to thank the Cal Poly Geological Sciences Department. And finally I would like to thank my advisors, Tom Harder and Dr. Jeff Marshall, for their continuous support and assistance throughout the duration of my senior thesis.

7.0 References

California Department of Water Resources, 1970, Meeting Water Demands In The Chino-Riverside Area, Appendix A: Water Supply, Bulletin no. 104-3.

California Division of Mines and Geology, 1986, "Geologic Map of the San Bernardino Quadrangle, California".

Driscoll, F.G., 1986. *Groundwater and Wells.* Johnson Screens, St. Paul, Minnesota.

Durham, D.L., and Yerkes, R.F., 1964, Geology and oil resources of the eastern Puente Hills, southern California: U.S. Geological Survey Professional Paper 420-B, p. 62.

Eckis, R., 1928, Alluvial fans of the Cucamonga District, southern California: Journal of Geology, v. 36, no. 3, p. 224-247.

Eckis, R., 1934, Geology and ground water storage capacity of valley fill: California Divisions of Water Resources Bulletin no. 45, 279 p.

Ehlig, P.L., 1975, Basement rocks of the San Gabriel Mountains south of the San Andreas fault, southern California, in Crowell, J.C., ed., San Andreas fault in southern California: Sacramento, California: California Division of Mines and Geology Special Report 118, p. 177-186.

Eldridge, G.H., 1907, The Puente Hills oil district, southern California: U.S. Geological Survey Bulletin no. 309, p. 102-137.

Fetter, C.W., 1994. *Applied Hydrogeology.* Prentice Hall, Upper Saddle River, New Jersey.

Geoscience Support Services, Inc., 2001, Geohydrologic Analysis and Ground Water Flow Model of the Proposed Chino Desalter System Project Area.

Jacob, C. E., 1950. *Engineering Hydraulics*. J. Wiley and Sons, New York.

Mendenhall, W.C., 1908, Groundwaters and irrigation enterprises in the Foothill Belt, southern California: U.S. Geological Survey Water Resources Paper no. 219, 180 p.

Morton, D.M., and Matti, J.C., 1987, The Cucamonga fault zone, Geologic setting and Quaternary history: U.S. Geological Survey Professional Paper 1339, p. 179-203.

Nourse, J.A., 2002, Middle Miocene reconstruction of the central and eastern San Gabriel Mountains, southern California, with implications for evolution of the San Gabriel fault and Los Angeles basin, in Barth, A., ed., Contributions to Crustal Evolution of the Southwestern United States: Boulder, Colorado, Geological Society of America Special Paper 365, p. 161-185.

Shelton, J.S., 1955, Glendora volcanic rocks, Los Angeles basin, California: Geological society of America Bulletin, v. 66, p. 45-90.

Todd, D.K., 1959. *Groundwater Hydrology*. J. Wiley and Sons, New York.

Welenco, 1996, Water and Environmental Geophysical Well Logs, v. 1, p. 153.

Williams, D.E., An EWRI-ASCE International Manual On Water Well Design, Construction, Testing, and Maintenance, Chapter 5 – Water Well Construction, Development, and Testing, (Not Yet Published).

Woodford, A.O., Shelton, J.S., and Moran, T.G., 1946, Miocene conglomerates of Puente and San Jose Hills, California: American Association of Petroleum Geologists Bulletin, v. 30, p. 514-560.

Yerkes, R.F., 1972, Geology and oil resources of the western Puente Hills area, southern California: U.S. Geological Survey Professional Paper 420-C, p. 63.

FIGURES

GENERAL PROJECT LOCATION

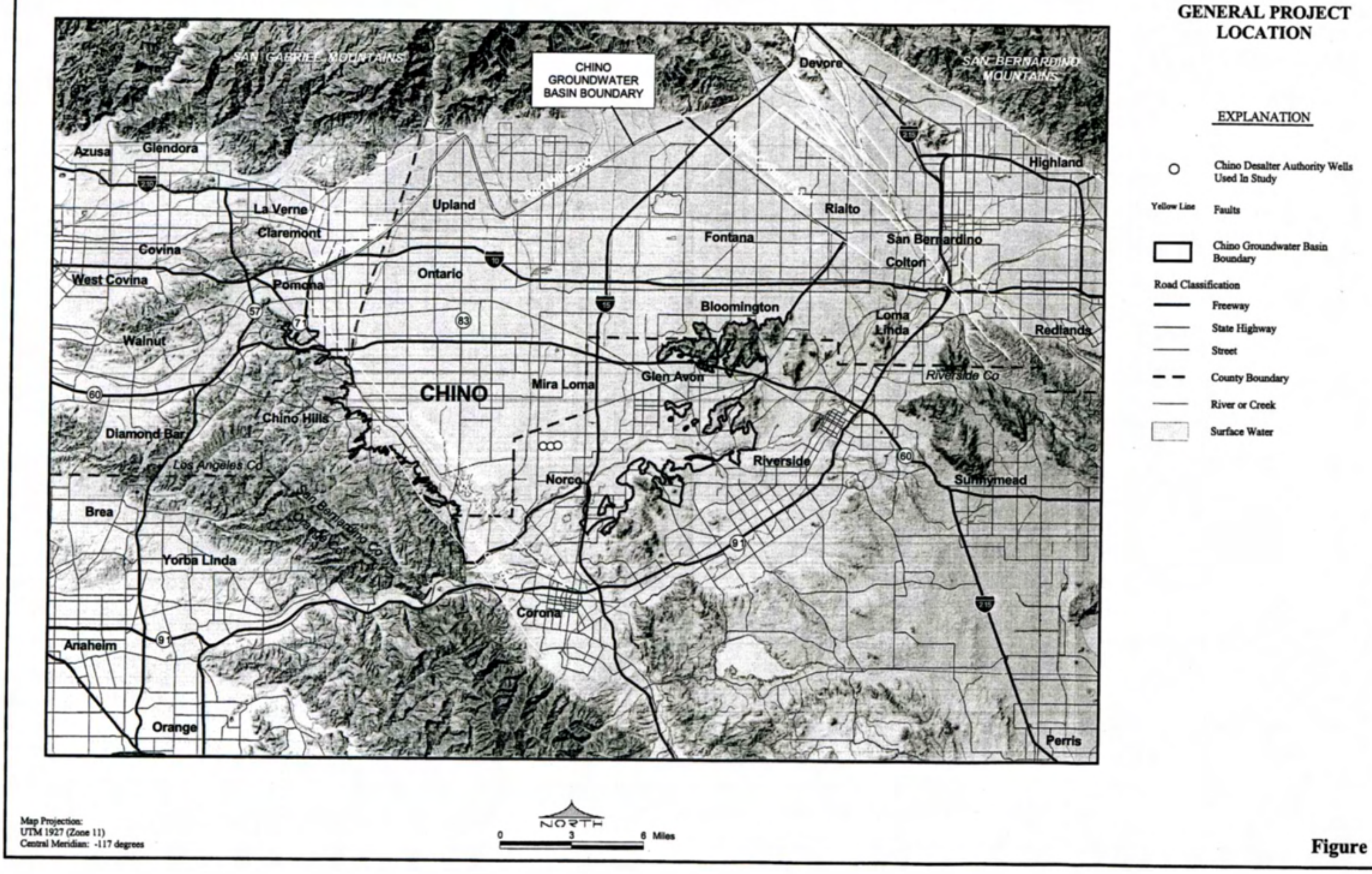
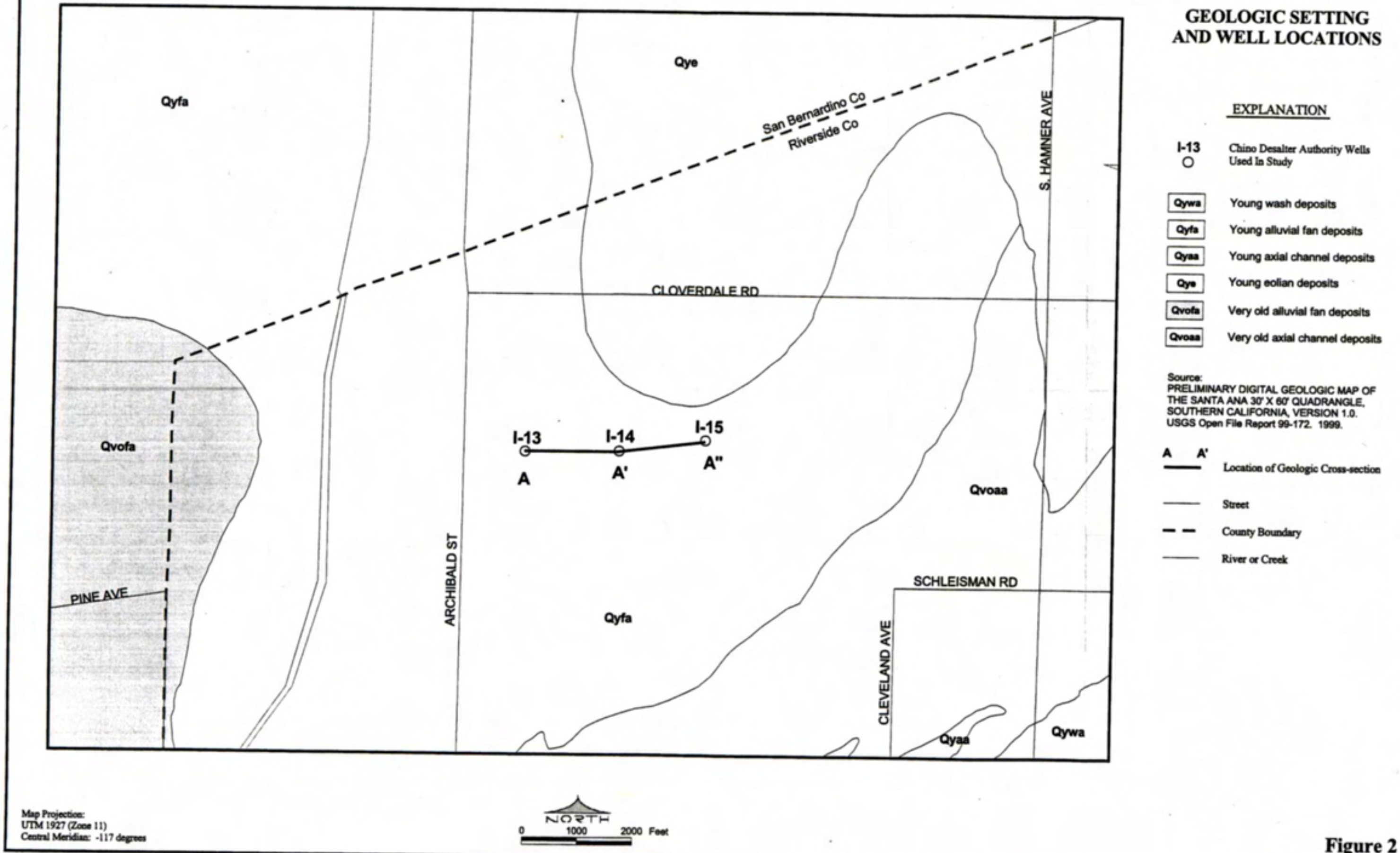


Figure 1

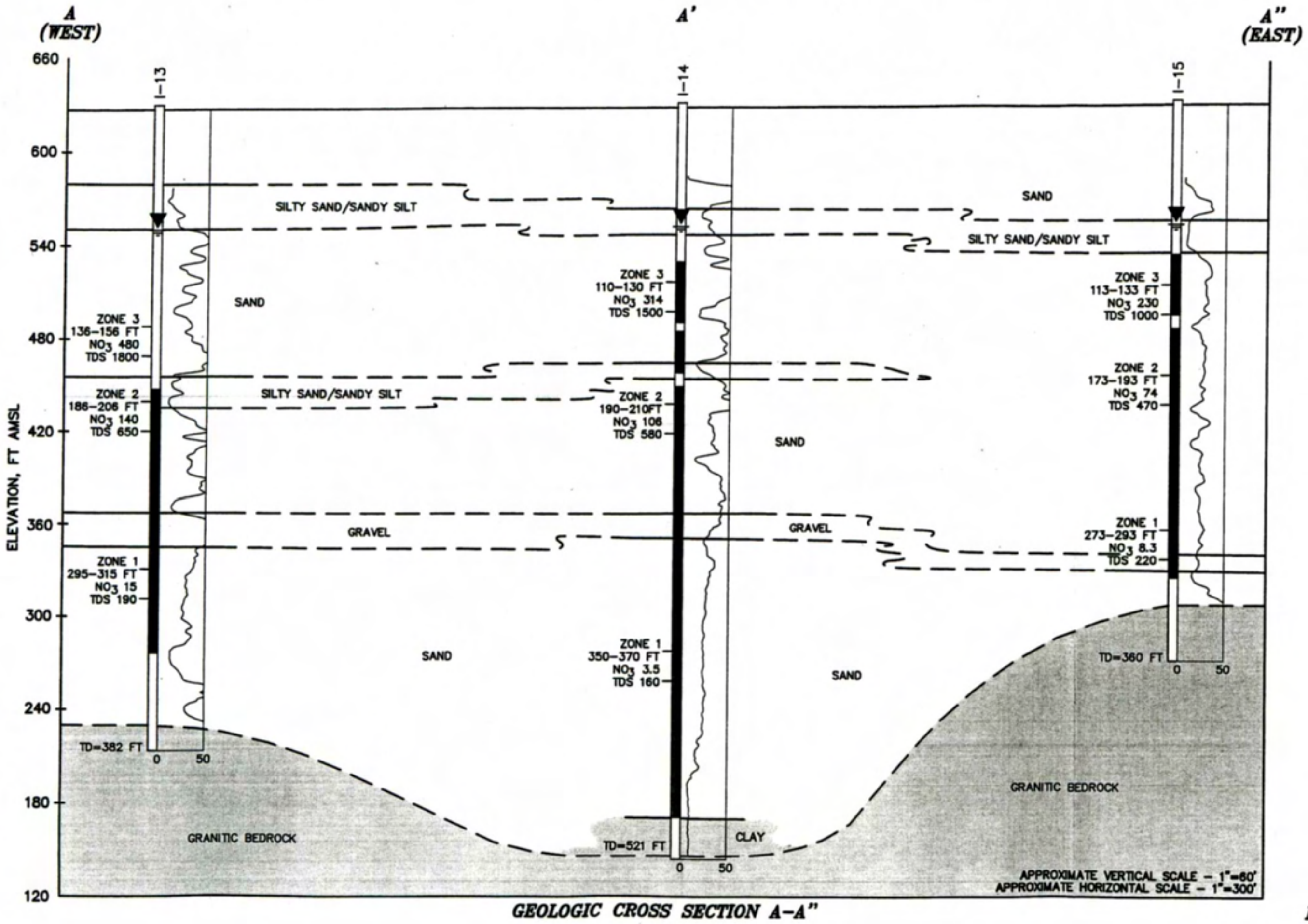
GEOLOGIC SETTING AND WELL LOCATIONS



Source:
PRELIMINARY DIGITAL GEOLOGIC MAP OF THE SANTA ANA 30' X 60' QUADRANGLE, SOUTHERN CALIFORNIA, VERSION 1.0. USGS Open File Report 99-172. 1999.

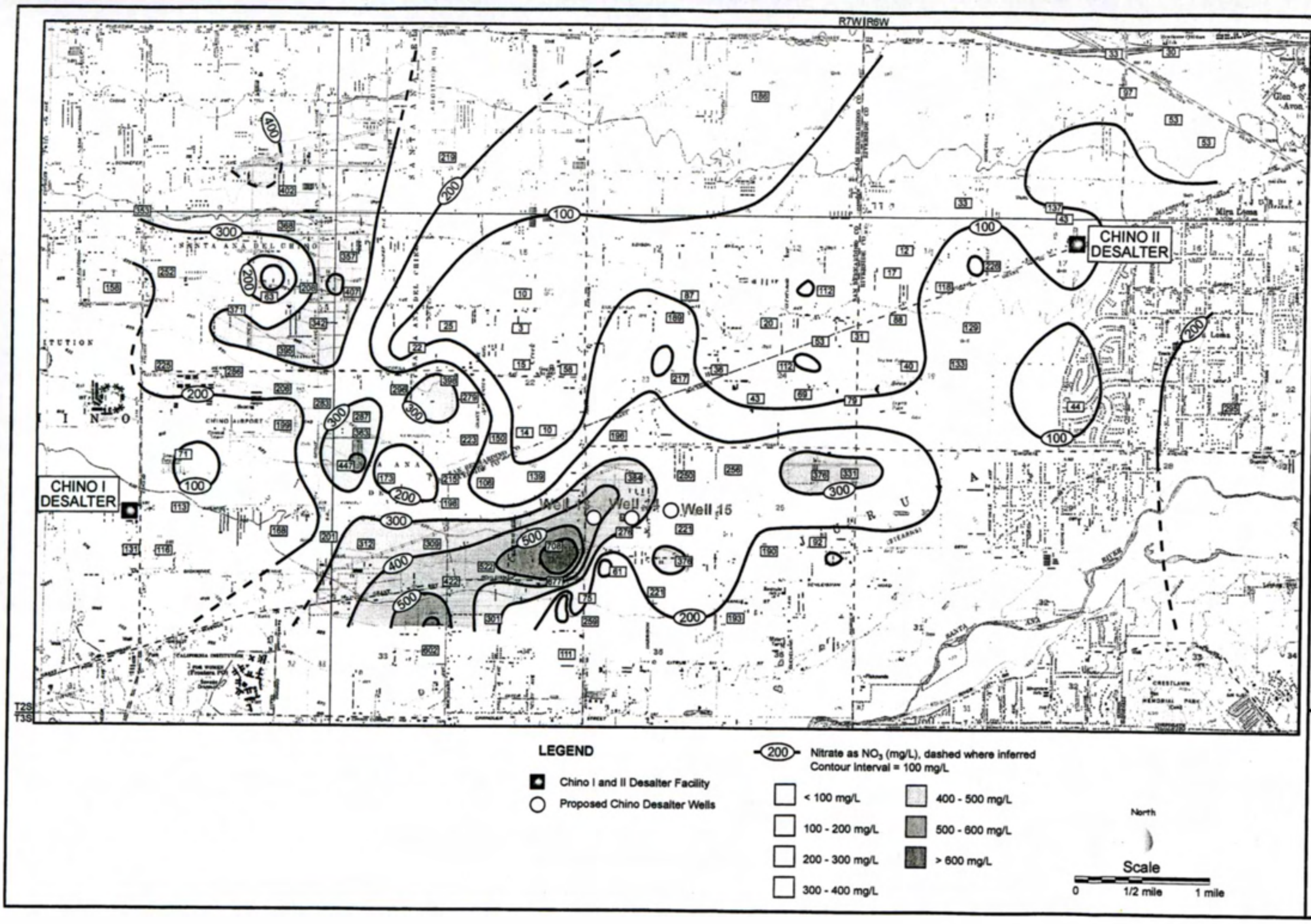
Map Projection:
UTM 1927 (Zone 11)
Central Meridian: -117 degrees

Figure 2



GEOLOGIC CROSS SECTION A-A''

FIGURE 3

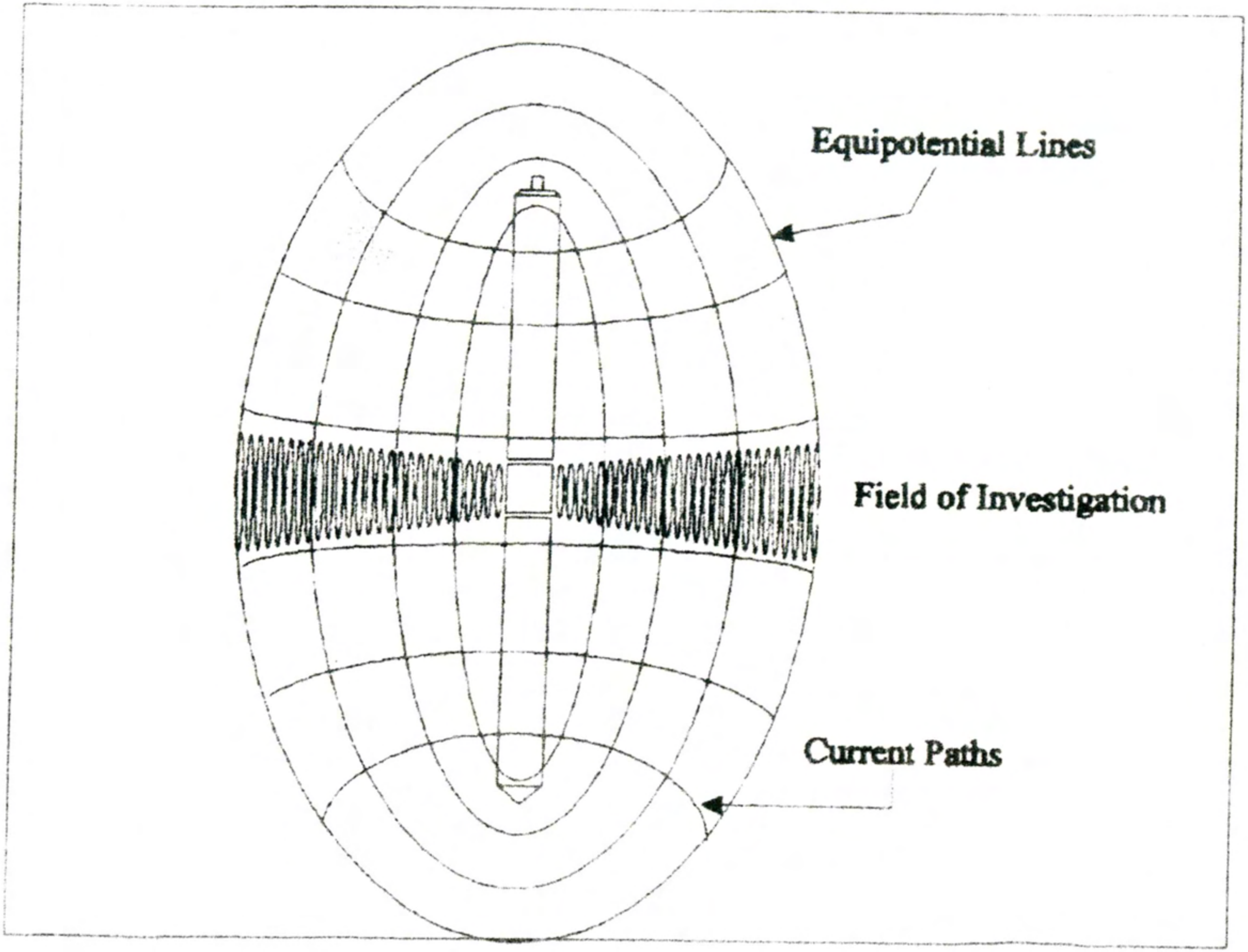


NITRATE CONTOUR MAP - 1999

Figure 4

Figure 5

Electrical Field around the Guard Sonde

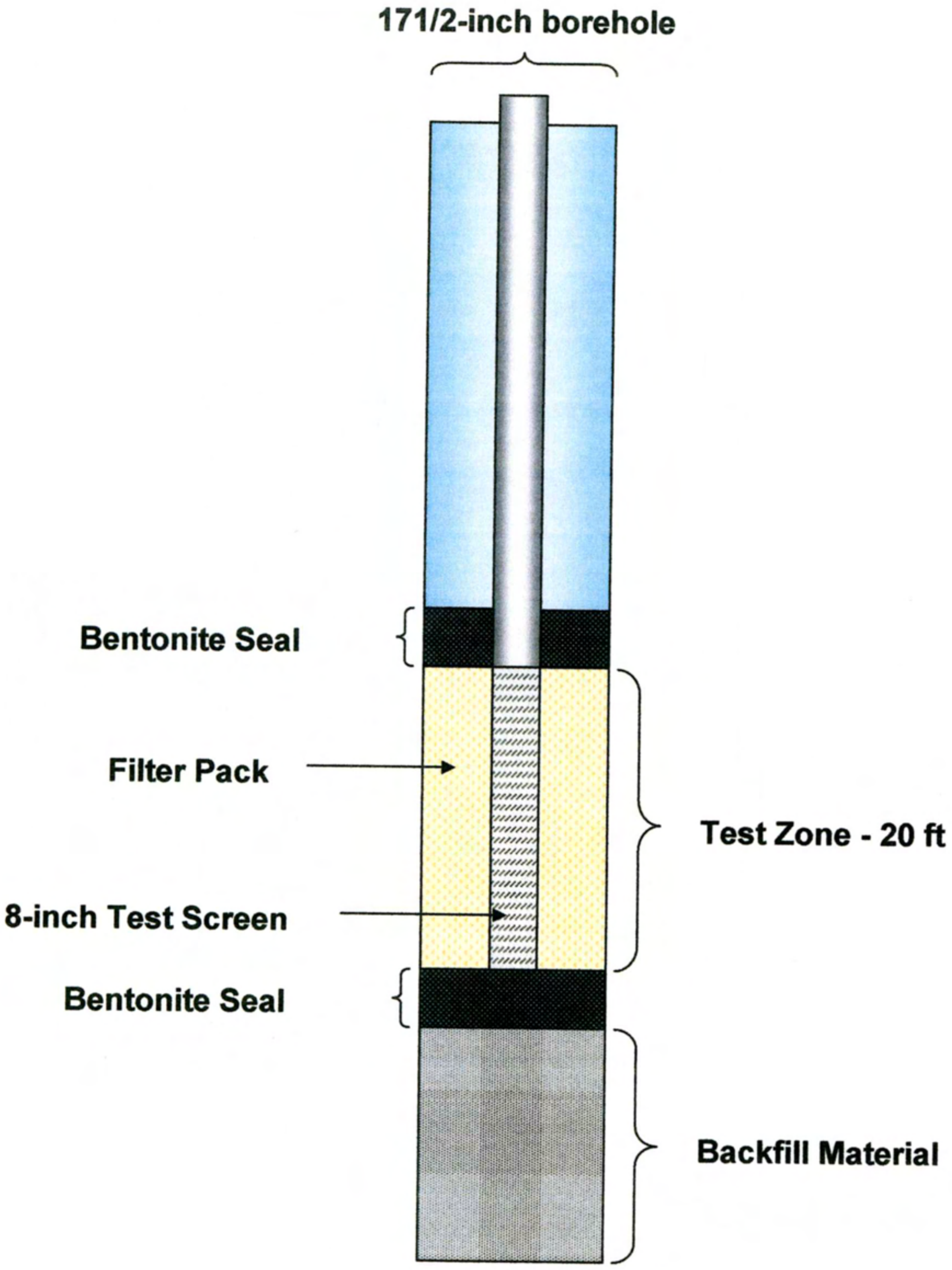


1-Jun-04

(Welenco, 1996)

Figure 6

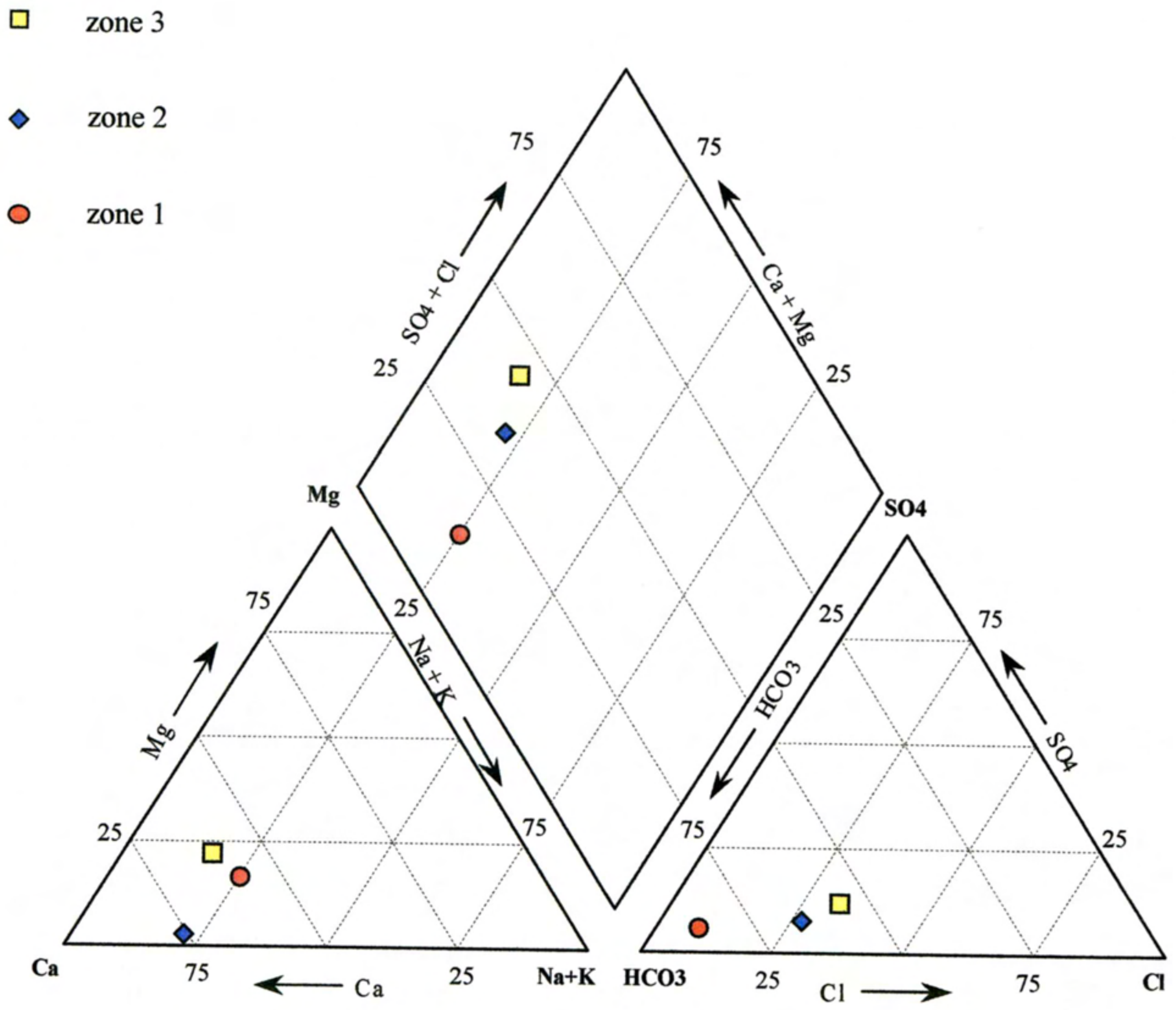
Schematic Diagram of Zone Test Tool



1-Jun-04

Figure 7a

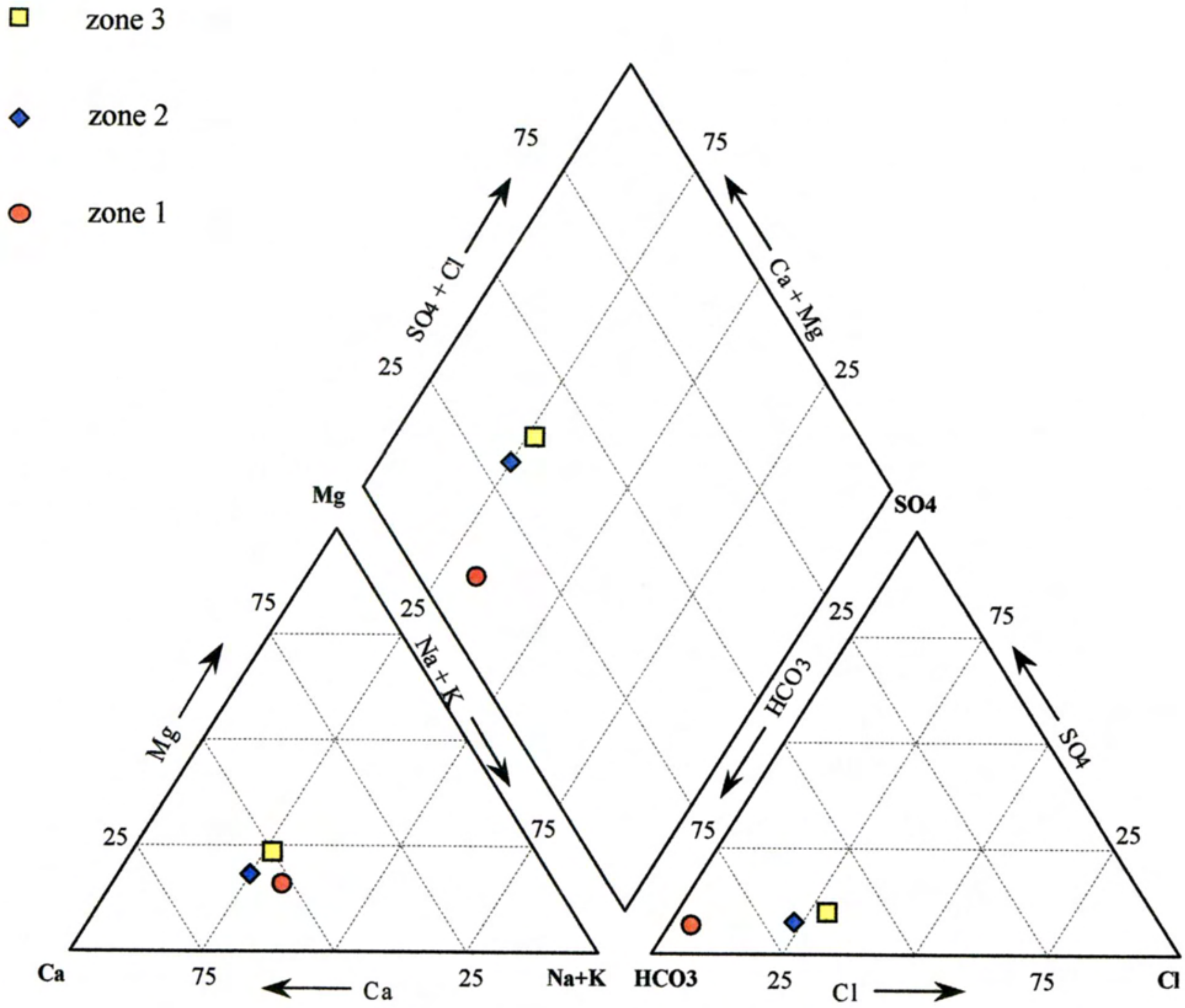
Trilinear Diagram
Isolated Aquifer Zone Test Water Quality Data
Chino Desalter Authority Well I-13



1-Jun-04

Figure 7b

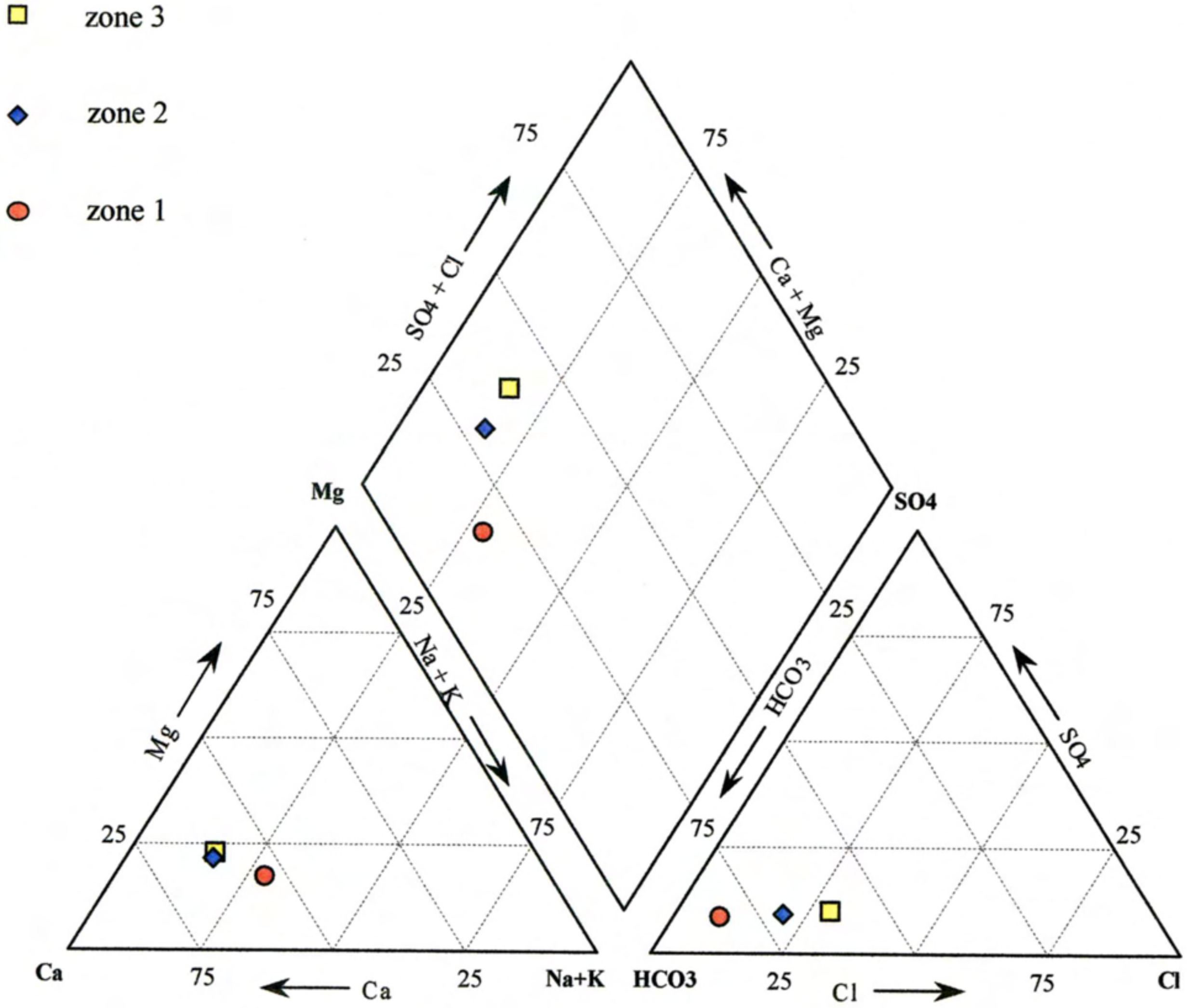
Trilinear Diagram
Isolated Aquifer Zone Test Water Quality Data
Chino Desalter Authority Well I-14



1-Jun-04

Figure 7c

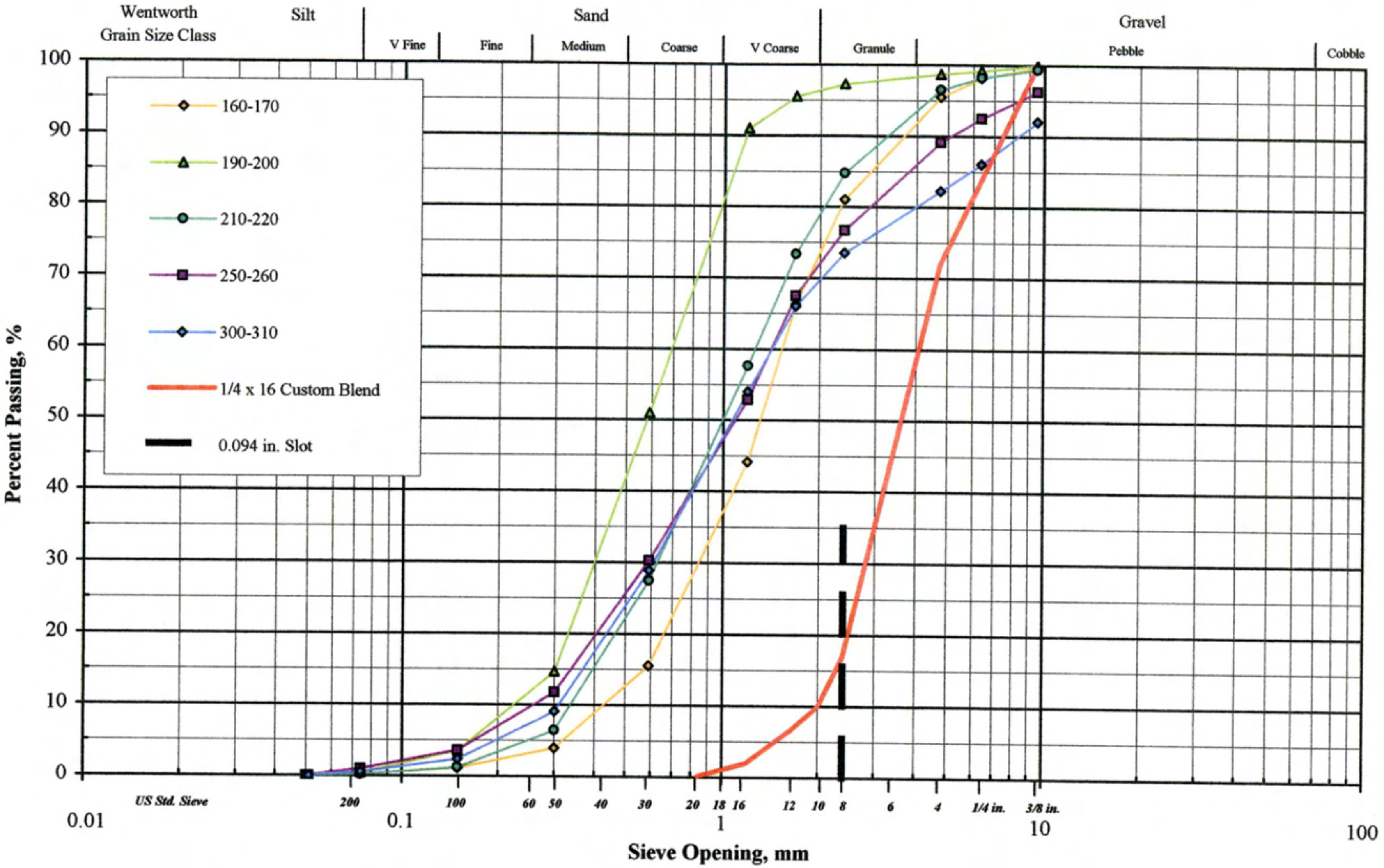
Trilinear Diagram
Isolated Aquifer Zone Test Water Quality Data
Chino Desalter Authority Well I-15



1-Jun-04

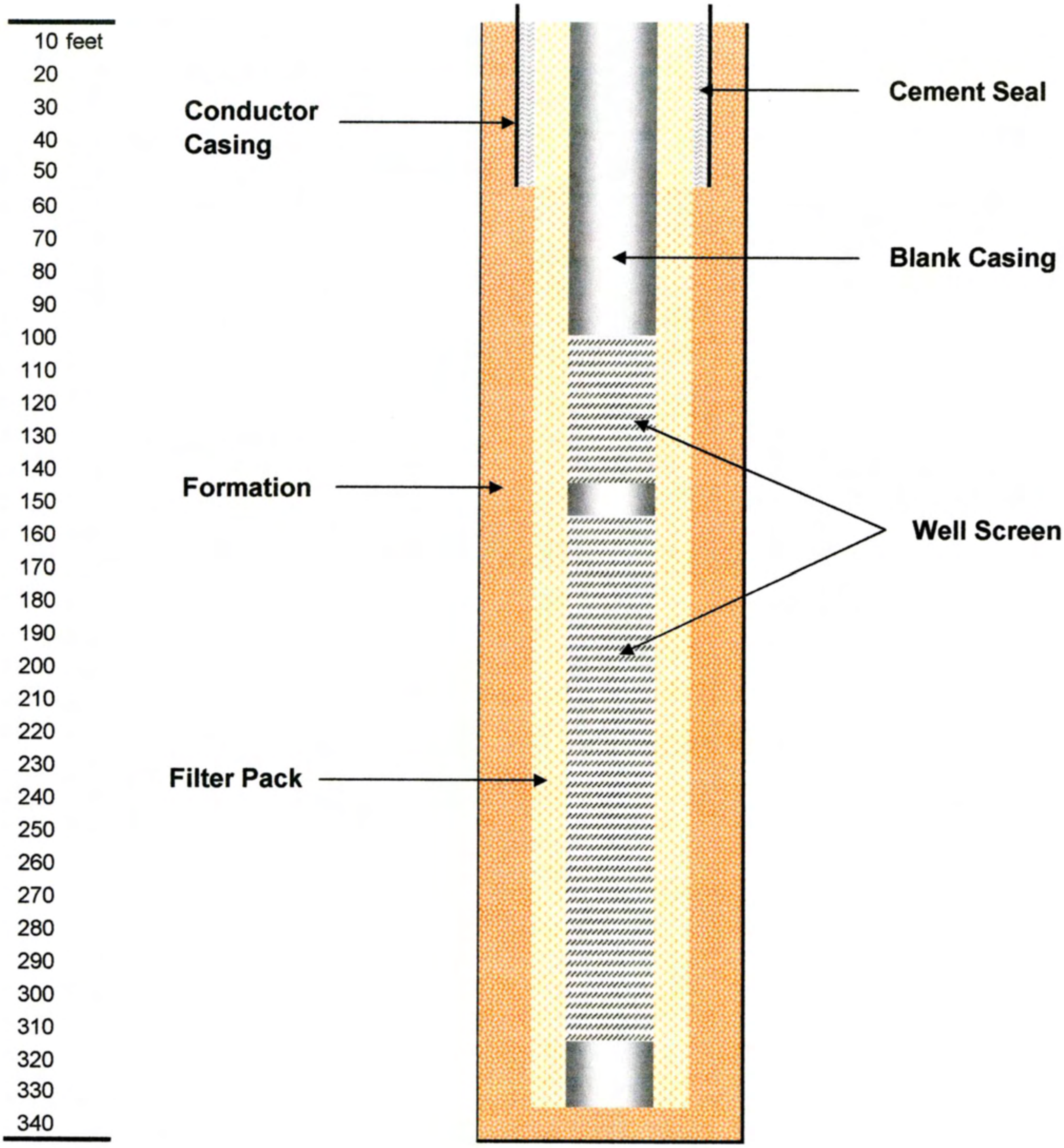
Figure 8

Mechanical Grading Analysis
Chino Desalter Authority Well I-15



1-Jun-04

Cross Section of CDA Well I-15

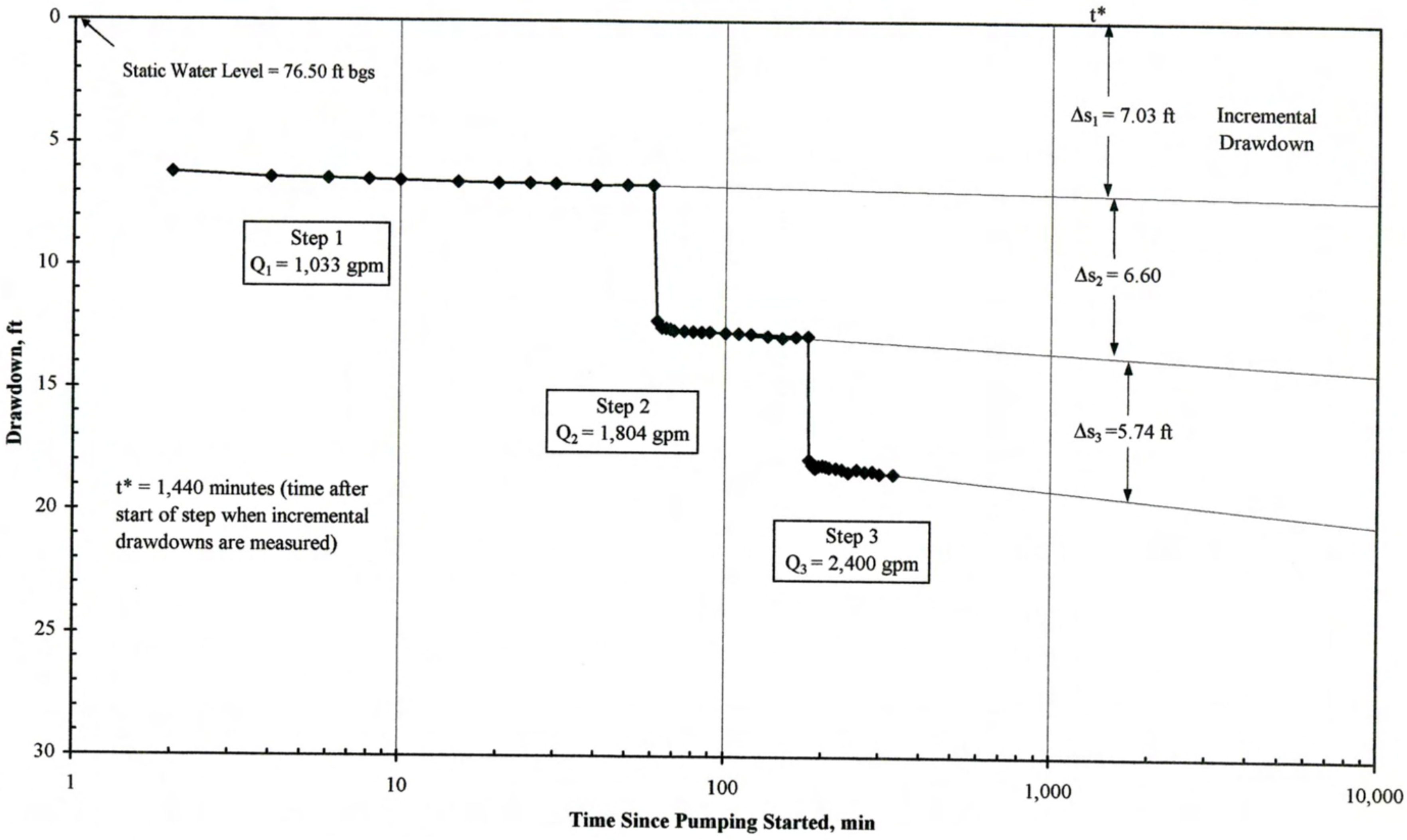


*This cross section represents a typical CDA well

1-Jun-04

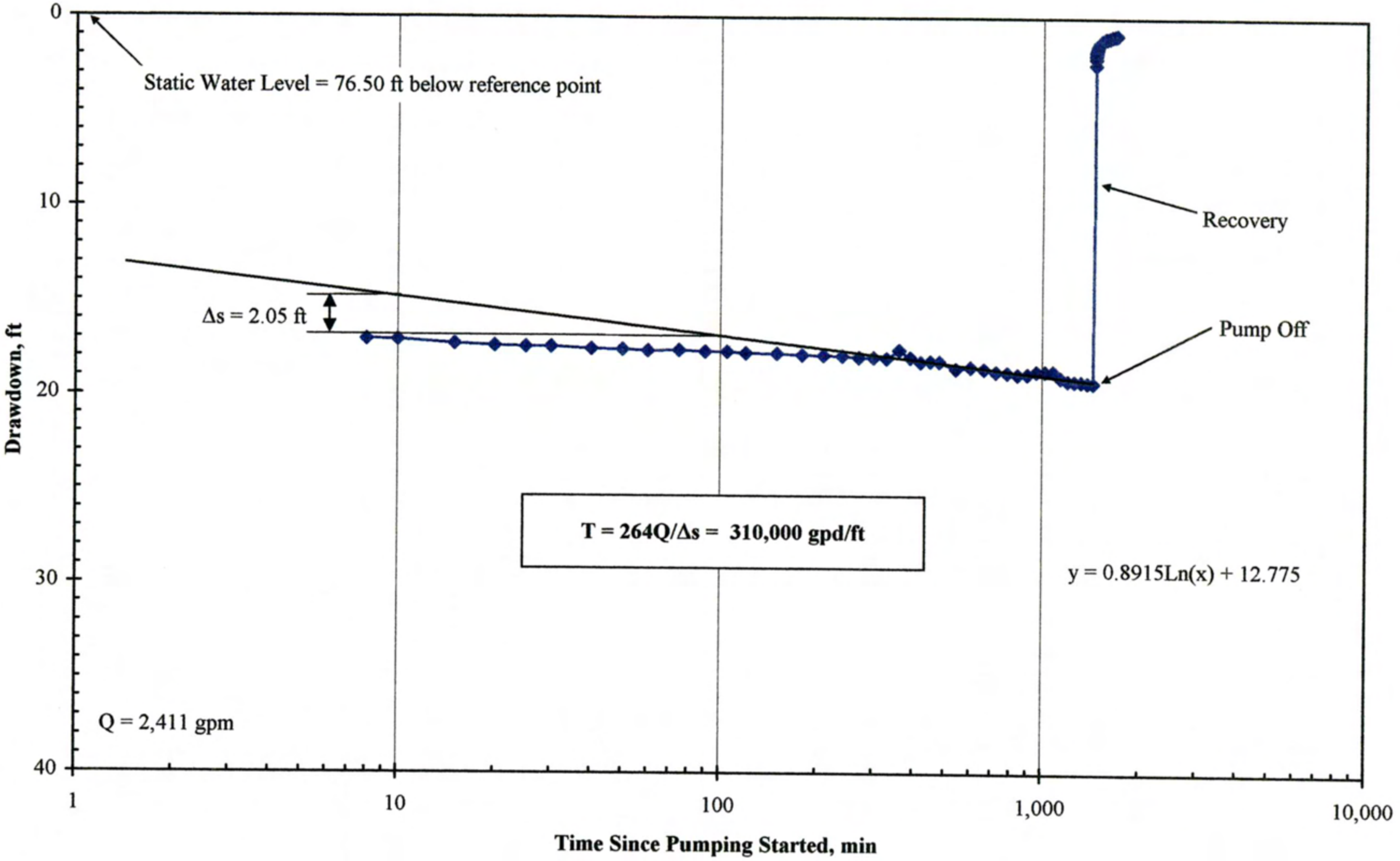
Figure 10

Step Drawdown Test
Chino Desalter Authority Well I-15



1-Jun-04

Figure 11

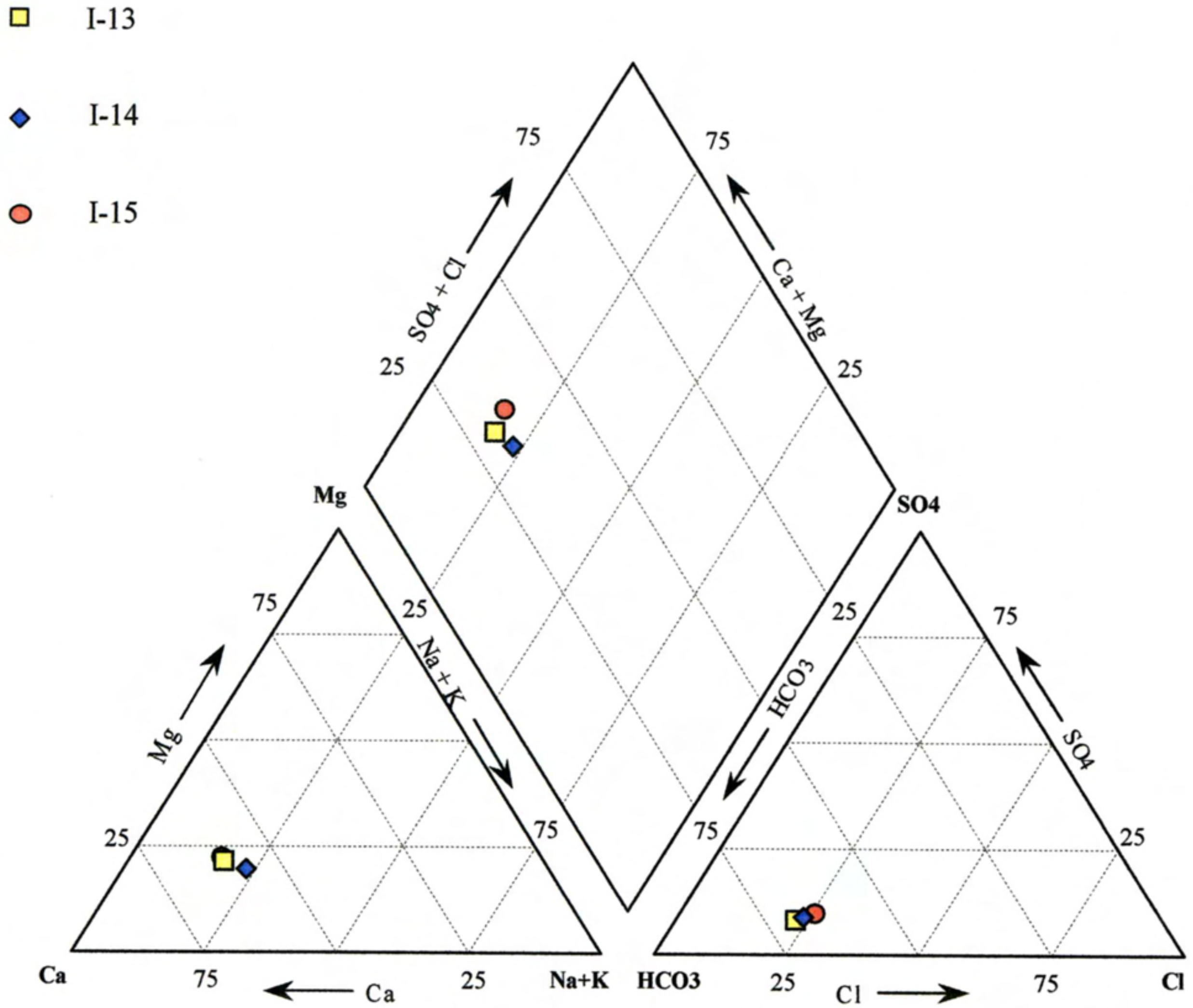


24-Hour Constant Rate Pumping Test
Chino Desalter Authority Well I-15

1-Jun-04

Figure 12

Trilinear Diagram
Title 22 Water Quality Data
Chino Desalter Authority Wells I-13, I-14, & I-15



1-Jun-04

TABLES

Summary of U.S. Standard Sieves Used for Analysis

U.S. Standard Sieve No.	Sieve Opening [in.]	Sieve Opening [mm]
1/4	0.25	6.3
3/8	0.375	9.53
4	0.187	4.75
8	0.094	2.38
12	0.066	1.68
16	0.047	1.19
20	0.033	0.84
30	0.023	0.58
40	0.017	0.43
50	0.012	0.3
100	0.006	0.15
200	0.0029	0.075

* The 30 sieve was used instead of the 40 sieve on CDA I-15

Table 2

Summary of Nitrate Concentration - Isolated Aquifer Zone Testing

CDA Well No.	Zone	Depth Interval (ft bgs)	Static Water Level (ft bgs)	Pumping Water Level (ft bgs)	Average Discharge Rate (gpm)	Nitrate Concentration (mg/L)
I-13	1	295-315	73.8	111.2	153	15
	2	186-206	74.0	106.5	157	140
	3	136-156	74.0	86.5	155	480
I-14	1	350-370	74.4	138.2	73	3.6
	2	190-210	73.3	95.2	166	106
	3	110-130	73.6	89.2	173	314
I-15	1	273-293	74.5	86.0	161	8.3
	2	173-193	74.6	91.3	157	74
	3	113-133	76.0	89.9	161	230

*** Nitrate MCL is defined to be 45 mg/L**

1-Jun-04

Summary of Water Quality - Chino Desalter Authority Well I-13

Chemical	Symbol	Reporting Units	Analysis Result	MCL
Calcium	Ca	mg/L	88	-
Magnesium	Mg	mg/L	19	-
Sodium	Na	mg/L	29	-
Potassium	K	mg/L	2.2	-
Hydroxide	OH	mg/L	< 3	-
Carbonate	CO3	mg/L	< 3	-
Bicarbonate	HCO3	mg/L	250	-
Sulfate	SO4	mg/L	23	250
Chloride	Cl	mg/L	48	250
Nitrate	NO3	mg/L	93	45
Fluoride	F	mg/L	0.2	2
Total Dissolved Solids	TDS	mg/L	460	1000
pH	-	-	7.5	6.5 - 8.5
color	-	-	< 3	15
odor	-	-	< 1	3
Turbidity	-	-	< 0.20	5
Aluminum	Al	µg/L	ND	1000
Antimony	Sb	µg/L	ND	6
Arsenic	As	µg/L	ND	50
Barium	Ba	µg/L	150	1000
Beryllium	Be	µg/L	ND	4
Cadmium	Cd	µg/L	ND	5
Chromium	Cr	µg/L	ND	50
Chromium VI	Cr-VI	µg/L	5.5	-
Copper	Cu	µg/L	ND	1000
Iron	Fe	µg/L	ND	300
Lead	Pb	µg/L	ND	-
Manganese	Mn	µg/L	ND	50
Mercury	Hg	µg/L	ND	2
Nickel	Ni	µg/L	ND	100
Selenium	Se	µg/L	ND	50
Silver	Ag	µg/L	ND	100
Thallium	Tl	µg/L	ND	2
Zinc	Zn	µg/L	ND	5000

1-Jun-04

Summary of Water Quality - Chino Desalter Authority Well I-14

Chemical	Symbol	Reporting Units	Analysis Result	MCL
Calcium	Ca	mg/L	120	-
Magnesium	Mg	mg/L	25	-
Sodium	Na	mg/L	54	-
Potassium	K	mg/L	2.8	-
Hydroxide	OH	mg/L	< 3	-
Carbonate	CO3	mg/L	< 3	-
Bicarbonate	HCO3	mg/L	350	-
Sulfate	SO4	mg/L	36	250
Chloride	Cl	mg/L	72	250
Nitrate	NO3	mg/L	130	45
Fluoride	F	mg/L	0.1	2
Total Dissolved Solids	TDS	mg/L	670	1000
pH	-	-	7.4	6.5 - 8.5
color	-	-	< 3	15
odor	-	-	< 1	3
Turbidity	-	-	< 0.20	5
Aluminum	Al	µg/L	ND	1000
Antimony	Sb	µg/L	ND	6
Arsenic	As	µg/L	ND	50
Barium	Ba	µg/L	220	1000
Beryllium	Be	µg/L	ND	4
Cadmium	Cd	µg/L	ND	5
Chromium	Cr	µg/L	ND	50
Chromium VI	Cr-VI	µg/L	9.7	-
Copper	Cu	µg/L	ND	1000
Iron	Fe	µg/L	ND	300
Lead	Pb	µg/L	ND	-
Manganese	Mn	µg/L	ND	50
Mercury	Hg	µg/L	ND	2
Nickel	Ni	µg/L	ND	100
Selenium	Se	µg/L	ND	50
Silver	Ag	µg/L	ND	100
Thallium	Tl	µg/L	ND	2
Zinc	Zn	µg/L	ND	5000

Summary of Water Quality - Chino Desalter Authority Well I-15

Chemical	Symbol	Reporting Units	Analysis Result	MCL
Calcium	Ca	mg/L	120	-
Magnesium	Mg	mg/L	27	-
Sodium	Na	mg/L	38	-
Potassium	K	mg/L	2.5	-
Hydroxide	OH	mg/L	< 3	-
Carbonate	CO3	mg/L	< 3	-
Bicarbonate	HCO3	mg/L	320	-
Sulfate	SO4	mg/L	38	250
Chloride	Cl	mg/L	74	250
Nitrate	NO3	mg/L	120	45
Fluoride	F	mg/L	0.2	2
Total Dissolved Solids	TDS	mg/L	660	1000
pH	-	-	7.5	6.5 - 8.5
color	-	-	3	15
odor	-	-	< 1	3
Turbidity	-	-	< 0.20	5
Aluminum	Al	µg/L	ND	1000
Antimony	Sb	µg/L	ND	6
Arsenic	As	µg/L	ND	50
Barium	Ba	µg/L	220	1000
Beryllium	Be	µg/L	ND	4
Cadmium	Cd	µg/L	ND	5
Chromium	Cr	µg/L	ND	50
Chromium VI	Cr-VI	µg/L	4.6	-
Copper	Cu	µg/L	ND	1000
Iron	Fe	µg/L	ND	300
Lead	Pb	µg/L	ND	-
Manganese	Mn	µg/L	ND	50
Mercury	Hg	µg/L	ND	2
Nickel	Ni	µg/L	ND	100
Selenium	Se	µg/L	ND	50
Silver	Ag	µg/L	ND	100
Thallium	Tl	µg/L	ND	2
Zinc	Zn	µg/L	ND	5000

APPENDIX A

Pictures

Picture 1

Bucket auger drill rig

Picture 2

36-inch outside diameter steel conductor casing

Picture 3

36-inch outside diameter steel conductor casing (50 foot section)

Picture 4

36-inch outside diameter steel conductor casing installation

Picture 5

17½-inch diameter tri-cone button bit

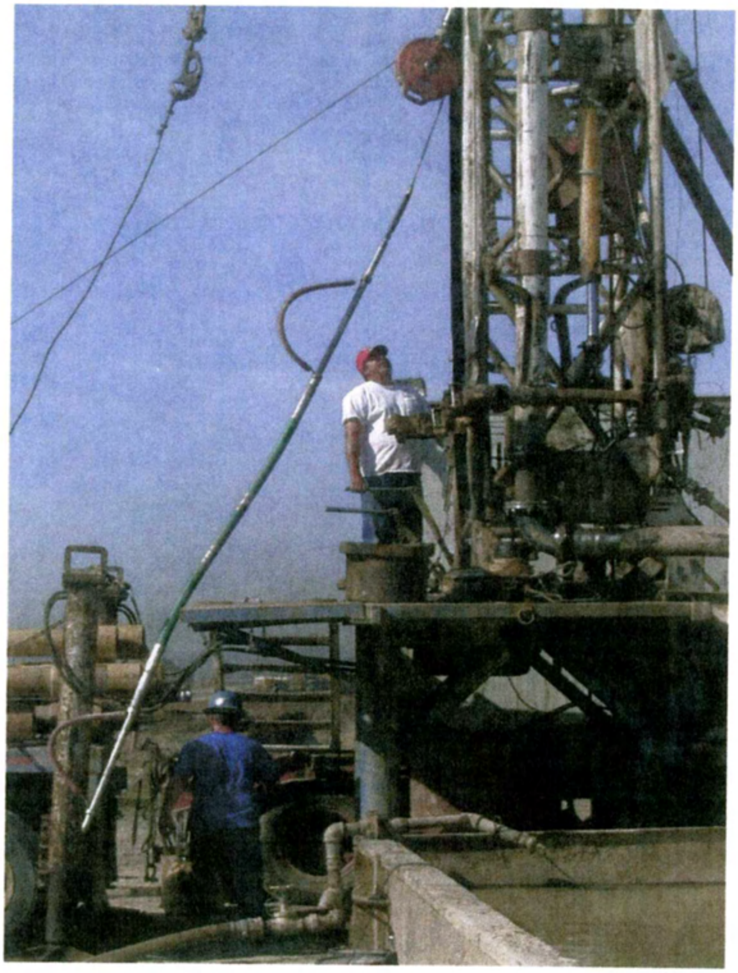
Picture 6

Chip trays showing continuous borehole section

Picture 7

Resistivity logging tool

Picture 8



Sonic logging tool

Picture 9

26-inch outside diameter reaming bit

Picture 10

Airlifting and Swabbing tool

APPENDIX B

Borehole Lithologic Logs

BOREHOLE LITHOLOGIC LOG
Chino Desalter Authority Well I-13

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
0 to 50	No Sample																														-	No sample - Conductor Borehole.
50 to 60	10YR 5/3 Brown					60	40	•			•	•						•	•				•	•	•	•					SM	SILTY SAND: fine to coarse-grained sand; with silt (sample contains a lot of polybore fluid additive).
60 to 70	10YR 5/3 Brown					60	40	•			•	•						•	•				•	•	•	•					SM	SILTY SAND: fine to coarse-grained sand; with silt (sample contains a lot of polybore fluid additive).
70 to 80	No Sample																														-	No Sample
80 to 90	10YR 5/3 Brown					>95	<5	•			•	•						•	•				•	•	•	•					SP	SAND: fine to coarse-grained sand; trace silt.
90 to 100	10YR 5/6 Yellowish Brown					>95	<5	•			•	•						•	•				•	•	•	•					SP	SAND: fine to coarse-grained sand; trace fine-grained gravel up to 12mm; trace silt.
100 to 110	10YR 5/6 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•	•				•	SP	SAND with GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 25mm; trace silt.
110 to 120	10YR 5/4 Yellowish Brown					90	10	•			•	•						•	•				•	•	•	•					SP-SM	SAND with SILT: fine to coarse-grained sand (predominately fine-grained sand); with silt; trace fine-grained gravel up to 19mm.
120 to 130	10YR 5/4 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•	•					SP	SAND: fine to coarse-grained sand; trace metamorphic angular gravel up to 1"; trace silt.
130 to 140	10YR 5/6 Yellowish Brown					>95	<5	•				•	•					•	•				•	•	•	•				•	SP	SAND: fine to coarse-grained sand (predominately medium-grained sand); trace silt; trace sub-rounded coarse-grained metamorphic gravel up to 25mm.

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-13

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
140 to 150	10YR 5/6 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•	•					SP	SAND: fine to coarse-grained sand (predominately medium-grained sand); trace silt; trace angular fine-grained metamorphic gravel up to 15mm.
150 to 160	10YR 5/3 Brown					>95	<5	•			•	•	•					•	•				•	•	•	•					SP	SAND: fine to medium-grained sand; trace silt; trace metamorphic coarse-grained gravel up to 25mm.
160 to 170	10YR 5/3 Brown					95	5	•				•	•					•	•				•	•	•	•				•	SP-SM	SAND with SILT: fine to medium-grained sand (trace coarse-grained sand); with silt; trace fine-grained gravel.
170 to 180	10YR 6/4 Light Yellowish Brown					95	5	•				•	•					•	•				•	•	•	•					SP-SM	SAND with SILT: fine to medium-grained sand (predominately fine-grained sand).
180 to 190	10YR 6/4 Light Yellowish Brown					95	5	•				•	•				•		•				•	•	•	•					SP-SM	SAND with SILT: fine to medium-grained sand (predominately fine-grained sand); trace low plasticity clay.
190 to 200	10YR 6/4 Light Yellowish Brown					95	5	•				•	•				•		•				•	•	•	•					SP-SM	SAND with SILT: fine to medium-grained sand (predominately fine-grained sand); trace low plasticity clay.
200 to 210	10YR 5/3 Brown					>95	<5	•			•	•	•					•	•				•	•	•	•				•	SP	SAND: fine to coarse-grained sand; trace silt; trace fine-grained gravel.
210 to 220	10YR 5/3 Brown					>95	<5	•			•	•						•	•				•	•	•	•					SP	SAND: fine to medium-grained sand (trace coarse-grained sand); trace fine-grained gravel up to 10mm; trace silt.
220 to 230	10YR 5/3 Brown					>95	<5	•			•	•						•	•				•	•	•	•					SP	SAND: fine to medium-grained sand (trace coarse-grained sand); trace fine-grained gravel up to 10mm; trace silt.
230 to 240	10YR 5/3 Brown					>95	<5	•			•	•						•	•				•	•	•	•				•	SP	SAND: fine to medium-grained sand (trace coarse-grained sand); trace fine-grained gravel up to 10mm; trace silt.

BOREHOLE LITHOLOGIC LOG
Chino Desalter Authority Well I-13

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
240 to 250	10YR 5/3 Brown					>95	<5	•			•	•						•	•				•	•	•	•					SP	SAND: fine-grained sand (trace medium to coarse-grained sand); trace silt.
250 to 260	10YR 5/3 Brown					100		•			•							•	•				•	•	•	•					GP	GRAVEL WITH SAND: fine to coarse-grained gravel up to 40mm; with fine to coarse-grained sand.
260 to 270	2YR 5/3 Light Olive Brown					>95	<5	•			•	•						•	•				•	•	•	•					SP	SAND: fine to medium-grained sand (trace coarse-grained sand); trace silt.
270 to 280	10YR 5/2 Grayish Brown					>95	<5	•			•	•						•	•				•	•	•	•					SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 25mm; trace silt.
280 to 290	2YR 5/3 Light Olive Brown					>95	<5	•			•	•						•	•				•	•	•	•					SP	SAND: fine to coarse-grained sand; some fine to coarse-grained gravel up to 25mm; trace silt.
290 to 300	10YR 6/3 Pale Brown					>95	<5	•			•	•	•				•		•				•	•	•	•				•	SP	SAND: fine to coarse-grained sand; trace silt; trace low plasticity clay; trace fine-grained metamorphic gravel up to 13mm.
300 to 310	10YR 5/4 Yellowish Brown					>95	<5			•	•	•	•					•	•				•	•	•	•					SP	SAND WITH GRAVEL: fine to coarse-grained sand; with angular coarse-grained gravel up to 25mm; trace silt.
310 to 320	10YR 5/4 Yellowish Brown					80	20	•				•	•				•		•				•	•	•	•					SP	SILTY SAND: fine to medium-grained sand; with silt; trace low plasticity clay; trace coarse-grained sand.
320 to 330	10YR 6/4 Light Yellowish Brown					>95	<5	•				•	•					•	•				•	•	•	•				•	SP	SAND: fine-grained sand; trace silt.
330 to 340	2.5YR 6/4 Light Yellowish Brown					>95	<5	•				•	•					•	•				•	•	•	•					SP	SAND: fine to medium-grained sand (contains sub-rounded coarse-grained quartz); trace silt.

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-13

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
340 to 350	5.3YR Light Olive Brown					>95	<5	•				•	•					•	•				•	•	•	•				•	SP	SAND: fine to medium-grained sand; trace silt; trace coarse-grained gravel.
350 to 360	2.5Y 5/4 Light Olive Brown					>95	<5	•				•	•					•	•				•	•	•	•					SP	SAND: fine to medium-grained sand; trace silt; trace coarse-grained gravel.
360 to 370	2.5Y 3/1 Very Dark Gray					100			•		•							•	•				•	•	•	•					SP	SAND: fine to medium-grained sand.

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-14

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
0 to 10	-																														-	FILL
10 to 20	-																														-	FILL
20 to 30	5Y 6/4 pale olive	•				>95	<5			•	•	•						•	•				•	•	•	•					SP	SAND: fine to coarse-grained sand; trace fine to coarse-grained gravel up to 25mm; trace clay and silt.
30 to 40	10YR 5/4 yellowish brown		•			60	40			•	•	•						•	•				•	•	•	•					SM	SILTY SAND: fine to coarse-grained sand; with silt and clay; some fine to coarse-grained gravel to 50mm.
40 to 50	10YR 6/6 brownish yellow		•			40	60			•	•	•					•		•				•	•	•	•					ML	SANDY SILT: silt; with fine-grained sand; trace fine-grained gravel.
50 to 60	2.5Y 4/3 olive brown			•		100		•			•	•	•					•	•	•	•		•	•	•						SP	SAND: fine to medium-grained sand; trace coarse-grained gravel.
60 to 70	2.5Y 4/3 olive brown			•		100		•			•	•	•					•	•	•	•		•	•	•						SP	SAND: fine to medium-grained sand; trace coarse-grained gravel.
70 to 80	2.5Y 4/3 olive brown			•		90	10		•		•	•	•				•		•				•	•	•						SP-SM	SAND WITH SILT: fine to coarse-grained sand; with silt.
80 to 90	2.5Y 4/3 olive brown			•		100				•	•	•						•	•				•	•	•			•			SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine-grained gravel up to 18mm.
90 to 100	2.5Y 5/3 light olive brown			•		95	5			•	•	•	•					•	•				•	•							SP-SM	SAND WITH SILT: fine to coarse-grained sand; with silt; trace fine-grained gravel up to 8mm.

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-14

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
100 to 110	2.5Y 4/3 olive brown			•		100				•	•	•	•					•	•				•	•						•	SP	SAND WITH GRAVEL: medium to coarse-grained sand (trace fine-grained sand); with fine-grained gravel up to 18mm (trace coarse-grained gravel).
110 to 120	2.5Y 4/3 olive brown			•		100				•	•	•	•					•	•				•	•	•						SP	SAND WITH GRAVEL: medium to coarse-grained sand (trace fine-grained sand); with fine to coarse-grained gravel up to 30mm.
120 to 130	2.5Y 4/3 olive brown			•		100				•	•	•	•					•	•				•	•	•						SP	SAND: fine to coarse-grained sand; some fine-grained gravel up to 15mm.
130 to 140	2.5Y 4/3 olive brown			•		100				•	•	•	•					•	•				•	•	•						SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 22mm.
140 to 150	2.5Y 4/4 olive brown			•		>95	<5	•			•	•						•	•				•	•						•	SP	SAND: fine-grained sand (some medium-grained sand); trace silt.
150 to 160	2.5Y 4/4 olive brown			•		100				•	•	•	•					•	•				•	•	•						SP	SAND: fine to medium-grained sand; trace fine-grained gravel up to 19mm.
160 to 170	2.5Y 4/4 olive brown			•		100				•	•	•	•					•	•				•	•	•						SP	SAND: fine to medium-grained sand; trace fine-grained gravel up to 15mm.
170 to 180	2.5Y 4/6 light olive brown			•		90	10			•	•	•	•				•		•				•	•	•					•	SP-SM	SAND WITH SILT: fine to coarse-grained sand; with silt and clay balls; trace fine-grained gravel up to 15mm.
180 to 190	2.5Y 4/4 olive brown			•		95	5			•	•	•	•					•	•				•	•	•						SP-SM	SAND WITH SILT: fine to coarse-grained sand; trace fine-grained gravel up to 10mm; trace clay balls.

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-14

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
190 to 200	2.5Y 4/4 olive brown			•		100				•	•	•	•					•	•				•	•	•						SP	SAND: fine to medium-grained sand (trace coarse-grained sand); trace fine-grained gravel up to 20mm.
200 to 210	2.5Y 4/4 olive brown			•		100				•	•	•	•					•	•				•	•	•						SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 50mm.
210 to 220	2.5Y 4/4 olive brown			•		100				•	•	•	•					•	•				•	•	•						SP	SAND WITH GRAVEL: fine to medium-grained sand (trace coarse-grained sand); with fine to coarse-grained gravel up to 40mm.
220 to 230	2.5Y 4/4 olive brown			•		100				•	•	•	•					•	•				•	•	•	•				•	SP	SAND: fine to medium-grained sand; trace fine-grained gravel up to 10mm.
230 to 240	2.5Y 4/4 olive brown			•		100				•	•	•	•					•	•				•	•	•	•					SP	SAND: fine to coarse-grained sand; some fine to coarse-grained gravel up to 50mm.
240 to 250	2.5Y 4/4 olive brown			•		<85	>15			•	•	•	•					•	•				•	•	•					•	SM	SILTY SAND: fine to medium-grained sand (trace coarse-grained sand); with silt and clay balls; trace fine-grained gravel up to 8mm.
250 to 260	2.5Y 5/2 grayish brown			•		100				•	•	•	•					•	•				•	•	•			•	•		SP	SAND WITH GRAVEL: medium to coarse-grained sand; with fine to coarse-grained gravel up to 22mm; trace fine-grained sand.
260 to 270	2.5Y 5/2 grayish brown			•		100				•	•	•	•					•	•				•	•	•			•	•		GP	GRAVEL WITH SAND: fine to coarse-grained gravel up to 30mm; with medium to coarse-grained sand (trace fine-grained sand).

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-14

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
270 to 280	2.5Y 4/3 olive brown			•		100				•	•	•	•					•	•				•	•	•			•	•		GP	GRAVEL WITH SAND: fine to coarse-grained gravel up to 30mm; with medium to coarse-grained sand (trace fine-grained sand).
280 to 290	2.5Y 6/3 light yellowish brown			•		100				•	•	•	•					•	•				•	•	•			•	•		SP	SAND: fine to medium-grained sand; trace fine-grained gravel up to 19mm.
290 to 300	2.5Y 5/3 light olive brown			•		100				•	•	•	•					•	•				•	•	•			•	•		SP	SAND: fine to medium-grained sand; trace fine-grained gravel up to 15mm.
300 to 310	2.5Y 5/3 light olive brown			•		100				•	•	•	•					•	•				•	•	•			•	•	•	SP	SAND: fine to medium-grained sand; increasing trace fine-grained gravel up to 10mm; trace clay balls.
310 to 320	2.5Y 5/3 light olive brown			•		100				•	•	•	•					•	•				•	•	•			•	•		SP	SAND: fine to coarse-grained sand, trace fine-grained gravel up to 7mm; trace clay balls up to 15mm.
320 to 330	2.5Y 5/3 light olive brown			•		100			•		•	•	•					•	•				•	•	•			•	•		SP	SAND: fine to medium-grained sand (trace coarse-grained sand); trace fine-grained gravel up to 7mm.
330 to 340	2.5Y 6/6 olive yellow			•		>95	<5		•		•	•	•					•	•				•	•	•			•	•		SP	SAND: fine to coarse-grained sand (predominantly medium-grained sand); trace fine-grained gravel up to 7mm.
340 to 350	2.5Y 6/6 olive yellow			•		>95	<5		•		•	•	•					•	•				•	•	•			•	•		SP	SAND: fine to coarse-grained sand (predominantly medium-grained sand); trace fine-grained gravel up to 7mm; trace clay balls up to 20mm.
350 to 360	2.5Y 4/4 olive brown			•		>95	<5			•	•	•	•					•	•				•	•	•						SP	SAND: fine to medium-grained sand (trace coarse-grained sand); trace fine-grained gravel up to 10mm; trace clay balls.

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-14

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
360 to 370	2.5Y 4/4 olive brown			•		90	10			•	•	•	•					•	•				•	•	•					•	SP-SM	SAND WITH SILT: fine to medium-grained sand (trace coarse-grained sand); with silt and clay balls; trace fine-grained gravel up to 13mm.
370 to 380	2.5Y 4/4 olive brown			•		>95	<5			•	•	•	•					•	•				•	•	•						SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine-grained gravel up to 19mm; trace clay balls.
380 to 390	2.5Y 4/4 olive brown			•		>95	<5			•	•	•	•					•	•				•	•	•				•		SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 35mm; trace silt.
390 to 400	2.5Y 4/4 olive brown			•		>95	<5			•	•	•	•					•	•				•	•	•				•		SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 40mm; trace silt and clay balls.
400 to 410	2.5Y 4/4 olive brown			•		>95	<5			•	•	•	•					•	•				•	•	•				•	•	SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 40mm; trace silt and clay balls.
410 to 420	2.5Y 4/4 olive brown			•		>95	<5			•	•	•	•					•	•				•	•	•				•		GP	GRAVEL WITH SAND: fine to coarse-grained gravel up to 50mm; with fine to coarse-grained sand; trace silt.
420 to 430	2.5Y 4/4 olive brown			•		90	10			•	•	•	•					•	•				•	•	•				•		SP-SM	SAND with SILT: fine to coarse-grained sand; with silt and clay balls; some fine-grained gravel up to 19mm.
430 to 440	2.5Y 4/4 olive brown			•		>95	<5			•	•	•	•	•				•	•				•	•	•				•		SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 25mm; trace silt and clay balls.

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-14

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
440 to 450	2.5Y 5/2 grayish brown			•		>95	<5			•	•	•	•					•	•				•	•	•			•	•		SP	SAND: fine-grained sand (trace medium and coarse-grained sand); trace fine-grained gravel up to 8mm; trace silty clay balls.
450 to 460	2.5Y 7/2 light gray			•		>95	<5			•	•	•	•	•				•	•				•	•	•				•	•	SP	SAND: fine to coarse-grained sand; some fine-grained gravel up to 10mm; trace silt.
460 to 470	2.5Y 7/2 light gray			•		90	10			•	•	•	•					•	•				•	•	•			•	•		SP-SC	SAND WITH CLAY: fine to coarse-grained sand (predominantly fine to medium-grained); with white clay balls; abundant mica grains.
470 to 480	2.5Y 4/3 olive brown			•		<85	>15			•	•	•						•	•				•	•	•			•	•		SC	CLAYEY SAND: fine to coarse-grained sand (predominantly fine to medium-grained); with white clay balls up to 20mm; some fine to coarse-grained gravel up to 25mm.
480 to 490	2.5Y 4/3 olive brown			•		<85	>15			•	•	•	•					•	•				•	•	•			•			SC	CLAYEY SAND: fine to coarse-grained sand; with silt and clay; some fine to coarse-grained gravel up to 22mm.
490 to 500	2.5Y 4/3 olive brown			•		<85	>15			•	•	•	•					•	•				•	•	•			•	•		SC	CLAYEY SAND: fine to coarse-grained sand (predominantly fine to medium-grained); with silt and clay.
500 to 510	5Y 5/2 olive gray			•		75	25			•	•	•					•		•				•	•	•			•	•		SC/SM	CLAYEY/SILTY SAND: fine to coarse-grained sand; with green sandy clay balls up to 35mm; some fine-grained gravel up to 8mm; contains granitic fragments.
510 to 521	5Y 5/2 olive gray			•		80	20			•	•	•						•	•				•	•	•			•	•		SC/SM	CLAYEY/SILTY SAND: fine to coarse-grained sand; with green sandy clay balls up to 35mm; some fine-grained gravel up to 6mm; contains granitic fragments.

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-15

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
0 to 10	2.5Y 5/2 Grayish Brown		•			<5	>95			•			•				•		•				•		•			•			ML	SILT: silt; trace low plasticity clay; trace fine to medium-grained sand.
10 to 20	2.5Y 5/4 Light Olive Brown		•			<5	>95			•			•					•	•				•		•	•		•			ML	SILT: silt; trace fine to medium-grained sand.
20 to 30	2.5Y 6/4 Light Yellowish Brown		•			<5	>95			•			•					•	•				•		•	•		•			ML	SILT: silt; trace fine to medium-grained sand; trace well-cemented silt balls up to 100mm.
30 to 40	2.5Y 6/2 Light Brownish Gray		•			40	60			•		•	•				•		•				•	•	•	•		•			SM	SILTY SAND: fine to coarse-grained sand (predominantly fine to medium-grained sand); with silt; trace fine-grained gravel up to 6mm; trace low plasticity clay.
40 to 50	2.5Y 6/2 Light Brownish Gray		•			<5	>95			•		•	•				•		•				•			•		•			CL-ML	SILTY CLAY: low to medium plasticity clay; with silt; trace fine-grained sand.
50 to 60	10YR 5/3 Brown					100		•			•	•						•	•				•	•	•			•			SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 40mm.
60 to 70	10YR 5/2 Grayish Brown					>95	<5	•			•	•	•					•	•				•	•	•						SP	SAND: fine-grained sand (trace medium to coarse-grained sand); trace fine-grained gravel up to 8mm.
70 to 80	10YR 5/2 Grayish Brown					100		•			•	•						•	•				•	•	•			•	•		SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 25mm.
80 to 90	10YR 5/4 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND: fine to coarse-grained sand (predominantly fine-grained sand); trace clay balls up to 15mm.
90 to 100	2.5YR 6/3 Light Yellowish Brown					>95	<5	•				•	•					•	•				•	•	•			•			SP	SAND: fine to medium-grained sand (predominantly fine-grained sand); trace fines.

BOREHOLE LITHOLOGIC LOG
Chino Desalter Authority Well I-15

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
100 to 110	10YR 5/2 Grayish Brown					100		•			•	•	•					•	•				•	•	•			•	•	•	SP	SAND: fine to medium-grained sand (predominantly fine-grained sand); some angular fine-grained gravel up to 15mm.
110 to 120	10YR 5/2 Grayish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•	•		SP	SAND: fine to coarse-grained sand (predominantly fine-grained sand); some coarse-grained gravel up to 20mm; trace clay balls up to 5mm.
120 to 130	10YR 5/2 Grayish Brown					100		•			•	•	•					•	•				•	•	•			•	•		SP	SAND: fine to coarse-grained sand (predominantly fine-grained sand); some fine-grained gravel up to 10mm.
130 to 140	10YR 5/2 Grayish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND: fine to medium-grained sand (predominantly fine-grained sand); trace fines.
140 to 150	10YR 5/4 Yellowish Brown					>95	<5		•		•	•	•					•	•				•	•	•						SP	SAND: fine to medium-grained sand (predominantly fine-grained sand); trace silt.
150 to 160	10YR 5/3 Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND: fine to medium-grained sand (predominantly fine-grained sand); trace fine-grained gravel up to 8mm.
160 to 170	10YR 5/2 Grayish Brown					100		•			•							•	•				•	•	•			•	•		SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine-grained gravel up to 15mm.
170 to 180	10 YR 5/4 Yellowish Brown					100		•			•	•	•					•	•				•	•	•			•			GP	GRAVEL WITH SAND: fine to coarse-grained gravel (predominantly fine-grained gravel); with fine to coarse-grained sand (predominantly coarse-grained sand).
170 to 180	10 YR 5/4 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND WITH GRAVEL: fine to coarse-grained sand (predominately coarse-grained sand); with fine to coarse-grained gravel up to 25 mm.

BOREHOLE LITHOLOGIC LOG
Chino Desalter Authority Well I-15

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
180 to 190	10YR 5/4 Yellowish Brown					>95	<5		•		•	•	•					•	•				•	•	•			•			SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 25mm.
190 to 200	10YR 5/4 Yellowish Brown					>95	<5	•				•	•					•	•				•	•	•			•		•	SP	SAND: fine to medium-grained sand (predominantly fine-grained sand); trace fine-grained gravel up to 10mm; trace fines.
200 to 210	10YR 5/4 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND: fine to coarse-grained sand (predominantly fine to medium-grained sand); trace coarse-grained gravel up to 22mm; trace fines.
210 to 220	10YR 5/4 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•		•	SP	SAND WITH GRAVEL: fine to coarse-grained sand (predominantly medium to coarse-grained sand); with fine-grained gravel up to 10mm; trace fines.
220 to 230	10YR 5/4 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND: fine to coarse-grained sand (predominantly fine to medium-grained sand); trace fine-grained gravel up to 10mm; trace fines.
230 to 240	10YR 5/4 Yellowish Brown					>95	<5	•				•	•					•	•				•	•	•			•			SP	SAND: fine to medium-grained sand (trace coarse-grained sand); trace fines.
240 to 250	10YR 6/4 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND: fine to coarse-grained sand (predominantly fine to medium-grained sand); trace fine-grained gravel up to 7mm; trace fines.
250 to 260	10YR 6/4 Yellowish Brown					>95	<5		•		•	•						•	•				•	•	•			•		•	SP	SAND WITH GRAVEL: fine to coarse-grained sand (predominately medium to coarse-grained sand); with fine-grained gravel up to 15mm; trace fines.

BOREHOLE LITHOLOGIC LOG
Chino Desalter Authority Well I-15

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
260 to 270	10YR 6/4 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND: fine to coarse-grained sand (predominantly fine to medium-grained sand); trace fines.
270 to 280	10YR 6/4 Yellowish Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND: fine to coarse-grained sand (predominantly fine to medium-grained sand); trace fines.
280 to 290	10YR 5/3 Brown					>95	<5			•	•	•						•	•				•	•	•			•			SP	SAND: fine to coarse-grained sand; trace fine-grained gravel up to 15mm; trace fines.
290 to 300	10YR 5/3 Brown					100				•	•	•						•	•				•	•	•			•			GP	GRAVEL WITH SAND: fine to coarse-grained gravel up to 25mm; with fine to coarse-grained sand.
300 to 310	10YR 5/3 Brown					100				•	•							•	•				•	•	•			•		•	SP	SAND WITH GRAVEL: fine to coarse-grained sand; with fine to coarse-grained gravel up to 35mm.
310 to 320	10YR 5/3 Brown					>95	<5	•			•	•	•					•	•				•	•	•			•			SP	SAND: fine to coarse-grained sand; trace fine-grained gravel up to 8mm.
320 to 330	10YR 5/3 Brown					>95	<5	•			•	•	•					•	•				•	•	•	•		•			SP	SAND: fine to coarse-grained sand (predominantly medium to coarse-grained sand); trace fine-grained gravel up to 8mm.
330 to 340	10YR 5/3 Brown					>95	<5	•			•	•	•					•	•				•	•	•	•		•			SP	SAND: fine to coarse-grained sand (predominantly fine to medium-grained sand).
340 to 350	10YR 5/3 Brown					>95	<5	•			•	•	•					•	•				•	•	•	•					SP	SAND: fine to coarse-grained sand (predominantly fine to medium-grained sand); trace fine-grained gravel up to 10mm.

BOREHOLE LITHOLOGIC LOG

Chino Desalter Authority Well I-15

Sample Depth (ft)	Color: Munsell Name and Class	Moisture Content			Particle % Dist.			Sorting			Grain Shape				Plasticity				Cementation				Mineral Composition						Alteration Visible	Grading Analysis	Rock Type (USCS Group)	Comments
		Dry	Moist	Saturated	Cobbles	Sand & Gravel	Silt & Clay	Well	Medium	Poor	Angular	Sub-Angular	Sub-Rounded	Rounded	High	Medium	Low	None	None	Weak	Moderate	Strong	Quartz	Feldspar	Mica	Amphibole	Evaporites	Other				
350 to 360	10YR 5/2 Grayish Brown					100				•	•							•	•				•	•	•			•			SP	SAND: fine to coarse-grained sand (predominantly medium to coarse-grained sand); trace fine-grained gravel up to 30mm.