3.0 AQUIFER PROPERTIES

The important properties of the site aquifers include hydraulic conductivity (permeability), saturated thickness and storage capacity. Hydraulic conductivity is a representation of the transmitting ability of the aquifers while the product of saturated thickness and hydraulic conductivity is transmissivity. Transmissivity is the total transmitting ability of the aquifer and is the primary measure of ground water conveyance capacity of the confined Chinle aquifers. Specific yield is the primary measure of storage capacity of the unconfined alluvial aquifer. Storage coefficient is the corresponding descriptor of storage capacity for confined aquifers such as the Chinle aquifers, and is typically several orders of magnitude smaller than the unconfined alluvial storage parameter, specific yield.

3.1 SATURATED THICKNESS OF THE ALLUVIUM

The saturated thickness of the San Mateo alluvial aquifer is defined as the difference between the water-level elevation and the elevation of the base of the alluvium. Saturated thicknesses of the alluvium have increased significantly in the areas where fresh water has been injected during the restoration program. Contours of saturated thickness of the alluvial aquifer in the Grants Project area are presented on Figure 3-1, and were determined by calculating the difference between the water-level elevation and the elevation of the base of the alluvium. The saturated thickness of the alluvium on the site reaches a maximum of 60 feet below the southwest corner of the Large Tailings disposal area, and tapers to zero at the periphery of the alluvial aquifer.

3.2 HYDRAULIC CONDUCTIVITY, TRANSMISSIVITY AND STORAGE

3.2.1 ALLUVIAL AQUIFER

The contours of hydraulic conductivity for the alluvial aquifer in the Grants Project area are presented on Figure 3-2. Data used to construct the contours were collected from pump tests of the alluvial aquifer. This figure indicates that the hydraulic conductivity of the alluvial aquifer in the Large Tailings area is greatest on its southwest side and generally decreases to the east. A zone of lower hydraulic conductivity exists near the western edge of the Small Tailings area and extends in a southwesterly direction into Murray Acres. In most areas measured, hydraulic conductivity was 50 ft/day or less. However, hydraulic conductivity of the alluvium is greater (exceeding 200 ft/day) in the northern portion of Pleasant Valley Estates as well as to the west of this subdivision. In the San Mateo alluvium in Section 28, and in the Rio San Jose alluvium, the hydraulic conductivity also exceeds 200 ft/day (see west side of Figure 3-2).

The specific yield, or storage capacity, of the alluvial aquifer in the Grants Project area varies from 0.038 to 0.28, based on pump test results. A specific yield of 0.2 is considered to best represent the overall alluvial aquifer in the Grants Project area, based on numerical modeling of the ground water system.

3.2.2 UPPER CHINLE AQUIFER

Properties in the Upper Chinle aquifer vary significantly over the site due to the effects of secondary permeability, specifically fracturing of the sandstone due to faulting. Transmissivity (hydraulic conductivity times aquifer thickness) is the most influential aquifer conveyance property for a confined aquifer. Adjacent to the east side of the East Fault, transmissivity of the Upper Chinle aquifer is approximately 2000 gal/day/ft (see Figure 3-3), but it decreases to less than 100 gal/day/ft east of this area. High transmissivity values also exist in the area west of the East Fault on the south side of the Small Tailings area. The zones of higher transmissivity are well correlated with their proximity to the faults and probably are the result of fracturing of the sandstone during displacement along the faults. These zones of high transmissivity can affect ground water flow rates and gradients.

Hydraulic conductivity (permeability) of the Upper Chinle aquifer varies from less than 0.01 ft/day to greater than 100 ft/day. The Upper Chinle aquifer is a confined aquifer and, in general, has a storage coefficient estimated to be 5E-05. The specific yield of this confined aquifer is estimated to be 0.1, which is significantly less than that of the alluvial aquifer.

3.2.3 MIDDLE CHINLE AQUIFER

Like the Upper Chinle, the hydraulic properties of the Middle Chinle aquifer vary significantly over the area due to the effects of secondary permeability associated with faulting. Adjacent to the east side of the East Fault, Middle Chinle aquifer transmissivity is approximately 500 gal/day/ft (see Figure 3-4) but it decreases to less than 100 gal/day/ft east of this area. Areas of higher transmissivity have also been observed in the Middle Chinle aquifer west of the East Fault on the south side of the Small Tailings area.

Hydraulic conductivity of the Middle Chinle aquifer varies from less than 0.1 to greater than 50 ft/day. Like the Upper Chinle, the Middle Chinle aquifer is a confined aquifer with a typical storage coefficient of 3E-05. The specific yield of this confined aquifer is estimated to be 0.1, which again is significantly less than that of the alluvial aquifer.

3.2.4 LOWER CHINLE AQUIFER

Aquifer properties of the Lower Chinle aquifer vary over a wide range. Transmissivity of the Lower Chinle aquifer has been determined to range from less than 20 to 1590 gal/day/ft. Other than the HMC wells, only 2 or 3 wells are being used that are completed in the Lower Chinle aquifer. The Lower Chinle aquifer is only usable as a water source in the areas near its subcrop with the alluvium, where adequate secondary permeability has resulted from weathering and faulting.

The permeability of the Lower Chinle aquifer varies from less than 0.1 to slightly greater than 4 ft/day. The storage coefficient of the confined Lower Chinle aquifer varies from 3.4E-05 to 1.2E-04. The specific yield for the Lower Chinle aquifer is estimated to be less than 0.1.

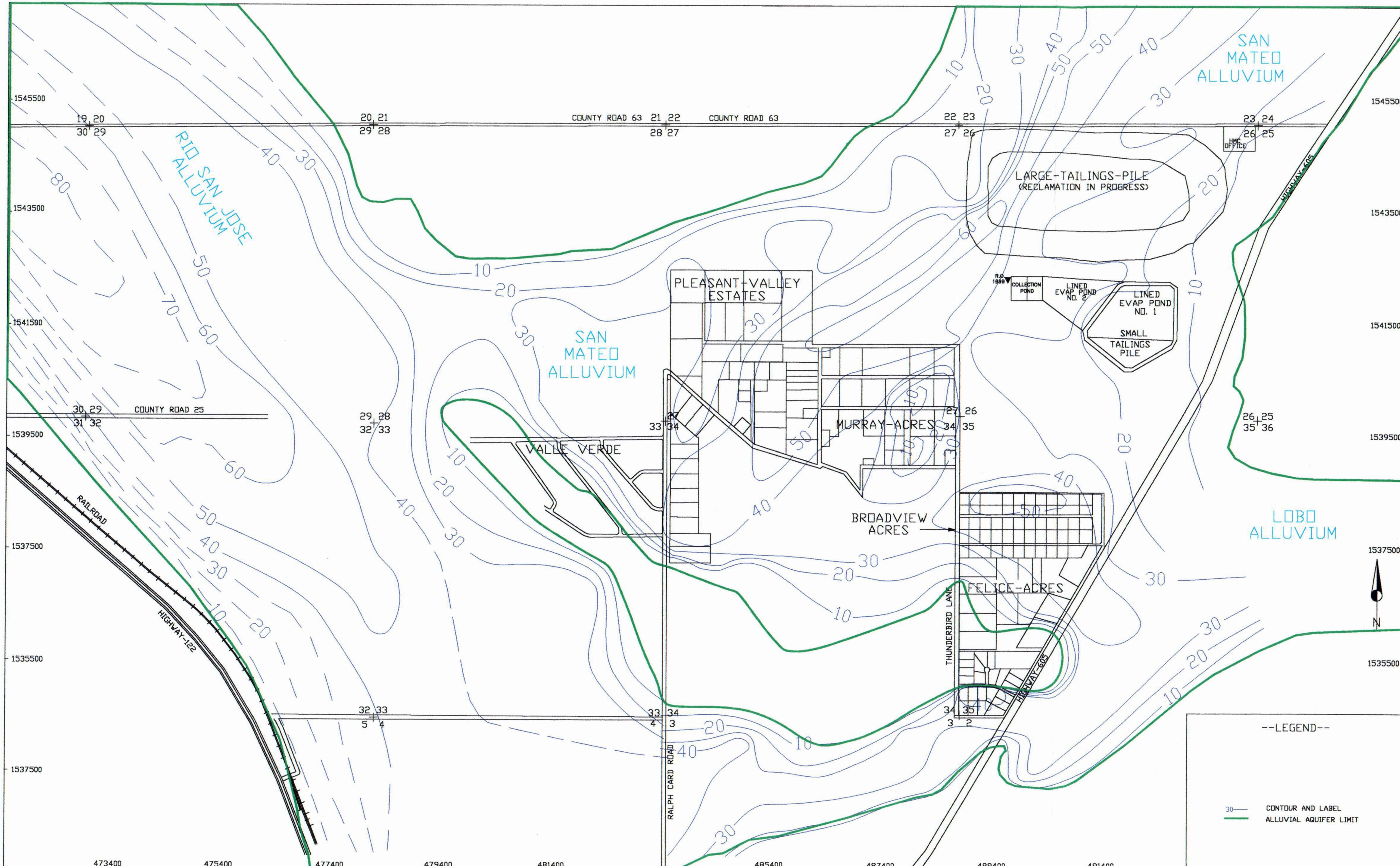

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FIGURE 3-1. SATURATED THICKNESS OF THE ALLUVIAL AQUIFER, 2002, FEET

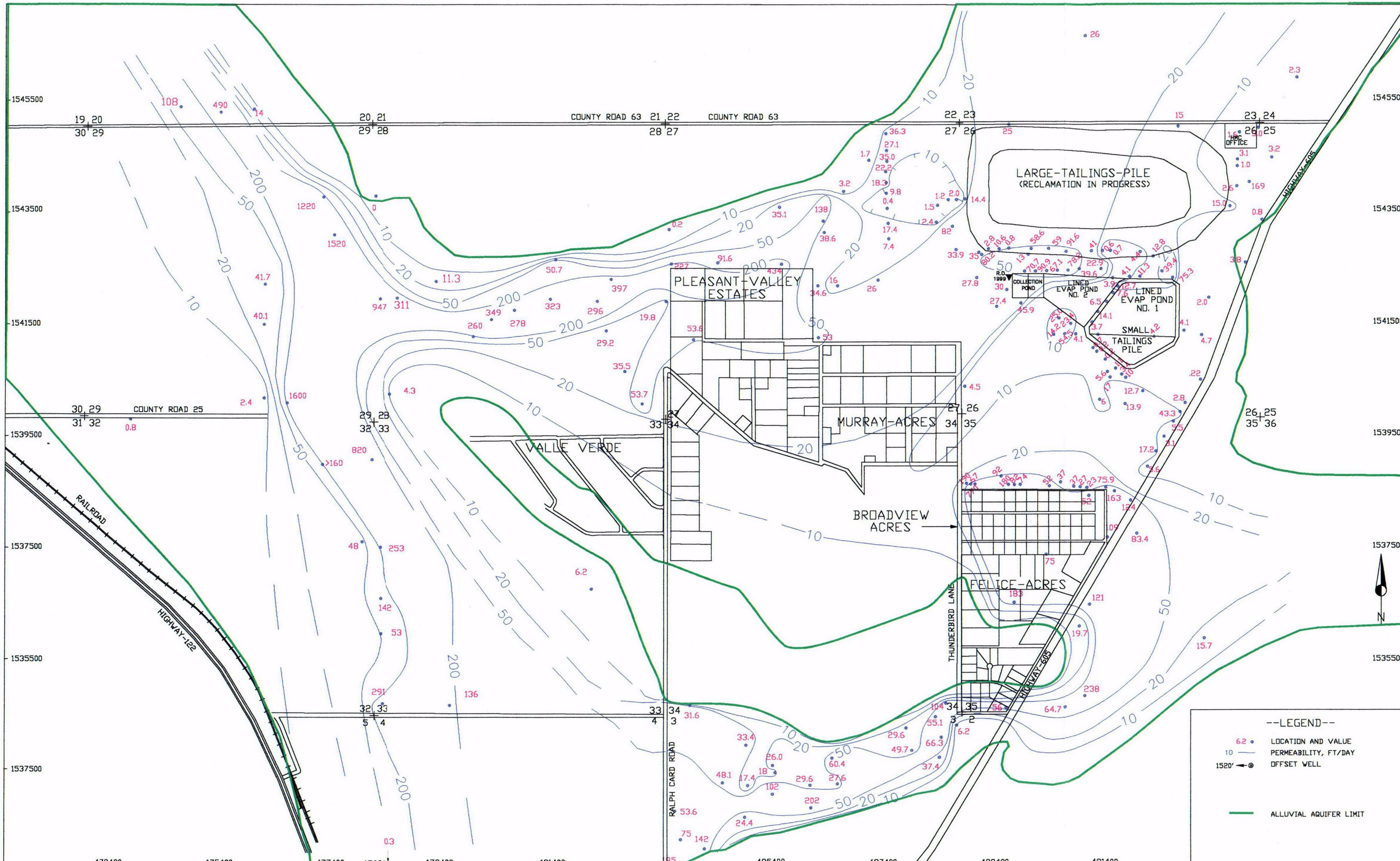

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FIGURE 3-2. HYDRAULIC CONDUCTIVITY (PERMEABILITY) OF THE ALLLUVIAL AQUIFER, FT/DAY

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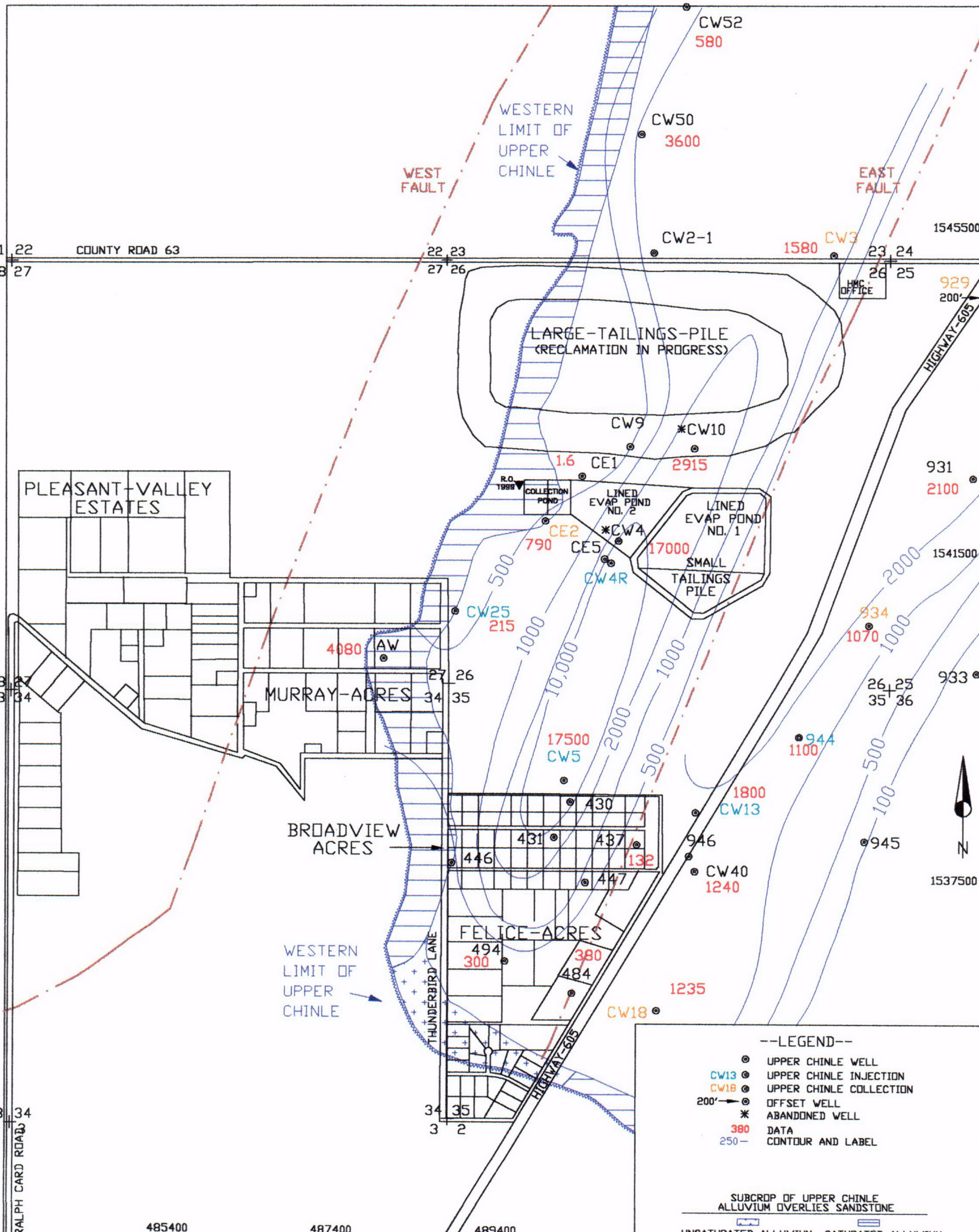

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	FIGURE 3-3. TRANSMISSIVITY OF THE UPPER CHINLE AQUIFER, GAL/DAY/FT	c:\dd\projects\2003-06\UP1600
		page 3-6

C03

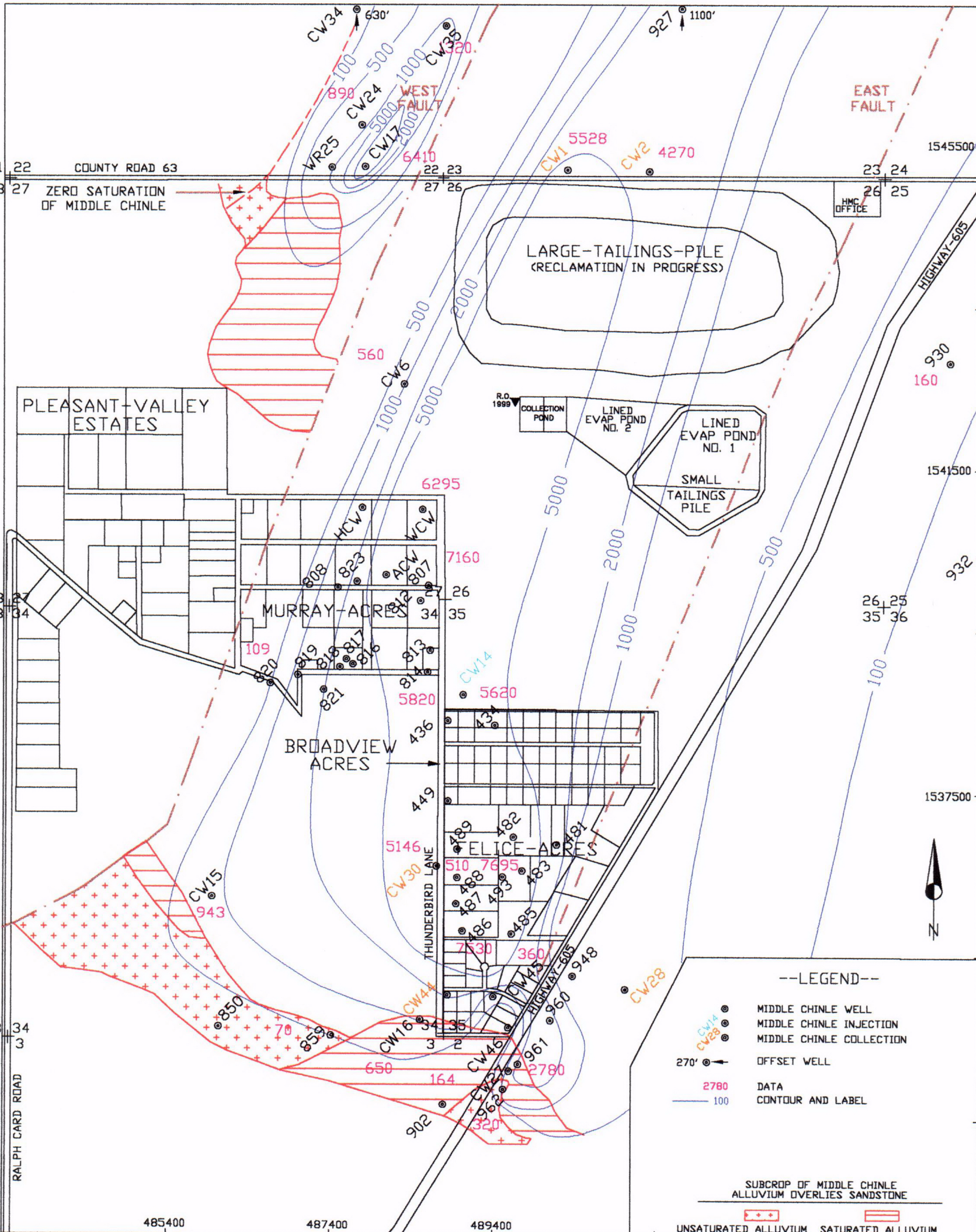

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FIGURE 3-4. TRANSMISSIVITY OF THE MIDDLE CHINLE AQUIFER, GAL/DAY/FT

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4.0 GROUND WATER FLOW

This section presents water level and ground water flow information for the Grants Project area aquifers. The interpretation of direction of ground water flow is based on water-level elevation mapping. This information, in conjunction with the aquifer properties presented in the previous section, is necessary in identifying and characterizing the communication between the various aquifers.

4.1 ALLUVIAL AQUIFER

Depths to water in the alluvial wells have been routinely presented in well data tables and in the water level appendix in the annual reports. That data has not been duplicated in this report. The 2002 alluvial well data is summarized in Figure 4-1, which presents water-level elevation contours for the alluvial aquifer.

Ground water in the alluvial aquifer flows under the tailings area from the north and converges toward the collection wells, as shown in Figure 4-1. The injection of fresh water down-gradient of the site, in conjunction with pumping from the collection wells, forces ground water in the alluvium to converge radially inward to the points of collection. Water-level elevations in the alluvium vary from 6,540 feet above mean sea level (ft-msl) on the east side of the tailings area to a low of 6,500 ft-msl on the western edge of Pleasant Valley Estates. Ground water in the alluvial aquifer is 40-80 feet below ground surface in this area.

In the area immediately west of the Grants Project site, flow in the San Mateo alluvium is forced through the western portion of Section 28 due to a constriction in the alluvial aquifer caused by the presence of Chinle shale above the piezometric surface. The San Mateo alluvial water then mixes with the Rio San Jose alluvial water and continues to flow to the south. Alluvial ground water that flows through the northern portion of Section 3 joins the Rio San Jose alluvial ground water system in the eastern portion of Section 4.

Post-restoration flow directions are anticipated to return to pre-restoration flow directions for the alluvial ground water. Post-restoration alluvial ground water is expected to flow toward and under the Large Tailings pile from the north and then turn in a more westerly flow path, exiting the San

Mateo alluvial system in the western area of Section 28. Less than one-fourth of the alluvial ground water will flow around the southern end of Felice Acres through Section 3 and join the Rio San Jose alluvial system in Section 4. Currently, the up-gradient flow in the Rio San Jose alluvium enters the area shown in the northwestern portion of Figure 4-1 and then flows in a southerly direction.

4.2 UPPER CHINLE

Depth to water in the Upper Chinle wells varies over the area but, in general, is less than 100 feet below the land surface except for areas of current pumping or injection activity (see Table 2-3). Water-level elevations in the Upper Chinle aquifer and the present direction of ground water flow are shown in Figure 4-2. The information presented in this figure is based on 2002 data. Between the two faults, ground water in the Upper Chinle is flowing toward the Large Tailings area from the north and is converging to Upper Chinle collection well CW3. Injection of fresh water into Upper Chinle well CW5 has created a gradient that forces flow back toward collection wells CE2 and CW3. Well CE2 is located south of the collection ponds.

Flow in the Upper Chinle aquifer in Broadview and Felice Acres area is to the south, where it discharges to the alluvial aquifer in the subcrop area. Flow east of the East Fault is parallel to the fault northeast of injection well CW13. The high permeability zone adjacent to the fault results in a preferential flow path that is parallel to the fault, with lateral flow occurring at some distance from the fault. South of injection well CW13, the flow is parallel to the fault and towards collection well CW18. In the area east of the high permeability zone near the East Fault, the Upper Chinle aquifer consists of lower permeability material. Flow through this material is toward the collection wells.

As discussed previously, water-level elevation contours of the alluvial aquifer are presented on Figure 4-1. The contours from the eastern half of this figure are also shown on Figure 4-3 with the Upper Chinle contours, allowing comparison of piezometric "heads" in the two aquifers. "Head" is the term used for the static water-level elevation in a well or aquifer. Similarities in head in the alluvial and Upper Chinle aquifers are indicative of some degree of communication between the aquifers. The head in the alluvial aquifer, up-gradient of the site, is higher than the head in the

Upper Chinle. Therefore, ground water in the up-gradient area is flowing from the alluvial aquifer into the Upper Chinle aquifer in the subcrop area. However, the heads in the two aquifers are very similar on the west side of the Large Tailings pile in the subcrop area and to the south in the collection pond area.

The transmitting capacity of the Upper Chinle aquifer in the subcrop area controls the rate of inflow of alluvial water. The transmitting capacity in some areas of the subcrop is limited by the presence of some residual lower-permeability Chinle shale. The movement of alluvial water into the Upper Chinle is greatly restricted in those areas. Further, the direction of ground water flow between the alluvial and Upper Chinle aquifers may change in some areas due to seasonal recharge or pumping withdrawals from one of the aquifers. Seasonal pumping, such as for an irrigation supply, can cause a temporary reversal of the head relationship between the aquifers.

In the Broadview Acres subdivision, the alluvial and Upper Chinle aquifers reveal similar head, indicating potential communication. Several wells in the Broadview Acres subdivision are completed in both the Upper Chinle and alluvial aquifers, which results in localized communication in the immediate area of these wells. In southern Felice Acres, Upper Chinle water discharges to the alluvium, where the head is significantly higher in the Upper Chinle than in the alluvial aquifer. Conversely, alluvial water discharges to the Upper Chinle on the east side of the East Fault, as indicated by the higher head in the alluvium in this area.

Post-restoration ground water flow information is shown on Figure 4-4. The post-restoration Upper Chinle flow between the faults is from the north to the south, while flow immediately east of the East Fault is to the northeast. Farther east of the East Fault, flow is to the east. The greater transmissivity of the Upper Chinle aquifer adjacent to the East Fault allows greater water conveyance in a direction parallel to the fault. The lower transmissivity of the aquifer farther to the east results in ground water flow perpendicular to the fault. The post-restoration alluvial aquifer ground water flow direction is also shown on this figure for comparison of the two aquifers' post restoration flow directions.

4.3 MIDDLE CHINLE

Water levels for the background Middle Chinle wells are presented in Table 2-4 (page 2-10). Fall 2002 water-level elevations for the Middle Chinle aquifer are presented on Figure 4-5. The hydraulic gradient of ground water flow in the Middle Chinle aquifer is steeper in its subcrop area in the southern portion of Felice Acres near wells CW44, CW45 and CW46. The gradient increase is due to the influx of water from the alluvial aquifer to the Middle Chinle aquifer in the subcrop area. Immediately east of the East Fault, flow direction is primarily to the south due to pumping of collection well CW28.

Ground water flow in the Middle Chinle aquifer on the west side of the West Fault is in a southwest direction, eventually discharging to the alluvial aquifer in the subcrop area. Thus, alluvial aquifer water is prevented from entering the Middle Chinle aquifer in the subcrop area on the west side of the West Fault. West of the West Fault, the Middle Chinle aquifer water flows from areas up-gradient of the site to the south toward the subcrop area.

A mound in the Middle Chinle aquifer near well CW14 has been created by injection of fresh water into this well. Thus, ground water is flowing radially outward in the immediate vicinity of well CW14. Between the two faults and north of well CW14, water in the Middle Chinle aquifer flows in a northerly direction down-gradient toward collection wells CW1 and CW2, located north of the tailings area. The head in the wells in the Middle Chinle aquifer on each side of the two faults is significantly different than the head in the wells between the two faults. This indicates that the ground water in this aquifer is not connected at the contact of each of the two faults.

The Middle Chinle and alluvial flow systems are shown on Figure 4-6 for comparison. The water-level elevation in the Middle Chinle aquifer between the two faults is significantly lower than that of the alluvial aquifer, indicating a lack of communication in the area of the tailings pile. Similarly, Middle Chinle water-level elevations east of the East Fault are significantly lower than the water-level elevations in the alluvial aquifer in that area. However, west of the West Fault and west of the Large Tailings pile, the head in wells in the Middle Chinle aquifer is similar to the head of the alluvial aquifer, indicating that there may be aquifer communication in this area. Water-level elevations in the Middle Chinle on the south side of Felice Acres are slightly lower than those in the alluvial aquifer. The presence of the subcrop in this area allows ground water to flow from the alluvial aquifer to the Middle Chinle aquifer. Water-quality changes also demonstrate communication of the alluvial and Middle Chinle aquifers in this area.

In the Middle Chinle aquifer, the indicated ground water velocity is slightly less than 1 ft/day. The naturally occurring direction of ground water flow in the Middle Chinle aquifer between the two faults is to the north. This data indicates that this area of the Middle Chinle aquifer between the two faults contained alluvial water prior to the introduction of tailings seepage to the ground water in the alluvium. Alluvial water also moves from the subcrop area into the Middle Chinle aquifer located east of the extrapolation of the East Fault into the subcrop. Based on water-quality changes, the indicated velocity in this area is significantly less than 1 ft/day. These aquifer patterns and characteristics have been used to project ground water flow patterns following site restoration.

Projected post-restoration ground water flow patterns of the Middle Chinle aquifer are presented on Figure 4-7. The projected post-restoration alluvial ground water flow system is depicted in green. The post-restoration ground water flow in the Middle Chinle aquifer west of the West Fault is expected to continue to flow from the north and discharge into the alluvial aquifer at the subcrop. Post-restoration ground water flow in the Middle Chinle aquifer between the two faults and east of the East Fault is expected to be from the subcrop area back to the north. Flow farther east of the East Fault in the Middle Chinle is likely to move to the east.

4.4 LOWER CHINLE

Water-level elevation data for the background Lower Chinle wells is presented in Table 2-5. Water-level elevation information and flow directions for the Lower Chinle aquifer based on 2002 data are presented on Figure 4-8. Flow west of the West Fault in the Lower Chinle is mainly to the northeast. Flow between the two faults is to the northwest and north, indicating that the flow of some Lower Chinle water is uninterrupted by the West Fault.

A comparison between the alluvial and the Lower Chinle aquifers (see Figure 4-9) shows that water-level elevations in the alluvial aquifer are higher than those of the Lower Chinle. The exception to this is in the subcrop areas (see, for example the west-central portion of Section 3) where the hydraulic communication between the two aquifers results in very similar heads. Across the site, the head differential indicates the only communication between the alluvial and Lower Chinle aquifers is in these isolated subcrop areas.

The flow directions in the Lower Chinle following termination of the restoration program are expected to be very similar to those being observed with current monitoring. The irrigation supply well located in Section 3 is the only component of the restoration program that should slightly affect the piezometric surface in the Lower Chinle aquifer. Therefore, Figure 4-8 is believed to accurately reflect post-restoration conditions.

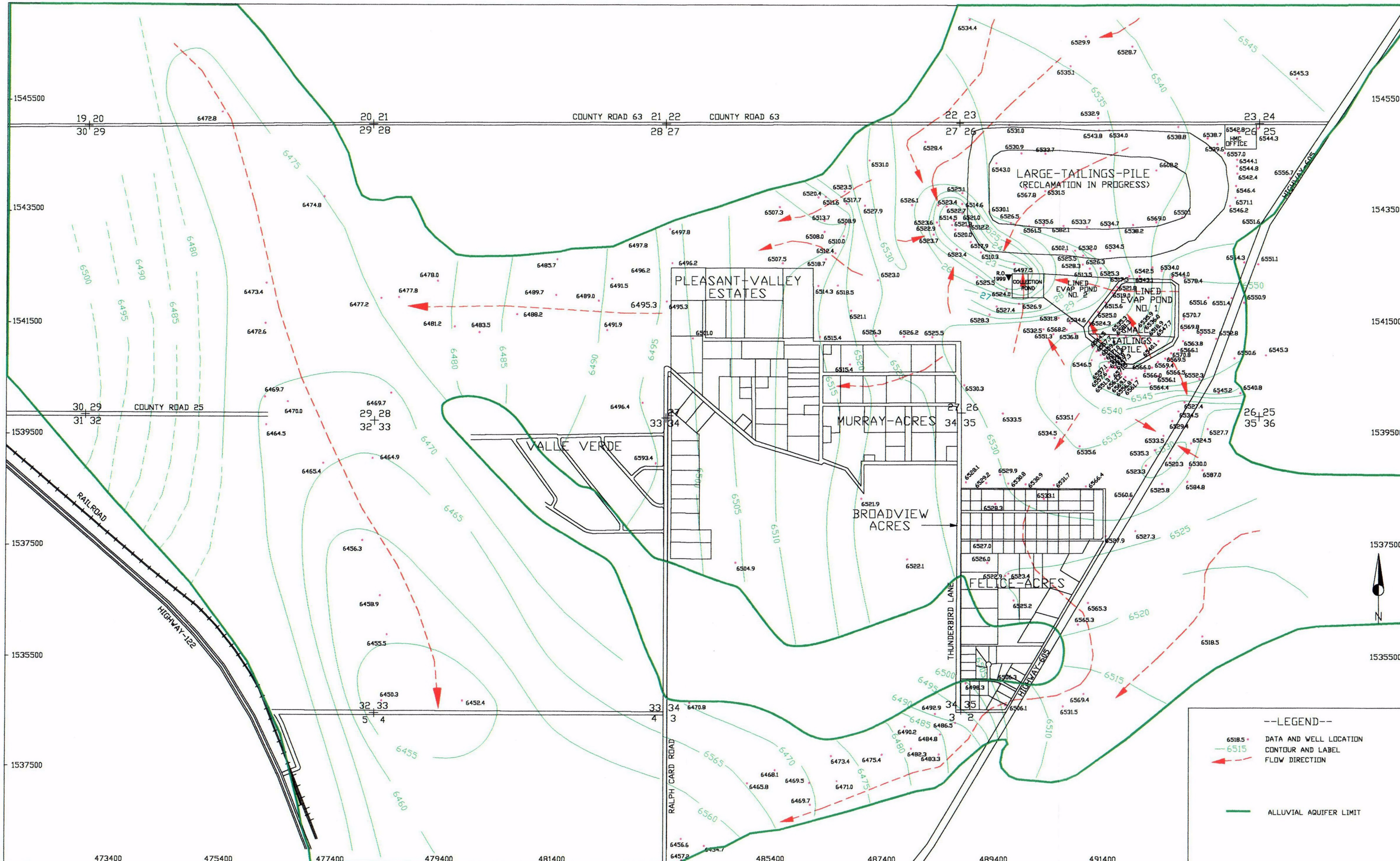

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FIGURE 4-1. WATER-LEVEL ELEVATIONS OF THE ALLUVIAL AQUIFER, 2002, FT-MSL

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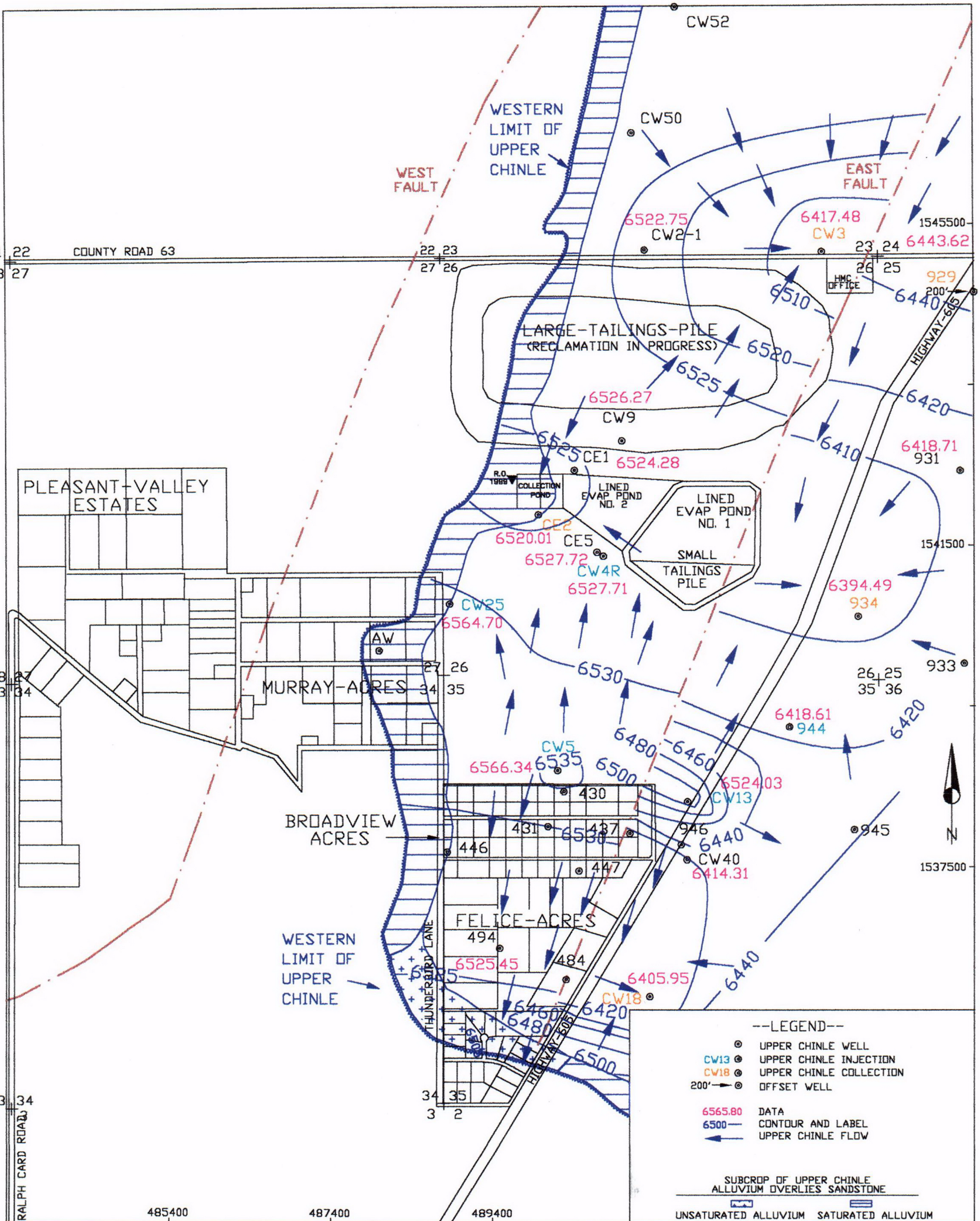

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FIGURE 4-2. WATER-LEVEL ELEVATIONS OF THE UPPER CHINLE AQUIFER, 2002, FT-MSL		c:\dd\projects\2003-06\UP1600
		page 4-8

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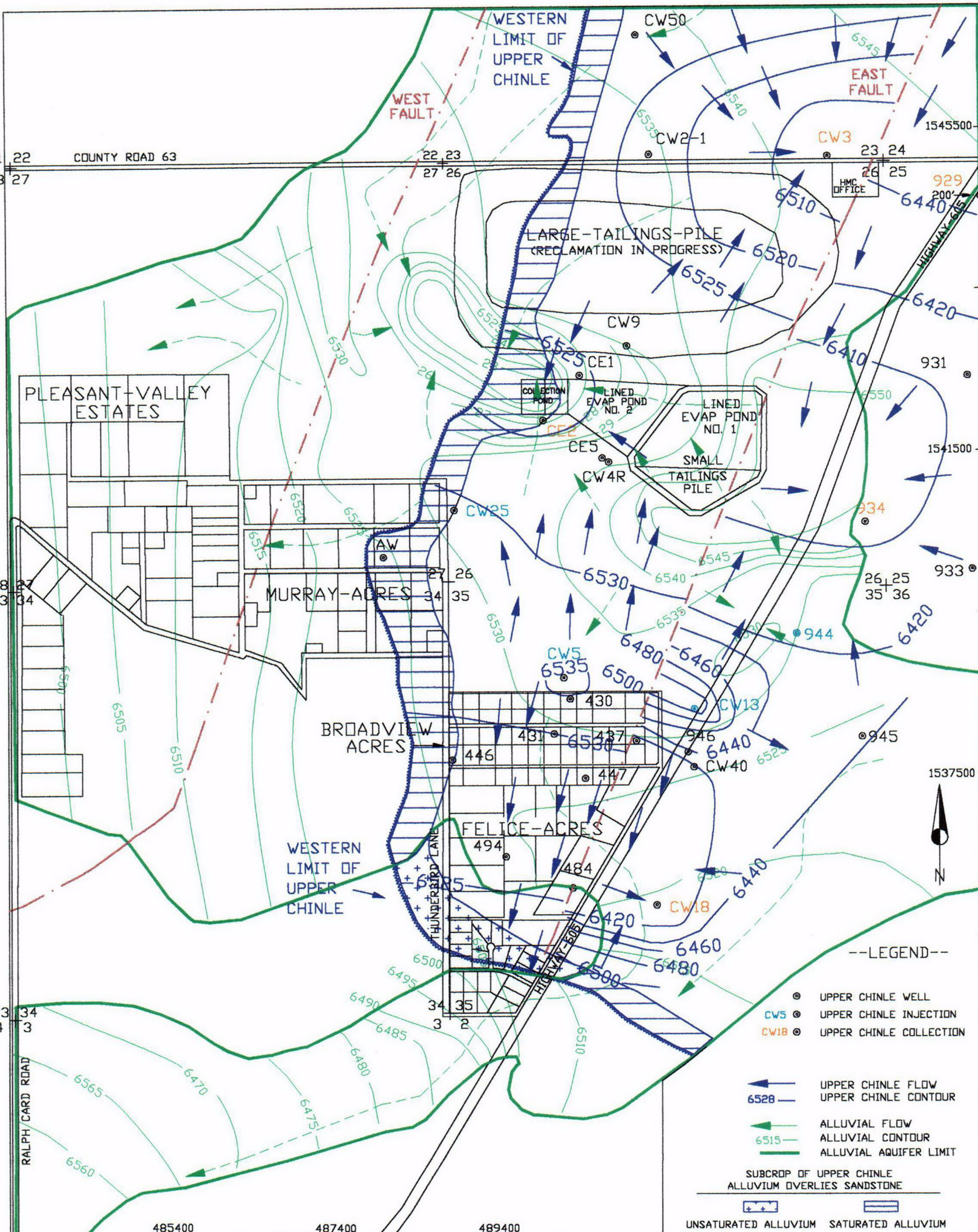

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FIGURE 4-3. WATER-LEVEL ELEVATIONS OF THE UPPER CHINLE AND ALLUVIAL AQUIFERS, 2002, FT-MSL

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