5.0 EXISTING STANDARDS AND BACKGROUND CONCENTRATIONS

This section presents the present site standards and the full range of background concentrations. Averaging data, which does not account for natural concentrations above the mean, has been used to set present site standards.

5.1 SITE STANDARDS

Six water-quality site standards (U, Se, Mo, Ra226 + Ra228, Th230 and V) have been set for the Homestake site by the United States Nuclear Regulatory Commission (NRC). These site standards are applicable at three points of compliance. Points of compliance wells are S4, D1 and X (see Figure 5-1 for locations).

Table 5-1 presents the six site standards, which were set by averaging only three data values from one of five background wells available at the time. Some of these wells had 13 years of data at the time. The background data set was 100 times larger than the three data values used at the time of setting the standards. These established site standards are presently exceeded by the average background values for some of the constituents because the site standard was based on three values from only one well. Therefore, naturally occurring concentrations will cause compliance issues at this site. The New Mexico standards for uranium, selenium, molybdenum, radium-226 plus radium-228, sulfate, chloride, TDS and nitrate for this site are also presented in Table 5-1. The State standards were also set by averaging data, which does not account for the upper half of natural concentrations.

TABLE 5-1. GRANTS PROJECT WATER-QUALITY STANDARDS AND BACKGROUND

Constituents	Homestake Standards		
	NRC	NEW MEXICO	95% BACKGROUND LEVEL
Uranium	0.04	5	0.15
Selenium	0.10	0.12	0.27
Molybdenum	0.03	1.0@	0.05
Sulfate	-----	976	1870
Chloride	-----	250	112
TDS	-----	1770	3060
Nitrate	-----	12.4	23
Vanadium	0.02	-----	-----
RA-226 + Ra228	5	30	-----
Thorium-230	0.3	-----	-----

**NOTE: All concentrations are in mg/l except; Ra-226 + Ra-228 and Th-230, which are in pCi/l.
@ = Irrigation Standard.**

5.2 BACKGROUND WATER QUALITY

The hydrologic background conditions at the Grants site are those that exist upgradient or north of the Large Tailings pile. These conditions have been monitored since 1976. Alluvial wells DD, P, P1, P2, P3, P4, Q, R and ND, located just north of the Large Tailings on the Homestake property, have been used for monitoring alluvial background water quality. Additional upgradient wells located further north were sampled in 2001 (wells 914,916, 920, 921, 922 and 950, see Figure 5-1 for locations). Information gathered from these wells has been used to further define the piezometric surface and water-quality conditions in the upgradient alluvial aquifer. These far upgradient wells were not used in establishing the 95% levels.

Table 5-2 presents the period of record and normal sampling frequency for the background and far upgradient wells. This table shows that wells DD, P, Q and R were initially monitored in 1976. Upgradient alluvial well ND was started monitoring in 1983. Wells P1 and P2 monitoring was initiated in 1992 while wells P3 and P4 monitoring was started in 1998. The majority of the monitoring in the far upgradient wells was started in 1994.

TABLE 5-2. BACKGROUND MONITORING PERIOD AND FREQUENCY

WELL NAME	PERIOD OF RECORD	TYPICAL SAMPLING FREQUENCY
	BACKGROUND ALLUVIAL WELLS	
DD	1976 - 2000	Annually
ND	1983 - 2000	Annually
P	1976 - 2001	Quarterly
P1	1992 - 1999	Quarterly
P2	1992 - 2000	Quarterly
P3	1998 - 2001	Annually
P4	1998 - 2001	Annually
Q	1976 - 2000	Quarterly
R	1976 - 2000	Quarterly
	FAR UPGRADIENT WELLS	
914	1983 - 2001	Variable
916	1994 - 2001	Annually
920	1981 - 2001	Annually
921	1994 - 2001	Annually
922	1981 - 2001	Annually
950	1994 - 2001	Variable

Background water quality data has been developed at this site with some wells containing 25 years of quarterly measurements.

Figure 5-1 presents the latest water-quality data for the background wells for six parameters: sulfate, uranium, selenium, chloride, TDS and nitrate. All molybdenum concentrations in these upgradient wells are less than 0.03 mg/l. The sulfate

concentrations for the nine upgradient wells vary from 526 to 1420 mg/l. The sulfate concentrations for the far upgradient wells vary from 46 to 1380 mg/l. Uranium concentrations also vary over a large range, from less than 0.02 to 0.19 mg/l. The uranium concentrations in the far upgradient wells vary over a similar range from 0.001 to 0.21 mg/l. Four wells have natural uranium concentrations that are four times the NRC site standard of 0.04 mg/l. Selenium concentrations vary over an even larger range, from 0.01 to 0.43 mg/l in the background wells and less than 0.005 to 0.63 mg/l in the far upgradient wells. The largest background for selenium is six times the NRC site standard.

Chloride concentrations in water sampled from the background wells ranged from 47 to 67 mg/l and for the far upgradient wells ranged from a low of 27 mg/l to a high of 136 mg/l. The TDS concentrations varied from 1290 to 2470 and 399 to 2690 mg/l for the background and far upgradient respectively. Nitrate concentrations also vary naturally over a large range in the alluvial aquifer from 1.3 to 17.4 mg/l for the wells north of the Large Tailings.

The 95th percentile of the historical background data for this site was defined by ERG (1999a and 1999b). The 95% level is being used to define the upper limit of background. The average background concentration has been used in the past for establishing the standards. The 95% level is a better value for use in setting site standards because it better defines the full range of background. Figures 5-1 and Table 5-1 present the 95% background levels for the Grants constituents.

The 95% background level was selected to define the full range of background for establishing the site standards (see ERG 1999a and 1999b for detail discussion of the statistical analysis). Even with the 95% level, 5% of the natural background concentrations would be expected to exceed the site standard. Two of the latest uranium concentrations in the 9 background wells slightly exceed the 95% level of 0.15 mg/l. Also, two of the 6 far upgradient latest uranium concentrations exceeded the 95% level.

These number of exceedances indicate that the 95% level may be a few hundredths too low. One background selenium concentration and two of the far upgradient selenium concentrations also exceed the selenium 95% level. This also indicates that the selenium 95% level may be several hundredths too low. None of the sulfate or TDS latest values exceed the 95% level while only one far upgradient chloride concentrations exceed the 95% level. This indicates that the 95% levels are adequate for these three parameters.

The two ERG reports present the statistical theory used in developing the 95% levels. Tables 73 through 94 in the ERG report present the calculation for the Homestake Grants site, 9 background wells (near upgradient) for uranium. Tables 95 through 113 present the calculations for the far upgradient wells, which were not used in selecting the 95% levels. The near upgradient or background wells are the 9 Grant site background wells used in developing the 95% levels presented in this report.

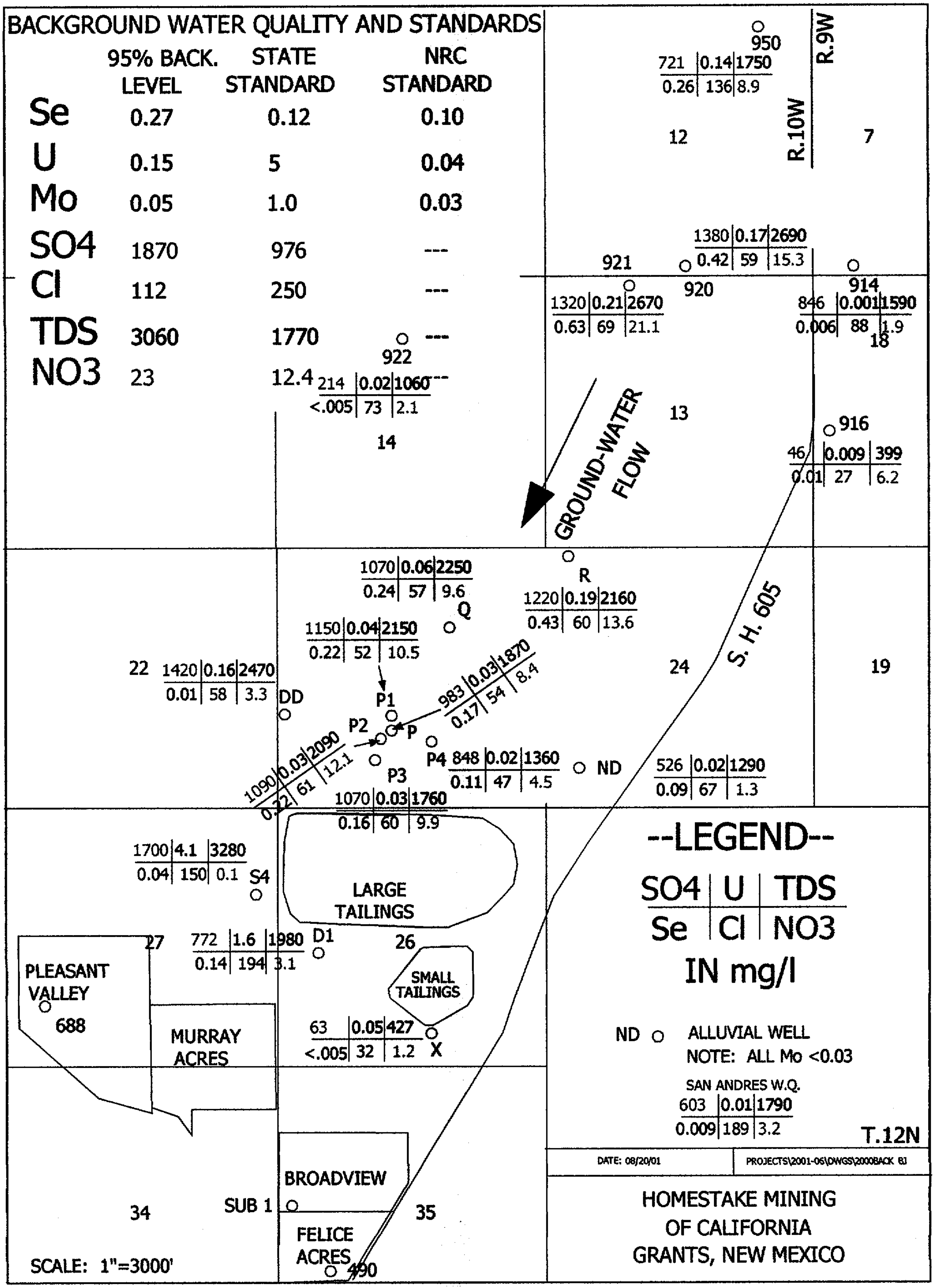


FIGURE 5-1. BACKGROUND GROUND-WATER QUALITY

6.0 WATER QUALITY

The water type in each of the aquifers at the Grants site is the first subsection presented in this water quality section. The water type is useful in defining where the connections between the ground-water systems have enabled the alluvial water quality to affect the type of water in the bedrock aquifers. The areas of the bedrock aquifers where the water type has been changed is labeled the mixing zone and contain the areas where ground-water restoration is needed in these systems. The areas of restoration zones are smaller than the mixing zones.

6.1 WATER TYPE

Stiff diagrams have been used to convey the type of ground water that exists in the different aquifers. Stiff diagrams use the concentration of eight major constituents in milliequivalents per liter (meq/l). The four anions are plotted on the right side of a vertical line at four locations while the four cations are plotted on the left side at three locations. Sodium and potassium cations are combined for the plot. The shape of the resulting diagram indicates water type while the size relates to concentration. Stiff diagrams are a good means to see the difference in water quality type.

Figure 6-1 shows the comparison of the stiff diagrams between the upgradient alluvial water. This diagram shows the major cation is calcium and the major anion is sulfate for the alluvial wells. The type of water is very similar in each of these wells except for well ND, which has the highest sodium, bicarbonate and chloride levels. All the remainder constituents in well ND water are significantly lower than the typical alluvial water quality. The stiff diagram for well ND shows that the water quality in alluvial well ND is very similar to the Chinle water type. This alluvial well shows that the water quality type can be different in some portions of the alluvium. Very low calcium concentration in the well is typical of the Chinle natural water quality. A higher natural sodium concentration is also typical of the Chinle water type, therefore, it is likely that a subsurface discharge of Chinle water to the alluvial aquifer on the east side occurs affecting the natural water quality in the alluvial aquifer in this area.

Figure 6-2 presents stiff diagrams comparisons for the Upper Chinle wells CW3, CW4R, 494, CW40, 934 and 945. These stiff diagrams show that sodium is the major cation while sulfate is the major anion. The shapes of these diagrams are significantly different than the upgradient alluvial diagrams except for Upper Chinle wells CW4R and 494 where the alluvial water has affected the Upper Chinle water quality. Wells CW4R and 494 exist in the mixing zone in the Upper Chinle aquifer where alluvial water flowing in this area for a very long time has removed the ability of the sandstone to change the water quality type. Very low calcium concentrations and higher natural sodium concentrations are the main differences between the Upper Chinle and alluvial diagrams. Naturally higher chloride concentrations in well 945 cause this diagram to look different than the majority of the Upper Chinle diagrams. Chloride concentrations have naturally increased in the low permeability zone east of the East Fault as water slowly moves east in this area.

The other significant difference in the Upper Chinle stiff diagrams is the higher bicarbonate concentrations in well CW40. The bicarbonate concentration in well CW40 has been affected by the fresh water injection into CW13 even though the calcium concentration has stayed low as the San Andres water has moved through the Upper Chinle at CW40. The bicarbonate concentration has significantly increased above the natural levels in the Upper Chinle. The remainder constituents have stayed fairly similar to the natural levels in the Upper Chinle. The ability of the Upper Chinle Sandstone to decrease the calcium concentrations in the CW13 injected water as it flows by well CW40 shows how the Chinle Sandstones can alter the water quality type of water that moves through it. The calcium concentration in the San Andres water injected into well CW13 is typically 230 mg/l while the latest calcium value for well CW40 is 11 mg/l. The Upper Chinle sandstone at well CW40 has been exposed to the San Andres water for several years which has not been long enough to remove the ability of the sandstone to change the water type. Some areas of the Chinle Sandstones do not have the ability to alter the water type. The Upper Chinle sandstone in the areas of wells CW4R and 494 has lost its ability to change the water type.

Major constituent water quality has also been posted in Figure 6-3 to view the variation in concentrations for calcium, sodium, bicarbonate and chloride concentration in the alluvial aquifer. This data is also tabulated in the upper left corner of Table 6-3 for ease in comparing concentrations. The wells north of the Large Tailings are all upgradient of the site and not influenced by the tailings. These wells show that the background calcium concentration typically varies from 202 to 349 mg/l. The exception is the calcium concentration of 31 mg/l in well ND. Sodium background concentrations have varied from 234 to 381 mg/l. Bicarbonate background concentrations have also varied over a large range from 149 to 376 mg/l. Chloride background concentration is a constituent that varies over a smaller range with concentrations varying from 47 to 67 mg/l. The different type of water can also be seen by comparing these concentrations. The calcium concentration from alluvial well ND separates it from the other background wells.

Concentrations for a few select wells are also presented downgradient of Large Tailings. The three POC wells, S4, D1 and X and three wells in the subdivisions are presented. The concentrations for the San Andres water quality, which is used for injection into the alluvial aquifer, are noted in the legend. Calcium concentrations are typically above 200 mg/l downgradient of the tailings with lowest concentrations at the POC well X, which have been significantly influenced by the R. O. product injection. This figure shows that the calcium concentration in the alluvial water is typically above 200 mg/l.

Figure 6-4 shows the same information for the Upper Chinle wells. Calcium concentrations are naturally low in the Upper Chinle but have similar concentration to the alluvial water quality where the alluvial water has affected the Upper Chinle water quality. Concentrations of sodium are typically higher in the Upper Chinle. Bicarbonate concentrations are also naturally higher in the Upper Chinle than in the alluvial water quality. Natural chloride concentrations are fairly similar to the chloride concentrations in the alluvial aquifer except for the area east of the East Fault where chloride concentrations naturally increase in the low permeability zone.

A pattern has been added for the Upper Chinle aquifer where the water quality has been influenced by the alluvial water quality and labeled Mixing Zone. Connection in this area between the alluvial aquifer and the Upper Chinle aquifer has changed the water quality type in this area. The water quality type in the pattern area shown on Figure 6-4 is similar to the water quality in the alluvial aquifer. This area includes all the subcrop area where direct connections between the alluvial aquifer and Upper Chinle aquifer exist but also includes the area to the south of the Large Tailings for some distance east of the subcrop area. Water has moved through this area from the subcrop into the Upper Chinle aquifer which discharges back to the alluvial aquifer in the south side of Felice Acres. All of the mixing zone in the Upper Chinle aquifer has not been affected by tailing's seepage but all of the restoration zones (see Figure 6-10A and 6-11A) in the Upper Chinle aquifer exist within the mixing zone.

Comparison of the water quality type for the Middle Chinle wells is presented in Figure 6-5. The stiff diagrams are very similar in shape to the Upper Chinle diagrams. The water quality type is very similar in the Middle Chinle except for the difference in water quality in Middle Chinle well CW45. The higher calcium concentration and the lower sodium concentration in CW45 make the water quality type closer to the alluvial type in this Middle Chinle well. Figure 6-6 presents the posting of the calcium, sodium, bicarbonate and chloride concentrations for the Middle Chinle wells. This shows that the calcium concentrations are low in the Middle Chinle west and east of the East Fault except in the area that has been affected by the connection with the alluvial aquifer south of Felice Acres. A pattern (mixing zone) has been added to this figure to show where the concentrations are above the 30 mg/l. Water quality in this area is similar to the alluvial aquifer and therefore the alluvial background concentrations are applicable to this area.

All of the mixing zone in the Middle Chinle aquifer does not require restoration (see Figure 6-12A for restoration area). None of the Middle Chinle west of the West Fault requires any restoration because these concentrations are all natural. The area in the

Middle Chinle that does require restoration is near the subcrop area on the south side of Felice Acres.

Flow in the Middle Chinle west of the West Fault is from the north to the southwest. This flow discharges to the alluvial aquifer in the subcrop area. The water quality type shown on Figure 6-7 for the four wells west of the West Fault in the Middle Chinle are substantially different than the water quality at well CW2. The stiff diagram for well CW2 has been added to this figure for comparison purposes. The water quality in the Middle Chinle west of the West Fault is similar to the water quality in the alluvial aquifer. Connection with the alluvial aquifer north of the site exists with the Middle Chinle allowing alluvial water to flow through the Middle Chinle to the southwest and discharge in its subcrop area. This has changed the water quality of the Middle Chinle west of the West Fault to a water quality type similar to the alluvial aquifer water type. Water quality west of the West Fault has to be natural due to the direction of ground water flow in the Middle Chinle aquifer in this area. The entire area of the Middle Chinle aquifer west of the West Fault contains a pattern because the alluvial aquifer water type in this area has affected the entire aquifer. This shows that some areas of the Chinle aquifers naturally contain water quality very similar to the alluvial water quality. Figure 6-6 shows the pattern in the Middle Chinle aquifer west of the West Fault. This figure also shows the calcium, sodium, bicarbonate and chloride data for the Middle Chinle wells in this area which all contain a water type similar to the alluvium.

The type of water in the Lower Chinle naturally varies due to this aquifer existing in the Chinle shale and depending on secondary permeability for adequate movement of water through this unit. The type of water quality therefore is considerably different over the Lower Chinle aquifer. Figure 6-8 presents a stiff diagram for five selected Lower Chinle wells. Figures 6-9A and 6-9B present the calcium, sodium, bicarbonate and chloride concentration comparisons for the Lower Chinle aquifer wells. This data shows that the water quality in the Lower Chinle aquifer naturally varies a large amount. The alluvial aquifer has influenced some of the water quality in the Lower Chinle aquifer (see well

CW42) near its subcrop areas but the major constituents naturally increase as ground water flows downgradient in the shale. Therefore, the zone that has been affected by the alluvial water quality is more difficult to define in this aquifer. The Lower Chinle aquifer near well CW42 is the area that requires restoration (see Figure 6-14B for the restoration area). The alluvial water has affected the water type at well CW42 and therefore the alluvial restoration standards are appropriate for the Lower Chinle in this area.

6.2 RESTORATION AREAS

The areas of restoration in the Chinle aquifers are covered by the areas where the alluvial aquifer has affected the water quality in the Chinle aquifers. Figure 6-10A presents an overlay that shows the areas that need restoration in the Upper Chinle aquifer. These areas were defined where the uranium and selenium exceed the 95% background levels of 0.15 and 0.27 mg/l respectively. The outer border of the overlay needs to be lined up with the border on Figure 6-10B. Figure 6-10B presents the most recent TDS, sulfate, uranium and selenium concentrations for the Upper Chinle aquifer with the area pattern based on the area shown where the aquifer has been affected by the alluvial water quality. The TDS and sulfate concentrations in the Upper Chinle aquifer are all less than the upper limit of background and therefore no restoration of the Upper Chinle aquifer is needed relative to these two parameters.

All uranium concentrations that exceed the 95% level, 0.15 mg/l, are within the area affected by the alluvial water quality (mixing zone). Therefore, the background concentrations for the alluvial water quality are appropriate for restoration and uranium concentrations at the Grants site. Two areas are shown on Figure 6-10A that require restoration in the Upper Chinle aquifer for uranium. The main area is in the subcrop. A small restoration area also exists in Felice Acres.

None of the selenium concentrations exceed the 95% level in the Upper Chinle aquifer. A small restoration area in the Upper Chinle is shown to the west of well CE2. Some

decreases in the selenium concentration in well CE2 will occur as the uranium concentration is restored.

Figure 6-11A presents an overlay for Figure 6-11B and shows the area of restoration based on the 95% background level of 0.05 mg/l for molybdenum. Figure 6-11B presents molybdenum concentrations, the remainder important restoration standard for the Upper Chinle along with nitrate, radium-226 and radium-228 concentrations. All the molybdenum concentrations that exceed the 95% level of 0.05 mg/l in water quality exist within the area affected by the alluvial aquifer. Therefore, the background alluvial aquifer water quality is appropriate for molybdenum concentrations for Upper Chinle restoration, also. The restoration area for molybdenum is similar to the uranium restoration area. All nitrate, radium-226 and radium-228 concentrations are very low in the Upper Chinle aquifer; therefore, no restoration of these three parameters is needed.

The TDS and sulfate concentrations in the Middle Chinle aquifer all are lower than the 95% level for these two constituents and therefore do not need any additional restoration. Figure 6-12A presents the restoration areas for uranium and selenium for the Middle Chinle aquifer while Figure 6-12B gives the TDS, sulfate, uranium and selenium concentrations for the Middle Chinle. All uranium concentrations that exceed the 0.15 mg/l upper limit of background exist within areas of the Middle Chinle aquifer affected by the alluvial ground water (mixing zone). Therefore, the alluvial aquifer water quality background is appropriate to be used for the background concentrations for the Middle Chinle aquifer in this affected zone. An area in Felice Acres and to the west and south of Felice Acres is the main area of Middle Chinle uranium restoration. A small area also exists around Middle Chinle well 434 for uranium.

All selenium concentrations that exceed the 95% level of alluvial background in the Middle Chinle aquifer also exist in the area affected by the alluvial aquifer and therefore the alluvial aquifer background water quality is appropriate for defining restoration

standards in selenium in the Middle Chinle aquifer. Selenium restoration is in the same area as uranium but smaller.

None of the molybdenum concentrations exceed the 95% level in the Middle Chinle. Figure 6-13 lists the molybdenum concentrations for the Middle Chinle aquifer, along with nitrate, radium-226 and radium-228. All molybdenum, nitrate, radium-226 and radium-228 concentrations in the Middle Chinle aquifer are low and need no restoration.

The Lower Chinle aquifer naturally becomes poorer quality water as the ground water flows down dip in this portion of the Chinle shale. The TDS generally increases downgradient. Figure 6-14A presents the TDS, sulfate, uranium and selenium concentrations for the west side for the Lower Chinle aquifer. Figure 6-14B presents the overlay of the uranium restoration area while 6-14C presents the TDS, sulfate, uranium and selenium for the east side of the Lower Chinle aquifer. The TDS, which is presented in blue, shows that concentrations exceed 3000 mg/l west of the West Fault as this ground water moves down dip. Similar increases in TDS probably exist in the Lower Chinle between the two faults and east of the East Fault as it moves further down dip. These TDS concentrations greater than 3060, the 95% level of background, are natural and therefore do not need restoration. Sulfate concentration in well CW33 also exceeds the 95% background level but these sulfate concentrations are natural in the Lower Chinle aquifer and therefore do not need restoration. Higher natural concentrations in the Lower Chinle aquifer can be justified but the alluvial background concentrations are appropriate for the Lower Chinle restoration because the area of the Lower Chinle restoration is near its subcrop and the alluvial water quality best represents that area.

Figure 6-14B shows a restoration area for only uranium near well CW42 that exceed the background level and have been influenced by ground-water flow from the alluvial aquifer into the Lower Chinle in this area. Restoration of this area therefore to the 95% level of alluvial background concentrations is appropriate. The limit of the uranium restoration area is based on the CW42 concentration, limit of uranium in the alluvial

aquifer and area of the Lower Chinle subcrop. No selenium concentrations in the Lower Chinle exceed the full range of natural background concentrations in the alluvial aquifer.

Figures 6-15A and 6-15B present the molybdenum, nitrate and radium226 and radium228 concentrations for the Lower Chinle aquifer. All of these concentrations are below the natural background levels and therefore no restoration in the Lower Chinle aquifer is needed relative to these constituents.

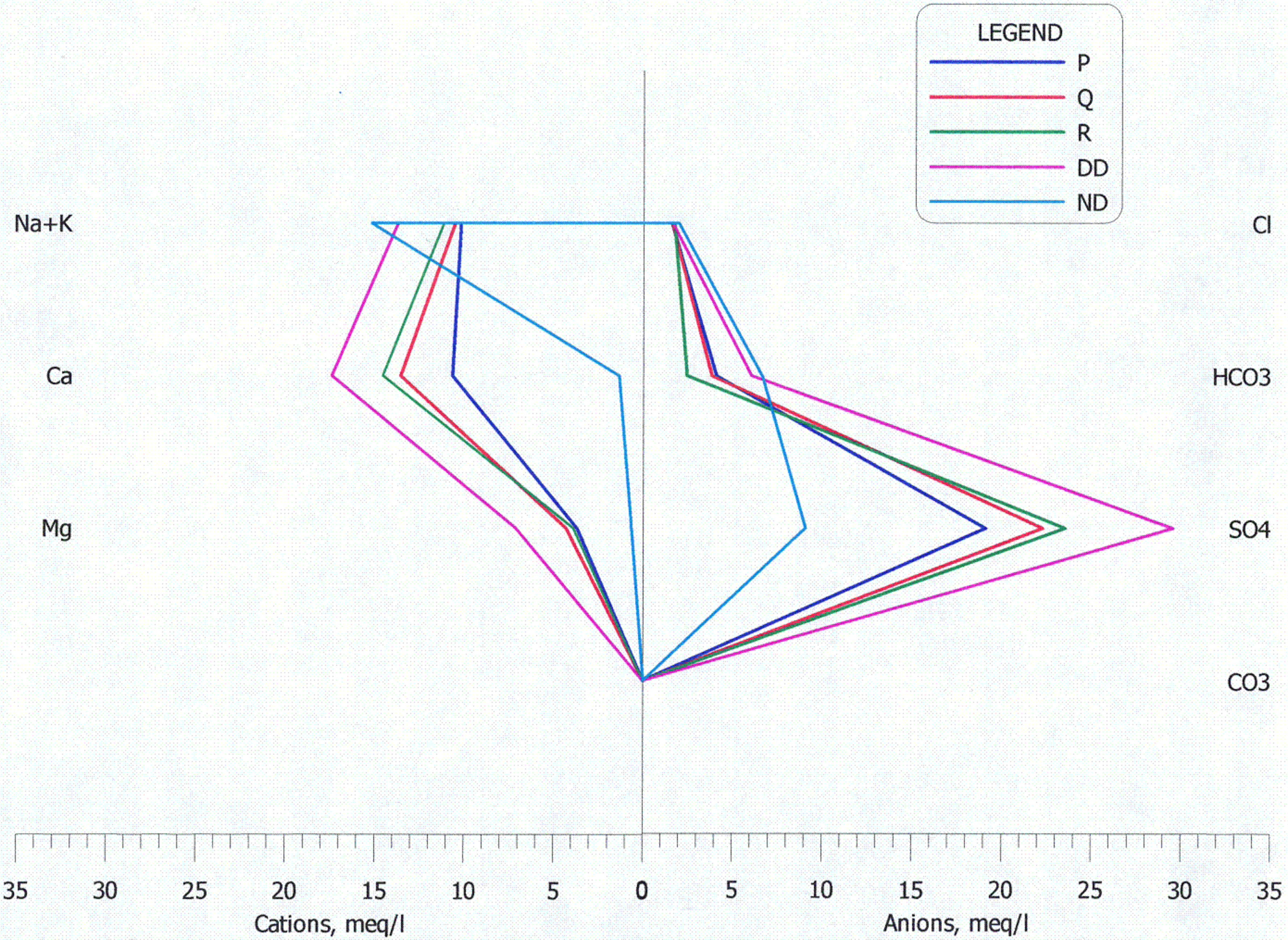


FIGURE 6-1. STIFF DIAGRAM COMPARISON FOR UPGRADIENT ALLUVIAL WATER QUALITY.

C01

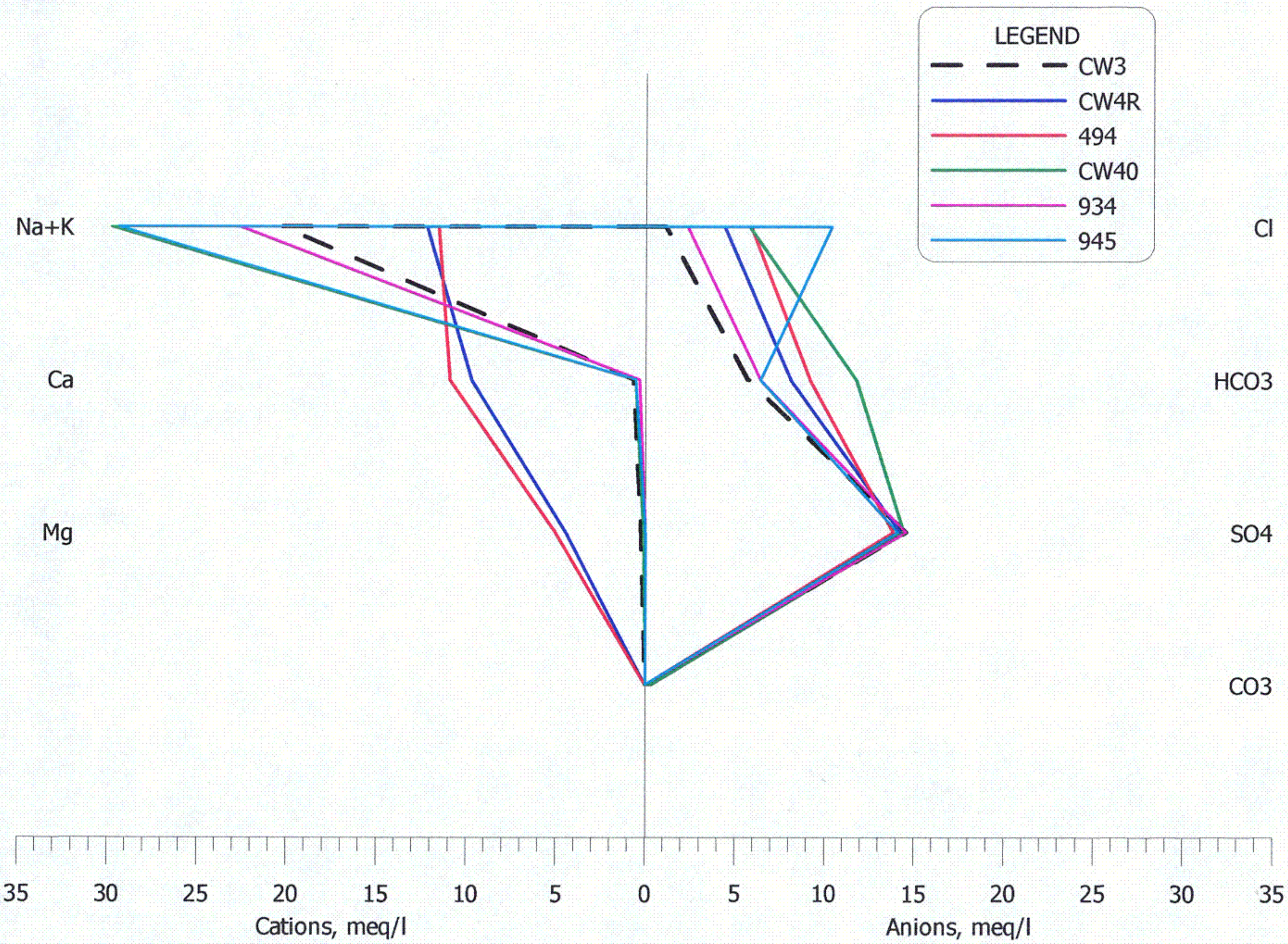


FIGURE 6-2. STIFF DIAGRAM COMPARISON FOR UPPER CHINLE WATER QUALITY.

C02

BACKGROUND WATER QUALITY

Well	Ca	Na	HCO3	Cl
BACKGROUND				
DD	349	312	369	58
ND	31	381	376	67
P	238	239	243	54
P1	267	248	244	52
P2	260	240	236	54
P3	274	265	237	60
P4	202	234	188	47
Q	272	238	234	57
R	271	258	149	60
FAR UPGRADIENT				
914	120	314	51	88
916	6	130	252	27
920	416	233	228	59
921	367	301	232	69
922	3	385	591	73
950	65	467	276	136

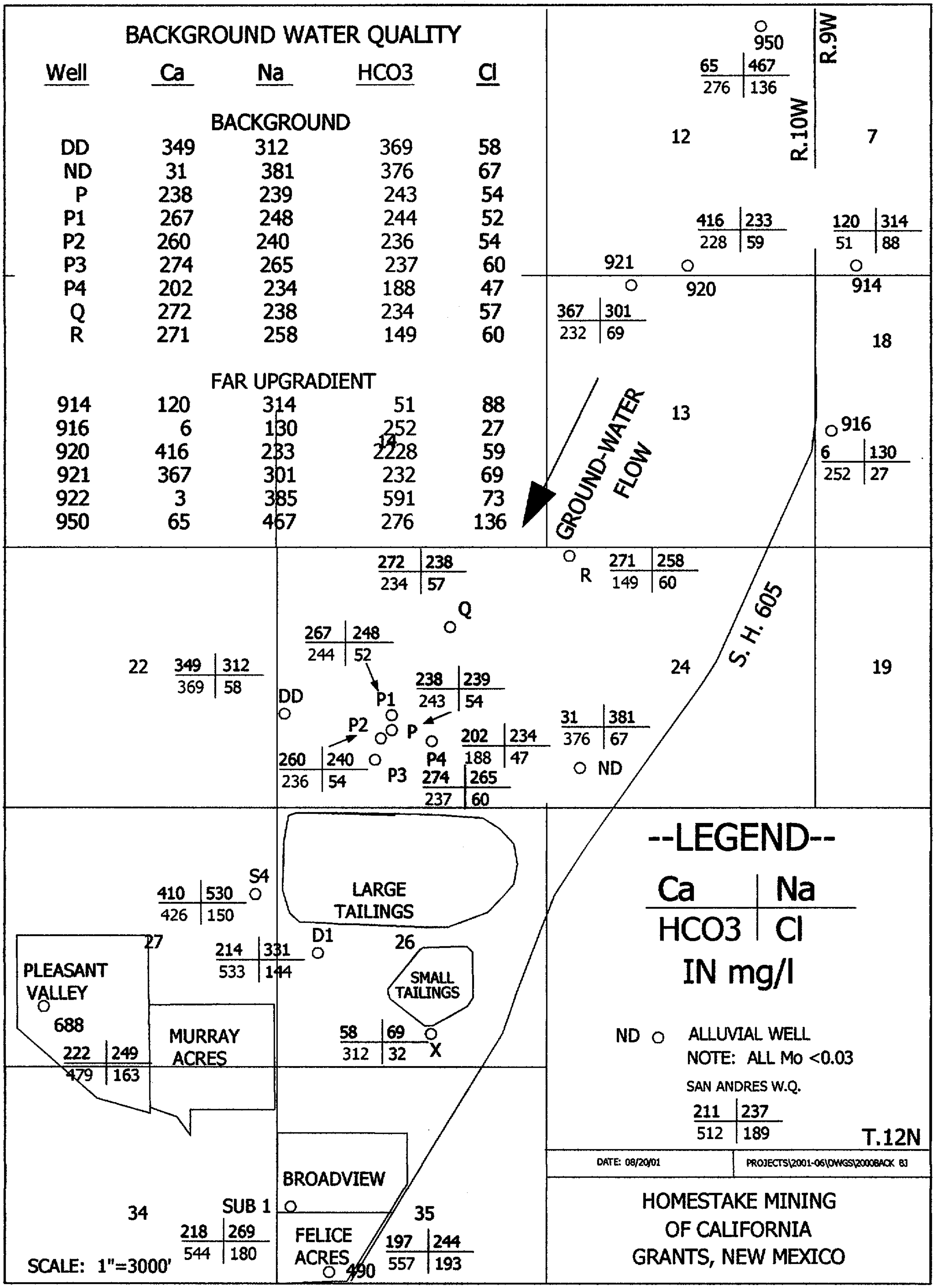
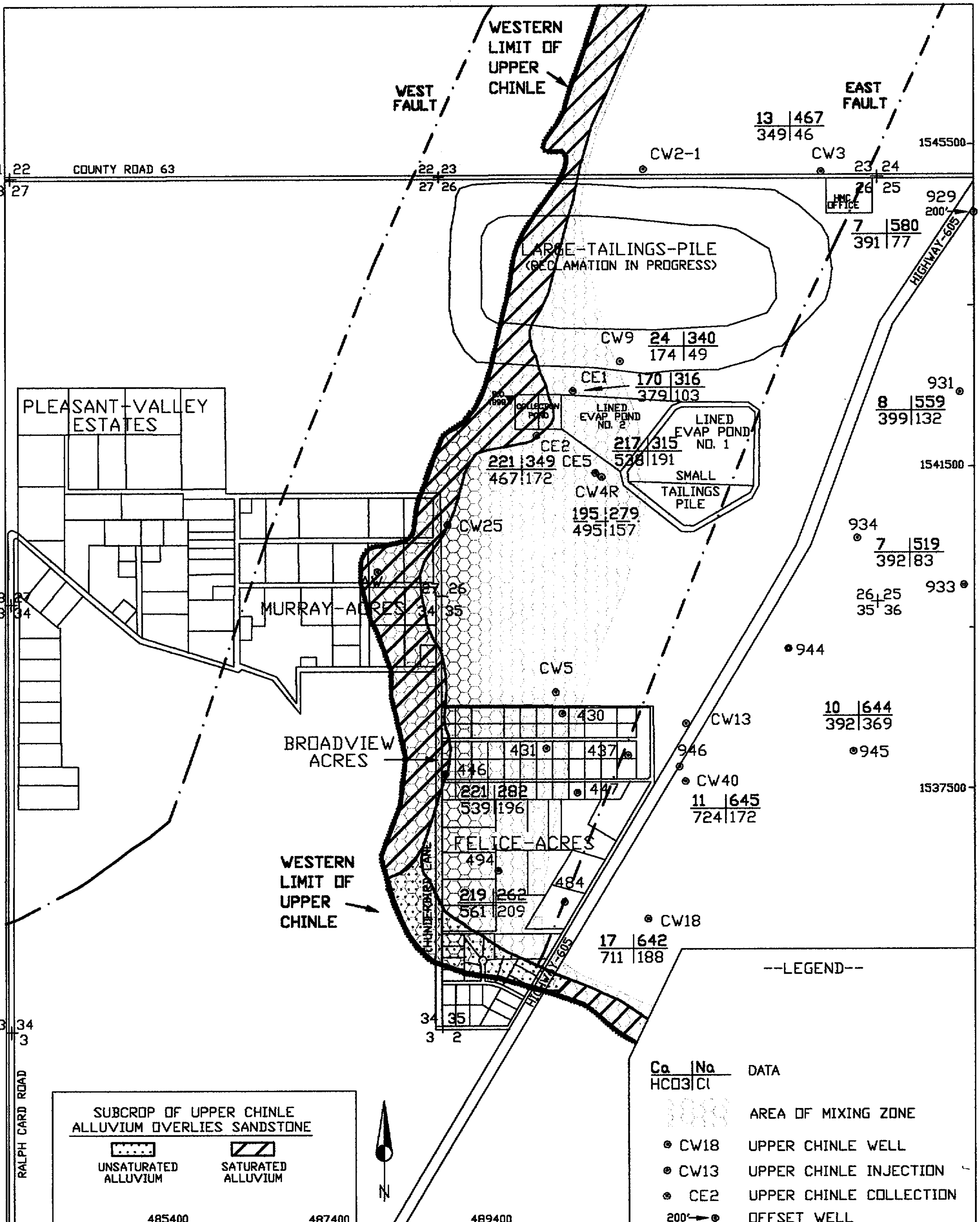


FIGURE 6-3. Ca, Na, HCO3 AND Cl CONCENTRATION COMPARSIONS FOR THE BACKGROUND ALLUVIAL WELLS



SCALE: 1"=1600' | HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W | DATE: 12/07/01

FIGURE 6-4. Ca, Na, HCO3 and Cl CONCENTRATION COMPARSIONS FOR THE UPPER CHINLE AQUIFER, IN mg/l

D\R13\HMC\UP1600

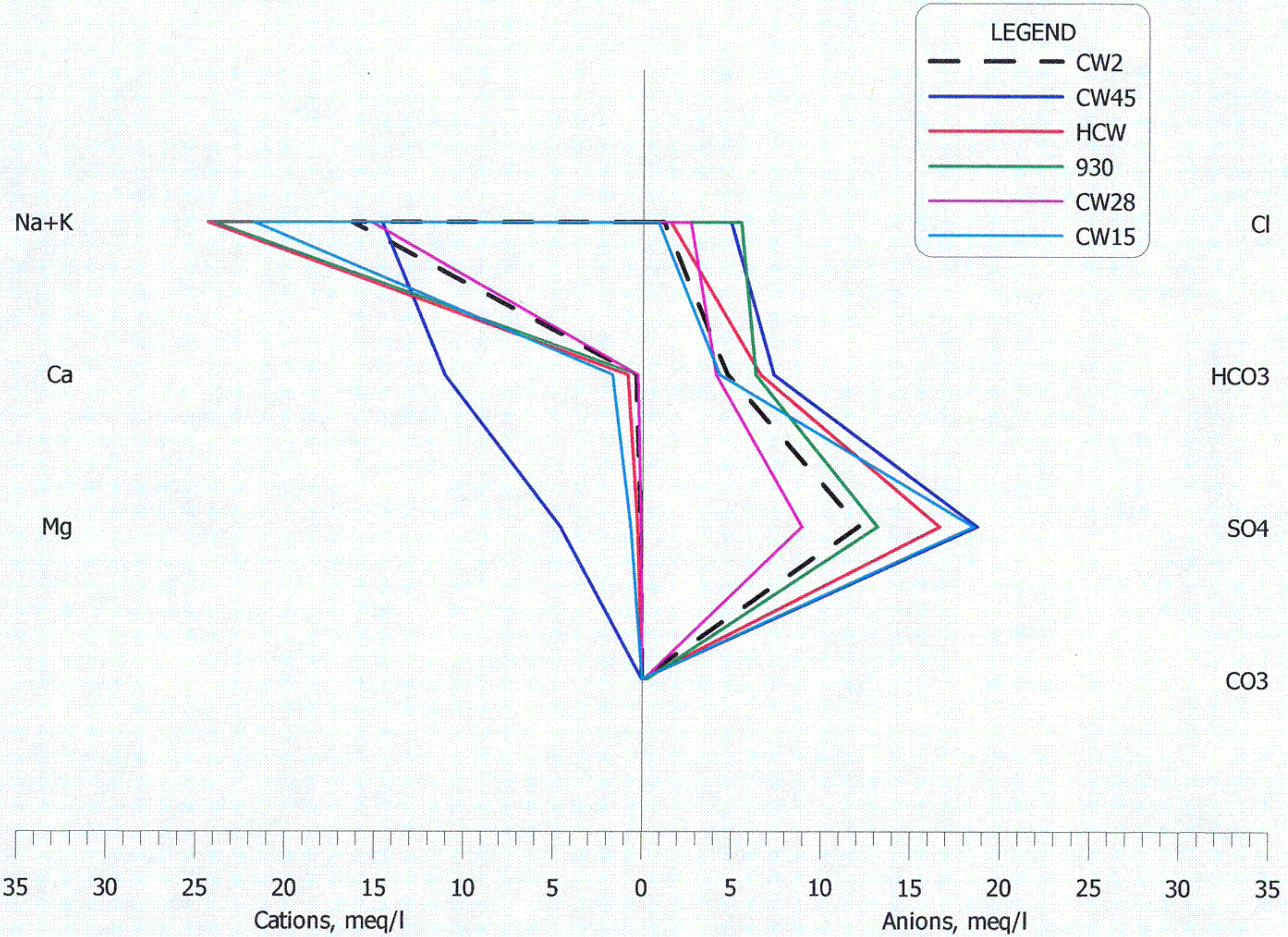


FIGURE 6-5. STIFF DIAGRAM COMPARISON FOR MIDDLE CHINLE WATER QUALITY EAST OF WEST FAULT.

C03

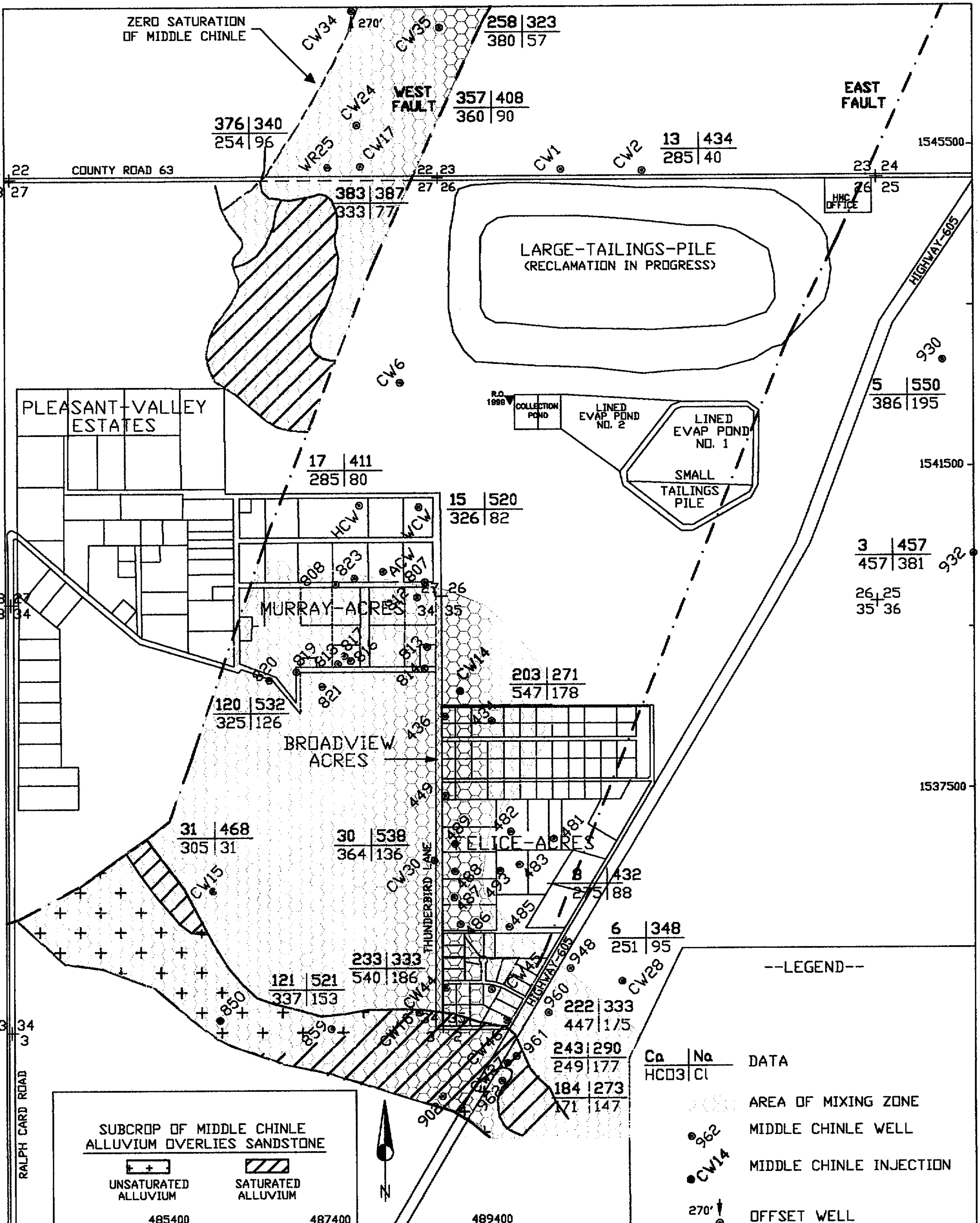


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FIGURE 6-6. Ca, Na, HCO3 and Cl CONCENTRATION COMPARSIONS FOR THE MIDDLE CHINLE AQUIFER, IN mg/l

D\R13\HMC\MID1600 th

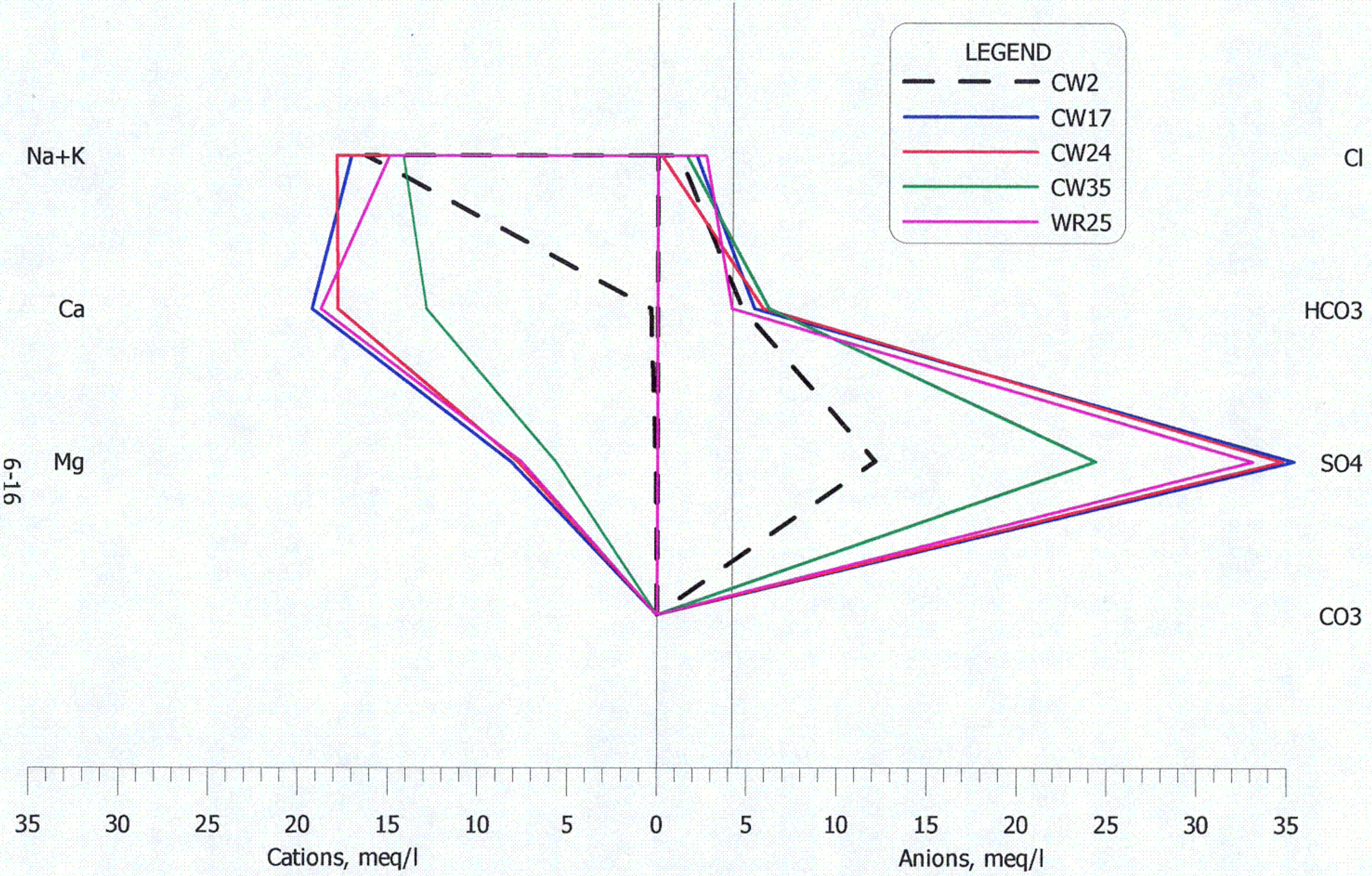

FIGURE 6-7. STIFF DIAGRAM COMPARISON FOR MIDDLE CHINLE WATER QUALITY WEST OF WEST FAULT.

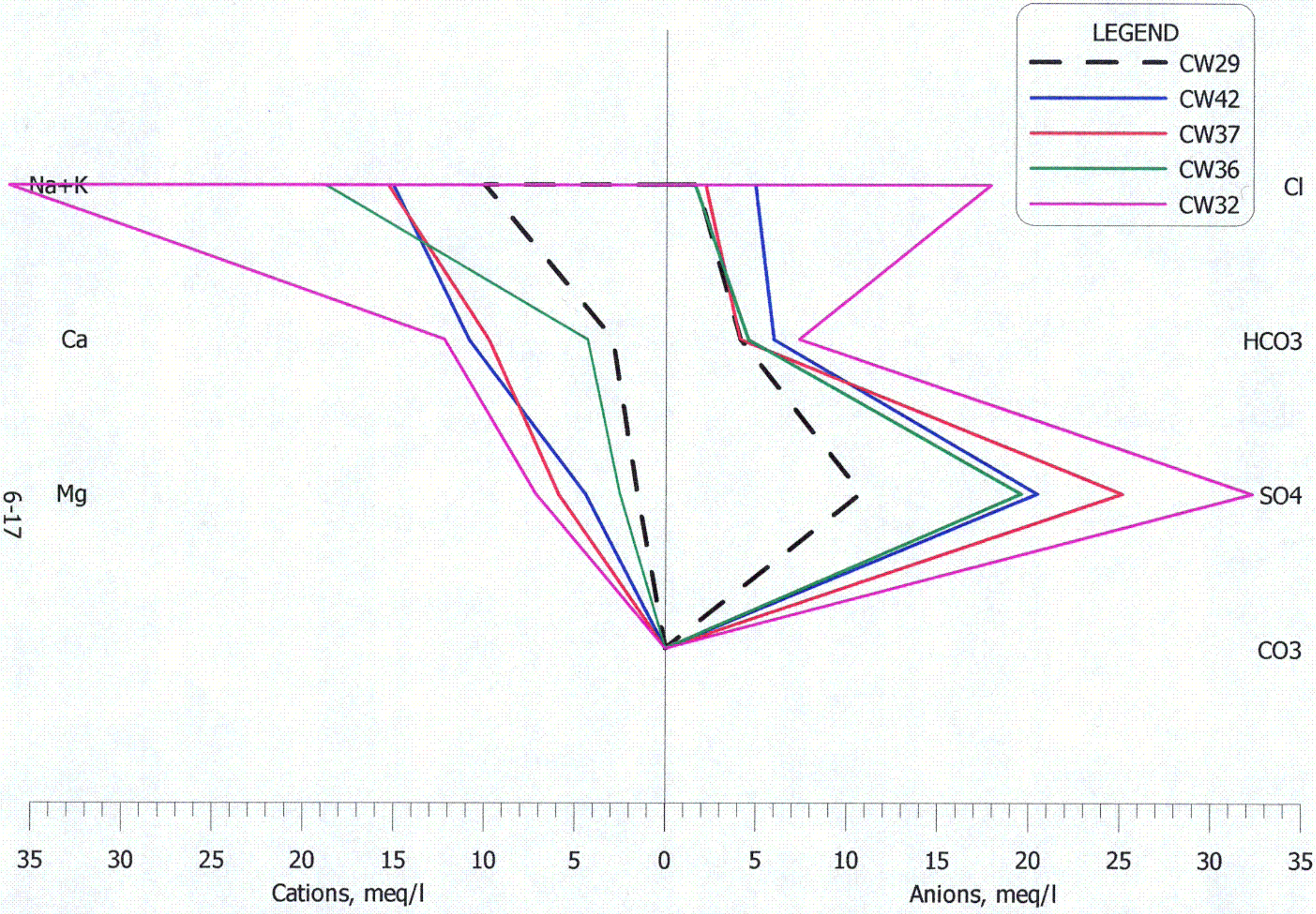

FIGURE 6-8. STIFF DIAGRAM COMPARISON FOR LOWER CHINLE WATER QUALITY.

C05

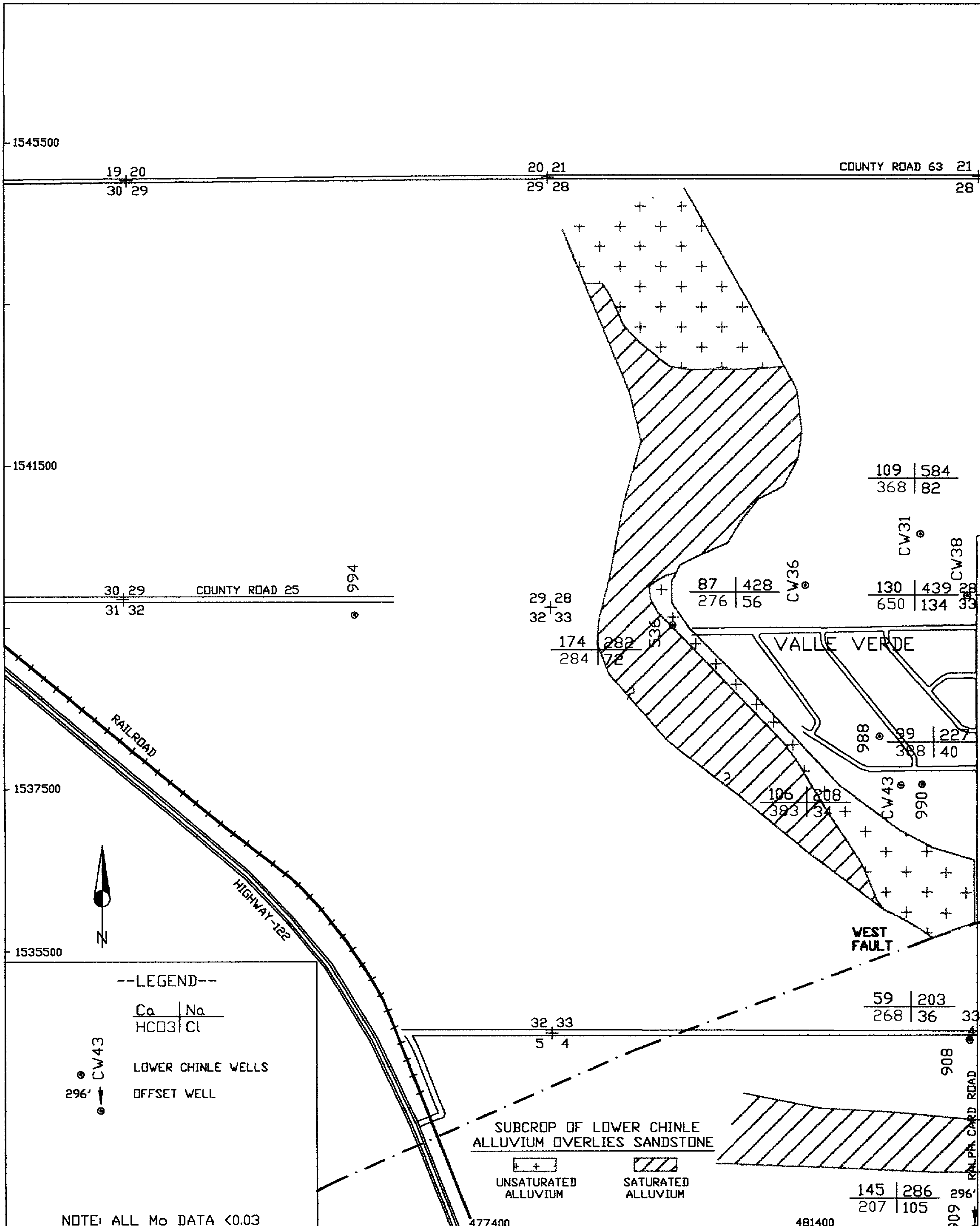

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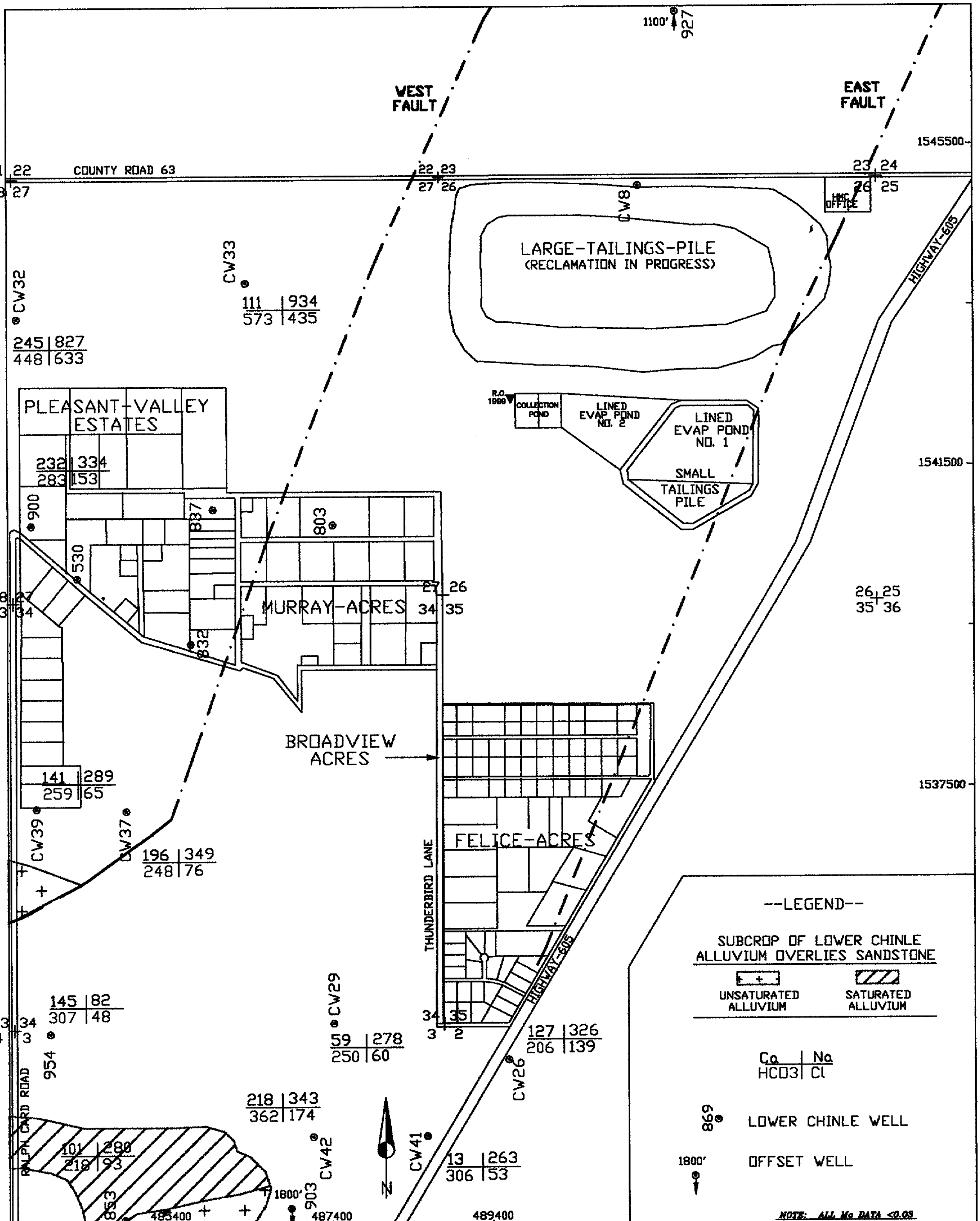
FIGURE 6-9A. Ca, Na, HCO3 AND Cl CONCENTRATION COMPARISONS FOR THE LOWER CHINLE AQUIFER, (WEST AREA), IN mg/l

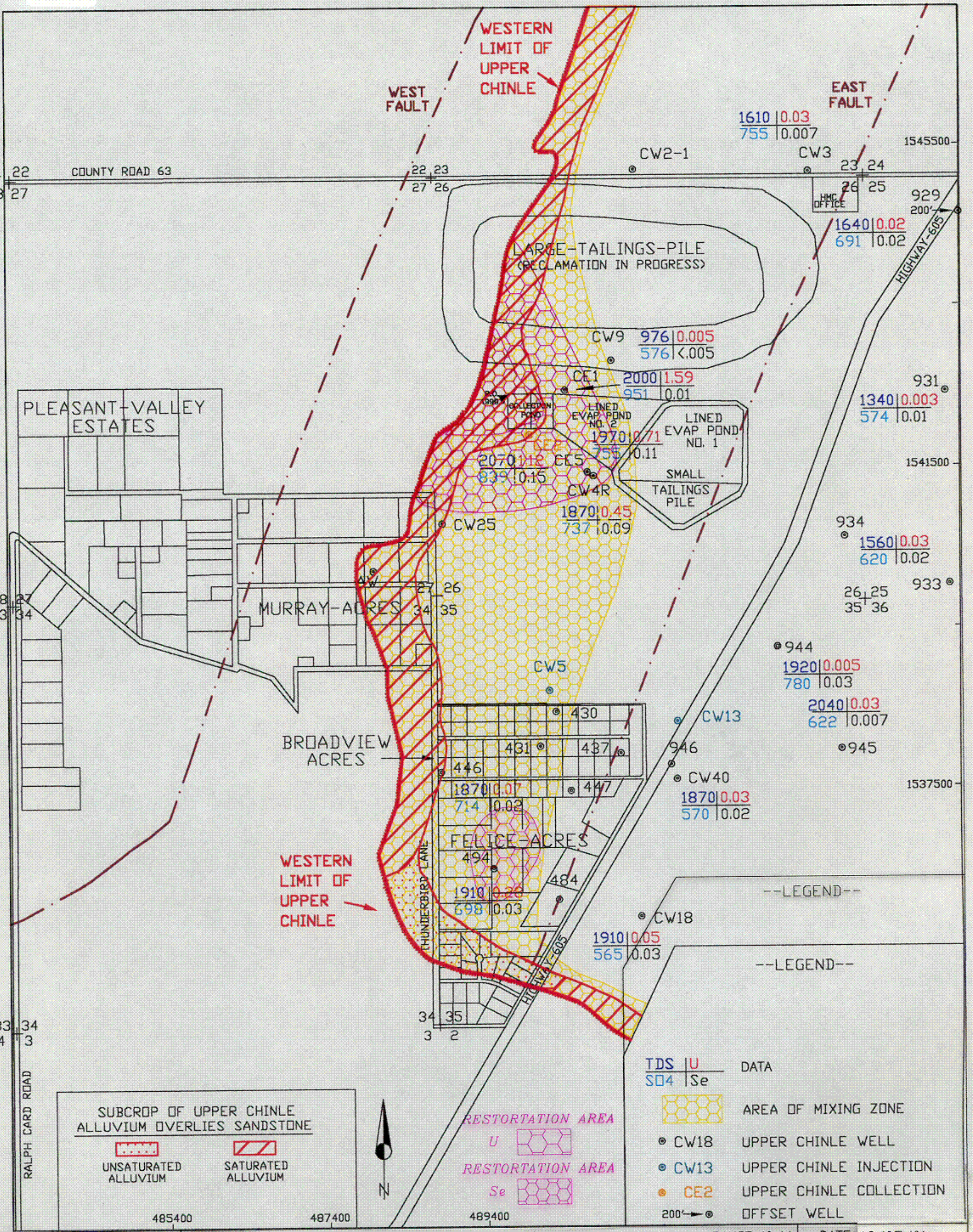
D:\R13\HMC\LOW1600 lh



SCALE: 1"=1600'	HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W	DATE: 12/09/01

FIGURE 6-9B. Ca, Na, HCO3 AND Cl CONCENTRATION COMPARSIONS FOR THE LOWER CHINLE AQUIFER, IN mg/l

D:\R13\HMC\LOW1600 Ch

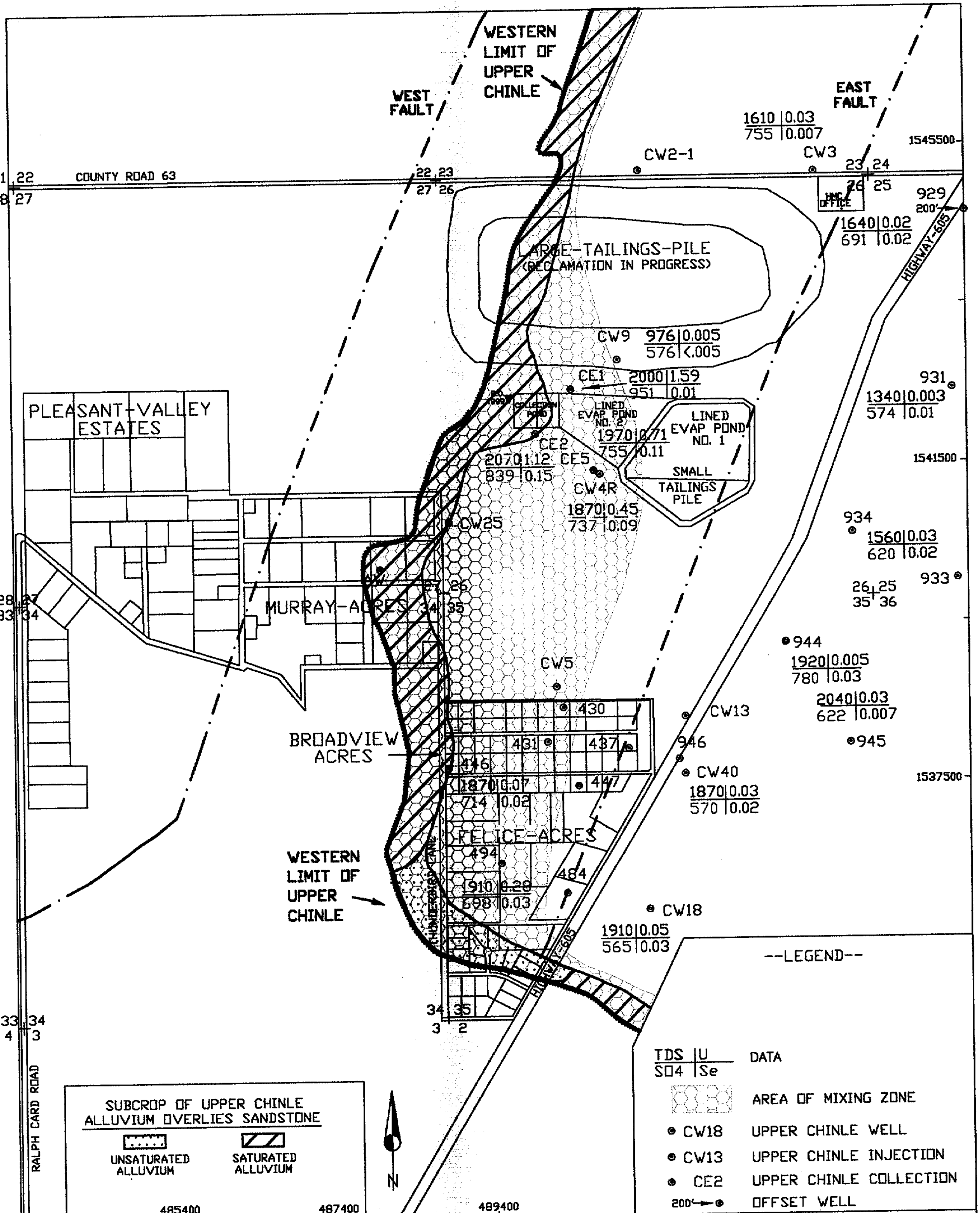


SCALE: 1"=1600' | HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W | DATE: 12/07/01

FIGURE 6-10A. U AND Se RESTORATION AREAS FOR UPPER CHINLE, OVERLAY

D:\R13\HMC\OVERLAY Uh

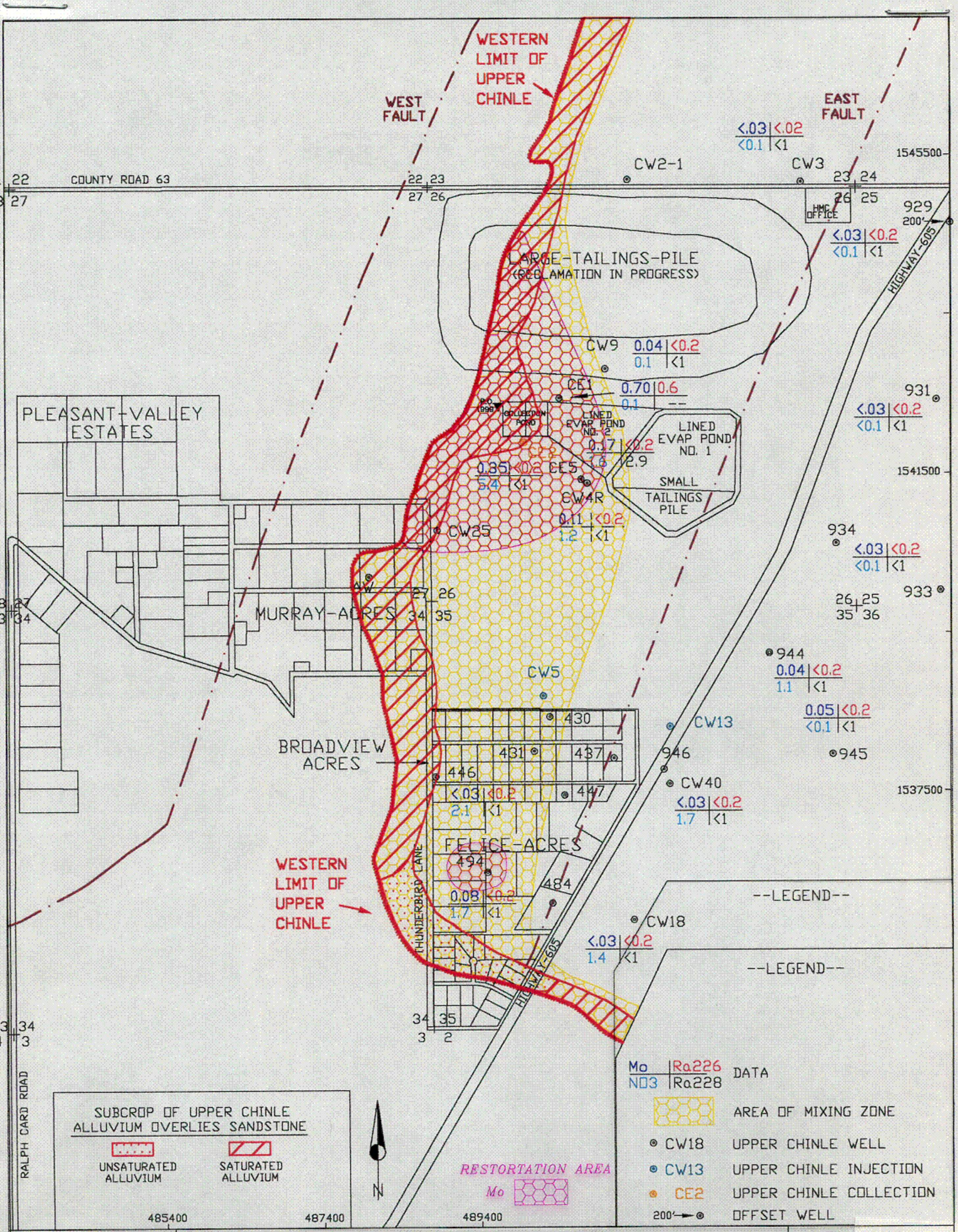
C06



SCALE: 1"=1600' | HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W | DATE: 12/07/01

FIGURE 6-10B. TDS, SO4, U AND Se, CONCENTRATION COMPARSIONS FOR THE UPPER CHINLE AQUIFER, IN mg/l

D\R13\HMC\UP1600

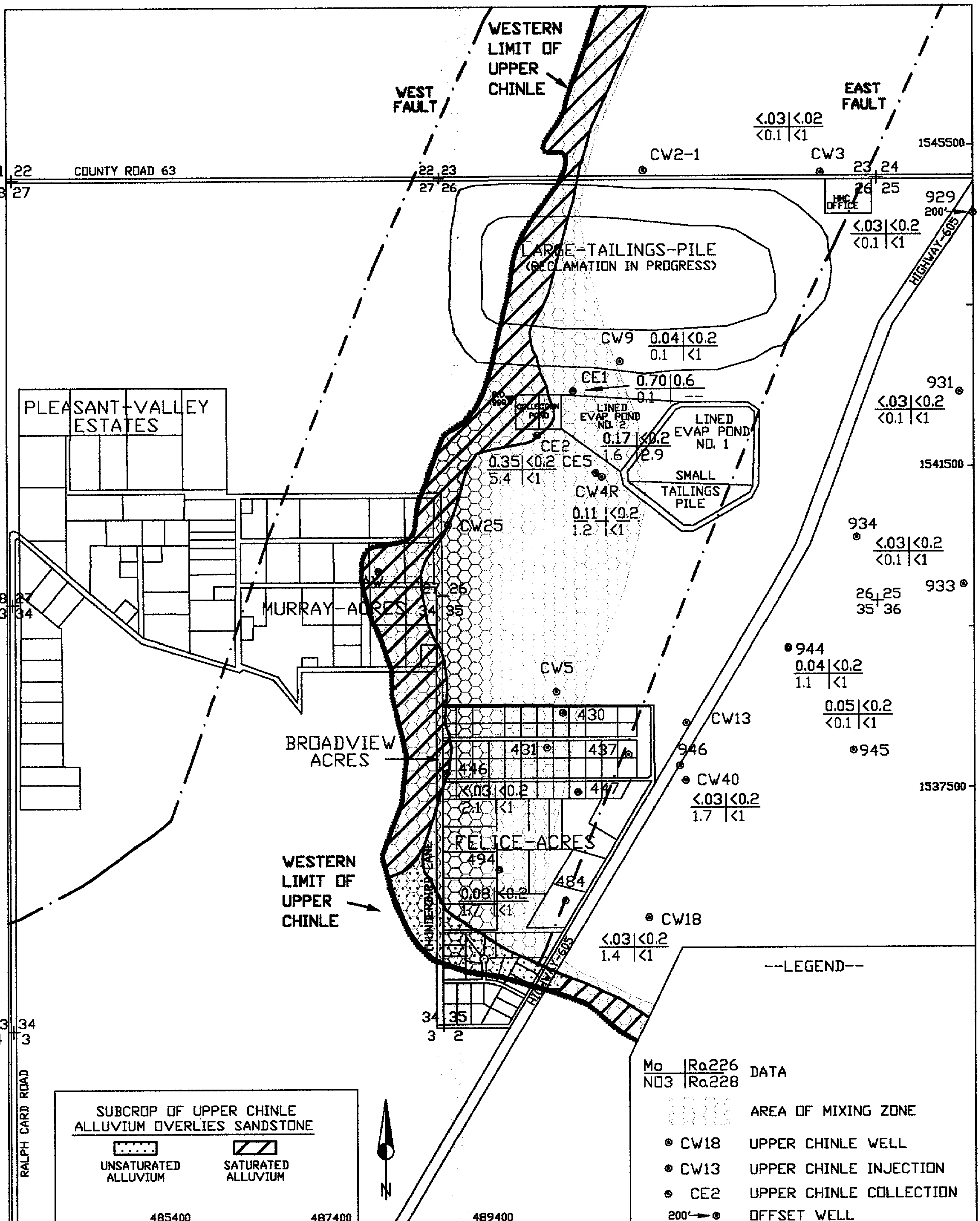


SCALE: 1"=1600' | HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W | DATE: 12/07/01

FIGURE 6-11A. Mo RESTORATION AREA FOR UPPER CHINLE, OVERLAY

D:\R13\HMC\OVERLAY lh

C07



SCALE: 1"=1600' | HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W | DATE: 12/07/01

FIGURE 6-11B. Mo, NO3, Ra226 AND Ra228 CONCENTRATION COMPARSIONS FOR THE UPPER CHINLE AQUIFER, IN mg/l, except for radium in pCi/l

D\R13\HMC\UP1600

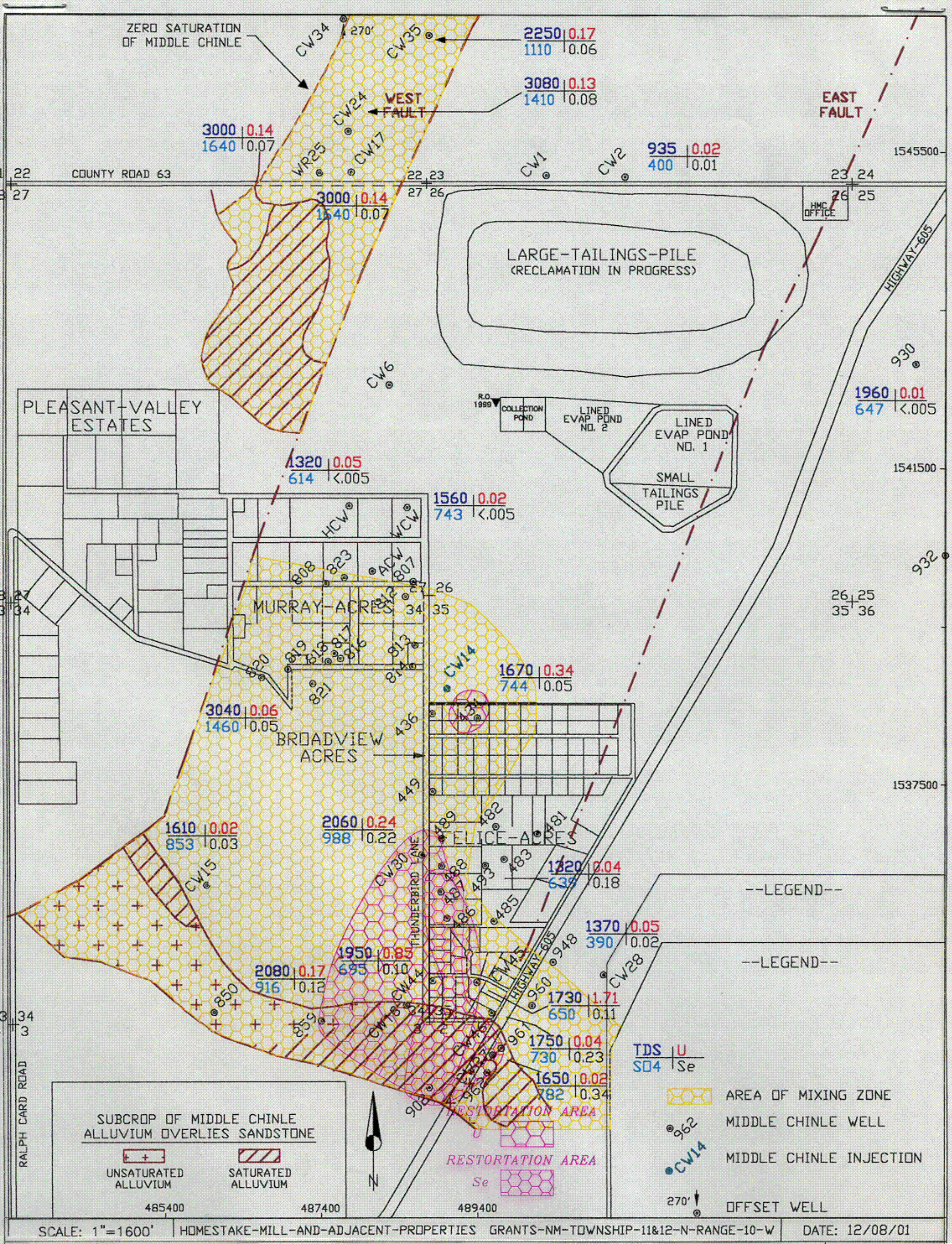
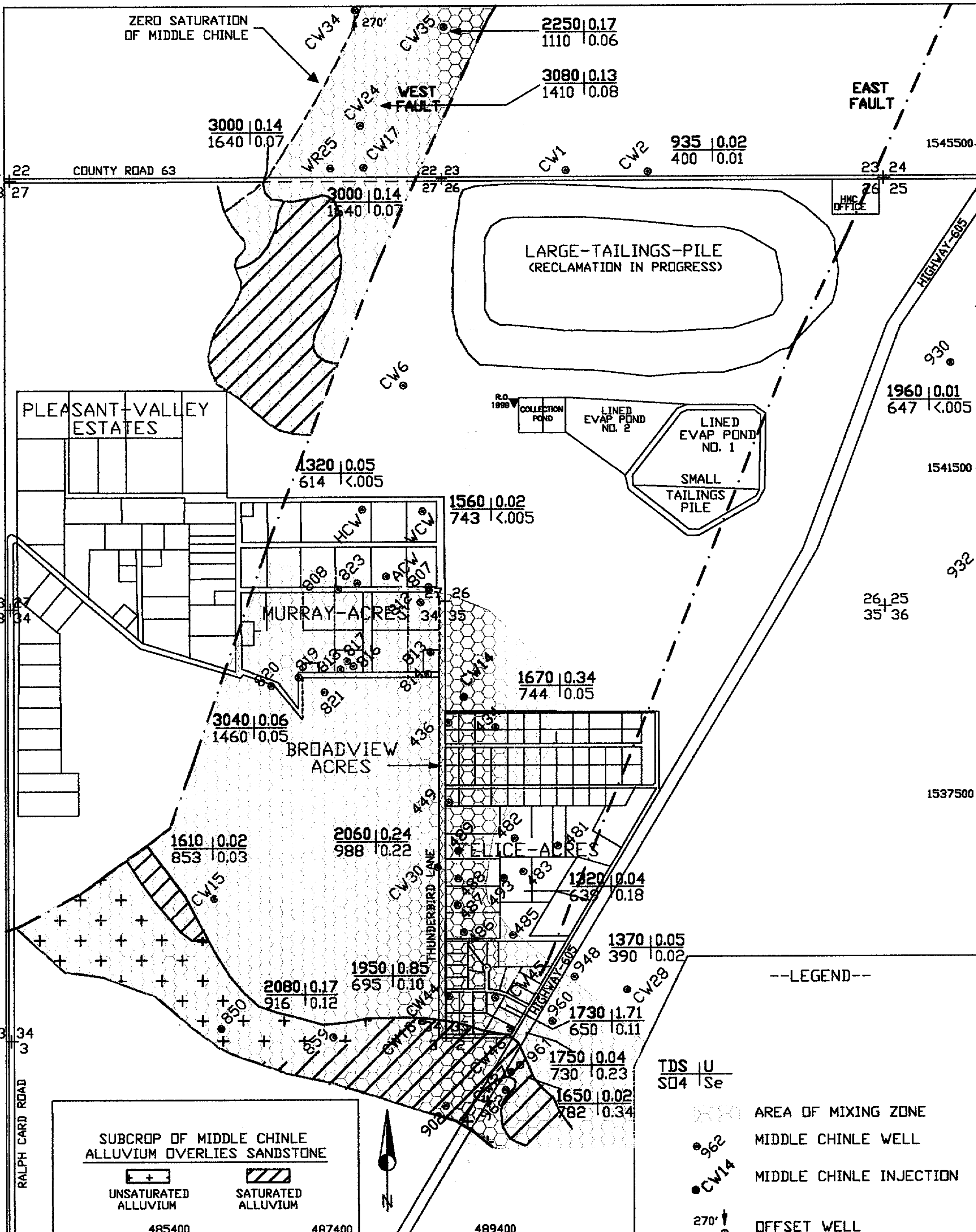


FIGURE 6-12A. U AND Se RESTORATION AREAS FOR THE MIDDLE CHINLE, OVERLAY

D:\R13\HMC\OVERLAY th

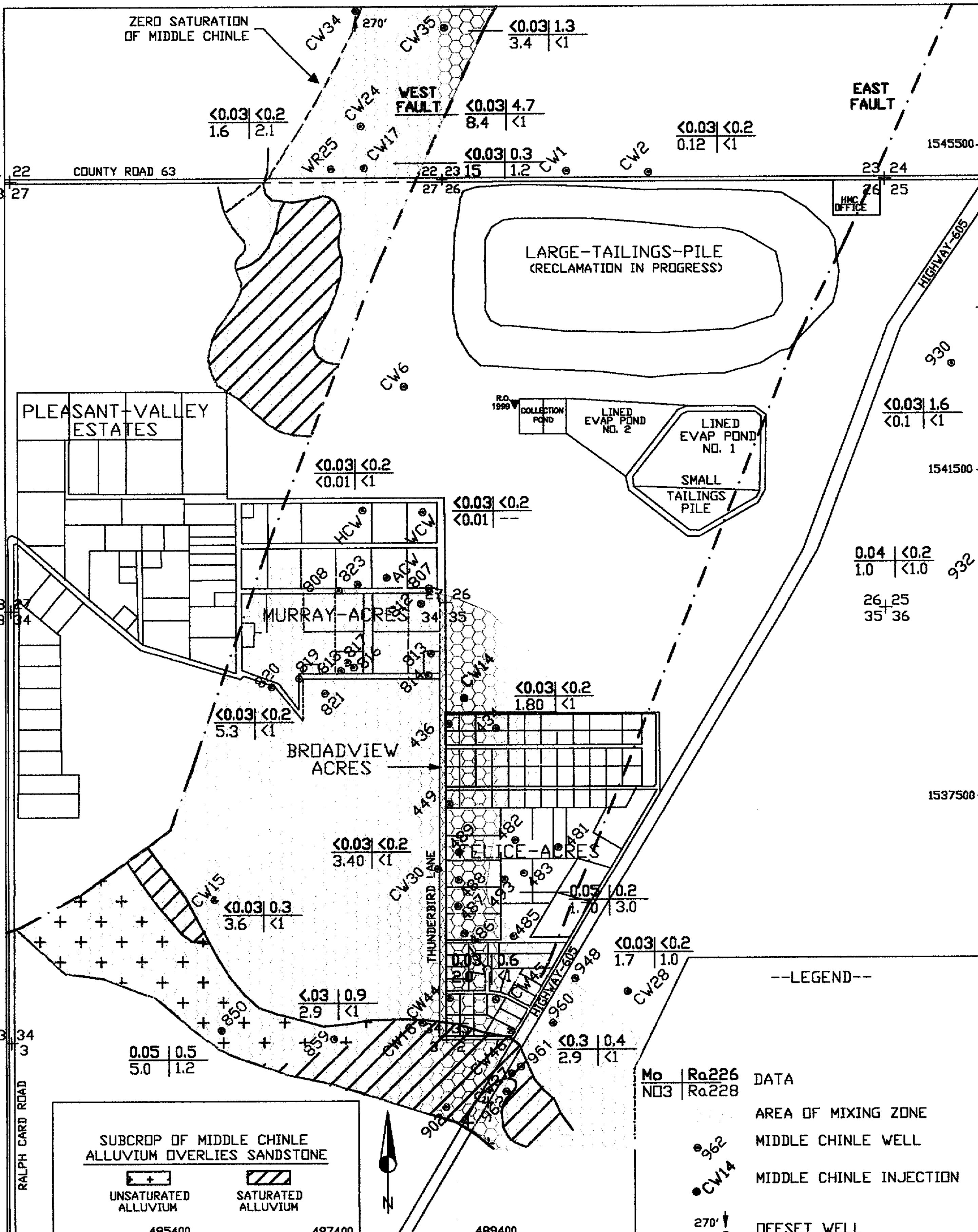
C08



SCALE: 1"=1600'	HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W	DATE: 12/08/01

FIGURE 6-12B. TDS, SO4, U AND Se CONCENTRATION COMPARISONS FOR THE MIDDLE CHINLE AQUIFER, IN mg/l

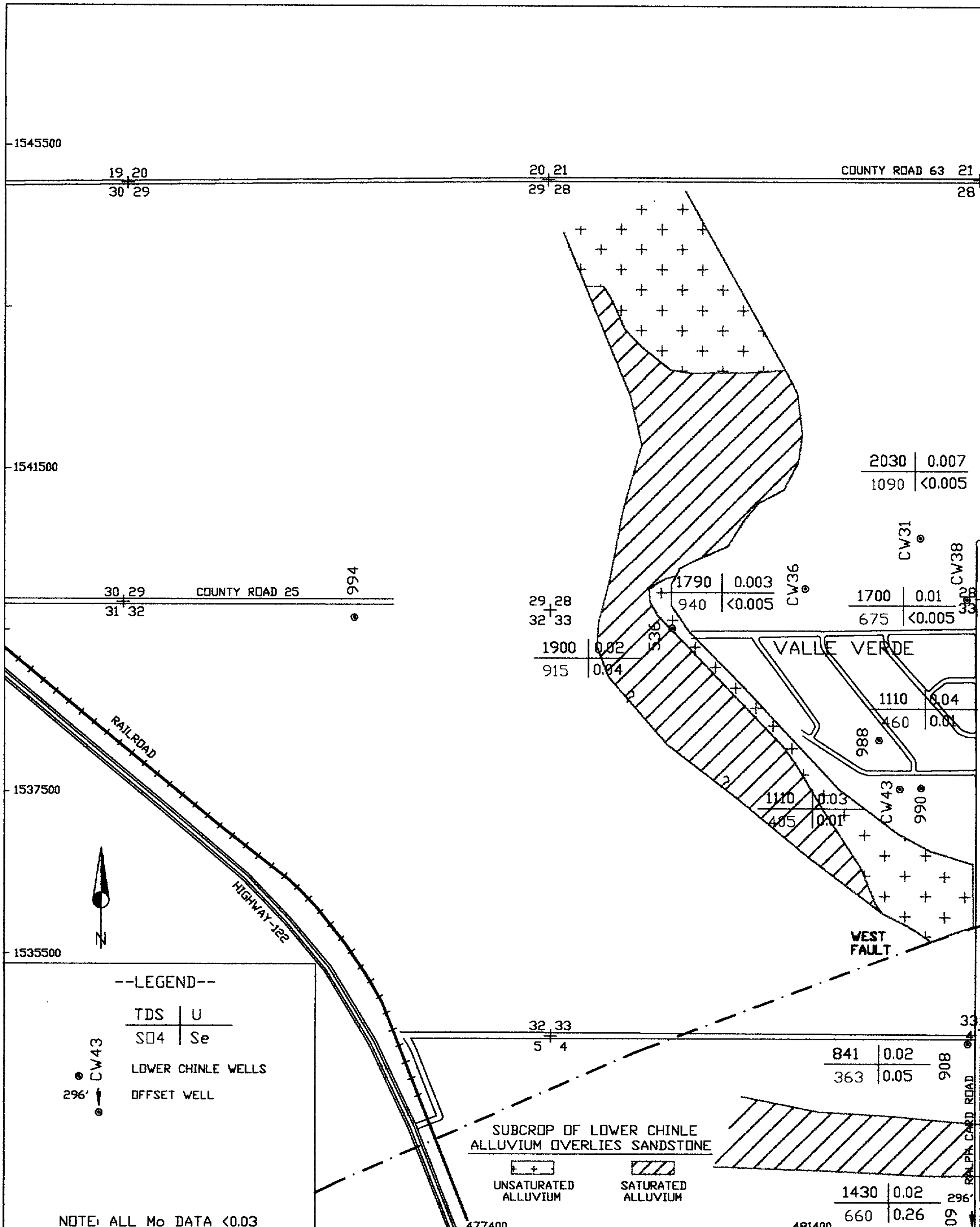
D\R13\HMC\MID1600 lh



SCALE: 1"=1600'	HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W	DATE: 12/08/01

FIGURE 6-13. Mo, NO3, Ra226 AND Ra228 CONCENTRATION COMPARISONS FOR THE MIDDLE CHINLE AQUIFER, IN mg/l, except for radium in pCi/l

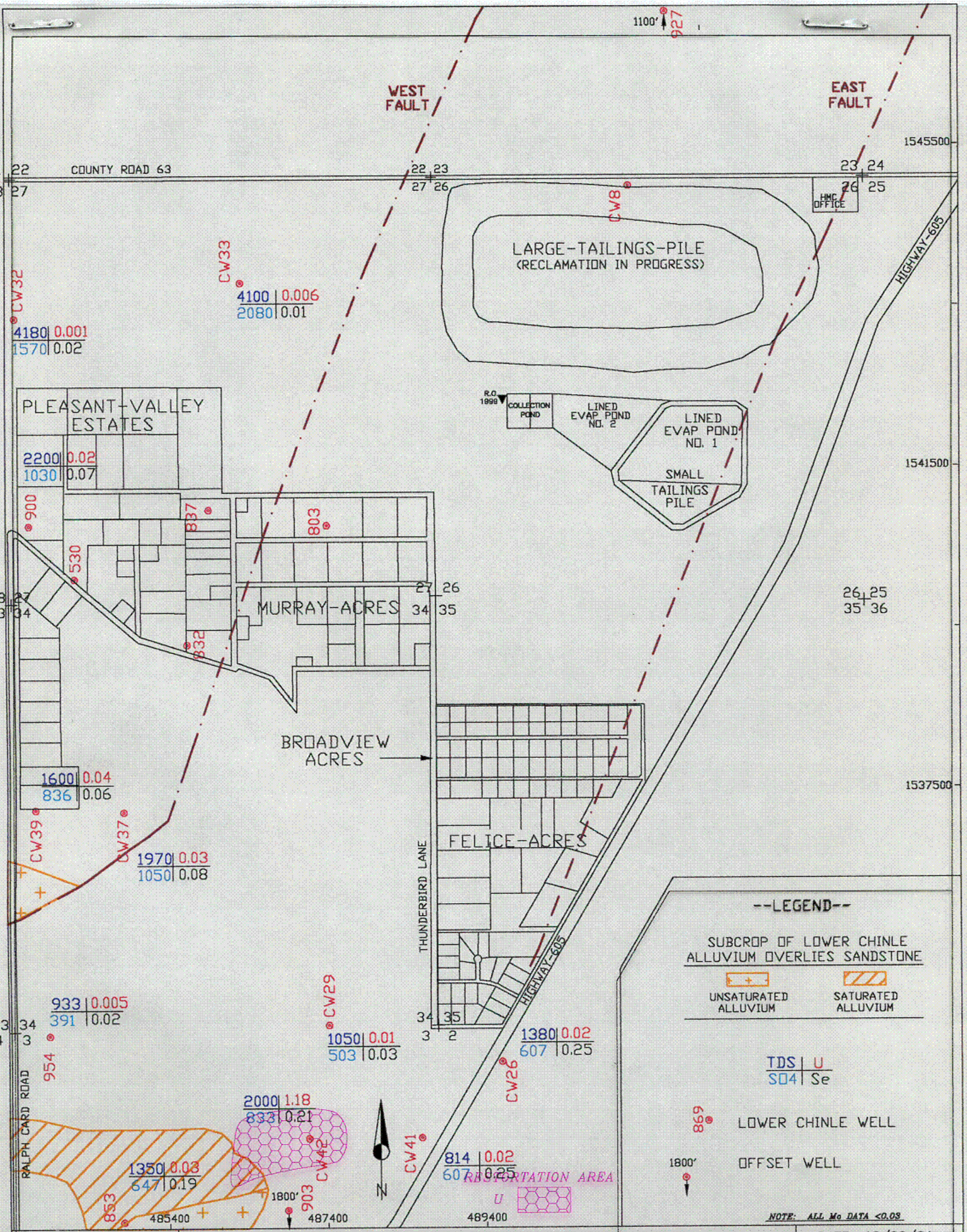
D\R13\HMC\MID1600



SCALE: 1"=1600'	HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W	DATE: 12/09/01

FIGURE 6-14A. TDS, SO4, U AND Se CONCENTRATION COMPARISONS FOR THE LOWER CHINLE AQUIFER (WEST AREA), IN mg/l

D:\R13\HMC\LOW1600 th

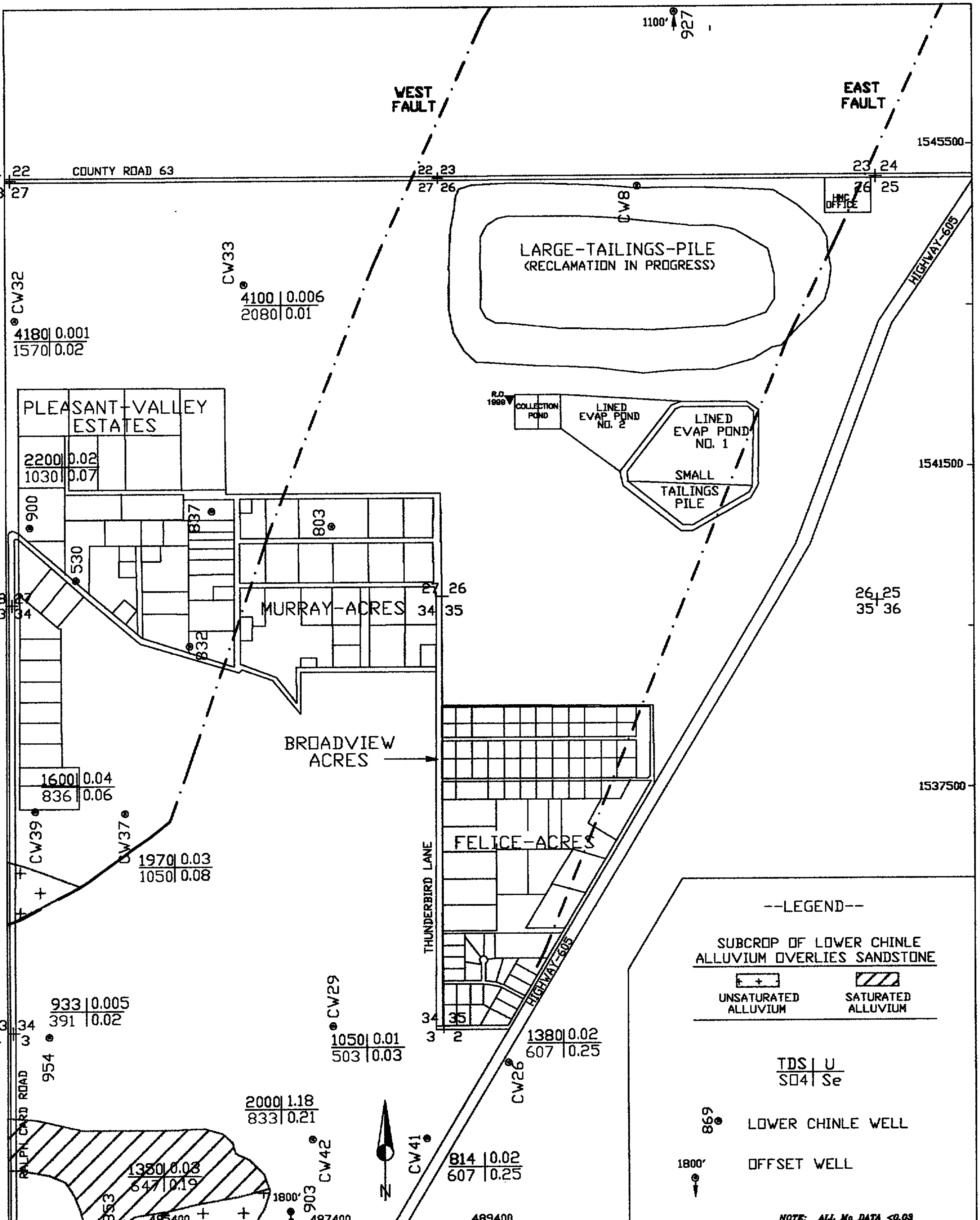


SCALE: 1"=1600' | HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W | DATE: 12/09/01

FIGURE 6-14B. U RESTORATION AREA FOR THE LOWER CHINLE, OVERLAY

D:\R13\HMC\OVERLAY

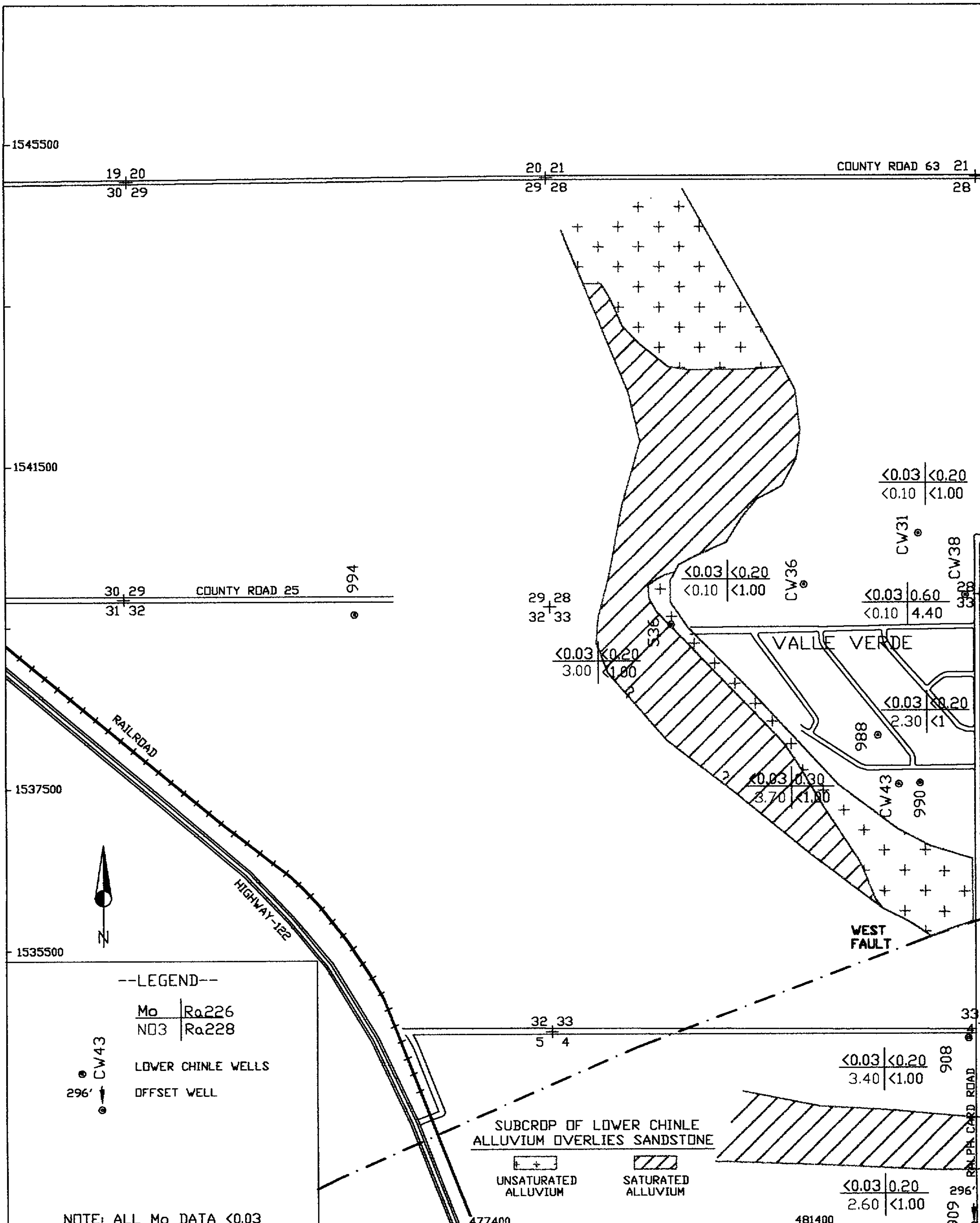
C09



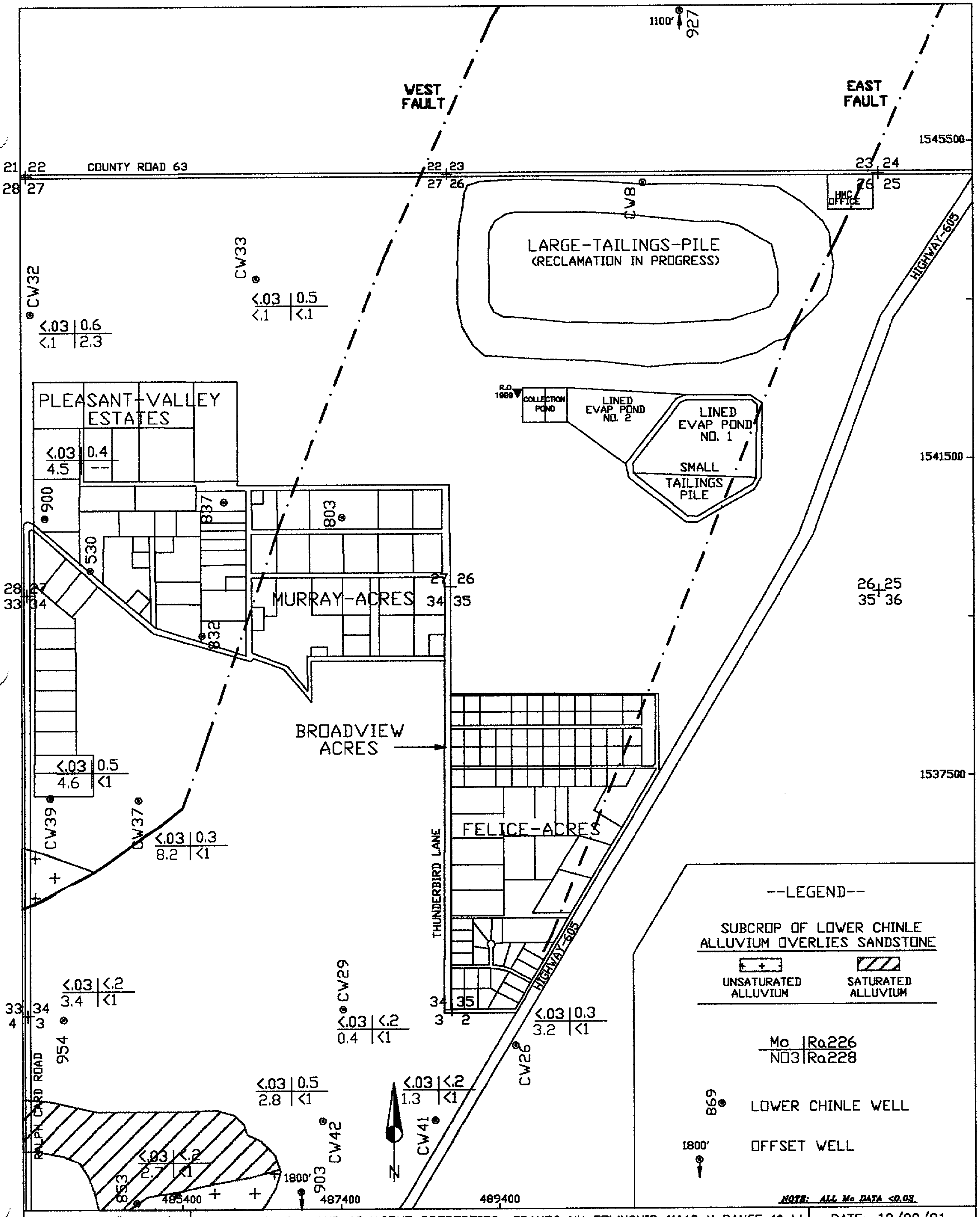
SCALE: 1"=1600'	HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W	DATE: 12/09/01

FIGURE 6-14C. TDS, SO4, U AND Se CONCENTRATION COMPARSIONS FOR THE LOWER CHINLE AQUIFER, IN mg/l

D:\R13\HMC\LOW1600 th



SCALE: 1"=1600'	HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W	DATE: 12/09/01
	FIGURE 6-15A. Mo, NO3, Ra226 AND Ra228 CONCENTRATION COMPARISONS FOR THE LOWER CHINLE AQUIFER (WEST AREA), IN mg/l, except for radium in pCi/l.	D:\R13\HMC\LOW1600 IN
		page 6-30



SCALE: 1"=1600' | HOMESTAKE-MILL-AND-ADJACENT-PROPERTIES GRANTS-NM-TOWNSHIP-11&12-N-RANGE-10-W | DATE: 12/09/01

FIGURE 6-15B. Mo, NO3, Ra226 AND Ra228 CONCENTRATION COMPARSIONS FOR THE LOWER CHINLE AQUIFER, IN mg/l, except for radium in pCi/l

D:\R13\HMC\LOW1600

7.0 REFERENCES

Environmental Restoration Group, 1999a, Statistical Evaluation of Alluvial Groundwater Quality Upgradient of the Homestake Site near Grants, NM, Molybdenum, Selenium and Uranium, Consulting Report for Homestake Mining Company, Grants, New Mexico.

Environmental Restoration Group, 1999b, Statistical Evaluation of Alluvial Groundwater Quality Upgradient of the Homestake Site near Grants, NM, Nitrate, Sulfate and Total Dissolved Solids, Consulting Report for Homestake Mining Company, Grants, New Mexico.

STATISTICAL EVALUATION OF ALLUVIAL GROUNDWATER QUALITY UPGRADIENT OF THE HOMESTAKE SITE NEAR GRANTS, NM

CHLORIDE
NITRATE
SULFATE
TOTAL DISSOLVED SOLIDS

Prepared for:

Homestake Site
Grants, NM

Prepared by:

Environmental Restoration Group, Inc.
12809 Arroyo de Vista NE
Albuquerque, NM 87111

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EXCUTIVE SUMMARY

Chloride, nitrate, sulfate, and total dissolved solids (TDS) are present in variable concentrations in alluvial groundwater upgradient of the Homestake site, located near Grants, New Mexico. Although none of these constituents are expected to be augmented as groundwater passes under the site, the state of New Mexico has established concentration limits for these constituents in groundwater. The purpose of this report is to statistically characterize upgradient concentrations of chloride, nitrate, sulfate, and TDS in the alluvial aquifer and to demonstrate that much of the groundwater upgradient of the site exceeds the state standards for all constituents except chloride and finally to propose site-specific groundwater limits to replace the state standards for evaluation of potential site impacts to groundwater downgradient of the site.

Samples were collected at near and far upgradient wells from 1976 to 1998. Fifteen wells provided the upgradient well data, nine are near upgradient wells and six are far upgradient wells. Close examination of the groundwater database provided justification for elimination of select samples. Samples were eliminated based upon extreme concentrations when compared to replicate samples. Only a minor percentage of samples were eliminated; the completeness of the data set was not compromised.

Statistical analyses were preformed on the individual data sets (constituent specific) to determine distribution, statistical similarities between near and far upgradient data, and upper tolerance limits. Results of the distribution analysis indicated that all data sets were nonparametrically distributed. The nitrate, sulfate and TDS near and far upgradient background data sets were shown to be statistically similar and so analyses on the combined data set was performed.

The 95th percentile was calculated as the non-parametric upper tolerance limit for all analyzed data sets. The 95th percentile should be used to compare to downgradient well concentrations to determine if "above expected background concentrations" exist. If the downgradient concentration is greater than the 95th percentile, contamination may be indicated. However, it should be noted that since the 95th percentile was calculated as the upper tolerance limit, statistically 5% of the time one would expect the upper tolerance limit to be exceeded. Because the nitrate, sulfate and TDS near and far upgradient data sets were statistically similar, the combined data set 95th percentile should be representative of upgradient background concentrations. Because the chloride near and far upgradient data sets were not statistically similar, it is advised to use the near upgradient 95th percentile for downgradient well concentration comparisons. A summary table of the parameter, data set, distribution, 95th percentile, range, arithmetic mean and sample number is provided as Table ES-1.

Table ES-1. Summary Table for Upgradient Wells, Statistical Analysis

Parameter	Data Set	Distribution	95th Percentile	Range	Arithmetic Mean	Sample #
Chloride	Near Upgradient	Nonparametric	71	21 to 116.63	52.2	336
	Far Upgradient	Nonparametric	112.1	21.9 to 116	70.27	47
Nitrate	Near Upgradient	Nonparametric	22.95	0.35 to 33.2	10.83	351
	Far Upgradient	Nonparametric	24.28	<0.05 to 26	10.98	47
	Combined	Nonparametric	23.28	<0.05 to 33.2	10.84	398
Sulfate	Near Upgradient	Nonparametric	1866.88	324 to 1975	1090.79	366
	Far Upgradient	Nonparametric	1655.7	43.3 to 1744	999.56	47
	Combined	Nonparametric	1848.8	43.3 to 1975	1080.41	413
TDS	Near Upgradient	Nonparametric	3060	954 to 4250	1923.02	331
	Far Upgradient	Nonparametric	2730.7	318 to 2930	1819.6	47
	Combined	Nonparametric	3053	318 to 4250	1910.16	378

R E P O RT

1.0 INTRODUCTION

Chloride, nitrate, sulfate, and total dissolved solids (TDS) are present in variable concentrations in alluvial groundwater upgradient of the Homestake site, located near Grants, New Mexico. Although none of these constituents are expected to be augmented as groundwater passes under the site, the state of New Mexico has established concentration limits for these constituents in groundwater. The purpose of this report is to statistically characterize upgradient concentrations of chloride, nitrate, sulfate, and TDS in the alluvial aquifer and to demonstrate that much of the groundwater upgradient of the site exceeds the state standards for all constituents except chloride and finally to propose site-specific groundwater limits to replace the state standards for evaluation of potential site impacts to groundwater downgradient of the site.

This report was prepared at the request of Homestake Mining Company. Homestake Mining Company provided the chemical analysis data, and George Hoffman from Hydro-Engineering, a contractor for the Homestake site, provided the well location map presented in this report as well as other valuable information, both printed and verbal, used in this assessment.

1.1 Monitor well network

Figure 1 shows the location of the fifteen upgradient monitor wells for which ground water quality data were provided. Alluvial wells DD, ND, P, P1, P2, P3, P4, Q, and R are located within approximately one mile of the site and are referred to in this report as near upgradient background wells, four of these wells (DD, P, Q, and R) have been sampled since 1976, data from well ND extends back to 1983, wells P1 and P2 have been sampled since 1992 and wells P3 and P4 were sampled for the first time in 1998. The sampling frequency varies by well and over time, but generally most of the near upgradient wells were sampled at least twice per year through 1998. These data were combined into a statistical set of data based upon geochemical similarities and knowledge of the completion interval (Hoffman 1999).

Data from six additional wells farther upgradient of the site were also provided for this analysis. Wells 914, 916, 920, 921, 922, and 950 are located approximately two to three miles upgradient of the Homestake site and are collectively referred to in this report as far upgradient background wells. In addition to being located farther from the site, these wells were not installed by Homestake. Because completion logs are not available (personal communication, G. Hoffman) it cannot be determined whether these wells access alluvial groundwater, water from a deeper water bearing unit, or some combination from both groundwater sources. These wells have been sampled less frequently than the near upgradient wells. These data were combined into a statistical data set based upon upgradient placement in relation to the Homestake site and lack of completion interval knowledge.

A statistical comparison analyses between well sets was performed and the two data sets were combined into a single data set when statistically defensible.

1.2 Data preparation

The database provided for analysis consisted of six fields describing, well identification number, sample date, measured parameter, laboratory identification where the sample was processed, remark code (qualifiers) and concentration (mg/L).

Examination of the database revealed isolated problems with individual data values. Three large outliers were removed based on replicate measurements and the range of all measurements for the well. A nitrate concentration of 61.1 mg/L for Well P collected on 4/15/81 was removed from the data set. The replicate measurement was 9.2 mg/L and the range for Well P was 0.35 mg/L to 22 mg/L. A nitrate concentration of 109 mg/L for Well R collected on 3/19/87 was also removed from the data set. The replicate measurement was 9.0 mg/L and the range for Well R was 4.6 mg/L to 23.8mg/L. Finally, a sulfate concentration of 1663 mg/L for Well R collected on 9/15/87 was removed from the data set. The replicate measurement was 816 mg/L and the range for Well R was 651.7 mg/L to 1226 mg/L. It should be noted that removal of maximum measurement outliers is conservative with respect to the calculation of the parametric or nonparametric upper tolerance limit. None of the removed data appears on any table in this report.

The laboratory code field entries in the database indicate that many of the water samples were analyzed on-site (lab code Homestake), with frequent verification analyses provided by independent laboratories. When the dates reported for the on-site and verification results differed by only one or two days, the data were assumed to represent the same sampling round and one of the dates was changed to agree with the other. The database also includes rare cases of what appear to be replicate analyses of a water sample by the same laboratory. Replicate measurements were removed and replaced by a single data value equal to their arithmetic average. Master data tables and corrected data tables are provided for each constituent so all changes to the original set of data can be tracked.

Multiple measurements of constituent concentrations made by different laboratories on split or replicate samples of a well can be expected to be correlated, which violates the assumption of independence required by most statistical procedures. Therefore, as a last step before processing, the on-site and any verification lab results for a sampling round were averaged together to produce one value for the concentration of a constituent in each well on that date. This process equates the number of data to the number of sampling rounds for a well, and should produce more stable data with less noise.

The data used for statistical evaluation are presented for each constituent in tabular form in the back of this report. Chloride data and associated statistical analyses are presented in Appendix A, nitrate in Appendix B, sulfate in Appendix C and TDS in Appendix D.

2.0 METHODS

2.1 Distribution Analyses

A distribution analysis was performed to determine if a particular data set was parametric or non-parametric. The data first were subjected to an *a priori* screen (Section 2.1.1). The number of non-detects was then evaluated for the data set (Section 2.1.2). If greater than 15% non-detects existed, the data set was considered non-parametric and the distribution analysis was concluded. If fewer than 15% non-detects existed, the data were subjected to five numerical and two graphical procedures to determine the distribution type. The numerical procedures included the coefficient of variation (Section 2.1.3), the Studentized range test (Section 2.1.4), the coefficient of skewness (Section 2.1.5), the Shapiro-Wilk Test of Normality if the sample size was less than or equal to 50 or the Shapiro-Francia test if the sample size was greater than 50 (Section 2.1.6), and Filliben's statistic (Section 2.1.7). The graphical procedures used were the histogram (Section 2.1.8) and the probability plot (Section 2.1.9). The results of the procedures were compared and the distribution was determined (Section 2.1.10). The T_n statistic was then calculated for the parametric data sets as a second screening mechanism for outliers (Section 2.1.11). If a data set contained fewer than 15% non-detects but failed the numerical and graphical procedures for a parametric distribution, the data set was often carried through to the T_n statistic procedure to determine if outliers were present. In some instances, outliers are identified and removed during the T_n statistic procedure causing a data set that had initially failed to pass the parametric numerical and graphical tests. If outliers were identified during the T_n statistical test, the outliers were removed and either the Shapiro-Wilk or the Shapiro-Francia test, as appropriate, was performed again to determine any changes in the distribution type.

2.1.1 Rejection of Outliers: *A Priori* Test

The *a priori* test is a screening test used to eliminate outliers before the distribution analysis is performed. This test is applied to all data whether parametric or non-parametric. An observation that is 4 or 5 times as large as the rest of the data is generally considered suspect (EPA 1989). Conservatively, for this *a priori* test, outliers are defined as maximum values greater than three times the next highest value. Non-transformed data are used for this screening test. If a data value fails the *a priori* test, it is removed from the data set for all following statistical analyses. The data point, however, must be explained as either potential sampling error, laboratory error, an anomalously high value, or some other factor contributing to an unexpectedly "high concentration".

2.1.2 Determination of Percent Non-detects

If the percentage of non-detects was less than 15%, the non-detect was replaced by the detection limit divided by two. A parametric distribution analyses was then performed on the modified data set. If the percentage of non-detects was greater than 15%, the distribution was considered non-parametric and a distribution analysis was not performed (EPA 1989, 1992).

2.1.3 Coefficient of Variation

The coefficient of variation (CV) is a unitless measure that determines dispersion for a set of data. The CV is commonly used in environmental statistical analyses because variability (expressed as a standard deviation) is often proportional to the mean. The CV may be used to determine whether or not the data follow a normal curve by comparing the sample CV to 1. EPA guidance (EPA 1998) suggests that the use of the CV is most valid if the data is non-negative. If the CV was greater than 1, the normality of the data was considered suspect. However, this method cannot be used to conclude the opposite, i.e. the distribution is normal if the CV is less than 1 (EPA 1998). This test was used as a preliminary screening test in conjunction with other more powerful distribution determining tests. The CV was calculated by dividing the standard deviation by the mean. Further information is provided in Guidance for Data Quality Assessment, Practical Methods for Data Analysis (EPA 1998).

The following formula is used to calculate CV:

$$CV = \frac{s}{\overline{X}}$$

where,

CV = coefficient of variation
s = standard deviation, and

$\overline{X}$ = sample mean

2.1.4 Studentized Range Test

Almost 100% of the area of a normal curve lies within +/-5 standard deviations from the mean. The Studentized range test for normality was developed based on this fact. This test compares the range of the sample (w) divided by the sample standard deviation (s) to a critical value range. If (w/s) exists outside of the critical value range, the data set fails the test. The Studentized range test does not perform well if the data are asymmetric. If the data appear to be lognormally distributed the test should not be applied (EPA 1998).

The following formula is used to perform the Studentized Range Test:

$$\frac{w}{s} = \frac{X_n - X_1}{s}$$

where,

w/s = sample range divided by the sample standard deviation
X_n = the maximum value of the data set
X_1 = the minimum value of the data set, and
s = the sample standard deviation

2.1.5 Coefficient of Skewness

The coefficient of skewness indicates to what degree a data set is skewed or asymmetric with respect to the mean. Data from a perfectly shaped normal distribution have a coefficient of skewness of zero, while asymmetric data have either positive or negative skewness depending on whether the right- or left-hand tail of the distribution is longer and "skinnier" than the opposite tail. A small degree of skewness (between -1 and +1) is not likely to affect the results of statistical tests based on an assumption of normality. However, if the coefficient of skewness is larger than 1 (in absolute value) and the sample size is small (e.g., n<25), statistical research has shown that standard normal theory-based tests are much less powerful than when the absolute skewness is less than 1 (Gayen, 1949). Therefore, it is considered a failure of the test for normality if the coefficient of skewness exceeds 1. The formula for the coefficient of skewness γ_i is shown below, where n is the number of data points, x_i is an individual sample observation, $\bar{x}$ is the mean of the data set, and σ is the standard deviation.

$$\gamma_i = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^3}{\left(\frac{n-1}{n}\right)^{\frac{3}{2}}(\sigma)^3}$$

The Coefficient of Skewness can also be used to evaluate whether the distribution of a data set is more normal or lognormal, based on the closeness of γ_i to zero.

2.1.6 Shapiro-Wilk (n<50) or Shapiro-Francia (n≥50) Test of Normality

The Shapiro-Wilk Test of Normality is based on the premise that, if a set of data is normally distributed, the ordered values should be highly correlative with corresponding quantiles taken from a normal distribution (Shapiro and Wilk, 1965). In particular, the Shapiro-Wilk Test of Normality gives substantial weight to evidence of non-normality in the tails of a distribution, where the robustness of statistical tests based on the normality assumption is the most severely affected (EPA, 1992).

The Shapiro-Wilk test statistic (W) will tend to be large (close to 1) when the data is normally distributed. Only when the plotted data show significant bends or curves will the test statistic be small. The Shapiro-Wilk Test of Normality is considered to be one of the best available tests of normality (Miller, 1986; Madansky, 1988).

The following formula is used to calculate W:

$$W = \left[\frac{b}{\sigma\sqrt{n-1}} \right]^2$$

where,

$$b = \sum_{i=1}^{k} b_i = \sum_{i=1}^{k} a_{n-i+1}\left(x_{(n-i+1)} - x_i\right)$$

and σ = standard deviation,
n = number of data points,
a_{n-i+1} = coefficients determined from Table A-1in EPA (1992) for $3 \leq n \leq 50$
K = greatest integer less than or equal to n/2

Normality of the data should be rejected if the Shapiro-Wilk statistic is too low when compared to the critical values provided in Table A-2 (EPA, 1992). Otherwise, the data are assumed to be approximately normal for purposes of further statistical analysis.

The Shapiro-Francia Test of Normality is also based on the premise that, if a set of data is normally distributed, the ordered values should be highly correlative with corresponding quantiles taken from a normal distribution (Shapiro and Francia 1972).

The Shapiro-Francia test statistic (W') will tend to be large (close to 1) when the data is normally distributed. Only when the plotted data show significant bends or curves will the test statistic be small. Normality of the data should be rejected if the Shapiro-Francia statistic is below calculated critical values (EPA 1992). Otherwise, the data are assumed to be approximately normal for purposes of further statistical analysis.

The following formula is used to calculate W':

$$W' = \frac{\left[\sum_i m_i x_i\right]^2}{(n-1)SD^2 \sum_i m_i^2}$$

where,

W' = test statistic
x_i = represents the ith ordered value of the sample

n = the number of samples within the data set
SD = the sample standard deviation
m_i = the approximated expected value of the ith ordered Normal quantile.

The values for m_i can be approximately computed as

$$m_i = \Phi^{-1}\left(\frac{i}{n+1}\right)$$

where,

m_i = the approximated expected value of the ith ordered Normal quantile
Φ^{-1} = the inverse of the standard Normal distribution with zero mean and unit variance
n = the number of samples within the data set

2.1.7 Filliben's Statistic

Filliben's statistic is approximately equivalent to the Shapiro-Wilk and Shapiro-Francia tests as described by Filliben (1975). This test correlates well with the use of probability plots, because the essence of the test is to compute the common correlation coefficient for points on a probability plot (EPA 1992). Since the correlation coefficient is a measure of the linearity of the points on a scatterplot, Filliben's statistic will be high when the plotted points fall along a straight line and low when there are significant bends and curves in the probability plot. Comparison of the Shapiro-Wilk and Filliben's statistic has indicated very similar statistical power for detecting non-normality (Ryan and Joiner, 1976). Critical values for the correlation coefficient have been derived in EPA 1992. If the calculated value is less than the critical value, there is significant evidence of non-normality.

Filliben's statistic may be computed as:

$$r = \frac{\Sigma_{i=1}^{n} X_i M_i}{\left(\sqrt{\Sigma_i M_i^2}\right)(SD)\left(\sqrt{n-1}\right)}$$

where,
r = Filliben's statistic
X_i = represents the ith smallest ordered concentration value
n = the number of samples within the data set
SD = the sample standard deviation
M_i = the median of the ith order statistic from a standard Normal distribution.

The ith Normal order statistic median may be approximated as $M_i = \Phi^{-1}(m_i)$, where as before Φ^{-1} is the inverse of the standard Normal cumulative distribution and m_i can be can be computed as follows (given sample size n):

$m_i = 1 - (0.5^{1/n})$ for i = 1

$m_i = (i - 0.3175)/(n + 0.365)$ for 1<i<n

$m_i = 0.5^{1/n}$ for i = n

2.1.8 Histograms

Histograms are useful for visually determining whether the data sets are skewed, and if so, in what direction. Histograms are created by determining the range of sample concentrations, then dividing the concentration range into equal intervals. Samples are then placed into the appropriate concentration intervals. The concentration range forms the x-axis. Calculating the percentage of samples per concentration interval compared to the total number of samples, or simply plotting the number of data values that fall within an interval, provides the y-axis in terms of percent frequency or frequency, respectively, of a particular concentration interval.

2.1.9 Probability Plots

Another simple and useful graphical test for determining normality is to plot the data on probability paper. The y-axis is scaled to represent probabilities according to the normal distribution, and the data are arranged in increasing order. An observed value is plotted on the x-axis, and the proportion of observations less than or equal to each observed value is plotted as the y-coordinate. The scale is constructed so that, if the data are normal, the points when plotted will approximate a straight line. Visually apparent curves or bends indicate that the data do not follow a normal distribution (EPA, 1992).

Probability plots are particularly useful for spotting irregularities within the data when compared to a specific distributional model such as the normal distribution. It is easy to determine whether departures from normality are occurring more or less in the middle ranges of the data or in the extreme tails. Probability plots can also indicate the presence of possible outlier values that do not follow the basic pattern of the data and can show the presence of significant positive or negative skewness.

The probability for a particular data value x is calculated as

$$\text{Probability} = 100*((i-3/8)/(n+1/4))$$

where,

i = ranked order of x_i from i to n
n = number of samples

2.1.10 Determination of Distribution

Upon completion of the *a priori* screen, percent non-detect determination, and graphical and numerical distribution analysis, a determination of the distribution was made (EPA, 1992).

2.1.11 The T_n Statistic Test

The T_n Statistic test was performed on the near and far upgradient background data after the *a priori* screen and initial distribution analysis had been completed. The test was run iteratively until the largest remaining value in the data set passed. If a particular data set had fewer than 15% non-detects but failed the parametric distribution tests, it was often carried over to the T_n Statistic and analyzed using the parametric distribution that it most closely resembled. In some instances, identification and removal of outliers during the T_n Statistic procedure allows for the

previously failed data set to pass the parametric numerical and graphical tests. If failures were reported during the T_n statistical test, the values were removed and the mean and standard deviation were recalculated on the censored data set. Failures of the T_n Statistic are defined as T_n calculated values that exceed the critical value (EPA, 1989). The censored data set was then used for all additional statistical tests. (Removed data points are considered either potential sampling error, laboratory error, an anomalously high value, or some other factor contributing to an unexpectedly large concentration).

To calculate the T_n statistic, the following formula is used:

$$T_n = \frac{(x_n - \bar{x})}{\sigma}$$

where
T_n = T_n statistic,
X_n = individual sample,
$\bar{x}$ = mean of sample set, and
σ = standard deviation.

2.2 Determination of Upper Tolerance Limit

This section describes two methods, one for parametric data and the other for non-parametric data that establish the maximum expected background concentration using a 95 percent confidence limit. A parametric upper tolerance limit (Section 2.2.1) is calculated for parametric data sets, while a 95th percentile (considered a non-parametric upper tolerance limit)(Section 2.2.2) is calculated for non-parametric data sets.

2.2.1 Parametric Upper Tolerance Limit

A tolerance interval establishes a concentration range that is constructed to contain a specified proportion (P%) of the population with a specified confidence coefficient, Y. The proportion of the population included, P, is referred to as the coverage. The probability with which the tolerance interval includes the proportion P% of the population is referred to as the tolerance coefficient.

A coverage of 95% was used as recommended by EPA (1989). By using this coverage, random observations from the same distribution would exceed the upper tolerance limit less than 5% of the time. Similarly, a tolerance coefficient of 95% was used. This means that there is a confidence level of 95% that the upper 95% tolerance limit would contain at least 95% of the distribution of observations from background groundwater data. These values were chosen to be consistent with the performance standards described in Section 2 of EPA 1989.

Tolerance intervals were constructed assuming that the data or the transformed data were normally distributed.

The formula for the UTL is as follows:

$$UTL = \bar{x} + t_{.05(n-1)} \cdot \sigma$$

where

$\bar{x}$ = the mean of the population,

$t_{.05(n-1)}$ is one-sided tolerance factor for n (Table 5, Appendix B, EPA 1989), and

σ = the standard deviation

2.2.2 95th Percentile

For non-parametric data sets, the 95[th] percentile value was used for expressing the upper range of background. The 95[th] percentile indicated that 95 percent of the data would be expected to be below that value, while 5 percent would be above the value. The calculated background was therefore insensitive to the magnitude of the largest 5 percent of the data points.

The 95[th] percentile was calculated electronically by the Microsoft Excel software program (Microsoft 1992).

2.3 Comparison Test

2.3.1 Introduction

A comparison test was performed between near upgradient and far upgradient data sets to determine if the two data sets were statistically similar. If the data sets were similar, then the data sets were combined to determine the upper tolerance limit for the larger data set. If the near and far upgradient data sets did not compare statistically, the data sets were not combined.

Comparison tests are of two basic types: parametric and non-parametric. Only a non-parametric test was applied to the Homestake background data. This test was the Wilcoxon Rank-sum test.

2.3.2. Wilcoxon Rank Sum Test

The Wilcoxon-Rank Sum (WRS) Test is a powerful nonparametric test to determine if data sets are statistically similar (EPA 1992). As a general rule, the WRS test should be used with caution if more than about 40% of the measurements are non-detects. All data were subjected to the WRS test in this analysis with the knowledge that the test power was greatly reduced when the non-detect percent was greater than 40.

In general the WRS test is performed by combining two data sets and ranking that set from highest to lowest. The ranked sum of each set is compared to determine if one set is statistically different than the other. A statistical software package (STATGRAPHICS) (Manugistics 1998) was used to perform this two-way procedure.

3.0 CHLORIDE

3.1 Introduction

Chloride concentrations measured in near upgradient wells range from 21 mg/L to 116.63 mg/L. None of the measurements are below the detection limit or above the New Mexico (NM) site standard of 250 mg/L.

Chloride concentrations measured in far upgradient wells range from 21.9 to 116 mg/L. These measurements are also all above the detection limit and below the NM site standard of 250 mg/L.

Table A-1 provides a statistical summary of the data by well for both near upgradient and far upgradient wells.

3.2 Chloride Near Upgradient

Table A-2 presents the chloride near upgradient background data set with the data not corrected for non-detects or duplicates. Tables A-3 through A-10 present the sampling date and the final data set (corrected for non-detects and duplicates) for the near upgradient background wells. Finally, Table A-11 is a summary table of all the final data sets for the near upgradient wells used in the statistical analyses. A distribution analysis was first performed for the chloride data. Then the 95th upper tolerance limit was calculated.

3.2.1 Distribution Analysis Results

3.2.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table A-12. No outliers were determined or eliminated from the chloride near upgradient background data set.

3.2.1.2 Determination of Percent Non-detects

Because the near upgradient chloride data set had less than 15% non-detects, distribution tests were applied to the data (Table A-1).

3.2.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table A-13). The CV value was 0.24 for the normal data and 0.07 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

3.2.1.4 Studentized Range Test

The normal data set failed the Studentized range test (Table A-14). The range (w) divided by the standard deviation (s) produced a result of 7.49. The critical value range was 5.47 to 6.94. When (w/s) falls outside the critical range, it implies that the data are not well modeled by a normal curve (EPA 1998).

3.2.1.5 Coefficient of Skewness

Both the normal and log-transformed data sets passed the coefficient of skewness test (Table A-15). The calculated coefficient of skewness was 0.3 for the normal set and –0.9 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness is less than 1, the normal distribution may provide a good approximation to the data set (EPA 1992).

3.2.1.6 Shapiro-Francia (n≥50) Test of Normality

Both data sets failed the Shapiro-Francia test (Table A-16). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.95, for the log-transformed data it was 0.92. Therefore, normality of the data was rejected (EPA 1992).

3.2.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table A-17). Though the critical value for the test could not be precisely determined, it is also evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=100 is 0.987 for 95% confidence. The calculated test statistic for the normal data was 0.974, for the log-transformed data it was 0.960. Therefore, normality of the data was rejected (EPA 1992).

3.2.1.8 Histograms

Figure A-1 depicts the histogram for the normal data set. The figure depicts a good distribution "fit" with slight right skewness implying that the normal distribution could provide an approximation to the data set. Figure A-2 depicts the histogram for the log-transformed data set. This figure depicts a good distribution "fit" implying that the normal distribution could provide a good approximation to the data set

3.2.1.9 Probability Plots

Figure A-3 shows the probability plot for the normal data set. There are at least four breaks in the plot. This probability plot depicts a fair to poor normal distribution "fit", implying the normal distribution will provide a fair to poor approximation to the data set. Figure A-4 is the probability plot for the log-transformed data set. There are at least three breaks in the plot. This probability plot depicts a poor normal distribution "fit", indicating that the normal distribution will provide a poor approximation to the data set.

3.2.1.10 Determination of Distribution

Based on the distribution analysis results, the chloride near upgradient background data set is non-parametric (Table A-18).

3.2.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the normal data set. The normal data set was selected because it approximated normality better than the transformed data set. Two outliers were detected using the T_n statistic (Table A-19).

3.2.1.12 Censored Shapiro-Francia ($n \geq 50$) Test of Normality

Both data sets failed the censored Shapiro-Francia test (Table A-20). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.969, for the log-transformed data it was 0.91. Therefore, normality of the data was rejected (EPA 1992).

3.2.2. Determination of Upper Tolerance Limit

3.2.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 71 mg/L (Table A-21). The chloride near upgradient background data set summary table is presented as Table A-22.

3.3 Chloride Far Upgradient

Table A-23 presents the chloride far upgradient background data set with the data not corrected for non-detects or duplicates. Tables A-24 through A-29 present the sampling date and the final data set (corrected for non-detects and duplicates) for the far upgradient background wells. Finally, Table A-30 is a summary table of all the final data sets for the far upgradient wells used in the statistical analyses. A distribution analysis was first performed for the chloride data. Then the 95th upper tolerance limit was calculated.

3.3.1 Distribution Analysis Results

3.3.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table A-31. No outliers were determined or eliminated from the chloride far upgradient background data set.

3.3.1.2 Determination of Percent Non-detects

Because the far upgradient chloride data set had less than 15% non-detects, distribution tests were applied to the data (Table A-1).

3.3.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table A-32). The CV value was 0.36 for the normal data and 0.11 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

3.3.1.4 Studentized Range Test

The normal data set failed the Studentized range test (Table A-33). The range (w) divided by the standard deviation (s) produced a result of 3.68. The critical value range was 3.83 to 5.35. When (w/s) falls outside the critical range, it implies that the data are not well modeled by a normal curve (EPA 1998).

3.3.1.5 Coefficient of Skewness

The normal data set passed the coefficient of skewness test while the log-transformed data set failed (Table A-34). The calculated coefficient of skewness was -0.1 for the normal set and –1.2 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness was less than 1 for the normal data set, the normal distribution may accurately approximate the data set (EPA 1992). Since the log-transformed data set fell outside the acceptable range, the normal distribution may be a poor approximation to the data.

3.3.1.6 Shapiro-Wilk (n<50)

Both data sets failed the Shapiro-Wilk test (Table A-35). The calculated W for the normal data was 0.93, for the log-transformed data it was 0.84 compared to a critical value of 0.946. Therefore, normality of the data was rejected (EPA 1992).

3.3.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table A-36). The calculated test statistic for the normal data was 0.974, for the log-transformed data it was 0.922 compared to a critical value of 0.975. Therefore, normality of the data was rejected (EPA 1992).

3.3.1.8 Histograms

Figure A-5 depicts the histogram for the normal data set. The figure depicts a good distribution "fit" implying that the normal distribution could provide a good approximation to the data set. Figure A-6 depicts the histogram for the log-transformed data set. This figure depicts a poor distribution "fit" implying that the normal distribution could provide a poor approximation to the data set

3.3.1.9 Probability Plots

Figure A-7 shows the probability plot for the normal data set. There are at least two sharp breaks in the plot. This probability plot depicts a poor normal distribution "fit", implying the normal distribution will provide a poor approximation to the data set. Figure A-8 is the probability plot for the log-transformed data set. There are at least three breaks in the plot. This probability plot also depicts a poor normal distribution "fit", with the same implication as above.

3.3.1.10 Determination of Distribution

Based on the distribution analysis results, the chloride far upgradient background data set is non-parametric (Table A-37).

3.3.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the normal data set. The normal data set was selected because it approximated normality better than the log-transformed data set. No outliers were detected using the T_n statistic (Table A-38).

3.3.2 Determination of Upper Tolerance Limit

3.3.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95^{th} percentile of the data was calculated. The 95^{th} percentile was determined to be 112.1 mg/L (Table A-39). The chloride far upgradient background data set summary table is presented as Table A-40.

3.4 Chloride Near and Far Upgradient Comparison Statistics Results

The chloride near upgradient background data set was not statistically similar to the chloride far upgradient background data set (Table A-41). Thus, distribution fitting and an upper tolerance limit calculation was not performed on the combined data set.

4.0 NITRATE

4.1 Introduction

Nitrate concentrations measured in near upgradient wells range from 0.35 mg/L to 33.2 mg/L. Less than 1% of the measurements are below the detection limit. Approximately 33% of the measurements are above the NM site standard of 12.4 mg/L.

Nitrate concentrations measured in far upgradient wells range from <0.1 (nondetect) to 26 mg/L. Approximately 15% of these measurements were below the detection limit and approximately 47% were above the NM site standard of 12.4 mg/L.

Table B-1 provides a statistical summary of the data by well for both near upgradient and far upgradient wells.

4.2 Nitrate Near Upgradient

Table B-2 presents the nitrate near upgradient background data set with the data not corrected for non-detects or duplicates. Tables B-3 through B-10 present the sampling date and the final data set (corrected for non-detects and duplicates) for the near upgradient background wells. Finally, Table B-11 is a summary table of all the final data sets for the near upgradient wells used in the statistical analyses. A distribution analysis was first performed for the nitrate data. Then the 95th upper tolerance limit was calculated.

4.2.1 Distribution Analysis Results

4.2.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table B-12. No outliers were determined or eliminated from the nitrate near upgradient background data set.

4.2.1.2 Determination of Percent Non-detects

Because the near upgradient nitrate data set had less than 15% non-detects, distribution tests were applied to the data (Table B-1).

4.2.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table B-13). The CV value was 0.53 for the normal data and 0.30 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

4.2.1.4 Studentized Range Test

The normal data set passed the Studentized range test (Table B-14). The range (w) divided by the standard deviation (s) produced a result of 5.67. The critical value range was 5.47 to 6.94. When (w/s) falls within the critical range, it implies that the data may be modeled by a normal curve (EPA 1998).

4.2.1.5 Coefficient of Skewness

The normal data set passed the coefficient of skewness test while the log-transformed data set failed (Table B-15). The calculated coefficient of skewness was 1.0 for the normal set and –1.6 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness is less than 1 for the normal data set, the normal distribution may provide a good approximation (EPA 1992). Since the coefficient of skewness was greater than –1 for the log-transformed data, the normal distribution may provide a poor approximation.

4.2.1.6 Shapiro-Francia ($n \geq 50$) Test of Normality

Both data sets failed the Shapiro-Francia test (Table B-16). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.94, for the log-transformed data it was 0.89. Therefore, normality of the data was rejected (EPA 1992).

4.2.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table B-17). Though the critical value for the test could not be precisely determined, it is also evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=100 is 0.987 for 95% confidence. The calculated test statistic for the normal data was 0.971, for the log-transformed data it was 0.947. Therefore, normality of the data was rejected (EPA 1992).

4.2.1.8 Histograms

Figure B-1 depicts the histogram for the normal data set. The figure depicts a fair distribution "fit" with right skewness implying that the normal distribution could provide a fair approximation to the data set. Figure B-2 depicts the histogram for the log-transformed data set. This figure depicts a fair distribution "fit" with left skewness implying that the normal distribution could provide a fair approximation to the data set

4.2.1.9 Probability Plots

Figure B-3 shows the probability plot for the normal data set. There are at least three breaks in the plot. This probability plot depicts a fair normal distribution "fit", implying the normal distribution may provide a fair approximation to the data set. Figure B-4 is the probability plot for the log-transformed data set. There are at least three breaks in the plot. This probability plot depicts a poor normal distribution "fit", indicating that the normal distribution will provide a poor approximation to the data set.

4.2.1.10 Determination of Distribution

Based on the distribution analysis results, the nitrate near upgradient background data set is non-parametric (Table B-18).

4.2.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the normal data set. The normal data set was selected because it approximated normality better than the transformed data set. Four outliers were detected using the T_n statistic (Table B-19).

4.2.1.12 Censored Shapiro-Francia ($n \geq 50$) Test of Normality

Both data sets failed the censored Shapiro-Francia test (Table B-20). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.96, for the log-transformed data it was 0.88. Therefore, normality of the data was rejected (EPA 1992).

4.2.2. Determination of Upper Tolerance Limit

4.2.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 22.95 mg/L (Table B-21). The nitrate near upgradient background data set summary table is presented as Table B-22.

4.3 Nitrate Far Upgradient

Table B-23 presents the nitrate far upgradient background data set with the data not corrected for non-detects or duplicates. Tables B-24 through B-29 present the sampling date and the final data set (corrected for non-detects and duplicates) for the far upgradient background wells. Finally, Table B-30 is a summary table of all the final data sets for the far upgradient wells used in the statistical analyses. A distribution analysis was first performed for the nitrate data. Then the 95th upper tolerance limit was calculated.

4.3.1 Distribution Analysis Results

4.3.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table B-31. No outliers were determined or eliminated from the nitrate far upgradient background data set.

4.3.1.2 Determination of Percent Non-detects

Because the far upgradient nitrate data set had less than 15% non-detects, distribution tests were applied to the data (Table B-1).

4.3.1.3 Coefficient of Variation

The normal data set passed the CV screen while the log-transformed data set failed (Table B-32). The CV value was 0.78 for the normal data and 1.50 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal. However if the CV is greater than 1, the normal distribution may be a poor approximation to the data.

4.3.1.4 Studentized Range Test

The normal data set failed the Studentized range test (Table B-33). The range (w) divided by the standard deviation (s) produced a result of 3.03. The critical value range was 3.83 to 5.35. When (w/s) falls outside the critical range, it implies that the data are not well modeled by a normal curve (EPA 1998).

4.3.1.5 Coefficient of Skewness

The normal data set passed the coefficient of skewness test while the log-transformed data set failed (Table B-34). The calculated coefficient of skewness was 0.1 for the normal set and –1.3 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness was less than 1 for the normal data set, the normal distribution may accurately approximate the data set (EPA 1992). Since the log-transformed data set fell outside the acceptable range, the normal distribution may be a poor approximation to the data.

4.3.1.6 Shapiro-Wilk (n<50)

Both data sets failed the Shapiro-Wilk test (Table B-35). The calculated W for the normal data was 0.897, for the log-transformed data it was 0.734 compared to a critical value of 0.946. Therefore, normality of the data was rejected (EPA 1992).

4.3.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table B-36). The calculated test statistic for the normal data was 0.963, for the log-transformed data it was 0.869 compared to a critical value of 0.975. Therefore, normality of the data was rejected (EPA 1992).

4.3.1.8 Histograms

Figure B-5 depicts the histogram for the normal data set. The figure depicts a poor distribution "fit" implying that the normal distribution could provide a poor approximation to the data set. Figure B-6 depicts the histogram for the log-transformed data set. This figure also depicts a poor distribution "fit" implying that the normal distribution could provide a poor approximation to the data set

4.3.1.9 Probability Plots

Figure B-7 shows the probability plot for the normal data set. There are at least three breaks in the plot. This probability plot depicts a fair normal distribution "fit", implying the normal distribution may provide a fair approximation to the data set. Figure B-8 is the probability plot for the log-transformed data set. There are at least three breaks in the plot. This probability plot depicts a poor normal distribution "fit", indicating that the normal distribution may be a poor approximation of the data.

4.3.1.10 Determination of Distribution

Based on the distribution analysis results, the nitrate far upgradient background data set is non-parametric (Table B-37).

4.3.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the normal data set. The normal data set was selected because it approximated normality better than the log-transformed data set. No outliers were detected using the T_n statistic (Table B-38).

4.3.2 Determination of Upper Tolerance Limit

4.3.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 24.28 mg/L (Table B-39). The nitrate far upgradient background data set summary table is presented as Table B-40.

4.4 Nitrate Near and Far Upgradient Comparison Statistics Results

The nitrate near upgradient background data set was statistically similar to the nitrate far upgradient background data set (Table B-41). Thus, distribution fitting and an upper tolerance limit calculation was performed on the combined data set.

4.5 Nitrate Combined Data Set

Table B-42 is a summary table of all the final data sets for the combined upgradient wells used in the statistical analyses. A distribution analysis was first performed for the nitrate data. Then the 95th upper tolerance limit was calculated.

4.5.1 Distribution Analysis Results

4.5.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table B-43. No outliers were determined or eliminated from the nitrate combined upgradient background data set.

4.5.1.2 Determination of Percent Non-detects

Because the combined upgradient nitrate data set had less than 15% non-detects, distribution tests were applied to the data (Table B-1).

4.5.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table B-44). The CV value was 0.57 for the normal data and 0.47 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

4.5.1.4 Studentized Range Test

The normal data set failed the Studentized range test (Table B-45). The range (w) divided by the standard deviation (s) produced a result of 5.37. The critical value range was 5.47 to 6.94. When (w/s) falls outside the critical range, it implies that the data are not well modeled by a normal curve (EPA 1998).

4.5.1.5 Coefficient of Skewness

The normal data set passed the coefficient of skewness test while the log-transformed data set failed (Table B-46). The calculated coefficient of skewness was 0.8 for the normal set and –2.9 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness was less than 1 for the normal data set, the normal distribution may accurately approximate the data set (EPA 1992). Since the log-transformed data set fell outside the acceptable range, the normal distribution may be a poor approximation to the data.

4.5.1.6 Shapiro-Francia (n>50)

Both data sets failed the Shapiro-Francia test (Table B-47). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.96, for the log-transformed data it was 0.72 Therefore, normality of the data was rejected (EPA 1992).

4.5.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table B-48). Though the critical value for the test could not be precisely determined, it is also evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=100 is 0.987 for 95% confidence. The calculated test statistic for the normal data was 0.980, for the log-transformed data it was 0.851. Therefore, normality of the data was rejected (EPA 1992).

4.5.1.8 Histograms

Figure B-9 depicts the histogram for the normal data set. The figure depicts a fair distribution "fit" implying that the normal distribution could provide a fair approximation to the data set. Figure B-10 depicts the histogram for the log-transformed data set. This figure depicts a poor distribution "fit" implying that the normal distribution could provide a poor approximation to the data set

4.5.1.9 Probability Plots

Figure B-11 shows the probability plot for the normal data set. There are at least two breaks in the plot. This probability plot depicts a fair normal distribution "fit", implying the normal distribution may provide a fair approximation to the data set. Figure B-12 is the probability plot for the log-transformed data set. There are at least three breaks in the plot. This probability plot depicts a poor normal distribution "fit", indicating that the normal distribution may be a poor approximation of the data.

4.5.1.10 Determination of Distribution

Based on the distribution analysis results, the nitrate combined upgradient background data set is non-parametric (Table B-49).

4.5.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the normal data set. The normal data set was selected because it approximated normality better than the log-transformed data set. Four outliers were detected using the T_n statistic (Table B-50).

4.5.1.12 Censored Shapiro-Francia ($n \geq 50$) Test of Normality

Both data sets failed the censored Shapiro-Francia test (Table B-51). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.973, for the log-transformed data it was 0.71. Therefore, normality of the data was rejected (EPA 1992).

4.5.2 Determination of Upper Tolerance Limit

4.5.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 23.28 mg/L (Table B-52). The nitrate combined upgradient background data set summary table is presented as Table B-53.

5.0 SULFATE

5.1 Introduction

Sulfate concentrations measured in near upgradient wells range from 324 mg/L to 1975 mg/L. None of the measurements are below the detection limit. Approximately 56% of the measurements are above the NM site standard of 976 mg/L.

Sulfate concentrations measured in far upgradient wells range from 43.3 to 1744 mg/L. None of these measurements were below the detection limit and approximately 51% were above the NM site standard of 976 mg/L.

Table C-1 provides a statistical summary of the data by well for both near upgradient and far upgradient wells.

5.2 Sulfate Near Upgradient

Table C-2 presents the sulfate near upgradient background data set with the data not corrected for non-detects or duplicates. Tables C-3 through C-10 present the sampling date and the final data set (corrected for non-detects and duplicates) for the near upgradient background wells. Finally, Table C-11 is a summary table of all the final data sets for the near upgradient wells used in the statistical analyses. A distribution analysis was first performed for the sulfate data. Then the 95th upper tolerance limit was calculated.

5.2.1 Distribution Analysis Results

5.2.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table C-12. No outliers were determined or eliminated from the sulfate near upgradient background data set.

5.2.1.2 Determination of Percent Non-detects

Because the near upgradient sulfate data set had less than 15% non-detects, distribution tests were applied to the data (Table C-1).

5.2.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table C-13). The CV value was 0.32 for the normal data and 0.05 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

5.2.1.4 Studentized Range Test

The normal data set failed the Studentized range test (Table C-14). The range (w) divided by the standard deviation (s) produced a result of 4.75. The critical value range was 5.47 to 6.94. When (w/s) falls outside the critical range, it implies that the data may not represent a normal distribution (EPA 1998).

5.2.1.5 Coefficient of Skewness

The normal and log-transformed data sets passed the coefficient of skewness test (Table C-15). The calculated coefficient of skewness was 0.9 for the normal set and –0.4 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness is less than 1, the normal distribution may provide a good approximation (EPA 1992).

5.2.1.6 Shapiro-Francia ($n \geq 50$) Test of Normality

Both data sets failed the Shapiro-Francia test (Table C-16). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.89, for the log-transformed data it was 0.92. Therefore, normality of the data was rejected (EPA 1992).

5.2.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table C-17). Though the critical value for the test could not be precisely determined, it is also evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=100 is 0.987 for 95% confidence. The calculated test statistic for the normal data was 0.945, for the log-transformed data it was 0.961. Therefore, normality of the data was rejected (EPA 1992).

5.2.1.8 Histograms

Figure C-1 depicts the histogram for the normal data set. The figure depicts a poor distribution "fit" with right skewness implying that the normal distribution could provide a poor approximation to the data set. Figure C-2 depicts the histogram for the log-transformed data set. This figure depicts a fair distribution "fit" with left skewness implying that the normal distribution could provide a fair approximation to the data set

5.2.1.9 Probability Plots

Figure C-3 shows the probability plot for the normal data set. There are at least eight breaks in the plot. This probability plot depicts a poor normal distribution "fit", implying the normal distribution may provide a poor approximation to the data set. Figure C-4 is the probability plot for the log-transformed data set. There are at least seven breaks in the plot. This probability plot depicts a poor normal distribution "fit", indicating that the normal distribution will provide a poor approximation to the data set.

5.2.1.10 Determination of Distribution

Based on the distribution analysis results, the sulfate near upgradient background data set is non-parametric (Table C-18).

5.2.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the lognormal data set. The lognormal data set was selected because it approximated normality better than the non-transformed data set. No outliers were detected using the T_n statistic (Table C-19).

5.2.2. Determination of Upper Tolerance Limit

5.2.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 1866.88 mg/L (Table C-20). The sulfate near upgradient background data set summary table is presented as Table C-21.

5.3 Sulfate Far Upgradient

Table C-22 presents the sulfate far upgradient background data set with the data not corrected for non-detects or duplicates. Tables C-23 through C-28 present the sampling date and the final data set (corrected for non-detects and duplicates) for the far upgradient background wells. Finally, Table C-29 is a summary table of all the final data sets for the far upgradient wells used in the statistical analyses. A distribution analysis was first performed for the sulfate data. Then the 95th upper tolerance limit was calculated.

5.3.1 Distribution Analysis Results

5.3.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table C-30. No outliers were determined or eliminated from the sulfate far upgradient background data set.

5.3.1.2 Determination of Percent Non-detects

Because the far upgradient sulfate data set had less than 15% non-detects, distribution tests were applied to the data (Table C-1).

5.3.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table C-31). The CV value was 0.60 for the normal data and 0.19 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

5.3.1.4 Studentized Range Test

The normal data set failed the Studentized range test (Table C-32). The range (w) divided by the standard deviation (s) produced a result of 2.83. The critical value range was 3.83 to 5.35. When (w/s) falls outside the critical range, it implies that the data are not well modeled by a normal curve (EPA 1998).

5.3.1.5 Coefficient of Skewness

The normal data set passed the coefficient of skewness test while the log-transformed data set failed (Table C-33). The calculated coefficient of skewness was -0.4 for the normal set and –1.4 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness was less than 1 for the normal data set, the normal distribution may accurately approximate the data set (EPA 1992). Since the log-transformed data set fell outside the acceptable range, the normal distribution may be a poor approximation to the data.

5.3.1.6 Shapiro-Wilk (n<50)

Both data sets failed the Shapiro-Wilk test (Table C-34). The calculated W for the normal data was 0.843, for the log-transformed data it was 0.726 compared to a critical value of 0.946. Therefore, normality of the data was rejected (EPA 1992).

5.3.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table C-35). The calculated test statistic for the normal data was 0.935, for the log-transformed data it was 0.863 compared to a critical value of 0.975. Therefore, normality of the data was rejected (EPA 1992).

5.3.1.8 Histograms

Figure C-5 depicts the histogram for the normal data set. The figure depicts a poor distribution "fit" implying that the normal distribution could provide a poor approximation to the data set. Figure C-6 depicts the histogram for the log-transformed data set. This figure also depicts a poor distribution "fit" implying that the normal distribution could provide a poor approximation to the data set

5.3.1.9 Probability Plots

Figure C-7 shows the probability plot for the normal data set. There are at least three breaks in the plot. This probability plot depicts a poor normal distribution "fit", implying the normal distribution may provide a poor approximation to the data set. Figure C-8 is the probability plot for the log-transformed data set. There are at least

four breaks in the plot. This probability plot depicts a poor normal distribution "fit", indicating that the normal distribution may be a poor approximation of the data.

5.3.1.10 Determination of Distribution

Based on the distribution analysis results, the sulfate far upgradient background data set is non-parametric (Table C-36).

5.3.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the normal data set. The normal data set was selected because it approximated normality better than the log-transformed data set. No outliers were detected using the T_n statistic (Table C-37).

5.3.2 Determination of Upper Tolerance Limit

5.3.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 1655.7 mg/L (Table C-38). The sulfate far upgradient background data set summary table is presented as Table C-39.

5.4 Sulfate Near and Far Upgradient Comparison Statistics Results

The sulfate near upgradient background data set was statistically similar to the sulfate far upgradient background data set (Table C-40). Thus, distribution fitting and an upper tolerance limit calculation was performed on the combined data set.

5.5 Sulfate Combined Data Set

Table C-41 is a summary table of all the final data sets for the combined upgradient wells used in the statistical analyses. A distribution analysis was first performed for the sulfate data. Then the 95th upper tolerance limit was calculated.

5.5.1 Distribution Analysis Results

5.5.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table C-42. No outliers were determined or eliminated from the sulfate combined upgradient background data set.

5.5.1.2 Determination of Percent Non-detects

Because the combined upgradient sulfate data set had less than 15% non-detects, distribution tests were applied to the data (Table C-1).

5.5.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table C-43). The CV value was 0.36 for the normal data and 0.08 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

5.5.1.4 Studentized Range Test

The normal data set failed the Studentized range test (Table C-44). The range (w) divided by the standard deviation (s) produced a result of 5.02. The critical value range was 5.47 to 6.94. When (w/s) falls outside the critical range, it implies that the data are not well modeled by a normal curve (EPA 1998).

5.5.1.5 Coefficient of Skewness

The normal data set passed the coefficient of skewness test while the log-transformed data set failed (Table C-45). The calculated coefficient of skewness was 0.3 for the normal set and –3.3 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness was less than 1 for the normal data set, the normal distribution may accurately approximate the data set (EPA 1992). Since the log-transformed data set fell outside the acceptable range, the normal distribution may be a poor approximation to the data.

5.5.1.6 Shapiro-Francia (n>50)

Both data sets failed the Shapiro-Francia test (Table C-46). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.94, for the log-transformed data it was 0.70 Therefore, normality of the data was rejected (EPA 1992).

5.5.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table C-47). Though the critical value for the test could not be precisely determined, it is also evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=100 is 0.987 for 95% confidence. The calculated test statistic for the normal data was 0.972, for the log-transformed data it was 0.837. Therefore, normality of the data was rejected (EPA 1992).

5.5.1.8 Histograms

Figure C-9 depicts the histogram for the normal data set. The figure depicts a good distribution "fit" implying that the normal distribution could provide a good approximation to the data set. Figure C-10 depicts the histogram for the log-transformed data set. This figure depicts a poor distribution "fit" implying that the log normal distribution could provide a poor approximation to the data set

5.5.1.9 Probability Plots

Figure C-11 shows the probability plot for the normal data set. There are at least three breaks in the plot. This probability plot depicts a fair normal distribution "fit", implying the normal distribution may provide a fair approximation to the data set. Figure C-12 is the probability plot for the log-transformed data set. There are at least four breaks in the plot. This probability plot depicts a poor normal distribution "fit", indicating that the normal distribution may be a poor approximation of the data.

5.5.1.10 Determination of Distribution

Based on the distribution analysis results, the sulfate combined upgradient background data set is non-parametric (Table C-48).

5.5.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the normal data set. The normal data set was selected because it approximated normality better than the log-transformed data set. No outliers were detected using the T_n statistic (Table C-49).

5.5.2 Determination of Upper Tolerance Limit

5.5.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 1848.8 mg/L (Table C-50). The sulfate combined upgradient background data set summary table is presented as Table C-51.

6.0 TDS

6.1 Introduction

TDS concentrations measured in near upgradient wells range from 954 mg/L to 4250 mg/L. None of the measurements are below the detection limit. Approximately 54% of the measurements are above the NM site standard of 1770 mg/L.

TDS concentrations measured in far upgradient wells range from 318 to 2930 mg/L. None of these measurements were below the detection limit and approximately 55% were above the NM site standard of 1770 mg/L.

Table D-1 provides a statistical summary of the data by well for both near upgradient and far upgradient wells.

6.2 TDS Near Upgradient

Table D-2 presents the TDS near upgradient background data set with the data not corrected for non-detects or duplicates. Tables D-3 through D-10 present the sampling date and the final data set (corrected for non-detects and duplicates) for the near upgradient background wells. Finally, Table D-11 is a summary table of all the final data sets for the near upgradient wells used in the statistical analyses. A distribution analysis was first performed for the TDS data. Then the 95th upper tolerance limit was calculated.

6.2.1 Distribution Analysis Results

6.2.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table D-12. No outliers were determined or eliminated from the TDS near upgradient background data set.

6.2.1.2 Determination of Percent Non-detects

Because the near upgradient TDS data set had less than 15% non-detects, distribution tests were applied to the data (Table D-1).

6.2.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table D-13). The CV value was 0.28 for the normal data and 0.04 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

6.2.1.4 Studentized Range Test

The normal data set passed the Studentized range test (Table D-14). The range (w) divided by the standard deviation (s) produced a result of 6.03. The critical value range was 5.47 to 6.94. When (w/s) falls within the critical range, it implies that the data may be modeled by a normal curve (EPA 1998).

6.2.1.5 Coefficient of Skewness

Both the normal and log-transformed data sets passed the coefficient of skewness test (Table D-15). The calculated coefficient of skewness was 1.0 for the normal set and 0.2 for the log-transformed data set compared to an acceptable range of −1 to 1. Because the coefficient of skewness is less than 1 for the data sets, the normal distribution may provide a good approximation (EPA 1992).

6.2.1.6 Shapiro-Francia (n≥50) Test of Normality

Both data sets failed the Shapiro-Francia test (Table D-16). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.92, for the log-transformed data it was 0.973. Therefore, normality of the data was rejected (EPA 1992).

6.2.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table D-17). Though the critical value for the test could not be precisely determined, it is also evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=100 is 0.987 for 95% confidence. The calculated test statistic for the normal data was 0.957, for the log-transformed data it was 0.986. Therefore, normality of the data was rejected (EPA 1992).

6.2.1.8 Histograms

Figure D-1 depicts the histogram for the normal data set. The figure depicts a fair distribution "fit" with right skewness implying that the normal distribution could provide a fair approximation to the data set. Figure D-2 depicts the histogram for the log-transformed data set. This figure depicts a fair distribution "fit" also with right skewness implying that the normal distribution could provide a fair approximation to the data set

6.2.1.9 Probability Plots

Figure D-3 shows the probability plot for the normal data set. There are at least three breaks in the plot. This probability plot depicts a poor normal distribution "fit", implying the normal distribution may provide a poor approximation to the data set. Figure D-4 is the probability plot for the log-transformed data set. There are at least four breaks in the plot. This probability plot depicts a fair normal distribution "fit", indicating that the normal distribution could provide a fair approximation to the data set.

6.2.1.10 Determination of Distribution

Based on the distribution analysis results, the TDS near upgradient background data set is non-parametric (Table D-18).

6.2.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the lognormal data set. The lognormal data set was selected because it approximated normality better than the non-transformed data set. No outliers were detected using the T_n statistic (Table D-19).

6.2.2. Determination of Upper Tolerance Limit

6.2.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 3060 mg/L (Table D-20). The TDS near upgradient background data set summary table is presented as Table D-21.

6.3 TDS Far Upgradient

Table D-22 presents the TDS far upgradient background data set with the data not corrected for non-detects or duplicates. Tables D-23 through D-28 present the sampling date and the final data set (corrected for non-detects and duplicates) for the far upgradient background wells. Finally, Table D-29 is a summary table of all the final data sets

for the far upgradient wells used in the statistical analyses. A distribution analysis was first performed for the TDS data. Then the 95th upper tolerance limit was calculated.

6.3.1 Distribution Analysis Results

6.3.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table D-30. No outliers were determined or eliminated from the TDS far upgradient background data set.

6.3.1.2 Determination of Percent Non-detects

Because the far upgradient TDS data set had less than 15% non-detects, distribution tests were applied to the data (Table D-1).

6.3.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table D-31). The CV value was 0.49 for the normal data and 0.10 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

6.3.1.4 Studentized Range Test

The normal data set failed the Studentized range test (Table D-32). The range (w) divided by the standard deviation (s) produced a result of 2.94. The critical value range was 3.83 to 5.35. When (w/s) falls outside the critical range, it implies that the data are not well modeled by a normal curve (EPA 1998).

6.3.1.5 Coefficient of Skewness

The normal data set passed the coefficient of skewness test while the log-transformed data set failed (Table D-33). The calculated coefficient of skewness was -0.4 for the normal set and –1.1 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness was less than 1 for the normal data set, the normal distribution may accurately approximate the data set (EPA 1992). Since the log-transformed data set fell outside the acceptable range, the normal distribution may be a poor approximation to the data.

6.3.1.6 Shapiro-Wilk (n<50)

Both data sets failed the Shapiro-Wilk test (Table D-34). The calculated W for the normal data was 0.832, for the log-transformed data it was 0.783 compared to a critical value of 0.946. Therefore, normality of the data was rejected (EPA 1992).

6.3.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table D-35). The calculated test statistic for the normal data was 0.928, for the log-transformed data it was 0.896 compared to a critical value of 0.975. Therefore, normality of the data was rejected (EPA 1992).

6.3.1.8 Histograms

Figure D-5 depicts the histogram for the normal data set. The figure depicts a poor distribution "fit" implying that the normal distribution could provide a poor approximation to the data set. Figure D-6 depicts the histogram for the log-transformed data set. This figure also depicts a poor distribution "fit" implying that the normal distribution could provide a poor approximation to the data set

6.3.1.9 Probability Plots

Figure D-7 shows the probability plot for the normal data set. There are at least three breaks in the plot. This probability plot depicts a poor normal distribution "fit", implying the normal distribution may provide a poor approximation to the data set. Figure D-8 is the probability plot for the log-transformed data set. There are at least three breaks in the plot. This probability plot depicts a poor normal distribution "fit", indicating that the normal distribution may be a poor approximation of the data.

6.3.1.10 Determination of Distribution

Based on the distribution analysis results, the TDS far upgradient background data set is non-parametric (Table D-36).

6.3.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the normal data set. The normal data set was selected because it approximated normality better than the log-transformed data set. No outliers were detected using the T_n statistic (Table D-37).

6.3.2 Determination of Upper Tolerance Limit

6.3.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 2730.7 mg/L (Table D-38). The TDS far upgradient background data set summary table is presented as Table D-39.

6.4 TDS Near and Far Upgradient Comparison Statistics Results

The TDS near upgradient background data set was statistically similar to the TDS far upgradient background data set (Table D-40). Thus, distribution fitting and an upper tolerance limit calculation was performed on the combined data set.

6.5 TDS Combined Data Set

Table D-41 is a summary table of all the final data sets for the combined upgradient wells used in the statistical analyses. A distribution analysis was first performed for the TDS data. Then the 95th upper tolerance limit was calculated.

6.5.1 Distribution Analysis Results

6.5.1.1 Rejection of Outliers: *A Priori* Test

Results of the *a priori* test are presented in Table D-42. No outliers were determined or eliminated from the TDS combined upgradient background data set.

6.5.1.2 Determination of Percent Non-detects

Because the combined upgradient TDS data set had less than 15% non-detects, distribution tests were applied to the data (Table D-1).

6.5.1.3 Coefficient of Variation

Both the normal and log-transformed data sets passed the CV screen (Table D-43). The CV value was 0.31 for the normal data and 0.05 for the log-transformed data compared to the critical value of 1. According to EPA 1998, if the CV is less than 1, the data may be, but does not necessarily have to be normal.

6.5.1.4 Studentized Range Test

The normal data set passed the Studentized range test (Table D-44). The range (w) divided by the standard deviation (s) produced a result of 6.56. The critical value range was 5.47 to 6.94. When (w/s) falls within the critical range, it implies that the data may be modeled by a normal curve (EPA 1998).

6.5.1.5 Coefficient of Skewness

The normal data set passed the coefficient of skewness test while the log-transformed data set failed (Table D-45). The calculated coefficient of skewness was 0.4 for the normal set and –1.5 for the log-transformed data set compared to an acceptable range of –1 to 1. Because the coefficient of skewness was less than 1 for the normal data set, the normal distribution may accurately approximate the data set (EPA 1992). Since the log-transformed data set fell outside the acceptable range, the normal distribution may be a poor approximation to the data.

6.5.1.6 Shapiro-Francia (n>50)

Both data sets failed the Shapiro-Francia test (Table D-46). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.96, for the log-transformed data it was 0.888 Therefore, normality of the data was rejected (EPA 1992).

6.5.1.7 Filliben's Statistic

Both data sets failed Filliben's Statistic (Table D-47). Though the critical value for the test could not be precisely determined, it is also evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=100 is 0.987 for 95% confidence. The calculated test statistic for the normal data was 0.982, for the log-transformed data it was 0.944. Therefore, normality of the data was rejected (EPA 1992).

6.5.1.8 Histograms

Figure D-9 depicts the histogram for the normal data set. The figure depicts a good distribution "fit" implying that the normal distribution could provide a good approximation to the data set. Figure D-10 depicts the histogram for the log-transformed data set. This figure depicts a fair distribution "fit" implying that the normal distribution could provide a fair approximation to the data set

6.5.1.9 Probability Plots

Figure D-11 shows the probability plot for the normal data set. There are at least two breaks in the plot. This probability plot depicts a fair normal distribution "fit", implying the normal distribution may provide a fair approximation to the data set. Figure D-12 is the probability plot for the log-transformed data set. There are at least three breaks in the plot. This probability plot depicts a poor normal distribution "fit", indicating that the normal distribution may be a poor approximation of the data.

6.5.1.10 Determination of Distribution

Based on the distribution analysis results, the TDS combined upgradient background data set is non-parametric (Table D-48).

6.5.1.11 The T_n Statistic Test

Though the data set was determined to be nonparametric, the T_n statistic outlier test was applied to the normal data set. The normal data set was selected because it approximated normality better than the log-transformed data set. One outlier was detected using the T_n statistic (Table D-49).

6.5.1.12 Censored Shapiro-Francia (n≥50) Test of Normality

Both data sets failed the censored Shapiro-Francia test (Table D-50). Though the critical value for the test could not be precisely determined, it is evident from comparison of tabulated critical values to n that the critical value approaches 1 as n increases. The critical value for n=99 is 0.976 for 95% confidence. The calculated W' for the normal data was 0.966, for the log-transformed data it was 0.884. Therefore, normality of the data was rejected (EPA 1992).

6.5.2 Determination of Upper Tolerance Limit

6.5.2.1 95th Percentile

Because the data was determined to be non-parametrically distributed, the 95th percentile of the data was calculated. The 95th percentile was determined to be 3053 mg/L (Table D-51). The TDS combined upgradient background data set summary table is presented as Table D-52.

7.0 SUMMARY

Samples were collected at near and far upgradient wells from 1976 to 1998. Fifteen wells provided the upgradient well data, nine are near upgradient wells and six are far upgradient wells. Close examination of the groundwater database provided justification for elimination of select samples. Samples were eliminated based upon extreme concentrations in comparison to replicate samples.

Statistical analyses were preformed on the individual data sets to determine distribution, statistical similarities between near and far upgradient data, and upper tolerance limits. Results of the distribution analysis indicated that all data sets were nonparametrically distributed. The nitrate, sulfate and TDS near and far upgradient background data sets were shown to be statistically similar and so analyses on the combined data set was performed.

The 95th percentile was calculated as the non-parametric upper tolerance limit for all analyzed data sets. The 95th percentile should be used to compare to downgradient well concentrations to determine if "above expected background concentrations" exist. If the downgradient concentration is greater than the 95th percentile, contamination may be indicated. However, it should be noted that since the 95th percentile was calculated as the upper tolerance limit, statistically 5% of the time one would expect the upper tolerance limit to be exceeded. Because the nitrate, sulfate and TDS near and far upgradient data sets were statistically similar, the combined data set 95th percentile should be representative of upgradient background concentrations. Because the chloride near and far upgradient data sets were not statistically similar, it is advised to use the near upgradient 95th percentile for downgradient well concentration comparisons. A summary table of the parameter, data set, distribution, 95th percentile, range, and sample number is provided as Table E-1.

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