5.0 AQUIFER WATER COMPOSITION AND QUALITY

The chemical characteristics of water in each of the aquifers in the Grants Project area are evaluated and described in this section. The chemical data review of the various aquifers provides a useful tool in determining where the communication exists between the ground water systems and where seepage that has migrated into the alluvial aquifer has affected the water in the Chinle aquifers. The areas of the Chinle aquifers in which the chemical composition of water has been altered by inflow of alluvial water are herein labeled "the mixing zone". The focus of the ground water restoration in the Chinle aquifers is within the mixing zone. Because of the common element of alluvial water within the mixing zone, the mixing zone is considered a single ground water unit. References to the mixing zone will be in singular terminology despite the fact that portions of the mixing zone exist within each Chinle aquifer.

Stiff diagrams are used in the following sections to present the differences in water quality that exist in the different aquifers. The stiff diagrams are prepared using the concentrations of eight major constituents in milli-equivalents 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 composition while the magnitude or size relates to concentration.

5.1 ALLUVIAL WATER COMPOSITION AND QUALITY

A comparison of stiff diagrams, by alluvial well, for the near up-gradient alluvial water is shown on Figure 5-1. This diagram shows that the major cation is calcium and the major anion is sulfate in background alluvial water. The composition of water is very similar in each of these wells, indicating a general consistency of water composition in the background alluvial system.

An exception is well ND, which has the highest sodium, bicarbonate and chloride levels of the alluvial wells. Sodium is the major cation in well ND water. Concentrations of the remaining major ionic constituents in well ND water are significantly lower than those of the typical background alluvial water. Water in well ND has very low calcium concentrations and other water-quality characteristics (such as a greater natural sodium concentration) that are similar to the characteristics observed in Chinle aquifer water. The differences in well ND water composition demonstrate some naturally occurring variation in water type within the alluvium on the eastern portion of the project. Given the similarities in alluvial well ND water composition and the Chinle water, there may be a localized subsurface discharge of Chinle water to the alluvial aquifer on the east side of the up-gradient area that affects water quality in the alluvial aquifer.

Major ionic constituent concentrations have been posted on Figure 5-2 to show the spatial variation in calcium, sodium, bicarbonate and chloride concentration in the alluvial aquifer. This data is also tabulated in the upper left corner of Figure 5-2. The wells north of the Large Tailings area are all up-gradient of the site and not influenced by seepage from the tailings. A review of chemistry data from the up-gradient wells reveals that the background calcium concentration in alluvial water varies from 202 to 349 mg/l. As previously noted, the exception is the calcium concentration of 31 mg/l in well ND. Calcium concentrations vary over a larger range down-gradient of the tailings. Background concentrations of sodium vary from 234 to 381 mg/l in alluvial water. Concentrations of bicarbonate in the up-gradient alluvial wells vary over a wide range, from 149 to 376 mg/l. The range of measured background chloride concentrations is much smaller at 47 to 67 mg/l.

Major ionic constituent concentrations for wells down-gradient of the Large Tailings area are also presented on Figure 5-2. The locations and constituent concentrations are presented for the three Point of Compliance (POC) wells (S4, D1 and X) and three wells in the adjacent subdivisions. Typical concentrations of major ionic constituents in the San Andres deep aquifer water, that is used in the ground water restoration program for injection into the alluvial aquifer, are noted in the legend. Calcium concentrations in alluvial water are typically greater than 200 mg/l down-gradient of the tailings, with the lowest concentrations being observed at the POC well X. However, the water quality near well X has been influenced by injection of reverse osmosis (R. O.) product water.

5.2 REGIONAL CHINLE WATER QUALITY

Water-quality results for Chinle Formation wells are presented in Gordon (1961) for eight Chinle wells and numerous other Chinle wells in Baldwin and Rankin (1995). These reports indicate only that the wells are completed in the Chinle Formation and not any specific sandstone. The water-quality results in Gordon (1961) are for Chinle wells generally within ten miles of the Grants site. Figure 16 of Baldwin and Rankin (1995) shows the location of Chinle wells with water-quality data. These wells are mainly in the southeast or southwest portions of Cibola County in New Mexico. Both the results in Gordon (1961) and Baldwin and Rankin (1995) show a large range in concentrations for the Chinle water quality. The calcium concentration in some of the Chinle wells is very low while the calcium concentration is large in other Chinle wells. None of this water-quality data is useful in defining background concentrations of the Chinle aquifers at the Grants site but is useful in confirming that the natural range in concentrations in this aquifer system can be very large.

5.3 UPPER CHINLE WATER COMPOSITION AND QUALITY

A stiff diagram comparison for the northern Upper Chinle wells CW3, CW9, CW10, CW50 and CW52 is presented in Figure 5-3. Sodium is the major cation in water collected from these wells, and sulfate is the major anion with one exception. Bicarbonate and sulfate are the major anions in well CW52 water. As would be expected, the shapes of the diagrams for water from the Upper Chinle aquifer from wells CW3 and CW9 are significantly different than those for the up-gradient alluvial wells. For example, a comparison of stiff diagrams of water from Upper Chinle well CW3 and alluvial aquifer water reveals that well CW3 water has lower calcium concentrations and higher natural sodium concentrations than alluvial water.

The stiff diagrams for Upper Chinle wells CW10 and CW50 are similar to the alluvial diagrams because in the area that these wells represent the inflow of alluvial water has affected the Upper Chinle water quality. These wells are located in the area defined as the Upper Chinle mixing zone. The similarities with alluvial water indicate that the long-term exposure of the Upper Chinle sandstone to alluvial water in the mixing zone results in minimal alteration of water composition in this localized area. In this area, the sandstone unit itself is no longer influencing water composition due to the duration of contact with alluvial water.

Well CW52 is the farthest north of the Upper Chinle wells. Even though the major anion in this well is bicarbonate, the water composition from well CW52 is considered characteristic of mixing zone water due to its other characteristics. This well is located in the area of transition from mixing zone to Upper Chinle non-mixing zone water composition.

A stiff diagram comparison is presented on Figure 5-4 for water from Upper Chinle wells 931, 934, CW13, and CW18, which are located east of the East Fault. The injection of San Andres water into well CW13 has resulted in an anomalously higher bicarbonate concentration observed in water from well CW18 because San Andres water has higher bicarbonate and calcium concentrations than Upper Chinle water. The concentration of calcium and the other major ionic constituents in well CW18 water are comparable to natural levels found in the Upper Chinle non-mixing zone. The concentration of calcium in the San Andres water injected into well CW13 is typically 230 mg/l. The most recent calcium value for water collected from well CW18 was 49 mg/l. The elevated bicarbonate concentration in water from well CW18 indicates that San Andres water has reported to this area.

However, the absence of elevated calcium concentrations demonstrates that the Upper Chinle sandstone has some capacity to alter the composition of water, but the changes are specific to the constituent. The Upper Chinle sandstone at well CW18 has been exposed to San Andres water for several years, but the selective changes in Upper Chinle water quality indicate ongoing ion exchange processes and water composition alteration. This contrasts with the discussion in a previous paragraph where it was noted that little or no alteration of water composition occurs after prolonged exposure of the Upper Chinle sandstone to alluvial water in the mixing zone. Other examples of mixing zone areas where no significant alteration of invasive water composition occurs are areas near wells CW50 and CW10.

Upper Chinle well locations and selected ion constituent concentrations are presented in Figure 5-5. Calcium concentrations are naturally low in the Upper Chinle aquifer water, but concentrations in the mixing zone are similar to those found in alluvial water. Concentrations of sodium are typically higher in the Upper Chinle water than in the San Mateo alluvial aquifer. Bicarbonate concentrations are also naturally higher in the Upper Chinle water than in the alluvial water. Naturally occurring chloride concentrations measured in Upper Chinle water are similar to measured chloride concentrations in the alluvial aquifer except for the area east of the East Fault, where chloride concentrations naturally increase in the lower permeability areas of the Upper Chinle aquifer.

A pattern has been added to Figure 5-5 to distinguish the mixing zone area in which the Upper Chinle aquifer water quality has been influenced by inflow of alluvial water. A calcium concentration of less than 30 mg/l has been used to indicate the non-mixing zone. A calcium concentration of 30 mg/l reasonably separates the higher values near the subcrop and the lower concentrations away from the subcrop. The 2003 calcium concentration in well CW9 was below 30 at 24 mg/l but was still placed in the mixing zone because historical values have been above 30 mg/l. The 2003 calcium concentration from well CW18 was above 30 mg/l but was placed in the non-mixing zone because historical values have been below 30 mg/l prior to the injection influence of CW13 discussed earlier.

Communication between the alluvial aquifer and the Upper Chinle aquifer has permitted alluvial water to enter the Upper Chinle aquifer resulting in a change in water composition in this area. The water quality in the Upper Chinle mixing zone shown on Figure 5-5 is similar to the water quality of the alluvial aquifer. The mixing zone for the Upper Chinle includes all the subcrop area, where direct communication between the alluvial aquifer and Upper Chinle aquifer exists, but also includes the area south of the Large Tailings extending to the East Fault. Background alluvial water has moved into the Upper Chinle in the subcrop area north of the tailings. This water then moves in the Upper Chinle aquifer and eventually discharges back to the alluvial aquifer on the south side of Felice Acres. Seepage from the tailings below the Large Tailings Pile enters portions of the alluvial aquifer which migrates to the Upper Chinle aquifer subcrop in this area. This water commingles with Upper Chinle water as it moves down-gradient south of the tailings areas. Portions of the mixing zone that are a greater distant from the tailings area have not been affected by tailings seepage.

The areal extent of the Upper Chinle mixing zone prior to the tailings deposition is believed to be similar to its present day extent and location. Upper Chinle wells that have had elevated selenium and uranium concentrations from tailings seepage such as CE2, CW4R, CW5 and CW25 are within the present mixing zone. Calcium concentrations in the Upper Chinle water near these four wells were believed to be elevated prior to the tailings deposition due to historical flow of alluvial water through this mixing zone portion of the Upper Chinle aquifer.

5.4 MIDDLE CHINLE WATER COMPOSITION AND QUALITY

Stiff diagram comparisons of the water-quality composition for the Middle Chinle wells are presented on Figure 5-6. The stiff diagrams for the five Middle Chinle well waters are consistent with each other in shape and are similar to typical Upper Chinle stiff diagrams. A plan view that includes well locations and posting of calcium, sodium, bicarbonate and chloride concentrations for Middle Chinle wells is presented on Figure 5-7. Calcium concentrations are low in the Middle Chinle aquifer west and east of the East Fault except in the area that has been affected by the subcrop connection with the alluvial aquifer south of Felice Acres. Higher calcium concentrations are typically found in samples from the Middle Chinle aquifer west of the West Fault. A mixing zone pattern has been added to this figure to show an area of calcium concentrations equal to or greater than 30 mg/l. Middle Chinle aquifer water quality in this area is similar to that of the alluvial aquifer, and therefore this area is considered to be within the Chinle/alluvial mixing zone.

Although well 434 is outside of the mixing zone, the measured calcium concentration in water from this well is high at over 200 mg/l. The elevated calcium concentration in this area is believed attributable to a poor well completion that creates communication between the alluvial aquifer and the Middle Chinle aquifer in the well annulus.

A stiff diagram comparison of the four Middle Chinle wells west of the West Fault and wells CW1 and CW2 that are located between the two faults immediately up-gradient of the LTP is presented on Figure 5-8. The stiff diagrams for the wells west of the West Fault are substantially different from those for wells CW1 and CW2. The concentrations in the Middle Chinle west of the West Fault are higher than the alluvial aquifer background concentrations and they generally increase to the south. Communication with the alluvial aquifer north of the site and west of the West Fault allows alluvial water to flow through the Middle Chinle aquifer to the southwest and discharge in its subcrop area. This has altered the water quality of the Middle Chinle aquifer west of the West Fault to a water quality similar to the alluvial aquifer water. However, the direction of ground water flow west of the West Fault precludes the entry of seepage-altered alluvial water in this area. The mixing zone pattern on Figure 5-7 covers the entire portion of 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. All of these Middle Chinle wells contain water of a quality similar to that of the alluvial aquifer.

Unlike the mixing zone in the Middle Chinle west of the West Fault, the mixing zone in the Middle Chinle between the two faults and southeast of Felice Acres have been affected by tailings seepage through hydraulic contact with seepage-altered alluvial water at its subcrop. The uranium concentration in alluvial well 496, for example, is elevated at 0.44 mg/l which illustrates the affects from tailings seepage in southern Felice Acres. However, the major constituent concentrations of the alluvial water at the subcrop of the Middle Chinle with the alluvium are well within background concentrations. Therefore tailings seepage has affected some minor constituents even though the major constituents have not been significantly changed in the mixing zone in the Middle Chinle aquifer in this area.

5.5 LOWER CHINLE WATER COMPOSITION AND QUALITY

The natural water composition in the Lower Chinle aquifer varies considerably, reflecting the limited permeability and dependence on fracture permeability within Chinle shale for ground water conveyance in this aquifer. The chemical composition of water for the Lower Chinle aquifer also differs from that of the other Chinle aquifers. Stiff diagram comparisons are provided for the six southern Lower Chinle wells and the five northern Lower Chinle wells on Figures 5-9 and 5-10, respectively. Based on the calcium concentration, water of Lower Chinle well CW41 is similar to the typical water composition for the Upper and Middle Chinle non-mixing zones while water composition in samples from other wells varies widely. The calcium, sodium, bicarbonate and chloride concentrations in the Lower Chinle aquifer wells are presented on Figure 5-11. Review of this data confirms that the range of concentrations of major ion constituents in the Lower Chinle aquifer is relatively broad. Inflow of alluvial aquifer water has probably affected some of the Lower Chinle aquifer water near its subcrop area. It is also typical that major constituent concentrations naturally increase as ground water flows down-gradient in a shale. This natural increase is due to the long residence time of water in the low permeability rock. The poor quality of water in the Lower Chinle aquifer may reflect both of these influences.

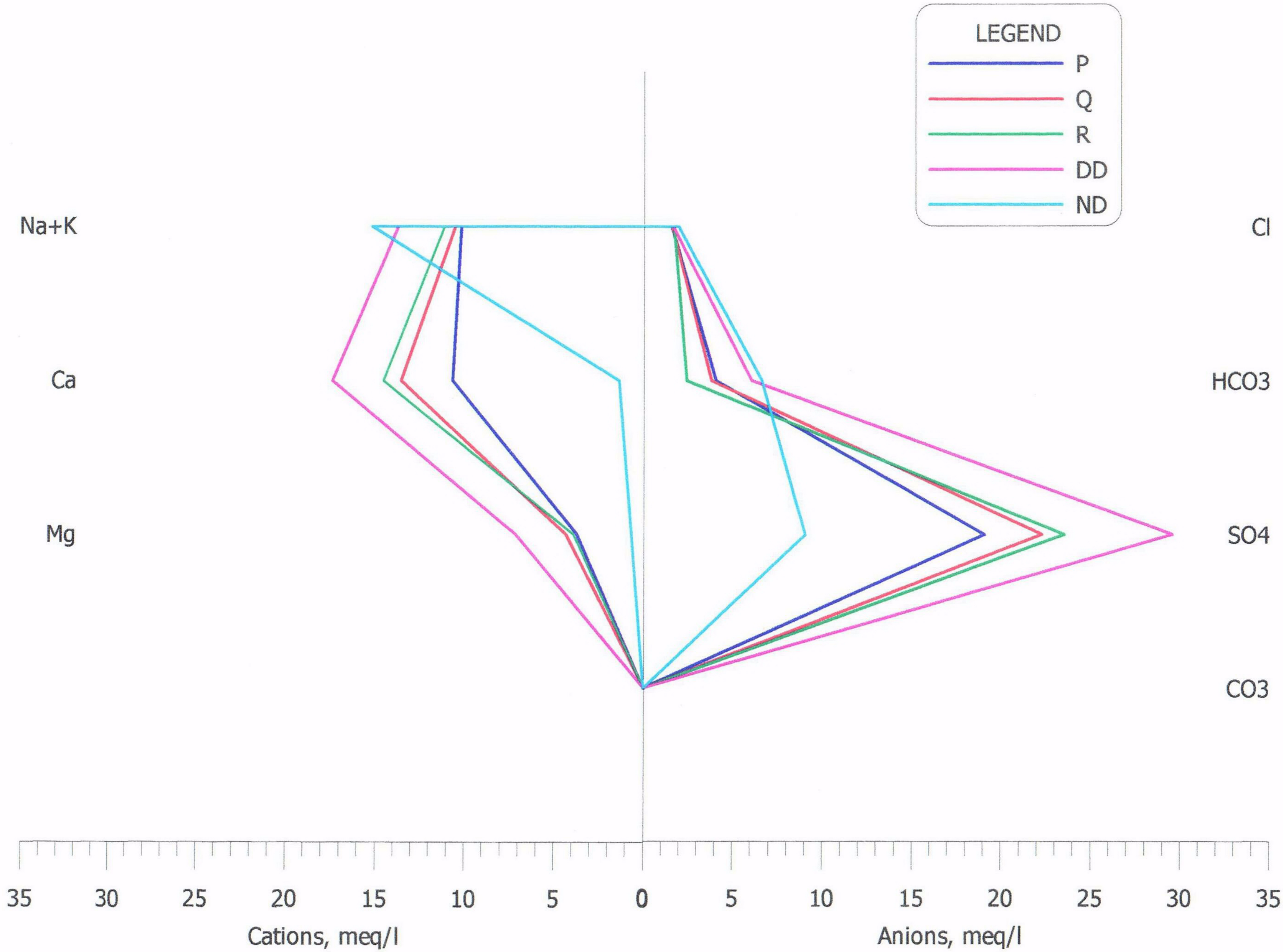
The natural deterioration of water quality as the ground water moves down-gradient from the subcrop makes it more difficult to define the mixing zone in the Lower Chinle aquifer. The mixing zones for the Lower Chinle aquifer are adjacent to the subcrop areas. A comparison of differences in calcium concentration is not useful in distinguishing between the mixing zone and the non-mixing zone for the Lower Chinle aquifer because calcium concentrations generally increase in the down-gradient direction in a shale. Only well CW41 contains water with calcium concentrations less than 30 mg/l. The data from well CW41 indicates that the water quality found in the mixing zone has not influenced this well but calcium cannot necessarily be used in the remainder of the Lower Chinle wells to select the area of the mixing zone.

The concentrations of major constituents in the alluvial water at the Lower Chinle subcrop area have not been affected by seepage from the tailings. Therefore, the current mixing zone in the Lower Chinle is also unaffected, and thus, very likely the same as it was prior to the deposition of tailings.

5.6 WATER COMPOSITION AND QUALITY OF THE MIXING ZONES

The preceding discussions of water quality in the mixing zones of the Chinle aquifers describe the natural alteration of water composition that occurs in the mixing zones after prolonged influx of alluvial water. Although the water composition in the mixing zones may be very similar to alluvial water based on the major ion constituents, the concentrations of minor constituents may be significantly different in the ground water systems. Minor constituents are considered to be those constituents that are present in very low concentrations, typically a few mg/l or less.

One particular example is selenium. Concentrations of selenium in the mixing zones are lower than selenium concentrations in the alluvial aquifer. Selenium concentrations in the Upper Chinle aquifer are presented in Figure 5-12. A typical background selenium concentration in the alluvial aquifer up-gradient of the Large Tailings pile is approximately 0.2 mg/l. A comparison of selenium concentrations in the up-gradient mixing zone in the Upper Chinle (see Figure 5-12) reveal much lower concentrations varying between 0.03 and 0.007 mg/l. In summary, the chemical composition of mixing zone water in the Chinle aquifers and the alluvial water are similar, but the similarities do not consistently extend to minor constituents such as selenium. For this reason, the mixing zones for the Upper, Middle and Lower Chinle are treated as one mixing zone and distinguished from the alluvial aquifer. This combined mixing zone is considered a separate ground water system for the evaluation of background water quality.



5-9

FIGURE 5-1. STIFF DIAGRAM COMPARISON OF NEAR UP-GRADIENT ALLUVIAL WATER QUALITY.

C01

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 UP-GRADIENT				
914	120	314	51	88
916	6	130	252	27
920	416	233	2228	59
921	367	301	232	69
922	3	385	591	73
950	65	467	276	136

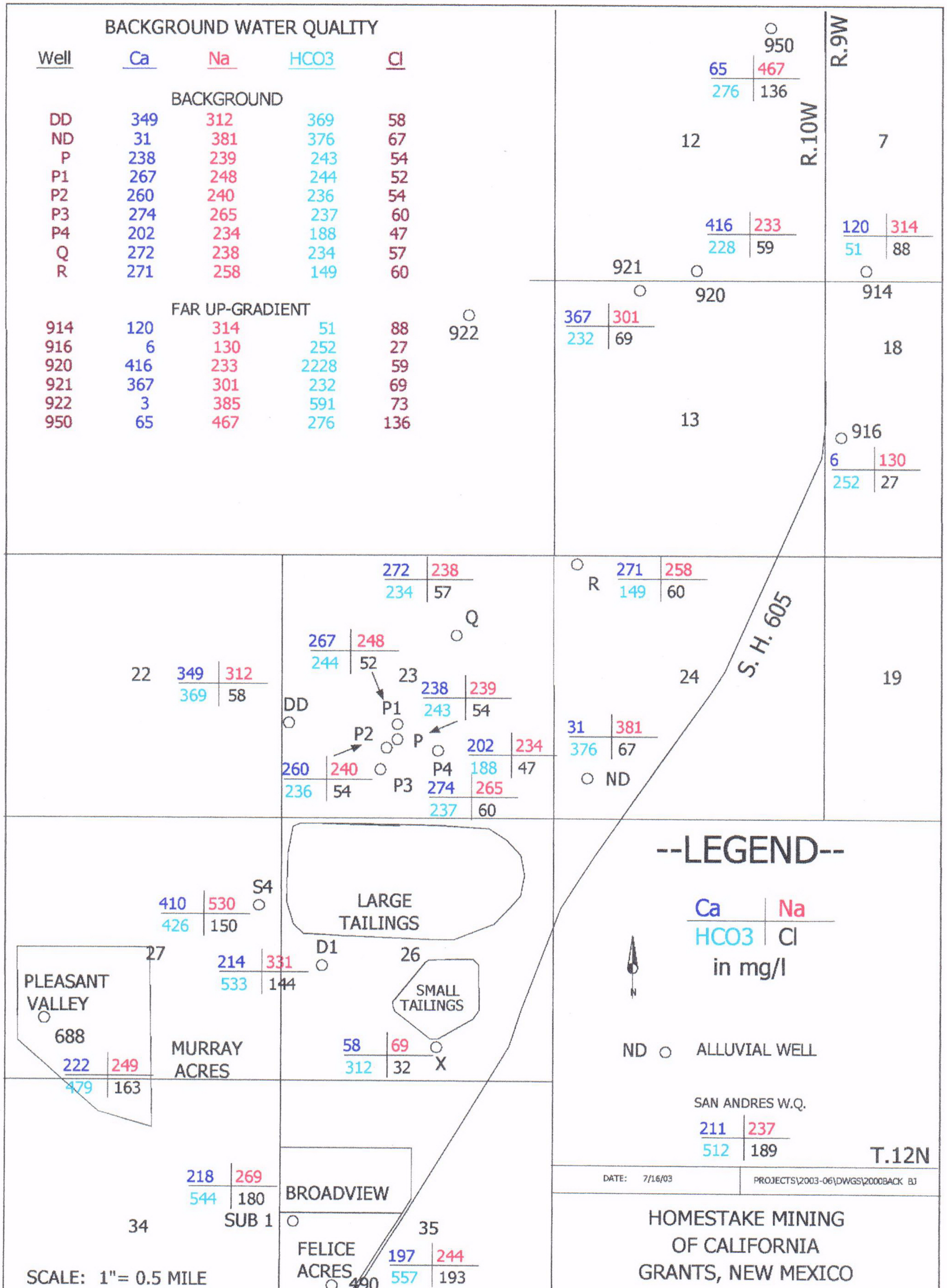


FIGURE 5-2. Ca, Na, HCO3 AND Cl CONCENTRATION COMPARISONS OF THE BACKGROUND ALLUVIAL WELLS

C02

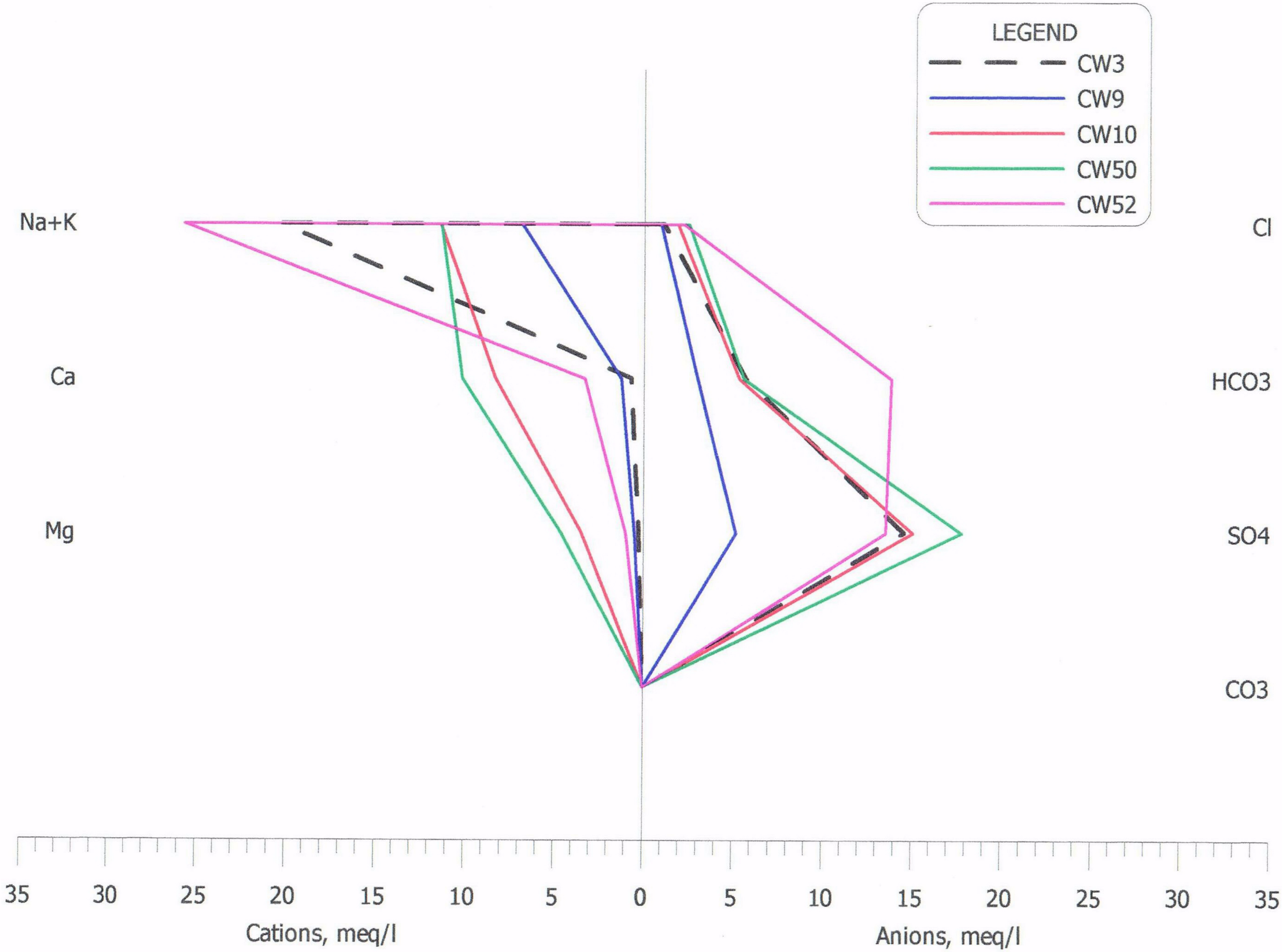


FIGURE 5-3. STIFF DIAGRAM COMPARISON OF UPPER CHINLE WATER QUALITY IN THE NORTH WELLS.

C03

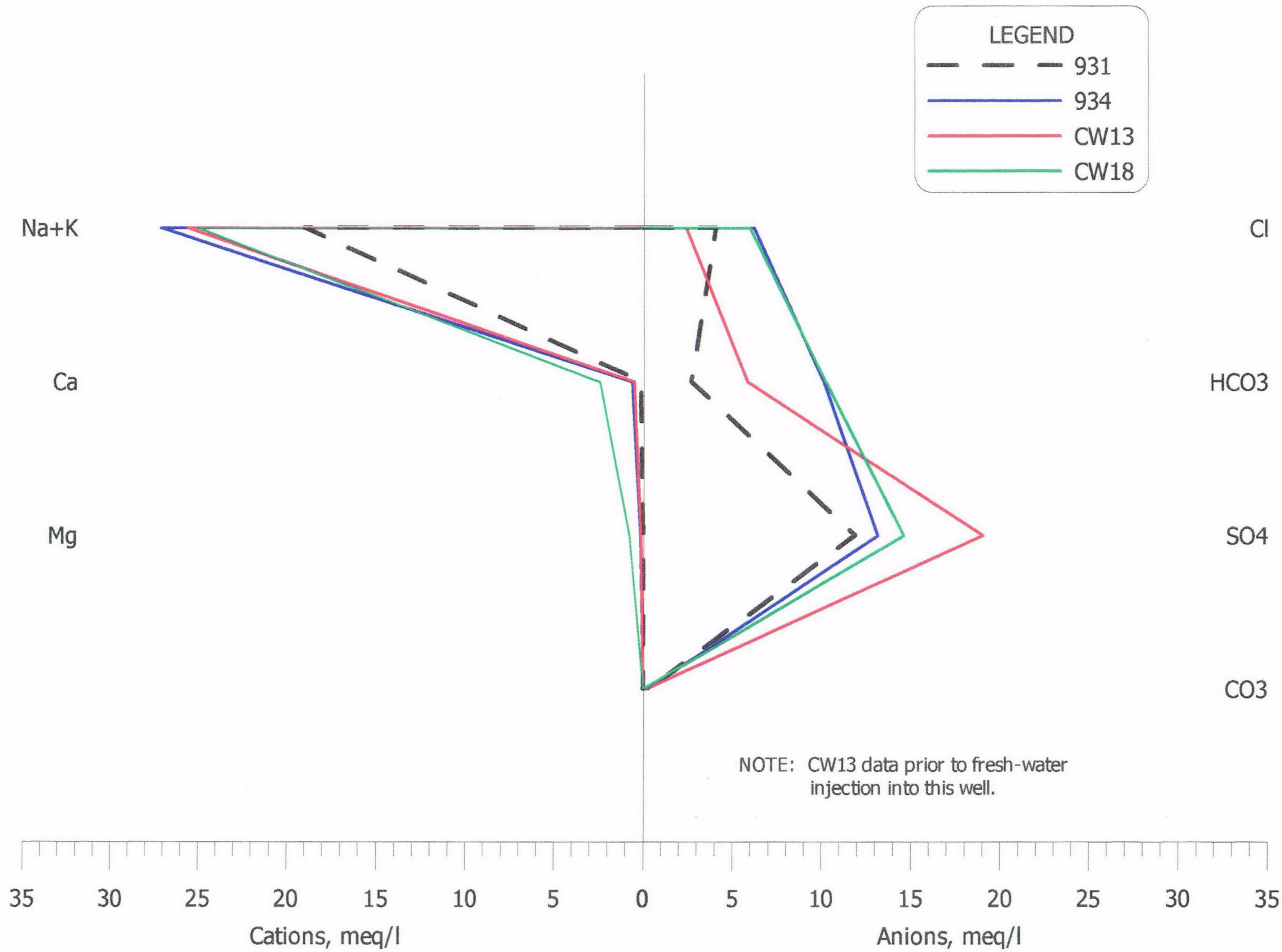


FIGURE 5-4. STIFF DIAGRAM COMPARISON OF UPPER CHINLE WATER QUALITY IN THE EAST WELLS.

C04

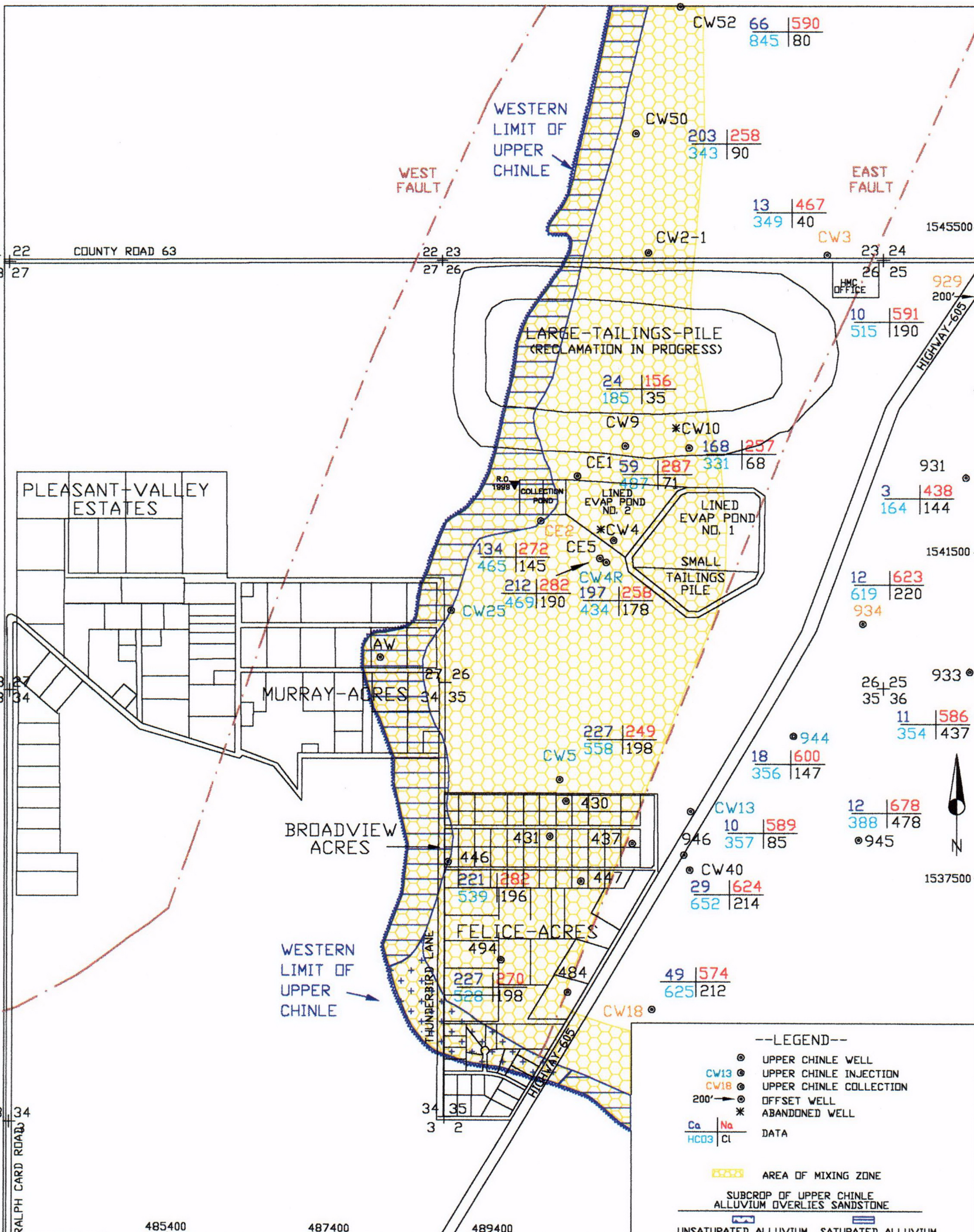


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	FIGURE 5-5. Ca, Na, HCO3 and Cl CONCENTRATION COMPARISONS OF THE UPPER CHINLE AQUIFER, in mg/l	c:\dd\projects\2003-06\UP1600
		page 5-13

C05

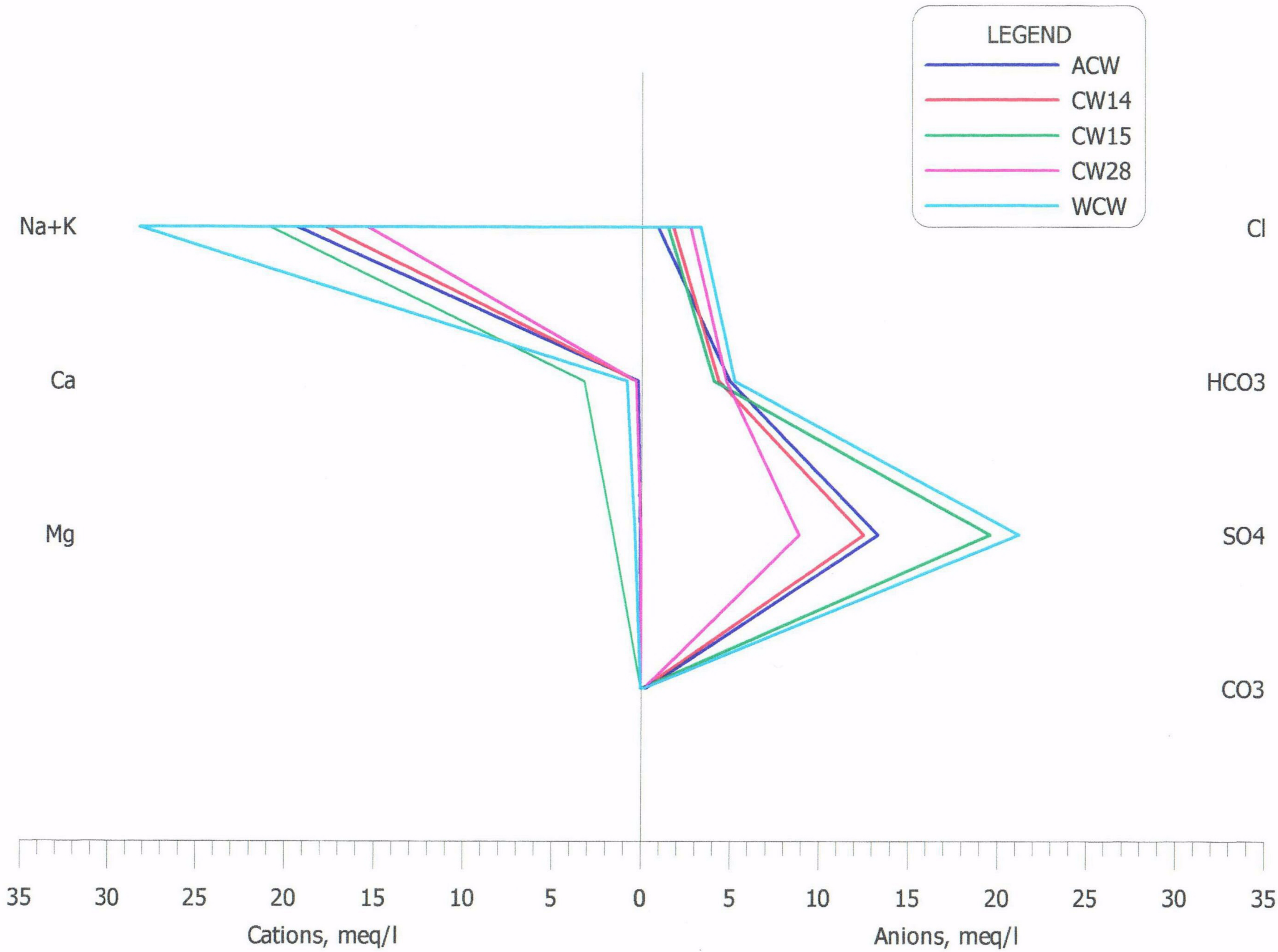

FIGURE 5-6. STIFF DIAGRAM COMPARISON OF MIDDLE CHINLE WATER QUALITY IN THE SOUTH WELLS.

C06

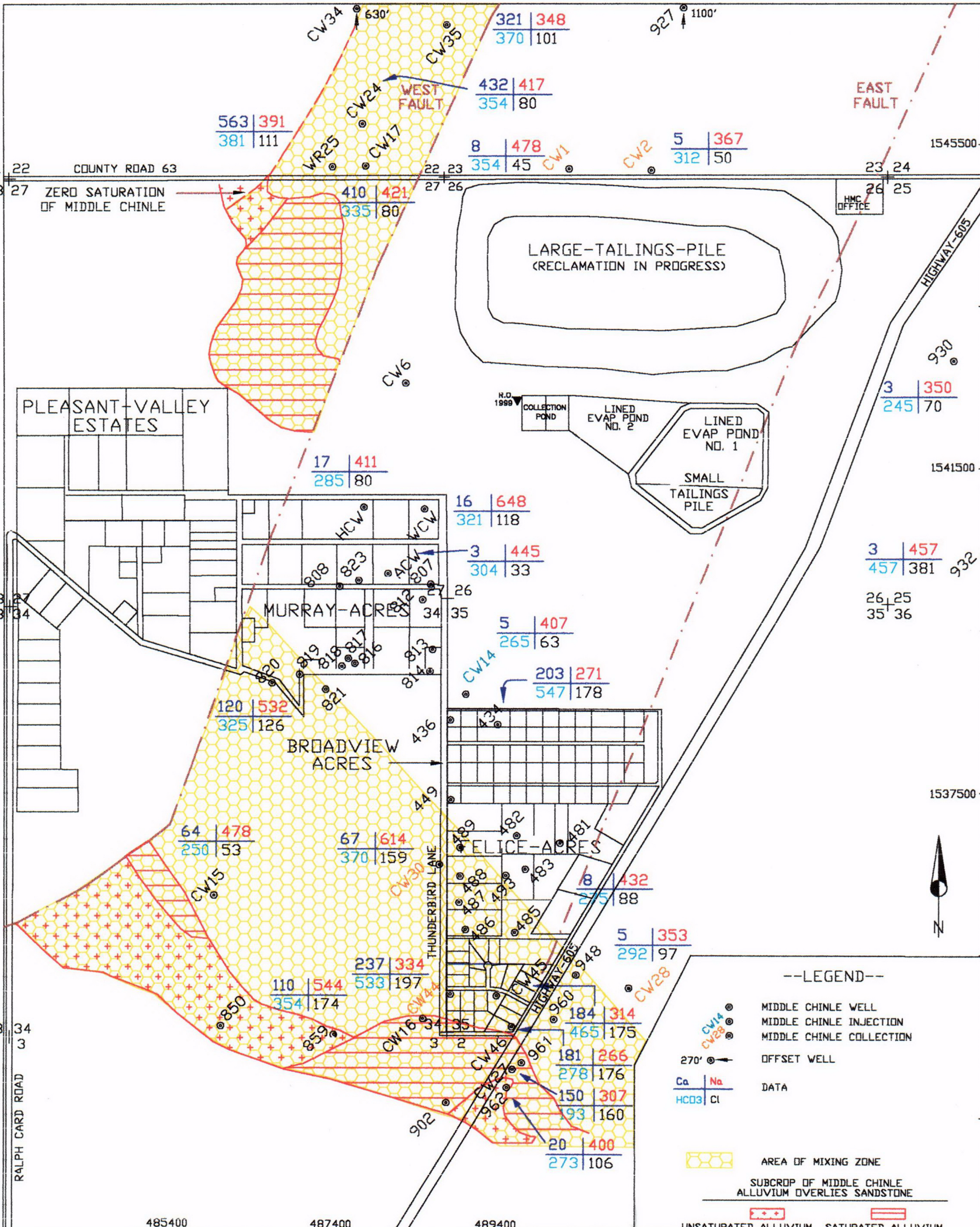

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FIGURE 5-7. Ca, Na, HCO3 and Cl CONCENTRATION COMPARISONS OF THE MIDDLE CHINLE AQUIFER, in mg/l

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C07

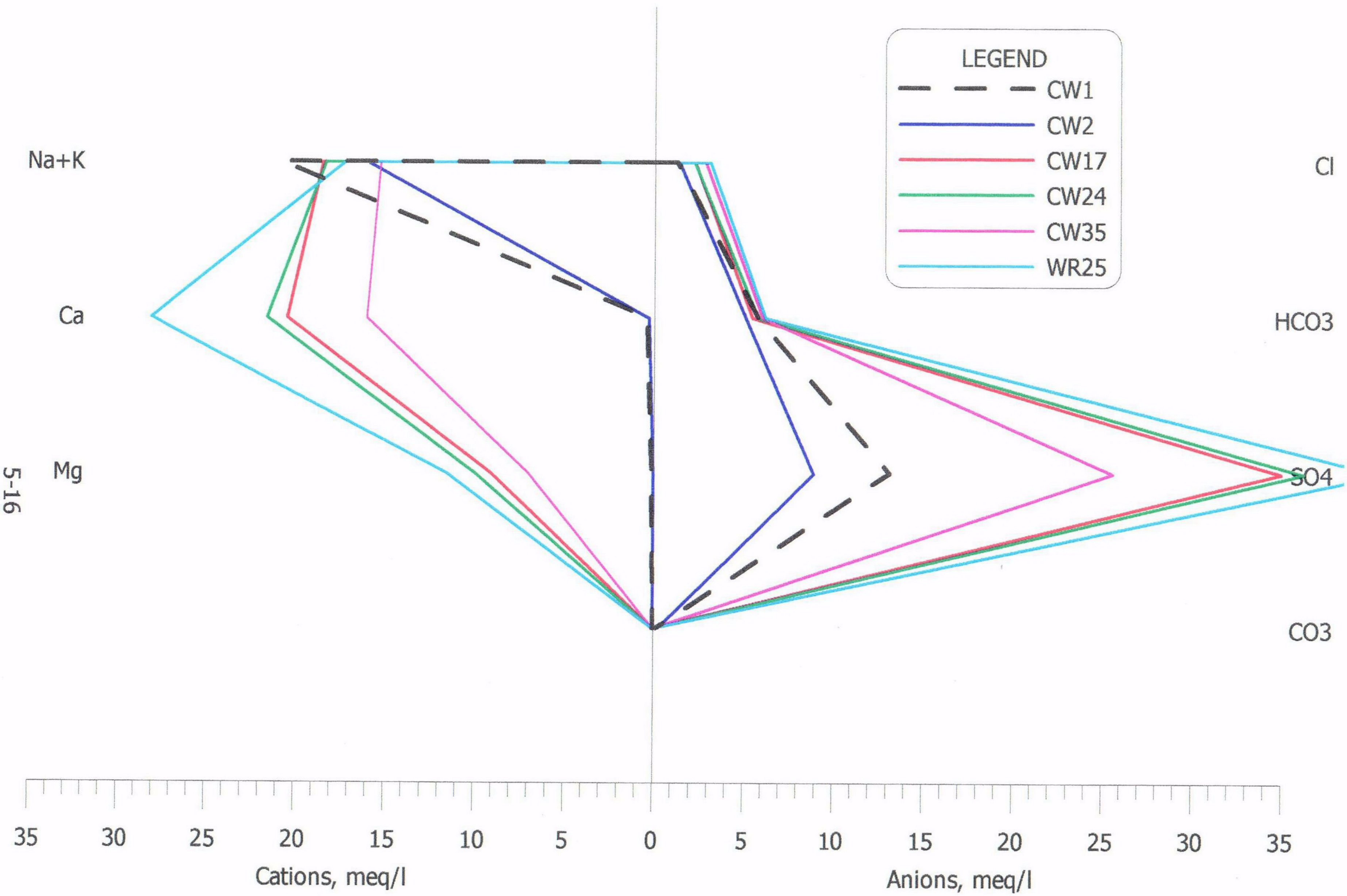

FIGURE 5-8. STIFF DIAGRAM COMPARISON OF MIDDLE CHINLE WATER QUALITY IN THE NORTH WELLS.

5-16

C08

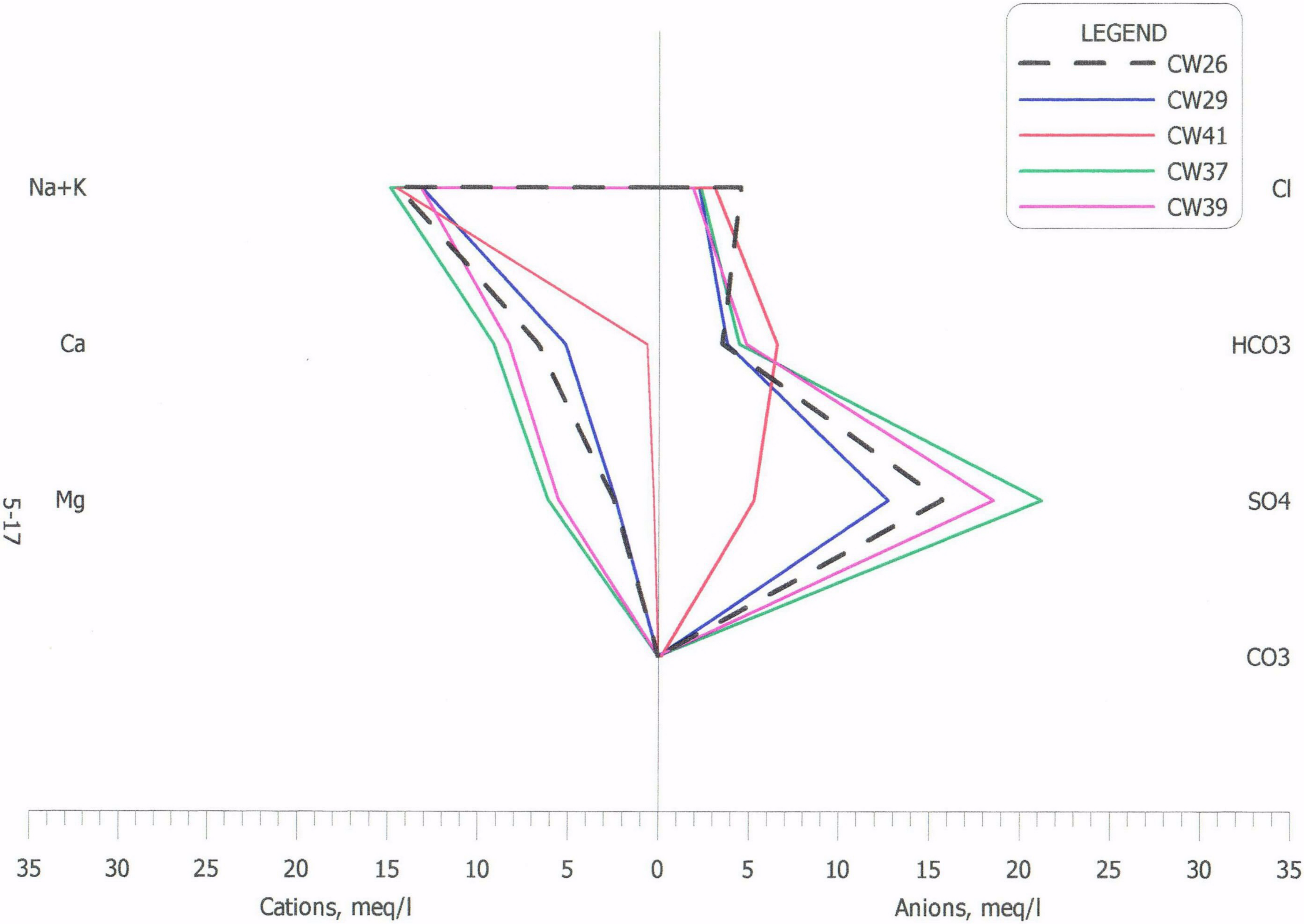

FIGURE 5-9. STIFF DIAGRAM COMPARISON OF LOWER CHINLE WATER QUALITY IN THE SOUTH WELLS.

C09

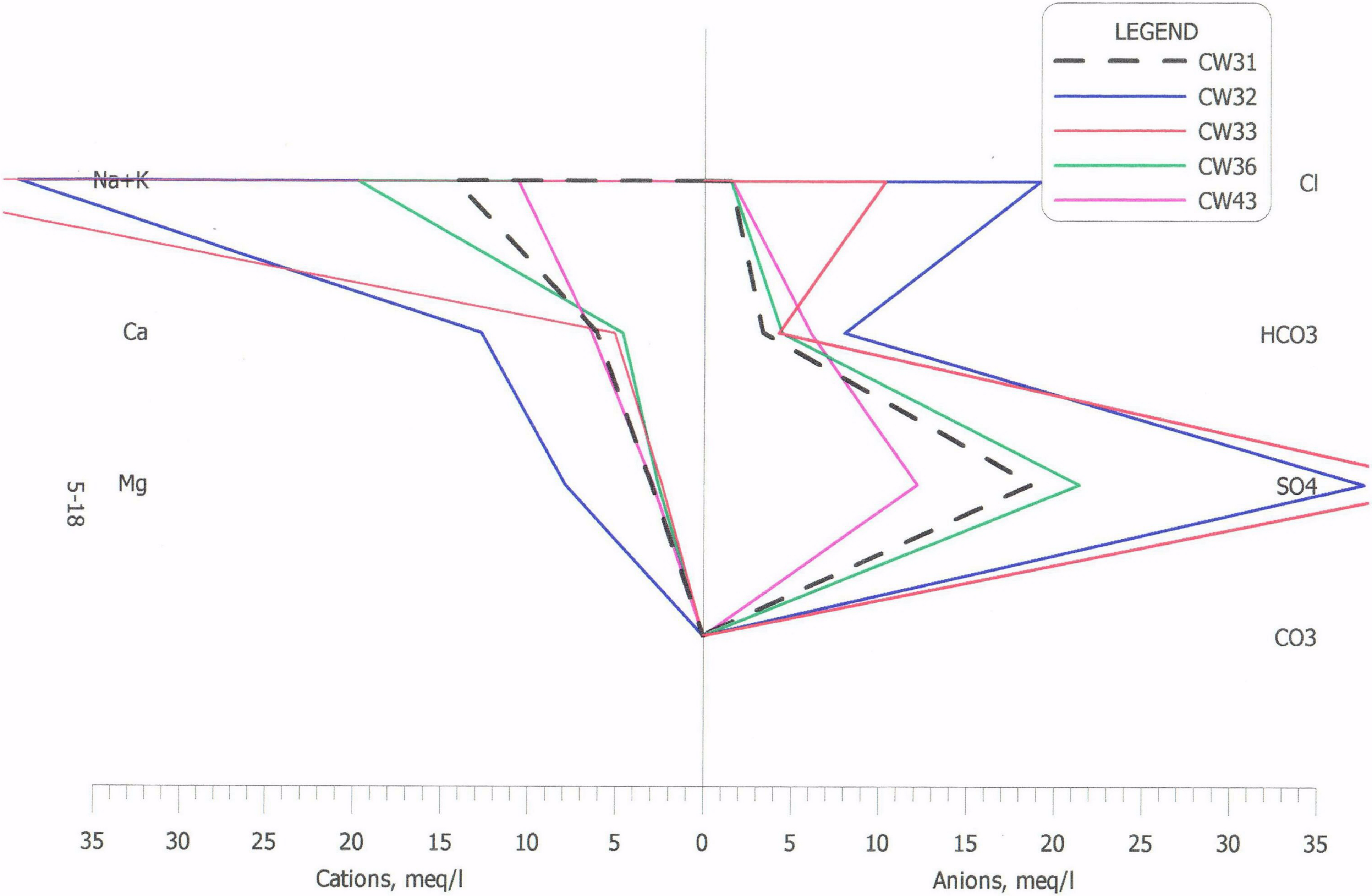

FIGURE 5-10. STIFF DIAGRAM COMPARISON OF LOWER CHINLE WATER QUALITY IN THE NORTH WELLS.

C10

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FIGURE 5-11. Ca, Na, HCO3 AND Cl CONCENTRATION COMPARISONS OF THE LOWER CHINLE AQUIFER, in mg/l

C11

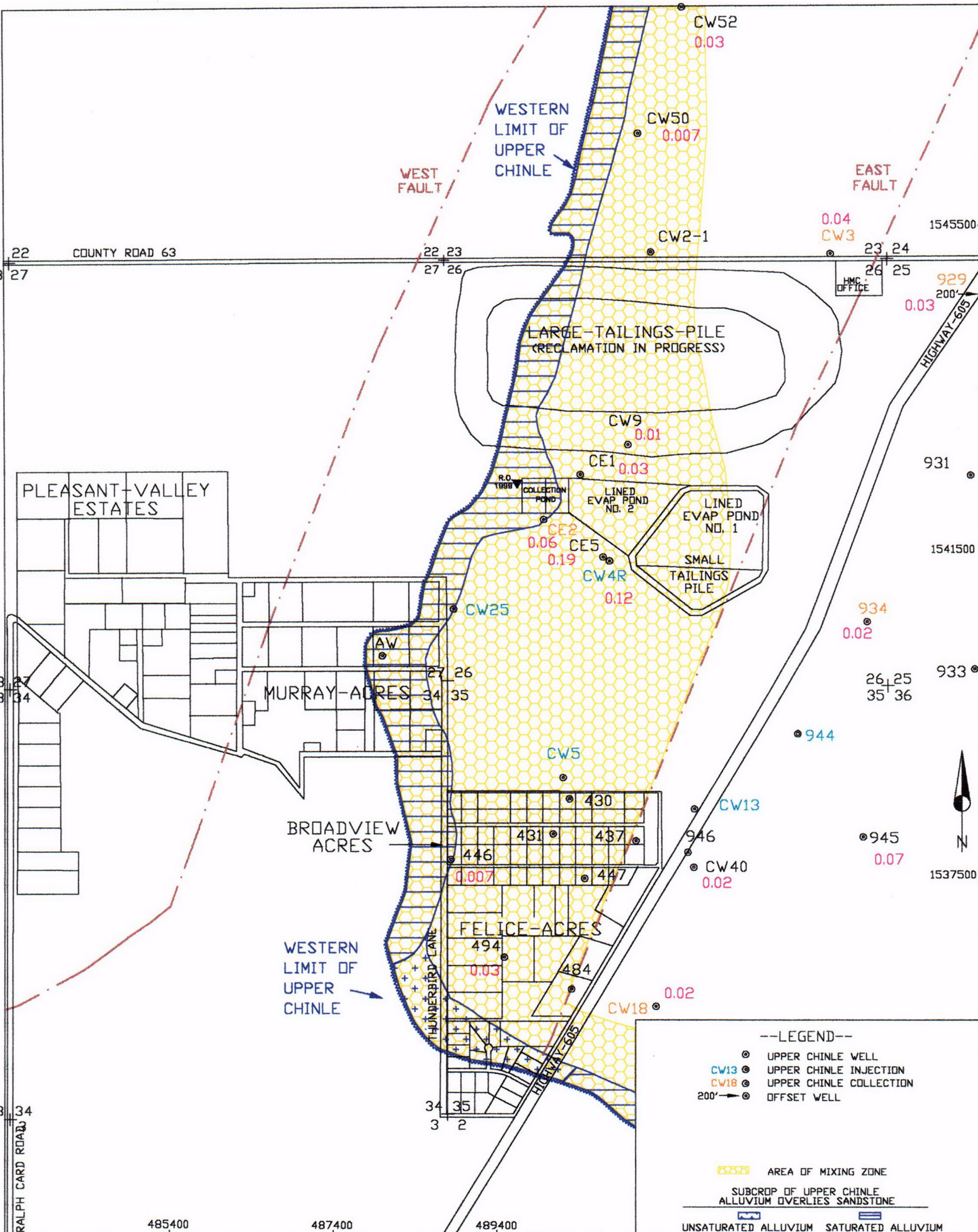

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FIGURE 5-12. SELENIUM CONCENTRATION COMPARISONS OF THE UPPER CHINLE AQUIFER, 2003, in mg/l

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C12