SOIL CHARACTERIZATION AND ATTENUATION STUDIES

Prepared For:

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GRANTS RECLAMATION PROJECT

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1 *INTRODUCTION*

Alluvial aquifer wells for Homestake's Grants Reclamation Project contain levels of uranium and selenium which could exceed groundwater standards. Soils may have the ability to naturally attenuate metals and nonmetals through application of alluvial well waters. Potential attenuation processes include the adsorption of metals on the soil exchange complex, chelation of metals and non-metals, formation of stable chemical complexes in the soil, immobilization of metals in reducing environments such as wetlands, chemical adsorption and complexation, armoring or coating of elements by other chemicals such as calcium carbonates, and vegetative uptake.

Since the capabilities of the area soils to attenuate metals was unknown, a study was undertaken to collect baseline soil data for use in evaluating the potential processes for removal of uranium and selenium from alluvial waters. Baseline soil data was used for development and interpretation of natural soil attenuation capabilities and provided basic design information for other project studies, such as, potential anaerobic wetland systems. The baseline characterization also allowed for a determination of potential metal loading calculations and risk assessments

A field and laboratory program was designed to gather the soils information necessary to characterize the site soils and develop soil information necessary to evaluate natural selenium and uranium removal resulting from potential land application options. Initially the soil baseline characterization centered on the soil conditions located in the south ½ of Section 28, Section 34, Township 12 North, Range 10 West and also included the north ½ of Section 3, Township 11 North, Range 10 West. Following the intital field studies, additional sites were added to the study. These areas included the NE1/4 of Section 28, NW1/4 Section 27, SE1/4 Section 29, S1/2 Section 20, S1/2 Section 21, S1/2 Section 22, Section 25, NE1/4 Section 32, and S1/2 Section 33, Township 12 North, Range 10 West. The entire study area is shown on Figure 1-1.

Since land application by irrigation could be one option selected for attenuation of these elements from the alluvial waters, agronomic management concerns also needed to be addressed. These issues included the possibility of salt loading of the soils to a point where vegetative productivity is reduced or the soil loading of undesirable concentrations of sodium which would result in lower water infiltration and hydraulic conductivity rates. Efficient management of the land applied water requires a balance of rates of infiltration necessary to achieve attenuation of metals and of rates necessary to achieve leaching of salts and sodium below the active root zone. For this reason, soil infiltration studies were conducted in the field to determine efficient irrigation application rates. Agronomic and metal loading irrigation rate schedules were developed to assist in water management decisions.

The preliminary soil characterization data was also utilized in the design of column attenuation studies. The column attenuation studies were designed to supplement the baseline data characterization by evaluating the natural ability of the site soils to attenuate selenium and uranium. Bench testing was conducted to evaluate the potential to artificially attenuate selenium by the addition of common chemicals to the soils. The bench tests were followed up by a small scale field pilot test of the procedures. Finally, since land application by irrigation is a potential selenium and uranium removal process, vegetative uptake of these metals was studied.

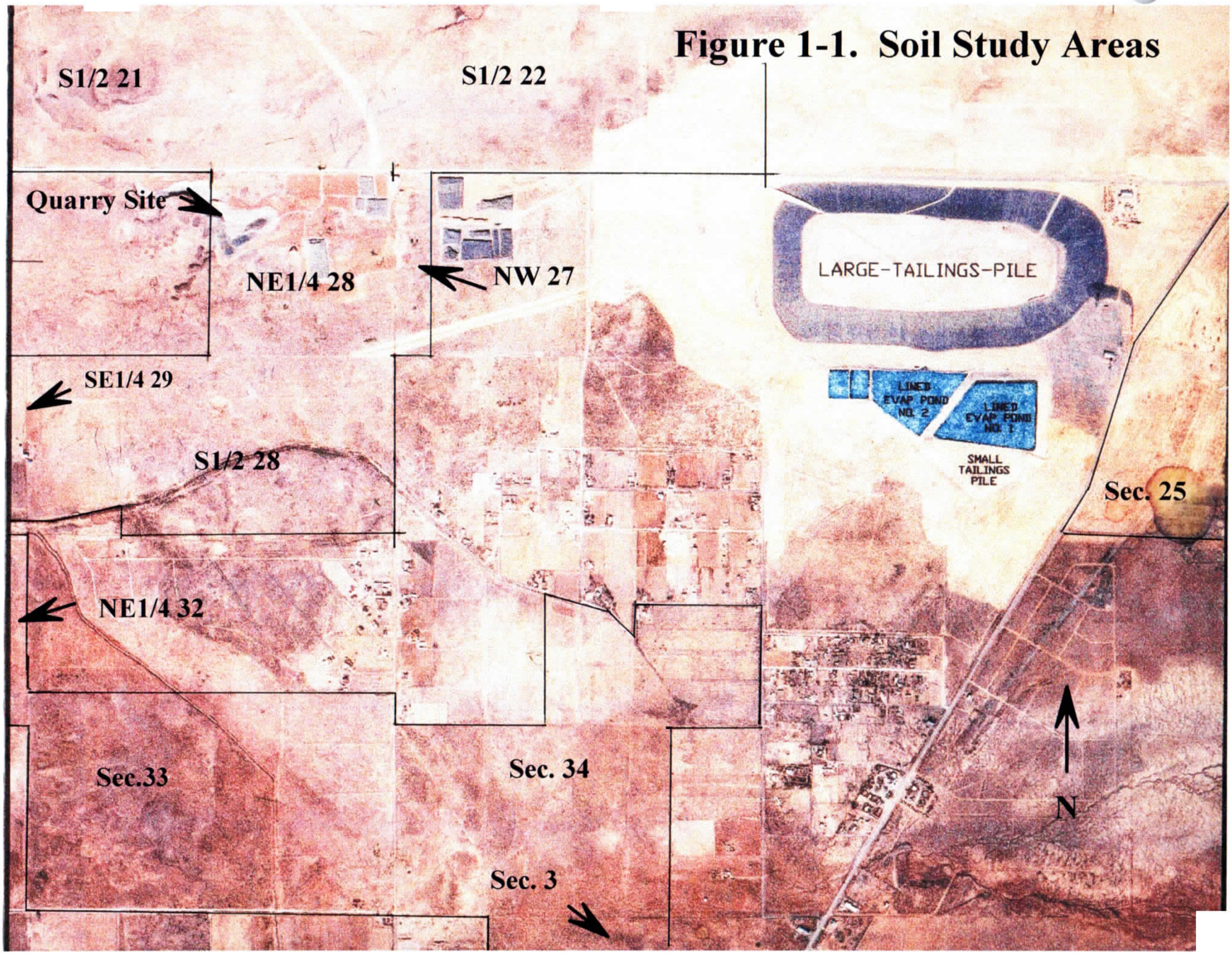
Figure 1-1. Soil Study Areas
S1/2 21
S1/2 22
Quarry Site
NE1/4 28
NW 27
LARGE-TAILINGS-PILE
SE1/4 29
LINED EVAP POND NO. 2
LINED EVAP POND NO. 1
SMALL TAILINGS PILE
S1/2 28
Sec. 25
NE1/4 32
Sec.33
Sec. 34
N
Sec. 3

2 *ATTENUATION THEORY REVIEW*

As stated previously, the process of selenium and uranium attenuation or immobilization could result from several complex chemical, physical, or biological processes. While the processes may be numerous, this study focussed on three specific processes which may attenuate selenium and uranium in an arid climate utilizing land application procedures. Those processes are adsorption of metals of the soil cation exchange complex, chemical adsorption of metals, and vegetative uptake of metals. The theory of these three processes are briefly discussed in this section.

Soils have the ability to adsorb cations onto the soil cation exchange complex associated primarily with the negatively charged soil clay fraction, and, to a lesser extent, the soil organic fraction. Positively charged metal ions, such as uranium, may be directly adsorbed onto the clay layers if free exchange sites exist, or the uranium may replace or substitute other cations on the soil exchange complex. Uranium is a cationic metal whose activity and ionic strength depends extensively on its oxidation state and that strength may range anywhere from a +2 to +6 valence. In the case of the alkaline, semi-arid to arid soils located at the site, the exchange complex is naturally occupied predominantly by calcium (+2), magnesium (+2), and sodium (+1) ions, all cations which can be readily replaced on the exchange complex by uranium. In general, as the strength of cations increases, the ability of those cations to replace lower strength cations on the exchange complex also increases. The ability of the project site soils to adsorb uranium onto the exchange complex is dependent on the amount of clay in the soils and on the amount of cation exchange capacity (CEC) directly associated with those clays (Hausenbuiller, 1978; Buol, et al., 1973).

Elemental selenium is an anion that will not directly adsorb onto the clay exchange complex. Selenium at the site will be predominantly comprised of the selenate species (Se 6+) and, to a lesser extent, selenite (Se 4+). Data from the site indicates that approximately 90 percent of the

alluvial water selenium is present in the selenate form. Reduced species of selenium, such as selenides (Se 2-), are not expected to be naturally present at the site in significant quantities. The species of selenium present in soils and water is directly related to soil or water reduction-oxidation (redox) potential and to pH. These two processes are largely responsible for controlling the solubility and chemical speciation of selenium. (Elrashidi, et al., 1989; McNeal and Balistrieri, 1989).

Generally, soils and waters with high redox and high pH will be dominated by selenate selenium. These conditions exist at the site as evidenced by site data on the selenate/selenite ratio. Selenites (Se 4+) occur under moderte pH and mildly oxidizing conditions and may also be are sorbed onto iron oxide complexes. Selenates (Se 6+) are not readily absorbed by iron oxides and are extremely mobilein the environment and they are the most likely species of selenium to be uptaken by vegetation or easily leached deeper in the soil profile (Elrashidi, et al., 1987; Merril, et al., 1986; Balistrieri & Chao, 1987, 1989; Gissel-Nielsen & Bisbjerb, 1979; Eisler, 1985). Selenium attenuation may also occur in reducing environments, such as anoxic wetlands, where methylation of selenium takes place (Elrashidi, etal., 1989), however, these conditions are not likely to be naturally present at the site.

The ferric hydroxide-ferric selenite adsorption process could be an important attenuation mechanism if selenium is present in the selinite form or is readily converted to the selenite form. Selenate is the dominate selenium species in the alluvial groundwater at the Grants Reclamation project, due largely to high redox and high pH conditions. At mildly oxidizing or moderate pH conditions, selenite would become more prevalent. It is now well known in industry that water treatment processes which utilize iron-coprecipitation technology has shown moderate success in removal of selenium when selenites are present (UNOCAL, 1996). This process utilizes sodium or calcium based chemicals to neutralize acid mine drainage and removes metals from the treated water by floculation with polymers. The sludge produced by this process is dominantly an "iron-hydroxide" sludge which is very stable in a basic (pH>6.0) environment (UNOCAL,

1996). Unfortuantely, this process seldom removes enough selenium to achieve required surface water discharge standards. In order for this process to be efficient at removing selenium to water quality standards, selenate must be converted to selenite prior to adsorption. *RIMCON* believes the moderate removal of selenium in water treatment plants using this process is due to the fact that chemical reaction times are short-lived and that adsorption sites are quickly consumed by multiple metals present in the neutralized water. However, it is still theoretically possible to utilize the iron-coprecipitation process to remove selenium from groundwater (UNOCAL, 1996).

In recent years, the accumulation of selenium in plants has been studied extensively. Most research has been centered on uptake of selenium in agricultural regions irrigated with high selenium waters. Some plants, known as primary selenium inidcator species, actually require selenium to survive and are capable of taking up selenium in very high concnetrations (several thousand mg Se per kg). (Mikkelsen et al., 1989; Rosenfeld and Beath, 1964; Banuelos et al., 1997). As briefly discussed earlier, the uptake of selenium by plants is governed largely by the species of selenium present in soil and water. Selenate is very mobile in natural environments and is not readily precipitated by various soil properties and is readily taken up by plants. The capacity of different plant species to take up selenium varies widely. Banuelos et al., 1997, have studied the removal of selenium by several forage plants, including Birdsfoot trefoil (Lotus corniculatus L.) and alfalfa (Medicago sativa L.). Their research shows that both trefoil and alfalfa efficiently remove selenium from soils which had been irrigated with high selenium content waters. Trefoil was more efficient at selenium removal than alfalfa but had significantly lower forage yields resulting in both plants removing similar amounts of selenium. Their research noted the importance of harvesting the plants before selenium accumulates in excess of 5 mg/kg, a level which is considered potentially toxic to livestock. Removal of selenium by vegetative uptake may become an important process if alluvial waters are land applied to soils through irrgiation practices.

3 *SOIL BASELINE STUDIES*

A field investigation, coupled with laboratory verification of field conditions, was utilized to define the characteristics of the soils at the project site. Initially, the soil investigations were centered on the investigation of parts of Sections 28 and 34, Township 12 North, Range 10 West and Section 3, Township 11 North, Range 10 West. Additional characterization of soils occurred in parts of Sections 20, 21, 22, 25, 29, 32, and 33 of Township 12 North, Range 10 West. These areas are shown on Figure 1-1.

3.1 SOIL CHARACTERIZATION PROCEDURES

Prior to initiation of the field work, all pertinent soil data for the mill site was reviewed. A published soil survey for Cibola County, New Mexico (Natural Resource Conservation Service, 1993) was obtained and the descriptions and classifications of all site soils were reviewed. The published soil survey served as the baseline information of soil conditions for the site. In addition, prior to this study, three soil samples were obtained by Homestake from Murray Acres subdivision located in the SE1/4 of Section 27, T12N, R10W and three soil samples were obtained from the Broadview Acres subdivision located in the NW1/4 of Section 35, T12N, R10W. The samples were taken in 1994 and analyzed for molybdenum, selenium, and uranium. The location of these samples is shown on Figure 3-1 and Figure 3-3 of this section.

Soil transects were established across the study areas and a backhoe was utilized to excavate soil characterization pits along each transect. A total of 71 backhoe trenches were dug throughout the study area for the purpose of providing detailed soil descriptions and for sampling purposes. In addition, five (5) hand auger sites were also excavated for the study. Standard soil profile descriptions for each trench were developed documenting important soil parameters such as soil horizon type and depth, color, soil texture, structure, plasticity, lime content, salt content, root abundance and location, and horizon boundary conditions. Other information, such as, trench location, topography, slope, vegetation, parent material sources, and the presence or absence of

artifacts were noted. Since parts of Section 33, 34, and Section 3 were irrigated in the late 1940's, particular attention was given to detailing any visible affects of past irrigation on these soils. The soils in the irrigated areas were compared to similar soils in non-irrigated areas and obvious differences were noted.

Bulk composite samples were obtained from selected representative trenches for laboratory analyses and for column and bench testing. Sample composites were made from soil horizons exhibiting similar profile characterisitics, particularly similar soil textures. Column and bench test methods are reported later in Sections 5.0 and 6.0. A total of 64 composite samples were submitted to the laboratory for baseline characterization of soil particle size and texture, including sand, silt, and clay content, electrical conductivity (EC), exchangeable sodium percentage (ESP), cation exchange capacity (CEC), selenium, and uranium. The results of the laboratory evaluations were utilized as a verification of observed field conditions, provided irrigation interpretation information, and provided baseline data for column, bench, and field selenium and uranium attenuation tests.

3.2 BASELINE SOIL CHARACTERISTICS

The following discussio provides a description of the baseline soil conditions at the Grants Reclamation project study sites.

3.2.1 MURRAY ACRES AND BROADVIEW ACRES

The soil sampling in these subdivisions was conducted in 1994 and results of the sampling are shown in Table 3-1. No soil survey characterization was conducted at the time of the sampling, however, the Cibola County soil survey provides published information for the sites. The soils in both subdivision are dominated by the San Mateo soil series and are characterized by sandy loam textured surfaces and sandy clay loam subsurfaces. Heavy clay alluvial soils may be present at depths of 40 inches or greater. The soils are suitable for sprinkler irrigation and have

a moderate water infiltration capacity. With proper management, the soils may also be flood irrigated with furrow irrigation practices.

The soils of Murray Acres have molybdenum levels below laboratory detection limits. Selenium levels in these soils range from very low (non-detect) to moderately high (1.81 mg/kg). Uranium levels for all three samples are moderately high and range from 1.54 pCi/g to 4.82 pCi/g (2.27 mg/kg to 7.12 mg/kg). The soils of Broadview Acres also had molybdenum levels below laboratory detection limits. Selenium levels were significantly higher than the levels exhibited in Murray Acres and ranged from 0.86 mg/kg to 2.19 mg/kg and averaged 1.51 mg/kg. In addition, uranium levels were moderately high to high and ranged from 3.47 pCi/g to 11.38 pCi/g (5.13 mg/kg to 16.81 mg/kg).

3.2.2 SECTIONS 34 and 3 CONDITIONS

Because of their proximity to each other and their similar characteristics, the results of Section 34 and Section 3 evaluations are presented together in this section. The published soil survey for this area has identified the major soil mapping unit for Section 34 as the Sparank clay loam with minor inclusions of San Mateo sandy loams. The southeast corner of Section 34 and the north half of Section 3 have been mapped as the Venadito clay loam mapping unit. Both the Sparank and Venadito soils have very high clay contents with low soil water permeabilities. All of these soils formed on alluvial plains and are typically young soils. A total of 17 backhoe trenches were excavated for detailed evaluation and characterization of the Section 34 and Section 3 soils. Refer to Figure 3-1 for the location of Section 34/3 backhoe trenches and Appendix A for detailed soil profile descriptions.

Typically, the surface layers were dark yellowish brown sandy clay loam to clay soils about 3 inches thick. The upper part of the underlying material is massive dark yellowish brown clay loam to clay soils ranging from 15 to 40 inches thick. Often, a buried heavy textured surface

horizon was noted at depths of approximately 25 to 30 inches indicating different alluvial deposition periods. This entire area is underlain by loamy fine sands and fine sands to the depth of backhoe trenching. Generally, these soils had higher surface soil clay contents in the northern part of Section 3 and the southern portion of Section 34 than in other portions of the area. The depth to sands was much shallower (15 to 25 inches) near the centerline of Section 34. These soils, while mapped as the Sparank series by the NRCS, with San Mateo inclusions, appear to be represented by the San Mateo series as the section centerline is approached. The general boundaries of these soils, as delineated by the trenches, are been depicted on Figure 3-1.

Table 3-2 presents by soil series the results of the laboratory data sampled to verify field observations and to provide a baseline for irrigation and attenuation interpretations. As expected, the clay content of the Section 34/3 surface soils was high and ranged from 22 percent to 60 percent. The results of the CEC analyses followed normal trends, that is, as clay content generally increased, the CEC also increased. CEC values ranged from less than 10 meq/100g in the sands to up to 40 meq/100g in the clays.

Baseline selenium levels were low in these soils and ranged from non-detect to 0.40 mg/kg. It does not appear that selenium levels were related to clay content and selenium values were variable within soil textural units. Uranium concentrations were variable and ranged from 0.20 to 5.85 pCi/g (0.30 to 8.64 mg/kg) with the majority of the soils exhibiting uranium levels less than 1.0 pCi/g (1.477 mg/kg).

The effects of irrigation in the 1940's were evident in these soils. Most of the soils showed visible concentrations of salts at various depths in the soil profiles. The location of the salt concentrations corresponds to the point in the profile where downward soil water movement balances with upward capillary rise of soil water during times of irrigation with depths generally ranging from 20 to 40 inches. Electrical conductivity data shows the salt content in the root zone of these soils ranging up to approximately 10 mmhos/cm with a mean electrical conductivity in

the root zone of approximately 2.4 mmhos/cm. Salt levels in excess of 8 mmhos/cm in the root zone would be considered potentially toxic to many irrigated row crops. It appears that the largest concentrations of salts exist in the southern third of Section 34 as evidenced by both field observations and laboratory data. It is highly likely that these areas in the lower portion of the field were areas where flood irrigation waters often collected and pooled for periods of time, resulting in concentration of salts.

The ESP values were variable throughout Section 34 and Section 3. ESP values were low in the deeper sands, as expected, and ranged up to 14.5 percent in the clays. The amount of exchangeable sodium in the soil system is directly related to clay content and CEC levels, and to the sodium concentrations and salinity levels of the irrigation waters.. The clays have significantly more exchange sites than do sands and sodium can easily be adsorbed onto these sites. Because sodium tends to fit easier into the clay interlayers, it often is preferentially adsorbed over calcium and magnesium. When sodium is present on the exchange sites and the interlayers, significant soil swelling can occur when the soils are wet and significant decreases in soil water permeability occurs. Review of the literature suggests that the Sparank soil series normally does not have significant concentrations of exchangeable sodium. It appears that the location of the elevated sodium levels also occurs in the southern third of Section 34. It is highly likely that the presence of the exchangeable sodium is directly related to the irrigation waters and to the higher clay contents of these soils.

3.2.3 SECTIONS 27, 28, and 29 CONDITIONS

The western ¼ of the NW ¼ of Section 27 and most of Section 28 were evaluated for soil characteristics. In addition, the SE ¼ of Section 29 has been flood irrigated and sprinkler irrigated with Bluewater River or local well water for several years and was evaluated for irrigation purposes. The published soil survey has identified the major soil mapping unit in the S1/2 and NE1/4 of Section 28 and the Section 27 study area as the Glenberg-San Mateo

Complex. The NW1/4 of Section 28 was not sampled since it is largely covered by a rock quarry. These soils are much sandier than the Sparank and Venadito soils in Section 34. They developed on alluvial plains and are typically young soils. A total of 25 backhoe trenches and 1 hand auger site was evaluateded in the Sections 27 and 28 soils for characterization. Locations of the backhoe trenches are shown on Figure 3-2 and detailed soil profile descriptions for each trench (or hand auger site) are provided in Appendix B. Note that portions of the surface soils of the NE1/4 of Section 28 have been disturbed by quarry activities.

Typically, the surface horizon is dark yellowish brown sandy loams to sandy clay loams about 4 inches deep. The subsurface is typically dark yellowish brown sandy loam textures and ranges to 25 inches deep. Below 25 inches, the soils are stratified loamy sands with very low clay content. Several swales exist in the study area (see Figure 3-2) which have slightly higher clay content in the surface horizons than exhibited by the other site soils. These swale soils have been characterized in trenches S28-2, S28-5, and S28-10, NW27-1, and NW27-2. Sites S28-1, S28-2, S28-5, and S28-11 had buried lenses of clay with depth. It is likely that these clay lenses are discontinuous and are not areally extensive. Site S28-13 was an auger hole site and was mapped as the Sparank series similar to those described in Section 34. The boundaries between these soils are depicted on Figure 3-2.

As discussed above, the soils within the NE1/4 of Section 28 have been disturbed by rock quarry activities. Topsoil has been removed from some areas and stockpiled for future use on the area. In addition, rock was stockpiled in the area and, even though the stockpiles are now gone, the rock base for the stockpiles still exist in two locations. These bases are approximately 8 inches thick and very compacted. Haul roads in the area are also still present and very compacted and, in places, rock up to 15 inches in diameter have been scattered over small areas. Refer to Figure 3-2 for the location of these features.

Representative bulk soil samples were taken from sites S28-2, S28-3, and S28-9, NE28-2, NE28-4, NE28-5, NE28-7, and NW27-1 for characterization of the Section 27 and 28 soils. Table 3-2 summarizes the soil laboratory data, by soil series, for these areas. The clay content of these soils were very low when compared to the Section 34 soils. With the exception of the soils represented by the S28-2 trench, the clay content is generally less than 15 percent. Sand content of these soils often exceeded 80 percent of the overall soil texture. Correspondingly, the CEC values were also very low and averaged less than 10 meq/100g resulting in limited exchange sites for attenuation purposes. Only the S28-2 surface soils exhibited CEC values in excess of 10 meq/100g.

Selenium concentrations are similar to those present in the Section 34 soils and are generally low. Selenium levels ranged from non-detect up to 0.182 mg/kg and again, there does not appear to be any relationship between selenium levels and clay content. Uranium concentrations were also low with the majority of the samples averaging less than 0.30 pCi/g (0.44 mg/kg). Only the surface of site S28-2 exhibited a uranium level in excess of 1.0 pCi/g (1.477 mg/kg). With the exception of the single value for uranium in excess of 1.0 pCi/g, there does not appear to be a relationship between clay content and uranium content. This relationship is not surprising since the clay content and the CEC of these soils are both very low.

Salinity levels were also very low in these soils with electrical conductivities averaging only 0.40 mmhos/cm. These soils were not previously irrigated and do not exhibit salt accumulations in the root zones. As with the low salinity levels, the exchangeable sodium percentages were also very low. Visual examination of the soil profiles did not reveal characteristic soil traits associated with elevated sodium levels and the mean ESP is only 0.50 percent.

The irrigated soils in the SE1/4 of Section 29were mapped as the Venadito clay loam soil series and were expected to be similar to the soils found in the N1/2 of Section 3. However, field examination and laboratory analyses indicate they are more similar to the Sparank series. Refer

to the detailed soil description of these soils in Section 3.2 of this report. Composite soil samples were obtained from this site using a hand auger. Those samples have been identified as sites G-1 (SE29-1) and G-2 (SE29-2). Refer to the detailed soil profile descriptions located in Appendix B. Laboratory data for these soils is summarized in Table 3-2 by soil series.

These soils have been irrigated for several years with Bluewater River or local well water and show no evidence of salt loading or sodium loading from the irrigation waters. This water is expected to be low in these parameters and the soils verify this assumption. The textures for these soils are similar to previously described Sparank soils. In addition, the CEC of these soils is similar to other Sparank soils with a mean CEC of 29.1 meq/100g. As stated above, these soils did not exhibit elevated salt characteristics in the field and the laboratory data verifies this condition with a mean electrical conductivity of less than 1.0 mmhos/cm and, exchangeble sodium percentages are also very low. The mean selenium concentration was also low at 0.06 mg/kg. Uranium was similar to the other Sparank soils with a mean concentration of 0.45 pCi/g (0.66 mg/kg).

3.2.4 SECTIONS 20, 21, and 22 CONDITIONS

As with the Section 34 and Section 3 soils, the soil descriptions for Sections 20, 21, and 22 have been combined due to their proximity to each other and to their similarities. The southern third of Section 22 and the southern third of the SE1/4 Section 21 have been presented in the published soil survey as the Glenberg-San Mateo complex. Note that these soils are similar to the majority of the Section 28 soils. The central third of these areas have been mapped in the published soil survey as the Sparank-San Mateo Complex. As described previously, the Glenberg-San Mateo Complex is very sandy while the Sparank soils have significant clay contents. A total of 3 backhoe trenches were excavated in Section 21 and 10 trenches were excavated in Section 22. Section 20 and the SW1/4 of Section 21 have soils dominated by the presence of basalt at the surface or very near the surface. These soils are not suitable for

irrigation and were not evaluated further. Refer to Figure 3-3 for the location of the backhoe trenches and Appendix C for detailed soil descriptions.

Examination of sites S21-3, S22-8, S28-9, and S28-10 depict soils very similar to those described in Section 28. That is, the surface horizons are typically dark yellowish brown sandy loam textures about 4 inches deep. Subsurface soils are also dark yellowish brown sandy loam textures and range up to 25 inches deep. At depths greater than 25 inches, the soils are stratified loamy sands. Clay lenses were not present anywhere within the documented soil profiles. Because of their similarity to the Section 28 soils, these soils were not sampled for laboratory analyses or for column testing. As with the Section 28 soils, salts were not evident in these profiles and the soils did not exhibit characteristic traits associated the presence of elevated levels of exchangeable sodium. The approximate boundary separating these sandier soils from the soils to the north is shown on Figure 3-3.

The central portion of Sections 21 and 22 have been characterized by backhoe trenches S21-1, S21-2, S22-1, S22-2, S22-3, S22-4, S22-5, S22-6, and S22-7. These sites exhibit dark yellowish brown to dark brown clay loam surface horizons about 4 inches deep. The subsurface horizons are dark brown clay loam to clay textures up to 40 inches thick. As with the Section 34 soils, the majority of these soils had stratified loamy sands below the clay horizons to the depth of excavation. Sites S22-5, S22-6, and S22-7 had clay thicknesses to 50 inches and the backhoe was not able to penetrate these soils to excavate deeper to determine if stratified sands exists below the clays at these sites. These soils are similar to the Sparank soils located in Section 34 with the exception that the Section 21/22 Sparank soils were never irrigated and did not exhibit visible salts in the clay horizons. Refer to the location of the Sparank soils on Figure 3-3.

3.2.5 SECTION 25 CONDITIONS

The western portion of the Section 25 soils have had their surface horizons removed as part of the wind-blown contaminant clean-up project. The soils located along the western edge of Section 25 have been previously mapped as the Mespun loamy sand series. These are deep wind-blown soils characterized by yellowish brown loamy sand surface horizons about 2 inches thick. The underlying material is typically brown loamy sands to sands to greater than 60 inches. Permeability of these soils is rapid and available water holding capacities are low.

The majority of the rest of Section 25 has been mapped as the Penistaja sandy loam series. Typically, the surface layer is brown fine sandy loams about 4 inches thick. The upper part of the subsoil is brown sandy clay loams about 20 inches thick. This layer is characterized by a strong, very blocky structural horizon with low permeability. The lower part of the subsoil is light brown and yellowish brown sandy loams to depths greater than 60 inches.

Five backhoe trenches, represented as S25-1 through S25-5, were excavated to characterize these soils. Refer to Figure 3-4 for the location of these backhoe trenches and Appendix D for detailed trench descriptions. Representative bulk soil samples were obtained from these sites and saved for submission to the laboratory for analyses, as necessary.

3.2.6 SECTIONS 32 AND 33 CONDITIONS

Some soils in the NW1/4 of Section 32 are being sporatically irrigated and additional acreage is in the process of being leveled for future irrigation from Bluewater River or local well waters. The irrigable soils in this area are mapped as the Aparejo clay loam and the Venadito clay loam. The areas suitable for irrigation are relatively small (approximately 2 to 10 acres), isolated units requiring signifcant ditching to spread water to these areas. The largest mapping unit in the NW1/4 Section 32 is the Viuda-Penistaja-rock outcrop complex. This unit covers approximately 100 acres of the quarter section and is dominated by the presence of basalt bedrock at the surface

or at shallow depths. The unit is not suitable for irrigation and was not studied further. Figure 3-5 depicts the location of these soils.

Refer to Section 3.2.2 of this report for detailed soil descriptions of the Venadito soils. The Venadito soil was represented in this study by hand auger site NE32-1. The Aparejo soil, represented by site NE32-2, typically has a reddish brown clay loam surface horizon about 6 inches thick. The upper part of the underlying material is reddish brown and light reddish brown clay loam about 40 inches thick and the lower part to a depth of 60 inches or more is light reddish brown clay loam. Bulk soil samples were obtained from each site and submitted for laboratory analyses.

Results of the laboratory analyses for site NE32-1 show a clay loam textures throughout the soil profile and a corresponding mean CEC value of 29 meq/100g. Salinity and exchangeable sodium levels are low in these soils and show no adverse affects of previous irrigation. Selenium levels are non-detectable and uranium levels are also low with a mean value of 0.38 pCi/g (0.56 mg/kg). The results of the laboratory analyses for the Aparejo soil, represented by site NE32-2, show a clay loam surface texture with a moderate CEC of 29.6 meq/100g. The subsurface soils are sandy loams with a slightly lower CEC of 25.3 meq/100g, reflecting the lower clay content of the soils. The substratum for this site is sandy. As with site NE32-1, salinity levels and exchangeable sodium percentages are very low for these soils. Selenium is non-detectable and uranium concentrations are low with a mean value of 0.36 pCi/g (0.53 mg/kg).

The southern 3000 feet of Section 33 was also examined for soil characterization. This area is split by the Rio San Jose ditch and two distinct soil areas exist. The area to the east of the ditch has been leveled and flood irrigated in the past. This area was most likely last irrigated in the early 1950's. These soils are dominated by the Vendito clay loam series and are nearly identical to the soils described for Section 34. Field examination of site S33-1 indicated that this soil was

similar to the Aparejo clay loam , sandy substratum soils, rather than the Venadito series. Figure 3-5 shows the location of these clay loam soils.

Backhoe trenches were excavated at two sites within these soils, identified as sites S33-1 and S33-2 were sampled for laboratory characterization. While the previously irrgiated soils in Section 34 showed evidence of past irrigation and salt accumulation, these soils did not show visible evidence of salt loading in the field. The soils appeared to be slightly better drained than the Section 34 soils and irrigation water was not allowed to pond at the lower end of the fields.

The laboratory analyses for site S33-1 confirm the high clay content described in the field and has a corresponding high CEC mean value of 38 meq/100g. These soils also show minor affects of previous irrigation with slightly elevated salinity concentrations (mean = 2.13 mmhos/cm) and slightly elevated exchangeable sodium percentages (mean = 2.85%). Selenium was detectable in these soils but was at low levels (mean = 0.18 mg/kg). Interestingly, these soils had uranium concentrations in excess of 1.0 pCi/g with a mean of 1.17 pCi/g (1.72 mg/kg). The chemistry of site S33-2 was similar to S33-1 with a slightly lower CEC mean value of 25.2 meq/100g, reflecting the lower clay content of the soils. Salinity levels and exchangeable sodium percentages were lower in theses soils, also reflecting the lower clay content and higher permeability of this site. Selenium concentrations were similar to site S33-1 with a mean of 0.15 mg/kg and uranium concentrations were slightly lower with a mean of 0.85 pCi/g (1.25 mg/kg). The surface soils at site S33-2 exceeded 1.0 pCi/g. Both of these sites probably reflects the quality of the previous irrigation water since unirrigated similar sites do not show the elevated salinity, sodium, or uranium concentrations.

The soils located west of the Rio San Jose ditch are significantly different than those east of the ditch. While significant areas of clay loam soils were mapped along the west side of this section and were thought to have flood irrigation potential, only the extreme southwest corner had clay loam surface soils to 20 inches and had stratified sands below that depth. The majority of the soils mapped as clay loam series were actually more similar to the Mespun soils described in

Section 25 discussions. Approximately 10 acres of clay loam soils with flood irrigation potential exists to the west of the ditch.

The largest soil unit in this area, comprising approximately 100 acres, is the Mespun loamy sand series. This unit is hummocky, due to wind blown sands, and has high infiltration rates. Refer to Section 3.2.5 for a description of the Mespun soils. Figure 3-5 depicts the location of the Section 33 soils. Nine backhoe trenches were excavated in the areas west of the ditch. These trenches are identified on Figure 3-5 as sites S33-3 through S33-11. Selected representative soils were submitted to the laboratory for analyses.

The sand content of the Mespun soils averaged 80 percent and the clay content was very low. Correspondingly, the CEC mean valu for these soils is also low at 10.7 meq/100g. As expected, salinity levels and exchangeable sodium percentages for these soils are very low. Selenium concentrations and uranium levels are also low for these soils.

3.3 DISCUSSION

While the data for soils sampled in the Murray Acres and Broadview Acres subdivisions is limited, some evidence exists to suggest that the soils have selenium and uranium concentrations higher than most surrounding soils. The reason for the presence of the higher uranium and selenium is unclear, however, in mineralized areas it is common for localized areas of these elements to occur. Other localized elevated concentrations of these elements occurred in the Section 34 soils.

The soils located in the SE ¼ of Section 33, the majority of Section 34, and the majority of Section 3 all were irrigated in the 1940's and early 1950's with Bluewater River or local well waters. These soils are dominated by heavy clay textures and have very slow permeabilities. All

of these soils were mechanically leveled to allow for flood irrigation. The soils were left bare after farming ceased and wind has altered the soil surface, creating minor hummocks. Primary vegetation are forbs, weeds and saltbrush.

All of these soils showed signs of previous heavy irrigation by the buildup of moderate salt levels immediately below the root zone. As expected, salt loading at the bottom of flood irrigated fields was more concnetrated than salt loading along the upper end of fields. Irrigation water was likely allowed to pond for short periods at the end of the fields during irrigation, increasing salt concnetrations in the irrigation waters. While the irrigation waters were relatively low in salt content, this investigation exhibits the potential problem of salt loading in these heavy clay soils if high salinity waters are land applied to these soils. With minor land leveling, these soils are suitable for flood irrigation and are not suitable for sprinkler irrigation due to the very slow infiltration rates and to equipment limitations resulting from the high clay content of the soils. Irrigation management and scheduling must be based on the slow infiltration rates and management of salt loading by leaching after the crop season will be necessary.

The soils located in Section 27 and 28 are ideal for sprinkler irrigation. These soils have sandy textures and very high permeability rates, often in excess of 6 inches per hour. Due to their high sand content, these soils are not suited for flood irrigation. Sprinkler irrigation management would be based on the amount of irrigation water available for irrigation of these areas. That is, the size of a given irrigation area would need to be based on the irrgiation well supply rate in gallons per minute and irrigation scheduling must take into account the agronomic requirements of the crop to be grown. Generally, irrigation planning is conducted on a monthly basis and the water supply must slightly exceed the expected crop water use and evaporation for peak irrigation months. Peak irrigation months for the Grants area will be in late May, June, July, and early August.

The NE1/4 of Section 28 has been used extensively in recent years as a rock quarry and rock stockpile areas. Many areas have had the surface soils removed and stockpiled. Stockpile bases were constructed of quarry rock which remain in place and numerous roads were constructed through the area. Additionally, large rocks were spread on relatively undisturbed areas. Some earthwork involving the removal of the rock stockpile bases and scattered rocks would be necessary to prepare this area for irrigation. Haul roads and stockpile areas would need to be ripped and, if available coversoil should be re-applied.

The soils examined in the SE1/4 of Section 29 are dominated by clay loam textures and have been actively irrigated for several years. Because of their higher clay contents and slow permeabilities these soils are not best suited for sprinkler irrgiation. These soils do not show signs of salt loading from the recent irrigations, however, salt loading from irrigation with high salt content waters wold need to be managed. Irrigation scheduling must be based on the slow soil permeabilities and leaching of salts after the crop season will be necessary.

The soils examined in Section 20 all have basalt at shallow depths and are not suitable for irrigation. The soils examined in the southern 1/3 of Sections 21 and 22 are very similar to the Section 28 soils and would be suitable for sprinkler irrigation. The soils located in the middle 1/3 of these Sections are clayey and similar to the Section 34 soils. These soils would be suitable for flood irrigation with minor land leveling. Design of an adequate center pivot sprinkler system for the area would be difficult due to the interaction of the clay soils with the sandy soils. This area may be better suited for sideroll type irrigation systems.

Section 25 soils are sandy and have very high infiltration rates. Because the high permeabilities, these soils are not suitable for flood irrigation. Much of the surface horizons in this area have been removed as part of the wind blown contamination cleanup project. Management of irrigation waters would be based on the ability of the irrigation wells to supply enough water to the crop to meet peak crop water use and evaporation demands. In addition, the establishement

of a good crop stand will require additional agronomic practices to prevent significant wind erosion and seed movement.

Much of the soils in the NE1/4 of Section 32 are dominated by rock outcrops or bedrock at shallow depths and are not suitable for irrigation. The remainder of this area is comprised of small 2 to 10 acre parcels, some of which are occassionally flood irrgiated. The soils are generally clayey at the surface with some gravels present at depth. Most of these irrigable areas are small and would be difficult to irrigate continuosly because of the need for a significant array of water spreader ditches.

The soils located in the SE1/4 of Section 33 have been discussed previously. The soils in the SW1/4 are very diiferent than the heavy clay soils located east of the Rio San Jose ditch. These soils are very sandy and have very rapid infiltration rates. They are not suited for flood irrigation, but are ideal for center pivot sprinkler irrigation. Sideroll irrigation systems could be utilized but would require some land leveling before efficient operation could be achieved. As with the Section 25 soils, these soils would require additional agronomic practices to achieve an acceptable crop stand and to prevent erosion.

Table 3.1 - BROADVIEW ACRES AND MURRAY ACRES SOIL DATA

Sample I.D.	Location	Molybdenum mg/kg	Selenium mg/kg	Uranium pCi/g
S-3912	Broadview Acres	<2.9	1.52	3.47
S-3913	Broadview Acres	<2.9	2.19	11.38
S-3914	Broadview Acres	<2.9	0.86	4.31
Average		**<2.9**	**1.52**	**6.39**
S-3915	Murray Acres	<2.9	0.19	2.83
S-3916	Murray Acres	<2.9	1.81	4.82
S-3917	Murray Acres	<2.9	<0.10	1.54
Average		**<2.9**	**0.67**	**3.06**

Table 3-2. SOIL LABORATORY DATA

Sample ID	Depth inches	SAND %	SILT %	CLAY %	Texture	C.E.C. meq/100g	Elec. Cond. mmhos/cm	Exch. Sodium %	Selenium mg/Kg	Uranium pCi/g
San Mateo Series		***Section 34/3***								
S34-3	4 - 26	9.0	24.6	56.5	clay	40.7	1.78	2.01	0.114	1.03
S34-3	50 - 90	85.0	1.6	13.5	loamy sand	5.5	2.30	0.66	<0.050	0.20
S34-14	4 - 24	31.0	16.1	52.9	clay	27.2	4.50	2.28	0.194	0.79
S34-14	30 - 90	87.0	2.1	10.9	loamy sand	4.4	1.65	1.20	<0.050	0.20
Sparank Series		***Section 34/3***								
S34-5*	3 - 40	15.0	61.1	23.9	silt loam	36.6	1.58	1.76	0.143	0.84
S34-5	40 - 53	76.0	6.1	17.9	sandy loam	10.4	1.37	0.88	0.080	0.30
S34-5	53 - 73	85.0	2.1	12.9	loamy sand	5.7	1.14	0.97	0.068	0.76
S34-10	3 - 28	14.0	25.6	50.5	clay	32.5	1.06	1.54	0.129	1.01
S34-10	28 - 38	10.0	28.6	51.5	clay	35.5	1.20	1.94	0.059	0.82
S34-11*	3 - 15	14.0	29.6	56.5	clay	30.1	0.51	0.56	<0.050	1.36
S34-11	15 - 60	70.0	4.6	25.5	sandy clay loam	7.8	1.79	0.63	<0.050	0.58
S34-11	60 - 90	87.0	0.6	12.5	loamy sand	5.1	0.77	1.21	<0.050	0.26
Venadito Series		***Section 34/3***								
S34-1	3 - 24	12.0	29.1	58.9	clay	37.2	6.90	12.80	0.099	5.85
S34-1	24 - 36	51.0	11.1	37.9	sandy clay	25.8	5.41	14.40	0.131	0.43
S34-1	36 - 60	63.0	14.1	22.9	sandy clay loam	13.0	7.66	7.38	0.068	0.39
S34-7	3 - 28	8.0	35.6	56.5	clay	36.0	0.94	11.50	0.058	0.78
S34-7	28 - 40	65.0	10.6	24.5	sandy clay loam	9.1	4.81	9.04	0.405	0.43
S34-8	2 - 30	25.0	20.6	54.5	clay	27.3	1.75	13.00	0.310	1.26
S34-8	30 - 60	54.0	10.6	35.5	sandy clay	17.1	9.91	0.00	0.338	0.69
S34-13	4 - 18	20.0	19.6	50.5	clay	30.6	1.14	2.10	0.114	3.93
S34-13	18 - 30	38.0	14.6	47.5	clay	26.5	1.77	2.39	0.140	0.68
S3-1	0 - 14	8.0	26.1	55.9	clay	39.7	0.55	5.45	0.109	0.70
S3-1	14 - 38	9.0	26.1	54.9	clay	41.3	2.17	6.17	0.090	0.71

* - these soils may actually be part of the Aparejo series, sandy substratum

)

Sample ID	Depth inches	SAND %	SILT %	CLAY %	Texture	C.E.C. meq/100g	Elec. Cond. mmhos/cm	Exch. Sodium %	Selenium mg/Kg	Uranium pCi/g
Glenberg Series		***Section 28***								
S28-3	4 - 22	83.0	2.6	14.5	sandy loam	7.2	0.23	0.20	0.182	0.23
S28-3	40 - 60	87.0	3.6	9.5	loamy sand	4.6	0.24	0.69	<0.050	0.24
S28-9	0 - 40	76.0	8.1	15.9	sandy loam	9.1	0.43	0.56	0.059	0.33
S28-9	70 -90	83.0	5.1	11.9	loamy sand	6.1	0.43	0.61	0.142	0.22
NE28-2	0 - 6	88.0	4.1	7.9	loamy sand	6.0	0.20	0.14	<0.050	0.24
NE28-2	36 - 84	86.0	7.1	6.9	loamy sand	6.5	0.45	0.55	<0.050	0.20
NE28-4*	0 - 8**	83.0	15.7	1.3	loamy sand **	1.5	0.43	1.61	0.160	0.13
NE28-4	8 - 28	90.0	3.7	5.3	sand	7.0	0.34	0.35	<0.050	0.23
NE28-4	28 - 84	92.0	2.54	5.46	sand	5.6	0.37	0.53	<0.050	0.22
NE28-5*	0 - 12	81.0	11.7	7.3	loamy sand	6.98	0.34	1.19	0.100	0.50
NE28-5	25 - 84	87.0	7.7	5.3	loamy sand	5.89	0.60	0.99	<0.050	0.44
NE28-7*	0 - 8**	80.0	17.7	2.3	loamy sand **	2.15	0.50	1.94	0.12	0.51
NE28-7*	8 - 24	94.0	1.7	4.3	sand	4.58	0.61	1.57	0.05	0.23
NE28-7*	24 - 48	98.0	0.0	2.0	sand	2.51	0.31	1.83	<0.050	0.14
	* = surface disturbed			** = basalt fines (stockpile base)						
San Mateo Series		***Section 27/28***								
S28-2	0 - 40	69.0	8.1	22.9	sandy clay loam	14.3	0.34	0.29	0.137	1.06
S28-2	54 - 96	54.0	21.1	24.9	sandy clay loam	15.5	0.73	0.79	0.105	0.29
NE27-1	0 - 6	88.0	4.1	7.9	loamy sand	6.76	0.22	0.16	<0.050	0.34
NE27-1	24 - 80	66.0	14.1	19.9	sandy loam	7.09	0.33	0.30	<0.050	0.14
Sparank Series		***Section 28/29***								
G-1*	0 - 6	58.0	21.7	20.3	sandy clay loam	20.7	0.47	0.36	0.08	0.49
G-1	6 - 24	52.0	26.7	21.3	sandy clay loam	19.8	0.62	0.55	<0.050	0.41
G-1	24 - 36	31.0	29.7	39.3	clay loam	41.4	2.51	1.37	0.05	0.43
G-2**	0 - 6	30.0	38.1	31.9	clay loam	29.6	0.63	0.70	0.08	0.45
G-2	6 - 24	32.0	35.1	32.9	clay loam	34.0	0.67	0.80	0.07	0.55
* - G-1 is same as SE29-1			** - G-2 is same as SE29-2							
Mespun Series		***Section 32/33***								
S33-4	0 - 6	79.0	9.1	11.9	sandy loam	16.4	0.26	0.07	<0.050	0.37
S33-4	6 - 48	82.0	5.1	12.9	sandy loam	7.7	0.31	0.42	<0.050	0.36
S33-7	0 - 24	79.0	6.1	14.9	sandy loam	8.9	0.22	0.10	<0.050	0.30
S33-7	24 -48	79.0	6.1	14.9	sandy loam	10.5	0.27	0.19	<0.050	0.24

Sample ID	Depth inches	SAND %	SILT %	CLAY %	Texture	C.E.C. meq/100g	Elec. Cond. mmhos/cm	Exch. Sodium %	Selenium mg/Kg	Uranium pCi/g
Sparank Series		***Section 32/33***								
S33-1	0 - 6	45.0	21.7	33.3	clay loam	28.8	0.43	1.19	0.13	0.96
S33-1	6 -24	30.0	20.7	49.3	clay	41.6	2.59	3.65	0.19	1.23
S33-1	24 - 48	19.0	18.7	62.3	clay	43.6	3.37	3.73	0.23	1.32
S33-8	0 - 20	64.0	13.8	22.2	sandy clay loam	8.1	0.27	0.13	0.07	0.58
S33-8	20 - 48	22.0	35.8	42.2	clay	15.7	0.25	0.21	<0.050	0.35
S33-9	0 - 24	51.0	14.8	34.2	sandy clay loam	9.6	0.25	0.11	0.15	0.56
S33-9	24 - 48	29.0	33.8	37.2	clay loam	31.6	0.31	0.57	0.10	0.70
S33-10	0 - 12	34.0	34.8	31.2	clay loam	23.8	0.24	0.38	0.05	0.70
S33-10	12 - 30	29.0	33.8	37.2	clay loam	31.8	0.26	1.76	<0.050	0.38
S33-10	30 - 60	34.0	34.8	31.2	clay loam	26.6	0.80	1.21	<0.050	0.40
S32-1	0 - 6	32.0	31.1	36.9	clay loam	35.1	0.47	0.27	<0.050	0.47
S32-1	6 - 18	45.0	24.1	30.9	clay loam	32.7	0.50	0.48	<0.050	0.38
S32-1	18 - 36	37.0	31.1	31.9	clay loam	25.3	0.40	0.76	<0.050	0.38
Aparejo Series		***Sandy substratum***			***Section 32/33***					
S33-2	0 - 6	30.0	30.7	39.3	clay loam	37.7	0.32	0.15	0.18	1.12
S33-2	6 - 24	29.0	25.7	45.3	clay	36.2	0.27	0.43	0.19	1.02
S33-2	24 - 48	77.0	8.7	14.3	sandy loam	12.0	0.44	1.55	0.09	0.40
S32-2	0 - 12	37.0	31.1	31.9	clay loam	29.6	0.42	0.28	<0.050	0.34
S32-2	12 - 24	52.0	23.1	24.9	sandy clay loam	25.3	0.31	0.27	<0.050	0.34
S32-2	24 - 48	90.0	3.1	6.9	sand	20.7	0.30	0.28	<0.050	0.39

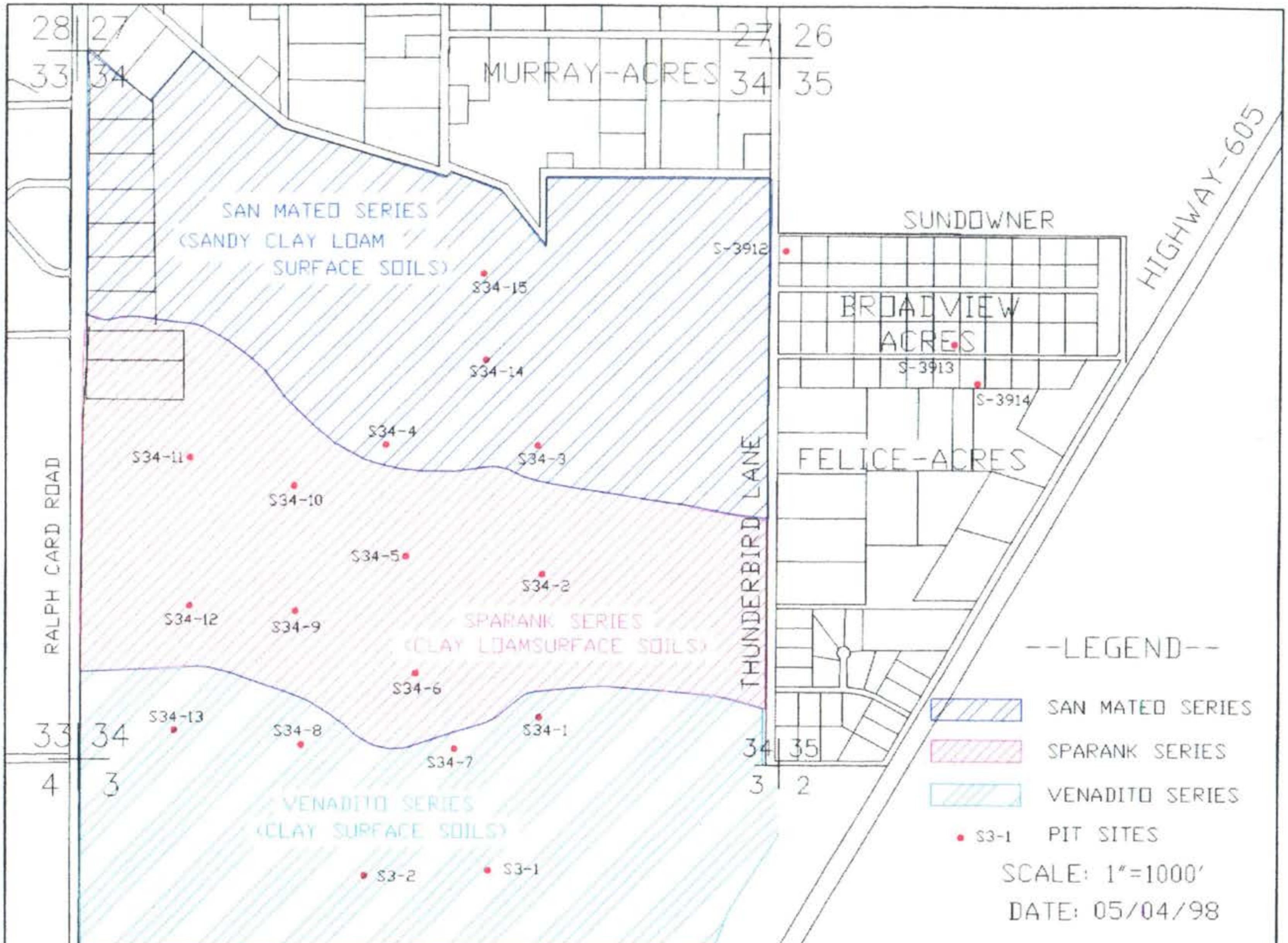

FIGURE 3-1. BACKHOE PIT LOCATIONS AND SOIL BOUNDARIES
IN SECTIONS 3 AND 34

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layer: figure3-1

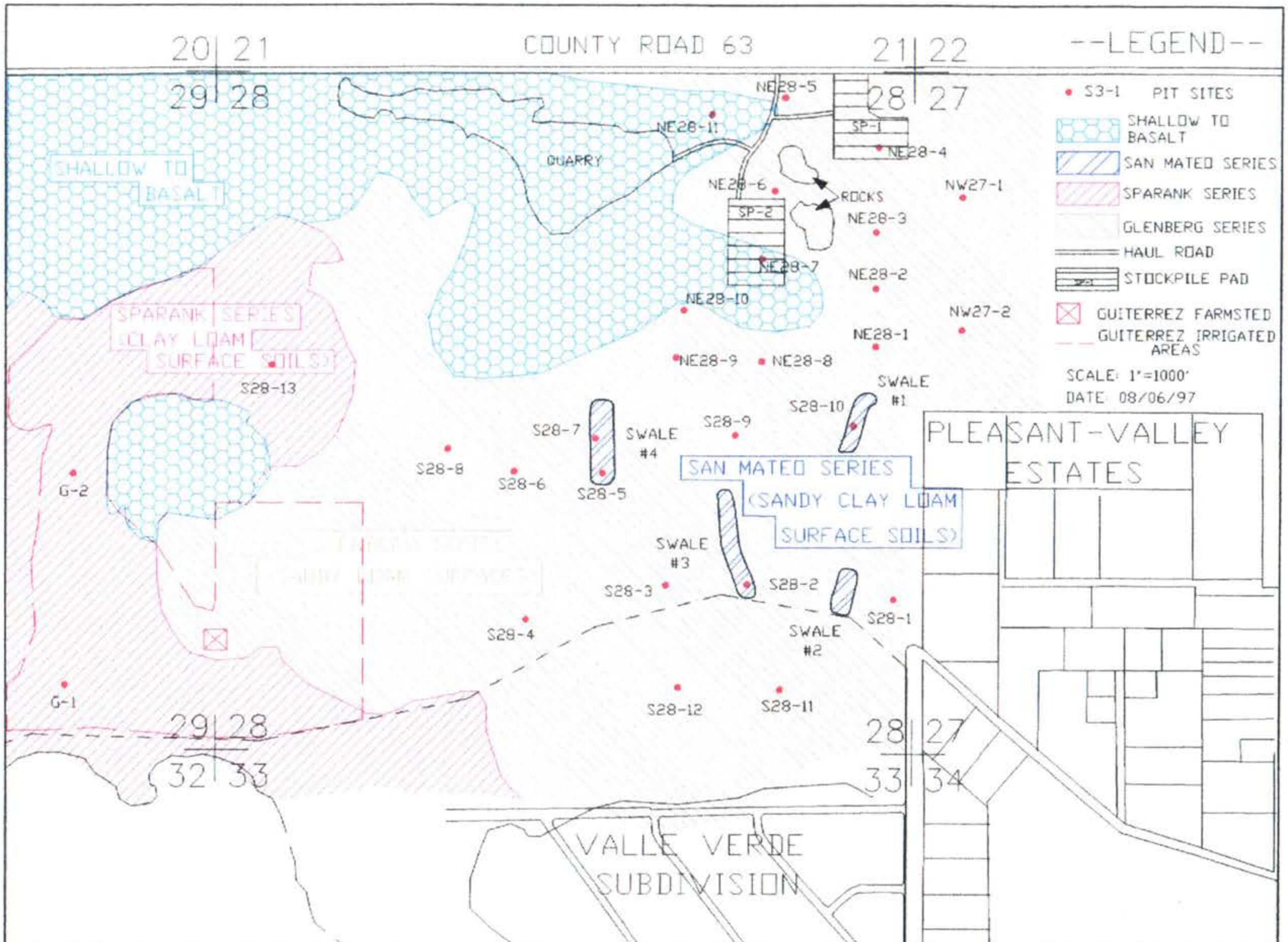

FIGURE 3-2. BACKHOE PIT LOCATIONS AND SOIL BOUNDARIES IN SECTION 27, 28, AND 29

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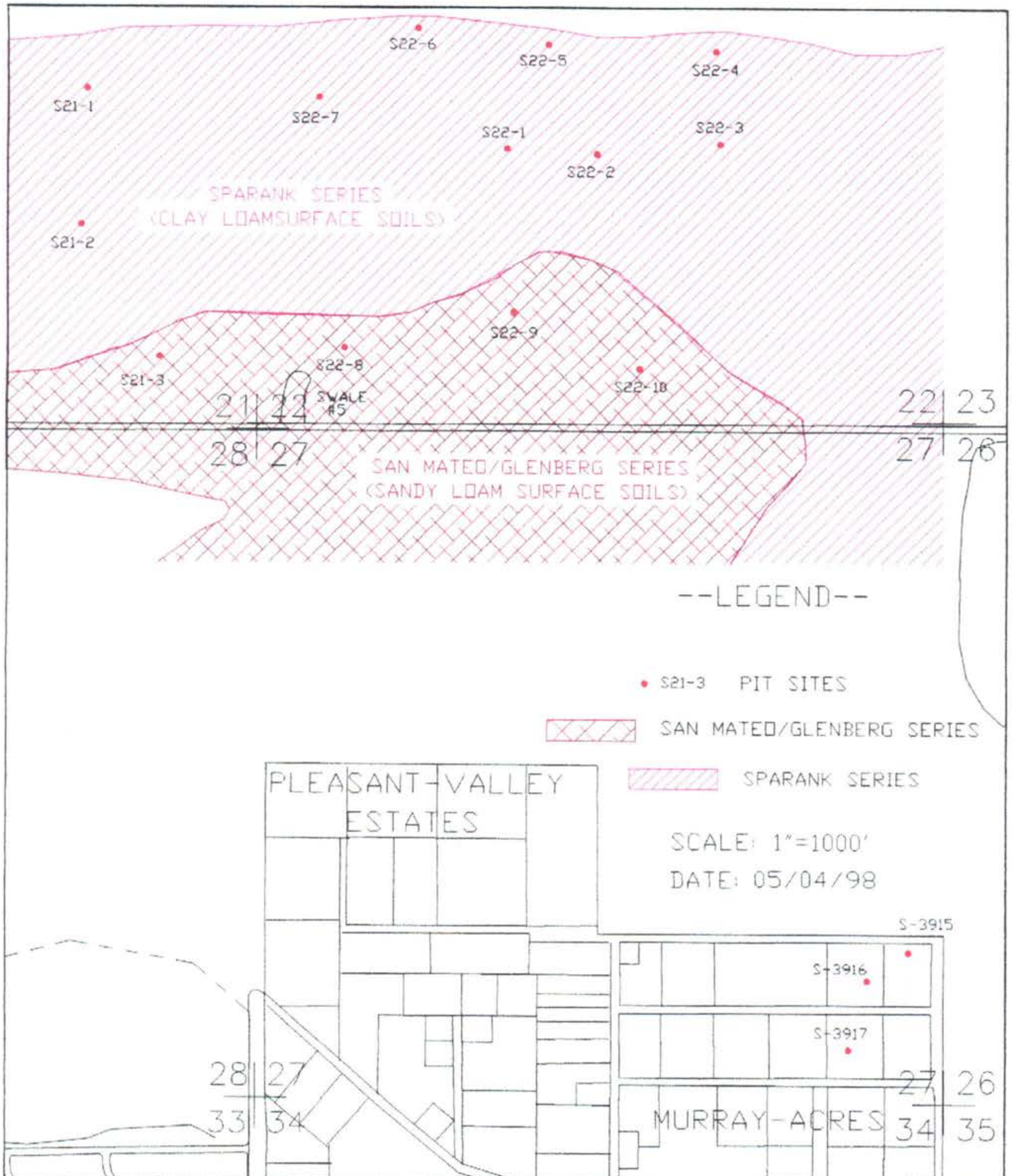

FIGURE 3-3. BACKHOE PIT LOCATIONS AND SOIL BOUNDARIES IN SECTIONS 21 AND 22

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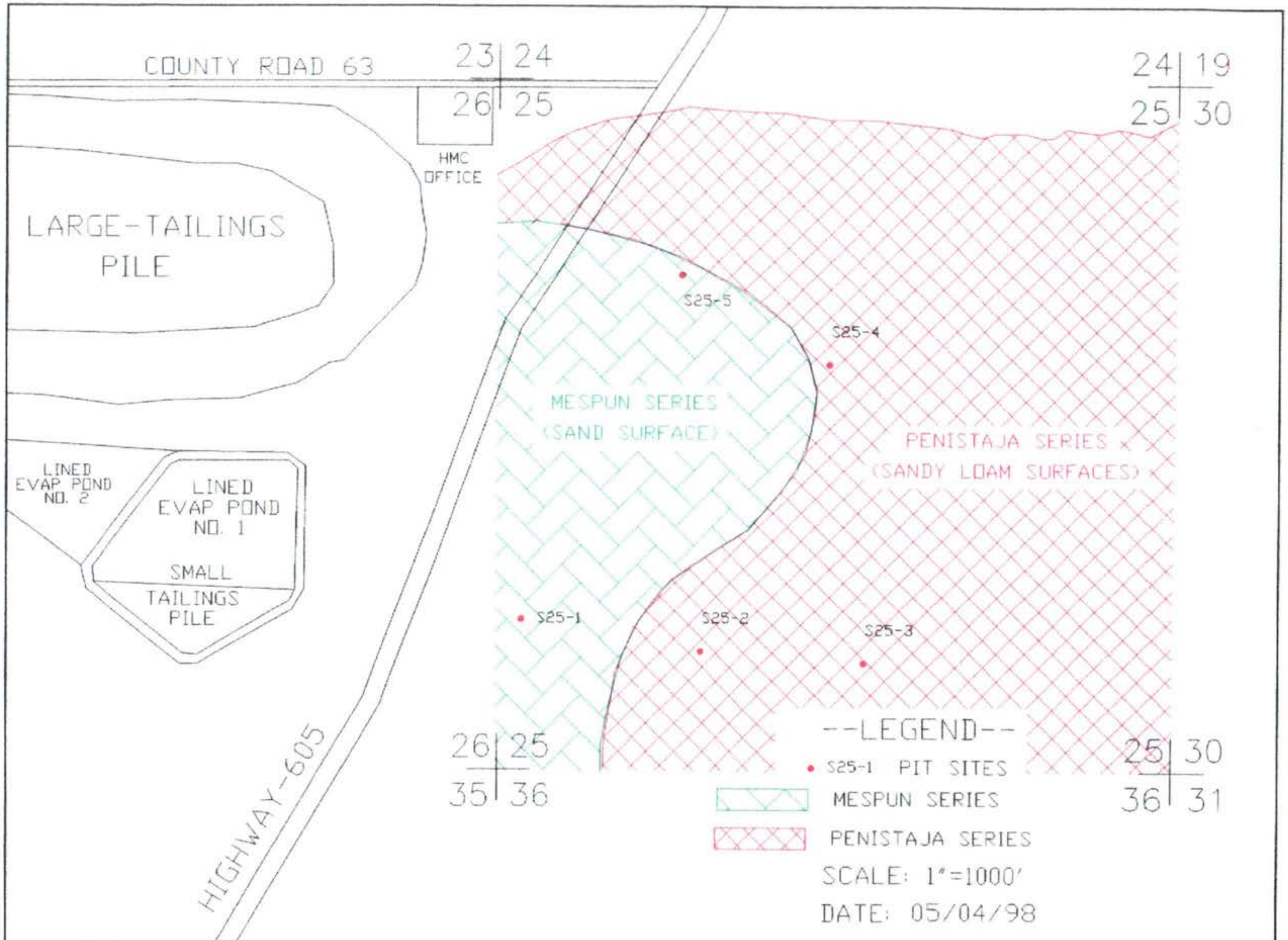

FIGURE 3-4. BACKHOE PIT LOCATIONS AND SOIL BOUNDARIES IN SECTION 25

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layer: figure3-4

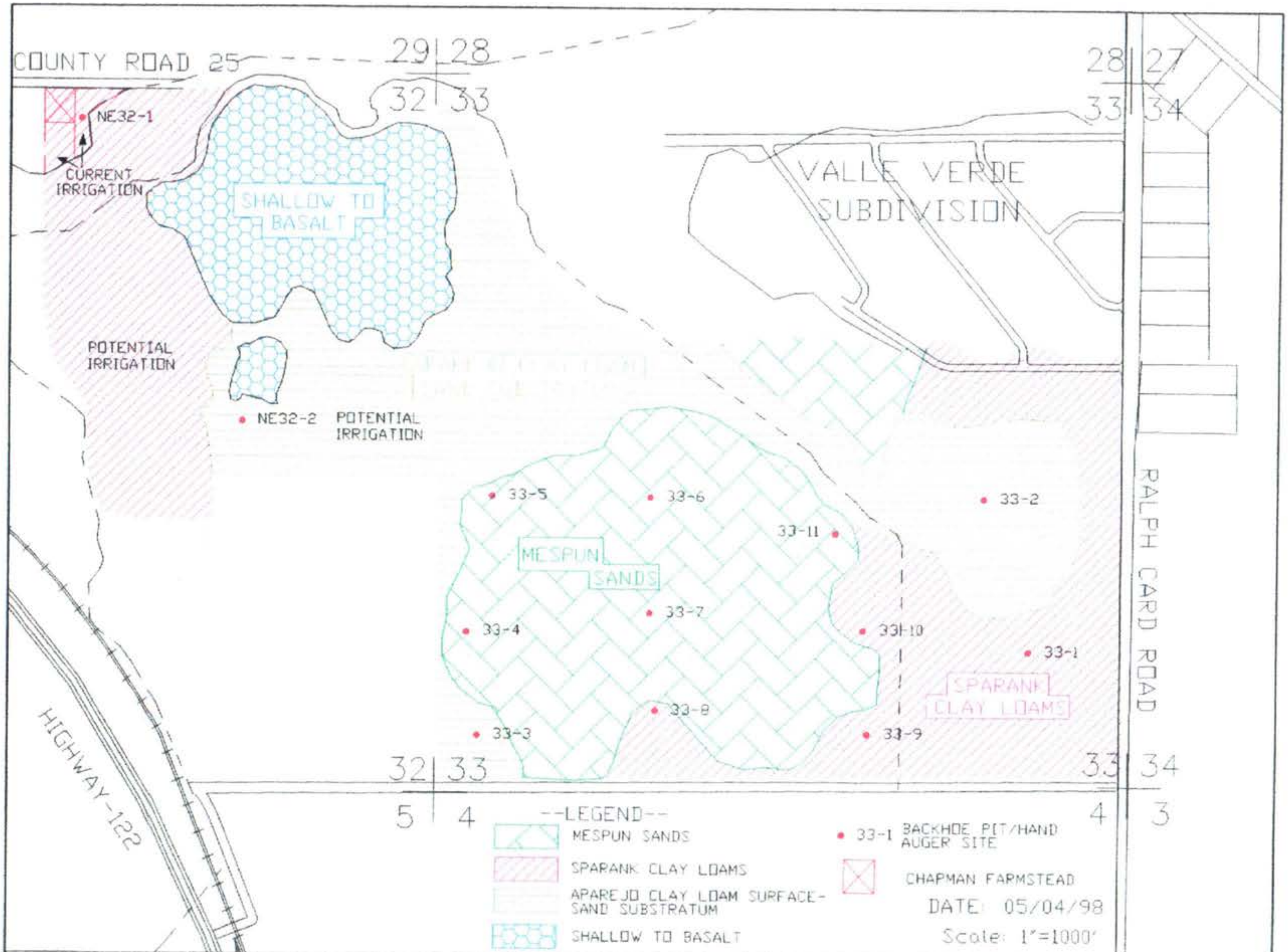

FIGURE 3-5 BACKHOE PIT LOCATIONS AND SOIL BOUNDARIES IN SECTIONS 32 AND 33

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Layer: figure3-5

4 INFILTRATION STUDIES

Because one of the possible alternatives for removal of uranium and selenium from collection well waters is land application or irrigation for natural attenuation by soils, the rate of collection well water infiltration into and through the soils must be known for efficient planning, scheduling and management practices. In addition, infiltration properties for the site soils will be important criteria for the possible design of an anoxic wetland system for the removal of selenium and uranium.

4.1 INFILTRATION METHODS

Standard Ring Permeameter (infiltrometer) tests (U. S. Bureau of Reclamation, 1978) to evaluate infiltration and hydraulic conductivity characteristics were performed at several of the sites. Infiltration test sites were selected from soil trench sites determined to be representative of the major soil types located within the study area. A total of 16 tests were conducted for this study. Generally, 2 tests were utilized at each site and consisted of a surface test and a subsurface test.

The double ring procedure utilized a 28 inch diameter outer ring and a 16 inch diameter inner ring. The outer ring was driven uniformly into the soil surface to a 3 to 4 inch depth. The inner ring was then centered inside the outer ring and also driven uniformly into the soil to a 3 or 4 inch depth. The space between the two rings was then filled with water and allowed to saturate the soils. Following saturation, the inner ring was filled with 8 inches of water and a constant head of water, supplied by a calibrated water cylinder, was maintained in the inner ring. As the water infiltrated the soil, the amount of water consumed for a given timeframe was monitored. The final infiltration volume was determined for the various measured time periods. The resultant infiltration rates, measured in inches per hour, were calculated and plots of the infiltration rates over time were constructed for each site. Results of the field tests were cross-referenced with published values for the site soils. Infiltrometer test results are presented in detail in Appendix F of this report.

4.2.1 SECTIONS 34 and 3

Nine infiltration tests were conducted at 5 backhoe trench sites in Section 34. The sites are identified as S34-1A (surface), S34-1B (subsoil), S34-1C (subsoil), S34-5A (surface), S34-5B (subsoil), S34-6 (surface), S34-11A (surface), S34-11B (subsoil), and S34-14 (surface) with locations corresponding with backhoe trench locations shown on Figure 3-1. With the exception of site 34-11, all soils have been described as representative of the Sparank clay loam series or Sparank series variants. Site 34-11 is representative of the San Mateo sandy clay loam soils. Refer to Section 3.2.2 for a detailed description of the Section 34 soils.

Results of the Section 34 infiltrometer evaluations are presented graphically as Figures F.2-1 through F.2-9 and in tabular form in Tables F.2-1 through F.2-9 in Appendix F . Most of the soil infiltrometer tests shown a normal initial soil wetting or saturation period followed by reasonably steady-state infiltration or permeability conditions. The calculated steady state infiltration for site 34-1A averaged 1.60 inches per hour. This rate compares favorably to a published range of infiltration values for these surface soils of 0.60 to 2.00 inches per hour. The subsoil infiltration values, represented by tests S34-1B and 1C, reached steady-state rates of 0.60 and 0.12 inches per hour, respectively. These values are comparable to the published infiltration value of <0.60 inches per hour for the Sparank subsoil conditions. While the surface soils at this site have a reasonable infiltration rate, the slow rate of infiltration of the subsoil will dictate the rate of application of collection well water on these soils which may only average 0.50 inches per hour.

Site 34-5 is described as a Sparank clay loam variant due to the presence of stratified sands in the subsoil materials. Infiltrometer test S34-5A for surface soils had a steady-state infiltration of 0.84 inches per hour following the initial saturation of the soils. This value compares to a published infiltration range for these soils of 0.60 to 2.00 inches per hour. The sandy subsoil

infiltration test (S34-5B) exhibited a steady-state rate of 5.80 inches per hour after initial saturation and compares to the published value for these sandy soils of 6.00 to 20.00 inches per hour. This area will accept irrigation application rates of up to 1.00 inches per hour due to the clay content of the surface soils.

Site S34-6 is very similar to site S34-5 and a single surface soil infiltrometer test was conducted. After initial saturation, the steady-state infiltration rate of the surface soil was 1.10 inches per hour as compared to published rates of 0.60 to 2.00 inches per hour. As with site S34-5, the irrigation application rate of these soils will be approximately 1.00 inches per hour.

Site S34-11 is similar to the tests conducted for sites S34-5 and S34-6 with the exception that the depth to loamy sands is shallower. Following initial saturation and wetting, the steady-state infiltration for the sandy clay loam surface soils (test S34-11A) was 0.72 inches per hour as compared to a published infiltration value of 0.60 to 2.00 inches per hour. The sandy subsoil infiltration results from test S34-11B are similar to the other Section 34 tests on sandy soils with an infiltration rate of 7.00 inches per hour. Again, as with the results of the S34-5 and S34-6 tests, the surface soil irrigation rate probably will be approximately 1.00 inches per hour.

The last infiltration tests conducted in Section 34 were at site S34-14, a surface soil infiltration site. This site exhibited a slightly higher infiltration rate than the rest of the Section 34 test sites. The steady-state infiltration rate for these soils was 1.20 inches per hour and again compares favorably to the published value of 0.60 to 2.00 inches per hour. This soil can handle slightly higher irrigation rates than the Section 34 areas characterized by the other infiltration tests.

In general, the slowest infiltration rates were present in the southern portion of Section 34. The results of site S34-1 infiltration tests can be expected to be similar for sites represented by backhoe trench S3-1, S3-2, S34-7, S34-8, and S34-13. The irrigation application rate of these soils probably cannot exceed 0.50 inches per hour due to their very heavy clay subsoils. Soils

represented by backhoe trenches S34-2, S34-5, S34-6, S34-9, S34-10, S34-11, and S34-12 can handle irrigation application rates of approximately 1.00 inches per hour. The soils represented by sites S34-3, S34-4, S34-14, and S34-15 may be able to handle irrigation application rates up to 1.50 inches per hour.

4.2.2 SECTION 28

Three sites were selected as representative of Section 28 soils for infiltration tests and are identified as backhoe trench sites S28-1, S28-2, and S28-3 and locations are shown on Figure 3-2. Refer to Appendix F for plots tables of the Section 28 infiltrometer results. Plots are denoted as Figures and Tables F.3-1 through F.3-3. The steady-state infiltration rate for site S28-1 is 5.70 inches per hour, the steady-state infiltration rate for site S28-2 was 9.00 inches per hour, and the infiltration rate for site S28-3 was 9.2 inches per hour. These rates compare favorably to the published infiltration rates for these sandy soils of 6.0 to 20.0 inches per hour. These soils can handle large irrigation application rates of greater than 6.0 inches per hour.

4.2.3 SECTIONS 21 and 22

Because the southern end of Section 21 and Section 22 is very similar to the Section 28 soils, only two infiltration tests were conducted. The sites selected as representative of the southern Section 22 soils were sites S22-11 and S22-12 as shown on Figure 3-3. Refer to Appendix F for plots (Figures F.4-1 and F.4-2) of the Section 22 infiltration test results. The steady-state infiltration rate for site S22-11 was 10.2 inches per hour as compared to the published rate of 6.0 to 20.0 inches per hour for this soil.

The steady state infiltration rate for site S22-12 was 7.8 inches per hour, again, compared to a published rate of 6.0 to 20.0 inches per hour. The results of these tests are also comparable to

the results of similar soils located in Section 28. Both of these sites indicate that the soils in the southern portion of Section 21 and 22 are capable of handling relatively high irrigation application rates.

4.2.4 SECTION 25

Two infiltration tests were conducted in Section 25 at sites S25-1 and S25-4. Refer to Appendix F for the plots and tabular results of these tests Figures and Tables F.5-1 and F.5-2). Site S25-1 is located in the Mespun loamy sand soils and, as expected, had a high steady-state infiltration rate of 7.0 inches per hour. These results compare favorably to the published infiltration values for the Mespun series surface soils of 6.0 to 20.0 inches per hour. This soil is capable of handling high irrigation application rates.

Site S25-4 is located in the Penistaja soil series and has a published infiltration rate of 0.60 to 2.0 inches per hour for surface soils. The field steady-state infiltration rate for this site was 1.7 inches per hour and compares accurately to the published values. The Penistaja soils are capable of handling moderate irrigation application rates.

5 *COLUMN ATTENUATION TESTS*

5.1 COLUMN STUDY METHODS

Column studies were established with the goal of evaluating the potential of the site soils to naturally attenuate uranium and selenium following passing of the alluvial well water through the soil. A brief description of the attenuation processes which may occur at the site has been previously described in Sections 1.0 and 2.0 of this report. A summary of the baseline soil conditions is presented in Section 3.0 . Four sites, S28-2, S28-9, S34-1, and S34-5, were selected as representative of the major soil conditions in Sections 28 and 34.

Eight columns were constructed of 3 inch diameter by 40 inch length PVC sections. Two columns were established for each selected site and consisted of a surface column and a subsurface column. Column soils consisted of soil samples composited from the bulk samples obtained during backhoe trenching. The composited samples were placed in the columns and packed to bulk densities similar to the undisturbed condition of the soil in the field. The soils were packed to 36 inches, leaving 4 inches empty in the columns for water application. Bulk densities were obtained from information referenced in the published soil survey.

Following are a brief description of each composited column sample: Column #1 - S28-2, 0 to 40 inches (sandy); Column #2 - S28-2, 84 to 96 inches (clay); Column #3 - S28-9, 0 to 40 inches (sandy); Column #4 - S28-9, 70 to 90 inches (sandy); Column #5 - S34-1, 0 to 24 inches (clay); Column #6 - S34-1, 24 - 36 inches (buried surface clay) and 36 to 60 (sands); Column #7 - S34-5, 3 to 40 inches (clay); Column #8 - S34-5, 40 - 53 inches (clay) and 53 to 73 inches (sands). Refer to the detailed profile descriptions for these soils in Appendix A and B. Baseline soil laboratory analyses for these soils are summarized in Table 3-1.

Each column was irrigated with water obtained from collection wells CW44 and 644. Baseline water conditions are summarized as follows: selenium - 0.206 mg/l; uranium - 0.623 mg/l; electrical conductivity - 3000 umhos/cm ; total dissolved solids - 1920 mg/l; sulfate - 903 mg/l;

pH - 7.78 std units; and Sodium - 320 mg/l. Pore volumes were calculated for each column following initial wetting. Saturated steady state conditions, representing irrigation cycles, were maintained in each column and due to significant differences in clay content, pore volumes, and saturation percentages, varying numbers of effluent samples were obtained from each column. The number of effluent samples obtained from these "irrigations" ranged from 7 samples for S28-9, 0 to 40 inches to 3 samples obtained from S34-5, 0 to 40 inches.

The initial effluent sample for each column was sent to Energy Laboratories, Inc. in Casper, Wyoming and analyzed for chloride, conductivity, sodium, salinity, selenium, sulfate, TDS, and uranium for comparison to the collection well water. Following the initial effluent sampling, all other samples were analyzed only for conductivity, sodium, selenium, and uranium. These parameters are considered the most important for attenuation and irrigation interpretations.

5.2 COLUMN TEST RESULTS

The results of the effluent sample laboratory characterization are presented in Table 5-1. All 8 columns appear to be efficiently removing uranium in significant quantities. That is, the columns filled with sand horizons removed uranium from each irrigation at a rate of 80 to 94 percent of total on average. Similarly, the clay filled columns removed uranium even more efficiently with a removal rate of 86 to 94 percent of the total for each irrigation. In addition, the concentration of uranium removed from both soil types was similar, averaging 0.54 mg/l per "irrigation" (range 0.503 to 0.588 mg/l) for the four sandy columns and 0.56 mg/l per "irrigation" (range 0.538 to 0.585 mg/l) for the four clayey columns.

While it was anticipated that uranium removal would be more efficient in the clay soils, it appears that the sands had sufficient clay content and corresponding CEC levels to effectively attenuate uranium. As described in Section 3.0, the exchange sites of the site soils are dominated by lower strength cations such as calcium, magnesium, or sodium. It is apparent

that the oxidation state and resultant multiple valence of the uranium in the collection well water results in the uranium being easily adsorbed onto soil exchange sites. It is apparent from the data that the soil exchange sites for both the sandy and clayey soils have not been saturated with uranium. That is, when the exchange sites are largely utilized by the uranium, the effluent data would begin to show an increase in uranium passing through the columns. When the column studies were terminated, the soils were still capable of removing more uranium from the input water.

The results of the selenium analyses on the effluent samples shows that the soil columns did not remove selenium from the collection well water. In fact, it appears that the column water is actually leaching selenium from the soils into the effluent waters. This relationship was true for all soils analyzed in the columns and indicates that natural mechanisms for selenium removal do not exist in the Section 34 and Section 28 soils. The average effluent water selenium level is 0.236 meq/L as compared to the baseline selenium level of 0.206 meq/L. While the increase is not large, it is evident that these soils are not removing selenium.

Conductivity values (2350 umhos/cm average) for the S28-2 and S28-9 columns indicate that the conductivity of the effluent water has stabilized at levels very similar to the collection well water. That is, it appears that irrigation water quantities will be sufficient to push the salts through the Section 28 root zone preventing buildup in the soils. The Section 34 columns had significant soil salt levels prior to adding collection well water. Sites S34-1, 0 to 24 inches, S34-1, 24 to 60 inches, and S34-5, 3 to 40 inches, appear to be leaching salts from the soils as evidenced by the data shown in Table 5-2. While the salts concentrations have decreased significantly with each subsequent effluent sample, the conductivities still remain significantly above baseline conditions. Site S34-5, 40 to 73 inches had significantly lower conductivities then the other Section 34 samples and the effluent samples exhibit conductivities similar to the collection well water. While some of the Section 34 effluent samples have conductivities above the baseline conditions, it appears that salts can be leached below the root zones of these soils

preventing toxicities to plants.

5.3 DISCUSSION

Results of the column studies indicate that both the sandy soils and clayey soils managed to remove uranium from the irrigation waters efficiently. These results were as expected based on cation ion exchange theory. However, since the clayey soils had significantly higher cation exchange capacities than do the sandy soils, they will continue to efficiently attenuate uranium for longer periods of time. It is expected that continued operation of the columns would have resulted in a saturation of the relatively few exchange sites associated with the sandy soils and a reduction in uranium removal would have occurred. The limiting factor for the sandy soils would then become the overall depth of the soils available for attenuation purposes. In the case of the sandy alluvial soils at the Grants site, the soils are relatively deep over the alluvial aquifer and significant attenuation capacity is available for the removal of uranium.

In the case of the clayey soils, the controlling factor for attenuation of uranium becomes the allowable concentration in the soils to prevent risk to the population. That is, the clayey soils will continue to remove uranium until the exchange sites are satisfied. At that point in time, the uranium will simply move deeper in the soil profile to new exchange sites if enough water is added to the soils to result in deeper leaching of irrigation waters. If deeper leaching does not occur, the uranium will concentrate in the soil in the zone where upward movement of water by capillary action and transpiration equals the downward leaching of water. This zone appears to be in the 20 to 40 inch depth of irrigated soils in the study area.

Actual uranium loading can be estimated by using cation exchange equilibirum models which would require the use of numerous soil chemistry, biological, and physics assumptions. Alternatively, the loading rates can be efficiently estimated in column or field studies by knowledge of the input water chemistry, soil cation exchange capacity information, "irrigation"

rates, and effluent water quality data. While these column studies could have been used to determine this information, continued operation for longer time periods would have been necessary. The reader is encouraged to read the results of the field pilot test studies in Section 6.0 for further information on uranium loading.

As stated previously, the soils did not remove selenium from the input water and appeared to actually add minor concentrations of selenium to the effluent waters. While selenium is biochemically very similar to sulfate, soils exhibit an ionic preference for sulfate over selenium. The alluvial well water has a significant concentration of sulfate (903 meq/L) as compared to selenium (0.206 meq/L). It appears that the site soils are selectively utilizing sulfate with respect to selenium, resulting in free selenium being added to the effluent waters in low concentrations. Under natural conditions, the site soils will not remove selenium in concentrations necessary to achieve groundwater selenium goals. Alternative methods will be required to remove selenium using land application techniques.

Table 5-1. Natural Metal Attenuation Column Test Results

SAMPLE ID.	DEPTH IN.	EFFLUENT RUN	Na mg/L	SO4 mg/L	Cl mg/L	TDs mg/L	Cond. umhos/cm	Se mg/L	U mg/L
S28-2	0 - 40	R1	20.6	532	121	1370	1560	0.124	0.067
		R2	24.0	872	150	2060	2140	0.232	0.192
		R3	160.0				2240	0.276	0.022
		R4	190.0				2400	0.242	0.199
		R5	256.0				2500	0.118	0.209
		R6	292.0				2520	0.176	0.199
		R7	300.0				2530	0.221	0.188
		Average	**177.5**	**702**	**135.5**	**1715**	**2270**	**0.198**	**0.154**
S28-2	84 - 96	R1	157.0	1264	229	2620	2890	0.361	0.038
		R2	159.0	957	163	1970	2290	0.254	0.020
		R3	106.0				2260	0.263	0.195
		R4	122.0				2340	0.241	0.028
		R5	214.0				2390	0.243	0.020
		Average	**151.6**	**1110.5**	**196.0**	**2295.0**	**2434**	**0.272**	**0.060**
S28-9	0 - 40	R1	39.1	582	143	1400	1640	0.114	0.011
		R2	76.9	883	155	2080	2230	0.208	0.047
		R3	144.0				2360	0.261	0.044
		R4	212.0				2380	0.276	0.037
		R5	258.0				2500	0.228	0.038
		R6	298.0				2540	0.170	0.035
		R7	303.0				2520	0.177	0.028
		Average	**190.1**	**732.5**	**149**	**1740**	**2310**	**0.205**	**0.034**
S28-9	70 - 90	R1	142.0	864	175	1940	2270	0.175	0.054
		R2	163.0	911	160	2020	2370	0.225	0.084
		R3	246.0				2460	0.208	0.096
		R4	281.0				2450	0.158	0.108
		R5	313.0				2500	0.159	0.103
		Average	**229.0**	**887.5**	**167.5**	**1980**	**2410**	**0.185**	**0.089**
S34-1	0 - 24	R1	1150.0	1198	1155	4370	6140	0.265	0.046
		R2	690.0	996	209	2460	3350	0.250	0.104
		R3	627.0				3120	0.284	0.098
		R4	613.0				3030	0.281	0.092
		R5	642.0				3090	0.244	0.096
		R6	634.0				3160	0.233	0.073
		Average	**726.0**	**1097**	**682**	**3415**	**3648**	**0.260**	**0.085**

SAMPLE ID.	DEPTH IN.	EFFLUENT RUN	Na mg/L	SO4 mg/L	Cl mg/L	TDs mg/L	Cond. umhos/cm	Se mg/L	U mg/L
S34-1	24 - 60	R1	2790.0	5595	1845	12800	14100	0.325	0.089
		R2	1280.0	2253	176	4600	5600	0.250	0.100
		R3	963.0				4700	0.281	0.073
		R4	758.0				3780	0.273	0.076
		R5	730.0				3630	0.232	0.079
		R6	659.0				3400	0.232	0.072
		Average	**1196.7**	**3924**	**1010.5**	**8700**	**5868.3**	**0.266**	**0.082**
S34-5	3 - 40	R1	480.0				4930	0.254	0.062
		R2	395.0				3660	0.095	0.106
		R3	350.0				2930		0.122
		Average	**408.3**	**0.0**	**0.0**	**0.0**	**3840**	**0.175**	**0.097**
S34-5	40 - 73	R1	329.0	1511	248	2990	3360	0.165	0.032
		R2	270.0	1048	160	2160	2590	0.212	0.048
		R3	278.0				2540	0.251	0.038
		R4	280.0				2430	0.229	0.031
		R5	291.0				2470	0.109	0.039
		R6	309.0				2520	0.101	0.045
		R7	277.0				2540	0.133	0.049
		R8	292.0				2560	0.197	0.051
		Average	**290.8**	**1279.5**	**204**	**2575**	**2626.3**	**0.175**	**0.042**

6 *BENCH TESTS AND FIELD PILOT TESTS*

Once laboratory results of column studies were obtained, laboratory bench tests were conducted in an effort to increase the ability of the soils to attenuate selenium. These test consisted of the extrapolation of water treatment technology to the site soils. As described in Section 2.0, iron hydroxides in soils have the ability to adsorb selenium if the selenium is in the selenite form or could be coverted from selenate to selenite. Previous analyses on selenium speciation at the site has indicated that the selenium is present largely in the selenate form with minor concentrations of selenite. If site soils do not have sufficient concentrations of iron hydroxides, it is theoretically possible to artificially supply the iron hydroxide source to the soils in concentrations which could result in selenium attenuation.

6.1 BENCH TEST AND FIELD TEST METHODS

6.1.1 BENCH TEST METHODS

Bench tests were conducted using a two phase approach. The first phase examined the ability of basalt and Chinle shale rock materials to naturally attenuate selenium without the alteration of their chemical properties. Samples of basalt rock fines from the site quarry and samples of Chinle shale from drilling were obtained for bench testing. Splits of the basalt composite sample were placed in a column and leached with collection well water. Splits of the Chinle shale composite sample were placed in a humidity cell and also leached for several days with the collection well water. Effluent samples were collected from these tests and submitted to the laboratory for analyses of selenium, uranium, and iron.

Iron chemical sources were obtained for testing of selenium adsorption following application of the iron chemicals to the humidity cell soils. Initially, it was assumed that sufficient oxides or hydroxides could be generated when iron was added to the soils to form stable iron hydroxide complexes for adsorption sites. Two soils, sites S28-2 (0 to 40 inches) and site S34-1 (3 to 24

inches) were selected for testing. Sample splits were placed in humidity cells and iron chemicals were added at a preliminary rate of 400 mg/kg iron. Following incorporation, the chemicals were dissolved with deionized water and then leached with the collection well water. Effluent samples were then collected and submitted to the laboratory for analyses of selenium, uranium, and iron.

The second phase of the bench testing evaluated the adsorption of selenium when a dissolved calcium hydroxide solution was mixed with a dissolved iron solution and added to the soil in a humidity cell. The iron chemicals used in the test were ferrous ammonium sulfate fertilizer (16% iron) and ferric chloride (50% iron). The iron chemicals were dissolved in deionized water, mixed with a slurry of calcium hydroxide and applied to the test soils. The ratio of ferrous ammonium sulfate to calcium hydroxide was approximately 1 part iron to 1 part calcium hydroxide. The ratio of ferric chloride to calcium hydroxide was approximately 1part iron to 10 parts calcium hydroxide. Following sufficient reaction time between the calcium hydroxide source and the iron chemicals, the humidity cells were then leached for several days with the collection well water. Effluent samples collected from the cells were then submitted to the laboratory for analyses of selenium, uranium, and iron.

6.1.2 PILOT FIELD TEST METHODS

The pilot testing of these procedures was also conducted using a two phase approach and also using two separate sites with different quality well waters. Two swales, Swale #1 located in Section 28 and Swale #5 located along the south edge of Section 22, were selected for flooding with the alluvial well water. Both sites had shallow 2 inch diameter wells installed for monitoring the potential removal of selenium and uranium from the alluvial irrgiation waters. Swale # 1 was irrigated with water from alluvial well #886. Swale #5 was irrgiated with water from the "P" alluvial wells located north of the millsite. Refer to Figure 3-2 for the location of these swales.

Both swales were flooded in July and August, 1997 without the addition of chemicals to evaluate the natural attenuation of selenium and uranium. Swale #1 was flooded at an average rate of 90 gallons per minute for several weeks. Swale #5 was flooded at a rate of 45 gallons per minute. The monitoring wells were shallow in Swale #1, identified as wells 4A through 4L and averaged 6 feet in depth. Figure 6-1 shows the location of the wells within Swale #1. Monitoring wells in Swale #5 were much deeper (approximately 30 feet) and are identified on Figure 6-2 as wells 4M through 4T. Because of the depth of the monitoring wells, Swale #5 was set up as a longer term test to evaluate both the removal of selenium and uranium from the waters and the possible mobilization of selenium from deep within the alluvial materials. In addition, Swale #5 was located in an area where the alluvial aquifer did not exist and would allow the input water to penetrate the Chinle shale. Bench test results have indicated that the Chinle shale showed some ability to attenuate selenium.

Prior to flooding, any water within the wells was sampled to establish baseline conditions and the well water was also sampled at that time. Water levels were monitored on a daily basis and, when irrigation water appeared in a well, it was sampled. Wells were then sampled on a routine basis and submitted to the laboratory for analysis of uranium and selenium. Results of the samples were then plotted against the input concentrations of selenium and uranium and removal percentages were calculated.

The second phase of the swale testing was conducted by adding iron and calcium hydroxide chemicals to the swale surface in a manner similar to that used for the bench testing of the procedure. Calcium hydroxide (slaked lime) was obtained from an acetylene gas manufacturing plant in Albuquerque and trucked to the site. The ferrous ammonium sulfate fertilizer used as an iron source in the bench tests was not readily available in New Mexico. A source of iron oxide fertilizer (28% iron) was located in Belen, New Mexico and also trucked to the site. While this material was not as soluble as the ferrous ammonium sulfate, it was thought that the fines would dissolve readily and the coarser fertilizer could serve as a longer-term treatment.

Approximately 4 tons of slaked lime were spread over the approximately 0.40 acre Swale #1 and 1500 pounds of the iron fertilizer was added to the swale. Following the spreading of the chemicals, the swale was flooded with water from well #886 at a rate of 90 gpm. It was clear from observation of the chemical reactions that the iron fertilizer did not have sufficient solubility to allow for adequate reaction with the slaked lime. Ferric chloride (50%) was then added to the well water as it entered the swale and allowed to react with the slaked lime to form iron hydroxides as possible adsorption sites for the selenium. Swale #5 received similar treatments as Swale #1, however, as stated previously, this test will be conducted for a longer time interval to allow for collection of water in deeper wells around the site.

The water was allowed to continuously flood each swale and samples were routinely taken from the observation wells placed in the swale. After examination of initial sample results, additional ferric chloride was added to the swale to consume more of the available slaked lime in an attempt to increase the amount of iron hydroxides available for adsorption. Time versus concentration plots were graphed to visually represent the results of this testing. Ideally, these tests will allow for the development of precise application rates and to examine the fate and longevity of the chemicals and the cost-effectiveness of this treatment technology.

6.2 BENCH TESTS AND FIELD PILOT TEST RESULTS

6.2.1 BENCH TEST RESULTS

As discussed in Section 5.0, the site soils do not appear to have the ability to attenuate selenium naturally. As a result, bench tests were initiated to examine ways of artificially removing selenium with soils by the addition of selective chemicals. The basalt rock did not remove selenium from the collection well water and, in fact, exhibited minor selenium leaching similar to the site soils. Further, chemical oxidation of the basalt fines did not visibly alter the fines

and no further testing on these materials appears warranted. The addition of iron to the basalt cell also did not show that selenium would be attenuated by this material. Refer to Table 6-1 and Figure 6-3 for a summary of the basalt test results.

The addition of iron chemicals to the Site 28 soils and the Site 34 soils also showed no evidence of selenium attenuation as a result of the added iron. Obviously adsorption sites had not been generated by this method. Again these results have been presented in Table 6-1 and Figure 6-3.

The leaching of the Chinle shale showed similar results as the basalt fines prior to the addition of iron to the Chinle humidity cell. However, after the addition of iron chemicals, continued leaching of the Chinle shale with the well CW44/644 water has shown some minor attenuation of selenium, assumed to be the selenite form of selenium. Figure 6-3 shows the selenium removal trends exhibited by continued leaching of the Chinle shale.

As described previously, the second phase of the bench testing involved the addition of an artificially produced iron oxyhydroxide solution to the Section 28 and Section 34 soils and to the Chinle shale sample. Results of this testing are shown in Table 6-2 and Figure 6-4 graphically depicts the results of this phase of the testing. As can be seen from the plots, nearly all of the selenium was removed from the leach water during the first leach cycle for all three cells. In fact the amount of selenium removed from the initial leach sample for both soils was significantly more than the total estimated selenite in the well water, indicating the removal of selenate from the water. As subsequent leaching cycles were conducted, the amount of selenium removal decreased over time and the plots began to level off, resulting in the removal of approximately one half (50%) of the selenium with each subsequent leach cycle. Refer to Section 6.3 for further discussion of these results.

6.2.2 SWALE #1 FIELD PILOT TEST RESULTS

Table 6-3 summarizes the selenium and uranium attenuation results of the preliminary field tests for flooding of Swale #1 without the addition of chemicals to the swale. The initial selenium concentration in well #886 at the start of flooding was 0.093 mg/l. While some minor amounts of selenium appear to have been removed from the well #886 alluvial water, the overall removal is not enough to achieve projected groundwater standards. In addition, the well water was analyzed only at the start of flooding. It is likely that some variability in selenium levels in the alluvial water has occurred and the actual measured levels of selenium in the monitoring wells is more reflective of well water quality than of actual selenium attenuation. Figure 6-5 provides a graphical plot of the data.

Review of the data in Table 6-3 indicates that a significant portion of the uranium concentrations in well #886 were being attenuated by the swale soils. Initially, the majority of the uranium was removed by the soils, however, as can be seen in Figure 6-6, the uranium concentration in the monitoring well water samples began to level off and gradually reflect the concentration of uranium in the well #886 water. The average removal of uranium over time was approximately equal to one half of the uranium content of the irrigation waters. Refer to discussions in Section 6.3 on the interpretation of these results.

Photographs 1 and 2, located at the end of this section show the configuration of Swale #1 prior to chemical addition. The swale is approximately 0.40 acres in size. Photograph 2 also shows some of the shallow monitoring wells in the swale. Photographs 3 and 4 show the placement of the slaked lime in the swale. Photograph 5 shows the beginning of the flooding of Swale #1 and the completely flooded swale and saturated slaked lime is shown in Photograph 6. Photographs 7, 8, and 9 show the addition of the ferric chloride and the swale after the completion of the addition of chemicals. Photograph 10 shows monitoring of one of the wells located in the center of the swale.

Table 6-4 summarizes the results of the uranium and selenium attenuation in Swale #1 after the addition of the iron hydroxide chemicals. Figure 6-7 shows that selenium is definitely being removed from the well #886 waters. The removal, on average, of over one half of the selenium reflects results of the bench test experiments. That is, while only approximately 10 percent of the selenium was in the selenite form, some of the selenate had to also be converted and removed by the adsorption process. In addition, the efficiency of attenuation was significantly better in some wells than in others. As an example, monitoring well #4H shows that the majority of selenium has been adsorbed in the vicinity of this well. This process appears, with additional refinement of the process, to be capable of adsorbing selenium at levels which would achieve groundwater standards of 0.05 mg/l. Section 6.3 provides further discussion and interpretations on these results.

The results of the uranium adsorption on the soil exchange complex indicate that the uranium concentrations in the monitoring wells generally are beginning to reflect the input water uranium content. These results are also presented in Table 6-4 and plotted on Figure 6-8 and show that the average uranium content in the monitoring wells is 0.24 mg/l. That is, on average, 44% of the uranium has been removed from the input water. When comparing these results to the previous Swale #1 flooding, these numbers are very similar to the monitoring well uranium concentrations present during the last sampling periods of the earlier field test. Since these numbers are similar to the previous test end concentrations, it is not likely that the added chemicals have affected the uranium attenuation process.

6.2.3 SWALE #5 FIELD PILOT TEST RESULTS

The Swale #5 results were intended to evaluate the ability of the natural soils to attenuate both uranium and selenium in an area where the alluvial aquifer did not exist. Photograph 11 shows the general position of the swale in Section 22. The swale was flooded in August

and early September and selenium and uranium results are shown in Table 6-5. The selenium content of the input water averaged 0.192 mg/l for the entire test. Uranium content of the in put water from the "P" wells was very low and averaged only 0.029 mg/l for the test.

Figure 6-9 shows the selenium data from the monitoring wells for both the intial flooding and for after the addition of chemicals in mid-September. Selenium results indicated that some selenium was being removed in the soil alluvial system before the addition of chemicals. Wells completed in the alluvium (4Q, 4M, and 4P) showed removal of only about 25% of the selenium on average. Wells completed in the Chinle shale (4O and 4R) showed that approximately 65% of the selenium was being removed during the initial flood stages. Note that the percent selenium removal may indicate that some selenate is also being removed from the waters.

In mid-September, iron hydroxide chemicals where added to the swale in the same manner as described above for Swale #1. This process is shown in Photographs 11 through 16. Photograph 12 shows the placement of slaked lime into the swale. Photographs 13 and 14 depict the swale chemistry after the addition of the iron fertilizer. Note the classic dark blue-green color exhibited by the ferrous iron. Photographs 15 and 16 show the flooded swale and the slow additon of the ferric chloride solution. The reaction of the ferric chloride with the slaked lime is apparent in the photo with the formation of the rust colored iron hydroxide sludge.

Results of selenium attenuation after the addition of the chemicals are also shown in Table 6-5 and graphically presented on Figure 6-9. As with the tests conducted before the chemical placement, monitoring wells completed in the alluvium still show some selenium removal. However, as can be seen in the Figure, the selenium values from the last sampling are beginning to approach the concentrations of the input water.

The results for the two monitoring wells completed in the Chinle shale are significantly different. Examination of the data and Figure 6-9 show that approximately one half of the selenium was still being removed from the input water. However, the last sampling period shows that a downward trend in the data, indicating possible increased attenuation of selenium, was evident. These results are similar to those exibited by the Chinle shale in the bench tests. Little evidence exists which shows the chemicals had any affect on the selenium removal process. However, it is likely that some selenium from the alluvium was being leached in the water and then partially attenuated by the Chinle shale.

Figure 6-10 shows the monitoring well results for the same time periods for the attenuation of uranium. While the removal of uranium was evident, the results are somewhat eratic and the input uranium content was very low. Concentrations of uranium in both the input water and the monitoring well data are both well below potential risk levels. After the addition of the chemicals, no significant diffierences were noted in the removal of uranium. While the uranium concentrations were very low, the trends help to confirm the results of the Swale #1 tests and show that uranium attenuation is not affected significantly by the addition of the chemicals.

6.3 DISCUSSION

The simple addition of iron to the site soils and the basalt sample did not result in the attenuation of selenium. The adsorption process requires the presence of iron oxyhydroxides and is specific to the selenite species. The mechanism to form sufficient iron oxyhydroxides or to convert selenate to selenite did not occur with this process for these materials. It did appear that the Chinle shale had some ability to attenuate selenium. Since the selenium removal had to include

some selenate which theoretically is not removed by this process, the mechanism of the chinle attenuation is not understood at this time.

The application of iron-coprecipitation technology to land application techniques may have merit for the attenuation of selenium. That is, the addition of iron oxyhydroxides in sufficient quantities appears to have attenuated a significant portion of the total selenium in both the bench tests and the field pilot tests for Swale #1. The initial removal of selenium in both the bench tests and the Swale #1 tests appears much more efficient than continued removal over time. It is likely that this process has effected the reduction-oxidation potential of the selenium. Since selenite represents approximately 10% of the total selenium, selenate had to be converted to selenite and adsorbed by the iron oxyhydroxide solution. As the chemicals oxidized with time, the removal of selenium became less efficient. The results of the field tests before chemical application indicate that biological reduction was not occuring at rates which significantly removed selenium.

At this point, it is not known whether additional chemicals would be required to remove higher concentrations of selenium or if longer retention times are necessary. Nevertheless, when the process was terminated, the average selenium removal rate was approximately 0.05 mg/l, the potential long term selenium groundwater standard. In addition, the swale was characterized by shallow hummocks and the chemicals tended to settle in the basins of the hummocks. While the actual ground surface coverage was not determined, it appears that the chemicals covered approximately 60% of the area as shown in Photograph 6. Since the flooded waters covered the entire hummock, it is likely that additional adsorption would occur with complete surface coverage by chemicals. Some concern still exists for the possible mobilization of alluvium selenium as the water passes throught the soil below the affected depth of the chemicals.

The attenuation of uranium in Swale #1 was also more efficient at the start of the field tests than at the end of the tests. The average uranium removal for the entire pilot test was approximately 45% of the total uranium. The available data is not sufficient to determine the degree of

exchange site saturation with uranium since the initial soil base saturation was not known. The base saturation gives an estimate of the number of exchange sites which have adsorbed base cations. In addition, the oxidation state of uranium is unknown and the ionic preference for uranium over other cations is also unknown. Regardless, it is not likely that the available exchange sites have been completely saturated with uranium. Rather, it is more likely that the easily exchangeable cations have been replaced by uranium or easily accessed exchange sites have been filled. In order for additional cation exchange to occur with the irrigation waters, longer retention times are probably necessary.

The relationships for selenium attenuation in Swale #5 show that when monitored at depths up to thirty feet, little effect was observed from the addition of chemicals. Shallow wells like the wells in Swale #1 may have shown more near-surface attenuation. If the chemicals allowed for some near-surface attenuation, then the water picked up selenium as it passed through the alluvium. However, without additional data, definative conclusions can not be reached. Regardless of these conclusions, approximately one half of the selenium that reached the Chinle shale was being removed in the shale. Since both selenite and selenate were being removed, the process of removal is not fully understood at this time. Additonal testing on the Chinle shale attenuation mechanisms would be necessary to reach a conclusion on the process. It is assumed that with continued leaching in a given confined area, the mobile selnium would quickly be leached from the soil to a depth were it may be attenuated by the Chinle shale.

Table 6-1. Selenium Attenuation Bench Test Results - Iron Addition Only

	Selenium mg/l			
Test #	Site 28	Site 34	Basalt	Chinle
1	0.199	0.187	0.202	0.177
2	0.167	0.188	0.200	0.187
3	0.188	0.192	0.178	0.186
4	0.210	0.199	0.198	0.167
5	0.198	0.187	0.189	0.166
Average	0.192	0.191	0.193	0.177

Note: Well #886 Selenium Content = 0.206 mg/l

Table 6-2. FeOH Selenium Attenuation Bench Test Results

	Selenium mg/l		
Test #	Site 28	Site 34	Chinle
1	0.010	0.003	0.215
2	0.081	0.004	0.056
3	0.122	0.088	0.003
4	0.146	0.098	0.002
5	0.166	0.102	0.041
Average	0.105	0.059	0.063

Note: Well #CW44/644 Selenium Content = 0.206 mg/l

Table 6-3. Swale #1 Selenium And Uranium Attenuation Pilot Test Results - With Irrigation Only -

Run	4A	4B	Well # 4C	4E	4F	4G	4H	Average
			Selenium - mg/l					
6/25/97	0.054	0.054	0.054	0.091	0.089	0.088	0.088	0.074
6/26/97	0.088	0.088	0.089	0.089	0.089	0.086	0.085	0.088
6/27/97	0.088	0.069	0.087	0.086	0.086	0.085	0.082	0.083
6/29/97	0.081	0.070	0.081	0.082	0.081	0.083	0.078	0.079
7/1/97	0.077	0.078	0.079	0.079	0.078	0.083	0.079	0.079
Average	0.078	0.072	0.078	0.085	0.085	0.085	0.082	0.081

Note: Well #886 Selenium content = 0.093 mg/l

Run	4A	4B	4C	4E	4F	4G	4H	Average
			Uranium - mg/l					
6/25/97	0.012	0.014	0.016	0.051	0.012	0.506	0.093	0.101
6/26/97	0.064	0.078	0.098	0.228	0.089	0.513	0.433	0.215
6/27/97	0.172	0.029	0.290	0.465	0.162	0.412	0.443	0.282
6/29/97	0.295	0.019	0.347	0.350	0.309	0.408	0.392	0.303
7/1/97	0.318	0.029	0.343	0.411	0.300	0.333	0.359	0.299
Average	0.172	0.034	0.219	0.301	0.174	0.434	0.344	0.240

Note: Well #886 Uranium Content = 0.543 mg/l

Table 6-4. Swale #1 FeOH Selenium and Uranium Pilot Test Results

Run	Well #886 Input H2O	4A	4B	Well # 4C	4D	4E	4H	Average
				Selenium	**mg/l**			
9/12/97	0.096		0.101	0.093		0.095	0.115	0.101
9/15/97	0.082	0.08	0.084	0.082	0.087	0.084	0.073	0.082
9/29/97	0.073	0.062	0.071	0.053	0.06	0.038	0.015	0.050
10/6/97	0.082	0.049	0.061	0.046	0.063	0.03	0.004	0.042
10-16-97	0.080	0.042	0.049	0.046	0.049	0.031	0.006	0.037
Average	**0.083**	0.047	0.073	0.064	0.052	0.056	0.043	**0.062**
				Uranium	**mg/l**			
9/15/97	0.370	0.340	0.265	0.410	0.239	0.401	0.151	0.301
9/19/97	0.360	0.370	0.307	0.358	0.316	0.359	0.191	0.317
9/29/97	0.286	0.300	0.278	0.256	0.258	0.318	0.062	0.245
10/6/97	0.311	0.282	0.304	0.246	0.296	0.308	0.133	0.262
10-16-97	0.300	0.305	0.344	0.406	0.281	0.359	0.224	0.320
Average	**0.325**	0.319	0.300	0.335	0.278	0.349	0.152	**0.289**

Table 6-5. Swale #5 FeOH Pilot Test - Selenium and Uranium Attenuation Results

Run	"P" Wells Input H2O	4M	4O	Well # 4P	4Q	4R	4T	Average
				Selenium	**mg/l**			
8/5/97	0.190	0.149	0.015	0.192	0.127	0.015		0.100
8/19/97	0.192	0.166	0.094	0.169	0.143	0.082		0.131
8/28/97	0.192	0.153	0.097	0.146	0.152	0.066	0.119	0.122
9/10/97	0.183	0.156	0.102	0.153	0.170	0.069	0.138	0.131
10/15//97	0.183	0.168	0.085	0.181	0.166	0.096	0.152	0.141
10/21/97	0.184	0.147	0.105	0.169	0.169	0.099	0.147	0.139
10/29/97	0.201	0.147	0.108	0.170	0.171	0.096	0.133	0.138
1/30/98	0.204	0.153	0.099	0.183	0.181	0.093	0.160	0.145
3/2/98	0.200	0.180	0.082	0.189	0.192	0.061	0.163	0.145
Average	0.192	0.158	0.087	0.172	0.163	0.075	0.145	0.132
				Uranium	**mg/l**			
8/5/97	0.025	0.019	0.034	0.013	0.012	0.027	0.012	0.020
8/19/97	0.026	0.016	0.019	0.014	0.024	0.021		0.019
8/28/97	0.027	0.016	0.015	0.012	0.015	0.019		0.015
9/10/97	0.028	0.015	0.013	0.013	0.015	0.016	0.010	0.014
10/15/97	0.030	0.020	0.023	0.016	0.017	0.017	0.018	0.019
10/21/97	0.030	0.021	0.017	0.014	0.015	0.015	0.018	0.017
10/29/97	0.030	0.020		0.017	0.014	0.017	0.015	0.014
1/30/98	0.035	0.019	0.024	0.023	0.019	0.018	0.021	0.021
3/2/98	0.032	0.024	0.034	0.028	0.020	0.020	0.021	0.025
Average	0.029	0.019	0.020	0.017	0.017	0.019	0.016	0.018

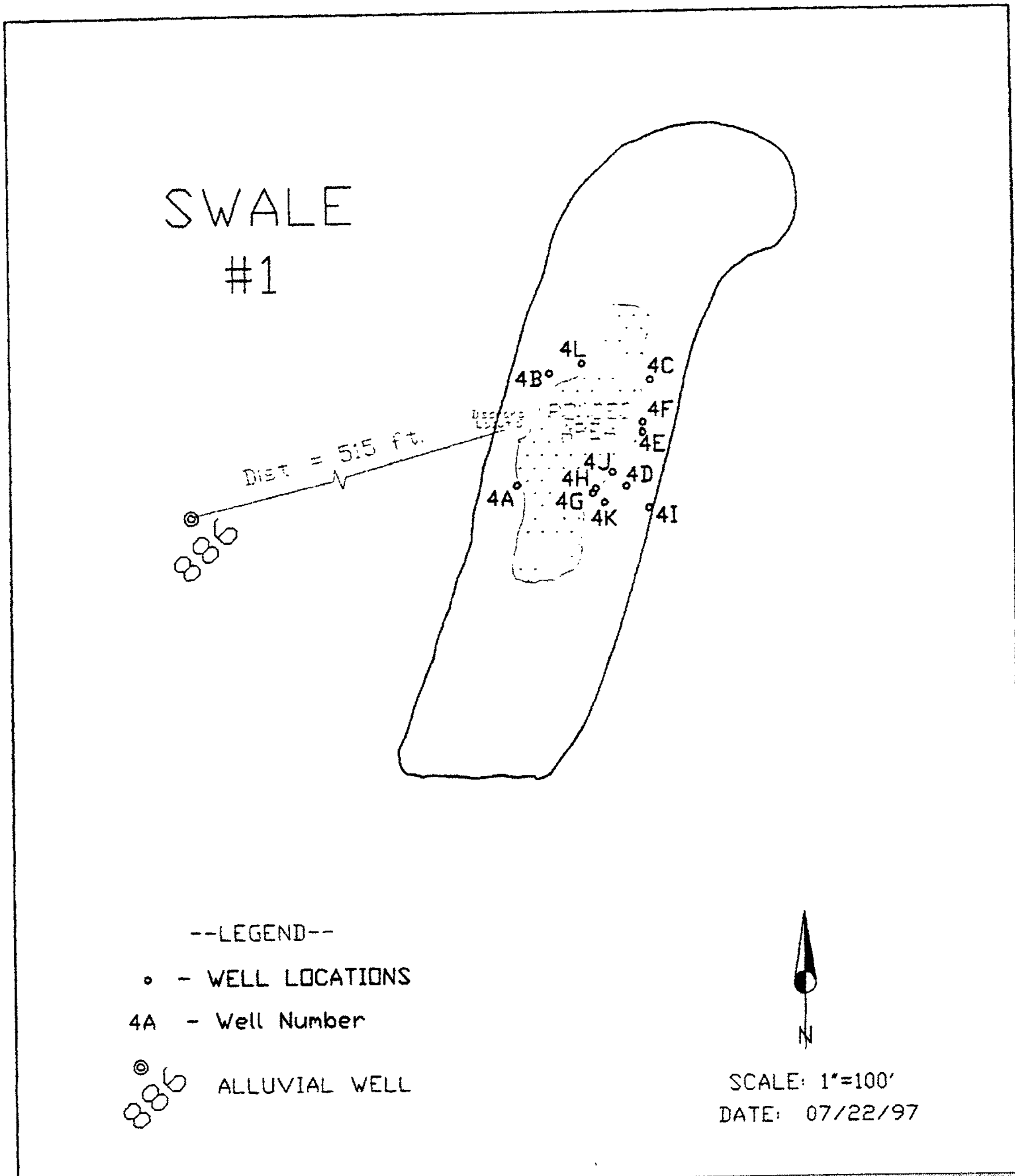

Figure 6-1. Swale #1 Paired Monitoring Well Locations

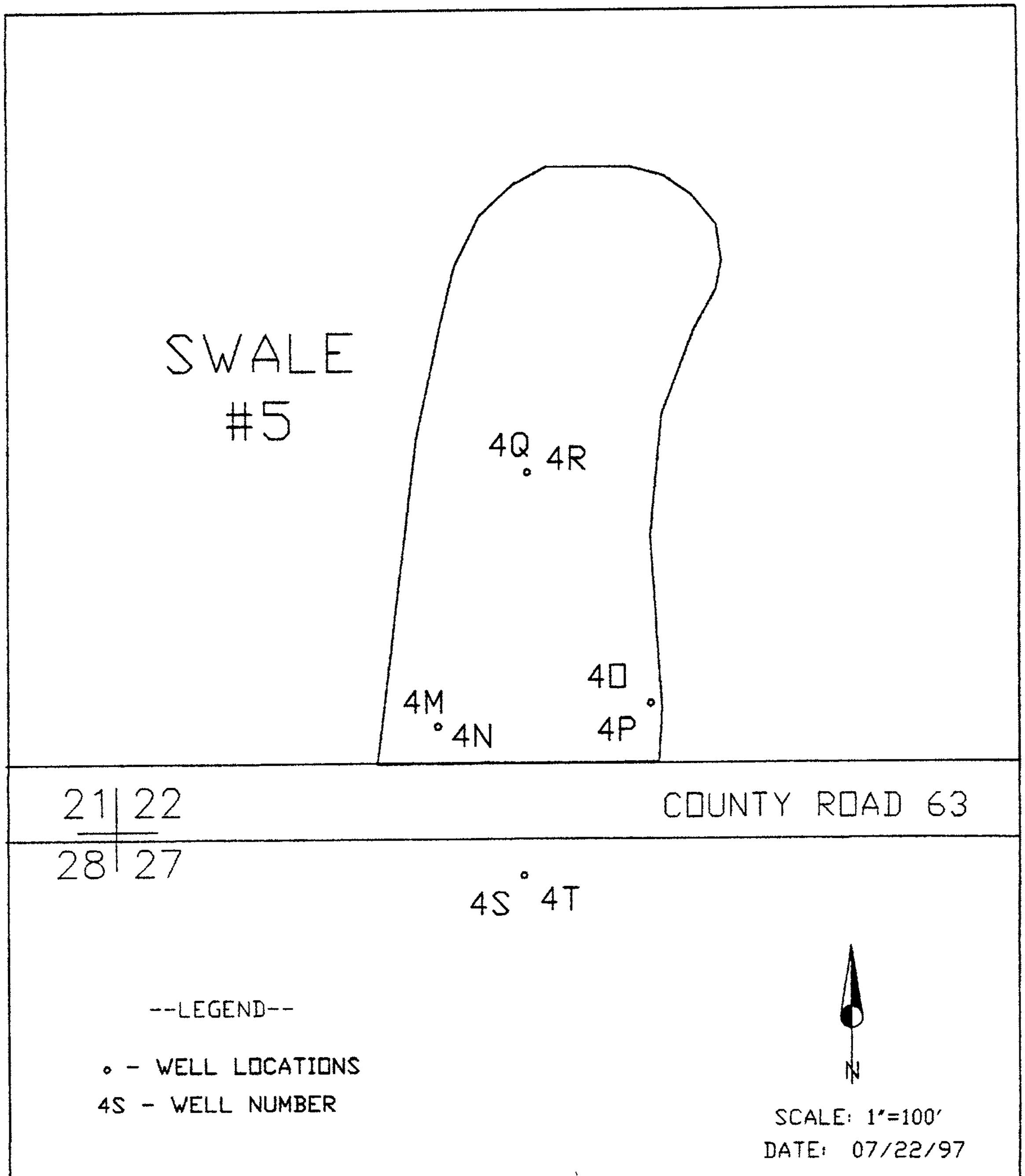

Figure 6-2. Swale #5 Paired Monitoring Well Locations

Figure 6-3. Selenium Attenuation Bench Test Results - Iron Addition Only
Well #CW44/644 Input Selenium = 0.206 mg/l

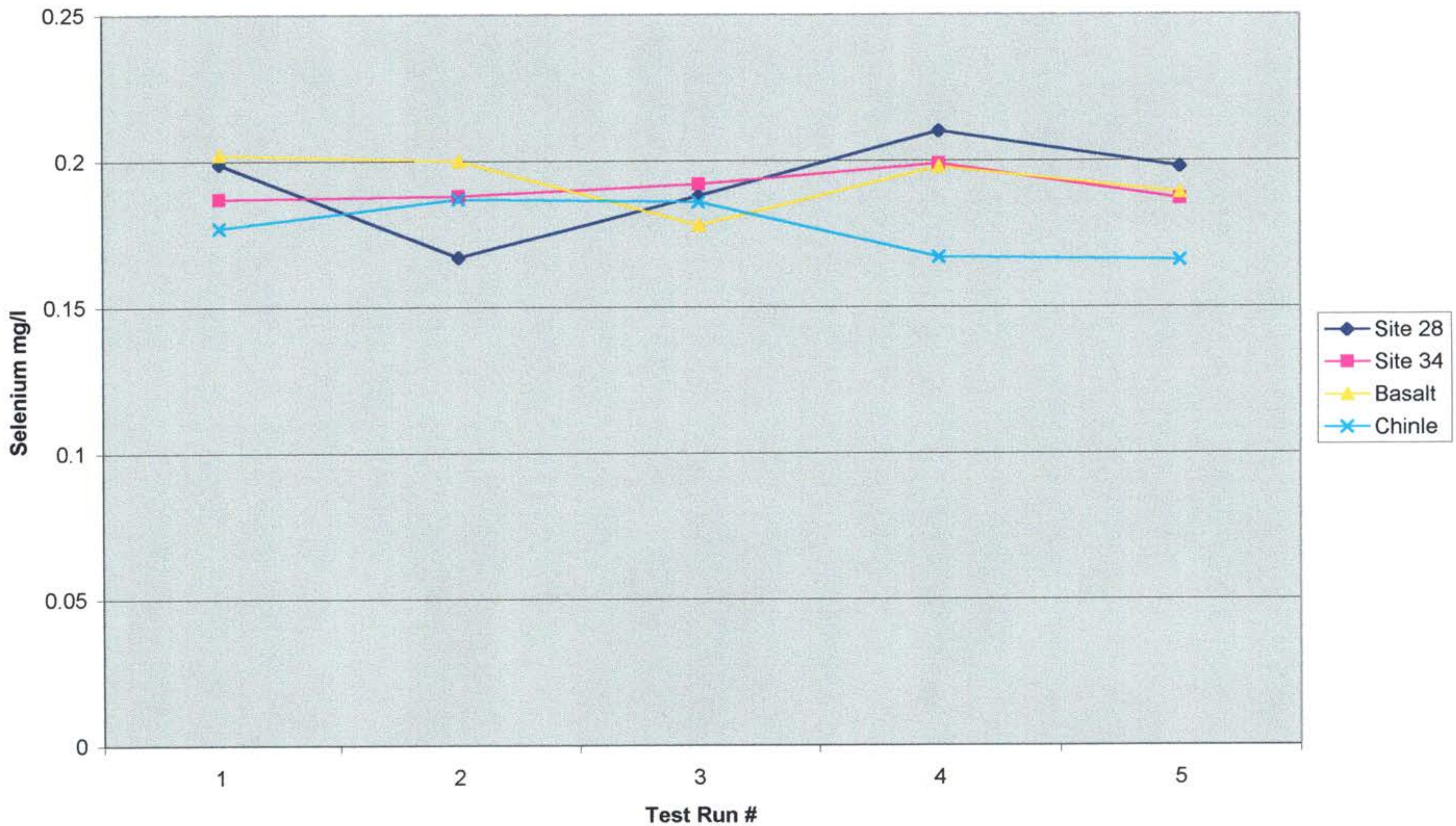

Figure 6-4. FeOH Selenium Attenuation Bench Test Results - CW44/644 Se=0.206mg/l

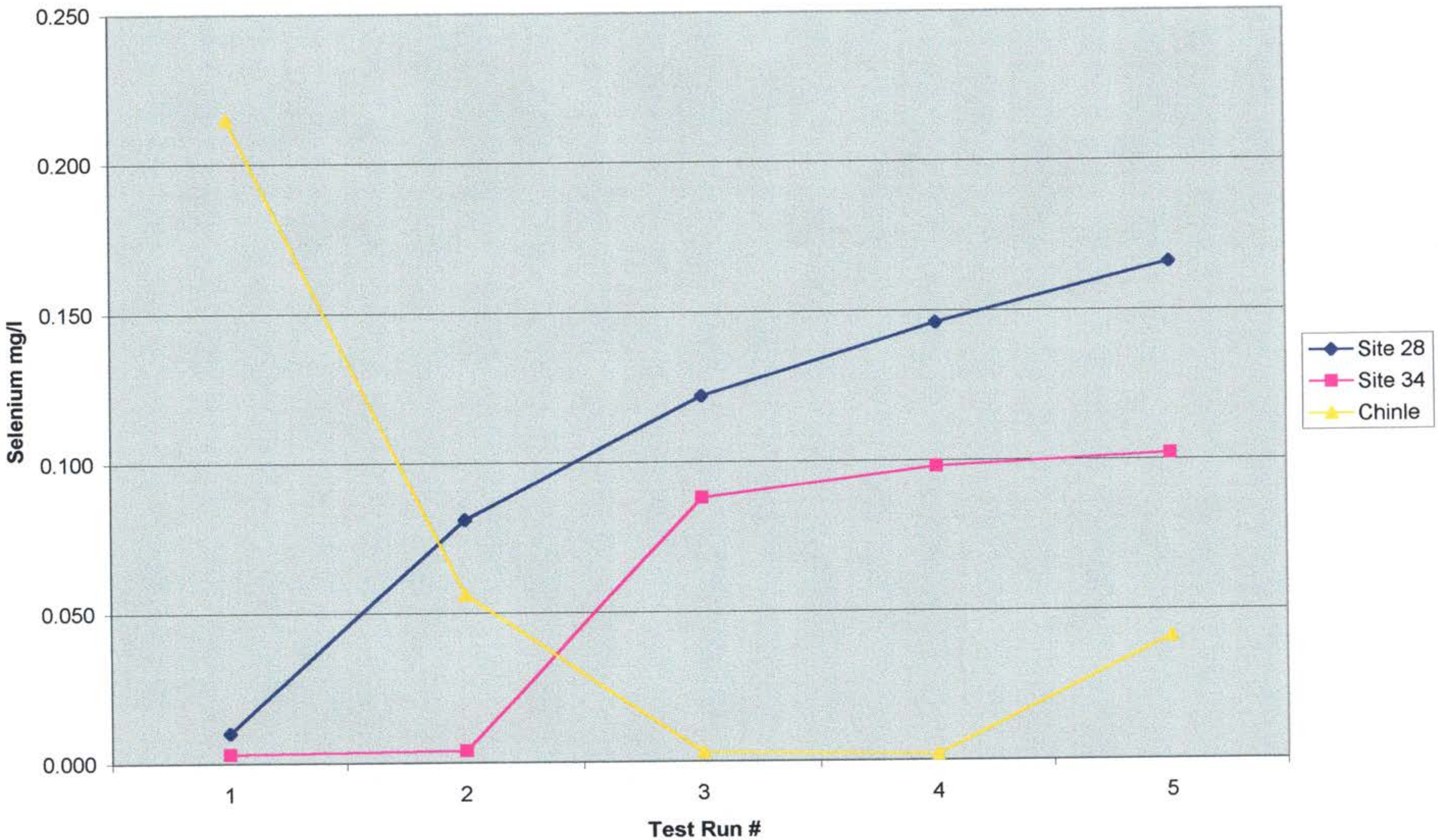

Figure 6-5. Swale #1 Selenium Attenuation Pilot Test Results With Irrigation Only
Well #886 Selenium = 0.093 mg/l

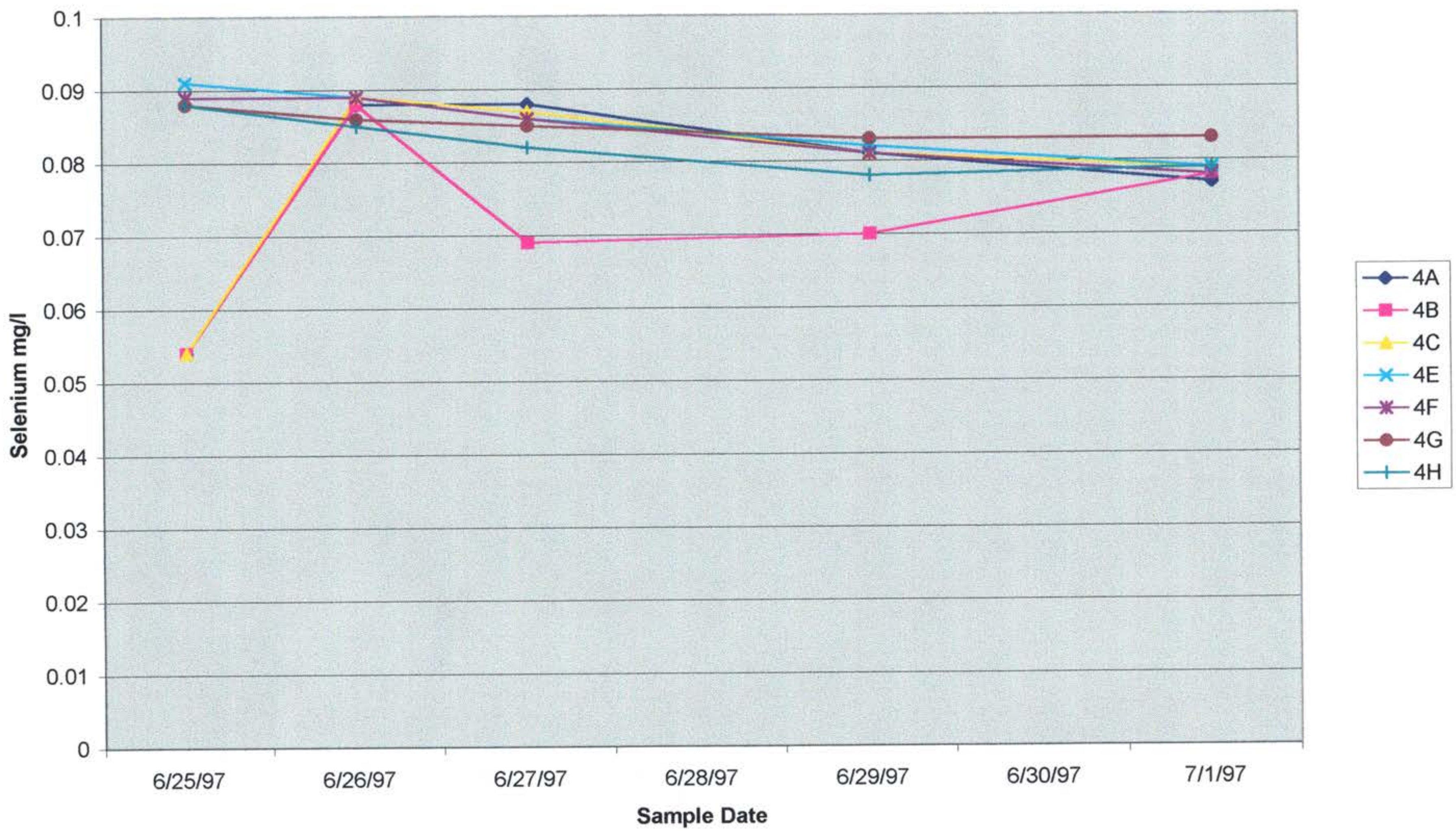

Figure 6-6. Swale #1 Uranium Attenuation Test Results With Irrigation Only
Well #886 Uranium = 0.543 mg/l

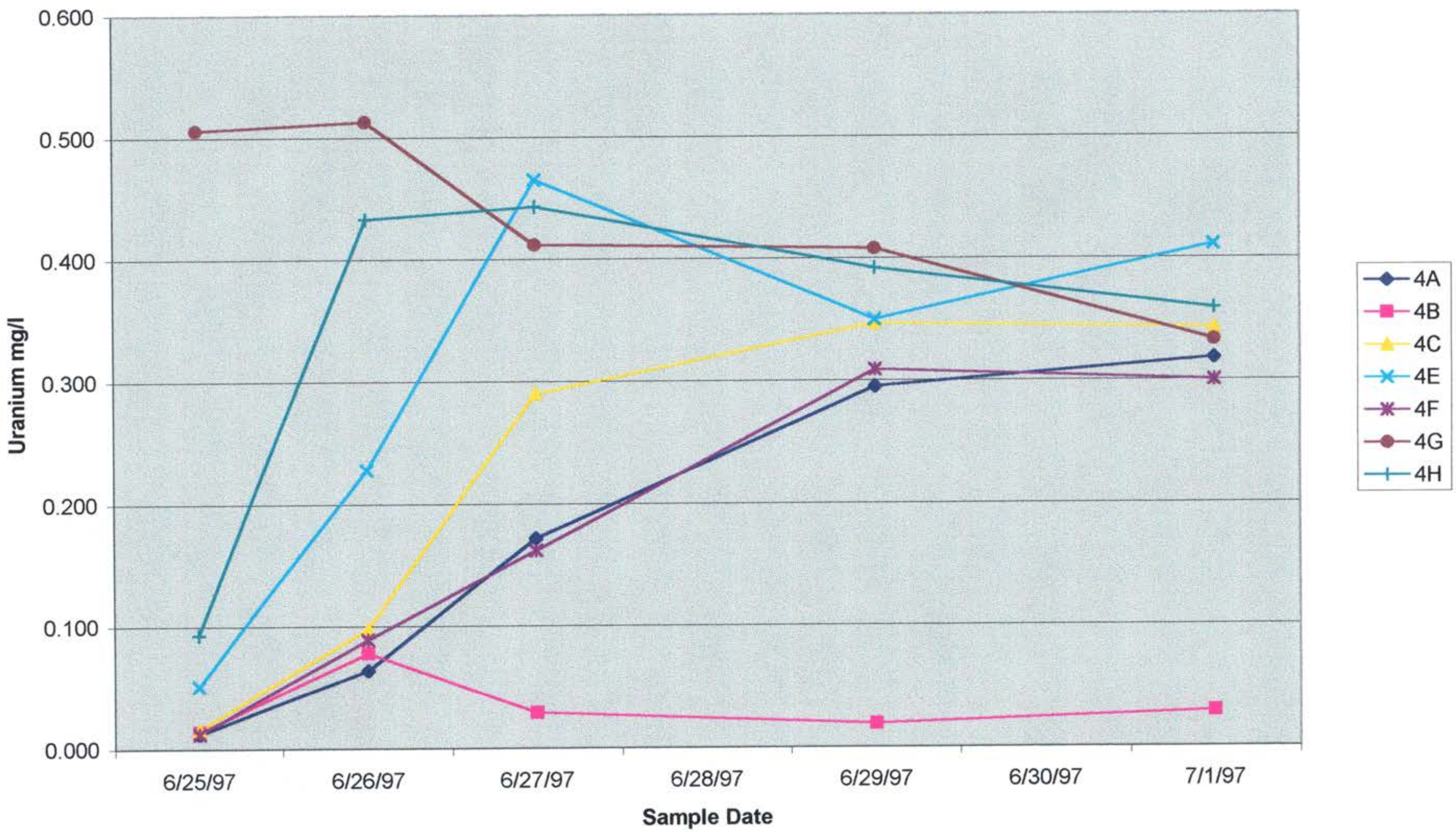

Figure 6-7. Swale #1 FeOH Selenium Attenuation Pilot Test Results

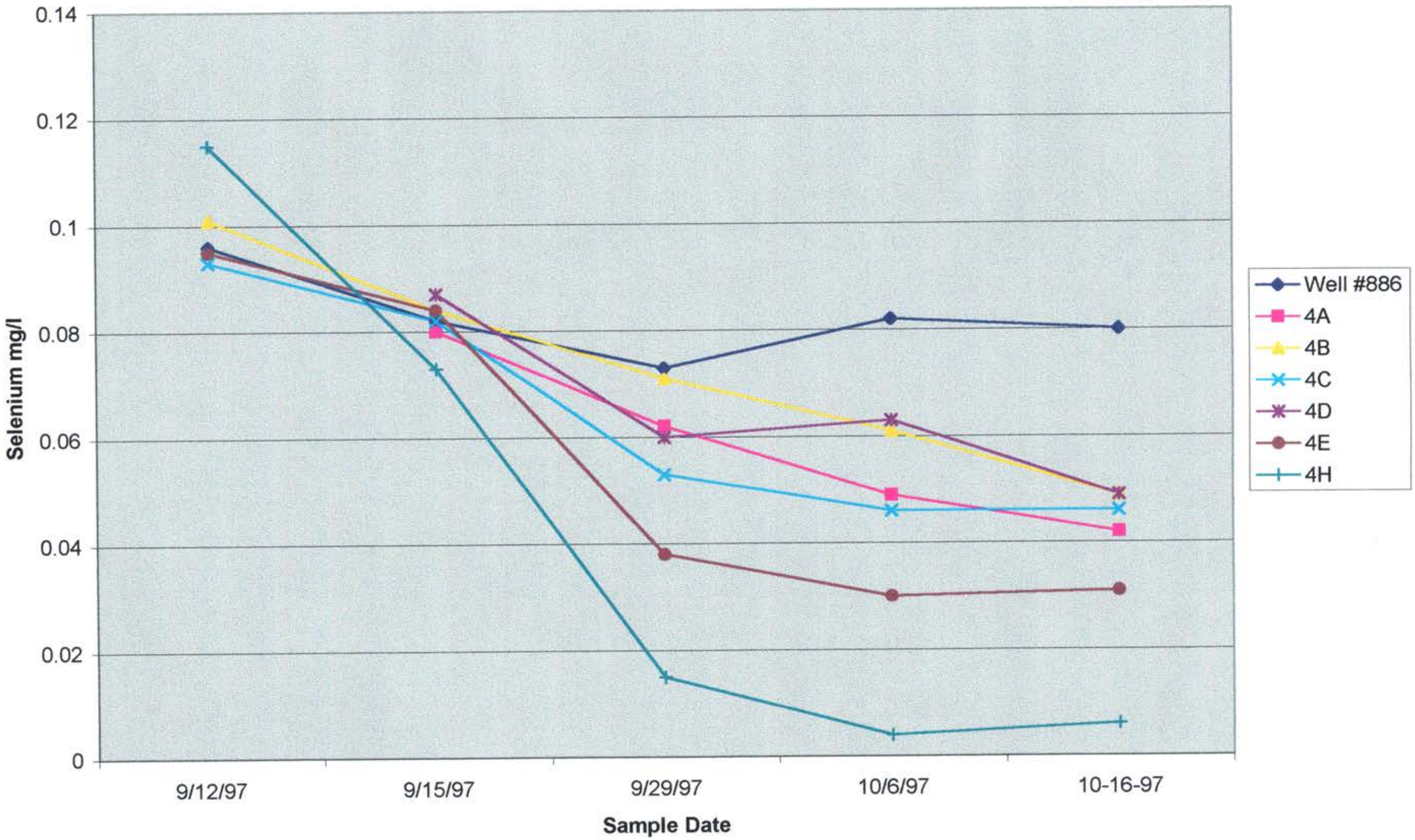

Figure 6-8. Swale #1 FeOH Uranium Attenuation Pilot Test Results

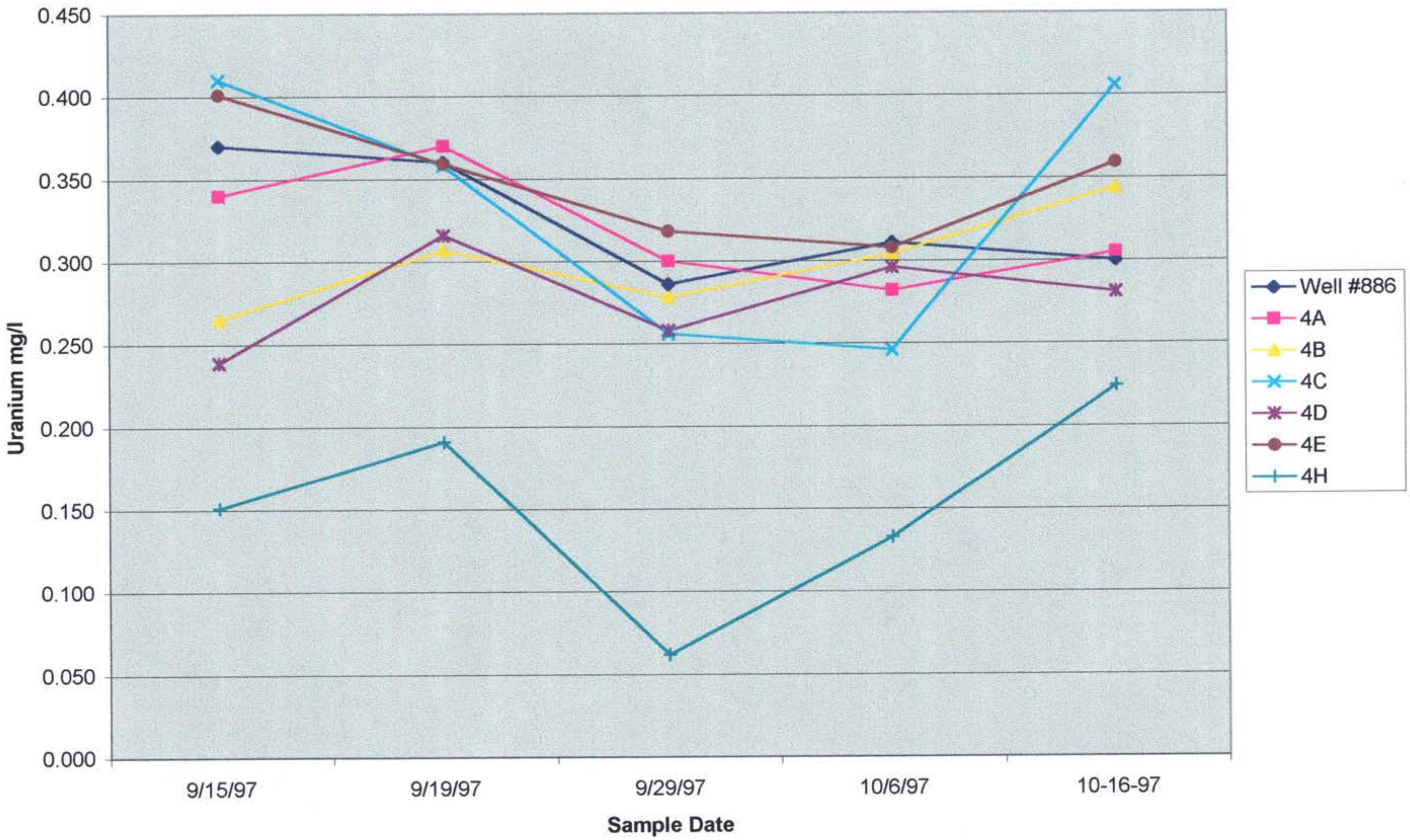

Figure 6-9. Swale #5 Selenium Pilot Test Results

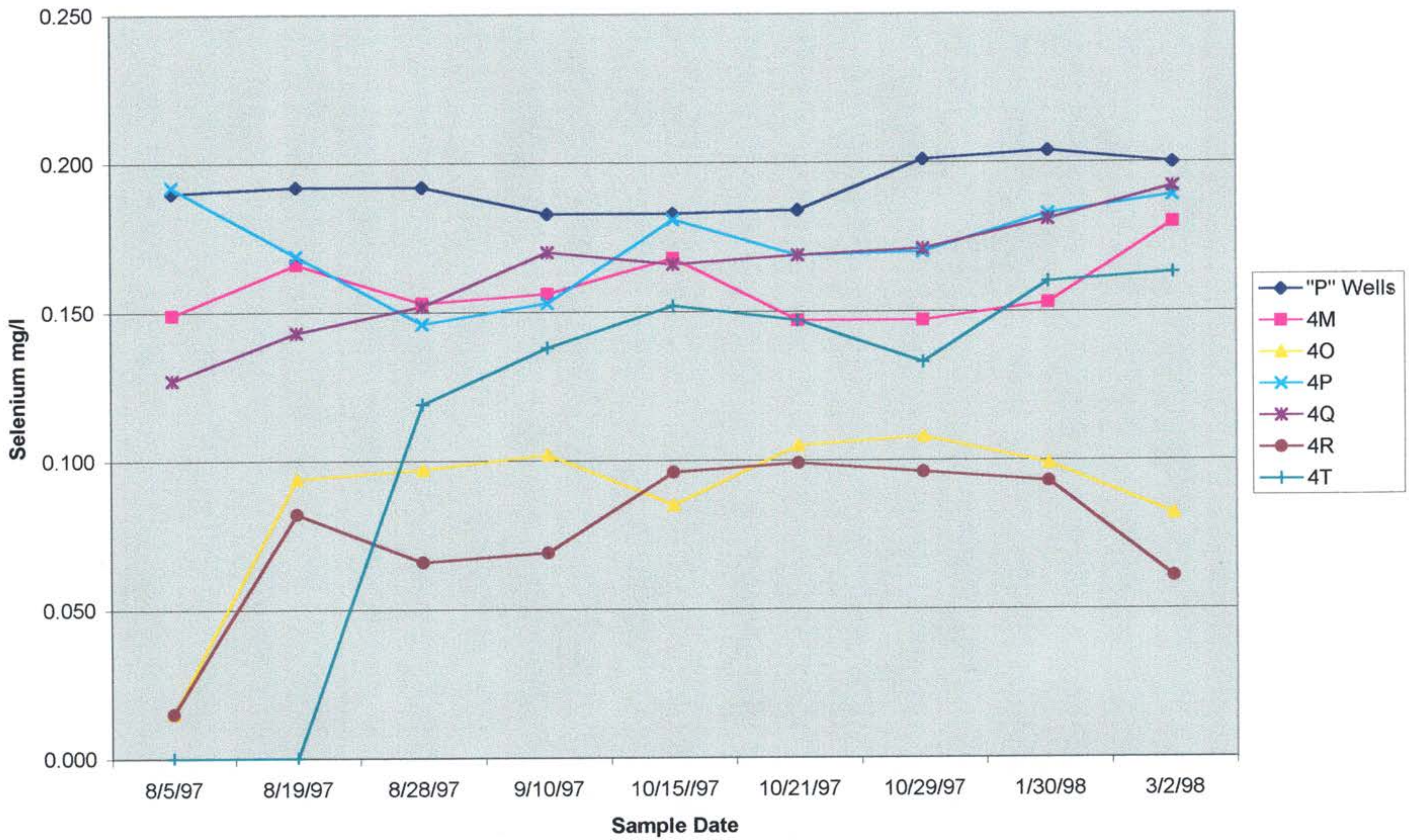

Figure 6-10. Swale #5 Uranium Pilot Test Results

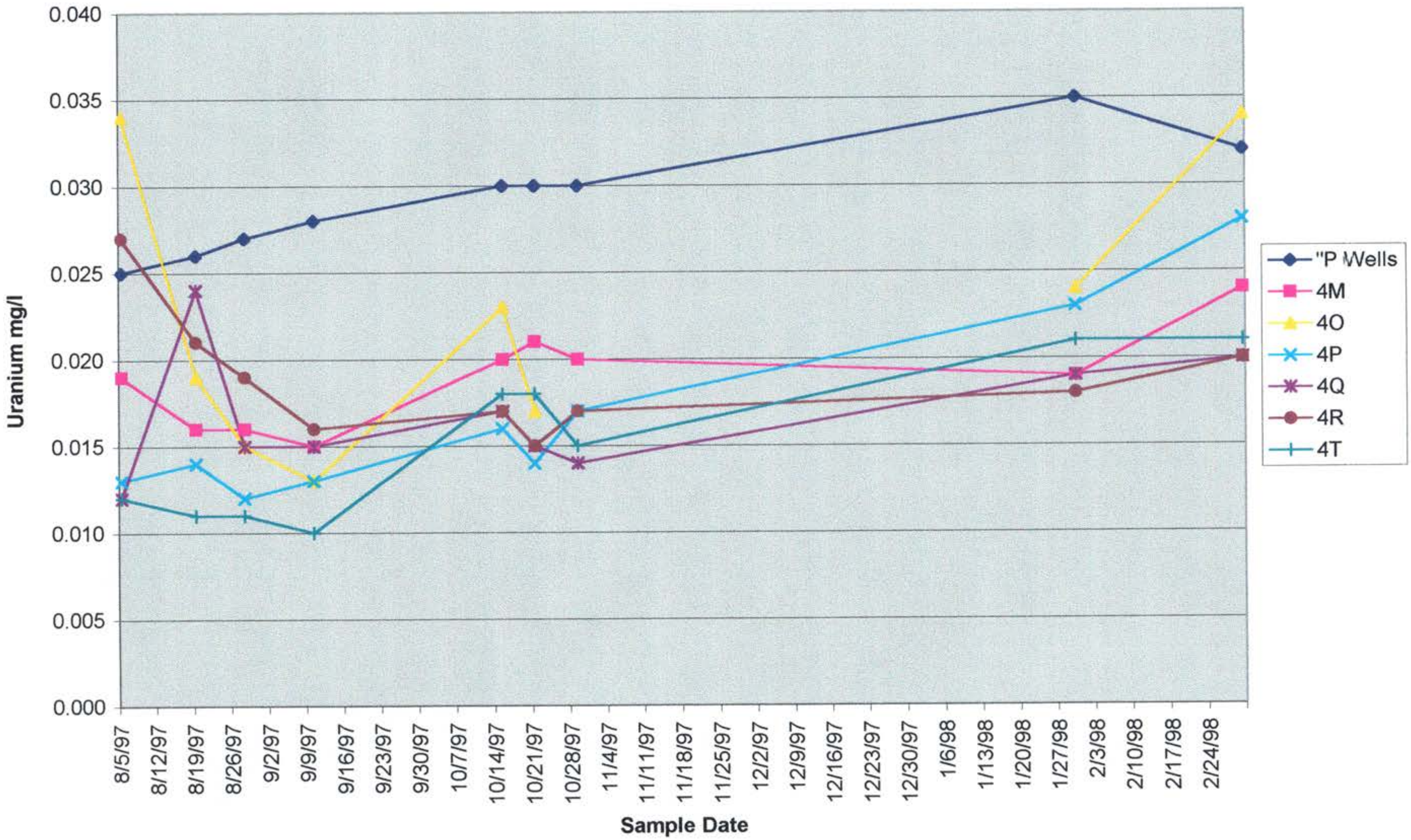


Photo 1: Section 28 swale


Photo 2: Section 28 swale- monitoring wells

Photo 3: Section 28 swale - start of slaked lime application

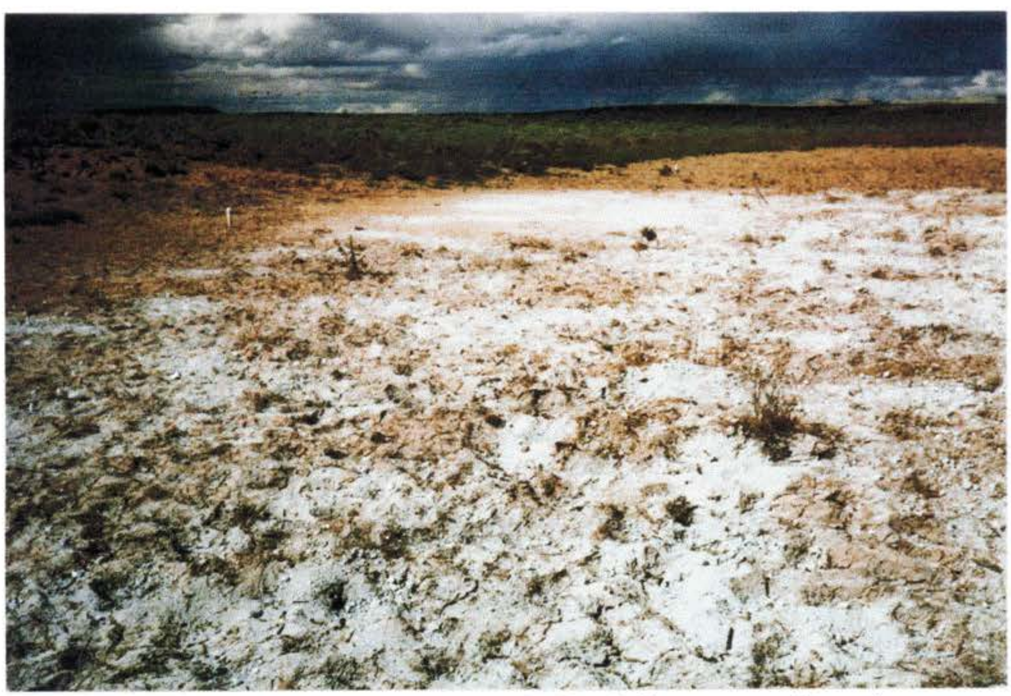

Photo 4: Section 28 swale - slaked lime application


Photo 5: Flooding of swale with well 886 water


Photo 6: Flooding swale

Photo 7: Ferric chloride application

Photo 8: Ferric chloride application

Photo 9: Completed ferric chloride application

Photo 10: Monitoring well sampling

Photo 11: Section 22 swale

Photo 12: Completed slaked lime application

Photo 13: Slaked lime and iron fertilizer reactions

Photo 14: Slaked lime and iron fertilizer reactions

Photo 15: Flooding of swale

Photo 16: Swale after ferric chloride application

7.0 IRRIGATION SCHEDULING

In order for irrigation of alluvial waters to be efficient from both a selenium and uranium attenuation standpoint and from a water consumption standpoint, proper scheduling of irrigation applications is necessary. Water balance parameters includes knowledge of the water holding capacity of the site soils, infiltration and permeability rates, vegetation or agronomic water useage, evaportranspirative losses, well pumping capacities, and climatic data including rainfall, temperature, and evaporation rates. Understanding this information allows for accurate estimates of projected water consumption for any time period. In addition, accurate record keeping of these parameters allows for adjustments of irrigation application schedules.

Soil baseline information has been provided in Section 3.0 and soil infiltration interpretations are provided in Section 4.0. For this study, numerous irrgation alternatives were evaluated and irrigation schedules were developed for each alternative. Each schedule was based intially on agronomic water demands. That is, the water useage was projected based on estimates on crop water use for any given time period. Crop water use was estimated only for alfalfa and pasture crops. Crop water use data was developed based on New Mexico data and are presented in Appendix G.

Schedules were developed for flood irrigation alternatives if the soil infiltration rates were too slow for sprinkler irrigation. In general, soils which had been previously irrigated in the 1940's and 1950's were only suitable for flood irrigation. Sprinkler irrigation schedules were developed for sandy soils where infiltration rates were too rapid to allow for flood irrigation. The goal was to maximize the use of shallow alluvial water from various wells. As an added benefit, attenuation of uranium would occur with irrigation to site soils. Attenuation of selenium under irrigation will likely occur by vegetative uptake of the element. Refer to Section 8.0 for a discussion of vegetative uptake. Appendix G contains the completed irrigation schedule and water consumption information for each alternative. This information has been presented before

8.0 VEGETATIVE UPTAKE OF SELENIUM AND URANIUM

Land application or irrigation of alluvial well water allows for possible vegetative uptake of selenium or uranium by crops. Vegetative uptake of these elements has potential benefits for the removal of metals from the alluvial water but must also be balanced against the potential for metal toxicity to occur. This study examined the uptake characteristics of two forage crops, Birdsfoot trefoil and alfalfa. Trefoil is commonly grown as a forage crop and may be harvested as hay or grazed. Forage production of trefoil is approximately one half of the production for alflafa.

8.1 VEGETATION UPTAKE TEST METHODOLOGY

As stated previously, Birdsfoot trefoil and alflafa were selected for this study. Both crops have been extensively studied in California for the removal of selenium from soils irrigated with high selenium content waters. As discussed in Section 2.0, selenate is the dominate selenium species available for uptake by vegetation. Selenate is the dominant selenium species at the Grants site and assumed to be available for vegetation uptake.

Eight inch diameter greenhouse containers were filled with low-selenium content soils. Two of the containers were planted with Birdsfoot trefoil at a rate of 8 pounds per acre. One container was planted with common alflalfa at a rate of 12 pounds per acre. The soil water holding capacity of each container was determined and irrigation amounts were based on water holding capacity and on the crop water use. Irrigation waters were the same as those used for the column tests described in Section 5.0. The selenium content of this water was 0.206 mg/l and the uranium content was 0.623 mg/l. The goal was to apply sufficient water to meet the crop demands without allowing for drainage of water from the pots. All applied selenium would be retained in the containers for possible uptake by the vegetation.

As the crops grew, additional water was added to meet crop water consumptive demands. When the crops were 6 inches high and beginning their bloom stage, they were harvested and sent to the laboratory for analysis of uranium content and selenium content. Total water use was calculated and removal percentages were determined. In addition, estimates of vegetative uptake for both crops on a large-scale irrigation basis were calculated.

8.2 VEGETATIVE UPTAKE RESULTS

The results of the vegetative uptake tests are shown in Table 8-1. Samples S-1 and S-2 were Birdsfoot trefoil and the selenium present in the vegetative dry matter was 4.0 mg/l and 5.2 mg/l, respectively. Results of the alalfa tests are indicated by sample S-3 and the selenium present in the alflafa dry matter was 2.6 mg/l. The total depth of applied irrigation water approximated 15 inches and represented a water consumption of nearly 6.2 liters per container at an average selenium concentration of 0.206 mg/l. Vegetation uranium concentrations were 2.04 and 1.48 mg/kg dry matter for the Birdsfoot trefoil containers and 2.66 mg/kg dry matter for the alfalfa.

It appears that the Birdsfoot trefoil removed nearly twice as much selenium as did the alfalfa test. However, the yield potential for alfalfa is nearly double that of trefoil and the net uptake by alfalfa and trefoil will be nearly identical in the field. Table 8-2 provides calculations on the actual percentage of selenium and uranium removal as compared to the input irrigation water. As stated previously, approximately 6.2 liters of water were applied to the plants during the test and all water was consumed by the plants or lost to evaporation. The applied water represented approximately one third of the estimated water consumption which would occur in the field in Grants. Allowing the plants to mature in the containers would have increased the overall water consumption when the root system developed further.

At an input selenium concentration of 0.206 mg/l, approximately 1.27 mg of selenium was added to the containers. Five mg/kg selenium was present in the plant tissue and resulted in only 0.11

mg of selenium removed from the input water or 8.7% of the total added selenium. Again, refer to Table 8-2 for these calculations.

Table 8-2 also shows the removal rates calculated for uranium. The input uranium content was 0.623 mg/l and the total uranium input was 3.83 mg. At 2.2 mg/kg uranium in the plant tissue, 0.05 mg of uranium was taken up by the plants with a resulted vegetative removal rate of only 1.3%. Since no leaching of input water was allowed to occur, the excess selenium and uranium remained in the container soil.

In order to put this data in perspective to field conditions, calculations were conducted using the vegetative removal data extrapolated to estimated field irrigation practices. These calculations are shown in Table 8-3 for both selenium and uranium. Based on the irrigation scheduling information presented in Section 7.0 and Appendix G, a conservative irrigation rate of 40 inches applied per season was utilized. This irrigation rate would indicate little potential for leaching of irrigation waters. Well #886 field concentrations were used for both selenium (0.086 mg/l) and uranium (0.543 mg/l). Assuming an 125 acre field of alfalfa, approximately 135,000,000 gallons (513,000,000 liters) of irrigation water would be applied to the entire field resulting in 97.2 lbs. (44,118,000 mg) of applied selenium and 610 lbs. (278,559,000 mg) of applied uranium for the irrigation season. Assuming a yield rate of 5 tons per acre and a 60% moisture content in the forage, only 2.5 lbs. (2.6%) selenium and 1.1 lbs. (0.020%) uranium would be removed from the water by the crop.

8.3 DISCUSSION

The percentages of vegetative removal of both selenium and uranium were low as compared to the amount of these elements applied to the soil through irrigation. It is expected that the percent removal by mature plants in the field would increase over the test rates. However, it is important to note that the selenium concentrations in the trefoil averaged approximately 5

mg/kg, the value commonly indicated in literature as the conservative threshold for potential selenium toxicity in livestock and wildlife.

The selenium remaining in the soil after vegetative uptake would be extremely mobile and would leach deeper in the soil profile by waters passing through the root zone. The final fate of the selenium would depend on the amount of irrigation water and precipitation entering the soil. That is, if combined precipitation plus irrigation waters were completely consumed by the vegetation or lost to evaporation, the selenium would remain in the plant root zone. If additional waters were applied above the water consumption demands of the vegetation, selenium would leach through the root zone to a point where the soil has stored all of the available water. Proper irrigation management in relation to climatic conditions and vegetative water consumption would allow for management of the selenium at some depth below the root zone. With continued leaching of salts and with excess water applied to achieve possible return flows to the aquifer, some selenium would eventually return to the aquifer. Again, this possibility can be greatly minimized with efficient irrigation scheduling.

The uranium removal percentages were less than the selenium removal. However, as described previously, the uranium is primarily removed from the irrigation waters by cation exchange within the soil profile. As exchange sites are used up in the soils, the uranium will migrate deeper in the soil profile where it will be attenuated by the exchange sites of the deeper soils. Refer to Section 6.0 for further discussion on the fate of uranium in the soils.

Table 8-1. Selenium and Uranium Vegetative Uptake Results

Sample ID	Sample Type	Selenium mg/kg	Uranium mg/kg
S-1	Trefoil	4.00	2.04
S-2	Trefoil	5.20	1.48
S-3	Alfalfa	2.60	2.66
Average		3.93	2.06

Table 8-2. Vegetative Bench Selenium and Uranium Attenuation Calculations

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Selenium

Birdsfoot trefoil selenium content approximately = 5.0 mg/kg dry matter

Applied input irrigation water = 6.2 liters   Input water slenium content = 0.206 mg/l

Sample Weight = 22.0 grams = 0.022 kg

Calculations: (6.2 liters X 0.206 mg/l) = 1.27 mg applied selenium

(0.022 kg X 5.0 mg/kg) = 0.11 mg vegetative selenium

(0.11 mg / 1.27 mg) X 100 = 8.7 % selenium removed

Uranium

Average vegetative uranium content = 2.2 mg/kg dry matter

Applied irrigation water = 6.2 liters   Input water uranium content = 0.623 mg/l

Sample weight = 22 grams or 0.022 kg

Calculations: (6.2 liters X 0.623 mg/l) = 3.86 mg applied uranium

(0.022 kg X 2.2 mg/kg) = 0.05 mg vegetative uranium

(0.05 mg / 3.86 mg) X 100 = 1.3% uranium removed

Table 8-3. Field Irrigation Vegetative Selenium and Uranium Attenuation

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Selenium

From Irrigation Schedules: Conservative irrigation applied depth = 40 inches

Irrigated acreage = 125 acres Applied irrigation water = 135,000,000 gallons annually

(135,000,000 gallons X 3.8 liters/gallon 0 = 513,000,000 liters

(513,000,000 liters X 0.086 mg/l) = 44,118,000 mg selenium applied annually

Average vegetative selenium content = 5.0 mg/kg dry matter

1 ton forage = (2000 lbs X 1kg/2.2 lbs.) = 909 kg/ton

(5 tons/acre X 125 acres) = 625 tons

625 tons @ 60% moisture content = 250 tons dry matter

(250 tons X 909 kg/ton) = 227,250 kg dry matter

(227,250 kg X 5.0 mg/kg) = 1,136,250 mg vegetative removal annually

Percentage Removal = (1,136,250 mg / 44,118,000 mg) X 100 = 2.6 % removed

Uranium

(513,000,000 liters X 0.543 mg/l) = 278,559,000 mg uranium applied

(227,250 kg dry matter X 2.2 mg/kg) = 499,950 mg vegetative uranium

Percentage Removal = (499,950 mg / 278,559,000 mg) X 100 = 0.20 % removed

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9 REFERENCES

Natural Resources and Conservation Service. 1993. Soil Survey of Cibola Area, New Mexico. United States Department of Agriculture. US Government Printing Office, Washington, D.C.

Hausenbuiller, R.L. 1978. Cation Exchange in Soils. In Soil Science, Principals and Practices. Wm. C. Brown Company Publishers.

Buol, S. W., Hole, F. D., and McCracken, R.J. 1973. Soil Genesis and Classification. Iowa State University Press, Ames, Iowa.

Elrashidi, R. L., Adriano, D. C., and Lindsay, W. L. 1989. Solubility, Speciation, and Transformations of Selenium in Soils. In Selenium in Agriculture and the Environment. Soil Science Society of America Special Publication Number 23. Pg. 51-63. Madison, WI.

McNeal, J. M. and Balistrieri, L. S. 1989. Geochemistry and Occurrence of Selenium: An Overview. In Selenium in Agriculture and the Environment. Soil Science Society of America Special Publication Number 23. Pg. 1-13. Madison, WI.

Merril, D. T., Mazione, M. A., Peterson, J. J., Parker, D. S., Chow, W., and Hobbs, A. O. 1986. Field evaluation of arsenic and selenium removal by iron coprecipitation. J. Water Pollution Control Federation 58:18-26.

Balistrieri, L. S. and Chao, T. T. 1989. Adsorption of Se by amorphous iron oxyhydroxide and manganese dioxide. Geochim. Cosmochim. Acta (in press)

Gissel-Nielsen, G. and Bisberg, B. 1970. The uptake of applied selenium from soils by plants. Plant Soil. 32:382-396.

Eisler, R. 1985. Selenium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biol. Report 85(1.5) U.S. Government Printing Office, Washington, D.C.

UNOCAL. 1995. Water treatment by iron coprecipitation. Unpublished technical report to Brohm Mining corporation, Deadwood, SD.

Mickelson, R. L., Page, A. L., and Bingham, F. T. 1989. Factors Affecting selenium Accumulation by Agricultural Crops. In Selenium in Agriculture and the Environment. Soil Science Society of America Special Publication Number 23. Pg. 65-94. Madison, WI.

Rosenfeld, I. And Beath, O. A. 1964. Accumulation of selenium by plants. In Selenium, Academic Press, Pg. 91-140, New York, NY.

Banuelos, G. S., Zambruski, S., Akohoue, S., and Beuselinck, P. 1997. Remediation of selenium and boron contaminated soils with Lotus Corniculatus L. U.S.Department of Agriculture, Agricultural research Service special Publication. In press.

APPENDIX A

SECTION 34, T12N, R10W AND SECTION 3, T11N, R10W
SOIL BACKHOE TRENCH LOGS

TABLE E - 1

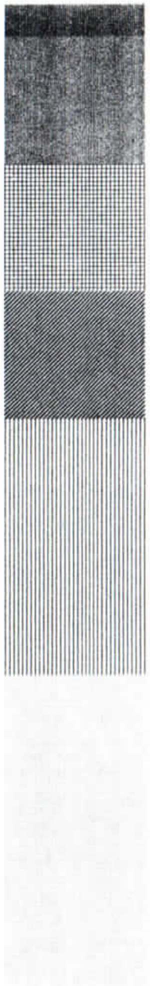
Site: S34-1

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 880 feet east, 685 feet north of S1/4 Corner, Section 34, T12N, R10W.
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained
Vegetation: forbs, saltbrush; Parent material: alluvium
Classification: Sparank Series; Fine, mixed, calcareous, mesic Ustic Torrifluvent

Date: 5-13-1997
Logged by: Dale A. Shay



HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 3	Dark yellowish brown (10YR4/4) light clay loam, mod. granular structure, mod. friable, mod. organic matter, common roots, smooth bdry
C1	3 - 14	Dark yellowish brown (10YR4/4) clay loam, massive, very firm, low organic matter, common roots, smooth gradual boundary
C2	14 - 24	Olive brown (2.5Y4/4) silty clay loam, massive, very firm, few roots, abrupt smooth boundary few salts, finely disseminated lime
IIAb	24 - 36	Very dark gray to black (2.5Y3/0) heavy clay loam to clay, massive, very hard, few roots, common disseminated lime, abundant salts, smooth gradual boundary
IIC1	36 - 60	Light brownish gray (10YR6/2) sandy clay loam, massive, very firm, common salts, finely disseminated lime, abrupt smooth boundary.
IIC2	60 - 90	Light gray (2.5Y7/2) stratified fine and medium sands, structureless, soft, few salts, iron mottles

NOTES: Bulk sampled for columns and laboratory analyses - 0 -24 inches; 36-44 inches; & 60-90 inches
No artifacts noted at site

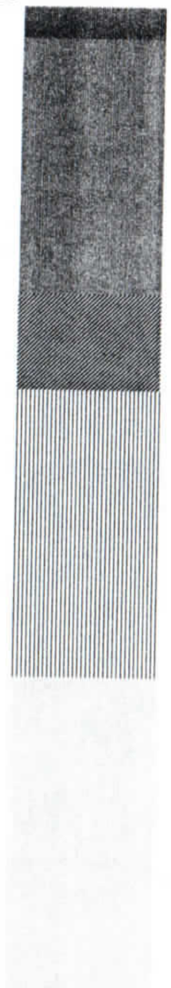
Site: S34-2

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 975 feet east, 1500 feet north, S1/4 corner, Section34, T12N, R10w
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained
Vegetation: forbs, saltbrush; Parent material: alluvium
Classification: Sparank Series; Fine, mixed, calcareous, mesic Ustic Torrifluvent

Date: 5-13-1997
Logged by: Dale A. Shay



HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 3	Dark yellowish brown (10YR4/4) clay loam, granular structure, mod. friable, low organic matter, common roots, smooth bdry
C1	3 - 28	Olive brown (2.5Y4/4) clay loam, massive, hard, common rrots, finely disseminated lime, smooth abrupt boundary
IIAb	28 - 36	Very dark gray to black (2.5Y3/0) heavy clay loam to clay, massive, very hard, few roots, common disseminated lime, abundant salts, smooth gradual boundary
IIC1	36 - 64	Pale brown (10YR6/3) clay loam, massive, hard, few roots, finely disseminated lime, few salts, clear abrupt boundary
IIC2	64 - 94	Light gray (2.5Y7/2) stratified fine and medium sands, structureless, soft, few salts, iron mottles

NOTES: No samples; transition site from S34-1 to S34-3
No artifacts noted at site

TABLE E - 3

Site: S34-3

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 900 feet east, 2500 feet north, S1/4 corner, Section 34, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: Sparank Series; Fine, mixed, calcareous, mesic Ustic Torrifluvent

Date: 5-13-1997

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 -4	Dark yellowish brown (10YR4/4) light clay loam, mod. granular structure, mod. friable, mod. organic matter, common roots, smooth bdry
C1	4 -18	Dark yellowish brown (10YR4/4) clay loam, massive, very firm, low organic matter, common roots, smooth gradual boundary
C2	18 - 26	Olive brown (2.5Y4/4) clay loam to silty clay loam, massive, hard, common roots, finely disseminated lime, smooth abrupt bdry
IIAb	26 -35	very dark gray (2.5Y 3/0) silty clay loam, massive, hard, few roots, finely disseminated lime, common salts, smooth abrupt boundary
IIC1	35 - 60	Light gray (2.5Y7/2) fine and medium sands, structureless, soft, clear smooth boundary
IIC2	60 - 90	Grayish brown (2.5Y5/2) medium sand, structureless, soft

NOTES: Sampled for laboratory analyses - 4-26 inches; 50-90 inches
No artifacts noted at site

TABLE E - 4

Site: S34-4

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 50 west, 2450 feet north of S1/4 corner, Section 34, T12N, R10W

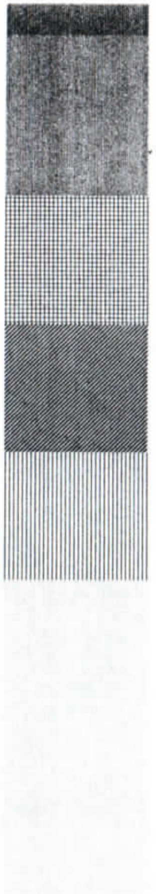
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: Sparank Series; Fine, mixed, calcareous, mesic Ustic Torrifluvent

Date: 5-13-1997

Logged by: Dale A. Shay



HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 3	Dark yellowish brown (10YR4/4) light clay loam, mod. granular structure, mod. friable, mod. organic matter, common roots, smooth bdry
C1	3- 17	Olive brown (2.5Y4/4) clay loam, massive, hard, few roots, few salts around roots, finely disseminatd lime, clear smooth bdry
C2	17 - 32	Olive brown (2.5Y4/4) silty clay loam, massive, very firm, few roots, abrupt smooth boundary few salts, finely disseminated lime
IIAb	32 - 45	Very dark gray to black (2.5Y3/0) heavy clay loam to clay, massive, very hard, few roots, common disseminated lime, abundant salts, smooth gradual boundary
IIC1	45 - 56	Light brownish gray (2.5Y6/2) clay loam to silty clay loam, massive, hard, fine disseminated lime, minor salts, clear smooth bdry
IIC2	56 - 94	Light gray (2.5Y7/2) stratified fine and medium sands, structureless, soft, few salts, iron mottles

NOTES: No samples
No artifacts noted at site

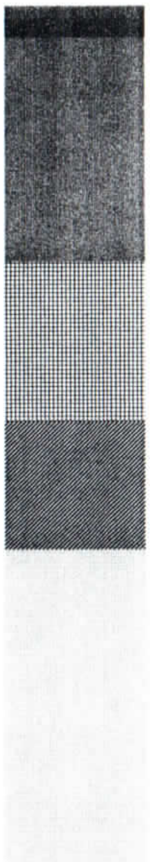
Site: S34-5

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 100 feet west, 1850 feet north of S1/4 corner, Section 34, T12N, R10W
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained
Vegetation: forbs, saltbrush; Parent material: alluvium
Classification: Sparank Series; Fine, mixed, calcareous, mesic Ustic Torrifluvent

Date: 5-13-1997
Logged by: Dale A. Shay



HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 3	Dark yellowish brown (10YR4/4) light clay loam, mod. granular structure, mod. friable, mod. organic matter, common roots, smooth bdry
C1	3 - 26	Olive brown (2.5Y4/4) clay loam, massive, hard, few roots, few salts around roots, finely disseminatd lime, clear smooth bdry
C2	26 - 40	Olive brown (2.5Y4/4) silty clay loam, massive, very firm, few roots, abrupt smooth boundary few salts, finely disseminated lime
IIAb	40 - 53	Very dark gray to black (2.5Y3/0) heavy clay loam to clay, massive, very hard, few roots, common disseminated lime, abundant salts, smooth gradual boundary
IIC1	53 - 90	Light gray (2.5Y7/2) stratified fine and medium sands, structureless, soft, few salts, iron mottles

NOTES: Bulk sampled for column and lab studies: 3-40 inches; 40-53 inches; 53-73 inches
No artifacts noted at site

TABLE E - 6

Site: 34-6

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 75 feet west, 1075 north of S1/4 corner, section 34, T12N, R10W

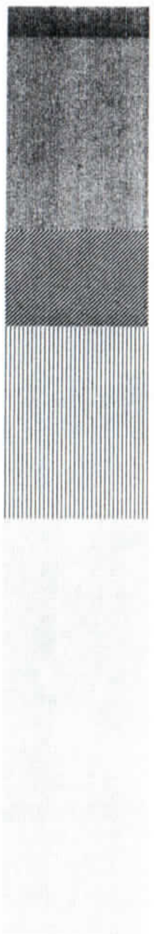
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: Sparank Series; Fine, mixed, calcareous, mesic Ustic Torrifluvent

Date: 5-13-1997

Logged by: Dale A. Shay



HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 3	Dark yellowish brown (10YR4/4) light clay loam, mod. granular structure, mod. friable, mod. organic matter, common roots, smooth bdry
C1	3 - 22	Olive brown (2.5Y4/4) clay loam to silty clay loam, massive, hard, few roots, clear smooth boundary
IIAb	22 - 30	Very dark gray (2.5Y3/0) clay loam to silty clay loam, massive, hard, few roots, fine disseminated lime, minor salts, clear abrupt boundary.
IIC1	30 - 48	Light brownish gray (2.5Y6/2) clay loam, massive, hard, fine disseminated lime, minor salts, abrupt smooth boundary
IIC2	48 - 90	Light gray (2.5Y7/2) stratified fine to medium sands, structureless, soft, few mottles, thin clay lenses minor salts in lenses.

NOTES: No samples
No artifacts noted at site

Site: S34-7

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 50 feet west, 200 feet north, of S1/4 corner, Section 34, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Date: 5-13-1997

Vegetation: forbs, saltbrush; Parent material: alluvium

Logged by: Dale A. Shay

Classification: Venadito series, very fine, montmorillonitic, mesic, Udorthentic Chromusterts

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 3	Dark yellowish brown (10YR4/4) light clay loam, mod. granular structure, mod. friable, mod. organic matter, common roots, smooth bdry
C1	3 - 28	Olive brown (2.5Y4/4) clay loam to silty clay loam, massive, hard, few roots, clear smooth boundary
IIAb	28 -34	Very dark gray (2.5Y3/0) clay loam to silty clay loam, massive, hard, few roots, fine disseminated lime, minor salts, tslickensides, clear smooth boundary
IIC1	34 - 48+	Light brownish gray (2.5Y6/2) clay, massive, slickensides, very hard, common salts

NOTES: No samples; expected very slow permeability; trenching discontinued due to hardness.
No artifacts noted at site

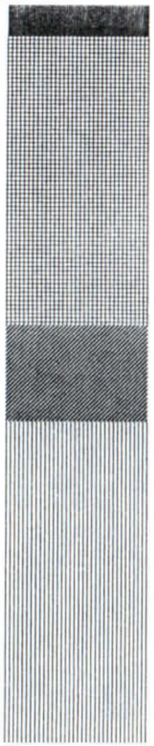
Site: S34-8

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 975 west, 275 feet north S1/4 corner, Section 34, T12N, R10W
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained
Vegetation: forbs, saltbrush; Parent material: alluvium
Classification: Venadito series, very fine, montmorillonitic, mesic, Udorthentic Chromusterts

Date: 5-13-1997
Logged by: Dale A. Shay



HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 2	Dark yellowish brown (10YR4/4) clay loam, granular structure, mod. friable, mod. organic matter, common roots, smooth boundary
C1	2 - 30	Olive brown (2.5Y4/4) clay, massive, very hard, few roots, mionor salts, finely disseminated lime, abrupt smooth boundary minor slickensides
IIAb	30 - 38	very dark gray (2.5Y3/0 to 4/0) sandy clay loam to clay laom, massive, hard, disseminated lime, common salts, clear wavy bdry.
IIC1	38- 75+	Light brownish gray (2.5Y6/2) sandy clay loam, massive, hard, disseminated lime, common salts

did not reach sands

NOTES: No samples; very slow permeability likely; salt loading likely; terminated trenching due to hardness
No artifacts noted at site

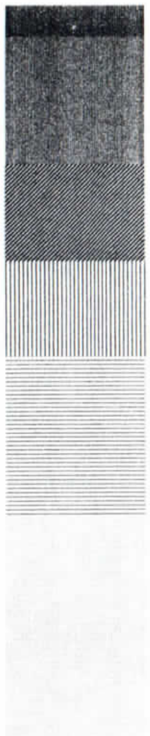
Site: S34-9

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL AT ATION & ATION STUDY

Cibola County - Grants, New Mexico

Location: 1000 feet west, 1175 feet north of S1/4 corner, Section 34, T12N, R10W
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained
Vegetation: forbs, saltbrush; Parent material: alluvium
Classification: Sparank series, Fine, mixed, calcareous, mesic Ustic Torrifluvent

Date: 5-13-1997
Logged by: Dale A. Shay



HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 3	Dark yellowish brown (10YR4/4) clay loam, granular structure, mod. friable, mod. organic matter, common roots, smooth boundary
C1	3 - 15	Olive brown (2.5Y4/4) clay loam, massive, hard, low organic matter, common roots, smooth clear boundary
IIAb	15 - 24	very dark gray (2.5Y3/0 to 4/0) sandy clay loam to clay laom, massive, hard, disseminated lime, common salts, clear wavy bdry.
IIC1	24- 32	Light brownish gray (2.5Y6/2) sandy clay loam, massive, hard, disseminated lime, common salts
IIC2	32 - 48	Light gray (2.5Y7/2) sandy clay loam to clay loam, massive, hard, disseminated lime, common salts, abrupt clear boundary
IIC3	48 - 70	Very pale brown (10YR7/3) stratified fine to medium sands, structureless, soft, common mottling few minor lenses of clay with minor salts

NOTES: No samples; Sparank series-variant
No artifacts noted at site

Site: S34-10

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 1175 feet west, 2300 feet north, of S1/4 corner, Section 34, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: Sparank series, Fine, mixed, calcareous, mesic Ustic Torrifluvent

Date: 5-13-1997

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 3	Dark yellowish brown (10YR4/4) clay loam, granular structure, mod. friable, mod. organic matter, common roots, smooth boundary
C1	3 - 24	Olive brown (2.5Y4/4) clay loam, massive, hard, low organic matter, common roots, smooth clear boundary
C2	24 - 38	Olive brown (2.5Y4/4) clay loam to clay, massive, very hard, few roots, disseminated lime, minor salts, smooth boundary clay is in thin lenses, salts in lenses
C3	38 - 60+	Light olive brown (2.5Y5/4) clay loam to clay, massive, disseminated lime, common salts

NOTES: Sampled for Lab analyses: 3-24 inches; 28-38 inches; did not reach sands due to hardness

No artifacts noted at site

Site: S34-11

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 2050 feet west, 2350 feet north S1/4 corner Section 34, T12N, R10w

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: Glenberg-variant; Coarse-loamy, mixed (calcareous), mesic Ustic Torrifluvents

Date: 5-14-97

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 3	Dark yellowish brown (10YR4/4) clay loam, granular structure, mod. friable, mod. organic matter, common roots, smooth boundary
C1	3 - 15	Olive brown (2.5Y4/4) clay loam, massive, hard, low organic matter, common roots, smooth clear boundary
C2	15 - 36	Light gray (2.5Y7/2) fine sand, massive, firm, few roots, disseminated lime, gradual smooth boundary iron mottling at 30 inches
C3	36 - 60	Brownish yellow (10YR6/8) stratidfied fine to medium sands, structureless, soft, gradual smooth boundary
C4	60 -90	Light yellowish brown (10YR6/4) stratified fine to medium sands, structureless, soft

NOTES: Sampled for lab analyses: 3-15 inches; 30-60 inches; 60-90 inches; shallow to sands compared to other Sec. 34 soils

No artifacts noted at site

Site: S34-12

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 2050 feet west, 1525 feet north, of S1/4 corner, Section 34, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: Sparank Series; Fine, mixed, calcareous, mesic Ustic Torrifluvent

Date: 5-14-97

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 -4	Dark yellowish brown (10YR4/4) clay loam, granular structure, mod. friable, mod. organic matter, common roots, smooth boundary
C1	4 - 15	Olive brown (2.5Y4/4) clay loam, massive, hard, low organic matter, common roots, smooth clear boundary
C2	15- 23	Olive brown (2.5Y4/4) clay, massive, hard, few roots, disseminated lime, abrupt smooth boundary
IIAb	23 - 48	Very dark gray (2.5Y3/0) clay loam, massive, hard, few roots, disseminated lime, minor to common salts, abruptsmooth bdry salts mnor near top of horizon, common at bottom
IIC1	48 - 54	Olive brown (2.5Y4/4) clay loam, massive, hard, disseminated lime, common salts, abrupt smooth boundary
IIC2	54 - 68	Light gray (2.5Y7/2) stratified fine to medium sands, structureless, soft, gradual smooth boundary
IIC3	68 - 90	Light brownish gray (2.5Y6/2) clay loam, massive, hard, disseminated lime, common salts

NOTES: No samples; clays located again below sands

No artifacts noted at site

Site: S34-13

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 2000 feet west, 500 feet north of S1/4 corner; Section 34, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: Venadito series; Very fine, montmorillonitic, mesic Udorthentic Chromusterts

Date: 5-14-97

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 -4	Dark yellowish brown (10YR4/4) clay loam, granular structure, mod. friable, mod. organic matter, common roots, smooth boundary
C1	4 -18	Olive brown (2.5Y4/4) clay loam, massive, hard, low organic matter, common roots, smooth clear boundary
C2	18 - 30+	Dark yellowish brown (10YR4/4) clay, massive, slickensides, very hard, no roots, disseminated lime

NOTES: Sampled for lab analyses: 4-18 inches, 18-30 inches; very low permeability; expected salt loading

No artifacts noted at site

Trenching terminated due to hardness

Site: S34-14

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 500 feet east, 475 feet north of center Section 34, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: San Mateo Variant; fine-loamy, mixed (calcareous), mesic Ustic Torrifluvents

Date: 5-14-97

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 -4	Dark yellowish brown (10YR4/4) heavy loam to clay loam, granular, friable, mod. organic matter, common roots, smooth clear bdry.
C1	4 - 16	Olive brown (2.5Y4/4) clay loam, massive, hard, low organic matter, common roots, smooth clear boundary
C2	16 - 24	Olive brown (2.5Y4/4) clay loam to clay, massive, hard, few roots, disseminated lime, abrupt smooth boundary
IIC3	24 - 96	Light gray (2.5Y7/2) stratified fine to medium sands, structureless, soft, disseminated lime (upper horizon)

NOTES: Sampled for lab analyses: 4 - 24 inches, 30 to 90 inches

No artifacts noted at site

Site: S34-15

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 400 feet east, 1025 feet north of center, Section 34, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: San Mateo Variant; fine-loamy, mixed (calcareous), mesic Ustic Torrifluvents

Date: 5-14-97

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 -4	Dark yellowish brown (10YR4/4) heavy loam to clay loam, granular, friable, mod. organic matter, common roots, smooth clear bdry.
C1	4 - 15	Olive brown (2.5Y4/4) clay loam, massive, hard, low organic matter, common roots, smooth clear boundary
C2	15 - 26	Olive brown (2.5Y4/4) clay loam to clay, massive, hard, few roots, disseminated lime, abrupt smooth boundary
IIC3	26 - 90	Light gray (2.5Y7/2) stratified fine to medium sands, structureless, soft, disseminated lime (upper horizon)

NOTES: Sampled for lab analyses: 4 - 24 inches, 30 to 90 inches

No artifacts noted at site

Site: S3-1

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 400 feet east, 575 feet south of N1/4 corner, Section 3, T11N, R10W

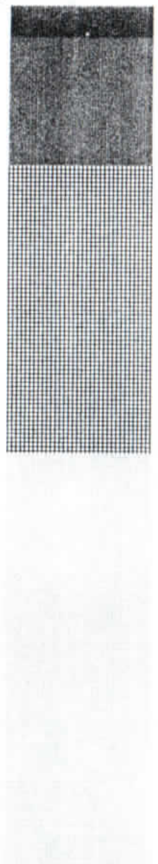
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: Venadito series, very fine, montmorillonitic, mesic, Udorthentic Chromusterts

Date: 5-14-97

Logged by: Dale A. Shay



HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 2	Dark reddish brown (7.5YR4/4) clay loam, granular, mod. friable, few roots, mod. organic matter, gradual smooth boundary
C1	2 - 14	Olive brown (2.5Y4/4) clay loam to silty clay loam, massive, hard, few roots, clear smooth boundary
C2	14 - 20	Olive brown (2.5Y4/4) clay, massive, hard, slickesides, few roots, disseminated lime, common salts, abrupt smooth bdry
C3	20 - 36	Light yellowish brown (2.5Y6/4) clay, massive, hard, some slickensides, disseminated lime, minor salts abrupt smooth bdry
C4	36 - 75	Light gray (2.5Y7/2) stratified fine to medium sands, structureless, soft

NOTES: Sampled for lab analyses: 0-14 inches, 14-36 inches;
No artifacts noted at site

Site: S3-2

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 300 feet west, 700 feet south of N!/4 corner, Section 3, T11N, R10W

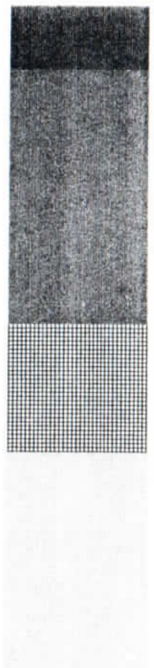
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: forbs, saltbrush; Parent material: alluvium

Classification: Venadito series, very fine, montmorillonitic, mesic, Udorthentic Chromusterts

Date: 5-14-97

Logged by: Dale A. Shay



HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 5	Dark reddish brown (7.5YR4/4) clay loam, granular, mod. friable, few roots, mod. organic matter, gradual smooth boundary
C1	5 - 28	Olive brown (2.5Y4/4) clay loam to silty clay loam, massive, hard, few roots, clear smooth boundary
C2	28 - 40	Olive brown (2.5Y4/4) clay, massive, hard, slickesides, few roots, disseminated lime, common salts, abrupt smooth bdry
C3	40 - 60	Light gray (2.5Y7/2) stratified fine to medium sands, structureless, soft

NOTES: Not sampled; trenching terminated due to hardness
No artifacts noted at site

APPENDIX B

SECTION 27, 28, 29 T12N, R10W SOIL BACKHOE TRENCH LOGS

Site: NW27-1

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 220 feet east, 1020 feet south of NW corner Section 27, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: grasses, sagebrush; Parent material: alluvium

Classification: Glenberg-variant; Coarse-loamy, mixed (calcareous), mesic Ustic Torrifluvents

Date: 1-21-98

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 6	Dark yellowish brown (10YR4/4) sandy loam, granular, very friable, abundant roots, mod. organic matter, clear, smooth bdry
C1	6 - 24	Dark yellowish brown (10YR4/4) sandy loam, massive, friable, abundant roots, disseminated lime, low organic matter, smooth bdry
C2	24 - 60	Light yellowish brown (10YR6/4) fine to medium sand, structureless, soft, common roots, disseminated lime, abrupt smooth bdry
C3	60 - 68	Light yellowish brown (10YR6/4) light clay loam, massive, hard, disseminated lime, few roots, minor salts, abrupt smooth boundary
C4	60 - 84	Very pale brown (10YR7/3) stratified fine to medium sands, structureless, soft

NOTES: Sampled at 0 to 6 inches; 24 to 80 inches

No artifacts noted at site

Swale where P wells are located

Site: NW27-2

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 260 feet east, 650 feet north of W1/4 corner Section 27, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: grasses, sagebrush; Parent material: alluvium

Classification: Glenberg Series: Coarse-loamy, mixed (calcareous), mesic Ustic Torrifluvent

Date: 1-21-98

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 -4	Dark yellowish brown (10YR4/4) sandy loam, granular, very friable, abundant roots, mod. organic matter, clear smooth boundary
C1	4 - 18	Dark yellowish brown (10YR4/4) sandy loam to loamy fine sand, structureless, friable, common roots, low org. matter , smooth bdry
C2	18 - 36	Light yellowish brown (10YR6/4) fine to medium sand, structureless, soft, common roots, disseminated lime, abrupt smooth bdry
C3	36 - 84	Light gray (10YR7/2) to pale brown (10YR6/3) stratified fine to medium sands, structureless, soft, disseminated lime, few roots

NOTES: Not sampled for lab analysis.
No artifacts noted at site

Site: NE28-1

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 320 feet west, 470 feet north of E1/4 corner Section 28, T12N, R10W
Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained
Vegetation: grasses, sagebrush; Parent material: alluvium
Classification: Glenberg Series: Coarse-loamy, mixed (calcareous), mesic Ustic Torrifluvent

Date: 1-21-98
Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 6	Reddish brown (5YR4/4) sandy loam to light sandy clay loam, granular, friable, abundant roots, mod. org. matter, clear smooth bdry
C1	6 - 15	Pale brown (10YR6/3) sandy loam, massive, friable, abundant roots, low organic matter, disseminated lime, gradual smooth boundary
C2	15 - 30	Light yellowish brown (10YR6/4) fine to medium sand, structureless, soft, common roots, disseminated lime, abrupt smooth bdry
C3	30 - 80	Dark yellowish brown (10YR4/4) stratified fine to medium sands, structureless, soft, few roots, disseminated lime, abrupt smooth bsry bdry (thin clay lenses at 46 inches)

NOTES: No samples
No artifacts noted at site

Site: NE28-2

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 340 feet west, 950 feet north of E1/4 corner, Section 28, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: grasses, sagebrush; Parent material: alluvium

Classification: Glenberg Series: Coarse-loamy, mixed (calcareous), mesic Ustic Torrifluvent

Date: 1-21-98

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
A1	0 - 6	Dark yellowish brown (10YR4/4) sandy loam, granular, very friable, abundant roots, mod. organic matter, clear smooth boundary
C1	6 - 24	Dark yellowish brown (10YR4/4) sandy loam to loamy fine sand, structureless, friable, common roots, low org. matter , smooth bdry
C2	24 - 36	Light yellowish brown (10YR6/4) fine to medium sand, structureless, soft, common roots, disseminated lime, abrupt smooth bdry
C3	36 - 84	Light gray (10YR7/2) to pale brown (10YR6/3) stratified fine to medium sands, structureless, soft, disseminated lime, few roots

NOTES: sampled 0 to 6 inches; 24 to 48 inches

No artifacts noted at site

Site: NE28-3

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 320 feet west, 1400 feet north of E1/4 corner Section 28, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: disturbed area

Classification: Glenberg Series: Coarse-loamy, mixed (calcareous), mesic Ustic Torrifluvent

Date: 1-21-98

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
	0 - 6	Surface soil has been removed from disturbance area
C1	6 - 24	Dark yellowish brown (10YR4/4) sandy loam to loamy fine sand, structureless, friable, common roots, low org. matter , smooth bdry
C2	24 - 36	Light yellowish brown (10YR6/4) fine to medium sand, structureless, soft, common roots, disseminated lime, abrupt smooth bdry
C3	36 - 84	Light gray (10YR7/2) to pale brown (10YR6/3) stratified fine to medium sands, structureless, soft, disseminated lime, few roots

NOTES: no samples

No artifacts noted at site

Site: NE28-5

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 940 feet west, 210 feet south of NE corner Section 28, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: disturbed area

Classification: Glenberg Series: Coarse-loamy, mixed (calcareous), mesic Ustic Torrifluvent

Date: 1-21-98

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
	0 - 6	Surface soil removed
C1	6 - 12	Dark yellowish brown (10YR4/4) sandy loam to loamy fine sand, structureless, friable, common roots, low org. matter , smooth bdry
C2	12 - 26	Light yellowish brown (10YR6/4) fine to medium sand, structureless, soft, common roots, disseminated lime, abrupt smooth bdry
C3	26 - 84	Very pale brown (10YR7/3) stratified fine to medium sands, structureless, soft

NOTES: sampled: 0 to 12 inches; 26 to 84 inches

No artifacts noted at site

Near north gate to basalt quarry

Site: NE28-6

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 1050 feet west, 920 feet south of NE corner Section 28, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Date: 1-21-98

Logged by: Dale A. Shay

Vegetation: disturbed area

Classifcation: Unknown

HORIZON	DEPTH-IN	DESCRIPTION
	0 - 8	Surface horizons have been excavated from site
C2	8 - 16	Dark reddish brown (10YR4/4) sandy clay loam, massive, firm, common roots, disseminated lime, clear smoth boundary
C3	16 - 24	Dark grayish brown (10YR4/2) sandy clay loam to clay loam, massive, hard, disseminated lime, abrupt smooth boundary
C4	24 - 48	Olive brown (2.5Y4/4) fine sand, structureless, soft, few roots, disseminated lime, gradual boundary
C5	48 - 84	Pale brown (10YR6/3) stratified laomy fine sand to fine sand, structureless, soft

NOTES: No samples;

No artifacts noted at site

Site: NE28-7

BACKHOE TRENCH LOG - HOMESTAKE MINING COMPANY SOIL ATTENUATION & IRRIGATION STUDY

Cibola County - Grants, New Mexico

Location: 1120 feet west, 1560 feet south of NE corner Section 28, T12N, R10W

Physiographic Position: Alluvial plain; Topography: nearly level <1% slope: drainage: well drained

Vegetation: disturbed area

Classification: unknown

Date: 1-21-98

Logged by: Dale A. Shay

HORIZON	DEPTH-IN	DESCRIPTION
	0 - 8	surface soil removed; black basalt fines base
C1	8 - 40	Dark yellowish brown (10YR4/4) sandy loam to loamy fine sand, structureless, friable, common roots, low org. matter , smooth bdry
R	40 +	Black basalt

NOTES: sampled: 0 - 8 inches; 8 - 40 inches

No artifacts noted at site