Grants Reclamation Project
Evaluation of Years 2000 Through 2007
Irrigation with Alluvial Ground Water

40-8903
SUA 1471

For:

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Executive Summary

This report characterizes changes in uranium and selenium concentrations in four alfalfa (*Medicago sativa*) hay fields supplied with irrigation water from groundwater with elevated levels of uranium and selenium. From 2000 through 2007, 270 to 394 acres were irrigated with this water. Uranium and selenium concentrations have been measured in the applied irrigation water and the affected soils each year and each hay crop since 2000.

The project plan established an upper limit for the uranium concentration in irrigation water at the U.S. Nuclear Regulatory Commission effluent standard of 0.44 milligrams per liter (mg/l) and selenium was set at a site-specific State of New Mexico Water Quality Control Commission standard of 0.12 mg/l.

The fields subject to irrigation are located in Sections 28, 33, and 34 in Township 12 North, Range 10 West near Grants, New Mexico. Fields in Sections 28 and 33 were irrigated using a center pivot irrigation system. The field in Section 34 and an additional portion of Section 33 was irrigated by flooding. The total amount of irrigation water applied to the fields is 7042 acre feet (ac-ft), ranging from 695 to 1034 ac-ft annually.

The background concentrations of uranium and selenium in the soil are averages of these constituents in samples collected prior to the irrigation program and outside of the irrigated area each year. The background concentrations are compared to the concentration in each 1-foot (ft) interval of the upper three feet of the soil. The difference between the treated soil and background concentration is the amount of constituent added from the irrigation. The amount of a constituent in the upper three feet of soil is then compared to the total amount of the constituent added over the life of the irrigation.

The mean background concentrations of uranium and selenium are similar in Sections 28 and 33 (center pivot areas). The concentrations in Section 34 are generally higher than in other fields, presumably because of their association with clay soils.

Mean background concentrations of uranium, in descending 1-ft layers (0-1 ft, 1-2 ft, 2-3 ft) are:

- Section 28: 0.55, 0.53, and 0.51, averaging 0.53 milligrams per kilogram (mg/kg).
- Section 33: 0.78, 0.69, and 0.71, averaging 0.73 mg/kg.
- Section 34: 1.96, 1.45, and 1.15, averaging 1.52 mg/kg

On a mass basis, the percentages of uranium applied to the irrigated fields excluding the Section 33 Flood area that remain in the upper three feet ranges from 71 to 138 percent.

The percentage of selenium applied to the fields excluding the Section 33 Flood area that remains in the upper three feet of the soil varies from 63 to 148 percent. The percentages above 100 are likely attributable to variability of solid characteristics as well as analytical accuracy capabilities at the low levels observed.

Uranium application to the fields is discussed by section below. The data collected in the flooded area of Section 33 are insufficient to show trends and are not presented further in this summary, although they are presented in the report.

Uranium concentrations in the treated soils in Section 28 were essentially constant and similar to background from 2003 through 2005. The most recent (2007) concentrations exceeded mean background by factors of 2.07 (0-1 ft), 1.91 (1-2 ft), and 1.80 (2-3 ft).

Uranium concentrations in the treated soils in Section 33 started to exceed background in 2003 (2002 not considered). The most recent (2007) concentrations exceeded the mean background by factors of 2.14 (0-1 ft), 1.94 (1-2 ft) and 1.83 (2-3 ft). Uranium accumulated in the upper two feet of soil at an approximate constant rate until 2004, when concentrations appear to have achieved a steady state. Steady state had appeared to have occurred in 2003 in the lower interval but the 2007 value shows an increase.

Uranium is accumulating in the upper two feet of the treated areas of Section 34. No trend is apparent in the lower layer. The data are summarized as follows:

- The 2007 results exceed background by factors of 2.56 (0-1 ft at 5.02 mg/kg), 2.10 (1-2 ft at 3.05 mg/kg), and 1.52 (2-3 ft at 1.75 mg/kg).
- The concentration in the upper interval appears to have been increasing at a relatively constant rate since 2000.
- The concentration in the middle interval appeared to have been in a steady state since 2000 until an increasing rate was observed in 2007.
- The concentration in the lower interval appears not to have stabilized. The most recent measurements are 1.21 (2006) and 1.75 (2007) mg/kg, respectively which indicate a start of a possible increasing trend.

The percentage of the mass of uranium and selenium applied to the fields that exists in the alfalfa is less than one percent.

Uranium is being retained in the upper layers of treated soil. Uranium levels are currently acceptable. The dose to man by way of the ingestion of beef is negligible, as indicated by food web uptake calculations.

The selenium uptakes in the hay are below the recommended upper limit for animal feed. Selenium retention in soils appears to be independent of time and application. The concentrations are not time-dependent, implying that absorption to soil is not retarding the movement of selenium through the soil. In addition, selenium and chloride --the latter a conservative constituent in terms of fate and transport-- are being retained at similar levels in varying soil types.

The monitoring of concentrations of uranium and selenium will continue as part of the ongoing irrigation program.

1.0 Introduction

This report characterizes changes in uranium and selenium concentrations in alfalfa (*Medicago sativa*) hay fields supplied with irrigation water from impacted groundwater sources near the Homestake Grants Reclamation Project.

Four hay fields have been irrigated with water containing elevated concentrations of uranium and selenium. Groundwater from wells adjacent to the Grants Reclamation Project was applied to hay fields situated in portions of Section 33 Pivot (150 acres) and Section 34 Flood (120 acres) during the 2000 through 2007 growing seasons and to a field in Section 28 (60 acres) during the 2002, 2003 and 2004 growing seasons. The field in Section 28 was expanded to 100 acres prior to the 2005 season and was irrigated in 2005 through 2007. Fields in Sections 33 and 28 were irrigated using a center pivot irrigation system, whereas the field in Section 34 was irrigated by flooding. Additionally, 24 acres were flood irrigated in Section 33 in 2004 and 2005, but not in 2006 and 2007. All Sections discussed in this report are located in Township 12 North, Range 10 West.

Uranium and selenium concentrations were measured in the applied irrigation water, affected soils and hay to determine constituent source terms and transfer to soils and hay. The measured results for the first growing season (2000) were compared to predictions made in 1999, which were based on published media transfer factors and other assumptions (ERG and HYDRO, 1999). The results from the first year of operation were reported previously (ERG and HYDRO, 2001). The report was updated for the 2001-2003 growing seasons in ERG and HYDRO, 2004 and updated again to include the 2004, 2005 and 2006 growing seasons (see ERG and HYDRO, 2005, 2006 and 2007).

Section 2 presents concentration data for several constituents in the irrigation water. Section 3 presents data on these same constituents in soil for background and irrigated areas. Section 4 addresses the constituent uptake in alfalfa hay. In Section 5, quantities of uranium and selenium ingested by beef-cattle and the resulting radiation dose to humans consuming this beef are calculated. The report ends with conclusions and references.

2.0 Source Constituents in Irrigation Water

The project plan (ERG and HYDRO, 1999) established an upper limit for the uranium concentration in irrigation water at the NRC effluent standard of 0.44 milligrams per liter (mg/l). The maximum allowable concentration of selenium in the irrigation supply was set at a State of New Mexico Water Quality Control Commission standard of 0.12 mg/l. With three exceptions, measured uranium and selenium concentrations have been below these limits since inception of the irrigation program through 2007. The exceptions occurred with two early 2005 uranium concentrations in Section 28 and one late 2001 selenium concentration in Section 33/34. Adjustments were made in the usage of new irrigation supply wells in early 2005. The average 2007 uranium and selenium concentrations for Section 28 water were 0.36 mg/l and 0.08 mg/l, respectively.

2.1 Sections 33 and 34 Irrigation

A common pipe connecting 13 wells supplied the irrigation water for Sections 33 and 34 from 2000 through 2002. Three wells were added and one dropped in 2003 while five wells were added in 2004. Four wells were added and three dropped in 2005. Eight additional wells added in 2006 bringing the total active wells to 29. One additional well was added in 2007 and the use of a previous supply well was discontinued. The pipeline supplied water to one of the two major fields at a time. Irrigation of the 24 flooded acres in Section 33, which occurred only during the 2004 and 2005 growing seasons, was only in conjunction with the irrigation of the Section 34 field and at a limited rate to maintain concentrations below the limits described in Section 2.0. Figures 2 through 9 show the irrigation supply well locations and supply lines for the 2000-2007 years.

Water samples collected at the end of the pipeline at the flood outlet or center pivot are composite samples from the group of supply wells. Table 1 presents the concentrations of uranium, selenium, total dissolved solids (TDS), sulfate, molybdenum, and chloride observed in the 2000-2007 irrigation water. Yearly averages are also presented in the table.

Average uranium and selenium concentrations were approximately 0.26 and 0.09 mg/l, respectively, over the eight growing seasons. The May 14, 2003 result for uranium (0.03 mg/l) is not included in the uranium average, because it is one order of magnitude lower than all other observations. Thus, it is assumed to be a laboratory artifact.

With one exception, the average concentrations of TDS and molybdenum were essentially constant from 2000 to 2007. The 2007 average concentrations were similar to previous averages. With the exception of the June 2006 measurement, TDS concentrations have ranged from 1390 to 1630 mg/l. Molybdenum concentrations were less than the 0.03 or 0.05 mg/l Method Detection Limits (MDLs), with the exception of four samples. Concentrations in four samples (0.06, 0.05, 0.07 and 0.41 mg/l) exceeded MDLs. The result of 0.41 mg/l is one order of magnitude higher than all other molybdenum results and attributed to laboratory error. The sulfate concentration ranged from 561 to 1020 mg/l. Chloride levels have been increasing slowly, and in 2007 were approximately 26 percent greater than initial measurements. Chloride concentrations have ranged from 94 to 247 mg/l in the seven years of monitoring.

Table 1. 2000 through 2006 Sections 33/34 Irrigation Supply Concentrations

		Parameter (mg/l)					
Year	Date	Uranium	Selenium	TDS	Sulfate	Chloride	Molybdenum
2000	8/6/2000	0.26	0.12	1530	650	105	<0.03
	8/15/2000	0.26	0.12	1550	660	106	<0.03
	8/18/2000	0.28	0.12	1570	623	115	<0.03
	8/19/2000	0.27	0.12	1550	612	109	<0.03
	8/24/2000	0.27	0.11	1530	608	106	<0.03
	8/27/2000	0.26	0.11	1530	601	103	<0.03
	8/29/2000	0.3	0.11	1580	624	109	<0.03
	9/2/2000	0.28	0.11	1550	615	104	<0.03
	Average	0.27	0.12	1549	624	107	<0.03
2001	4/20/2001	0.28	0.11	1620	693	120	<0.03
	4/27/2001	0.27	0.12	1590	688	120	<0.03
	5/6/2001	0.3	0.11	1630	597	108	0.06
	5/10/2001	0.25	0.09	1590	580	103	<0.03
	5/19/2001	0.28	0.1	1590	660	118	<0.03
	5/24/2001	0.24	0.11	1500	664	116	<0.03
	6/3/2001	0.27	0.1	1610	665	118	<0.03
	6/10/2001	0.27	0.1	1570	659	113	<0.03
	6/28/2001	0.27	0.11	1530	661	104	<0.03
	7/5/2001	0.22	0.1	1480	655	94	<0.03
	7/24/2001	0.21	0.09	1460	650	120	<0.03
	8/29/2001	0.28	0.1	1600	693	114	0.41
	9/1/2001	0.27	0.1	1610	573	128	<0.03
	9/1/2001	0.21	0.1	1570	561	121	<0.03
	9/17/2001	0.29	0.13	1600	634	100	<0.03
	Average	0.26	0.1	1570	642	113	0.04
2002	4/15/2002	0.21	0.09	1510	708	125	<0.03
	4/16/2002	0.25	0.1	1580	704	129	<0.03
	5/8/2002	0.25	0.11	1600	678	----	----
	5/8/2002	0.26	0.1	1580	737	----	----
	5/14/2002	0.25	0.09	1560	741	120	<0.03
	7/3/2002	0.23	0.1	1560	694	135	0.05
	7/31/2002	0.23	0.1	1580	678	123	<0.05
	10/2/2002	0.21	0.1	1570	703	----	----
	Average	0.23	0.1	1564	705	126	<0.03
2003	5/14/2003	0.03	0.05	1390	663	98.5	<0.03
	9/18/2003	0.22	0.08	1600	732	----	----
	Average	0.22	0.08	1600	732	----	----

Table 1. 2000 through 2007 Sections 33/34 Irrigation Supply Concentrations (cont'd)

Year	Date	Parameter (mg/l) Uranium	Selenium	TDS	Sulfate	Chloride	Molybdenum
2004	5/4/2004	0.28	0.11	1550	703	130	<0.03
	5/27/2004	0.25	0.08	1570	690	130	<0.03
	8/18/2004	0.27	0.08	1530	693	----	----
	10/6/2004	0.23	0.08	1560	629	133	<0.03
	Average	0.26	0.09	1553	679	131	<0.03
2005	4/19/2005	0.25	0.06	1520	1020	247	<0.03
	4/20/2005	0.25	0.06	1510	996	235	<0.03
	5/25/2005	0.23	0.06	1580	603	131	<0.03
	6/1/2005	0.24	0.06	1520	661	129	<0.03
	8/8/2005	0.27	0.06	1500	621	----	----
	9/26/2005	0.3	0.07	1550	659	124	<0.03
	10/11/2005	0.29	0.07	1580	612	125	<0.03
	10/24/2005	0.35	0.08	1610	683	144	<0.03
	Average	0.27	0.06	1546	732	162	<0.03
2006	4/10/2006	0.24	0.05	1520	654	134	<0.03
	6/26/2006	0.37	0.1	2000	875	192	0.07
	8/14/2006	0.27	0.07	1580	696	----	----
	10/10/2006	0.29	0.07	1500	639	128	<0.03
	Average	0.29	0.07	1650	716	151	0.04
2007	4/12/2007	0.28	0.06	1630	668	136	<0.03
	4/30/2007	0.27	0.06	1580	670	132	<0.03
	6/4/2007	0.23	0.06	1540	654	125	<0.03
	8/21/2007	0.3	0.05	1600	678	----	----
	10/22/2007	0.31	0.06	1570	661	143	<0.03
	Average	0.28	0.06	1584	666	134	<0.03

Notes:
* Indicates datum not used.

2.2 Section 28 Irrigation

Section 28 was irrigated from 2002 through 2007. Figures 10 and 11 show the locations of the four wells installed to supply water to the center pivot system in the first two years. Figures 12, 13 and 14 show that well 886 was added in 2004 and wells M9, MO, MQ, MR, and MS were added in 2005 and 2006. Alluvial well M16 was added in 2007 and wells M9 and MQ were not used (see Figure 15). Table 2 presents TDS, sulfate, chloride, molybdenum, uranium, and selenium concentrations obtained in the Section 28 irrigation water. One sample of irrigation water was collected during the first two irrigation seasons. Four and eight samples were collected in 2004 and 2005, respectively. Five samples were collected in both 2006 and 2007. Chloride and molybdenum were omitted as analytes in 2002 and one sample in 2004, 2006 and 2007.

The concentrations of TDS and sulfate were essentially constant from 2002 through 2007. The TDS concentration was 2,070 mg/l in 2002 and 2003 and averaged 2115, 2109, 1986 and 2122

mg/l in 2004, 2005, 2006 and 2007. The annual average sulfate concentrations varied from 881 to 936 mg/l.
The annual average concentrations of chloride and molybdenum varied from 171 to 185 mg/l and less than 0.03 to 0.04 mg/l, respectively.

Uranium concentrations increased gradually in Section 28 irrigation water. They were 0.23 mg/l in 2002, 0.24 mg/l in 2003, 0.27 mg/l in 2004, and stabilized in 2005 through 2007 at 0.35 to 0.36 mg/l.

The six-year average uranium concentration of 0.30 mg/l is assumed to be the average of the reported mean concentrations for the six years, 2002 through 2007 (0.23, 0.24, 0.27, 0.35, 0.35 and 0.36 mg/l).

Table 2. 2002 through 2007 Section 28 Irrigation Supply Concentrations

		Parameter					
Year	**Sampling Date**	**Uranium**	**Selenium**	**TDS**	**Sulfate**	**Chloride**	**Molybdenum**
2002	10/2/2002	0.23	0.08	2070	881	----	----
2003	5/14/2003	0.24	<0.005	2070	936	184	<0.03
2004	5/4/2004	0.23	0.07	2120	933	190	<0.03
	5/27/2004	0.29	0.07	2110	950	170	<0.03
	8/18/2004	0.27	0.06	2140	956	----	----
	10/6/2004	0.27	0.06	2090	838	194	<0.03
	Average	0.27	0.07	2115	919	185	<0.03
2005	4/12/2005	0.48	0.11	2220	955	176	0.09
	5/6/2005	0.51	0.12	2230	1010	192	0.11
	5/20/2005	0.33	0.08	2120	916	194	<0.03
	5/27/2005	0.26	0.06	2050	907	176	<0.03
	6/3/2005	0.33	0.08	2040	926	182	<0.03
	6/10/2005	0.33	0.07	2000	943	186	<0.03
	6/17/2005	0.31	0.08	2100	899	167	<0.03
	10/11/2005	0.28	0.06	2110	863	170	<0.03
	Average	0.35	0.08	2109	927	180	0.04
2006	3/1/2006	0.35	0.08	2230	926	197	0.04
	4/10/2006	0.35	0.09	2150	985	185	0.05
	6/26/2006	0.3	0.07	1550	645	158	<0.03
	8/14/2006	0.36	0.09	1980	928	----	----
	10/2/2006	0.38	0.09	2020	925	161	0.07
	Average	0.35	0.08	1986	882	175	0.04
2007	4/1/2007	0.32	0.08	2130	904	173	<0.03
	4/30/2007	0.41	0.09	2240	980	164	0.04
	6/26/2007	0.32	0.08	2010	856	163	<0.03
	8/17/2007	0.38	0.08	2130	978	----	----
	10/10/2007	0.39	0.09	2100	885	184	0.04
	Average	0.36	0.08	2122	921	171	0.04

Selenium concentrations were 0.08 mg/l in 2002 and less than 0.005 mg/l in 2003. The latter result is questionable because the concentration in each of the four supply wells was measured at

0.04 or 0.05 mg/l and no other water was introduced to the supply line (see HMC's 2003 Annual Report for individual well results). The average 2004 through 2007 selenium concentrations were similar to the 2002 value. Thus, the five-year average selenium concentration of 0.08 mg/l is assumed to be an average of the mean concentration reported from 2002 through 2007.

2.3 Irrigation Water Usage

Water usage was 715 (in 2000) and 695 (in 2001) acre-feet (ac-ft) on the 270 acres (Sections 33 and 34); 995 (in 2002) and 949 (in 2003) ac-ft on the 330 acres (Sections 33, 34 and 28); 1028 ac-ft in 2004 on the 354 acres; 1034 ac-ft in 2005 on the 394 acres; and 837 and 789 ac-ft in 2006 and 2007 respectively on 370 acres as the flood area in Section 33 was not irrigated.

3.0 Soil Concentrations

Samples have been collected from irrigated and non-irrigated soils and analyzed for uranium, selenium, and chloride to observe the effects of irrigation on their deposition over time. The incremental deposition of uranium and selenium constituents in soil was then used to calculate transfer coefficients from soil to hay. Chloride was tracked as a conservative constituent and used to verify observations of selenium deposition in soil.

Investigators labeled the first samples collected from irrigated areas as pre-operations samples. Samples collected from adjacent, fallow areas were labeled as background samples. Areas slated for irrigation that were sampled prior to irrigation (pre-operations) are essentially background areas until they are irrigated with impacted groundwater. Thus, to assist the reader, sampling areas are hereafter referred to as treated (irrigated areas) and untreated (non-irrigated areas) areas.

ACZ Laboratories, Inc. performed the analyses on the soil samples. When testing for chloride and sulfate, ACZ consistently returned qualifiers for those two constituents stating "analysis exceeded method hold time."

3.1 Background Soil Concentrations

Naturally-occurring uranium and selenium concentrations in untreated soils were determined in two studies. In 1998, Homestake Mining Corporation (HMC) characterized uranium and selenium concentrations in soils, prior to selecting fields for the irrigation study. In 1999, HMC investigated chloride concentrations in Sections 33 and 34 prior to the start of irrigation. HMC has also collected and analyzed soil samples immediately prior to and during the irrigation program.

3.1.1 1998 Investigation

The first investigation (RIMCON and Hydro-Engineering, 1998) was completed prior to the selection of treatment areas. Surface and near-surface soil samples were collected inside and outside the fields slated for irrigation. The samples were analyzed for uranium and selenium concentrations and parameters to define soil types.

At the time of sampling, surface soils in Sections 28, 33, and 34 were placed in three general categories: loamy sand, sandy loam, and sandy clay loam, respectively. The percentage of clay in these soils appeared to increase from Section 28 to 33 to 34, in ascending order (RIMCON and Hydro-Engineering, 1998).

The 1998 results are listed in Tables 3, 4 and 5 for Section 33, 34 and 28, respectively, along with recent "untreated area" background analyses. A "1998" in the comment column in the tables indicate the sample was taken during the 1998 background investigation.

Figure 1 shows the location of the soil samples collected in Sections 33, 34, and Section 28. Seven soil samples were analyzed for uranium and selenium from Section 33. The two eastern Section 33 soil results are included with the Section 34 results in Table 4 because the soil in eastern Section 33 is similar to the clay soils in Section 34. This figure also shows nine samples in Section 34 and one in the northern portion of Section 3 that are considered to be representative of the area for Section 34. Figure 1 also shows the location of seven samples in Section 28 and one along the western edge of Section 27 that were used to define the background concentrations in Section 28 in the 1998 investigation.

3.1.2 Background Determinations during Ongoing Investigation

Additional background samples were collected in treated (pre-operational) and untreated areas, starting in 1999. HMC continued to collect samples from the treated (post-treatment) and untreated areas in subsequent years.

All soil samples were analyzed by ACZ Laboratories, Inc. Uranium concentrations were determined using U.S. EPA Method 6020 ICP-MS, with an MDL of 0.03 mg/kg for all samples collected in 2000, 2002, 2003 and 2004; 0.01 mg/kg in 2001; 0.06 mg/kg in 2005; and 0.05 mg/kg in 1999, 2006 and 2007.

Selenium concentrations in samples collected from 1999-2001 were determined using Method 7742 Modified AA-Hydride, with an MDL of 0.1 mg/kg. The 2002 selenium analyses were determined using three methods. The samples were first analyzed using U.S. EPA Method 6020 ICP-MS, with an MDL of 0.8 mg/kg. The samples were then re-analyzed twice: first by way of U.S. EPA Method 7742 modified AA-Hydride, followed by EPA Method 6020 ICP-MS. The latter analysis was performed because selenium concentrations reported by way of U.S. EPA Method 7742 were below the relatively high MDL of 0.6 mg/kg. A lower MDL (0.05 mg/kg)

was then obtained in subsequent years, using EPA Method 6020. The EPA M6020 ICP-MS method was used for 2003, 2004, 2005, 2006 and 2007. All selenium concentrations reported in 2002 were below the MDL of 0.60 mg/kg, limiting the usefulness of the data. The 2002 results were not considered in evaluating trends in selenium concentrations, because selenium concentrations prior to and after 2002 exceeded the lowest MDL observed in 2002 by a factor of two.

3.1.3 Mean Background Soil Concentrations

Mean background is defined as the average of the untreated, pre-irrigation-treated and background concentrations of constituents in all such samples collected to date (see Tables 3 through 5 for updated mean background values). This value is designated by section and layer(s) and is updated with new data as they are obtained. Thus, it changes annually. The importance in having this value defined in this manner is to supplement and improve the background data set, as warranted. These mean background values will be used to calculate uptake of a constituent in the treated areas. Figures 16, 17 and 18 show the data used to calculate the mean uranium background concentrations for Section 33, 34 and 28 respectively. Figures 19, 20 and 21 give the mean background plots for selenium.

As of 2007, mean background uranium concentrations for the three Section 33 intervals are 0.78 (0-1 ft), 0.69 (1-2 ft), and 0.71 mg/kg (2-3 ft). The corresponding mean background concentrations for selenium and chloride are 0.14, 0.15, and 0.12 mg/kg; and 24, 37, and 30 mg/kg, respectively. Table 3 lists uranium, selenium, and chloride concentrations in the 1998 and 1999 background samples and those collected near the Section 33 irrigation area from 2000 through 2007. This table is broken into three depth intervals: 0-1, 1-2, and 2-3 ft. Results from a sample are listed in the depth interval if at least 6 inches (in) of the sample is from the interval.

In Section 34, the mean background uranium concentrations were 1.96 (0-1 ft), 1.45 (1-2 ft), and 1.15 (2-3 ft) mg/kg. Table 4 presents the constituents in Section 34 background soils. As in Section 33, the Section 34 soils generally show a decrease in mean uranium concentrations with increasing depth, but the difference between concentrations for each depth interval is greater in Section 34. A few results appeared to be outliers and were not used to calculate concentrations. Note that the six eastern samples from Section 33 are included in the Section 34 table because the soils from these two samples are primarily clays. The Sections 33 and 34 clay soils are combined in Table 4 to define the background concentrations for the two flood irrigated areas.

In Section 28, the mean background uranium concentrations were 0.55 (0-1 ft), 0.53 (1-2 ft), and 0.51 (2-3 ft) mg/kg. Table 5 presents the results for the Section 28 area.

The mean background concentrations of selenium are similar in Sections 28 and 33. Selenium concentrations in Section 34 are generally higher, presumably because of their association with clay soils.

Measurements for uranium, selenium, and chloride showed a high degree of variability between and within fields, with coefficients of variation (100 x standard deviation/mean) ranging between 22 and 86 percent.

Table 3. Pre-Operations and Background Soil Sample Results for Section 33

Interval (ft)	Location ID	Area	Depth (in)	Natural Uranium (pCi/g)	Natural Uranium mg/kg	Selenium mg/kg	Chloride (mg/kg)	Comment
0-1	S33-4	Treated	0-6	0.37	0.55	0.03	----	*1998
	S33-4	Treated	6-48	0.36	0.53	0.03	----	*1998
	S33-7	Treated	0-24	0.30	0.44	0.03	----	*1998
	S33-8	Treated	0-20	0.58	0.86	0.07	----	1998
	S33-9	Untreated	0-24	0.56	0.83	0.15	----	1998
	S33-10	Untreated	0-12	0.70	1.03	0.05	----	1998
	33A	Treated	0-6	0.24	0.36	0.10	13	1999
	33B	Treated	0-6	0.56	0.82	0.20	7	1999
	33C	Treated	0-6	0.44	0.65	0.05	35	**1999
	33D	Untreated	0-6	0.49	0.73	0.20	22	1999
	33D1	Untreated	0-6	0.77	1.14	0.20	18	2000
	BG-1	Untreated	0-12	0.66	0.98	0.10	32	2001
	BG-1	Untreated	0-12	0.58	0.85	----	2	&#2002
	BG-1	Untreated	0-12	0.53	0.78	0.12	21	2003
	BG-1	Untreated	0-12	0.60	0.88	0.27	28	2004
	BG-1	Untreated	0-12	0.53	0.78	0.18	27	2005
	BG-1	Untreated	0-12	0.60	0.88	0.18	18	2006
	BG-1	Untreated	0-12	0.60	0.89	0.39	68	2007
			Mean	0.53	0.78	0.14	24	
			SDV	0.14	0.20	0.10	17	
			CV	26.24	26.24	72.29	69	

Interval (ft)	Location ID	Area	Depth (in)	Natural Uranium (pCi/g)	Natural Uranium mg/kg	Selenium mg/kg	Chloride (mg/kg)	Comment
1-2	S33-4	Treated	6-48	0.36	0.53	0.03	----	*1998
	S33-7	Treated	0-24	0.30	0.44	0.03	----	*1998
	S33-8	Treated	0-20	0.58	0.86	0.07	----	1998
	S33-9	Untreated	0-24	0.56	0.83	0.15	----	1998
	S33-10	Untreated	12-30	0.38	0.56	0.03	----	*1998
	BG-2	Untreated	12-24	0.51	0.76	0.20	29	2001
	BG-2	Untreated	12-24	0.40	0.59		8	#2002
	BG-2	Untreated	12-24	0.35	0.52	0.12	25	2003
	BG-2	Untreated	12-24	0.53	0.79	0.24	32	2004
	BG-2	Untreated	12-24	0.47	0.69	0.15	71	2005
	BG-2	Untreated	12-24	0.60	0.88	0.16	21	2006
	BG-2	Untreated	12-24	0.60	0.89	0.44	73	2007
			Mean	0.47	0.69	0.15	37	
			SDV	0.11	0.16	0.12	25	
			CV	22.92	22.92	83.60	68	

Interval (ft)	Location ID	Area	Depth (in)	Natural Uranium (pCi/g)	Natural Uranium mg/kg	Selenium mg/kg	Chloride (mg/kg)	Comment
2-3	S33-4	Treated	6-48	0.36	0.53	0.03	----	*1998
	S33-7	Treated	24-48	0.24	0.35	0.03	----	*1998
	S33-8	Treated	20-48	0.35	0.52	0.03	----	*1998
	S33-9	Untreated	24-48	0.70	1.03	0.10	----	1998
	S33-10	Untreated	12-30	0.38	0.56	0.03	----	*1998
	S33-10	Untreated	30-60	0.40	0.59	0.03	----	*1998
	BG-3	Untreated	24-36	0.56	0.83	0.30	41	2001
	BG-3	Untreated	24-36	0.45	0.66		8	#2002
	BG-3	Untreated	24-36	0.45	0.67	0.12	22	2003
	BG-3	Untreated	24-36	0.55	0.81	0.26	31	2004
	BG-3	Untreated	24-36	0.53	0.79	0.15	@222	2005
	BG-3	Untreated	24-36	0.74	1.09	0.15	16	2006
	BG-3	Untreated	24-36	0.58	0.86	0.27	63	2007
			Mean	0.45	0.71	0.12	30	
			SDV	0.13	0.21	0.11	20	
			CV	28.05	29.66	85.58	66	

* = 1998 Se Reported as less than LLD of 0.05 mg/kg, used 0.025
** = 1999 Se MDL= 0.1 Reported as less than MDL, used 0.05 mg/kg
# = 2002 Se MDL= 0.8 All data reported as < MDL, did not use
CV = coefficient of variation
SDV = standard deviation

Table 4. Pre-Operations and Background Soil Sample Results for Section 34

Interval (ft)	Location ID	Area	Depth (in)	Natural Uranium (pCi/g)	Natural Uranium mg/kg	Selenium (mg/kg)	Chloride (mg/kg)	Comment
0-1	S33-1	Untreated	0-6	0.96	1.42	0.13	----	1998
	S33-1	Untreated	6-24	1.23	1.82	0.19	----	1998
	S33-2	Untreated	0-6	1.12	1.65	0.18	----	1998
	S33-2	Untreated	6-24	1.02	1.51	0.19	----	1998
	S3-1	Untreated	0-14	0.70	1.03	0.11	----	1998
	S34-1	Untreated	3-24	@5.85	@8.77	0.10	----	1998
	S34-3	Treated	4-26	1.03	1.52	0.11	----	1998
	S34-5	Untreated	3-40	0.84	1.24	0.14	----	1998
	S34-7	Untreated	3-28	0.78	1.15	0.06	----	1998
	S34-8	Untreated	2-30	1.26	1.86	0.31	----	1998
	S34-10	Untreated	3-28	1.01	1.49	0.13	----	1998
	S34-11	Untreated	3-15	1.36	2.01	0.03	----	*1998
	S34-13	Untreated	4-18	@3.93	@5.81	0.11	----	1998
	S34-14	Treated	4-24	0.79	1.17	0.19	----	1998
	34A	Treated	0-6	1.84	2.72	0.40	36	1999
	34B	Treated	0-6	1.60	2.36	0.40	54	1999
	34C	Treated	0-6	1.18	1.75	0.30	79	1999
	34D	Treated	0-6	2.44	3.60	0.60	36	1999
	34E	Treated	0-6	1.56	2.31	0.40	25	1999
	34F	Treated	0-6	2.05	3.03	0.80	68	1999
	34G	Treated	0-6	1.25	1.85	0.30	13	1999
	34H	Treated	0-6	2.29	3.38	0.70	43	1999
	34I	Treated	0-6	0.67	0.99	0.10	42	1999
	BG-1-34	Untreated	0-12	1.67	2.47	0.30	100	2001
	BG-1-34	Untreated	0-12	0.30	0.45		7	#2002
	BG-1-34	Untreated	0-12	1.58	2.33	0.42	83	2003
	BG-1-34	Untreated	0-12	1.89	2.79	0.75	151	2004
	BG-1-34	Untreated	0-12	1.63	2.41	0.53	@400	2005
	BG-1-33F	Untreated	0-12	1.06	1.56	0.47	30	2004
	BG-1-33F	Untreated	0-12	0.76	1.12	0.25	76	2005
	BG-1-33F	Untreated	0-12	1.05	1.55	0.56	24	2006
	BG-1-34	Untreated	0-12	2.07	3.06	0.69	@253	2006
	BG-1-33F	Untreated	0-12	1.21	1.79	0.38	64	2007
	BG-1-34	Untreated	0-12	2.23	3.30	0.74	@267	2007
			Mean	1.33	1.96	0.34	55	
			SDV	0.53	0.78	0.23	36	
			CV	39.98	40.00	67.91	66	

1-2	S33-1	Untreated	6-24	1.23	1.82	0.19	----	1998
	S33-2	Untreated	6-24	1.02	1.51	0.19	----	1998
	S3-1	Untreated	14-38	0.71	1.05	0.09	----	1998
	S34-1	Untreated	3-24	@5.85	@8.77	0.10	----	1998
	S34-3	Treated	4-26	1.03	1.52	0.11	----	1998
	S34-5	Untreated	3-40	0.84	1.24	0.14	----	1998
	S34-7	Untreated	3-28	0.78	1.15	0.06	----	1998
	S34-8	Untreated	2-30	1.26	1.86	0.31	----	1998
	S34-10	Untreated	3-28	1.01	1.49	0.13	----	1998
	S34-11	Untreated	15-60	0.58	0.86	0.03	----	*1998
	S34-13	Untreated	4-18	@3.93	@5.81	0.11	----	1998
	S34-13	Untreated	18-30	0.68	1.00	0.14	----	1998
	S34-14	Treated	4-24	0.79	1.17	0.19	----	1998
	BG-2	Untreated	12-24	1.30	1.92	0.20	120	2001
	BG-2	Untreated	12-24	0.36	0.53		4	#2002
	BG-2	Untreated	12-24	0.99	1.46	0.35	131	2003
	BG-2-34	Untreated	12-24	1.38	2.04	0.68	----	2004
	BG-2-34	Untreated	12-24	1.65	2.44	0.69	----	2005
	BG-2-33F	Untreated	12-24	0.88	1.30	0.39	35	2004
	BG-2-33F	Untreated	12-24	0.62	0.92	0.20	103	2005
	BG-2-33F	Untreated	12-24	0.78	1.15	0.35	20	2006
	BG-2-34	Untreated	12-24	@2.66	@393	@0.87	@219	2006
	BG-2-33F	Untreated	12-24	0.87	1.29	0.31	57	2007
	BG-2-34	Untreated	12-24	1.87	2.67	0.78	@271	2007
			Mean	0.98	1.45	0.26	67	
			SDV	0.36	0.53	0.21	51	
			CV	37.03	36.37	80.57	76	

Table 4. Pre-Operations and Background Soil Sample Results for Section 34 (concluded)

Interval (ft)	Location ID	Area	Depth (in)	Natural Uranium (pCi/g)	Natural Uranium mg/kg	Selenium (mg/kg)	Chloride (mg/kg)	Comment
	S33-1	Untreated	24-48	1.32	1.95	0.23	----	1998
	S33-2	Untreated	24-48	0.40	0.59	0.09	----	1998
	S3-1	Untreated	14-38	0.71	1.05	0.09	----	1998
	S34-1	Untreated	24-36	0.43	0.64	0.13	----	1998
	S34-5	Untreated	3-40	0.84	1.24	0.14	----	1998
	S34-7	Untreated	28-40	0.43	0.64	0.41	----	1998
	S34-8	Untreated	30-60	0.69	1.02	0.34	----	1998
	S34-11	Untreated	15-60	0.58	0.86	0.03	----	*1998
2-3	S34-13	Untreated	18-30	0.68	1.00	0.14	----	1998
	S34-14	Treated	30-90	0.20	0.30	0.03	----	*1998
	BG-3	Untreated	24-36	0.53	0.79	0.20	120	2001
	BG-3	Untreated	24-36	0.27	0.40		4	#2002
	BG-3	Untreated	24-36	1.12	1.66	0.36	141	2003
	BG-3-34	Untreated	24-36	0.93	1.38	0.40	@169	2004
	BG-3-34	Untreated	24-36	1.44	2.13	0.51	@354	2005
	BG-3-33F	Untreated	24-36	0.90	1.33	0.42	30	2004
	BG-3-33F	Untreated	24-36	0.61	0.90	0.19	81	2005
	BG-3-33F	Untreated	24-36	0.71	1.05	0.34	14	2006
	BG-3-34	Untreated	24-36	1.55	2.29	0.54	@259	2006
	BG-3-33F	Untreated	24-36	0.84	1.24	0.35	43	2007
	BG-3-34	Untreated	24-36	1.11	1.64	0.53	@246	2007
			Mean	0.78	1.15	0.27	62	
			SDV	0.37	0.55	0.17	53	
			CV	47.63	47.55	61.27	86	

@ = considered an outlier, did not use
* = 1998 Se Reported as less than LLD of 0.05 mg/kg, used 0.025
# = 2002 Se MDL= 0.8 All data reported as < MDL, did not use
CV = coefficient of variation
SDV = standard deviation

Table 5. Pre-Operations and Background Soil Sample Results for Section 28

Interval (ft)	Location ID	Area	Depth (in)	U-nat (pCi/g)	U-nat mg/kg	Selenium mg/kg	Chloride (mg/kg)	Comment
0-1	S28-2	Untreated	0-40	@1.06	@1.57	0.14	----	1998
	S28-3	Untreated	4-22	0.23	0.34	0.18	----	1998
	S28-9	Treated	0-40	0.33	0.49	0.06	----	1998
	NE27-1	Untreated	0-6	0.34	0.50	0.03	----	*1998
	NE28-2	Untreated	0-6	0.24	0.35	0.03	----	*1998
	NE28-4	Untreated	0-8	0.13	0.19	0.16	----	1998
	NE28-5	Untreated	0-12	0.50	0.74	0.10	----	1998
	NE28-7	Untreated	0-8	0.51	0.75	0.12	----	1998
	BG-1	Untreated	0-12	2.02	@2.99		14	#2002
	BG-1	Untreated	0-12	0.35	0.51	0.15	6	2003
	BG-1	Untreated	0-12	0.60	0.88	0.22	12	2004
	BG-1	Untreated	0-12	0.32	0.47	0.12	@283	2005
	BG-1	Untreated	0-12	0.42	0.62	0.10	19	2006
	BG-1	Untreated	0-12	0.53	0.78	0.23	32	2007
			Mean	0.37	0.55	0.13	17	
			SDV	0.14	0.21	0.07	10	
			CV	37.36	37.38	52.03	59	
1-2	S28-2	Untreated	0-40	@1.06	@1.57	0.14	----	1998
	S28-3	Untreated	4-22	0.23	0.34	0.18	----	1998
	S28-9	Treated	0-40	0.33	0.49	0.06	----	1998
	NE28-4	Untreated	8-28	0.23	0.34	0.03	----	*1998
	NE28-7	Untreated	8-24	0.23	0.34	0.05	----	1998
	BG-2	Untreated	12-24	@1.10	@1.62		13	#2002
	BG-2	Untreated	12-24	0.41	0.61	0.10	6	2003
	BG-2	Untreated	12-24	0.52	0.77	0.22	14	2004
	BG-2	Untreated	12-24	0.32	0.47	0.07	----	2005
	BG-2	Untreated	12-24	0.35	0.51	0.03	14	2006
	BG-2	Untreated	12-24	0.62	0.91	0.24	26	2007
			Mean	0.36	0.53	0.11	15	
			SDV	0.14	0.20	0.08	7	
			CV	37.95	37.83	71.14	49	
2-3	S28-2	Untreated	0-40	@1.06	@1.57	0.14	----	1998
	S28-9	Treated	0-40	0.33	0.49	0.06	----	1998
	NE27-1	Untreated	24-80	0.14	0.21	0.03	----	*1998
	NE28-4	Untreated	28-84	0.22	0.32	0.03	----	*1998
	NE28-5	Untreated	25-84	0.44	0.65	0.03	----	*1998
	NE28-7	Untreated	24-48	0.14	0.21	0.03	----	*1998
	BG-3	Untreated	24-36	@0.98	@1.45		13	#2002
	BG-3	Untreated	24-36	0.36	0.53	0.12	11	2003
	BG-3	Untreated	24-36	0.55	0.81	0.19	10	2004
	BG-3	Untreated	24-36	0.37	0.55	0.07	@290	2005
	BG-3	Untreated	24-36	0.39	0.58	0.06	16	2006
	BG-3	Untreated	24-36	0.54	0.80	0.25	30	2007
			Mean	0.35	0.51	0.09	16	
			SDV	0.15	0.22	0.08	8	
			CV	41.90	41.82	84.87	51	

@ = considered an outlier, did not use
* = 1998 Se Reported as less than LLD of 0.05 mg/kg, used 0.025
# = 2002 Se MDL= 0.8 All data reported as < MDL, did not use
CV = coefficient of variation
SDV = standard deviation

3.2 Constituents in Treated Soil

Uranium, selenium, molybdenum, calcium, magnesium, sodium, chloride, and sulfate levels were measured in soil samples from Sections 33 and 34 in 1999 (prior to irrigation) and after each of the 2000 through 2007 irrigation seasons. The pH, conductivity and sodium absorption ratio (SAR) were also measured or calculated for the samples.

Changes in soil chemistry between pre-irrigation samples and those collected after the first irrigation season in 2000 are described in ERG and HYDRO, 2001, 2004, 2005, 2006, 2007 and in this report.

Figures 2 through 9 show the locations of the Section 33 and Section 34 sampling sites for 2000, 2001, 2002, 2003, 2004, 2005, 2006 and 2007. Figures 10 through 15 present the locations of soil samples collected in Section 28 in 2002, 2003, 2004, 2005, 2006 and 2007. Figures 16 through 21 present uranium and selenium soil concentrations for the irrigation areas.

Composite samples were prepared from locations indicated within each irrigation area and in associated background locations. In 2000, the suffixes -1, -2, or -3 on sample labels indicate samples collected from 0-6 (-1), 6-18 (-2), or 18-36-in (-3) depth intervals. The ranges of sampling depths were changed in 2001, to better assess the impacts of irrigation. In 2001 to 2007, suffixes -1, -2, and -3 indicate composites from 0-1 ft, 1-2 ft, and 2-3 ft, respectively. Comparisons between data acquired in 2000 and data from subsequent years must be qualified by the change in sampling depths.

An example of compositing conducted in 2001 at Section 33 is as follows: the grab samples collected from 0-1 ft at soil sample locations EW2, EW4, EW6, WW2, WW4, WW6, NW2, NW4, NW6, SW2, SW4 and SW6 (see Figure 3 for sample locations) were composited into one sample labeled P-1. Grab samples from 1-2 ft at these locations were composited into one sample labeled P-2.

Table 6 presents the results for composite samples collected at each of the areas in 2000 through 2007. Appendix A gives the 1999 and 2000 individual sample results that were used to calculate the 2000 average values presented in Table 6. No samples were collected at Section 28 in 2001; irrigation in this area began in 2002. Composite samples collected at treated areas are labeled P (Section 33), F (Section 34) or N (Section 28). They are further subdivided by P-, F-, or N-1 (0-1 ft), P-, F-, or N-2, (1-2 ft) and P-, F-, or N-3 (2-3 ft). Thus, constituents in the composite samples represent an average condition in layers across the center pivot area, at 0-1 ft, 1-2 ft and 2-3 ft depth intervals.

Table 6. Irrigation Soil Analyses, 2000-2007

Sample Site	Date	U (mg/kg)	Se (mg/kg)	Mo (mg/kg)	pH (units)	Cond. (mmhos/cm)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	SAR (ratio)	Cl (mg/kg)	SO4 (mg/kg)
					SECTION 33 CENTER PIVOT							
P-1	12/7/2000	0.93	0.37	<1	7.9	0.987	4.00	1.27	5.67	3.40	26	98
	6/15/2001	0.94	0.3	<1	8.0	1.230	3.77	1.48	7.48	4.84	123	500
	11/20/2002	0.98	<0.6	<1	7.8	1.610	7.71	2.80	8.10	3.53	13	300
	11/18/2003	1.36	0.28	<1	7.8	2.200	7.99	3.25	13.50	5.69	55	590
	11/9/2004	1.78	0.45	<1	7.6	3.780	19.70	8.73	21.40	5.67	101	190
	11/5/2005	1.45	0.31	<1	8.1	2.060	9.35	4.02	11.20	4.33	51	460
	10/21/2006	1.87	0.36	<1	7.8	3.560	15.80	6.36	20.40	6.13	109	1020
	11/10/2007	1.67	0.44	<1	7.7	3.280	12.40	5.91	19.10	6.31	85	600
P-2	12/7/2000	0.81	0.45	<1	7.8	1.480	6.30	1.88	7.77	3.84	46	290
	6/15/2001	0.60	0.3	<1	7.9	1.120	4.32	1.45	6.11	3.60	109	500
	11/20/2002	0.89	<0.6	<1	7.8	2.190	10.10	3.78	13.10	4.97	14	600
	11/18/2003	1.14	0.19	<1	7.9	2.690	10.30	3.86	16.10	6.05	82	710
	11/9/2004	1.52	0.39	<1	7.6	4.300	19.40	10.80	27.50	7.07	155	200
	11/5/2005	1.15	0.21	2	8.1	3.940	15.10	7.68	27.30	8.09	94	420
	10/21/2006	1.62	0.15	<1	7.7	3.320	14.20	5.93	17.90	5.64	142	900
	11/10/2007	1.34	0.3	<1	7.7	5.300	19.60	11.00	37.00	9.46	187	900
P-3	12/7/2000	1.03	0.25	<1	7.6	1.720	8.35	2.29	8.33	3.71	36	210
	6/15/2001	0.54	0.1	<1	7.8	1.020	4.74	2.18	4.27	2.30	67	400
	11/20/2002	0.68	<0.6	<1	7.7	2.400	11.70	5.34	11.60	3.97	34	1000
	11/18/2003	1.00	0.18	<1	7.8	2.970	15.50	5.67	17.30	5.32	106	570
	11/9/2004	1.15	0.38	<1	7.6	3.440	15.90	9.31	19.30	5.43	137	220
	11/5/2005	1.00	0.3	1	8.0	4.500	18.70	10.50	147.00	38.50	197	580
	10/21/2006	1.05	0.14	<1	7.8	3.500	13.90	6.17	19.70	6.22	126	780
	11/10/2007	1.30	0.39	<1	7.6	4.670	20.30	10.60	26.40	6.72	174	670
BG-1	12/7/2000	1.14	0.2	<1	7.6	1.240	9.07	2.64	0.64	0.26	18	<50
	6/20/2001	0.98	0.1	1	7.9	0.231	1.51	0.48	0.43	0.43	32	<300
	11/20/2002	0.85	<0.6	<1	7.8	0.450	3.51	0.98	0.69	0.46	<4	<100
	11/18/2003	0.78	0.12	<1	7.8	0.700	4.13	1.15	0.60	0.36	21	160
	11/8/2004	0.88	0.27	<1	7.7	0.980	6.22	1.94	1.83	0.91	28	60
	11/5/2005	0.78	0.18	<1	8.1	0.835	5.20	1.54	1.60	0.87	27	570
	10/21/2006	0.88	0.18	<1	7.9	1.060	6.04	1.69	1.87	0.95	18	160
	11/10/2007	0.89	0.39	<1	7.7	1.510	7.57	2.80	2.03	0.89	68	280
BG-2	6/20/2001	0.76	0.2	<1	7.9	0.321	1.83	0.92	0.57	0.48	29	<300
	11/20/2002	0.59	<0.6	<1	7.7	1.250	7.58	3.04	3.56	1.54	8	<100
	11/18/2003	0.52	0.12	<1	7.7	0.670	4.27	1.28	0.70	0.42	25	90
	11/8/2004	0.79	0.24	<1	7.8	0.690	4.05	1.45	1.22	0.74	32	70
	11/5/2005	0.69	0.15	<1	8.1	0.745	4.24	1.45	1.41	0.83	71	2140
	10/21/2006	0.88	0.16	<1	8.0	0.757	3.63	1.60	1.47	0.90	21	120
	11/10/2007	0.89	0.44	<1	7.7	1.550	9.46	3.44	2.42	0.95	73	350
BG-3	6/20/2001	0.83	0.3	<1	7.9	0.385	2.41	1.12	0.48	0.36	41	300
	11/20/2002	0.66	<0.6	<1	7.9	0.580	3.39	1.32	1.79	1.17	8	300
	11/18/2003	0.67	0.12	<1	7.7	0.620	3.77	1.39	0.70	0.43	22	70
	11/8/2004	0.81	0.26	<1	7.8	0.720	4.13	1.54	1.50	0.89	31	80
	11/5/2005	0.79	0.15	2	8.3	0.607	3.39	1.26	1.23	0.80	222	6770
	10/21/2006	1.09	0.15	<1	8.0	1.080	5.54	2.55	2.20	1.09	16	200
	11/10/2007	0.86	0.27	<1	7.7	1.740	10.60	3.73	2.81	1.05	63	300
					SECTION 33 FLOOD							
F-1	11/5/2004	1.78	0.56	<1	7.6	2.810	19.10	7.21	11.30	3.11	114	190
	11/8/2005	1.35	0.31	1	7.8	2.690	16.80	6.23	10.20	3.01	66	1210
	10/28/2006	1.76	0.41	<1	7.8	1.480	8.25	2.91	4.79	2.03	72	1070
	11/10/2007	1.69	0.45	<1	7.8	2.000	9.35	3.6	8.85	3.48	98	450
F-2	11/5/2004	1.67	0.47	1	7.7	2.360	13.70	5.09	10.40	3.39	115	150
	11/8/2005	1.14	0.24	<1	7.8	2.260	13.30	4.68	9.22	3.08	57	620
	10/28/2006	1.24	0.26	<1	7.7	2.320	16.00	5.15	8.33	2.56	46	970
	11/10/2007	1.55	0.4	<1	7.8	3.070	16.90	6.58	13.00	3.79	63	390
F-3	11/5/2004	1.68	0.49	<1	7.7	2.400	18.40	6.52	11.60	3.28	115	150
	11/8/2005	1.00	0.2	<1	7.8	2.670	17.80	5.91	10.70	3.11	41	350
	10/28/2006	1.62	0.21	<1	7.7	1.840	10.90	3.38	5.93	2.22	52	970
	11/10/2007	1.51	0.4	<1	7.7	2.010	11.50	4.06	7.97	2.86	52	470

Table 6. Irrigation Soil Analyses, 2000-2007 (continued)

Sample Site	Date	U (mg/kg)	Se (mg/kg)	Mo (mg/kg)	pH (units)	Cond. (mmhos/cm)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	SAR (ratio)	Cl (mg/kg)	SO4 (mg/kg)
						SECTION 33 FLOOD (continued)						
BG-1	11/5/2004	1.56	0.47	1	7.8	0.770	3.49	1.40	2.51	1.60	30	110
	11/8/2005	1.12	0.25	<1	7.8	0.962	5.16	1.84	2.29	1.22	76	2720
	10/28/2006	1.55	0.56	<1	7.9	0.702	2.93	1.04	1.98	1.41	24	100
	11/10/2007	1.79	0.38	<1	7.8	0.800	4.30	1.55	1.96	1.15	64	140
BG-2	11/5/2004	1.30	0.39	<1	7.8	0.820	4.42	1.70	2.28	1.30	35	120
	11/8/2005	0.92	0.2	<1	7.8	0.829	4.13	1.52	2.41	1.43	103	1960
	10/28/2006	1.15	0.35	<1	7.8	0.470	1.94	0.71	1.37	1.19	20	210
	11/10/2007	1.29	0.31	<1	7.8	0.810	4.24	1.65	1.79	1.04	57	160
BG-3	11/5/2004	1.33	0.42	<1	7.8	0.940	5.13	2.06	2.79	1.47	30	160
	11/8/2005	0.90	0.19	<1	7.8	1.110	5.74	2.20	3.55	1.78	81	3200
	10/28/2006	1.05	0.34	<1	7.9	0.677	2.88	1.05	1.84	1.31	14	190
	11/10/2007	1.24	0.35	<1	7.8	0.710	3.80	1.41	1.96	1.21	43	260
						SECTION 34 FLOOD						
F-1	12/7/2000	3.35	0.68	<1	7.7	2.594	11.95	4.66	14.58	5.03	56	767
	8/8/2001	2.72	0.50	2	7.8	5.090	10.90	3.17	13.50	5.09	182	900
	11/22/2002	0.69	<0.6	<1	7.9	1.050	4.73	1.47	5.26	2.99	18	800
	11/26/2003	3.72	0.82	1	7.8	4.570	22.50	9.62	31.60	7.89	284	2620
	11/4/2004	4.43	1.15	2	7.7	5.220	20.50	8.98	40.40	10.52	398	680
	11/19/2005	3.94	1.10	2	8.0	5.420	20.80	8.64	37.60	9.80	416	5190
	10/28/2006	4.88	0.95	<1	7.9	3.500	12.20	5.72	22.90	7.65	445	5210
	11/10/2007	5.02	1.32	2	7.8	4.910	17.50	8.05	35.00	9.79	429	4400
F-2	12/7/2000	2.22	0.37	<1	7.6	3.237	14.42	6.01	18.58	5.85	78	1497
	8/8/2001	1.88	0.40	2	7.6	4.970	8.20	2.25	8.57	3.75	139	1400
	11/22/2002	0.46	<0.6	<1	8.0	1.030	3.85	1.12	6.06	3.84	10	200
	11/26/2003	1.90	0.40	<1	7.8	5.020	25.20	8.01	33.60	8.25	396	2480
	11/4/2004	2.27	0.63	<1	7.6	5.370	23.80	7.90	40.50	10.17	390	370
	11/19/2005	1.41	0.38	1	7.9	4.890	20.50	5.55	32.60	9.03	352	3980
	10/28/2006	2.25	0.45	<1	7.6	3.610	12.90	4.34	23.30	7.94	478	4230
	11/10/2007	3.05	0.94	<1	7.7	5.770	21.20	8.24	40.60	10.60	560	4000
F-3	12/7/2000	1.62	0.03	<1	7.6	3.397	13.63	5.02	22.21	6.75	56	980
	8/8/2001	1.15	0.30	<1	7.60	5.960	10.10	3.25	9.83	3.80	170	1800
	11/22/2002	0.42	<0.6	<1	8.0	0.930	3.63	1.53	4.90	3.05	3	<100
	11/26/2003	1.08	0.19	<1	7.8	4.420	23.90	6.53	25.80	6.61	302	1550
	11/4/2004	1.40	0.37	<1	7.6	4.800	25.30	7.39	34.90	8.63	166	210
	11/19/2005	2.62	0.68	2	8.0	4.550	17.40	5.78	32.90	9.66	560	5840
	10/28/2006	1.21	0.28	<1	7.5	3.860	18.50	5.18	23.20	6.74	302	2340
	11/10/2007	1.75	0.64	<1	7.6	5.28	24.2	6.25	32.7	8.38	337	1700
BG-1	8/8/2001	2.47	0.30	2	7.6	4.160	5.86	1.75	2.87	1.47	100	800
	11/22/2002	0.45	<0.6	<1	7.8	0.460	3.52	0.79	0.37	0.25	7	<100
	11/26/2003	2.33	0.42	<1	7.8	1.680	5.70	2.22	9.60	4.82	83	850
	11/3/2004	2.79	0.75	<1	7.8	2.320	8.67	2.05	13.30	5.74	151	490
	11/19/2005	2.41	0.53	2	7.7	3.230	12.80	3.50	15.40	5.39	400	1360
	10/28/2006	3.06	0.69	<1	7.8	2.200	9.53	2.22	10.60	4.37	253	810
	11/10/2007	3.30	0.74	2	7.7	3.650	19.10	4.81	19.60	5.67	267	800
BG-2	8/8/2001	1.92	0.20	2	7.5	4.730	7.94	2.60	4.53	1.97	120	300
	12/4/2002	0.53	<0.6	<1	7.8	0.410	3.03	1.06	0.32	0.22	4	<100
	11/26/2003	1.46	0.35	1	7.8	3.290	18.70	8.07	16.90	4.62	131	670
	11/3/2004	2.04	0.68	<1	7.7	4.040	19.70	4.51	26.10	7.50	220	280
	11/19/2005	2.44	0.39	2	7.9	4.460	20.80	4.99	23.90	6.66	349	1040
	10/28/2006	3.93	0.87	<1	7.7	2.400	12.30	2.59	10.90	3.99	219	810
	11/10/2007	2.67	0.78	2	7.7	4.280	21.00	5.02	25.80	7.15	271	1240
BG-3	8/8/2001	0.79	0.20	<1	7.6	8.200	6.35	2.12	2.77	1.35	120	100
	11/22/2002	0.40	<0.6	<1	7.9	0.360	2.51	1.14	0.35	0.25	4	<100
	11/26/2003	1.66	0.36	<1	7.7	2.460	12.80	5.95	10.70	3.49	141	370
	11/3/2004	2.04	0.40	<1	7.5	4.200	25.90	5.95	24.50	6.14	169	230
	11/19/2005	2.13	0.51	2	7.9	4.160	20.50	5.74	19.00	5.25	354	1280
	10/28/2006	2.29	0.54	<1	7.8	3.000	15.00	3.17	15.40	5.11	259	1040
	11/10/2007	1.64	0.53	<1	7.6	4.420	19.80	5.26	27.60	7.80	246	950

Table 6. Irrigation Soil Analyses, 2000-2007 (continued)

Sample Site	Date	U (mg/kg)	Se (mg/kg)	Mo (mg/kg)	pH (units)	Cond. (mmhos/cm)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	SAR (ratio)	Cl (mg/kg)	SO4 (mg/kg)
					SECTION 28 CENTER PIVOT							
N-1	11/19/2002	2.99	<0.6	2	7.7	4.27	20.80	9.40	26.90	6.92	48	3700
	11/24/2003	0.81	0.18	<1	7.8	1.95	8.47	3.94	10.00	4.01	24	400
	11/11/2004	0.89	0.37	<1	7.6	2.67	14.60	6.38	14.00	4.32	28	70
	11/15/2005	0.68	0.17	<1	7.9	2.65	13.90	6.55	11.40	3.57	42	430
	10/21/2006	1.11	0.16	2	7.6	2.37	12.70	6.20	9.35	3.04	57	280
	11/10/2007	1.14	0.47	<1	7.7	2.50	14.00	6.18	10.90	3.43	34	490
N-2	11/19/2002	1.47	<0.6	<1	7.7	4.51	20.60	7.60	29.00	7.72	68	3400
	11/24/2003	0.70	0.16	<1	7.9	2.42	9.47	3.73	15.70	6.11	49	450
	11/11/2004	0.80	0.23	<1	7.7	2.63	11.50	4.60	16.20	5.71	61	70
	11/15/2005	0.74	0.15	<1	7.9	4.09	15.70	7.75	26.60	7.77	87	330
	10/21/2006	1.14	0.09	2	7.7	2.56	12.50	6.43	12.90	4.16	18	610
	11/10/2007	1.01	0.34	<1	7.6	3.11	17.60	8.91	15.00	4.12	37	500
N-3	11/19/2002	0.74	<0.6	<1	7.6	4.51	22.90	7.57	26.40	6.76	39	1300
	11/24/2003	0.57	0.13	<1	7.8	2.55	13.20	5.28	13.40	4.41	74	380
	11/11/2004	0.7	0.23	<1	7.6	3.30	17.00	7.29	17.40	4.99	134	70
	11/15/2005	0.58	0.12	<1	7.9	4.29	14.90	7.44	6.00	1.8	118	420
	10/21/2006	1.06	0.08	2	7.8	3.58	15.20	8.21	26.00	7.6	37	670
	11/10/2007	0.92	0.25	<1	7.8	3.46	16.30	8.70	20.60	5.83	37	540
BG-1	11/19/2002	2.99	<0.6	2	8.0	0.82	3.33	0.91	4.20	2.88	14	700
	11/24/2003	0.51	0.15	<1	7.9	0.33	1.94	0.61	0.30	0.26	6	60
	11/11/2004	0.88	0.22	<1	7.4	1.16	6.93	1.99	3.91	1.85	12	20
	11/15/2005	0.47	0.12	<1	7.8	1.01	6.37	2.00	2.32	1.13	283	4380
	10/21/2006	0.62	0.10	2	7.7	0.46	2.41	0.71	0.57	0.45	19	80
	11/10/2007	0.78	0.23	<1	7.7	0.71	4.19	1.35	0.95	0.57	32	118
BG-2	11/19/2002	1.62	<0.6	<1	7.7	2.00	14.90	3.27	6.88	2.28	13	500
	11/24/2003	0.61	0.10	<1	8.0	0.35	1.69	0.81	0.60	0.53	6	120
	11/11/2004	0.77	0.22	<1	7.4	0.66	4.22	1.42	1.01	0.6	14	<10
	11/15/2005	0.47	0.07	<1	8.0	0.73	3.71	1.58	1.50	0.92	405	5350
	10/21/2006	0.51	<.05	1	7.8	0.53	2.22	0.95	0.89	0.7	14	<50
	11/10/2007	0.91	0.24	<1	7.6	0.95	5.95	2.18	1.45	0.71	26	99
BG-3	11/19/2002	1.45	<0.6	<1	7.8	1.51	9.24	1.95	6.29	2.66	13	500
	11/24/2003	0.53	0.12	<1	8.0	0.53	2.10	1.26	1.80	1.39	11	120
	11/11/2004	0.81	0.19	<1	7.5	0.80	4.74	2.03	1.60	0.86	10	10
	11/15/2005	0.55	0.07	<1	7.9	1.05	5.09	2.43	3.03	1.56	290	4340
	10/21/2006	0.58	0.06	1	7.9	0.44	1.33	0.68	1.25	1.25	16	70
	11/10/2007	0.8	0.25	<1	7.7	0.88	4.99	1.84	1.76	1.95	30	120

NOTE: 2000 Sample: 1 = 0 - 6 inches, 2 = 6 - 18 inches and 3 = 18 - 36 inches
2001 through 2007 Sample: 1 = 0 - 1 ft, 2 = 1 - 2 ft and 3 = 2 - 3 ft; BG samples are background.

Composite samples collected from untreated (background) areas are labeled BG-1, BG-2, or BG-3, representing the same three layers.

Table 7 lists concentrations of uranium and selenium in 1999 (background surface samples only), 2000 at 0-6, 6-18, and 18-36 in; and 2001, 2002, 2003, 2004, 2005, 2006 and 2007 for 0-1, 1-2 and 2-3 ft.

3.2.1 Section 33 Center Pivot

Twelve locations were sampled in the treated area of Section 33 in each of the seven latter years (2001 to 2007) and at the three depths described above. Fewer samples were collected in 2000. Corresponding depths were sampled at each of four background locations for the three analyzed depths (BG-1, BG-2, and BG-3) in untreated areas of Section 33 for the 2002 and 2003 samples. Ten background samples were composited together for the Section 33 soils in 2004, 2005, 2006 and 2007.

As stated in Section 3.1.3, the term "mean background" is defined as the average of all of the untreated, composite concentrations of a constituent determined from initial testing results to the most current. As defined, the mean background uranium concentration for Section 33 for all three layers is 0.73 mg/kg.

Generalized findings for uranium are as follows:

- Uranium concentrations in composite samples collected from the treated area in 2001 were slightly below associated background samples. The treated area results were 0.94 (0-1 ft), 0.60 (1-2 ft) and 0.54 (2-3 ft). The untreated area results were 0.98 (0-1 ft), 0.76 (1-2 ft) and 0.83 mg/kg (2-3 ft).

Uranium concentrations in the treated area started to exceed those in background samples in 2002. The most recent (2007) concentrations observed in the treated area were 1.67 (0-1 ft), 1.34 (1-2 ft) and 1.30 (2-3 ft); this compares to the corresponding mean background values of 0.78 (0-1 ft), 0.69 (1-2 ft) and 0.71 mg/kg (2-3 ft). The concentrations of uranium in the upper three feet of treated soil exceeded the mean background by factors of 2.14 (0-1 ft), 1.94 (1-2 ft) and 1.83 (2-3 ft). Uranium accumulated in the upper two feet of soil at an approximate constant rate until 2004, when concentrations achieved a steady state (see Figure 16).

Table 7. Summary of Irrigation Soil Analyses, 2000-2007

		Uranium (mg/kg)		Selenium (mg/kg)	
Section	Yearly Data	Treated Area	Background	Treated Area	Background
33 Center Pivot	1999 AVG:	—	0.61	—	0.12
	2000-1 AVG:	0.93	1.14	0.37	0.20
	2000-2 AVG:	0.81	—	0.45	—
	2000-3 AVG	1.03	—	0.25	—
	2001-1	0.94	0.98	0.30	0.10
	2001-2	0.60	0.76	0.30	0.20
	2001-3	0.54	0.83	0.10	0.30
	2002-1	0.98	0.85	<0.60	<0.60
	2002-2	0.89	0.59	<0.60	<0.60
	2002-3	0.68	0.66	<0.60	<0.60
	2003-1	1.36	0.78	0.28	0.12
	2003-2	1.14	0.52	0.19	0.12
	2003-3	1.00	0.67	0.18	0.12
	2004-1	1.78	0.88	0.45	0.27
	2004-2	1.52	0.79	0.39	0.24
	2004-3	1.15	0.81	0.38	0.26
	2005-1	1.45	0.78	0.31	0.18
	2005-2	1.15	0.69	0.21	0.15
	2005-3	1.00	0.79	0.30	0.15
	2006-1	1.87	0.88	0.36	0.18
	2006-2	1.62	0.88	0.15	0.16
	2006-3	1.05	1.09	0.14	0.15
	2007-1	1.67	0.89	0.44	0.39
	2007-2	1.34	0.89	0.30	0.44
	2007-3	1.30	0.86	0.39	0.27
28 Center Pivot	2002-1	2.99	2.99	<0.60	<0.60
	2002-2	1.47	1.62	<0.60	<0.60
	2002-3	0.74	1.45	<0.60	<0.60
	2003-1	0.81	0.51	0.18	0.15
	2003-2	0.70	0.61	0.16	0.10
	2003-3	0.57	0.53	0.13	0.15
	2004-1	0.89	0.88	0.37	0.22
	2004-2	0.80	0.77	0.23	0.22
	2004-3	0.70	0.81	0.23	0.19
	2005-1	0.68	0.47	0.17	0.12
	2005-2	0.74	0.47	0.15	0.07
	2005-3	0.58	0.55	0.12	0.07
	2006-1	1.11	0.62	0.16	0.10
	2006-2	1.14	0.51	0.09	<0.05
	2006-3	1.06	0.58	0.08	0.06
	2007-1	1.14	0.78	0.47	0.23
	2007-2	1.01	0.91	0.34	0.24
	2007-3	0.92	0.80	0.25	0.25

Table 7. Summary of Irrigation Soil Analyses, 2000-2007 (concluded)

		Uranium (mg/kg)		Selenium (mg/kg)	
Section	Yearly Data	Treated Area	Background	Treated Area	Background
34 Flood	1999 AVG:	---	2.44	---	0.44
	2000-1 AVG:	3.35	---	0.68	---
	2000-2 AVG:	2.22	---	0.37	---
	2000-3 AVG	1.62	---	0.30	---
	2001-1	2.72	2.47	0.50	0.30
	2001-2	1.88	1.92	0.40	0.20
	2001-3	1.15	0.79	0.30	0.20
	2002-1	0.69	0.45	<0.60	<0.60
	2002-2	0.46	0.53	<0.60	<0.60
	2002-3	0.42	0.40	<0.60	<0.60
	2003-1	3.72	2.33	0.82	0.42
	2003-2	1.90	1.46	0.40	0.35
	2003-3	1.08	1.66	0.19	0.36
	2004-1	4.43	2.79	1.15	0.75
	2004-2	2.27	2.04	0.63	0.68
	2004-3	1.40	1.38	0.37	0.40
	2005-1	3.94	2.41	1.10	0.53
	2005-2	1.41	2.44	0.38	0.69
	2005-3	2.62	2.13	0.68	0.51
	2006-1	4.88	3.06	0.95	0.69
	2006-2	2.25	3.93	0.45	0.87
	2006-3	1.21	2.29	0.28	0.54
	2007-1	5.02	3.30	1.32	0.74
	2007-2	3.05	2.67	0.44	0.78
	2007-3	1.75	1.64	0.64	0.53
33 Flood	2004-1	1.78	1.56	0.56	0.47
	2004-2	1.67	1.30	0.47	0.39
	2004-3	1.68	1.33	0.49	0.42
	2005-1	1.35	1.12	0.31	0.25
	2005-2	1.14	0.92	0.24	0.20
	2005-3	1.00	0.90	0.20	0.19
	2006-1	1.76	1.62	0.41	0.21
	2006-2	1.24	1.55	0.26	0.56
	2006-3	1.62	1.05	0.21	0.35
	2007-1	1.69	1.79	0.45	0.38
	2007-2	1.55	1.29	0.40	0.31
	2007-3	1.51	1.24	0.40	0.35

Notes:
2000 Sample: 1 = 0 - 6 inches, 2 = 6 - 18 inches and 3 = 18 - 36 inches
2001 through 2007 Sample: 1 = 0 - 1 ft, 2 = 1 - 2 ft and 3 = 2 - 3 ft

Generalized findings for selenium are as follows:

- Selenium concentrations in composite samples collected from the treated area have generally exceeded those in associated background samples. In addition, selenium

concentrations are similar at 1-2 ft and 2-3 ft in the treated areas. The most recent (2007) concentrations observed in the treated area are 0.44 (0-1 ft), 0.30 (1-2 ft), and 0.39 (2-3 ft) mg/kg; and in the mean background are 0.14 (0-1 ft), 0.15 (1-2 ft) and 0.12 (2-3 ft) mg/kg. The selenium concentrations in the top three feet of treated soil exceeded the mean background by factors of 3.14 (0-1 ft), 2.00 (1-2 ft) and 3.25 (2-3 ft). The 2007 selenium data from the treated and untreated areas both increased significantly resulting in questionable selenium results for 2007 (see Figure 19).

Generalized findings for other parameters are as follows:

The data in Table 6 show an overall increase in conductivity, SAR, calcium, magnesium and sodium concentrations in both treated and untreated soils in Section 33. The concentrations of sulfate and chloride have varied over time in the treated and background areas (e.g., concentrations of chloride in treated areas have generally increased, while in background areas, they have varied at generally low levels). The SAR for the treated areas has a discernable rising trend but there have been dramatic swings over the period of record.

Increasing amounts of salts and alkalinity (inferred from increases in calcium and magnesium) in the background areas cannot be explained using the current sampling program. The increase is not likely due to movement of contaminated groundwater from the irrigated fields because uranium concentrations in all intervals in the untreated area have been fairly similar over the period of years. The changes in salt and alkalinity levels in background samples may be due to a reduction in local precipitation.

3.2.2 Sections 33 and 34 Flood Areas

Composite soil samples were collected from three soil layers in the Section 34 flood irrigation area after the 2000 (15 samples from 3 depths at up to 9 locations), 2001 (30 samples from 3 depths at 10 locations), 2002 (36 samples from 3 depths at 12 locations), 2003 (33 samples from 3 depths at 11 locations); 2004, 2005, 2006 and 2007 (each with 36 samples from 3 depths at 12 locations) irrigation seasons. Two background samples were combined for each of the 2001 and 2002 background soil analyses for Section 34, one background sample was collected in 2003 and ten background samples were combined in 2004, 2005, 2006 and 2007 (see Figures 2 through 9 for sample locations). Uranium and selenium concentration data for Section 33 and 34 flood irrigation areas are presented in Figures 17 and 20, respectively. A comparison with background was not made for Section 33 Flood, because there are insufficient data to analyze.

Generalized findings for uranium concentrations in Section 34 relative to the 2007 mean background are as follows:

- 2000: Average concentrations in the treated areas are appreciably higher than those in the untreated areas when compared to those for subsequent years. However, this may reflect the difference in the sampling interval and calls this comparison into question.

- 2001: Concentrations in the treated area at 0-1 ft (2.72 mg/kg) are a factor of 1.39 greater than the 2007 mean background (1.96 mg/kg). The value of treated soil at 1-2 ft (1.88 mg/kg) exceeds the mean background (1.45 mg/kg) by a factor of 1.30.

- 2002: Concentrations decreased dramatically in the treated and untreated areas when compared to the 2001 values. Uranium concentrations observed in 2002 are not thought to be representative of this area.

- 2003: Concentrations in the treated area at 0-1 ft (3.72 mg/kg) exceeded the mean background (1.96 mg/kg) by a factor of 1.90. The 1-2 ft uranium level treated soil (1.90 mg/kg) exceeded the mean background by a factor of 1.45. The 2-3 ft interval treated uranium value was essentially the same as the mean background.

- 2004: Concentrations in the treated area at 0-1 ft (4.43 mg/kg) exceeded the 2007 mean background (1.96 mg/kg) by a factor of 2.26. The 1-2 ft of treated soil (2.27 mg/kg) exceeded the mean background (1.45 mg/kg) by a factor of 1.57, whereas the bottom interval was similar to mean background.

- 2005: Concentrations in the treated area at 0-1 ft (3.94 mg/kg) exceeded the untreated mean background (1.96 mg/kg) by a factor of 2.01, while the concentration of the second interval indicated no increase and the third interval indicated an anomalous increase.

- 2006: Concentrations in the treated area at 0-1 ft (4.88 mg/kg) exceed the untreated mean background (1.96 mg/kg) by a factor of 2.49. The concentration from 1-2 ft (2.25) is only 1.55 times the mean background of 1.45 mg/kg, indicating that less uranium has moved into the 1-2 ft interval than is retained in the upper interval. Essentially no increase was observed in the third interval, which is typical for the lower sampled interval.

- From 2001 to 2007, in Section 34 Flood, uranium concentrations increased in the 0-1 ft layer from 2.72 to 5.02 mg/kg, a factor of 1.84. The average uranium concentration in the first 3 feet of soil increased from 1.91 to 3.27 mg/kg, a factor of 1.71.

- Average uranium concentrations in deeper layers of treated soils were generally lower than those in the surface samples.

- 2002 uranium concentrations in both treated and background areas were consistently lower than those observed in 2001, 2003, 2004, 2005, 2006 and 2007. This anomaly is likely due to a systemic analytical bias and not representative of actual concentrations.

A comparison of the 2001, 2003, 2004, 2005, 2006 and 2007 results indicates that uranium is accumulating in the treated areas of Section 34, primarily in the upper and middle intervals. In

the Section 33 Flood, little accumulation of uranium has occurred due to the limited amount of irrigation on this area.

Generalized findings for selenium are as follows:

- 2001: The selenium concentration in the treated area at 0-1 ft (0.50 mg/kg) exceeded the mean background (0.34 mg/kg) by a factor of 1.47. The average of the first 3 feet of treated soil (0.40 mg/kg) exceeded the mean background (0.29 mg/kg) by a factor of 1.38.

- 2002: The selenium concentration at all depths in the treated and mean background area was reported as less than 0.60 mg/kg. As stated in Section 3.1.2, the MDL was too high to be useful in determining trends.

- 2003: The selenium concentration in the treated area at 0-1 ft (0.82 mg/kg) exceeded the mean background (0.34 mg/kg) by a factor of 2.41. The average of the first 3 feet of treated soil (0.47 mg/kg) exceeded the mean background (0.29 mg/kg) by a factor of 1.62.

- 2004: The selenium concentration in the treated area at 0-1 ft (1.15 mg/kg) exceeded the mean background (0.34 mg/kg) by a factor of 3.38. The average of the first 3 feet of treated soil (0.72 mg/kg) exceeded the mean background (0.29 mg/kg) by a factor of 2.48.

- 2005: The selenium concentration in the treated area at 0-1 ft (1.10 mg/kg) exceeded the mean background (0.34 mg/kg) by a factor of 3.24. The average of the first 3 feet of soil (0.72 mg/kg) exceeded the mean background (0.29 mg/kg) by a factor of 2.48.

- 2006: The selenium concentration in the treated area of Section 34 Flood at 0-1 ft (0.95 mg/kg) exceeds the mean background (0.34 mg/kg) by a factor of 2.79. The average of the first 3 feet of soil (0.56 mg/kg) exceeds the mean background (0.29 mg/kg) by a factor of 1.93.

- 2007: The selenium in the treated area of Section 34 Flood at 0-1 ft (1.32 mg/kg) exceeds the mean background (0.34 mg/kg) by a factor of 3.88 while at 1-2 ft (0.94 mg/kg) exceeds the mean background (0.26 mg/kg) by a factor of 3.62. The increased selenium in 2007 should be used with caution because the background selenium values also increased.

A comparison of the 2001, 2003, 2004, 2005, 2006 and 2007 results indicates that the selenium has accumulated in the treated areas of Section 34. The concentration of selenium peaked in the upper layer in 2004 and had gradually declined in 2005 followed by small increases in 2006 and 2007. The selenium concentration at 1-2 ft was 61% of those in the upper layer in 2007. The deepest interval (2-3) shows a small amount of selenium accumulation in the soil.

Generalized findings for other parameters are as follows:

- In the Section 33 Flood area, there have been decreases in sodium, SAR, conductivity, magnesium and chloride, whereas levels of sulfate have been increasing in the treated soils. Calcium levels have been variable. In untreated areas of Section 33, the concentrations of all constituents have declined except for sulfate, which is increasing in the lower two feet (1-2 and 2-3 ft). The treated area of Section 34 is exhibiting an increase in conductivity, SAR, and concentrations of calcium, magnesium, sodium, chloride, and sulfate. The concentrations and ratios also increased in untreated soils. The exception is conductivity, which has varied but has a generally decreasing trend.

3.2.3 Section 28 Center Pivot

Twelve locations were sampled in the treated area of Section 28 in 2002, 2003, 2004, 2005, 2006 and 2007 at the three, 1-ft depth intervals described above. Corresponding depths were sampled at each of the background locations in untreated areas of Section 28 (See Figure 10 for the five background locations that were composited for the three depths for 2002 and Figures 11 through 15 for the 2003 through 2007 locations). Graphical presentations of uranium and selenium concentrations are included in Figures 18 and 21 respectively.

Generalized findings for uranium from Table 7 are as follows:

- Uranium concentrations in composite samples collected from the treated and background areas in 2002 were, with one exception, at levels significantly above pre-operational and 2003 through 2007 treated levels. The 2002 data are likely elevated because of laboratory error and do not represent uranium concentrations in Section 28 soils. These data are not considered further.

- Uranium concentrations in the treated area slightly exceed those in the background area in 2003, 2004, 2005, 2006 and 2007. The most recent (2007) concentrations of uranium observed in the treated area were 1.14 (0-1 ft), 1.01 (1-2 ft) and 0.92 (2-3 ft); and 0.55 (0-1 ft), 0.53 (1-2 ft) and 0.51 mg/kg (2-3 ft) for the mean background. The treated intervals exceed the mean background by factors of 2.07 (0-1 ft), 1.91 (1-2 ft) and 1.80 (2-3 ft). All three interval concentrations of uranium in the treated area exceed background by an average factor of 1.93. Thus, uranium concentrations are essentially twice that of background and appear to have become fairly steady.

Generalized findings for selenium are as follows:

- Selenium concentrations in composite samples collected from the treated area and background area for the year 2002 were all below the relatively high MDA of 0.6 mg/kg and are not useful in trend analysis. In 2007, the selenium concentrations observed in the treated area were 0.47 (0-1 ft), 0.34 (1-2 ft) and 0.25 mg/kg (2-3 ft); mean background

concentrations were 0.13 (0-1 ft), 0.11 (1-2 ft), and 0.09 mg/kg (2-3 ft). When comparing the intervals, the three treated intervals exceeded mean background by 3.62 (0-1 ft), 3.09 (1-2 ft) and 2.78 (2-3 ft). In 2007, the average concentration of selenium in the treated area exceeded the mean background by a factor of 3.21, indicating that selenium was retained in the Section 28 soils in 2007. This is thought to be caused by a smaller amount of water moving beyond the 3 foot soil interval.

Generalized findings for other parameters are as follows:

Data for Section 28 in Table 6 show general decreases in conductivity, SAR and calcium, magnesium, sodium and sulfate concentrations in both treated and background soils from year 2003 to 2006 with some increase in 2007. The chloride and sulfate results in the untreated area are more variable.

3.2.4 Comparison of Applied and Measured Soil Concentrations

3.2.4.1 Uranium

It was assumed when planning the irrigation program that all the uranium would be deposited in the upper 1-ft of soil (ERG and HYDRO, 1999). It was estimated that water containing 0.44 mg/l of uranium applied at 3 ac-ft/year would conservatively supplement the concentration of uranium in the upper 1-ft of soil by 0.92 mg/kg per year. The actual average uranium concentrations in the applied water have always been lower than 0.44 mg/l. Actual application rates have been above and below 3 ft/yr.

The predictions of uranium accumulation in the soil have been superseded by actual measurements of uranium concentration in the irrigated areas. The measurements indicate that the applied uranium occurs throughout the upper three feet of the soil profile.

It is reasonable to adopt a mass balance approach to track the fate of the applied uranium. Actual applied uranium concentrations, application rates of irrigation water, and calculated increases in soil are presented in Tables 8 and 9.

The calculated data in Tables 8 and 9 are determined as follows:

a = cumulative masses of uranium applied per irrigation area, mg = $\Sigma_{2000\text{-}2007}$[(average concentration in water, mg/l) (volume of water in ac-ft) (28.3 l/ft^3) (43,560 ft^2/ac)]

b = mass of soil per irrigation area, kg = (3 ft)(no. of acres)(90 lbs/ft^3) (454 g/lb)(43,560 ft^2/ac) (10^{-3}kg/g)

c = measured concentration of uranium, mg/kg = (sum of measured concentrations of uranium or selenium in three 1-ft layers minus background concentrations)

d = measured mass of uranium, mg = (b)(c)/3

e = ratio of measured to applied masses of uranium, unitless = d/a

The assumptions are consistent with those reported previously (ERG and HYDRO, 1999). For example, soil density is assumed at 90 pounds per cubic foot (lb/ft^3).

The above-background concentrations of uranium in each section, in mg/kg, are: Section 33 Center Pivot (2.13); Section 33 Flood (0.19); Section 34 (5.26); and Section 28 (1.48). Based on this series of calculations, the ratios of measured to applied masses of uranium in the three feet of soil are: Sections 33 Pivot (0.71), 33 Flood (0.49), 34 (1.38), and 28 (0.76).

In Sections 33 Pivot and Section 28, 29 percent and 24 percent of the applied uranium is unaccounted for, respectively. The loss of uranium in the soil profile in these fields may be due to the sandy loam soils which have less adsorptive capacity than clay soils. On the other hand, all of the uranium applied to Section 34 is indicated to be retained in the upper three feet and this is attributed to the presence of clay soils. The measured amount of uranium being 38 percent larger than the applied amount questions the accuracy of the uranium values. The measured concentrations in Section 33 Flood are too close to background to consider the value of 49 percent to be reliable.

Accumulating uranium concentrations for each layer in each irrigation area are shown in Figures 16 (Section 33 Center Pivot), 17 (Sections 33 and 34 Flood), and 18 (Section 28 Center Pivot). Each figure is subdivided into upper, middle, and lower intervals. The horizontal line on each figure represents the mean background concentration.

Table 8. Uranium Applied in Irrigation Water

	Uranium Concentration (mg/l)		Acreages				Volume of Irrigation Water Applied (ft)			
Year	Section 28	Sections 33/34	Section 28	Section 33 Flood	Section 33 Pivot	Section 34	Section 28 Pivot	Section 33 Flood	Section 33 Pivot	Section 34 Flood
2000	NA	0.27	NA	NA	150	120	NA	NA	2.29	3.1
2001	NA	0.26	NA	NA	150	120	NA	NA	2.11	2.85
2002	0.23	0.23	60	NA	150	120	2.2	NA	2.36	3.3
2003	0.24	0.22	60	NA	150	120	2.57	NA	2.62	3.34
2004	0.27	0.26	60	24	150	120	3.04	1.26	2.85	3.23
2005	0.35	0.27	100	24	150	120	2.38	0.84	2.67	3.13
2006	0.35	0.29	100	NA	150	120	2.33	NA	1.94	2.61
2007	0.36	0.28	100	NA	150	120	2.42	NA	2.86	0.98

Notes:
NA = not irrigated

Table 9. Comparison of Measured Versus Applied Uranium

	Section			
	28 Pivot	33 Flood	33 Pivot	34 Flood
Applied Mass of Uranium (mg), a	346976649	16402452	797082529	815625525
Sum of 3-ft Measured Concentrations Minus Background (mg/kg), c	3.07-1.59= 1.48	4.75-4.56= 0.19	4.31-2.18= 2.13	9.82-4.56= 5.26
Mass of Soil (kg), b	533958480	128150035	800937720	640750176
Measured Mass of Uranium (mg), d	263419517	8116169	568665781	1123448642
Ratio of Measured to Applied Masses, e	0.76	0.49	0.71	1.38

3.2.4.2 Selenium

The applied and measured selenium concentrations in the upper 3-ft layer of soil were calculated in a similar manner and are presented in Tables 10 and 11.

The above-background concentrations of selenium in each section for the three layers, in mg/kg, are: Section 33 Center Pivot (0.72); Section 33 Flood (0.38); Section 34 (5.26); and Section 28 (1.48).Based on the same series of calculations shown above in Section 3.2.4.1, the ratios of measured to applied masses of selenium in the three feet of soil are: Sections 33 Pivot (0.63), 33 Flood (3.35), 34 (1.48), and 28 (1.14). The selenium results should be considered questionable with three of the ratios being above one for 2007.

Table 10. Selenium Applied in Irrigation Water

	Selenium Concentration (mg/l)a		Acreages				Volume of Irrigation Water Applied (ft)			
Year	Section 28	Sections 33/34	Section 28	Section 33 Flood	Section 33 Pivot	Section 34	Section 28 Pivot	Section 33 Flood	Section 33 Pivot	Section 34 Flood
2000	NA	0.12	NA	NA	150	120	NA	NA	2.29	3.1
2001	NA	0.1	NA	NA	150	120	NA	NA	2.11	2.85
2002	0.08	0.1	60	NA	150	120	2.2	NA	2.36	3.3
2003	0.08	0.08	60	NA	150	120	2.57	NA	2.62	3.34
2004	0.07	0.09	60	24	150	120	3.04	1.26	2.85	3.23
2005	0.08	0.06	100	24	150	120	2.38	0.84	2.67	3.13
2006	0.08	0.07	100	NA	150	120	2.33	NA	1.94	2.61
2007	0.08	0.06	100	NA	150	120	2.42	NA	2.86	0.98

Notes:
a. 2003 concentration of selenium is assumed. The value was reported as <0.005 mg/l, which is assumed to be a laboratory artifact.
NA = not irrigated

Table 11. Comparison of Measured Versus Applied Selenium

	Section			
	28 Pivot	33 Flood	33 Pivot	34 Flood
Applied Mass of Selenium (mg), a	114280671	4846179	306122147	292042932
Sum of 3-ft Measured Concentrations Minus Background (mg/kg), c	1.06-0.33= 0.73	1.25-0.87= 0.38	1.13-0.41= 0.72	2.90-0.87= 2.03
Mass of Soil (kg), b	533958480	128150035	800937720	640750176
Measured Mass of Selenium (mg), d	129929897	16232338	192225053	433574286
Ratio of Measured to Applied Masses, e	1.14	3.35	0.63	1.48

In Section 33 Pivot, 37 percent of the applied selenium is unaccounted for, respectively. The 2007 selenium results should be used with caution because their quantities are larger than the total amount of selenium applied.

Actual selenium measurements are also shown in Figures 19 (Section 33 Center Pivot), 20 (Sections 33 and 34 Flood), and 21 (Section 28 Center Pivot). As in Figures 16 through 18, each figure is subdivided into upper, middle, and lower intervals. The horizontal line on each figure represents the mean background concentration.

There are indications that selenium, when retained, is parted to the dissolved phase, rather than absorbed in soils. A review of Figures 19 through 21 indicates that the retention of selenium appears to be independent of time, implying that absorption to soil is not retarding the movement of selenium through the soil. In addition, selenium and chloride --the latter a conservative constituent in terms of fate and transport—had been retained at similar levels in varying soil types. Only 5, 17 and 52 percent of the chloride concentration applied was measured in the soil in 2007 for Sections 28, 33 and 34 areas respectively. These are similar percentages that were observed for selenium in 2006 and likely reasonable estimates of the true 2007 selenium percentages.

3.2.5 Summary of Soil Concentration Comparison

The data collected to date indicate that soil attenuation of uranium is of the same order of magnitude as that predicted by the pre-operational model.

The soil properties and method of irrigation differed for the Section 33 and 28 sites and the Section 33 flood and Section 34 flood areas. The irrigation water for the Section 33 and 28 sites was applied using center pivot systems while Section 34 was flood irrigated. An additional 24 acres of flood irrigation area was added in eastern Section 33 at the beginning of the 2004 season. The small incremental changes in concentrations in uranium and selenium along with the natural variability in both the center pivot and flood irrigation areas make it difficult to accurately determine the amount of increase in concentrations in the soil from year to year. The 2001 and 2002 data indicate that the soil concentrations were not continuing to increase with

time for either type of irrigation among the three irrigation sites. The 2003 and 2004 data show some increase in Sections 33 and 34 while concentrations slightly increased in 2004 in Section 28. A slight decrease was observed at all three sites in 2005. In 2006, an increase was observed in all sites except Section 28, where selenium decreased slightly in the two lower intervals. Concentrations generally increased or were fairly steady in 2007. Future sampling may further diminish the effects of analytical and natural variability and more clearly reveal trends in the accumulation of uranium and selenium.

The 2007 results indicate that uranium is being retained in all three intervals in Sections 28 and 33 whereas uranium is only being retained in the upper two intervals in Section 34. The 2007 results also indicate selenium is being retained but these results need to be confirmed with future measurements.

The uranium concentrations for the 2007 treated soil samples within the irrigation areas ranged from 0.92 to 5.02 mg/kg. The laboratory reported uranium MDL and PQL for the year 2003 and 2004 data were 0.03 and 0.1 mg/kg, respectively and 0.05 and 0.3 mg/kg for 2005, 2006 and 2007. The selenium concentrations in the irrigated areas for 2007 ranged from 0.25 to 1.32 mg/kg. The laboratory reported selenium MDL and PQL for the soil analysis was 0.05 and 0.3 mg/kg.

The mass balance approach to tracking uranium and selenium in soil indicates that irrigation can continue without concern for excessive accumulation of these constituents.

4.0 Hay Concentrations and Constituent Uptakes

Constituents in soil are known to be taken up by plants. The extent of plant uptake is dependent on many parameters, including the constituent and the plant species. The measured concentrations of uranium and selenium in each cutting of hay were measured and compared to the soil concentration measured at the end of the growing season. The ratio of the concentration in plants to that in the soil is defined as the transfer coefficient from soil to plant. The transfer coefficients have been calculated and compared to NRC values that are based on published studies. All hay data and transfer coefficients are based on concentrations calculated from dry weights of both soil and vegetation.

4.1 Measured Hay Concentrations

The vegetation samples were collected after the hay was cut and prior to the baling of hay. The samples are collected from a distribution similar to the soil sample site distribution. The hay samples were analyzed by an offsite vendor laboratory.

4.1.1 Section 33 Center Pivot

During the first and second cuttings in Section 33 in 2001, eight samples were taken from various portions of the field. Sixteen samples were collected from the third cutting. Eight samples were taken from each cutting in 2002. Twelve samples were taken from each cutting in 2003 through 2007. The individual results are reported in Appendix B where the concentrations are reported on a dry-weight basis. The uranium and selenium concentrations were generally slightly higher in the first cutting each year but were opposite this trend in 2007. The highest uranium concentration occurred in the first cutting of 2004. Selenium concentrations were generally lower for the second and third cuttings but were essentially the same in 2005. The highest selenium and uranium concentrations occurred in the third cutting of 2007. Table 12 presents the summary of the uranium and selenium concentrations in the Section 33 cuttings.

4.1.2 Sections 33 and 34 Flood Areas

In Section 34, ten samples were collected from the first two cuttings in 2001 and eight samples were collected from the third cutting. Six samples were collected from each of four cuttings in 2002. Twelve, seven, and 12 samples were collected from the first, second and third cuttings, respectively, in 2003. Twelve and six samples were analyzed for the first and second cuttings in 2004 and 2005, while 10 and six samples were collected for the first and second cuttings in 2006. Six samples were collected from the first cutting in 2007. Table 12 presents the average concentrations of uranium and selenium for Section 34. Higher uranium concentrations were observed in the second cutting in 2002 and third cuttings in 2001 and 2003. The highest selenium concentrations for each cutting were similar, and occurred in the first cuttings of 2001, 2003, 2004 and 2005; the second cutting of 2006, and in the fourth cutting in 2002. The hay was not cut on the Section 33 flood area in 2004, 2006 and 2007. Table 12 presents the summary of the uranium and selenium concentrations in the Section 34 cuttings.

4.1.3 Section 28 Center Pivot

Six samples were collected in 2002 from the first hay cutting in the Section 28 irrigation area. Only one cutting was obtained from Section 28 because a crop of millet was used to establish cover over the site prior to an alfalfa seeding. Twelve samples were collected from each of the three cuttings in 2003 through 2007. The average uranium concentrations have varied from 0.29 to 1.83 mg/kg. Selenium concentrations varied from 0.79 to 1.62 mg/kg. In general, uranium concentrations in the 2007 hay from Section 28 were similar to those observed in 2006. Table 12 presents the summary of the uranium and selenium concentrations in the Section 28 cuttings.

Table 12. Summary of Hay Analyses

	Irrigation Areas									
	Section 33			Section 34				Section 28		
Year	1st Cut	2nd Cut	3rd Cut	1st Cut	2nd Cut	3rd Cut	4th Cut	1st Cut	2nd Cut	3rd Cut
	Average Uranium Concentrations (mg/kg)									
2000	1.12	0.62	—	0.73	—	—	—	—	—	—
2001	0.58	0.57	0.30	0.55	0.38	0.71	—	—	—	—
2002	1.32	0.37	0.77	0.92	1.52	0.54	0.88	0.29	—	—
2003	0.73	0.70	0.73	0.89	0.56	1.15	—	0.99	0.98	1.14
2004	1.62	0.51	0.90	1.02	0.88	—	—	1.09	1.17	0.86
2005	0.84	0.64	0.71	1.82	0.88	—	—	1.83	0.94	1.43
2006	0.80	0.62	0.45	0.79	0.78	—	—	1.21	0.77	0.62
2007	1.04	1.18	1.60	1.02	—	—	—	0.90	1.59	1.17
	Average Selenium Concentrations (mg/kg)									
2000	1.10	1.40	—	0.50	—	—	—	—	—	—
2001	1.41	1.05	0.87	1.05	0.82	0.78	—	—	—	—
2002	1.80	1.17	1.81	0.83	1.14	1.06	1.17	0.79	—	—
2003	1.70	1.46	1.54	1.62	0.80	1.11	—	1.62	1.28	1.00
2004	1.24	0.69	1.24	1.19	0.25	—	—	1.03	1.07	1.02
2005	1.25	1.29	1.27	1.90	0.80	—	—	1.50	1.24	1.48
2006	1.25	1.29	1.00	0.75	1.40	—	—	1.17	1.27	0.95
2007	1.30	1.40	1.50	1.43	—	—	—	0.90	1.20	1.33

Notes:
No cuttings were obtained from the Section 33 Flood in 2004. This was a new field, with no hay production.

4.1.4 Background Concentrations in Hay and Special Study

In 2000, a composite sample was prepared from 10 samples collected from the second cutting in Section 33 (see Appendix B for data). The sample was split and one of the samples was washed with tap water prior to analysis. The results were 0.62 mg/kg and 0.58 mg/kg for uranium and 1.4 mg/kg and 1.5 mg/kg for selenium. These results indicate that uranium and selenium in the sample did not arise from material deposited on the exterior plant surfaces.

Two samples of baled hay collected from hay fields a few miles to the northwest of the Homestake Mining Company irrigation areas were taken in the year 2000 for comparison to that grown in this study. While it is not known what the constituent soil concentrations were, it is known that water from the shallow alluvial aquifer near the Grants Project was not used as a source for irrigation. The uranium concentrations were reported as 0.19 and 0.05 mg/kg; the selenium concentrations were 0.2 and 0.1 mg/kg. These data indicate lower levels of uranium and selenium in what is assumed to be background hay.

4.1.5 Summary of Hay Concentrations

Table 12 presents the summary of the hay concentrations for the 2000 through 2007 cuttings. No trends for uranium or selenium exist from the years 2003 to 2007. The data indicate a slight decrease in uranium concentration from the first cutting to the third cutting. No trend is evident for selenium. The average uranium concentrations for the 2007 hay cuttings ranged from 0.90 to 1.60 mg/kg. The laboratory reported an MDL and PQL for the year 2007 data of 0.03 and 0.1 mg/kg, respectively.

The average selenium concentrations in hay for 2007 ranged from 0.90 to 1.50 mg/kg. The laboratory reported MDL and PQL for the hay selenium analysis were 0.2 and 0.3 mg/kg. Prior years' results show a similar range of values for the upper limit. Recent studies have shown that selenium in cattle diets has a very important role in maintaining cattle health and nutrition. A minimum requirement for selenium in cattle feed appears to be about 0.1 mg/kg and in many regions of the country, selenium is added to feed. The National Research Council (NRC, 2000) has established 2 mg/kg as the Maximum Tolerable Concentration (MTC) for cattle feed. They note that toxicity is possible at levels as low as 5 mg/kg. Since the measured levels are below the MTC, further analysis of selenium in this report is considered unnecessary.

4.2 Measured Uranium Uptake in Alfalfa

The uptake of constituents from soil to plants is generally considered to be directly proportional to the concentration in soil. The ratio of the concentration in the plant to that in the soil is called the transfer coefficient. The transfer coefficient from NUREG/CR-5512 for uranium in vegetation is 1.7E-2 pCi/kg-plant/pCi/kg-soil. Since the quantity of uranium is proportional to the activity in units of picoCuries (pCi), the transfer coefficient can also be expressed as 0.017 mg/kg-plant/mg/kg-soil. An estimate of the plant uptake from the application of irrigation water is presented in ERG and HYDRO (1999). The average soil concentration for each field is tabulated in Table 13 and used to predict the hay uranium concentration.

Table 13. Average Uranium Concentrations in Soil and Hay

	Avg. Uranium Soil Concentration (mg/kg)			Avg. Uranium Hay Concentration (mg/kg)		
Year	Section 33	Section 34	Secton 28	Section 33	Section 34	Section 28
2000	0.92	2.4	----	0.87	0.73	----
2001	0.69	1.92	----	0.48	0.55	----
2002	0.85	0.52	1.64	0.82	0.97	0.29
2003	1.17	2.23	0.69	0.72	0.87	1.04
2004	1.48	2.7	0.8	1.01	0.95	1.04
2005	1.2	2.66	0.67	0.73	1.35	1.4
2006	1.51	2.78	1.1	0.62	0.79	0.87
2007	1.44	3.27	1.02	1.27	1.02	1.22
				Average:	0.89	

To measure an uptake factor in plants, the average soil concentration of all three layers was used since alfalfa roots extend to a depth of three feet or more. Table 13 presents the data for the average uranium in soil and hay by section and year. The transfer coefficient from soil to hay is calculated and shown in Table 14 for each year.

The calculated uranium transfer coefficients have a mean of 0.78 and standard deviation of 0.53. This is significantly higher than the published transfer coefficient of 0.017. The fact that the uranium uptake is higher than that predicted by the NRC published transfer coefficient might be explained by the fact that the uranium concentration in the soil moisture (and available to the plants) may be significantly higher in fields irrigated with contaminated water than for soil moisture within contaminated soil that is derived from clean groundwater or rain to support plant growth.

Table 14. Transfer Coefficient from Soil to Hay

Transfer Coefficients (mg/kg hay/mg/kg soil)			
Year	Section 33	Section 34	Section 28
2000	0.95	0.30	----
2001	0.70	0.29	----
2002	0.96	1.87	0.18
2003	0.62	0.39	1.51
2004	0.68	0.35	1.30
2005	0.61	0.51	2.09
2006	0.41	0.28	0.79
2007	0.88	0.32	1.20
	Mean	0.78	
	SDV	0.53	

Six hundred twenty-two pounds of uranium were applied in 2002, based on the average uranium concentration of 0.23 mg/l and 995 ac-ft of water. Slightly less was applied in 2003 and slightly more in 2004, 2005 and 2006. This is a very small amount considering that it was applied over 330 acres. The amount of uranium removed by uptake into the hay can be estimated based on the typical observed uranium concentration of 1 mg/kg in the hay. The amount of uranium contained in the 480 tons of hay produced in 2002 is about one pound. This shows that much less than 1% of the uranium that was supplied to the field in 2002 (622 pounds) was removed by the hay.

The amount of uranium and selenium being removed by the hay is insignificant. In 2002, for example, the amount of selenium contained in the 480 tons of hay produced is estimated at one pound. In 2002, less than one-half of one percent of the selenium applied to the field (243 pounds) is being removed by the hay. Similar calculated results for both uranium and selenium can be obtained for the other years.

5.0 Radiation Dose from Eating Beef

The dose to humans from eating beef initially requires a calculation of the uptake to beef from the vegetation followed by the transfer from beef to human. For dose calculation purposes here, we have used the average uranium in hay measurements from the 2000 through 2007 (Table 13 average concentration 0.89 mg/kg = 603 pCi/kg). The measured natural concentrations of uranium and selenium in hay grown in the region were presented in Section 4.1.4. The analysis that follows does not subtract the natural background concentrations in hay grown on untreated soils from the measured values in this study.

5.1 Vegetation to Livestock Uptake

The uranium concentration in meat (C_{bi}), as a result of cattle eating hay produced from the Grants site irrigation fields can be estimated by multiplying the rate of intake of vegetation by the transfer coefficient, then multiplying by the fraction of food supply and the concentration in the hay.

$$C_{bi} = QF_{bi}(F_{pg}C_{pgi} + F_hC_{hi})$$

Where the values of the parameters are discussed below:

Q	=	is the assumed feed ingestion rate, 27 kg(wet weight)/d, NUREG/CR-5512
F_{bi}	=	Transfer coefficient from vegetation to livestock, 2.0E-4, NUREG/CR-5512
F_{pg}	=	is the fraction of the total annual feed requirement (including pasture and other feed sources) from hay grown in irrigation area = 0.5
C_{pgi}	=	measured concentration in vegetation (pCi/kg) = 603 pCi/kg
F_h	=	is the fraction of the total annual feed requirement not from irrigated hay, = 0.5. Assumed 50% not grown on irrigated area.
C_{hi}	=	is the uranium concentration in the other fraction of feed not grown on the irrigated area = 0

C_{bi} = 27 kg/day (2.0E-4) {(0.5) (603) + (0.5) (0.0)} = 1.6 pCi/kg meat

5.2 Beef to Human Uptake

Total activity in the human body from eating only meat produced from the irrigated fields for a year can be calculated as follows:

$$I_i = U_{bk}C_{bi}$$

Where:

I_i = annual intake rate (pCi/y)

U_{bk} = ingestion rate of beef for an adult = (0.16 kg/d)(365d/y)

C_{bi} = concentration in meat (pCi/kg)

$$I_i = (1.6 \text{ pCi/kg meat})\ (0.16 \text{ kg/d})\ (365 \text{ day/y})$$

$$I_i = 93 \text{ pCi/y}$$

This annual intake of uranium from eating beef that feeds on the irrigated hay is very small. The ingestion dose is calculated from the following equation:

$$I_{(ing)} = I_i DCF_{(ing)}$$

Where:

$I_{(ing)}$ = ingestion dose mrem/y

$DCF_{(ing)}$ = ingestion dose conversion factor
5 rem/10 μCi, from 10 CFR 20 Appendix B

$$I_{(ing)} = (93 \text{ pCi/y})\ (1E\text{-}6\ \mu\text{Ci/pCi})\ (5 \text{ rem}/10\ \mu\text{Ci})\ (1E3 \text{ mrem/rem})$$
$$= 0.05 \text{ mrem/y}$$

While this scenario may be considered overly conservative, the projected radiation dose to humans is considered insignificant.

6.0 Conclusion

Uranium is being retained in the upper layers of treated soil. Uranium levels are currently acceptable. The dose to man by way of food web uptake calculations is negligible, at 0.05 mrem/yr.

The average increase of uranium in soil appears to be similar to that predicted although distributed to greater depths. The increase in concentrations in the hay was approximately 50 times higher than that predicted using the NRC's soil to vegetation transfer coefficient. The NRC transfer coefficient may not take into account constituent uptake via water application in addition to soil/vegetation transfer mechanisms. This much larger observed transfer coefficient

from water and soil contributions combined still results in negligible radiation doses to the public. Therefore, the use of alluvial water for irrigation of hay fields with slightly elevated concentrations of uranium is not a significant health concern.

The selenium uptakes in the hay are below the recommended upper limit for animal feed. Selenium retention in soils appears to be independent of time and application. The concentrations are not time-dependent, implying that absorption to soil is not retarding the movement of selenium through the soil. In addition, selenium and chloride --the latter a conservative constituent in terms of fate and transport-- are being retained at similar levels in varying soil types.

The monitoring of concentrations of uranium and selenium will continue as part of the ongoing irrigation program.

7.0 References

RIMCON and Hydro-Engineering, 1998. Soil Characterization and Attenuation Studies. Prepared for Homestake Mining Company, Grants, New Mexico.

Environmental Restoration Group and Hydro-Engineering, February 1999, Evaluation of the Use of Alluvial Ground Water for Irrigation, Consulting Report for Homestake Mining Company, Grants, New Mexico.

Environmental Restoration Group and Hydro-Engineering, 2001, Evaluation of the Year 2000 Irrigation with Alluvial Ground Water, Consultants Report for Homestake Mining Company, Grants, New Mexico.

Environmental Restoration Group and Hydro-Engineering, 2004, Evaluation of the Year 2000 Through 2003 Irrigation with Alluvial Ground Water, Consultants Report for Homestake Mining Company, Grants, New Mexico.

Environmental Restoration Group and Hydro-Engineering, 2005, Evaluation of the Year 2000 Through 2004 Irrigation with Alluvial Ground Water, Consultants Report for Homestake Mining Company, Grants, New Mexico.

Environmental Restoration Group and Hydro-Engineering, 2006, Evaluation of the Year 2000 Through 2005 Irrigation with Alluvial Ground Water, Consultants Report for Homestake Mining Company, Grants, New Mexico.

Environmental Restoration Group and Hydro-Engineering, 2007, Evaluation of the Year 2000 Through 2006 Irrigation with Alluvial Ground Water, Consultants Report for Homestake Mining Company, Grants, New Mexico.

NRC, 1992, NUREG/CR 5512: Residual Radioactive Contamination from Decommissioning, Final Report, U.S. Nuclear Regulatory commission, Washington, D.C.

NRC, 2000. National Research Council, 2000, "Nutrient Requirements for Beef Cattle." National Academy Press, Washington, D.C.

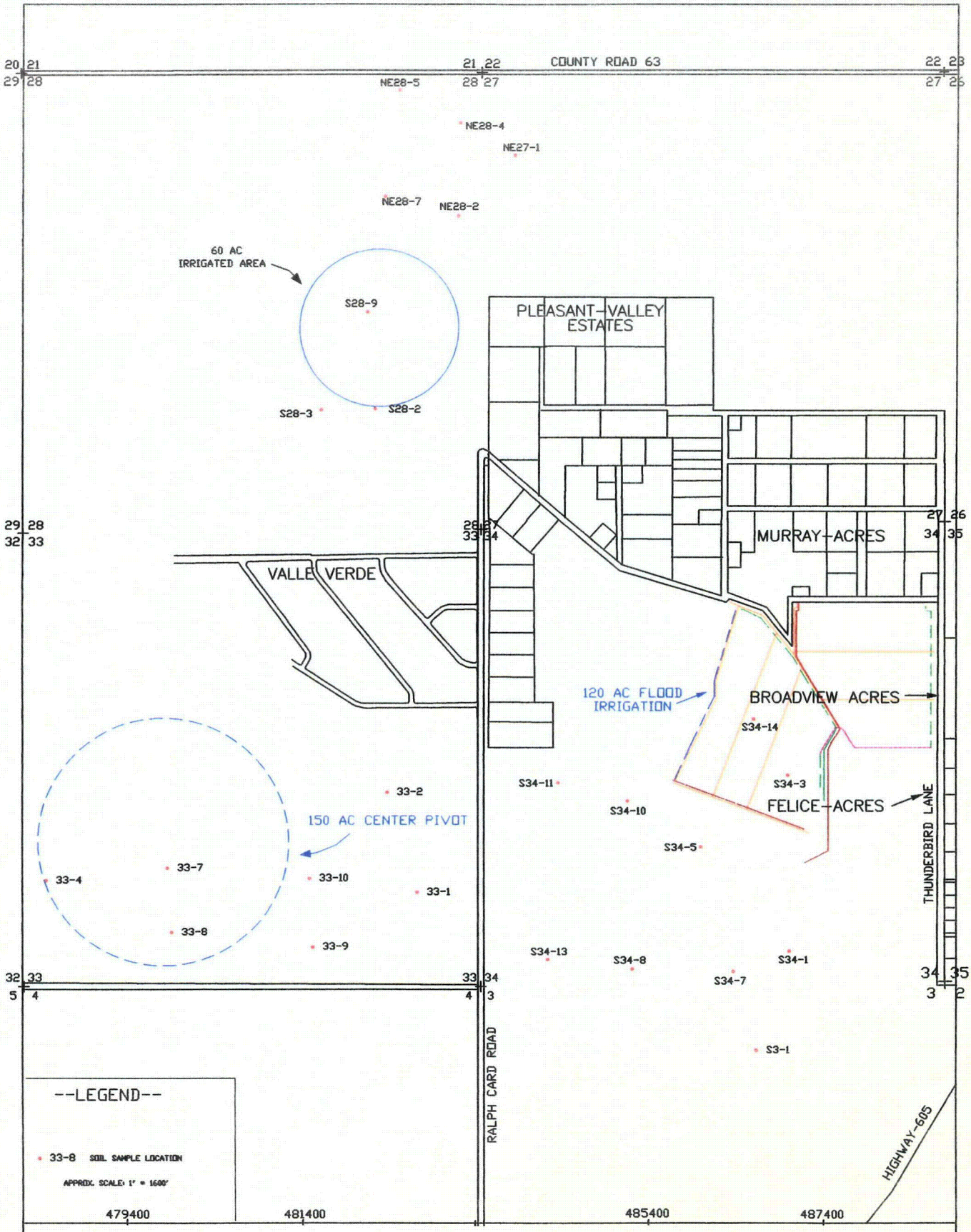

FIGURE 1. LOCATION OF IRRIGATION AREAS WITH SOIL SAMPLE LOCATIONS FROM THE 1998 INVESTIGATION

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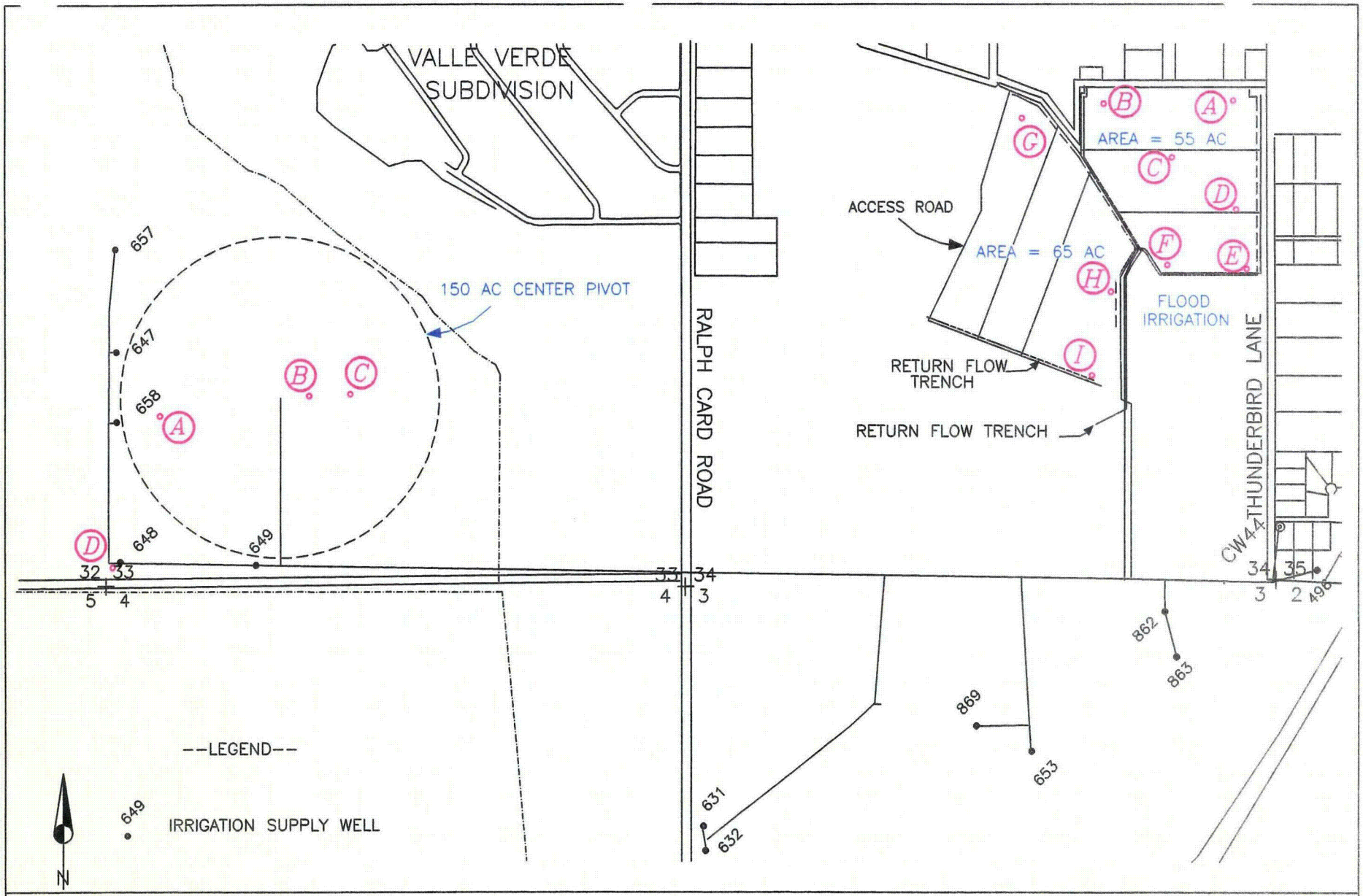

FIGURE 2. 1999 AND 2000 IRRIGATION AREAS WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

SCALE: 1" = 1200'

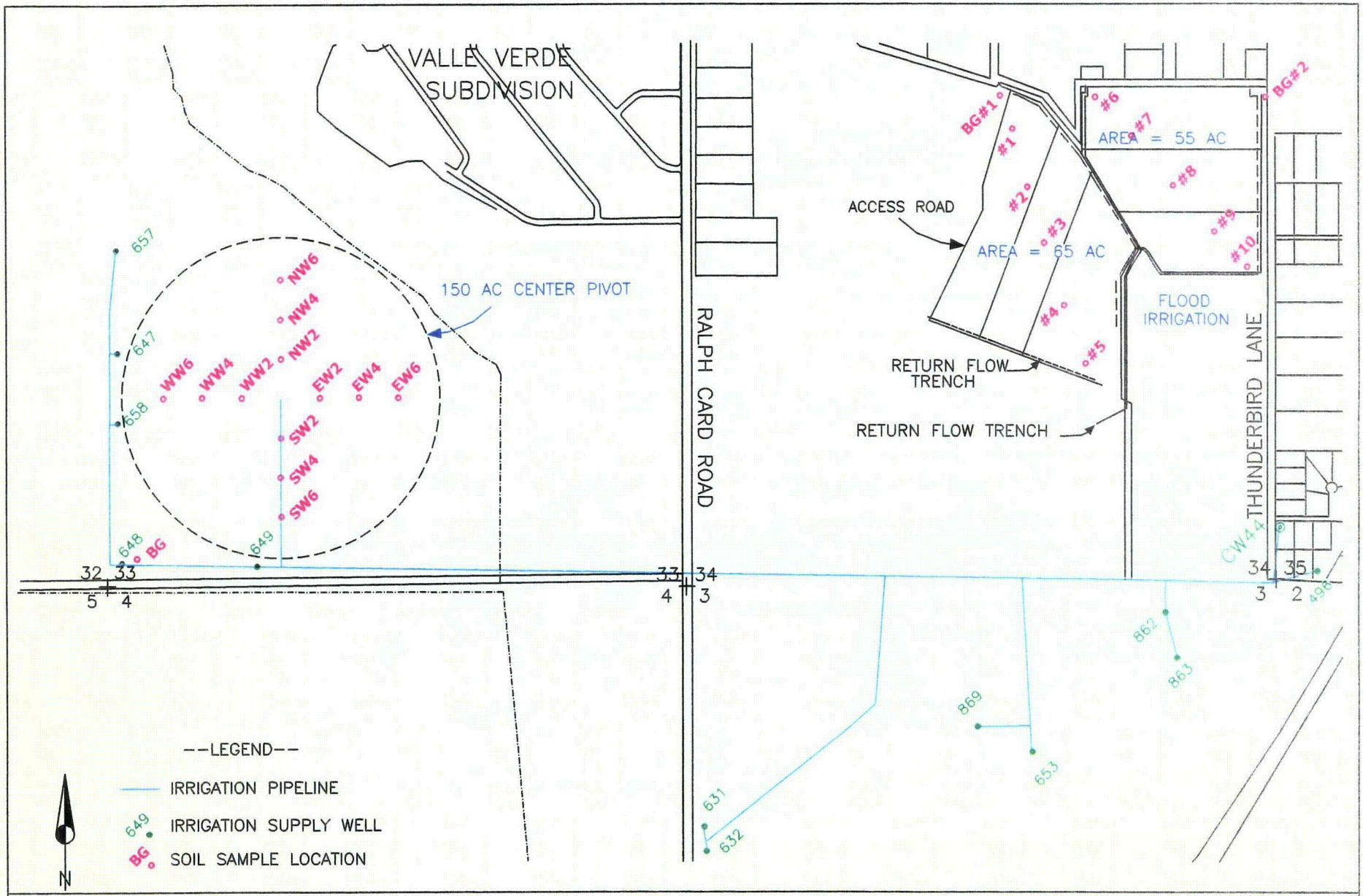

FIGURE 3. 2001 IRRIGATION AREAS WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

SCALE: 1" = 2400'

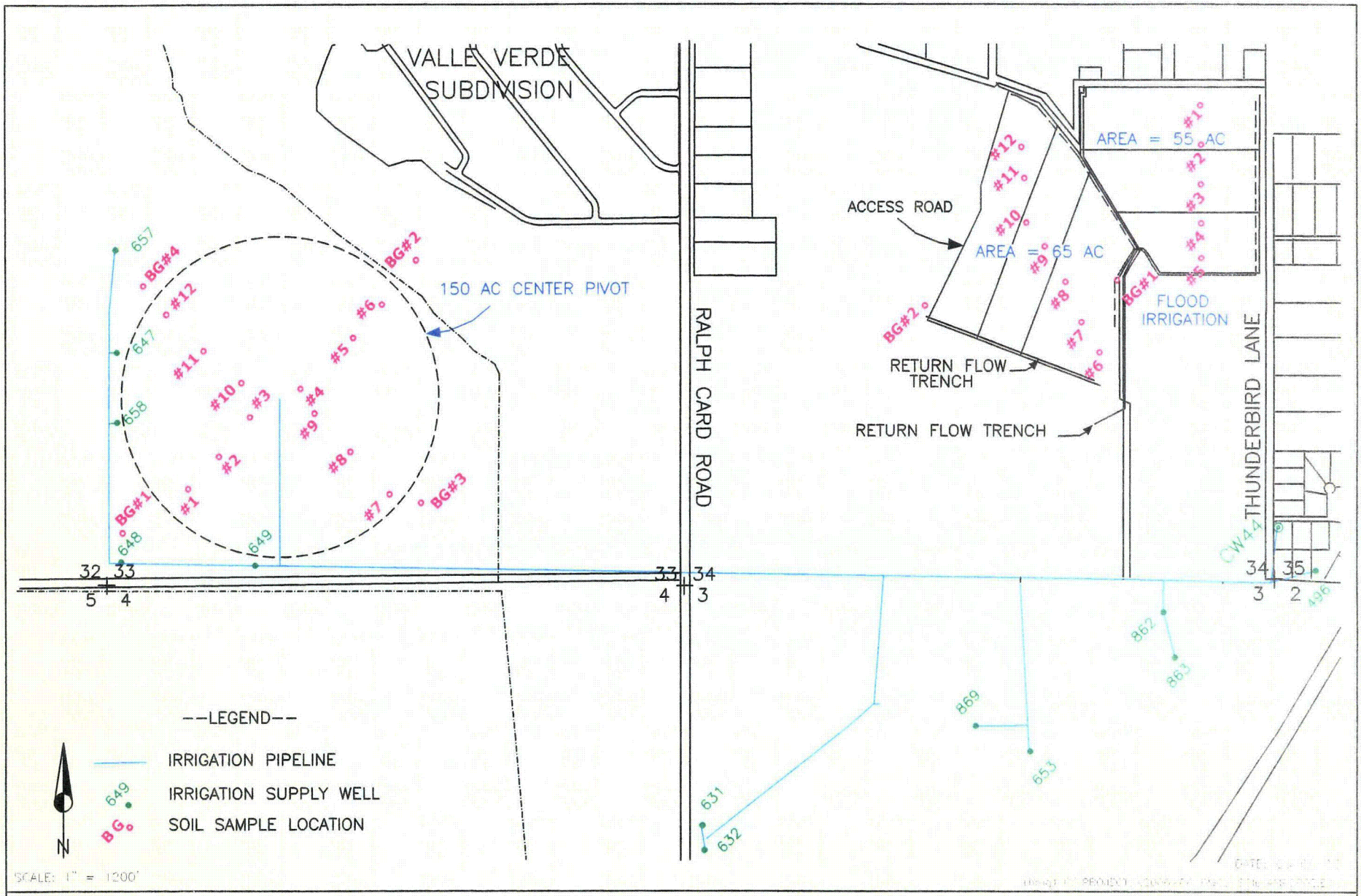

FIGURE 4. 2002 SECTIONS 33 AND 34 IRRIGATION AREAS WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

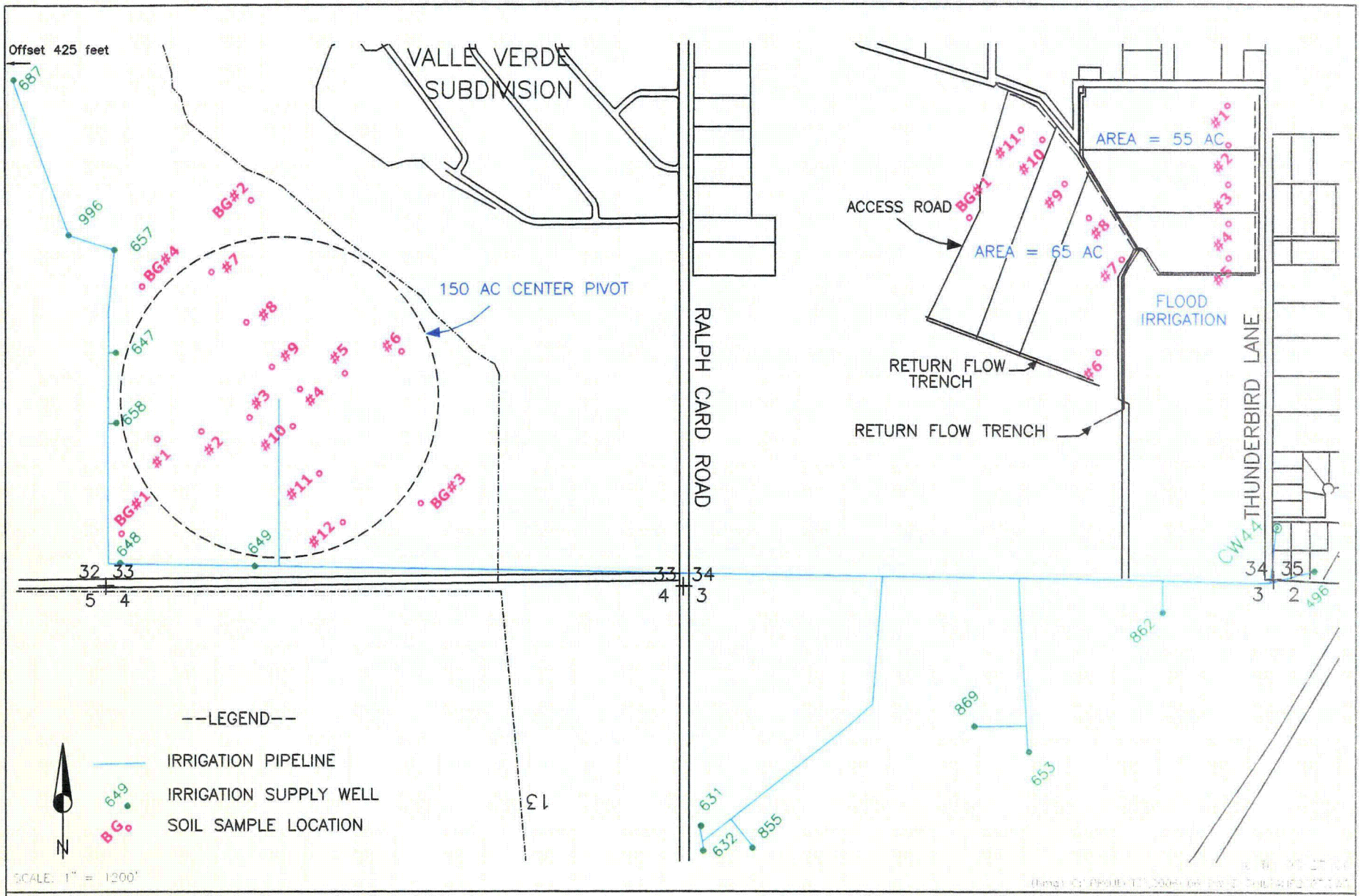

FIGURE 5. 2003 SECTIONS 33 AND 34 IRRIGATION AREAS WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

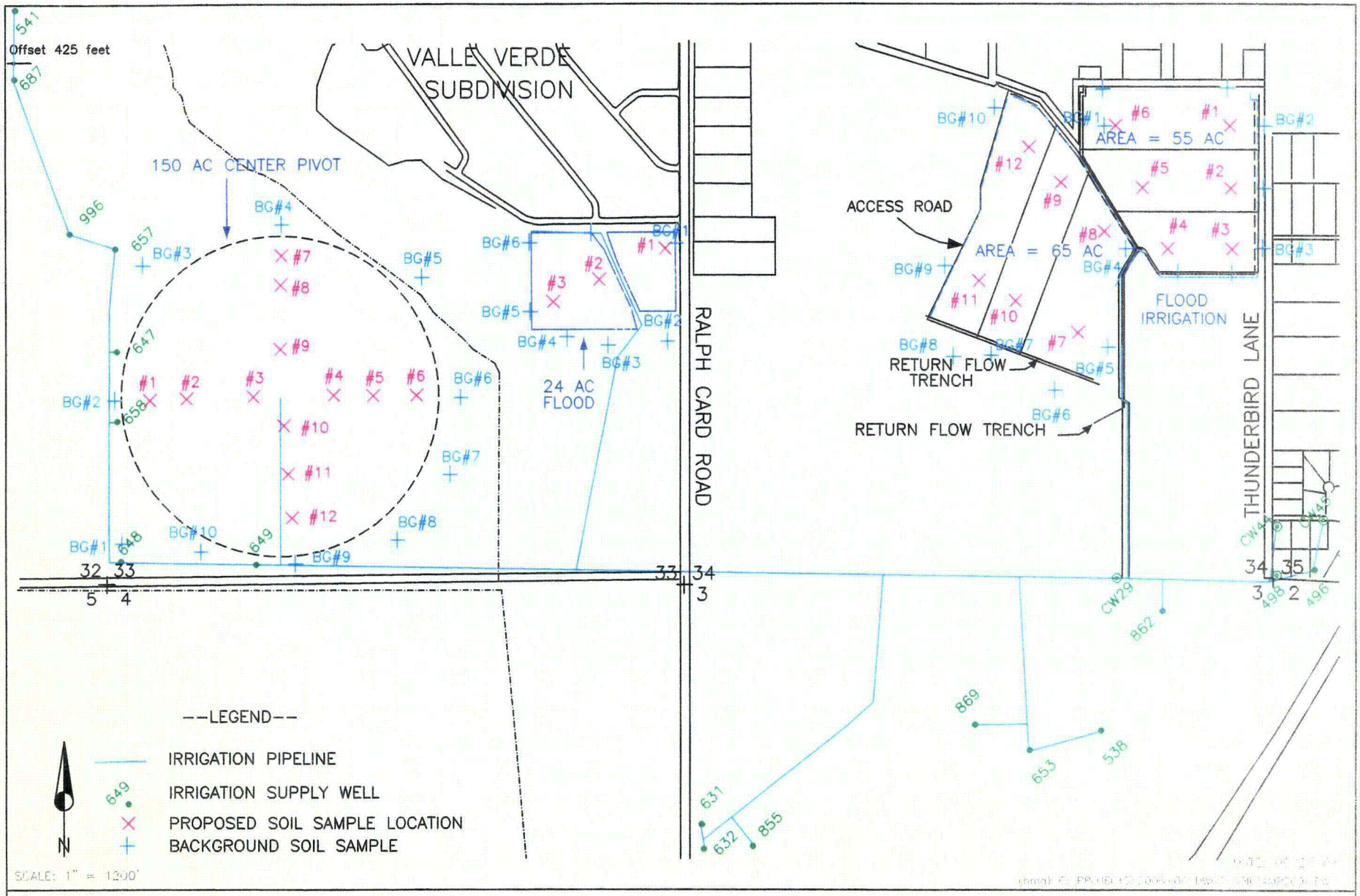

FIGURE 6. 2004 SECTIONS 33 AND 34 IRRIGATION AREAS WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

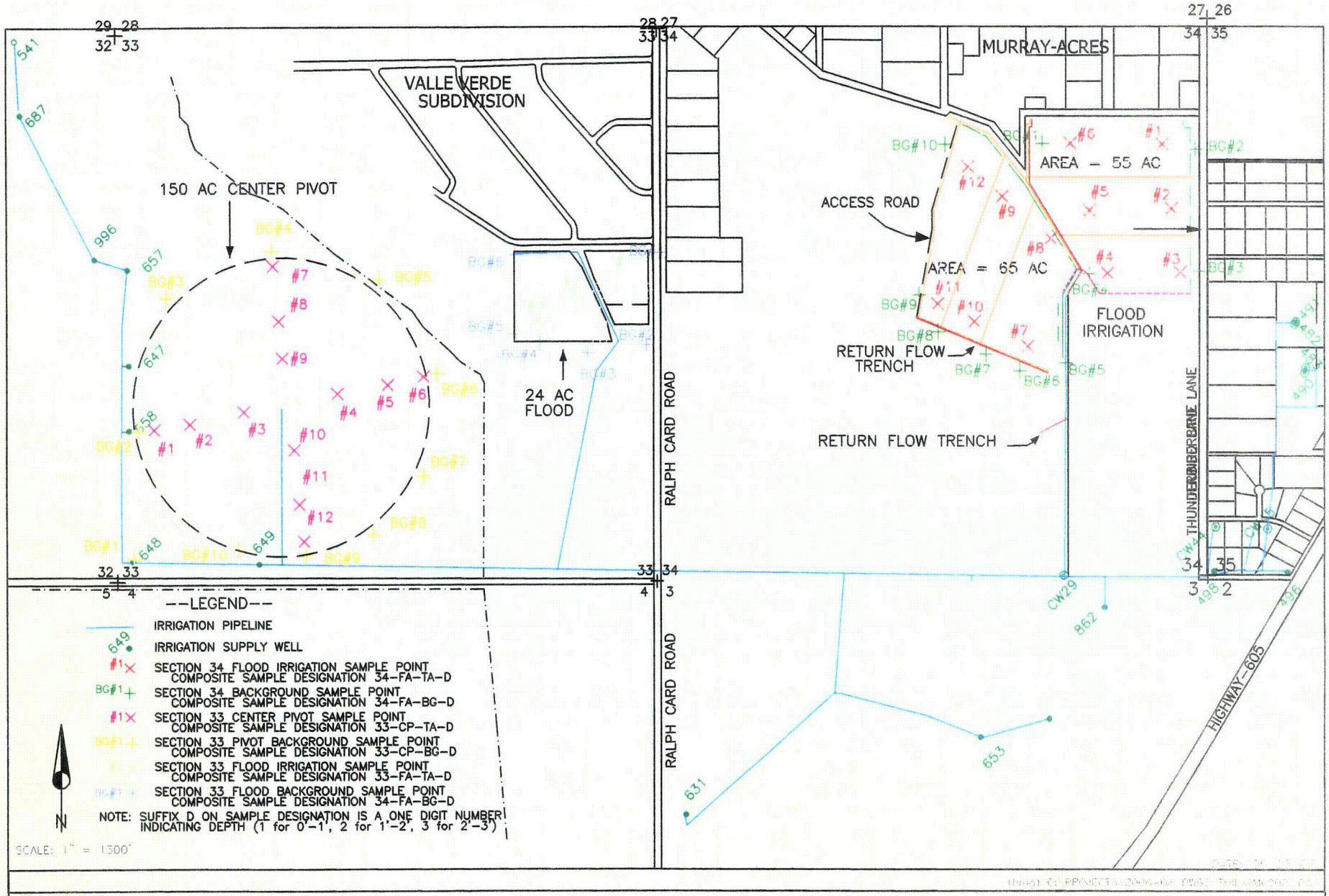

FIGURE 7. 2005 SECTIONS 33 AND 34 IRRIGATION AREAS WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

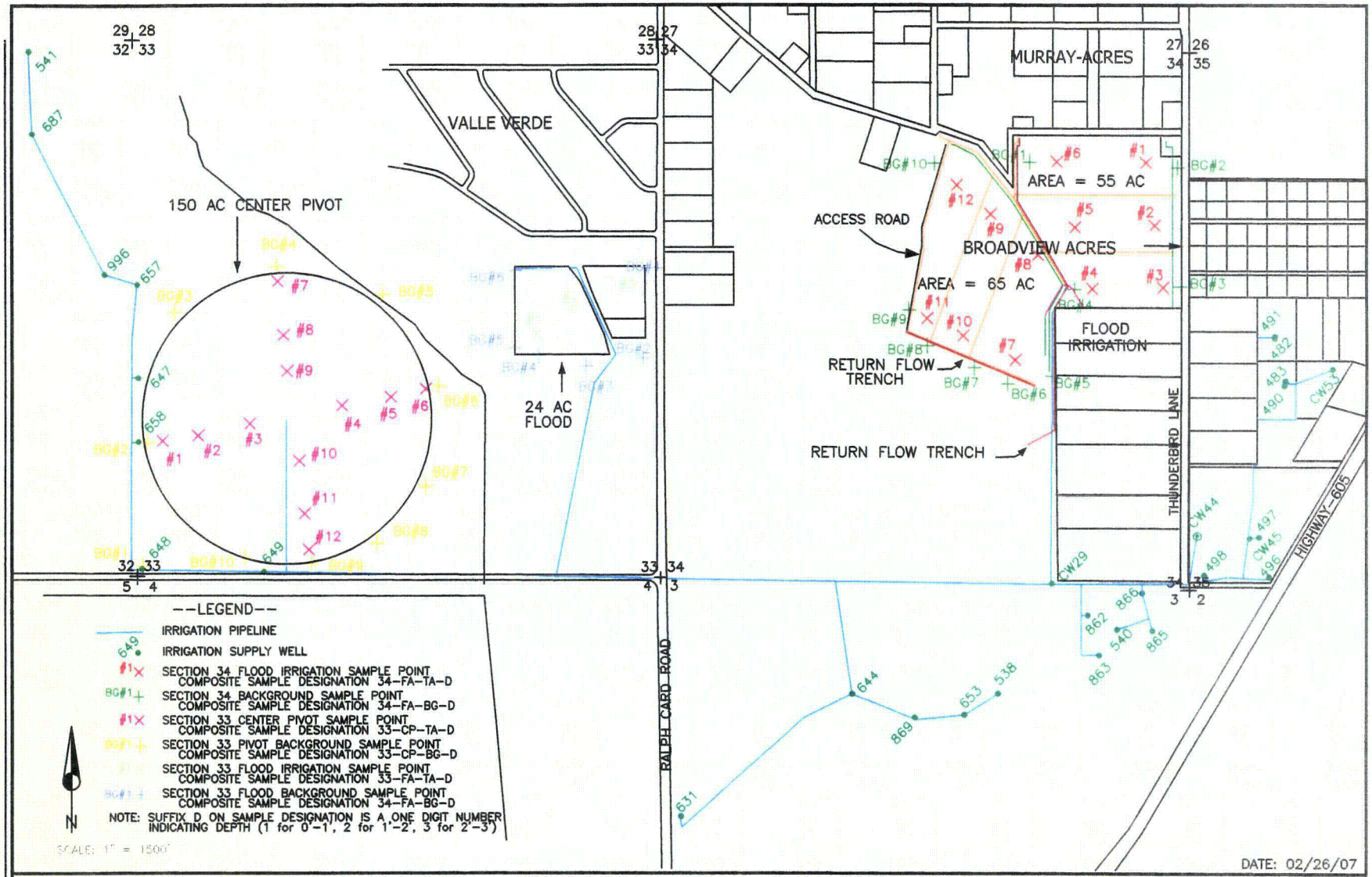

FIGURE 8. 2006 SECTION 33 AND 34 IRRIGATION AREAS WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

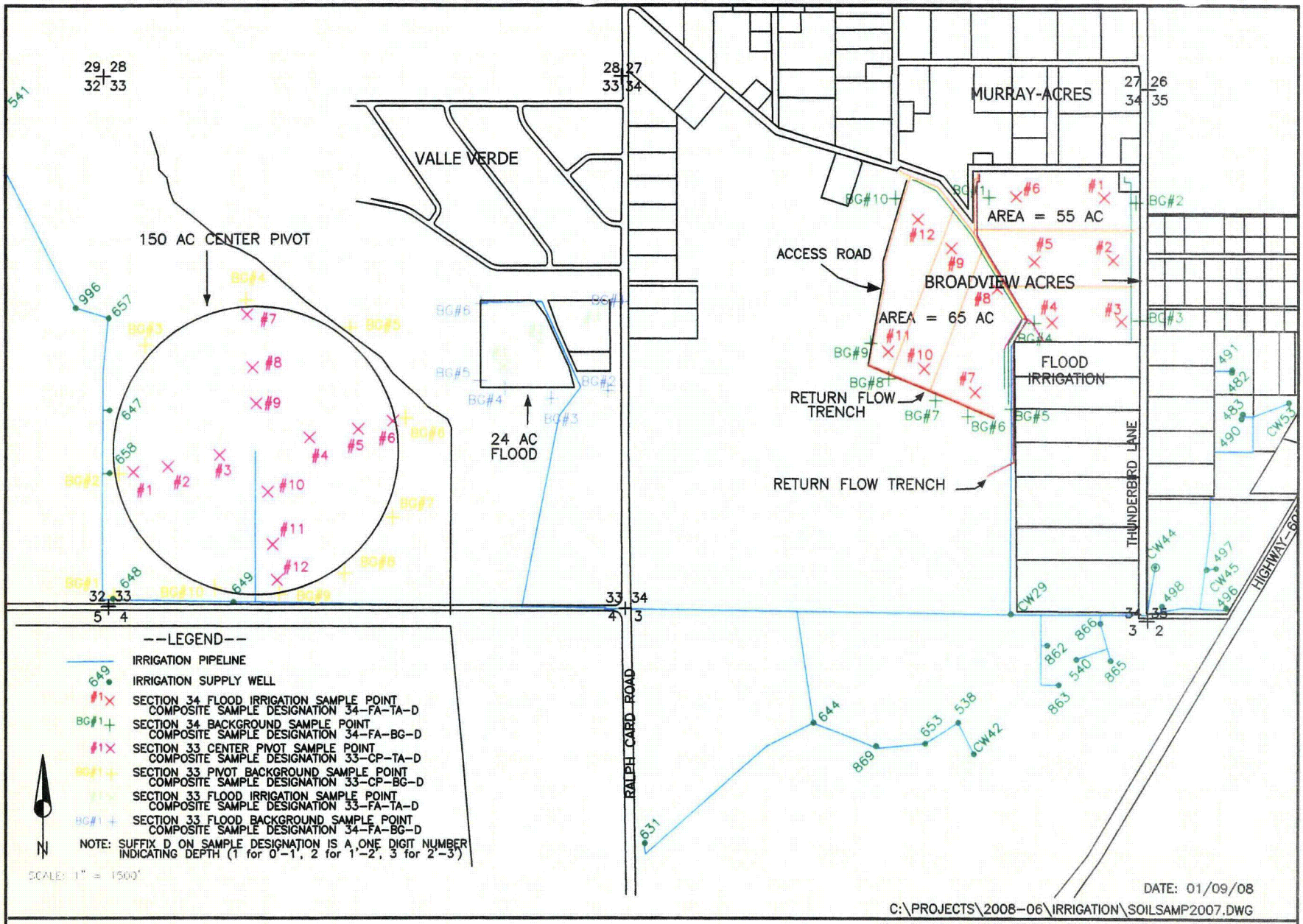

FIGURE 9. 2007 SECTION 33 AND 34 IRRIGATION AREAS WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

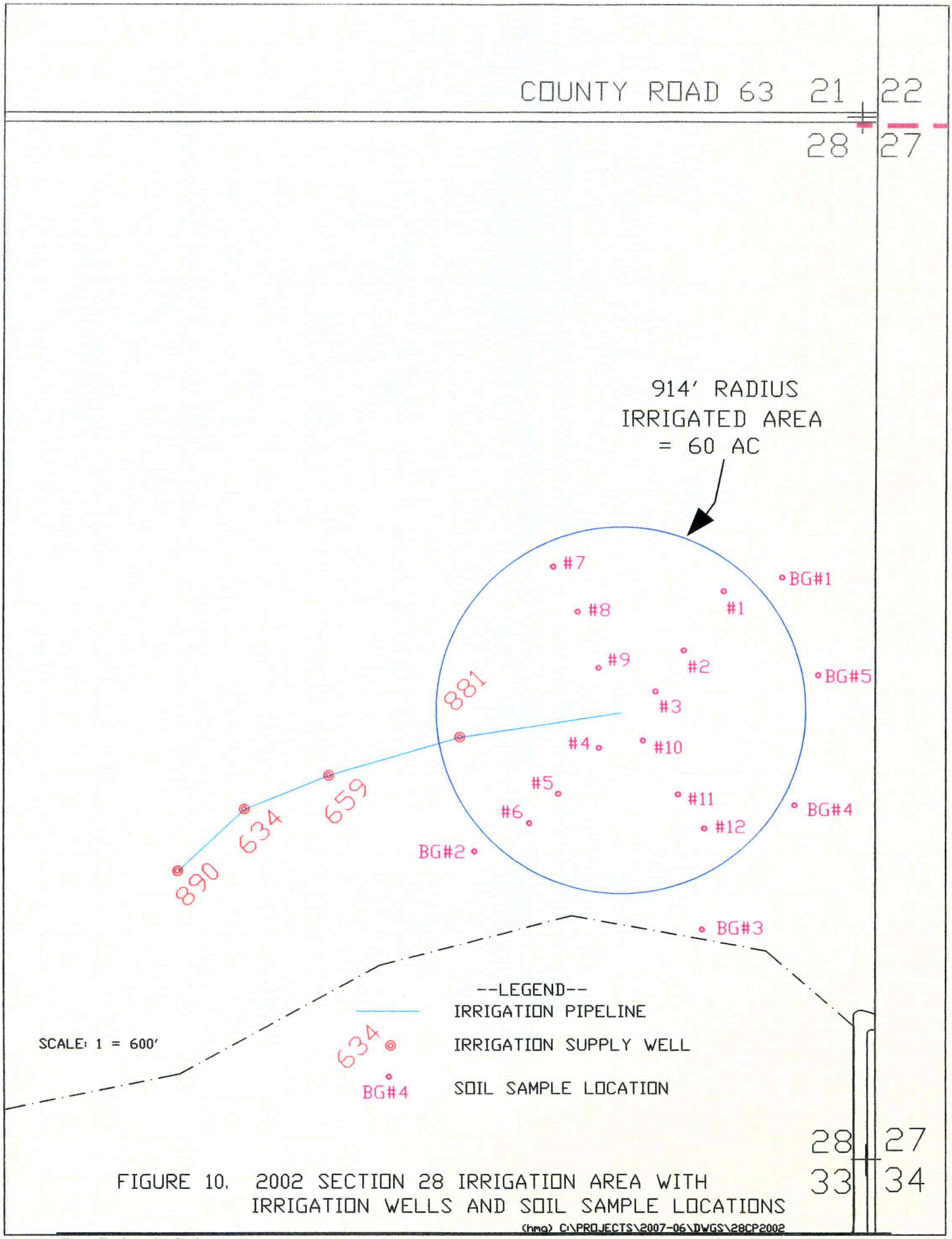

FIGURE 10. 2002 SECTION 28 IRRIGATION AREA WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

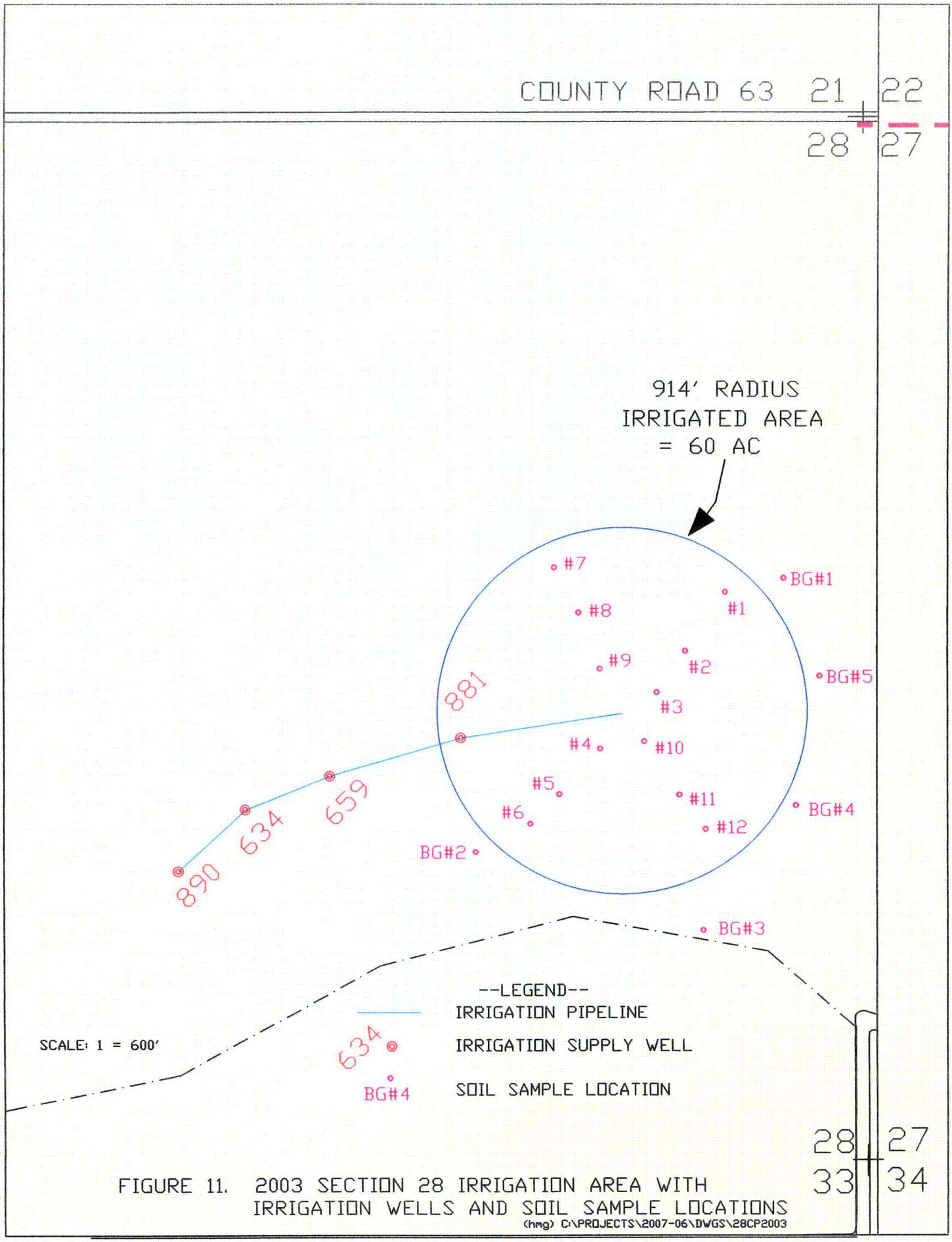

FIGURE 11. 2003 SECTION 28 IRRIGATION AREA WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

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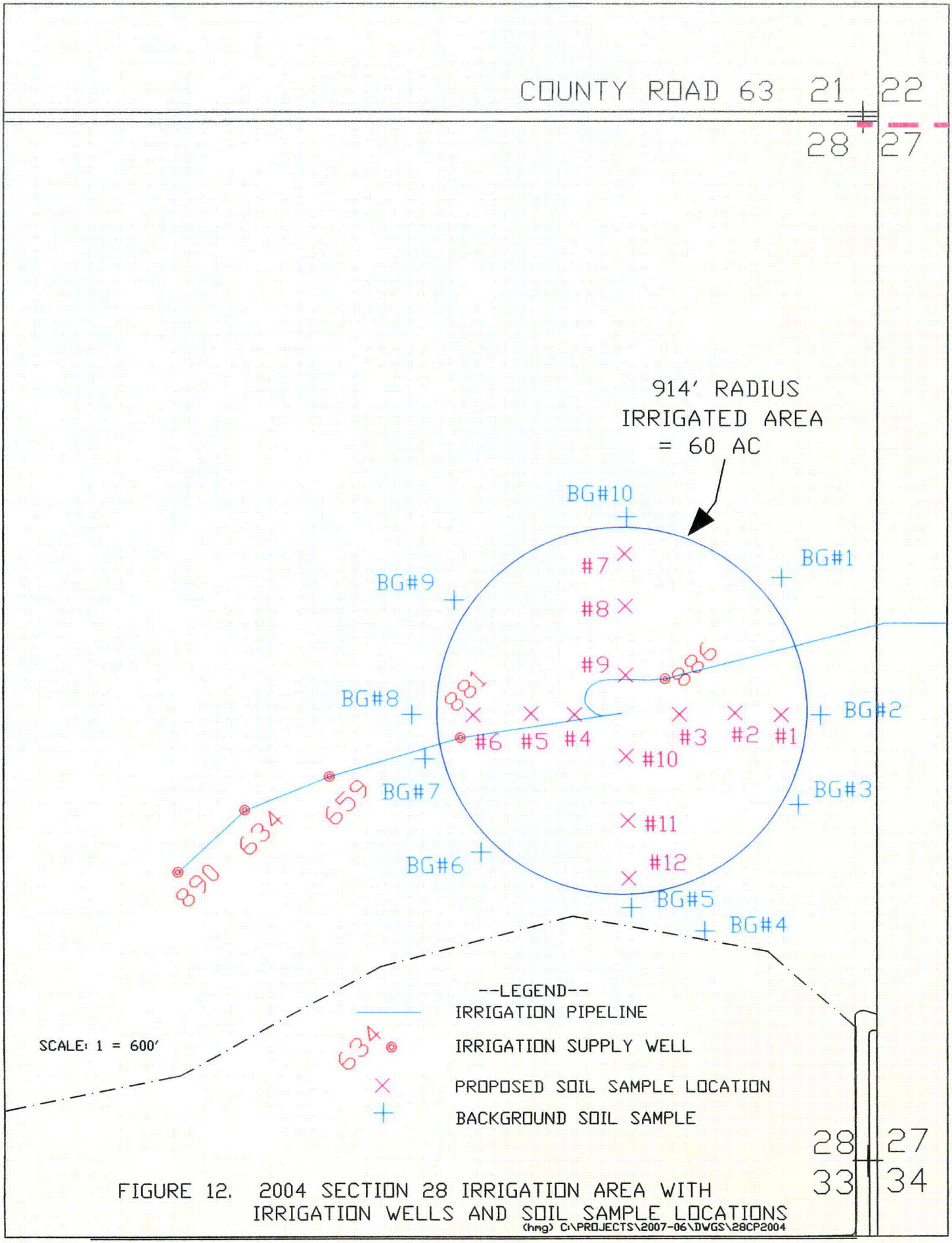

FIGURE 12. 2004 SECTION 28 IRRIGATION AREA WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

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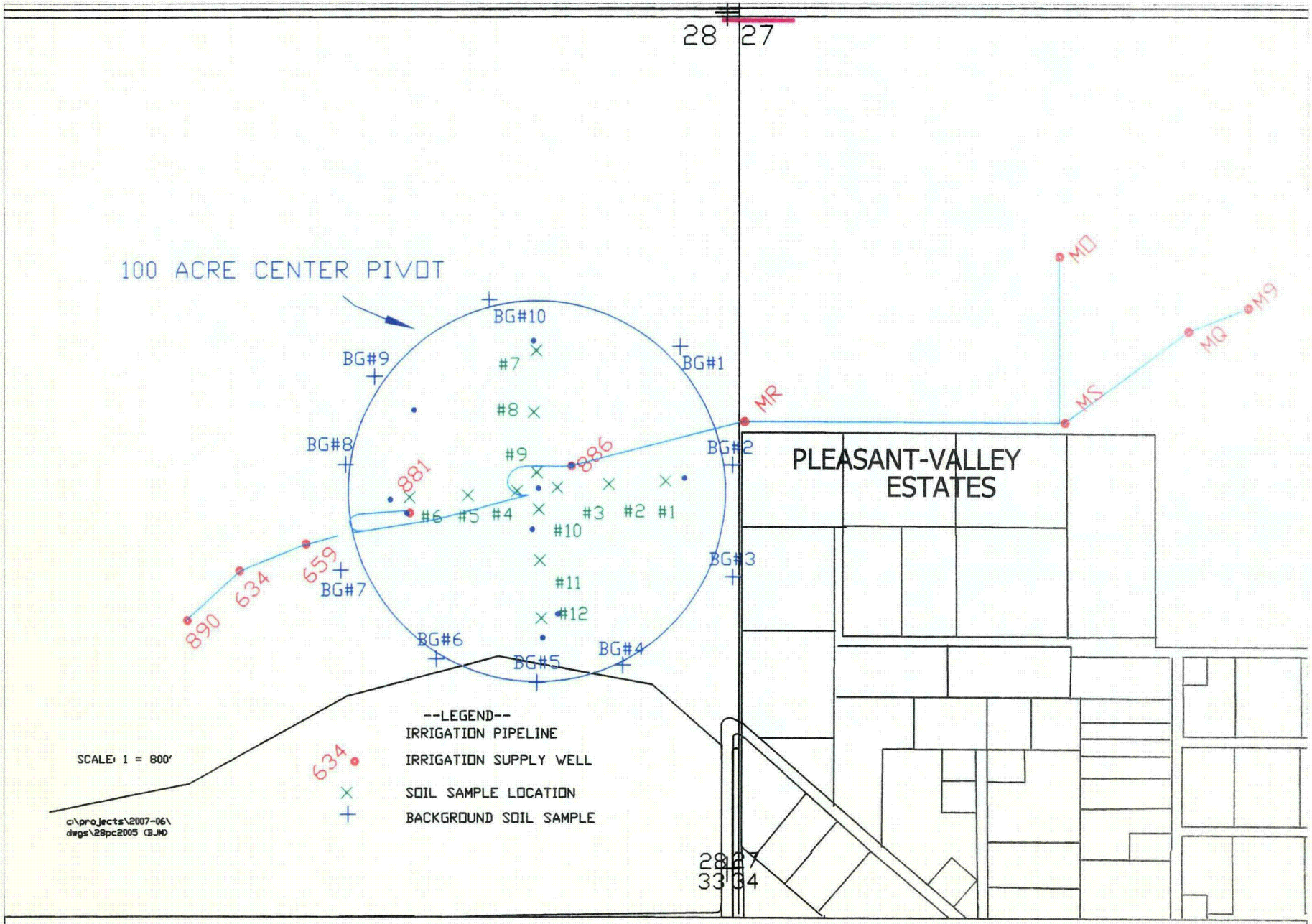

FIGURE 13. 2005 SECTION 28 IRRIGATION AREA WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

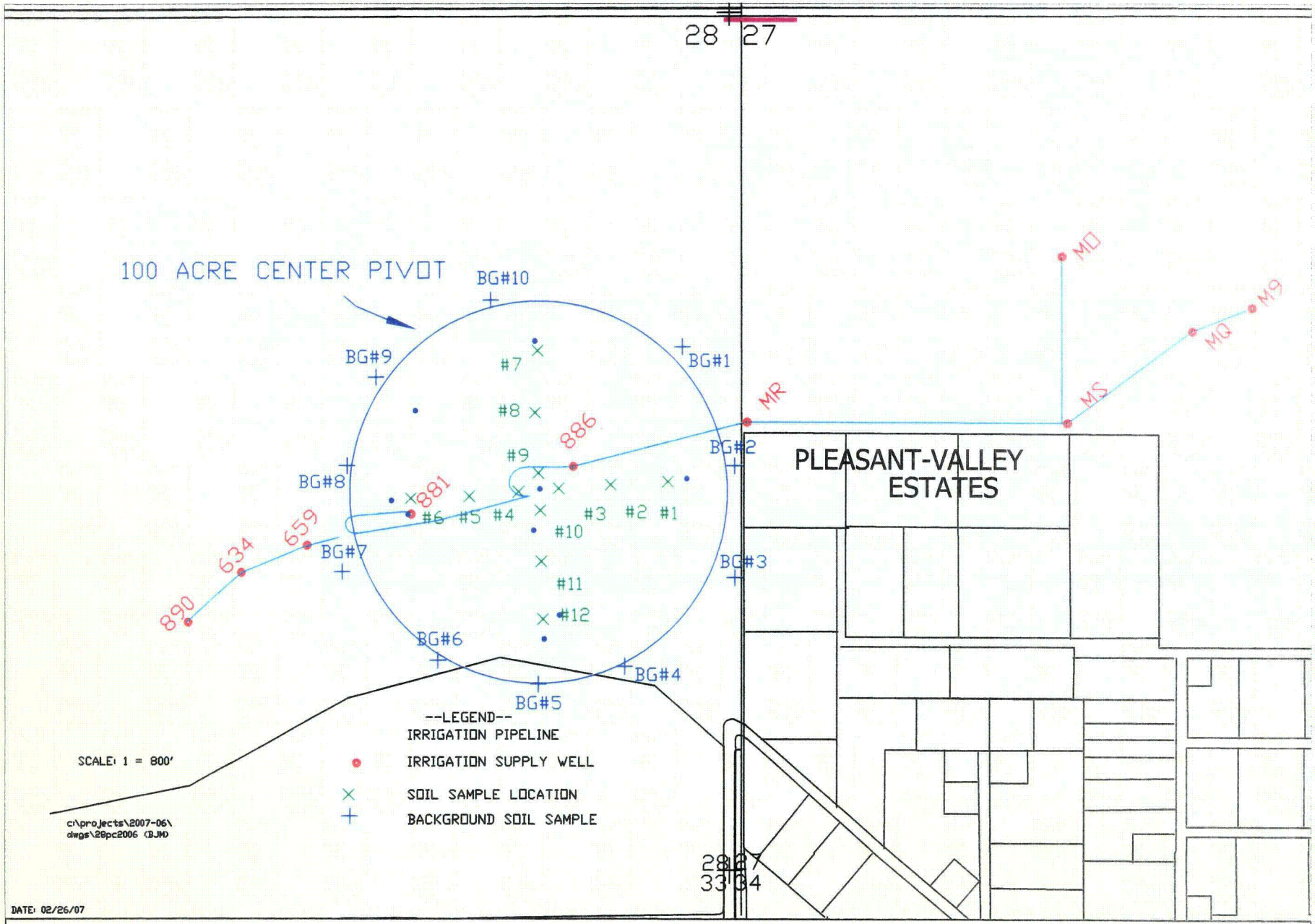

FIGURE 14. 2006 SECTION 28 IRRIGATION AREA WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

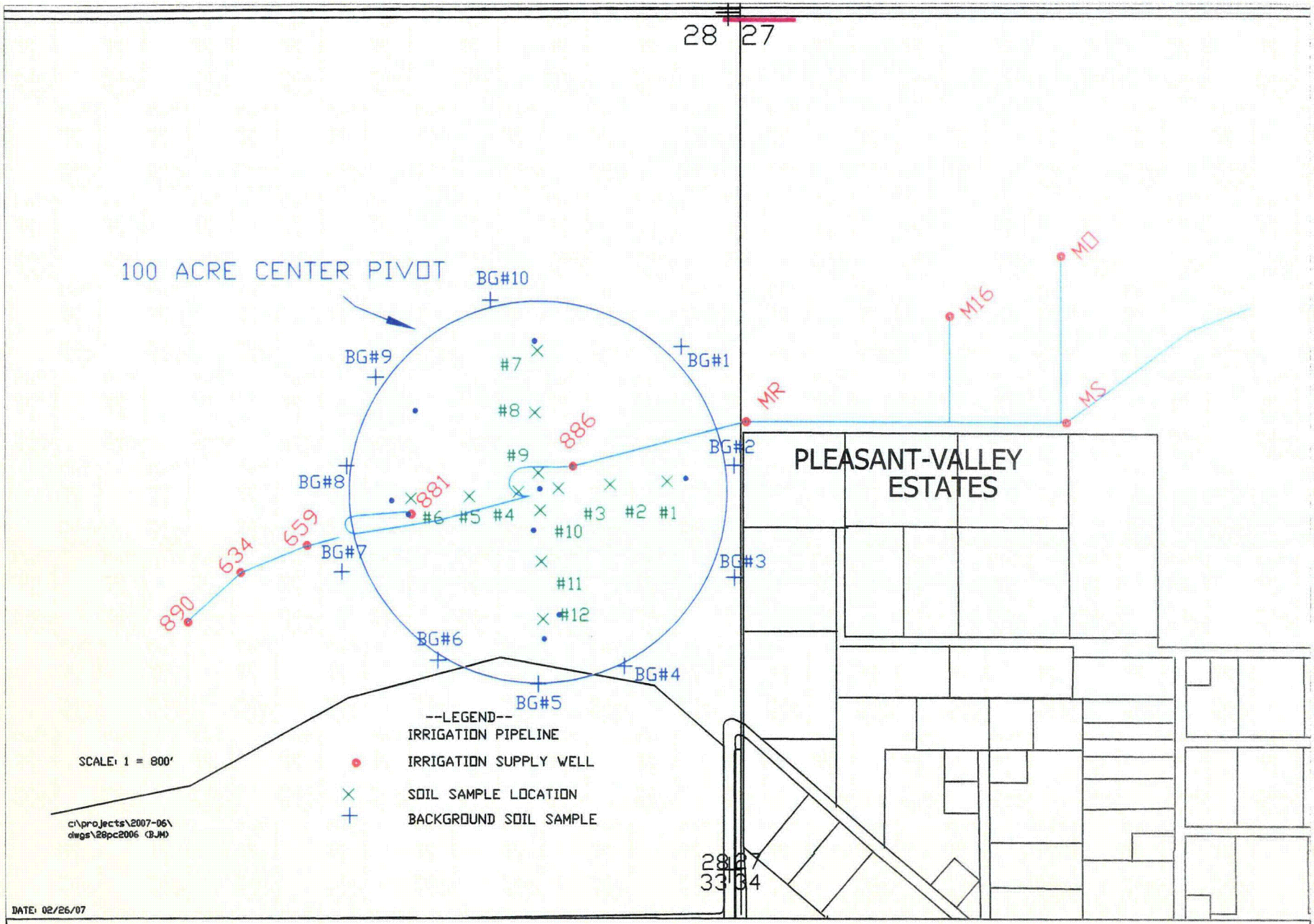

FIGURE 15. 2007 SECTION 28 IRRIGATION AREA WITH IRRIGATION WELLS AND SOIL SAMPLE LOCATIONS

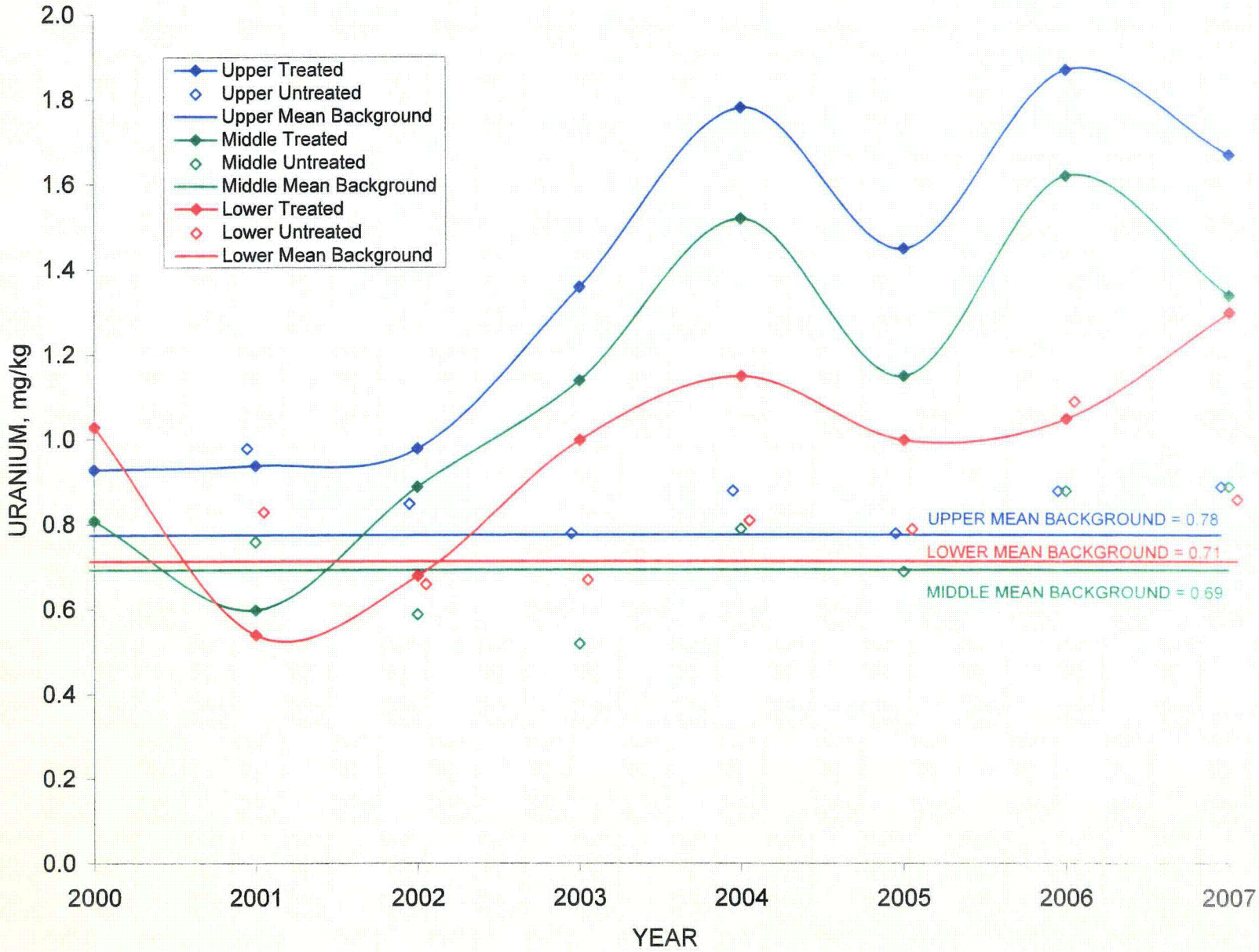

FIGURE 16. URANIUM CONCENTRATIONS VERSUS TIME FOR SECTION 33 CENTER PIVOT SOIL SAMPLES

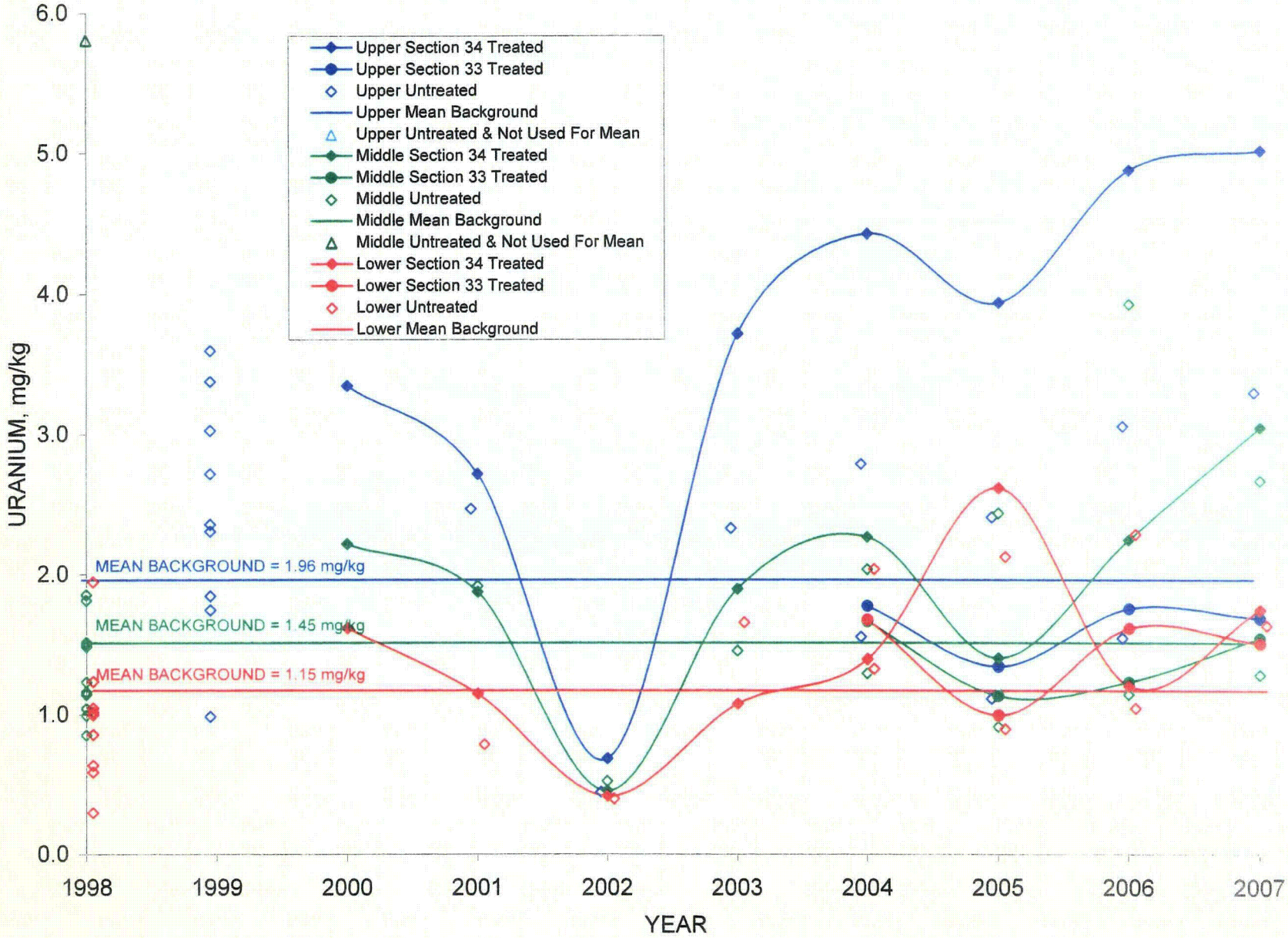

FIGURE 17. URANIUM CONCENTRATIONS VERSUS TIME FOR SECTIONS 33 AND 34 FLOOD SOIL SAMPLES

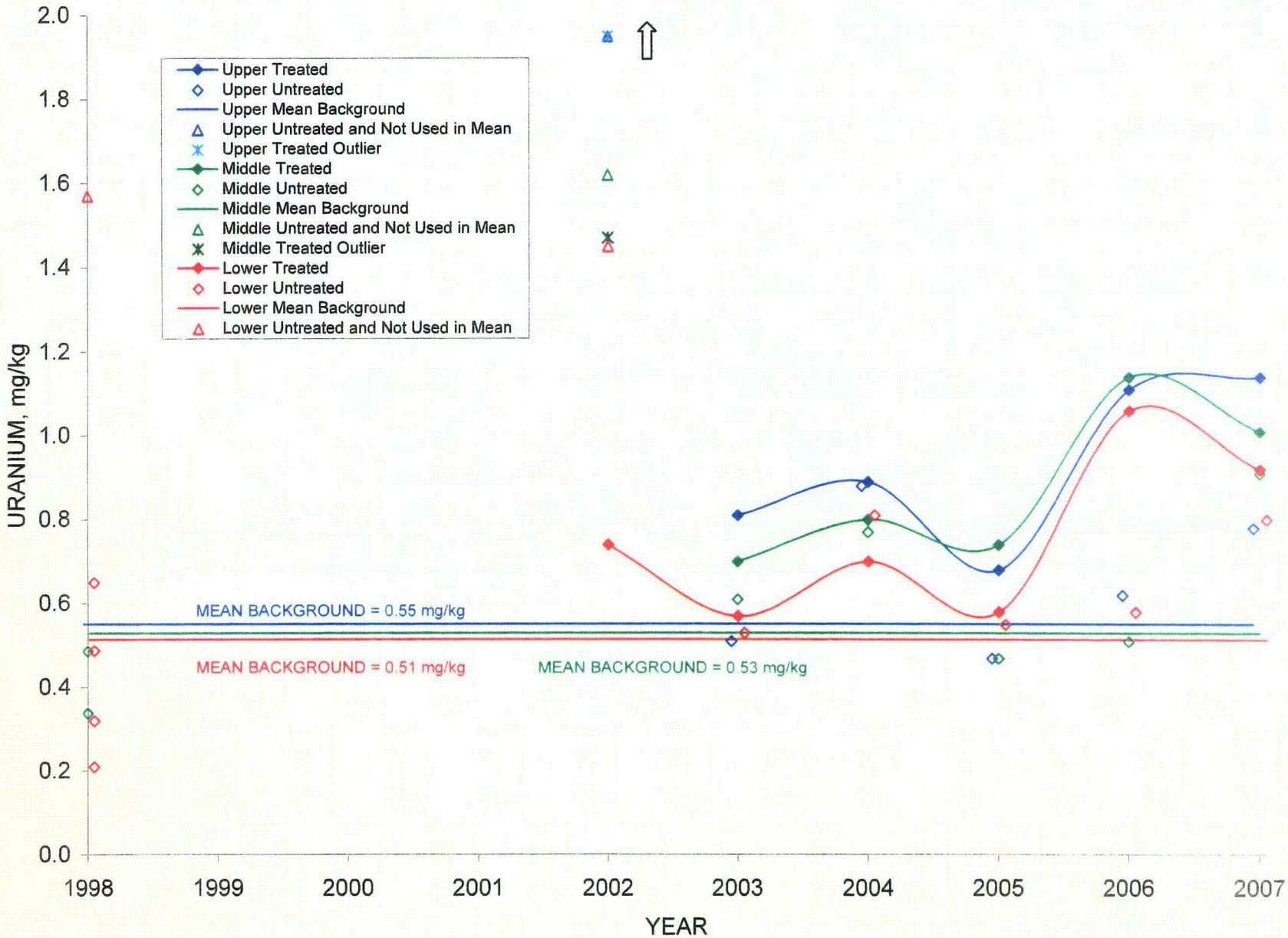

FIGURE 18. URANIUM CONCENTRATIONS VERSUS TIME FOR SECTION 28 CENTER PIVOT SOIL SAMPLES

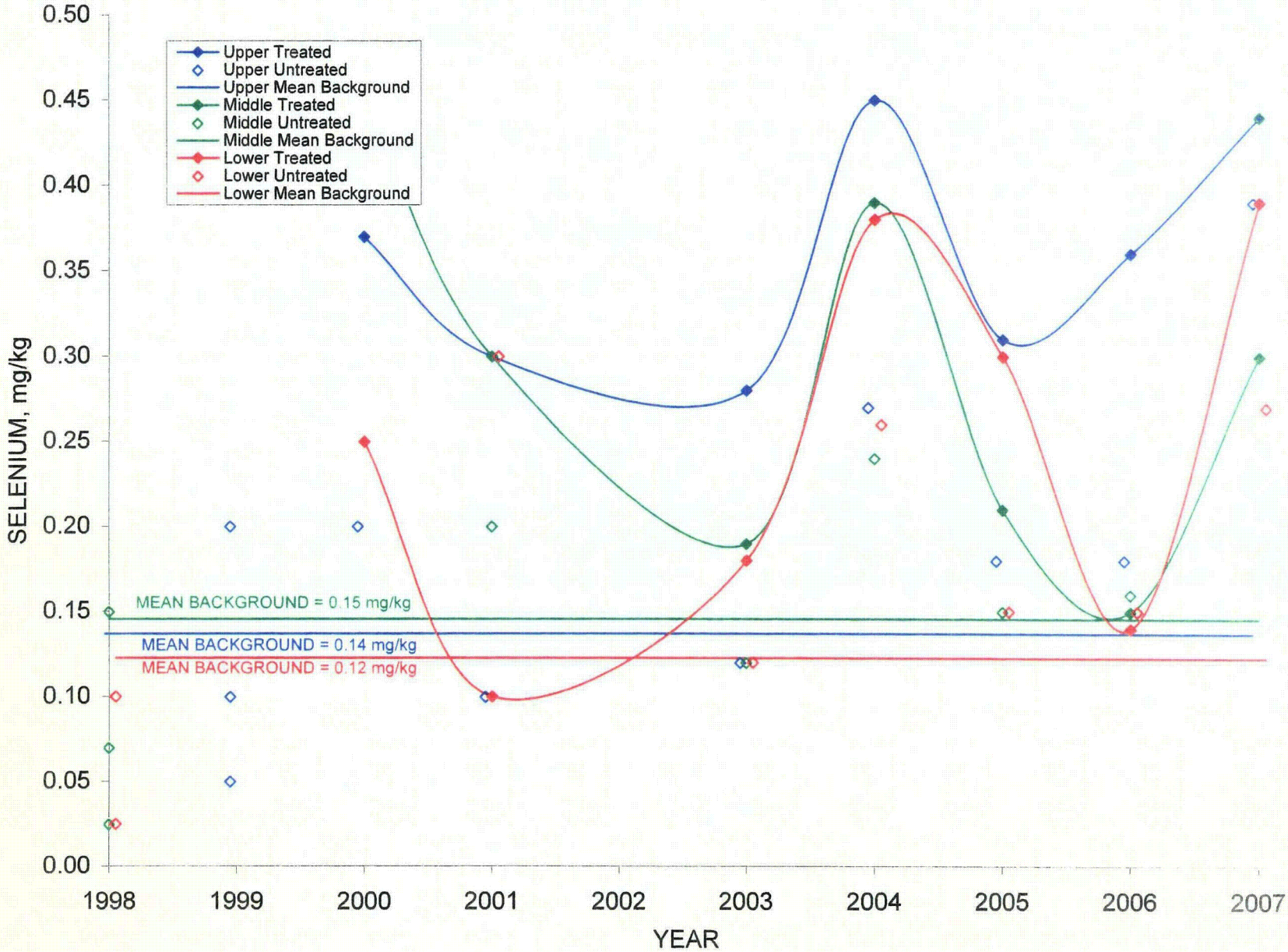

FIGURE 19. SELENIUM CONCENTRATIONS VERSUS TIME FOR SECTION 33 CENTER PIVOT SOIL SAMPLES

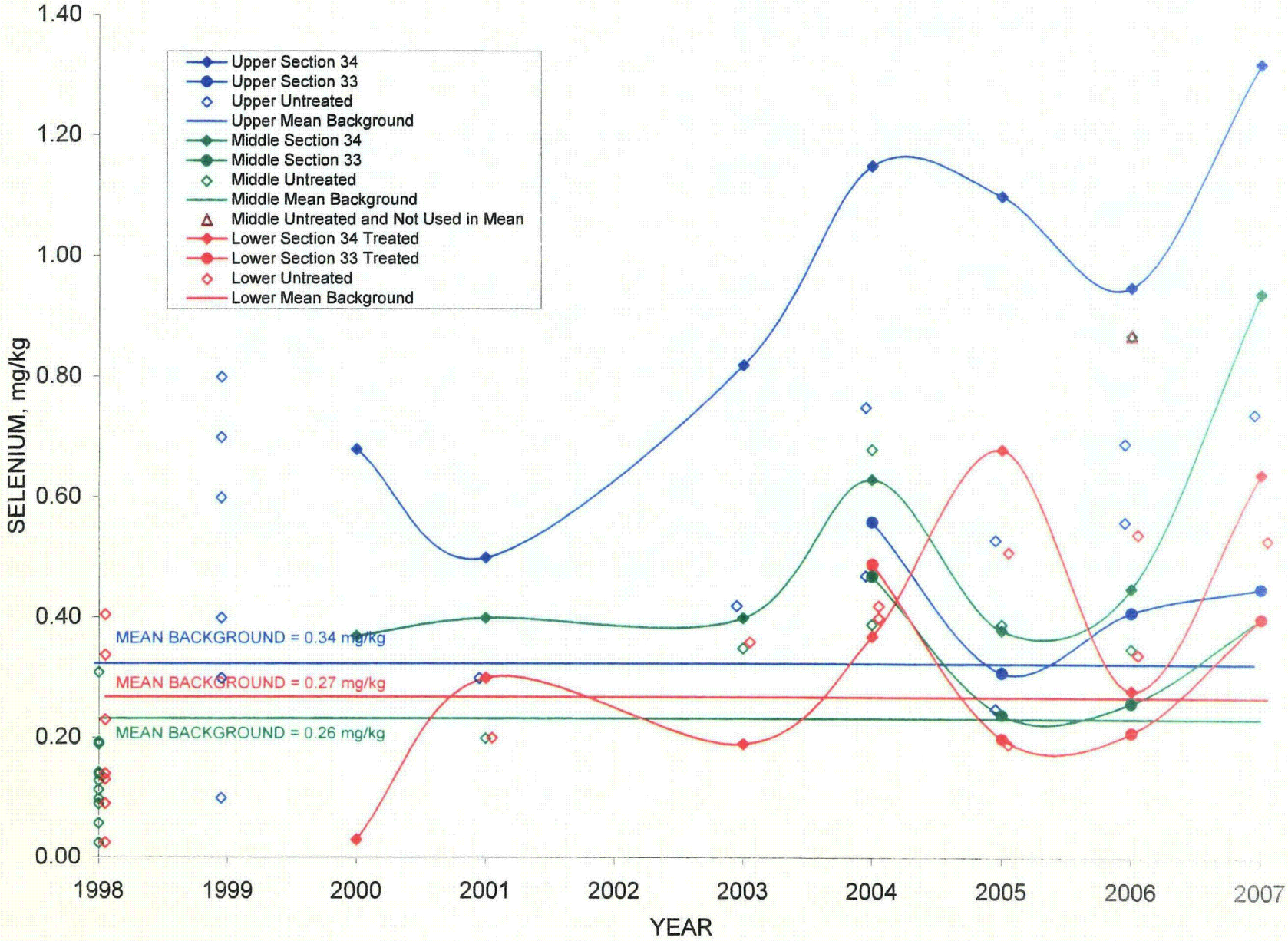

FIGURE 20. SELENIUM CONCENTRATIONS VERSUS TIME FOR SECTIONS 33 AND 34 FLOOD SOIL SAMPLES

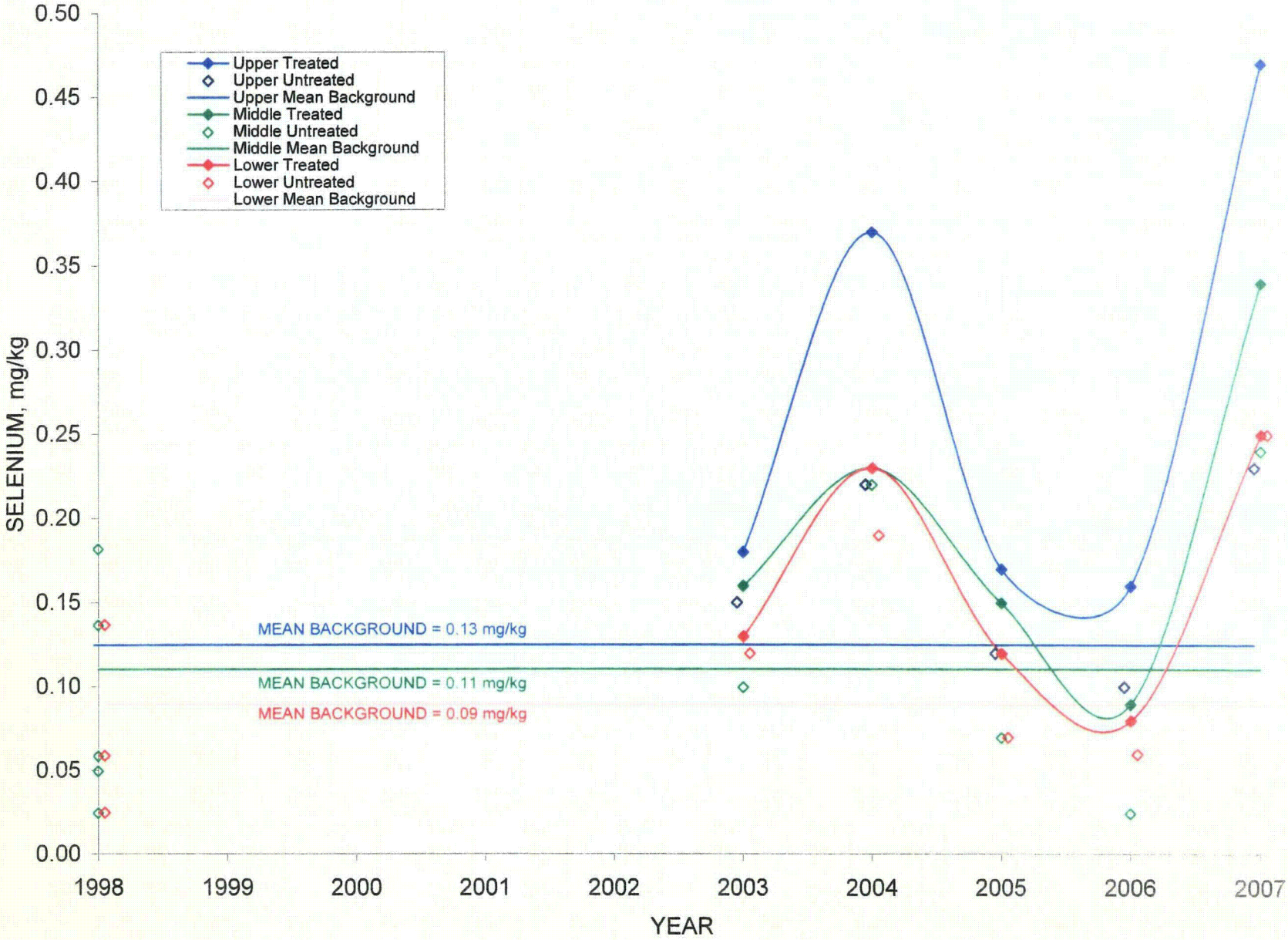

FIGURE 21. SELENIUM CONCENTRATIONS VERSUS TIME FOR SECTION 28 CENTER PIVOT SOIL SAMPLES

APPENDIX A

1999 and 2000 Soil Analysis

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A-2 1999 and 2000 Irrigation Soil Analyses for Section 34 ..... A-2

Table A-1. 1999 and 2000 Irrigation Soil Analyses for Section 33

Sample Site	Date	U (mg/kg)	Se (mg/kg)	Mo (mg/kg)	pH (units)	Cond. (mmhos/cm)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	SAR (ratio)	Cl (mg/kg)	SO4 (mg/kg)
						SECTION 33						
33A	10/1/1999	0.36	0.1	<1	7.7	0.350	2.51	0.68	0.28	0.22	13	330
33A1	12/7/2000	0.84	0.6	<1	7.8	1.890	7.84	2.28	10.4	4.62	50	220
33A2	12/7/2000	0.65	0.4	<1	7.7	1.950	8.84	2.55	10.1	4.23	53	210
33A3	12/7/2000	0.62	0.2	<1	7.6	2.170	11.70	3.33	10.0	3.65	49	210
33B	10/1/1999	0.82	0.2	<1	7.7	0.445	3.30	0.73	0.17	0.12	7	40
33B1	12/7/2000	1.05	0.2	<1	7.8	0.576	2.33	0.86	3.18	2.52	14	50
33B2	12/7/2000	0.96	0.5	<1	7.8	1.010	3.75	1.21	5.44	3.45	38	370
33B3	12/7/2000	1.44	0.3	<1	7.6	1.270	5.00	1.24	6.66	3.77	22	210
33C	10/1/1999	0.65	<0.1	<1	7.8	0.474	3.10	0.72	0.15	0.10	35	440
33C1	12/7/2000	0.91	0.3	<1	8	0.495	1.84	0.68	3.42	3.05	13	<50
33D	10/1/1999	0.73	0.2	<1	7.7	0.840	5.48	1.24	0.69	0.37	22	130
33D1	12/7/2000	1.14	0.2	<1	7.6	1.240	9.07	2.64	0.64	0.26	18	<50
	1999 AVG:	0.61	0.12	0.5	7.7	0.423	2.97	0.71	0.20	0.15	18	270
	2000-1 AVG:	0.93	0.37	0.5	7.9	0.987	4.00	1.27	5.67	3.40	26	98
	2000-2 AVG:	0.81	0.45	0.5	7.8	1.480	6.30	1.88	7.77	3.84	46	290
	2000-3 AVG:	1.03	0.25	0.5	7.6	1.720	8.35	2.29	8.33	3.71	36	210

NOTE: 2000 Sample: 1 = 0 - 6 inches, 2 = 6 - 18 inches and 3 = 18 - 36 inches

Table A-2. 1999 and 2000 Irrigation Soil Analyses for Section 34

Sample Site	Date	U (mg/kg)	Se (mg/kg)	Mo (mg/kg)	pH (units)	Cond. (mmhos/cm)	Ca (meq/l)	Mg (meq/l)	Na (meq/l)	SAR (ratio)	Cl (mg/kg)	SO4 (mg/kg)
						SECTION 34						
34A	9/29/1999	2.72	0.4	<1	7.7	3.56	17.10	7.40	16.6	4.74	36	1280
34A1	12/7/2000	2.78	0.6	<1	7.7	1.94	8.68	3.29	9.32	3.81	40	350
34A2	12/7/2000	2.49	0.4	<1	7.5	3.13	19.50	6.42	13.2	3.67	52	780
34A3	12/7/2000	1.37	0.2	<1	7.5	2.76	16.30	5.08	12.9	3.95	20	450
34B	9/29/1999	2.36	0.4	<1	7.7	3.89	17.60	7.36	20.3	5.75	54	3470
34B1	12/7/2000	3.61	0.6	<1	7.6	4.01	16.70	7.30	24.3	7.01	72	1020
34B2	12/7/2000	3.04	0.4	<1	7.6	5.03	18.90	9.26	32.8	8.74	159	3490
34B3	12/7/2000	2.02	0.3	<1	7.7	6.27	20.10	7.90	47.0	12.6	106	2220
34C	9/29/1999	1.75	0.3	<1	7.6	5.25	22.90	9.00	29.2	7.31	79	4560
34C1	12/7/2000	3.00	0.4	<1	7.8	1.61	5.46	2.13	9.64	4.95	58	470
34D	9/29/1999	3.60	0.6	<1	7.8	1.40	4.60	2.13	7.28	3.97	36	160
34D1	12/7/2000	3.29	0.5	<1	7.6	3.88	20.20	6.97	21.3	5.78	88	2520
34E	9/29/1999	2.31	0.4	<1	7.8	2.67	12.20	5.24	12.8	4.33	25	690
34E1	12/7/2000	4.21	0.7	<1	7.8	2.26	8.49	3.86	13.8	5.55	44	380
34F	9/29/1999	3.03	0.8	<1	7.7	4.76	22.80	8.80	23.1	5.81	68	5040
34F1	12/7/2000	4.68	1.3	2	7.8	4.18	19.40	9.43	23.0	6.06	66	1140
34G	10/6/1999	1.85	0.3	<1	7.6	1.62	9.39	3.60	1.59	0.62	13	100
34G1	12/7/2000	2.64	0.8	<1	7.6	1.69	8.19	3.50	8.18	3.38	25	150
34G2	12/7/2000	1.13	0.3	<1	7.6	1.55	4.85	2.34	9.73	5.13	24	220
34G3	12/7/2000	1.48	0.4	<1	7.7	1.16	4.50	2.08	6.72	3.70	41	270
34H	10/7/1999	3.38	0.7	<1	8	0.969	3.23	1.13	5.28	3.58	43	520
34H1	12/7/2000	4.23	1.0	<1	7.6	2.75	15.90	4.33	15.0	4.72	52	430
34I	10/7/1999	0.99	0.1	<1	7.8	1.46	4.99	0.89	8.29	4.83	42	480
34I1	12/7/2000	1.73	0.2	<1	7.5	1.03	4.57	1.11	6.72	3.99	59	440
	1999 AVG:	2.44	0.44	0.50	7.7	2.84	12.76	5.06	13.83	4.55	44	1811
	2000-1 AVG:	3.35	0.68	0.67	7.7	2.59	11.95	4.66	14.58	5.03	56	767
	2000-2 AVG:	2.22	0.37	0.50	7.6	3.24	14.42	6.01	18.58	5.85	78	1497
	2000-3 AVG:	1.62	0.30	0.50	7.6	3.40	13.63	5.02	22.21	6.75	56	980

NOTE: 2000 Sample: 1 = 0 - 6 inches, 2 = 6 - 18 inches and 3 = 18 - 36 inches

APPENDIX B

Hay Analyses

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Table B-1. 2000 Hay Analyses

Sample	Uranium (mg/Kg)	Selenium (mg/Kg)	Moisture Content (%)	Percent Solids (%)
Homestake Hay				
Section 33 - 1st Cut	1.12	1.1	2.8	93.9
Section 34 - 1st Cut	0.73	0.5	2.9	95.1
Section 33 - 2nd Cut - Unwashed	0.62	1.4	4.6	95.7
Section 33 - 2nd Cut - Washed	0.58	1.5	33.4	95.9
Other Hay				
Carver	0.19	0.2	13.1	96.4
Elkin	0.05	0.1	7.4	95.7

Table B-2. 2001, 2002, 2003 and 2004 Hay Analyses

Irrigation Area	Sample	2001 Uranium (mg/kg)	2001 Selenium (mg/kg)	2002 Uranium (mg/kg)	2002 Selenium (mg/kg)	2003 Uranium (mg/kg)	2003 Selenium (mg/kg)	2004 Uranium (mg/kg)	2004 Selenium (mg/kg)
Section 33 - 1st Cut	#1	0.460	0.950	0.89	1.40	0.58	2.25	6.90	1.60
	#2	0.650	1.500	1.60	2.17	0.62	1.73	2.40	1.50
	#3	0.700	1.450	1.51	1.39	0.87	2.08	1.90	1.30
	#4	0.550	1.650	0.99	1.89	0.70	1.56	1.70	1.50
	#5	0.690	1.400	1.10	1.40	0.87	2.01	1.50	1.30
	#6	0.490	1.850	1.45	1.83	0.80	1.16	0.70	1.20
	#7	0.500	0.950	1.21	1.93	0.95	1.52	0.90	0.90
	#8	0.600	1.550	1.81	2.36	0.83	1.59	0.70	1.00
	#9	----	----	----	----	0.68	0.90	0.70	0.70
	#10	----	----	----	----	0.63	2.15	0.80	0.90
	#11	----	----	----	----	0.59	1.02	0.80	1.70
	#12	----	----	----	----	0.64	2.48	0.50	1.30
	Average	*0.580*	*1.413*	*1.32*	*1.80*	*0.73*	*1.70*	*1.63*	*1.24*
Section 33 - 2nd Cut	#1	0.700	1.500	0.17	0.68	0.67	1.56	0.60	0.80
	#2	0.680	1.000	0.31	0.90	0.77	1.75	0.40	0.80
	#3	0.500	1.650	0.32	1.27	0.81	1.44	0.40	1.40
	#4	1.050	1.250	0.38	1.48	0.76	1.26	0.50	1.60
	#5	0.500	0.750	0.51	1.12	0.81	1.68	0.70	0.20
	#6	0.400	0.950	0.33	1.14	0.69	1.98	0.40	<0.2
	#7	0.350	0.550	0.35	1.57	0.57	1.67	0.40	0.60
	#8	0.350	0.750	0.59	1.23	0.39	0.60	0.40	0.70
	#9	----	----	----	----	0.68	0.99	0.90	0.90
	#10	----	----	----	----	0.89	2.07	0.50	0.40
	#11	----	----	----	----	0.82	1.36	0.40	0.50
	#12	----	----	----	----	0.54	1.22	0.50	0.30
	Average	*0.566*	*1.050*	*0.37*	*1.17*	*0.70*	*1.47*	*0.51*	*0.69*
Section 33 - 3rd Cut	#1 Pivot	0.252	0.990	0.54	1.36	0.49	1.05	0.71	1.10
	#2 Pivot	0.286	0.930	0.93	1.68	0.73	1.43	0.73	1.20
	#3 Pivot	0.322	1.260	1.10	1.64	0.90	2.00	0.46	1.10
	#4 Pivot	0.202	1.450	0.96	1.82	0.46	1.15	0.55	0.90
	#5 Pivot	0.289	1.090	0.78	2.12	0.43	1.36	0.67	1.40
	#6 Pivot	0.250	0.820	0.61	2.13	0.58	1.60	0.60	1.00
	#7 Pivot	0.312	0.620	0.69	1.66	0.57	1.59	1.20	1.60
	#8 Pivot	0.479	1.110	0.59	2.07	0.81	0.83	1.31	1.00
	#9 Pivot	0.177	0.510	----	----	0.45	1.39	1.39	1.30
	#10 Pivot	0.195	0.680	----	----	1.97	3.59	1.09	1.50
	#11 Pivot	0.205	0.680	----	----	0.60	1.20	0.92	1.40
	#12 Pivot	0.182	0.660	----	----	0.78	1.35	1.18	1.40
	#13 Pivot	0.703	1.080	----	----	----	----	----	----
	#14 Pivot	0.522	0.930	----	----	----	----	----	----
	#15 Pivot	0.263	0.620	----	----	----	----	----	----
	#16 Pivot	0.104	0.460	----	----	----	----	----	----
	Average	*0.296*	*0.868*	*0.78*	*1.81*	*0.73*	*1.55*	*0.90*	*1.24*

Table B-2. 2001, 2002, 2003 and 2004 Hay Analyses (cont.)

Irrigation Area	Sample	2001 Uranium (mg/kg)	2001 Selenium (mg/kg)	2002 Uranium (mg/kg)	2002 Selenium (mg/kg)	2003 Uranium (mg/kg)	2003 Selenium (mg/kg)	2004 Uranium (mg/kg)	2004 Selenium (mg/kg)
Section 34 - 1st Cut	#1	0.600	0.950	0.73	0.82	0.74	2.02	1.30	1.70
	#2	0.750	1.250	0.94	1.38	1.40	1.86	1.20	1.50
	#3	0.550	0.950	0.84	0.82	0.61	1.40	0.90	0.90
	#4	0.650	0.600	0.75	0.74	0.92	1.67	1.10	1.30
	#5	0.450	0.750	0.59	0.41	0.92	1.12	1.50	1.30
	#6	0.500	0.800	1.62	0.83	1.06	2.08	0.70	1.20
	#7	0.550	1.950	—	—	0.61	1.52	0.90	0.80
	#8	0.400	1.050	—	—	0.66	1.68	0.70	0.90
	#9	0.450	1.200	—	—	0.49	1.44	1.40	1.50
	#10	0.600	1.000	—	—	0.39	1.67	1.00	1.00
	#11	—	—	—	—	0.97	1.45	1.00	0.90
	#12	—	—	—	—	1.87	1.53	0.60	1.30
	Average	*0.550*	*1.050*	*0.91*	*0.83*	*0.89*	*1.62*	*1.03*	*1.19*
Section 34 - 2nd Cut	#1 Flood	0.203	0.900	1.63	0.95	0.69	1.18	0.80	<0.2
	#2 Flood	0.420	1.420	0.84	1.05	0.47	0.56	1.00	0.30
	#3 Flood	0.318	0.440	3.51	1.48	0.59	1.09	0.80	<0.2
	#4 Flood	0.402	1.050	0.89	0.96	0.44	0.50	0.90	0.30
	#5 Flood	0.358	0.530	0.53	1.28	0.71	0.92	0.70	0.50
	#6 Flood	0.195	0.330	1.72	1.14	0.58	0.54	1.10	0.20
	#7 Flood	0.450	1.120	—	—	0.41	0.79	—	—
	#8 Flood	0.514	0.660	—	—	—	—	—	—
	#9 Flood	0.408	1.160	—	—	—	—	—	—
	#10 Flood	0.535	0.610	—	—	—	—	—	—
	Average	*0.380*	*0.822*	*1.52*	*1.14*	*0.56*	*0.80*	*0.88*	*0.25*
Section 34 - 3rd Cut	#1 Flood	1.040	1.110	0.81	1.20	1.56	2.32	—	—
	#2 Flood	0.672	0.712	0.44	1.59	1.36	1.19	—	—
	#3 Flood	0.538	0.817	0.32	0.62	1.28	1.40	—	—
	#4 Flood	0.489	0.630	0.48	1.00	0.87	0.75	—	—
	#5 Flood	0.612	0.530	0.65	1.03	1.18	1.60	—	—
	#6 Flood	0.823	0.710	0.53	0.94	1.00	1.19	—	—
	#7 Flood	0.586	0.782	—	—	1.32	0.62	—	—
	#8 Flood	0.948	0.980	—	—	1.59	0.74	—	—
	#9 Flood	—	—	—	—	0.80	1.18	—	—
	#10 Flood	—	—	—	—	0.91	0.44	—	—
	#11 Flood	—	—	—	—	1.16	0.92	—	—
	#12 Flood	—	—	—	—	0.74	0.93	—	—
	Average	*0.714*	*0.784*	*0.54*	*1.06*	*1.15*	*1.11*	—	—
Section 34 - 4th Cut	#1 Flood	—	—	0.80	1.65	—	—	—	—
	#2 Flood	—	—	0.97	1.09	—	—	—	—
	#3 Flood	—	—	1.29	1.21	—	—	—	—
	#4 Flood	—	—	0.58	0.50	—	—	—	—
	#5 Flood	—	—	0.84	1.48	—	—	—	—
	#6 Flood	—	—	0.83	1.11	—	—	—	—
	Average	—	—	*0.89*	*1.17*	—	—	—	—

Table B-2. 2001, 2002, 2003 and 2004 Hay Analyses (cont.)

Irrigation Area	Sample	2001 Uranium (mg/kg)	2001 Selenium (mg/kg)	2002 Uranium (mg/kg)	2002 Selenium (mg/kg)	2003 Uranium (mg/kg)	2003 Selenium (mg/kg)	2004 Uranium (mg/kg)	2004 Selenium (mg/kg)
Section 28 - 1st Cut	#1 Pivot 2	—	—	0.40	0.81	0.68	1.30	1.16	1.00
	#2 Pivot 2	—	—	0.27	0.74	1.50	1.52	1.25	1.00
	#3 Pivot 2	—	—	0.28	0.65	1.74	1.18	1.79	1.10
	#4 Pivot 2	—	—	0.33	0.86	0.81	1.82	1.07	1.00
	#5 Pivot 2	—	—	0.23	0.99	0.86	1.70	1.57	1.40
	#6 Pivot 2	—	—	0.25	0.70	0.98	1.82	1.08	1.20
	#7 Pivot 2	—	—	—	—	0.61	1.54	0.94	1.10
	#8 Pivot 2	—	—	—	—	0.93	1.89	0.85	0.90
	#9 Pivot 2	—	—	—	—	1.28	1.53	0.67	0.70
	#10 Pivot 2	—	—	—	—	0.81	1.70	1.18	1.00
	#11 Pivot 2	—	—	—	—	0.83	1.87	0.68	1.00
	#12 Pivot 2	—	—	—	—	0.84	1.52	0.80	1.00
	Average	—	—	*0.29*	*0.79*	*0.99*	*1.62*	*1.09*	*1.03*
Section 28 - 2nd Cut	#1 Pivot 2	—	—	—	—	1.26	1.36	0.80	<0.2
	#2 Pivot 2	—	—	—	—	0.72	1.45	0.80	0.30
	#3 Pivot 2	—	—	—	—	0.77	1.14	0.70	0.40
	#4 Pivot 2	—	—	—	—	0.82	1.37	1.10	1.60
	#5 Pivot 2	—	—	—	—	1.21	1.31	1.30	1.20
	#6 Pivot 2	—	—	—	—	0.97	1.80	1.50	1.40
	#7 Pivot 2	—	—	—	—	0.66	1.15	1.20	1.80
	#8 Pivot 2	—	—	—	—	0.91	1.41	0.90	1.00
	#9 Pivot 2	—	—	—	—	0.88	0.84	1.50	1.30
	#10 Pivot 2	—	—	—	—	1.16	1.28	0.90	1.40
	#11 Pivot 2	—	—	—	—	0.94	1.08	1.90	1.20
	#12 Pivot 2	—	—	—	—	1.44	1.18	1.40	1.20
	Average	—	—	—	—	*0.98*	*1.28*	*1.17*	*1.08*
Section 28 - 3rd Cut	#1 Pivot 2	—	—	—	—	1.54	1.57	0.73	1.50
	#2 Pivot 2	—	—	—	—	0.79	0.86	1.12	1.60
	#3 Pivot 2	—	—	—	—	0.78	1.14	0.96	1.20
	#4 Pivot 2	—	—	—	—	1.33	1.29	1.12	1.80
	#5 Pivot 2	—	—	—	—	1.40	0.58	0.63	0.80
	#6 Pivot 2	—	—	—	—	1.14	1.41	0.79	1.10
	#7 Pivot 2	—	—	—	—	0.94	0.49	0.91	1.00
	#8 Pivot 2	—	—	—	—	1.44	0.96	0.49	0.40
	#9 Pivot 2	—	—	—	—	1.00	0.81	0.83	1.30
	#10 Pivot 2	—	—	—	—	0.81	0.37	1.20	0.60
	#11 Pivot 2	—	—	—	—	1.14	1.02	0.58	0.20
	#12 Pivot 2	—	—	—	—	1.35	1.46	0.84	0.80
	Average	—	—	—	—	*1.14*	*1.00*	*0.85*	*1.03*

Table B-3. 2005 through 2007 Hay Analyses

Irrigation Area	Sample	2005 Uranium (mg/kg)	2005 Selenium (mg/kg)	2006 Uranium (mg/kg)	2006 Selenium (mg/kg)	2007 Uranium (mg/kg)	2007 Selenium (mg/kg)
Section 33 - Pivot - 1st Cut	#1	0.9	1.5	0.7	1.2	0.7	0.7
	#2	0.8	1.5	1.2	1.4	0.9	1.2
	#3	0.8	0.8	0.1	1.2	1.3	1.6
	#4	1.1	0.8	1.1	1.3	0.7	0.7
	#5	0.7	1.2	0.7	1.5	0.9	1.3
	#6	0.9	1.2	0.9	1.2	1.2	1.5
	#7	0.8	1.5	0.8	1.2	0.8	1.0
	#8	0.8	1.5	0.9	1.1	1.0	1.3
	#9	0.6	1.0	0.6	1.1	1.6	1.8
	#10	1.0	1.1	1.0	1.4	1.1	1.4
	#11	0.9	1.6	0.9	1.2	1.3	1.7
	#12	0.8	1.3	0.7	1.2	1.0	1.1
	Average	*0.84*	*1.3*	*0.80*	*1.3*	*1.04*	*1.3*
Section 33 - Pivot - 2nd Cut	#1	0.6	1.3	0.6	1.4	1.7	1.2
	#2	0.5	1.3	0.7	1.5	0.8	0.6
	#3	0.7	1.4	0.7	1.0	0.9	1.5
	#4	1.3	1.4	0.6	1.8	1.1	1.5
	#5	0.6	1.2	0.5	0.5	1.2	0.7
	#6	0.8	1.1	0.6	2.1	1.2	1.6
	#7	0.6	1.6	0.7	1.1	1.3	1.1
	#8	0.5	1.4	0.5	0.7	0.9	1.6
	#9	0.6	1.0	0.7	1.0	0.8	1.0
	#10	0.6	1.6	0.4	1.6	2.1	2.0
	#11	0.5	1.0	0.7	1.4	0.9	1.6
	#12	0.4	1.2	0.7	1.4	1.2	1.8
	Average	*0.64*	*1.3*	*0.62*	*1.3*	*1.18*	*1.4*
Section 33 - Pivot - 3rd Cut	#1	0.7	1.1	0.5	1.6	1.7	1.2
	#2	0.7	1.3	0.5	1.0	2.0	1.2
	#3	0.4	0.8	0.6	1.0	1.8	1.2
	#4	0.5	0.9	0.4	0.9	1.5	1.9
	#5	0.9	1.2	0.6	0.9	1.5	1.9
	#6	0.8	1.6	0.4	0.8	0.9	1.6
	#7	0.8	1.3	0.3	0.9	1.7	1.7
	#8	0.6	1.2	0.4	1.0	1.5	1.9
	#9	1.0	2.6	0.5	1.2	2.0	1.3
	#10	0.6	1.2	0.3	0.7	1.4	1.5
	#11	0.7	0.9	0.5	1.1	1.3	1.1
	#12	0.8	1.1	0.4	0.9	1.9	1.0
	Average	*0.71*	*1.3*	*0.45*	*1.0*	*1.60*	*1.5*

Table B-3. 2005 through 2007 Hay Analyses (cont.)

Irrigation Area	Sample	2005 Uranium (mg/kg)	2005 Selenium (mg/kg)	2006 Uranium (mg/kg)	2006 Selenium (mg/kg)	2007 Uranium (mg/kg)	2007 Selenium (mg/kg)
Section 33 - Flood - 1st Cut	#1	0.5	0.3	----	----	----	----
	#2	0.3	<0.20	----	----	----	----
	Average	*0.40*	*<0.25*	----	----	----	----
Section 34 - Flood - 1st Cut	#1	2.0	1.8	0.7	0.9	1.3	2.4
	#2	1.8	1.7	1.1	0.9	0.7	1.3
	#3	1.4	2.0	1.2	0.6	0.9	1.0
	#4	0.6	1.7	0.8	0.6	1.2	1.6
	#5	2.4	2.0	0.8	0.7	0.8	1.4
	#6	2.1	1.7	0.7	1.0	1.2	0.9
	#7	1.6	2.5	0.8	0.8	----	----
	#8	3.0	2.7	0.6	0.7	----	----
	#9	2.2	1.7	0.6	0.9	----	----
	#10	2.4	1.5	0.6	0.4	----	----
	#11	1.0	1.9	----	----	----	----
	#12	1.3	1.6	----	----	----	----
	Average	*1.8*	*1.9*	*0.79*	*0.75*	*1.02*	*1.43*
Section 34 - Flood - 2nd Cut	#1	0.7	0.7	1.3	1.1	----	----
	#2	0.7	1.0	0.9	1.3	----	----
	#3	1.0	1.1	0.8	0.9	----	----
	#4	0.9	0.8	0.5	2.5	----	----
	#5	0.8	0.6	0.6	1.9	----	----
	#6	1.2	0.6	0.6	0.7	----	----
	Average	*0.88*	*0.80*	*0.78*	*1.4*	----	----

Table B-3. 2005 through 2007 Hay Analyses (cont.)

Irrigation Area	Sample	2005 Uranium (mg/kg)	2005 Selenium (mg/kg)	2006 Uranium (mg/kg)	2006 Selenium (mg/kg)	2007 Uranium (mg/kg)	2007 Selenium (mg/kg)
Section 28 - Pivot - 1st Cut	#1	1.6	1.4	1.0	0.6	0.7	1.0
	#2	1.6	1.7	1.2	1.1	1.1	1.2
	#3	2.1	1.7	1.0	0.8	0.9	1.2
	#4	1.8	1.8	1.5	1.3	0.9	0.9
	#5	1.8	1.1	1.5	1.3	0.6	0.6
	#6	1.5	1.5	1.3	1.7	0.6	0.7
	#7	1.5	1.6	0.7	1.1	0.6	0.7
	#8	1.9	0.9	1.3	1.5	1.0	0.7
	#9	3.3	1.5	1.3	1.1	1.3	1.0
	#10	1.9	1.5	1.4	1.4	0.7	1.1
	#11	1.7	2.4	1.3	1.2	0.9	1.0
	#12	1.3	0.9	1.0	0.9	0.9	0.9
	Average	*1.8*	*1.5*	*1.2*	*1.2*	*0.9*	*0.9*
Section 28 - Pivot - 2nd Cut	#1	0.8	1.3	0.5	1.5	1.3	1.4
	#2	0.9	1.4	0.9	1.2	0.7	1.0
	#3	1.0	1.4	1.3	1.5	0.8	0.8
	#4	0.8	1.1	0.7	1.7	1.0	1.0
	#5	1.0	1.3	0.6	1.3	0.9	0.9
	#6	0.9	1.3	0.6	1.5	1.5	1.3
	#7	1.1	0.9	0.8	1.0	2.4	1.1
	#8	0.6	1.2	1.0	1.3	1.8	1.6
	#9	0.9	1.3	0.7	0.8	1.3	1.1
	#10	0.9	1.0	0.6	1.2	1.7	1.3
	#11	1.5	1.1	0.7	1.1	2.2	1.1
	#12	0.9	1.6	0.8	1.1	3.5	1.2
	Average	*0.94*	*1.2*	*0.77*	*1.3*	*1.59*	*1.2*
Section 28 - Pivot - 3rd Cut	#1	1.2	1.6	0.8	0.9	1.6	1.8
	#2	1.2	1.8	0.7	0.7	1.1	1.3
	#3	1.0	1.9	0.7	0.7	0.9	1.5
	#4	1.7	1.4	0.9	1.0	0.6	1.0
	#5	1.5	1.4	0.7	1.1	0.8	1.4
	#6	1.5	1.2	0.8	1.1	1.7	1.6
	#7	1.4	1.2	0.9	1.0	1.1	1.3
	#8	1.2	1.3	0.2	1.1	1.2	1.2
	#9	1.8	1.3	0.5	1.0	1.4	1.2
	#10	1.4	1.5	0.3	1.0	1.5	1.3
	#11	1.8	1.2	0.4	0.8	1.2	1.4
	#12	1.4	1.9	0.5	1.0	0.9	1.0
	Average	*1.4*	*1.5*	*0.62*	*0.95*	*1.17*	*1.33*