ATTACHMENT 4

GROUND WATER MONITORING PLAN

SECTION 6

Site Hydrogeology, Geochemistry, and Environmental Monitoring

6.1 PRIOR SITE ASSESSMENTS

The geology and hydrogeology of Site A have been characterized by a series of investigations that began in 1959 when the site was assessed for use as a missile base. ESII and USEI conducted investigations since 1980 to characterize the hydrogeology at the site and to design the groundwater monitoring system. Reports of these investigations have been provided to IDEQ and EPA Region X.

The following provides a synopsis of the investigations that have been incorporated into the site characterization described in this report. For a detailed discussion of each investigation, refer directly to the document of interest.

1. Shannon and Wilson, 1959. Report to U.S. Army Corps of Engineers District, Walla Walla, WA on Subsurface Investigations and Surveys, Special Site Studies, Site Number M-E4, Mountain Home Air Force Base, Idaho.

   This report was prepared for the U.S. Army Corps of Engineers prior to development of the site as a missile base. It provides general information on the climate and regional geology, with more detailed information on subsurface exploration, geophysical exploration, laboratory test results, groundwater studies, and foundation conditions. Eight test borings, ranging from 100 to 250 feet deep were drilled. Seventeen seismic lines totaling 8,030 linear feet of traverse were accomplished. Sources of recharge and general water supply conditions were investigated, and a test well was drilled to a depth of 2,500 feet. The test well had an estimated yield of at least 845 gallons per minute (gpm) and a static water level 813 feet below grade. The report recommended that a second well be drilled, as the first was not free-flowing. This second well was installed at a later date.

2. Finite Resources, 1981. Wes Con A Site Groundwater Waiver Demonstration.

   This report included an attached report by Anderson and Kelly (1977) assessing the hydrology of the site. It relied on field reconnaissance, the Shannon and Wilson report, and several USGS reports. The report identified the deep artesian aquifer reported by Shannon and Wilson and speculated that a shallower perched, intermittent groundwater zone could exist during periods of wetter-than-normal precipitation. This report provided no original data.

3. J. M. Montgomery, 1984. Hydrogeologic Investigation for Envirosafe Services of Idaho, Inc., Bruneau, Idaho, Site A.

   The hydrogeologic study responded to an EPA-X administrative order. The study consisted of drilling, testing, retentive capacity analysis, and sampling. Three test wells were installed: one to 1,000 feet (AMW-3) and two to 250 feet (AMW-1 and AMW-2). Each hole was neutron-logged, and AMW-3 was caliper-logged. AMW-3 had a static water level of 930 feet. This report started the Phase I assessment.

4. CH_2M HILL, 1985. ESII Site A, Site Hydrogeology and Groundwater Monitoring Plan -Interim Status Report.

   A site characterization study was initiated to support the application for a Part B operating permit. The interim status report addressed the physiography, climatology, regional geologic setting, local geology, and local and regional hydrogeology. It identified aquifer characteristics based in part on the drilling logs for four additional test wells drilled into the 936-foot water-bearing zone. It also provided water quality data from samples collected from each of the test wells and additional television and geophysical logs of the boreholes.

5. Morrison-Knudsen Engineers, Inc. 1988. Site Characterization - Phase I, ESII Site A, Bruneau, Idaho.

   This report continued the Phase I site characterization effort. It included field geologic mapping, remote sensing, a hydrogeologic assessment, facility construction details, waste history, potential monitoring techniques, and a plan for a Phase II field investigation program.

6. Morrison-Knudsen Engineers, Inc., 1987. Site Characterization - Phase II Interim Report, Site A, Bruneau, Idaho.

   This report provided more detail than Phase I on fault interpretations, dip of volcanic units, joint and fracture characterization (including rose diagrams), water level monitoring, and interpretation of groundwater flow directions. The work included a high resolution seismic reflection survey, borehole television surveys, water level, hydrographs, and potentiometric surface maps of the shallow aquifer.

7. Morrison-Knudsen Engineers, Inc., 1988. Site Characterization Report - Phase II, ESII Site A, Bruneau, Idaho.

   This report presented the results of additional Phase II site characterization work. The following specific tasks were performed and discussed in the report:

   - Coring of two angle holes under waste containing units
   - Rock core characterization
   - Organic vapor monitoring and chemical analysis
   - Monitoring pipe installation
   - Continuous water-level monitoring
   - Water-level monitoring and aquifer sampling

8. Morrison-Knudsen Engineers, Inc., 1990. Geohydrological Characterization Report, Phase III, ESII Site A, Bruneau, Idaho.

   Morrison-Knudsen Engineers, Inc. drilled a core hole (ACH-11A), production well (APW-10), and two observation wells (AOB-11 and AOB-12) for additional site characterization and to determine aquifer characteristics by conducting a 7-day pumping test. The production well was pumped for 7 days at up to 75 gpm. Water levels were monitored in the newly-installed wells and most existing wells. The transmissivity, storage coefficients, and barometric efficiencies of the upper aquifer were calculated. Water level responses recorded during the test indicate there is good hydraulic communication across the site. Faulting has provided recharge paths allowing deep regional geothermal artesian water to reach the uppermost aquifer.

9. Morrison-Knudsen Corporation, March 13, 1992. ESII Site A, Vadose Zone Characterization, Geologic Data Review Report.

   Geologic reports, maps, borehole logs, geophysical logs, and supporting literature were analyzed to compile data useful for characterizing the vadose zone underlying Site A. Geologic data and pertinent discussions regarding lithology, stratigraphy, fractures and fracture zones, porosity, flow contacts, and structure were presented in this report.

10. Daniel B. Stephens and Associates, Inc. (DBS), August 11, 1992. ESII Site A, Response to Item 9 in IDEQ's July 9, 1992, letter to ESI, Analytical Modeling of Solute Mixing in the Uppermost Aquifer.

    The vertical mixing depth of potential solute migration from the vadose zone into the uppermost aquifer was calculated using an analytical mathematical model. This calculation is relevant to the issue of selecting the appropriate depth of monitoring wells at Site A. The analysis shows that solutes entering the uppermost aquifer would be confined to a plume that is less than 30 feet below the top of the aquifer within a horizontal distance of 300 feet downgradient of the source. The existing monitoring wells are completed at least 50 feet into the uppermost aquifer, and therefore the depth of the existing monitoring wells appears to be sufficient to intercept potential solutes that enter the uppermost aquifer.

11. Daniel B. Stephens and Associates, Inc. (DBS), August 11, 1992. ESII Site A, Vadose Zone Characterization, Supplemental Modeling Results.

This report presents supplemental numerical modeling performed in response to the request for additional information by DEQ at a June 23, 1992, meeting in Boise, Idaho. IDEQ staff requested that additional numerical modeling be performed that would consider:

1) an absence of confining layers in the vertical direction; and

2) a geologic media with a saturated hydraulic conductivity of 1×10^{-3} centimeters per second (cm/sec).

The saturated hydraulic conductivity of 1×10^{-3} cm/sec is not believed to be representative of the hydraulic properties of any significant component of the vadose zone underlying Site A. Utilizing the higher hydraulic conductivity, the wetting front advances rapidly, meeting the boundary of the modeled domain 20 meters below the bottom of the silo in approximately 3 years. These results are not particularly meaningful because of the unrealistically high saturated hydraulic conductivity.

12. Daniel B. Stephens and Associates, Inc. (DBS), August 18, 1992. Vadose Zone Characterization of ESII Site A.

Hydrogeologic data from Site A were critically reviewed with regard to their adequacy for describing moisture flow in the vadose zone. Additional data were collected where needed so that numerical simulations of moisture flow could be performed. Numerical simulations of moisture flow were performed for a variety of initial and boundary conditions, using hydraulic properties measured on Site A materials. These simulations suggest that the extent of vertical and lateral migration of any potential releases from Site A disposal units would be limited. The simulation results indicate that moisture migration to the water table would be extremely unlikely. The results also indicate that the proposed groundwater compliance well network is properly located to detect any potential releases.

13. Daniel B. Stephens and Associates, Inc. (DBSI), August 1992. Analysis of Optimum Borehole Interval for Monitor Wells at ESII Site A.

    This report supplements the summary of aquifer conditions under Site A and provides the basis for the borehole interval selected for new monitor wells. The well design is based on the general thickness and hydrologic properties of the upper aquifer.

14. Morrison-Knudsen Corporation, August 1992. Summary of Aquifer Conditions Underlying ESII Site A.

    The aquifer system underlying Site A consists of a deep geothermal water-bearing zone (geothermal aquifer) at approximately 2,000 feet below ground surface and another water-bearing zone (upper aquifer) approximately 1,000 feet below ground surface. The aquifers are interconnected by leakage as shown by the results of pumping tests and by the similarity in temperature and general chemistry. The emphasis of site characterization efforts has been to define the geohydrological conditions in the upper aquifer and the overlying vadose zone. The report provides a concise summary of the general thickness and hydrogeologic properties of the upper aquifer. The results of all the previous investigations have been used to characterize the hydrogeology at the site and to design an appropriate groundwater monitoring system for the site.

6.2 REGIONAL SETTING AND LOCAL LAND USE

Site A is located along the southern edge of the Western Snake River Plain on the edge of the upland mountain area of the Bruneau Plateau. The Bruneau Plateau extends northerly to the Bruneau and Snake River Valleys. Elevations at Site A range from about 3,620 to 3,660 feet above mean sea level (msl). The area around the facility is sagebrush desert and is currently used for grazing range cattle. The nearest private property is an undeveloped 40-acre tract about 4 miles north of the facility where a well is used for stock watering. The nearest domestic groundwater withdrawal well is located approximately 8 miles north/northwest at a utility station. Additional wells approximately 8 miles away from Site A are used for irrigation and monitoring purposes. The nearest private residential well is approximately 10 miles northwest of the site. See Appendix I for

well summary reports, well location maps, and selected well logs discussed in this section. A review of well logs available from the Idaho Department of Water Resources reveals that:

- The only well permits issued for the immediate vicinity of Site A (Township 9S, Range 5E, Owyhee County) are the monitoring wells installed by Envirosafe Services of Idaho, Inc. at Site A. (Townships are defined by township and range numbers and are generally thirty six square miles in area. Sections are generally 1 mile square or 640 acres, and there are generally 36 sections within a township.)
- There are no well logs recorded for Township 9S, Range 4E, which is west of Site A; nor in Township 9S, Range 6E, which is east of the site; Groundwater contour maps for Site A indicate that groundwater flows towards the northwest.
- In Township 8S, Range 5E, due north of Site A, there is one permitted well that is used for stock watering. This well is located in Section 16 and is reportedly 3,354 feet deep. This depth appears to be a typographic error, and the well is likely 354 feet deep. See original well log in Appendix I. Pumped yields are reported at a relatively low 24.5 gallons per minute, which is a further indication that the well is relatively shallow. This property is the closest privately-owned parcel in the vicinity of Site A, and the well location is slightly more than 4 miles north of the site.
- In Township 8S, Range 6E, northeast of Site A, there are two wells reported. Both are monitoring wells owned by the US Department of the Interior. One is in section 3 and one is in section 4. No additional information is available on these wells. Sections 3 and 4 are more than 9 miles away from Site A.
- An industrial well is reported in Township 8S, Range 4E, Section 9, eight miles north of Site A, which is indicated as being 200 feet deep. This well log appears to be filed in error, as the county location of the well is listed as Caribou County. No other well logs are recorded for Township 8S, Range 4E.There are 49 livestock, irrigation or domestic wells located in Township 7S, Range 4E, northwest of Site A. One of these appears to be one of the domestic wells closest to Site A; it serves a utility pump station located 8 miles northwest in Section 34. This well is finished in fractured lava rock at a depth of 288 feet below ground surface. The well produced 18 gallons per minute when pumped for one hour. No temperature data were reported.
- There are 35 irrigation, livestock, or domestic wells reported in Township 7S, Range 5E. A private domestic well is reported in Section 33, approximately 7 miles north of Site A. The

well was drilled in 1994 and has a reported yield of 1,830 gallons per minute with a reported water temperature between 95 and 97º F. The well is finished in hard red rock at 1,319 feet below ground surface. This appears to be the private domestic well closest to Site A. There is an additional irrigation well in Section 33, but there are no wells closer to Site A than this well and the domestic well described previously.

- In Township 7S, Range 6E, northeast of Site A, there are thirty-two irrigation, stock-watering or domestic wells recorded. An irrigation well in Section 34 is approximately 10 miles from the Site A property boundary. This well is finished to a depth of 300 feet in basalt. Water temperature is reported at 92° F with a yield of approximately 2,000 gallons per minute. Surface elevation at this site is approximately 2,400 feet above msl.

6.3 SITE GEOLOGY

6.3.1 General Stratigraphy

Recent and quaternary alluvium consisting of sediment sand, gravels, silt, and some thin basalt flows form the upper portion of the geologic subsurface at the site. The sediments range from a few feet to tens of feet in thickness, but seldom exceed 50 feet in depth within the property boundary. Fill consisting of sand and gravel occurs in areas that were excavated during the construction of the site and during site closure work in 1996/1997. It appears that fill areas do not exceed 75 feet in thickness.

Underlying the alluvial fill material are silicic volcanics of Tertiary age which comprise the principal lithologic units underlying Site A. These rocks are part of the Idavada Group and consist mostly of rhyolite and related volcanic rocks. The volcanic sequence persists to a depth of at least 2,502 feet, which is the deepest well penetration at Site A. The sequence is comprised predominately of alternating units of variable thickness of porphyritic latite and associated glassy phases bounded by flow breccia and pyroclastics consisting of welded ash, tuff, and breccia. Figure 6-1 shows the location of geologic cross sections which are profiled in Figures 6-2 and 6-3.

6.3.2 Structure

Site A is located along the south edge of the Western Snake River Plain, which is considered part of a graben (down-dropped block), with west to northwest-trending high-angle faults occurring in nearly continuous zones along the north and south sides of the plain.

Site A is located near major fault structures along the southern margin of the Snake River "downwarp." Regional faulting, as mapped by others associated with the Snake River Plain, is concentrated within this area. Vertical displacements of several hundred feet have been measured on some of the regional faults.

One northerly trending fault lies approximately 1,000 feet south of the site along a tributary drainage of Sugar Creek and expresses as much as 100 feet of vertical displacement as indicated by topography. A second fault, as mapped by others, to the southeast, trends northwesterly and projects across the northern portion of the site. Indicated displacement of this fault is approximately 300 feet, with movement on the north side up, relative to down on the south side. This indicates that the facility lies within a graben feature.

Most of the sequences underlying the site are intensely jointed and fractured. General joint features, as exhibited by local mapping and subsurface boreholes, are "blocky" and "shingly." However, jointing created by magma cooling and fracturing associated with faulting and movement is complicated and nonsystematic and is highly variable from one unit to another. Some portions of thick flows appear dense, containing only minor fractures.

Field mapping, a lineament analysis of aerial photography, and a high resolution seismic survey indicate west to northwest trending lineaments and faults crossing the area. The dominant joint/fracture orientations at the site are N 15-25 ^{o} W and N65-75 ^{o} E (as illustrated in Figure 6-4) approximately parallel and perpendicular to the major structural trend. Most of the joints and fractures are high angle. The joint/fracture apertures are open and are generally less than 1 inch in width.

Two possible faults crossing Site A have been identified by seismic reflection and lineament analysis. The locations of the possible faults are shown in Figure 6-5. Fault E-E' (Figure 6-5) has apparently produced an area of higher hydraulic conductivities and upward leakage from the underlying regional thermal groundwater system. Fault F-F' (Figure 6-5) may be responsible for the

steeper potentiometric gradients present across the southern portion of the site. The possible hydrogeologic impacts of Faults E-E' and F-F' are discussed in Section 6.4.

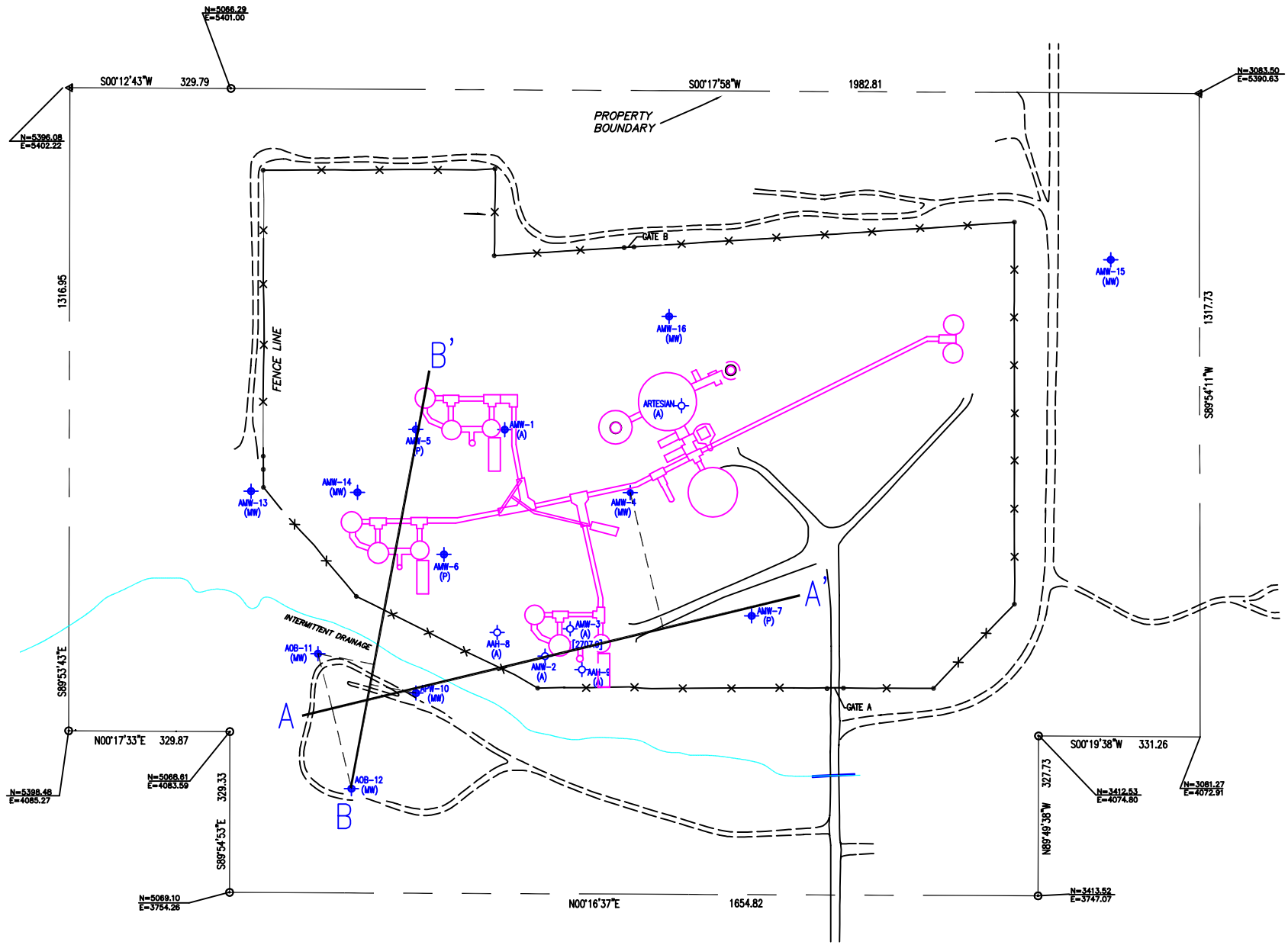
6.4 SITE HYDROGEOLOGY

6.4.1 Aquifer Identification

The deepest water-bearing zone known to exist at the site is at a depth of 2,076 feet below ground surface. The deep artesian wells which were once installed at the site were completed in this zone. This aquifer yields water at several hundred gallons per minute, and is under artesian conditions with a static water level about 835 feet below ground surface. Estimated static water level elevations of approximately 2,798 feet above mean sea level were measured in the artesian well. A minor water-bearing zone that produced 6 to 7 gpm was also encountered at 1,671 feet below ground surface, during construction of the artesian well (Shannon and Wilson, 1959).

Earlier work by others in the area indicates the general flow of the deep thermal systems is generally north by northwest toward the Snake River (approximately 20 miles north).

The uppermost aquifer underlying Site A is within a laterally continuous rhyolite lava flow where groundwater occurs under semi-confined conditions. The transmissivity apparently is the result of sheeting joints within the rhyolite flow central interior.



LEGEND

GROUNDWATER MONITORING WELLS/PIEZOMETERS

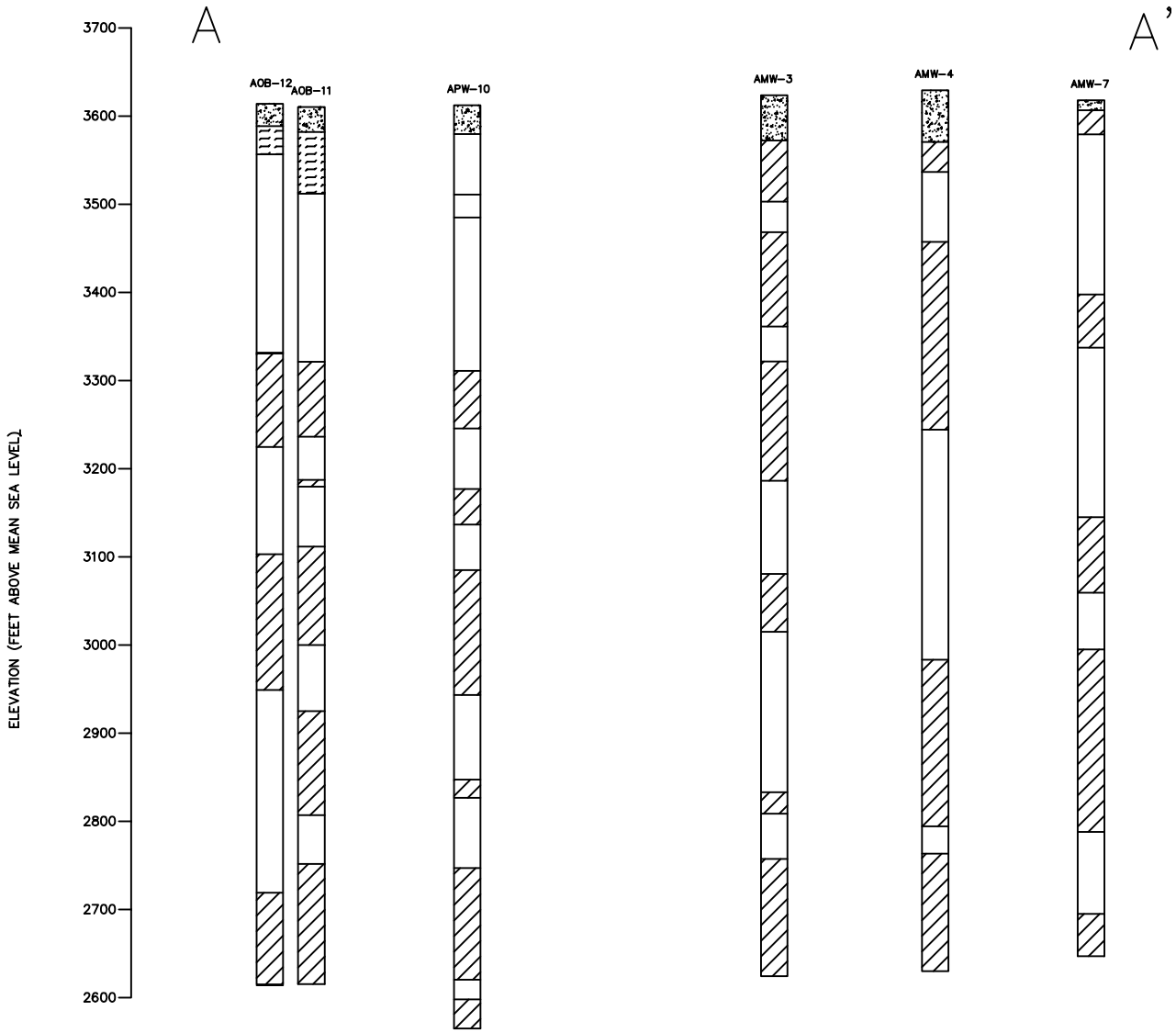
BROWN AND CALDWELL
Boise, Idaho

N

150 0 150 300

SCALE: 1 INCH = 300 FEET

FIGURE 6-1
SITE CROSS SECTION PLAN
US ECOLOGY IDAHO SITE A
BRUNEAU, IDAHO
OWYHEE COUNTY



LEGEND

- SAND AND GRAVEL
- TUFF
- RHYOLITE
- LATITE

P:\CAD\ES\128199\FIGURE 6-2.DWG

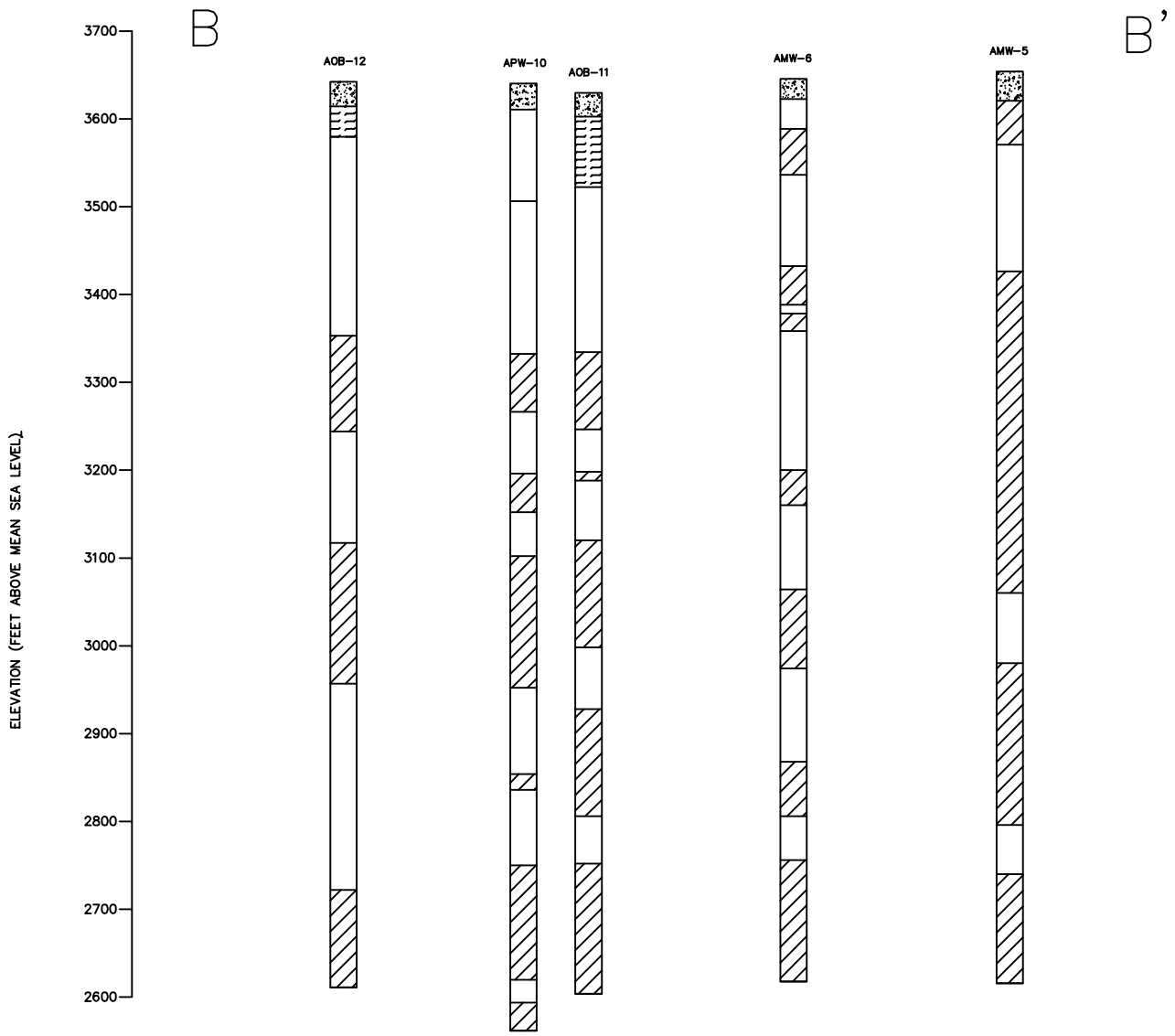
BROWN AND CALDWELL
Boise, Idaho

N

100 0 100 200

SCALE: 1 INCH = 200 FEET

FIGURE 6-2
GENERALIZED GEOLOGICAL CROSS SECTION
US ECOLOGY IDAHO SITE A
BRUNEAU, IDAHO
OWYHEE COUNTY



LEGEND

- SAND AND GRAVEL
- TUFF
- RHYOLITE
- LATITE

P:\CAD\ES\128199\FIGURE 6-3.DWG

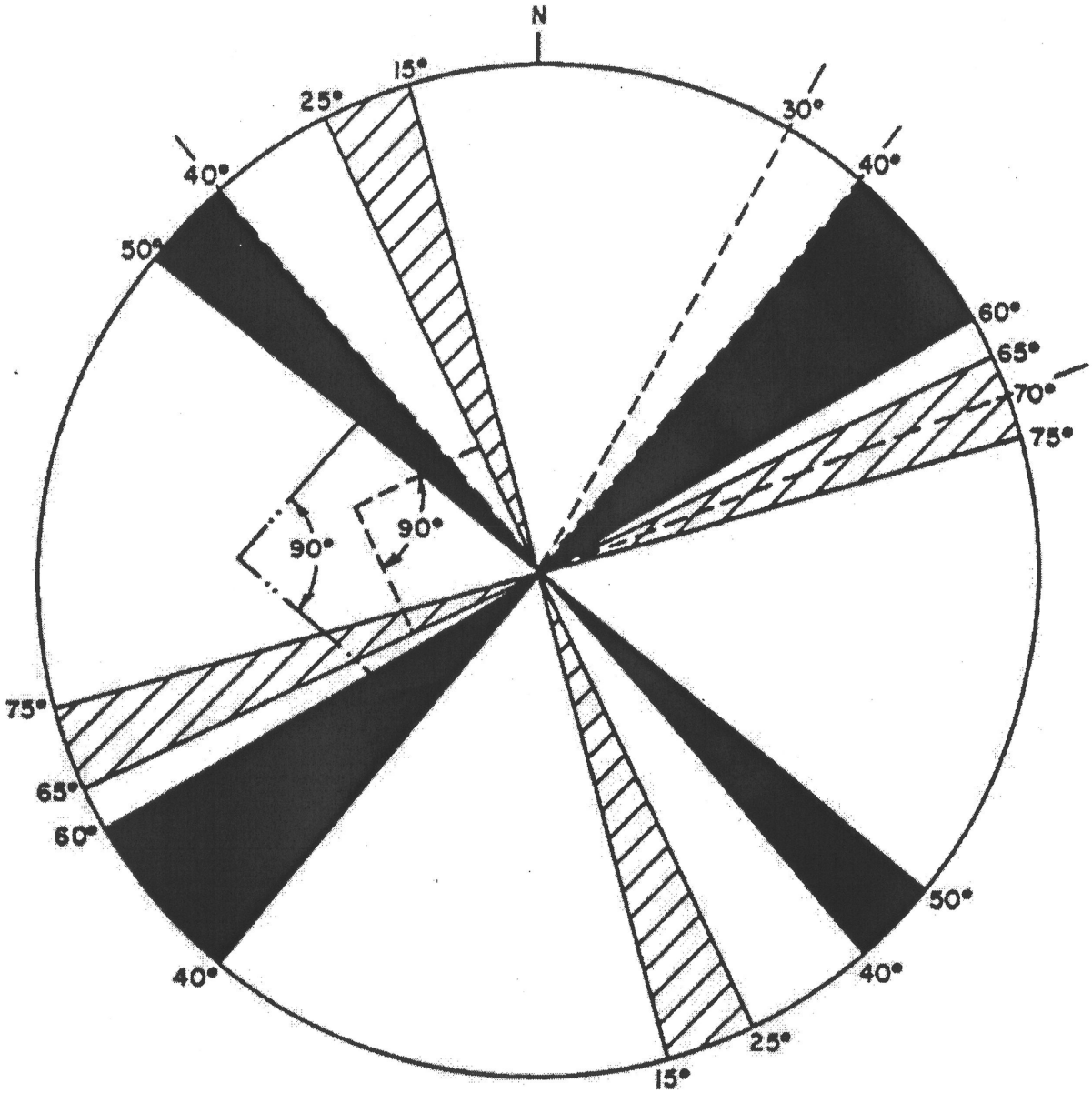
BROWN AND CALDWELL
Boise, Idaho

N

100 0 100 200

SCALE: 1 INCH = 200 FEET

FIGURE 6-3
GENERALIZED GEOLOGICAL CROSS SECTION
US ECOLOGY IDAHO SITE A
BRUNEAU, IDAHO
OWYHEE COUNTY



DOMINANT SURFACE LINEAMENTS FROM LINEAMENT INVESTIGATION

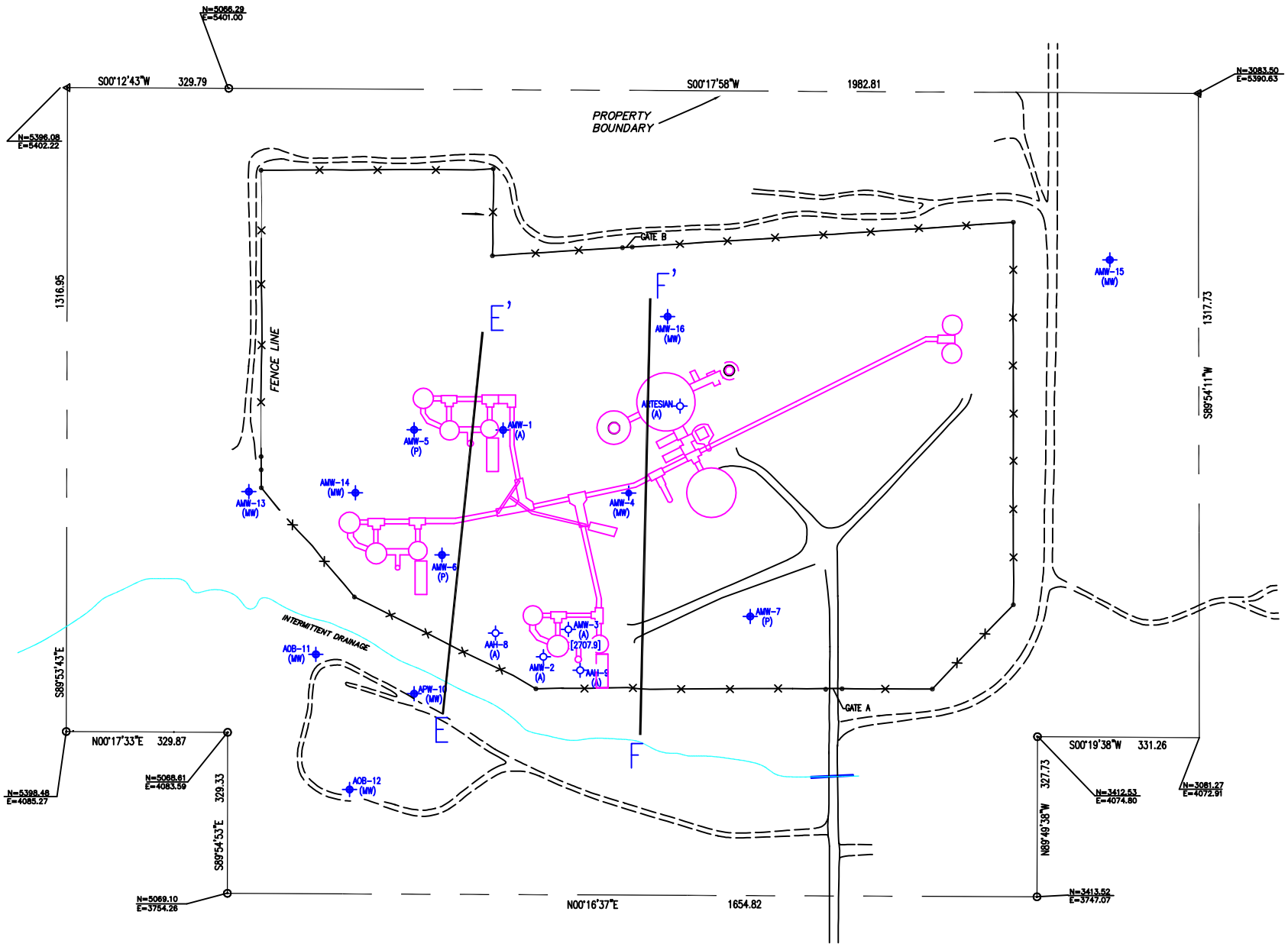
DOMINANT JOINT STRIKE ORIENTATIONS FROM BOREHOLE TV SURVEY

DOMINANT JOINT STRIKE ORIENTATIONS FROM FIELD MAPPING

ROWN AND CALDWELL
Boise, Idaho

FIGURE 6-4
DOMINANT JOINT/FRACTURE ORIENTATION
US ECOLOGY IDAHO SITE A
BRUNEAU, IDAHO
OWYHEE COUNTY

P:\CAD\ES\128199\FIG6-4.DWG



LEGEND

GROUNDWATER MONITORING WELLS/PIEZOMETERS

BROWN AND CALDWELL
Boise, Idaho

N

150 0 150 300

SCALE: 1 INCH = 300 FEET

FIGURE 6-5
LOCATION OF POSSIBLE FAULTS
US ECOLOGY IDAHO SITE A
BRUNEAU, IDAHO
OWYHEE COUNTY

P:\CAD\ES\128199\FIGURE 6-5.DWG

Through review and correlation of borehole geophysics and television video logs, the uppermost aquifer was defined to extend from the top of the saturation (approximately 980 feet below land surface) to the depth at which significant groundwater ceased to enter a well. This analysis (Morrison Knudson, 1992) indicates that the thickness of the uppermost aquifer ranged between 37 and 52 feet. Less significant contributions of groundwater to the wells may occur from minor fractures or less porous strata at greater depths in the rhyolite sequence. There is sufficient separation between the uppermost aquifers and deeper aquifer sequences of volcanic rocks of relatively low hydraulic conductivity (as evidenced by the head differential of approximately 95 feet between the artesian well and shallow Site A wells) and the difference in hydrologic characteristics (artesian versus semi-confined), to identify the uppermost aquifer as the zone requiring monitoring at Site A.

Existing monitoring wells and piezometers are completed in the uppermost water-bearing zone. Static water level of the uppermost aquifer beneath Site A ranges from approximately 2,705 feet to 2,695 feet above mean sea level.

As detailed in previous reports, the uppermost aquifer is hydraulically connected to the regional artesian aquifer via upward leakage of groundwater through faults and fracture systems. Groundwater in the uppermost aquifer beneath Site A is provided via a fault zone(s) located south of the site and apparently up Fault E-E' (Figure 6-5).

Evidence of recharge to the uppermost aquifer from leakage up Fault E-E' was observed during the recovery portion of the 7-day pumping test described in the Phase III Report (Morrison Knudson, 1990). Water levels in AMW-6 apparently rose 6 to 8 feet above pretest static water levels and temporarily formed a "recharge mound” in the vicinity of the well.

Table 6-1 provides tabulated water level data for Site A as measured during sampling events from 1984 to the present. Additional water level data are contained in the various investigative reports previously submitted to IDEQ regarding Site A. Figures 6-6 and 6-7 show that water levels in the primary aquifer have decreased over time. There may be a connection between closure events of 1996/1997 and the changes in water table elevation. At closure, the last remaining artesian well was plugged and abandoned and transducers were installed to measure water table elevations.

These transducers were removed in 1998 based on the belief that manual measurements would be more accurate and precise.

6.4.2 Groundwater Flow Direction

USEI obtains water level (or piezometric head) measurements from all monitoring wells and piezometers prior to each sampling event or prior to purging the well if the water level was not measured prior to starting the semi-annual sampling event. To minimize error caused by variations in barometric pressure, USEI obtains all water level measurements within a single day; or within consecutive days, during which the barometric pressure changes by no more than 0.5 inches of Mercury. USEI uses this data to determine the direction and rate of the groundwater flow annually. USEI submits a written review of the adequacy of the groundwater monitoring system relative to observed groundwater flow direction with the contour map. Groundwater elevation data is presented in Table 6-1 and Figures 6-6 and 6-7.

Figure 6-8 presents the most recent groundwater contour map and Figure 6-9 presents a groundwater contour map based on 1993 data. As can be seen, groundwater contours are essentially unchanged over this 23 year period. Groundwater generally flows to the north-northeast across the southern portion of Site A and to the north and northwest across the northern half of the site. Flow lines appear to converge to the north of Silo 1 in the general vicinity of well AOB-11. Groundwater flow directions around the Silo 3 complex are less well-defined but generally also converge toward AOB-11. The convergence of groundwater flow lines and more widely spaced potentiometric surface contour lines shown in the vicinity of AOB-11 are consistent with the higher aquifer transmissivities determined for this area from the pumping test conducted by Morrison Knudson.

Table 6-1: Site A Water Level Elevations; Fall 1984 to Spring 2016

USEI SITE A WATER LEVEL ELEVATION BY DATE													
WELL NUMBER	**AMW3**	**AMW4**	**AMW5**	**AMW6**	**AMW7**	**APW-10**	**AOB-11**	**AOB-12**	**AMW-13**	**AMW-14**	**AMW-15**	**AMW-16**	**ART**
EASTING	8,825.18	9,103.34	9,234.58	8,978.12	8,849.83	8,694.40	8,775.55	8,499.14	8,499.14	8,499.14	8,499.14	8,499.14	NA
NORTHING	11,582.64	11,458.61	11,896.60	11,840.41	11,210.62	11,898.20	12,098.52	12,030.89	12,030.89	12,030.89	12,030.89	12,030.89	NA
TOC. ELEV.	3,635.77	3,646.13	3,638.73	3,627.91	3,654.81	3,622.22	3,615.20	3,619.42	3,624.87	3,627.00	3,664.88	3,645.95	3,633.7
TOC. ELEV. 2		3,646.94		3,628.71	3,656.16	3,623.22	3,616.63	3,620.94	3,624.87	3,627.00	3,664.88	3,645.95	
DATE	**AMW3**	**AMW4**	**AMW5**	**AMW6**	**AMW7**	**APW-10**	**AOB-11**	**AOB-12**	**AOB-13**	**AOB-14**	**AOB-15**	**AOB-16**	**ART**
28-Nov-84	2,698.6												
07-Jun-85	2,698.8												
26-Jun-85	2,695.6	2,696.5	2,699.4	2,705.7									
16-Jul-85	2,696.5	2,696.9	2,695.5	2,710.7									
17-Jul-85					2,703.6								
18-Jul-85		2,697.9											2,793.7
29-Jul-85	2,696.7	2,697.1	2,694.2	2,700.4	2,687.0								2,798.1
31-Jul-85				2,702.4									
08-Aug-85			2,694.7										
09-Aug-85		2,697.1		2,691.9	2,704.1								2,798.9
20-Aug-85	2,697.6	2,697.5	2,695.4	2,694.6	2,704.4								
21-Aug-85				2,695.6									
22-Aug-85					2,703.4								
30-Aug-85	2,696.7	2,698.5	2,696.0	2,695.7	2,704.2								2,790.7
04-Sep-85	2,698.7	2,700.1	2,697.0	2,696.9	2,706.3								
09-Sep-85	2,700.1	2,700.9	2,698.8	2,698.9	2,707.4								
12-Sep-85	2,700.2			2,699.2	2,707.9								
13-Sep-85	2,701.5	2,701.3	2,699.2	2,699.4	2,708.3								
26-Sep-85	2,700.9	2,701.3	2,700.5	2,700.0	2,708.2								
03-Oct-85	2,700.6	2,702.3	2,698.8	2,699.8	2,708.4								
10-Oct-85	2,702.0	2,702.6	2,699.9	2,700.5	2,709.6								
17-Oct-85	2,702.3	2,702.9	2,700.9	2,701.9	2,710.4								
24-Oct-85	2,702.2	2,702.9	2,701.1	2,701.2	2,709.8								
31-Oct-85	2,702.5	2,703.2	2,701.4	2,702.5	2,710.1								
07-Nov-85	2,701.7	2,703.5	2,701.7	2,702.5	2,710.3								
14-Nov-85	2,703.2	2,703.6	2,701.6	2,702.4	2,710.1								
22-Nov-85	2,703.6	2,703.2	2,701.6	2,702.8	2,709.7								
19-Mar-86	2,705.0	2,709.8	2,703.8	2,703.7	2,711.9								
29-Sep-86	2,701.4	2,702.4	2,700.6	2,706.6	2,709.5								2,801.6

WELL NUMBER	AMW3	AMW4	AMW5	AMW6	AMW7	APW-10	AOB-11	AOB-12	AMW-13	AMW-14	AMW-15	AMW-16	ART
06-Nov-86	2,702.7	2,713.3	2,701.6	2,703.9	2,710.3								2,801.6
12-Dec-86	2,703.7	2,708.4	2,702.7	2,706.8	2,710.7								2,801.7
20-Jan-87	2,703.9	2,710.5	2,702.9	2,705.7	2,711.1								2,801.0
02-Mar-87	2,704.7	2,705.9	2,703.3	2,707.0	2,712.0								2,801.6
14-Apr-87	2,706.3	2,707.2	2,705.0	2,708.5	2,713.3								2,803.2
13-Jul-87			2,702.3										
28-Oct-87	2,702.9	2,703.7	2,701.8	2,704.7	2,710.9								2,801.3
26-Oct-88	2,702.4	2,702.9	2,701.1	2,701.1	2,710.4								
06-Apr-89	2,705.6	2,706.0	2,704.3	2,703.6	2,712.8								
16-Aug-89	2,702.7	2,703.5	2,701.2	2,700.1	2,710.7								2,793.9
30-Oct-89	2,702.2	2,703.1	2,700.9	2,702.8	2,710.7	2,700.0							2,801.1
08-Jan-90	2,696.1	2,695.5	2,695.0	2,694.8	2,706.8	2,694.1	2,693.4	2,692.7					
01-Mar-90	2,699.4	2,699.9	2,698.8	2,699.8	2,706.2	2,697.2	2,696.1	2,696.0					
02-Apr-90	2,706.5	2,707.8	2,705.5	2,706.0	2,713.9	2,704.7	2,702.9	2,703.1					2,801.5
25-May-90	2,706.2	2,707.8	2,705.4	2,706.2	2,714.2	2,703.9	2,701.4	2,701.8					2,802.6
08-Oct-90	2,704.0	2,704.9	2,702.7	2,702.4	2,712.1	2,701.9	2,699.6	2,699.8					2,797.8
19-Feb-91	2,706.7	2,707.4	2,705.4	2,705.1	2,714.1	2,704.5	2,701.8	2,702.1					
30-Apr-91	2,708.4	2,708.7	2,707.1	2,707.9	2,715.3	2,704.7	2,703.3	2,703.1					2,797.8
10-Oct-91	2,703.5	2,704.4	2,702.2	2,701.4	2,711.9	2,700.4	2,698.4	2,698.9					2,799.8
28-Apr-92	2,706.3	2,707.4	2,705.3	2,705.4	2,714.2	2,703.3	2,701.3	2,701.7					
29-Oct-92	2,704.3	2,704.6	2,702.3	2,700.9	2,711.9	2,700.6	2,698.5	2,699.0					2,800.4
11-May-93	2,707.9	2,708.5	2,706.5	2,705.1	2,714.9	2,704.7	2,702.8	2,702.5					2,801.3
14-Oct-93	2,704.3	2,704.7	2,702.3	2,701.0	2,712.0	2,700.6	2,698.6	2,699.0					2,800.8
01-Mar-97		2,709.3		2,705.7	2,716.9	2,706.9	2,705.0	2,707.6	2,703.1	2,705.8	2,721.7	2,707.5	
01-Jun-98		2,697.9		2,694.7	2,704.9	2,697.3	2,695.5	2,694.3	2,696.1	2,690.5	2,710.8	2,695.3	
28-Sep-98		2,699.1		2,692.6	2,705.9	2,695.3	2,694.3	2,695.4	2,697.2	2,695.8	2,708.5	2,694.1	
18-Aug-99		2,693.4		2,690.4	2,700.9	2,691.2	2,689.2	2,689.5	2,691.1	2,690.8	2,706.4	2,689.9	
10-Nov-99		2,692.4		2,689.7	2,700.0	2,690.6	2,688.6	2,688.8	2,691.0	2,690.0	2,705.6	2,688.9	
19-Jun-00		2,695.1		2,692.4	2,701.9	2,692.9	2,691.1	2,691.5	2,692.5	2,692.9	2,702.8	2,691.4	
05-Mar-01		2,697.6		2,695.0	2,704.3	2,695.8	2,693.8	2,694.2	2,695.6	2,695.5	2,710.1	2,694.3	
18-Dec-01		2,695.3				2,693.4	2,691.6	2,691.9	2,693.1	2,690.8	2,710.1		
15-May-02		2,697.5		2,696.2	2,704.4	2,695.6	2,693.8	2,694.0	2,695.6	2,695.4	2,709.7	2,694.2	
17-Oct-02		2,689.4		2,686.5	2,697.4	2,687.3	2,685.5	2,685.7	2,687.0	2,686.9	2,703.1	2,685.7	
20-May-03		2,692.6		2,689.8	2,699.2	2,690.5	2,688.7	2,689.0	2,690.3	2,690.1	2,704.5	2,689.0	
13-Oct-03		2,688.2		2,685.1	2,695.7	2,685.8	2,683.9	2,684.2	2,685.5	2,685.4	2,701.5	2,684.1	
17-May-04		2,691.4		2,688.5	2,698.3	2,689.2	2,687.4	2,687.7	2,689.0	2,688.9	2,703.6	2,687.7	
13-Oct-04		2,687.3		2,684.1	2,695.1	2,684.9	2,683.1	2,683.4	2,684.6	2,684.5	2,700.9	2,683.3	
24-May-05		2,690.6		2,687.8	2,697.6	2,688.5	2,686.8	2,687.0	2,688.3	2,688.1	2,703.2	2,686.9	
02-Nov-05		2,688.0		2,685.0	2,695.6	2,685.7	2,683.9	2,684.0	2,685.5	2,685.4	2,701.2	2,684.1	
13-Jun-06		2,691.4		2,688.6	2,698.4	2,689.3	2,687.6	2,687.7	2,689.1	2,689.0	2,703.8	2,687.8	

WELL NUMBER	AMW3	AMW4	AMW5	AMW6	AMW7	APW-10	AOB-11	AOB-12	AMW-13	AMW-14	AMW-15	AMW-16	ART
24-Oct-06		2,688.1		2,685.0	2,695.8	2,685.8	2,683.9	2,684.2	2,685.5	2,685.4	2,701.4	2,684.2	
22-May-07		2,689.1		2,686.0	2,696.5	2,686.8	2,685.0	2,685.2	2,686.5	2,686.4	2,702.1	2,685.2	
29-Oct-07		2,686.7		2,683.6	2,694.5	2,684.3	2,682.4	2,682.7	2,684.1	2,683.9	2,700.3	2,682.7	
05-May-08		2,690.0		2,687.1	2,697.1	2,687.9	2,686.1	2,686.3	2,687.6	2,687.6	2,702.5	2,686.3	
30-Sep-08		2,685.4		2,682.1	2,693.6	2,682.9	2,681.0	2,681.2	2,682.6	2,682.5	2,699.2	2,681.2	
19-May-09		2,688.7		2,685.7	2,696.1	2,686.4	2,684.6	2,684.7	2,686.2	2,686.1	2,701.6	2,684.8	
20-Oct-09		2,684.6		2,681.3	2,692.8	2,682.1	2,680.3	2,680.4	2,681.8	2,681.7	2,698.6	2,680.5	
18-May-10		2,687.7		2,684.6	2,695.2	2,685.4	2,683.6	2,683.8	2,685.1	2,685.0	2,700.8	2,683.8	
27-Sep-10		2,684.1		2,680.7	2,692.4	2,681.5	2,679.6	2,679.9	2,681.2	2,681.2	2,698.2	2,679.9	
16-May-11		2,687.8		2,684.6	2,695.0	2,685.5	2,683.6	2,683.8	2,685.2	2,685.0	2,700.5	2,683.8	
04-Oct-11		2,684.5		2,681.1	2,692.7	2,681.9	2,680.1	2,680.3	2,681.6	2,681.5	2,698.6	2,680.3	
01-May-12		2,687.8		2,684.8	2,695.2	2,685.5	2,683.7	2,683.9	2,685.3	2,685.1	2,700.8	2,684.0	
10-Oct-12		2,683.0		2,679.4	2,691.3	2,680.2	2,678.3	2,678.5	2,680.0	2,679.8	2,697.4	2,678.6	
14-May-13		2,686.0		2,682.7	2,693.5	2,683.4	2,681.5	2,681.7	2,683.2	2,683.1	2,699.2	2,681.8	
22-Oct-13		2,681.8		2,678.2	2,690.2	2,679.0	2,677.1	2,677.2	2,678.6	2,678.5	2,696.2	2,677.3	
27-May-14		2,684.2		2,680.8	2,692.1	2,681.6	2,679.7	2,679.6	2,681.2	2,681.2	2,698.0	2,679.9	
07-Oct-14		2,680.6		2,676.8	2,689.2	2,677.6	2,675.6	2,675.8	2,677.1	2,677.1	2,695.4	2,675.9	
12-May-15		2,683.3		2,679.9	2,691.3	2,680.6	2,678.7	2,678.9	2,680.3	2,680.2	2,697.3	2,679.0	
06-Oct-15		2,679.4		2,675.6	2,688.1	2,676.3	2,674.4	2,674.6	2,675.9	2,675.8	2,694.3	2,674.5	
11-May-16		2,682.6		2,679.1	2,690.4	2,680.0	2,678.0	2,678.3	2,679.6	2,679.5	2,696.4	2,678.3	
MAX. WL.	2,708.4	2,713.3	2,707.1	2,710.7	2,716.9	2,706.9	2,705.0	2,707.6	2,703.1	2,705.8	2,721.7	2,707.5	2,803.2
MIN. WL.	2,695.6	2,696.4	2,694.2	2,675.6	2,687.0	2,676.3	2,674.4	2,674.6	2,675.9	2,675.8	2,694.3	2,674.5	2,790.7
AVG. WL.	2,702.2	2,696.9	2,701.1	2,694.9	2,703.6	2,690.7	2,688.7	2,688.9	2,686.6	2,686.3	2,702.3	2,685.2	2,799.5
(n)	44	80	43	81	79	50	49	49	37	37	37	36	21

Figure 6-6: Site A Historical Water Levels in AMW 4, 6, & 7; 1990 to 2016

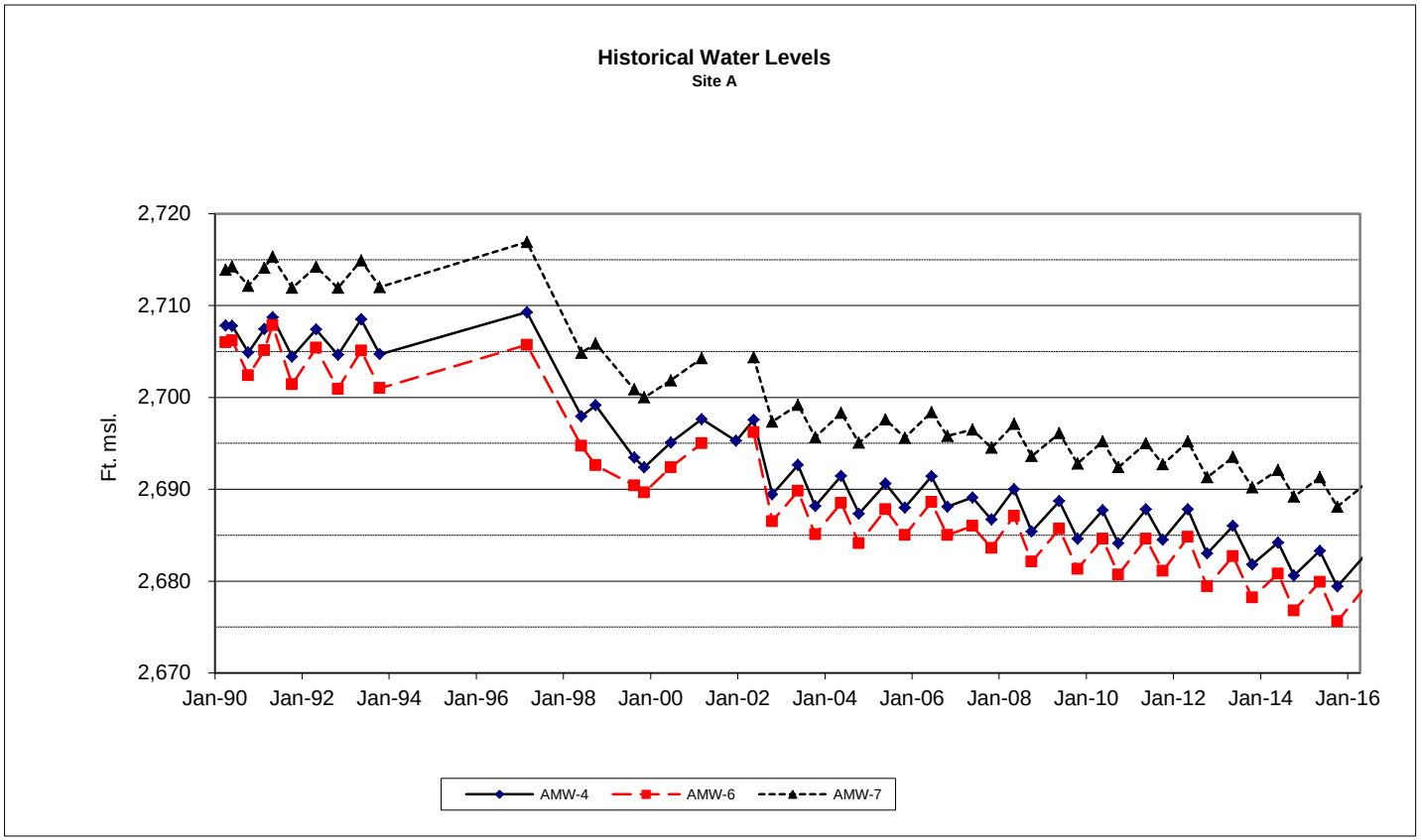
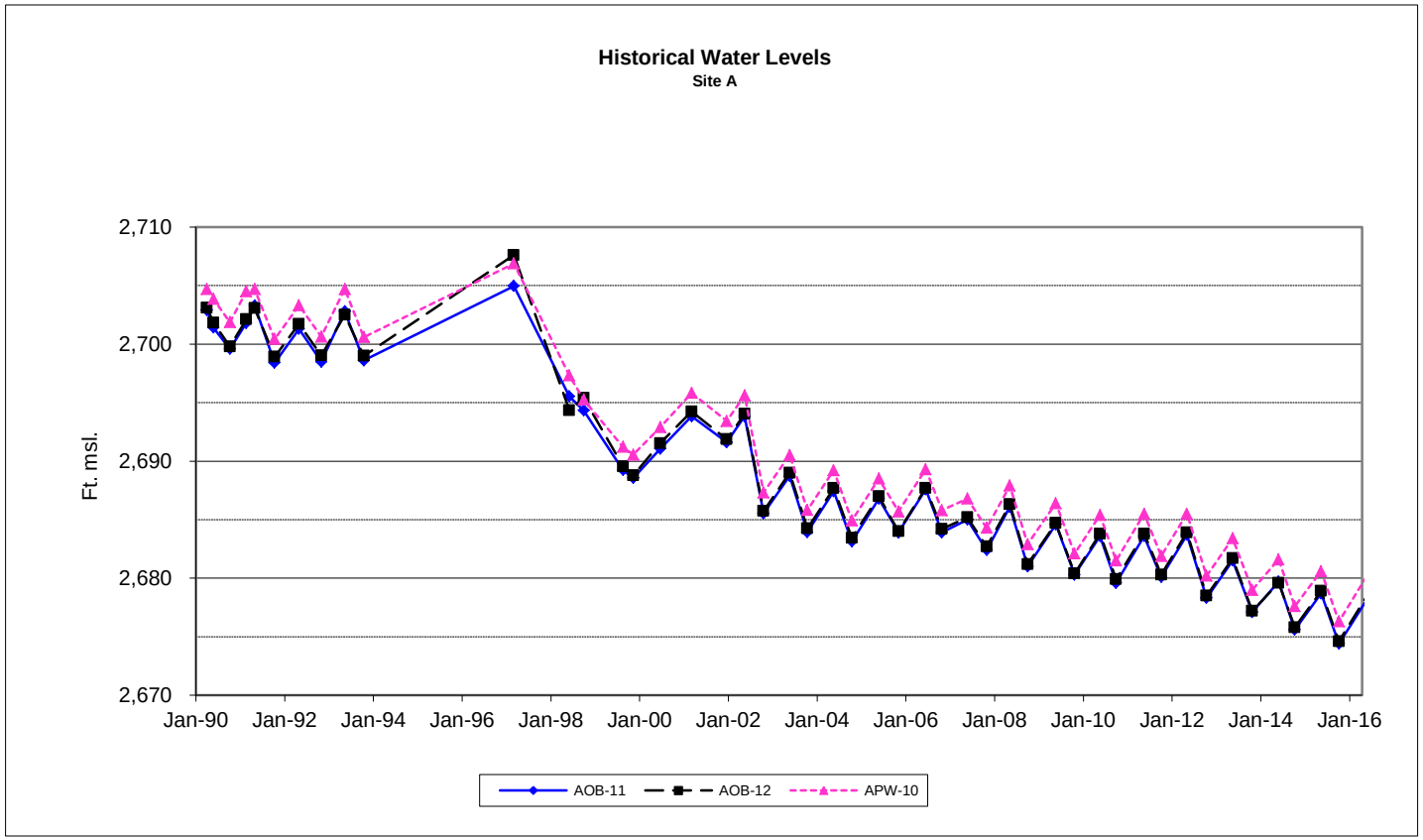


Figure 6-7: Site A Historical Water Levels in AOB-11, AOB-12 & APW-11; 1990 to 2016



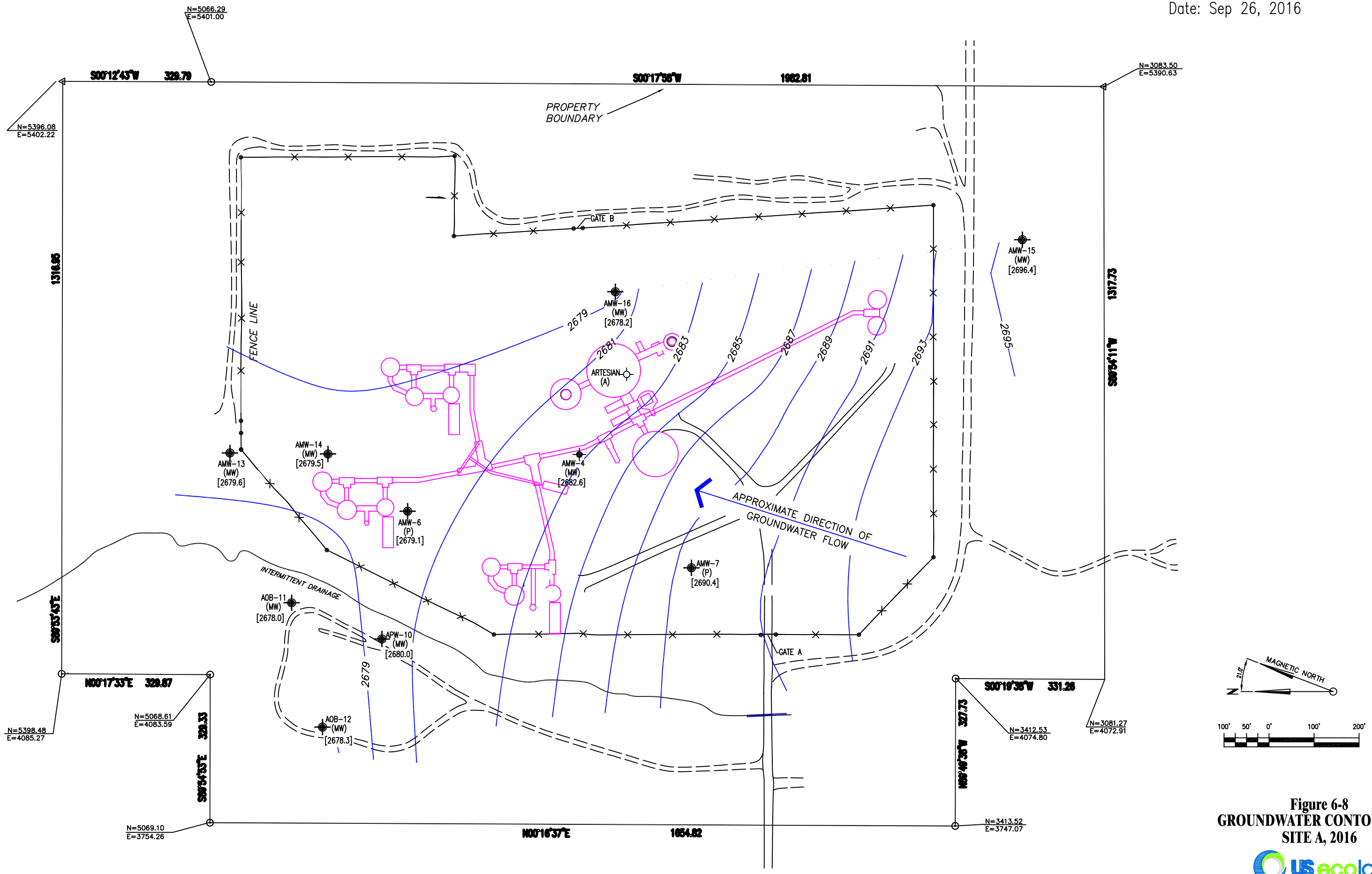
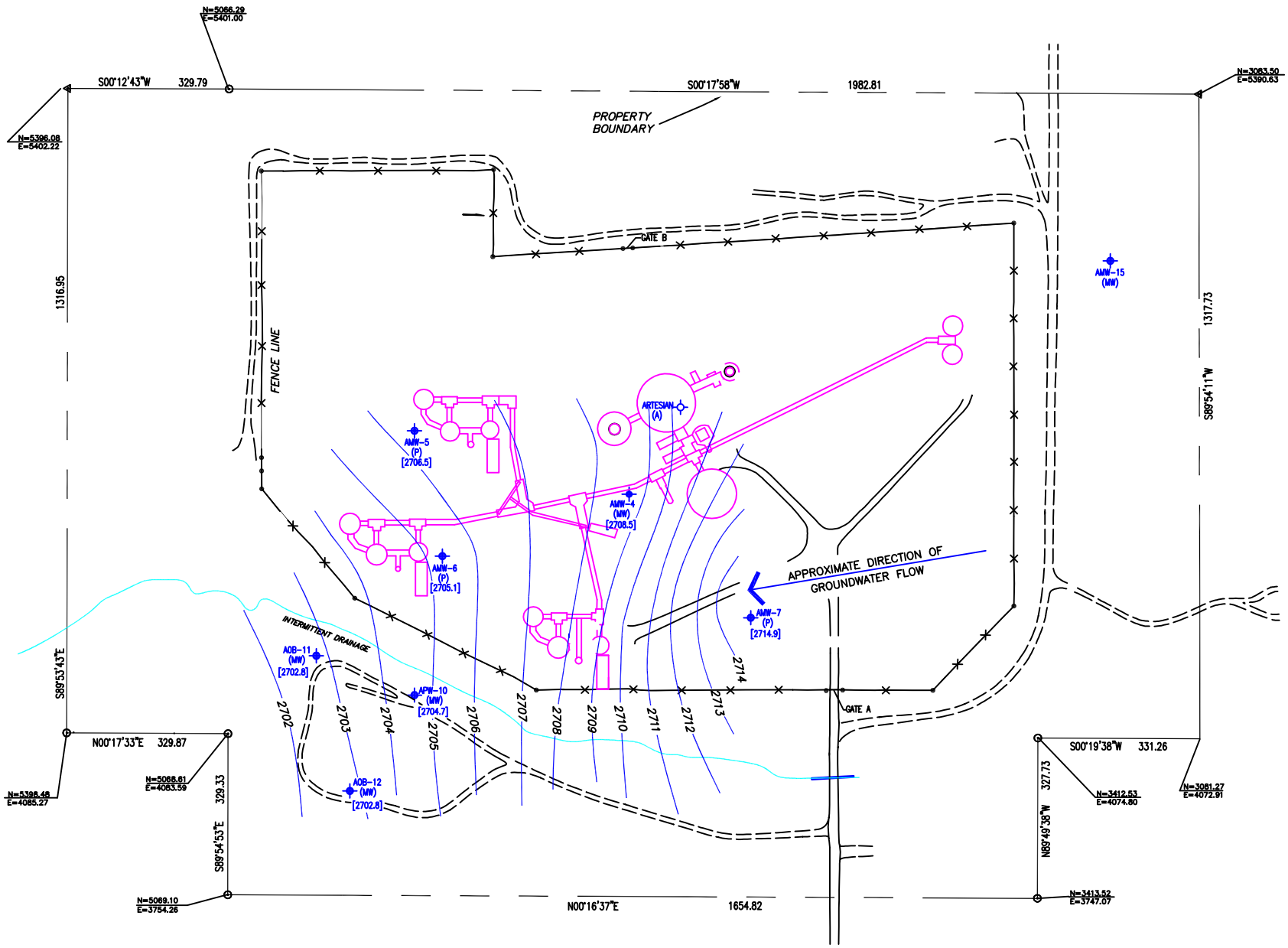


Figure 6-8
GROUNDWATER CONTOUR MAP
SITE A, 2016

US ecology



LEGEND

GROUNDWATER MONITORING WELLS/PIEZOMETERS

[2704.7] GROUNDWATER ELEVATION (5-11-1993)

2712 GROUNDWATER ELEVATION CONTOUR

BROWN AND CALDWELL
Boise, Idaho

N

150 0 150 300

SCALE: 1 INCH = 300 FEET

FIGURE 6-9
GROUNDWATER
CONTOUR MAP; 1993
SITE A BRUNEAU, IDAHO
OWYHEE COUNTY

P:\CAD\ES\128199\FIGURE 6-9.DWG

There are two distinct gradient regimes across the site. The southern two-thirds of the site has steep northerly gradients while the northern one-third has much flatter gradients. In addition, the northern one-third of the site can be split into two sub-regimes. Gradients in the northwest corner are to the west-northwest. Across the northeast corner of the site, the gradients are nearly flat with no discernible gradient direction. A possible gradient divide is present in the vicinity of AMW-14. This divided feature and flat gradients in the northeast corner have been historically present, and have been discussed and illustrated in various site characterization reports. Fracturing associated with Fault E-E' may be responsible for the generally higher aquifer transmissivities present across the northern half of the site.

6.4.3 Aquifer Characteristics

The uppermost aquifer was found to behave as a leaky confined aquifer based on analysis of the pumping test data provided in the Phase III report (Morrison Knudson, 1990). Table 6-2 provides a summary of the aquifer properties and methods of analysis presented in the Phase III report. The Phase III report concludes that the upper aquifer has a transmissivity of about 11,500 gallons per day per foot (gpd/ft) and a storage coefficient of 0.037.

A report prepared by Feast Geosciences (*Hydraulic Conductivity, Effective Porosity and Groundwater Velocity Calculations, USEI Site A,* Letter, Chuck Feast to Jim Hancock, February 2, 2003) provides an updated assessment of the Morrison Knudson report as supplemented by literature data. (See Appendix J.) The transmissivity, hydraulic conductivity, storativity, and effective porosity values presented in this report were prepared following EPA guidance (*Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Interim Final Guidance,* EPA, 1979). These values have been used for groundwater velocity calculations in Site A semi-annual groundwater reports prepared since that date. Darcy Velocities for the site vary from 3 to 13 feet per day over the southern portion of the site and 1 to 4 feet per day in the northwestern portion.

Table 6-2: Summary of Results of Pumping Test Data Analysis

Well	Q	ds	b	T	K	S	Technique	Comments
APW-10	61	--	90	--	--	--	S/L	Data did not form drawdown curve
	75	4.22	90	4,700	0.0025	--	S/L	3,000m+
	75	--	90	--	--	--	t/t’	Data did not form recovery curve
AMW-3	61	0.53	20	30,300	0.071	0.00063	S/L	200-3,000m, u < .01
	75	1.12	20	17,600	0.042	0.0071	S/L	3,000-7,000 m, u > .02
	61	--	20	9,700	0.023	0.0028	Leaky	600-1,500m, x = 0.3
	75	0.80	20	24,700	0.058	--	t/t’	180-1,200m
AMW-4	61	0.53	45	30,300	0.032	0.0044	S/L	Poor data curve, <3,000m, u > 0.02
	75	0.97	45	20,400	0.021	0.0087	S/L	Poor date curve, >3,000m, u > 0.02
	75	--	45	9,000	0.0094	0.0090	Leaky	
	75	--	--	--	--	--	--	Data did not form recovery curve
AMW-5	61	0.23	61	69,900	0.054	0.00098	S/L	<3,000m, poor date curve, u > 0.02
	75	--	61	5,700	0.0044	0.0093	Leaky	Poor curve match, >2,000m
	75	0.24	61	82,400	0.064	--	t/t’	Poor recovery curve
AMW-6	61	1.13	63	14,200	0.011	0.0015	S/L	150-760M, u >0.02, lower T 700-2,000m
	61	--	63	12,900	0.0097	0.0015	L/L	70-840m, recharge 1,000-3,000m
	75	--	--	--	--	--	t/t’	Data did not form recovery curve
AMW-7	61	--	--	--	--	--	S/L	Data did not form drawdown curve
	61	--	31	13,400	0.020	0.018	L/L	Poor curve match

Table 6-2: Summary of Results of Pumping Test Data Analysis (continued)

Well	Q	ds	b	T	K	S	Technique	Comments
	75	--	--	--	--	--	t/t’	Insufficient data
AOB-11	61	0.15	37	107,200	0.137	0.00026	S/L	40-3,000m, u <0.01
	75	0.72	37	27,400	0.035	0.055		3,000-7,000m, u>0.02
	61	--	37	22,500	0.029	0.0035	Leaky	150-1,500m, V – 0.3, lower T 1,500-3,000m
	75	0.34	37	58,100	0.074	--	t/t’	75-630m, lower T630-2, 800m
AOB-12	61	0.60	52	23,600	0.021	0.0018	S/L	30-400m, u >0.02, recharge 400-3,000m
	75	0.97	52	20,400	0.018	0.0085	S/L	3,000-7,000, u <0.02, recharge 7,000m +
	61	--	52	14,900	0.014	0.0021	Leaky	50-2,200m
	75	1.03	52	19,200	0.017	--	t/t’	30-250m
	75	0.47	52	42,100	0.038	--	t/t’	260-3,360m

Q = Pumping rate in gallons per minute (gpm)
ds = Rate of semilog drawdown (recovery) in ft/cycle
b = Estimated aquifer thickness (ft) based on geophysical logs
T = Transmissivity in gpd/ft
K = Calculated hydraulic conductivity in cm/sec
S = Storativity
S/L = Semi-Log (Cooper and Jacob, 1946)
L/L = Log-Log (Theis, 1935)
Leaky = Log-Log (Cooper, 1963)
t/t’ = Theis time ratio
m = Minutes
u and v are discussed in referenced analytical technique (Source: Morrison Knudson, 1990)

6.5 GROUNDWATER MONITORING NETWORK

6.5.1 Location of Sub-Units

Wastes are contained in sub-units which were part of the missile base structures at Site A. As part of the corrective action for the site, potentially contaminated surface soils and general debris were placed in several of the missile base structures prior to those structures being capped. Consequently, the entire missile base structure, including surface and subsurface features, is considered a corrective action management unit (CAMU) (see Drawing 2005-1). Since the bulk of the wastes are in Silos 1 and 3, the well locations are more densely spaced in the areas downgradient of these units. The Idaho DEQ has determined that the requirements of 40 CFR §264 Subpart F apply to Site A. A point of compliance, as required by 40 CFR §264.95 (b)(2), is shown on Figure 6-10.

6.5.2 Monitoring Well Network Description

Modifications to the monitoring well network occurred during site closure. Well logs and other data were submitted to IDEQ in March 1997 in the closure certification report. Vertical boreholes AMW-1 and AMW-2, well AMW-3, and angle vadose wells AAH-8 and AAH-9 were plugged and abandoned. The Artesian Well was also plugged and abandoned. Monitoring well AMW-5 was plugged and abandoned shortly after closure. Two new downgradient wells, AMW-13 and AMW-14, were constructed. A new upgradient monitoring well, AMW-15, was installed and developed, and a new piezometer, AMW-16, was installed. In spring 2003, AMW-16 was fitted with a submersible pump and added to the detection monitoring system.

All monitoring wells are equipped with a submersible pump and a water level sounding tube constructed of type-304 stainless steel. The pumps are set near the top of the water column. During site closure work, pressure transducers were installed to measure water depth. These were removed in 1998 to rely on more accurate hand measurements.

The groundwater monitoring well network now consists of eight wells completed in the uppermost aquifer and two piezometers as shown in Figure 6-10. Monitoring well and piezometer information is provided in Table 6-3.

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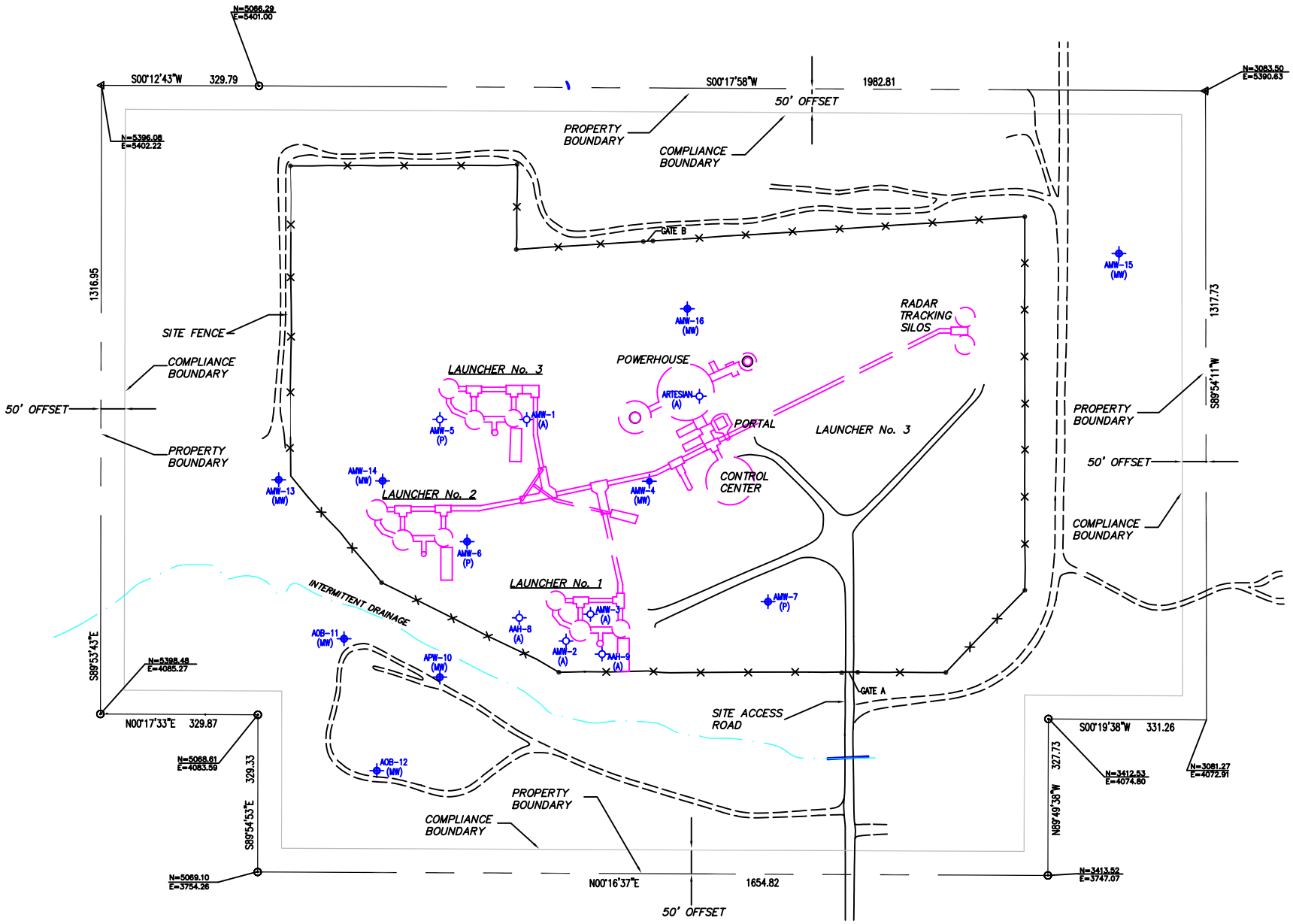
The geological strata at Site A contain numerous layers of competent volcanic and pyroclastic flows. The casings installed in the Site A wells penetrate through several of these layers in approximately the first 300 to 400 feet below ground surface, and are sealed with cement. Beneath the casing, the wells are open boreholes extending about 600 to 700 feet to the saturated zone. (See Table 6-3). The adequacy of partially cased wells to protect groundwater from release of liquids at Site A was evaluated by simulation conducted by Daniel B. Stephens and Associates (DBS, August 19, 1992). This study provides additional information relative to the potential for older wells at Site A to enhance vertical migration of contaminants. This evaluation concluded that lateral spreading of contaminants would be less than 60 to 150 feet (approximately 20 to 50 meters) from the edge of a silo. Additionally, vertical migration under the most conservative set of assumptions was limited to about 200 feet beneath the silo. Thus, provided the wells are located at least 150 feet from waste management units, the potential for enhanced vertical migration of liquids down a partially cased borehole appears to be very low. However, gasses which are heavier than air may migrate to the open areas of the boreholes, descend to the water table, and partition into groundwater within the wells.

Compounds of petroleum hydrocarbons have been found in some wells at the site, and the Idaho DEQ has concluded that these constituents are not from a regulated unit. A recent report on testing of residuals taken from a failed pump motor (Letter, January 31, 2006, "Report on Motor Residuals Test") supports the Agency's assessment. (See Appendix K.) The report showed that petroleum hydrocarbons were present in pump motor residuals in concentrations and locations that would account for constituents detected in prior groundwater samples. In addition, wells with detectable petroleum hydrocarbons frequently showed no further detections when failed pump motors were replaced.

Remaining constituents (such as chloroform) detected in recent years (See Table 6-5) are volatile organic compounds which are denser than air and which could have migrated from disposal areas into the vadose zone and preferentially followed boreholes to the water surface. Chloroform and similar constituents have been detected sporadically in small concentrations, and the lack of any geographic pattern or consistency in their appearance is an additional characteristic of the vagaries of gas migration and partitioning.



LEGEND

GROUNDWATER MONITORING WELLS/PIEZOMETERS

ABANDONED GROUNDWATER MONITORING WELLS

BROWN AND CALDWELL
Boise, Idaho

N

150 0 150 300

SCALE: 1 INCH = 300 FEET

FIGURE 6-10
MONITORING NETWORK
LOCATION MAP
US ECOLOGY IDAHO SITE A
BRUNEAU, IDAHO
OWYHEE COUNTY

P:\CAD\ES\128199\FIGURE 6-10.DWG

Table 6-3: Well Construction Details; Site A, Bruneau, Idaho

Well Construction Details						
Well No.	**Top of Casing Elevation (ft. above msl)**	**Total Depth (ft.)**	**Casing Depth (ft.)**	**Casing Diameter (in.)**	**Open Well diameter (in.)**	**Use**
AMW-4	3646.94	1,005	300	6	6	Downgradient Detection Monitoring Well
AMW-6	3628.71	997	397	6	6	Piezometer
AMW-7	3656.16	1,000	347	6	6	Piezometer
APW-10	3623.22	1,050	296	8	8	Downgradient Detection Monitoring Well
A0B-11	3616.63	1,003	300	8	8	Downgradient Detection Monitoring Well
AOB-12	3620.9	1,000	302	8	8	Downgradient Detection Monitoring Well
AMW-13	3624.87	1,000	400	8	8	Downgradient Detection Monitoring Well
AMW-14	3627	1,000	400	8	8	Downgradient Monitoring Well (Compliance Monitoring)
AMW-15	3664.88	1,000	300	8	8	Background Monitoring Well
AMW-16	3645.95	1,020	300	8	8	Downgradient Monitoring Well (Compliance Monitoring)

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6.5.3 Well Maintenance

The monitoring wells are inspected as part of the overall site inspection and monitoring schedules. Maintenance activities are documented and kept on file with the groundwater monitoring records throughout the post-closure care period.

6.6 GROUNDWATER SAMPLING AND ANALYSIS

6.6.1 Introduction to Groundwater Monitoring Programs

The groundwater monitoring program at Site A follows the standards for groundwater monitoring at hazardous waste landfills established in 40 CFR, Part 264, Subpart F. Detection monitoring, compliance monitoring, corrective action monitoring, and the special case of dense non-aqueous phase liquids are discussed below.

6.6.2 Detection Monitoring

Detection monitoring under the existing permit includes sampling designated monitoring wells on a semiannual basis. Individual parameters and specific trigger values are used to determine if resampling, expanded laboratory testing, compliance monitoring or further assessment is warranted. As noted below, sampling may also occur at other-than-scheduled times depending on analytical results and their comparison with method detection limits or with groundwater protection standards specified in the permit.

USEI currently analyzes groundwater samples for the 27 volatile organic compounds (VOCs) listed in Table 6-4, using U.S. EPA SW-846 Method 8260. The 27 compounds are the most mobile, soluble, and easily detectable by-products associated with a potential release of organic wastes from disposal units on site. The groundwater protection standards shown in Table 6-4 are based on the U.S. EPA RegionalScreening Levels, May 2016 version, for tapwater at a 1×10^{-4} cancer risk level. This risk is calculated as a cumulative risk. That is, risks for all detected constituents are added together. Groundwater protection standards apply to all wells in the compliance monitoring program. This level of protection was chosen due to the remoteness of Site A and the lack of possible points of exposure within 4 miles of the site.

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Detectable VOC concentrations are compared to the Practical Quantitation Limit (PQL) in Table 6-4. When concentrations above the PQL appear, USEI notifies the IDEQ Director in writing within seven calendar days, and decides whether to:

- Immediately collect two independent verification samples from any affected well, or
- Demonstrate that either an off-site source caused the increase, or that the increase resulted from an error in sampling, analysis, or evaluation, or
- Sample the well for constituents listed in 40CFR, Part 264, Appendix IX (a combination of 222 elements and compounds classified as volatile and semi-volatile compounds, metals and inorganics, pesticides, herbicides, PCBs, dioxins and furans), and prepare a report providing results of this testing, and proposing changes needed to the monitoring program based on comparing analytical results to the groundwater protection standards shown on Table 6-4.

If analytical results from both verification samples fail to confirm the detection of VOCs above the Practical Quantitation Limit, USEI resumes detection monitoring after notifying the IDEQ Director that the detection monitoring program is being resumed.

If analytical results from either verification sample confirm the presence of any VOC constituent above the PQL, USEI notifies the IDEQ Director within 7 days, and resamples the affected well for *Appendix IX* elements and compounds within 30 days, and submits a report within 60 days of sampling that either:

- Demonstrates that an off-site source caused the increase, or that the increase resulted from an error in sampling, analysis, or evaluation, or
- Provides results of the *Appendix IX* testing, and proposes changes to the monitoring program based on comparing analytical results to the groundwater protection standards shown on Table 6-4.

If USEI proposes (or the Director requires) that the affected well be entered into the compliance monitoring program, this change occurs after a permit modification has been prepared, submitted, reviewed, offered for public comment, and approved.

Table 6-4: Twenty Seven Selected VOC Compounds, CAS Numbers, Practical Quantitation Limits (PQLs), and Groundwater Protection Standards (GPSs)

Analyte (by Method 8260b)	CAS Number	PQL (ug/L)	GPS (ug/l)
1,1,2,2-Tetrachloroethane	79-34-5	1	7.6E+00
1,1,1-Trichloroethane	71-55-6	1	8E+05
1,1,2-Trichloro-1,2,2-Trifluoroethane (CFC 113)	76-13-1	1	5.5E+06
1,1,2-Trichloroethane	79-00-5	1	2.8E+01
1,1-Dichlorethane	75-34-3	1	2.8E+02
1,1-Dichloroethylene	75-35-4	1	2.8E+04
1,2-Dichloroethane	107-06-2	1	1.7E+01
1,2-Dichloropropane	78-87-5	1	4.4E+01
Benzene	71-42-2	1	4.6E+01
Bromodichloromethane	75-27-4	1	1.3E+01
Bromoform	75-25-2	1	3.3E+02
Bromomethane	74-83-9	1	7.5E+02
Carbon Tetrachloride	56-23-5	1	4.6E+01
Chlorobenzene	108-90-7	1	7.8E+03
Chlorodibromomethane	124-48-1	1	8.7E+01
Chloroethane	75-00-3	1	2.1E+06
Chloroform	67-66-3	2	2.2E+01
Chloromethane	74-87-3	1	1.9E+04
Cis-1,2-Dichloroethylene	156-59-2	1	3.6E+03
1,3-Dichloropropene	542-75-6	1	4.7E+01
Ethyl benzene	100-41-4	1	1.5E+02
Methylene Chloride	75-09-2	1	1.1E+03
Tetrachloroethylene (PCE)	127-18-4	1	1.1E+03
Toluene	108-88-3	1	1.1E+05
Trans-1,2-Dichloroethylene	156-60-5	1	3.6E+04
Trichloroethylene (TCE)	79-01-6	1	4.9E+01
Vinyl Chloride	75-01-4	1	1.9E+00

* Source: US EPA Regional Screening Levels May 2016, https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables-may-2016
Risk=1E-04

If the IDEQ Director concurs in the demonstration that an off-site source caused the increase, or that the increase resulted from an error in sampling, analysis, or evaluation, then the subject well is returned to the detection monitoring program.

If the IDEQ Director does not concur in the demonstration, then the Director will notify USEI to undertake *Appendix IX* sampling, prepare a report comparing the results with the groundwater protection standards shown on Table 6-4, and identifying changes needed in the monitoring program, all within 45 days of notice. *Appendix IX* testing results may not be used in this case to demonstrate that an off-site source caused the increase, or that the increase resulted from an error in sampling, analysis, or evaluation.

Analytical results are also compared to both detection monitoring criteria (the PQLs) and to compliance monitoring criteria (the GPSs). If two or more constituents exceed the PQL, but not the GPS, a risk assessment is completed using U.S. EPA Regional Screening Levels to determine whether a risk 1×10^{-4} excess incidence of cancer has been exceeded. If this risk level has been exceeded, then the affected well enters the Corrective Action Monitoring Program described below.

If analytical results for wells in the detection monitoring program indicate that the groundwater protection standards of Table 6-4 are exceeded, then the well shall enter the Corrective Action Monitoring Program.

Figure 6-11 provides a diagram of the decisions required to respond to groundwater monitoring data at Site A.

6.6.3 Compliance Monitoring

One site well (AMW-16) is currently included in the compliance monitoring program. In compliance monitoring, designated wells are sampled semi-annually for the Table 6-4 compounds and every three years for the *Appendix IX* elements and compounds. If new elements or compounds are detected as a result of the *Appendix IX* testing, then they are added to the existing list of analytes. This is done through a USEI notice to the IDEQ Director and through a subsequent permit modification, which is issued after an opportunity for public comment. The groundwater protection

standard for any new chemical constituent shall be determined using US EPA Regional Screening Levels for tapwater at a 1 X 10^{-4} cancer risk level.
Once designated, a compliance monitoring well remains within this expanded analysis program until six consecutive samples indicate that Practical Quantitation Limits have not been exceeded.

If two or more constituents exceed the PQL, but not the GPS, a risk assessment considering ingestion and inhalation of groundwater is performed following permit conditions. If results of this risk assessment indicate a risk greater than 1 x 10^{-4} excess incidence of cancer in a residential scenario, then each affected well enters the Corrective Action Monitoring Program described below. This change is accomplished through a notice to the IDEQ Director and the preparation, submittal, and review of a permit modification which is afforded an opportunity for public comment prior to approval.

If the GPS is not exceeded, the well remains in the compliance monitoring program.

6.6.4 Corrective Action Monitoring Program

No Site A wells are in the corrective action monitoring program.

In corrective action monitoring, USEI will submit a plan to the IDEQ Director detailing protective measures for groundwater resources downgradient of each affected well. These measures may include alternative concentration limits, additional site investigation, or active remediation.

Concentration limits established for Corrective Action Monitoring are either equal to background values, a specified list of maximum concentrations for metals and pesticides, or alternative concentration limits that take into account:

- The physical and chemical characteristics of the waste in the regulated unit, including its potential for migration,
- The hydrogeological characteristics of the facility and surrounding land,
- The quantity of groundwater and the direction of groundwater flow,
- The proximity and withdrawal rates of groundwater users,
- The current and future uses of groundwater in the area,

- The existing quality of groundwater, including other sources of contamination and their cumulative impact on groundwater quality,
- The potential for health risks caused by human exposure to waste constituents,
- The potential damage to wildlife, crops, vegetation, and physical structures caused by exposure to waste constituents, and
- The persistence and permanence of the potential adverse effects.

In a Corrective Action Monitoring Program, the permit specifies the measures to be taken if hazardous constituents exceed concentration limits at the compliance point during the compliance period. Semi-annual reports on the effectiveness of the program are required.

6.6.5 Dense Non-Aqueous Phase Liquids

The monitoring approach adopted for Site A with regard to dense nonaqueous phase liquids (DNAPLs) consists of both an examination of groundwater concentrations for elevated values and an examination of site groundwater samples for the presence of phased liquids, sheens, or aromas. Any DNAPLs entering the aquifer will be accompanied by other non-DNAPL compounds and by a plume of dissolved compounds issuing from the DNAPLs. The monitoring programs for Site A will detect these dissolved phase compounds. In addition, samples of the first water discharged during the pre-sample purging are collected in a clear glass container and allowed to settle for 15 minutes and then inspected for indications of nonaqueous phase liquids, sheens, or aromas.

Figure 6-11
Groundwater Monitoring Data Analysis
Site A

18 Miles South of Bruneau, Owyhee County, Idaho

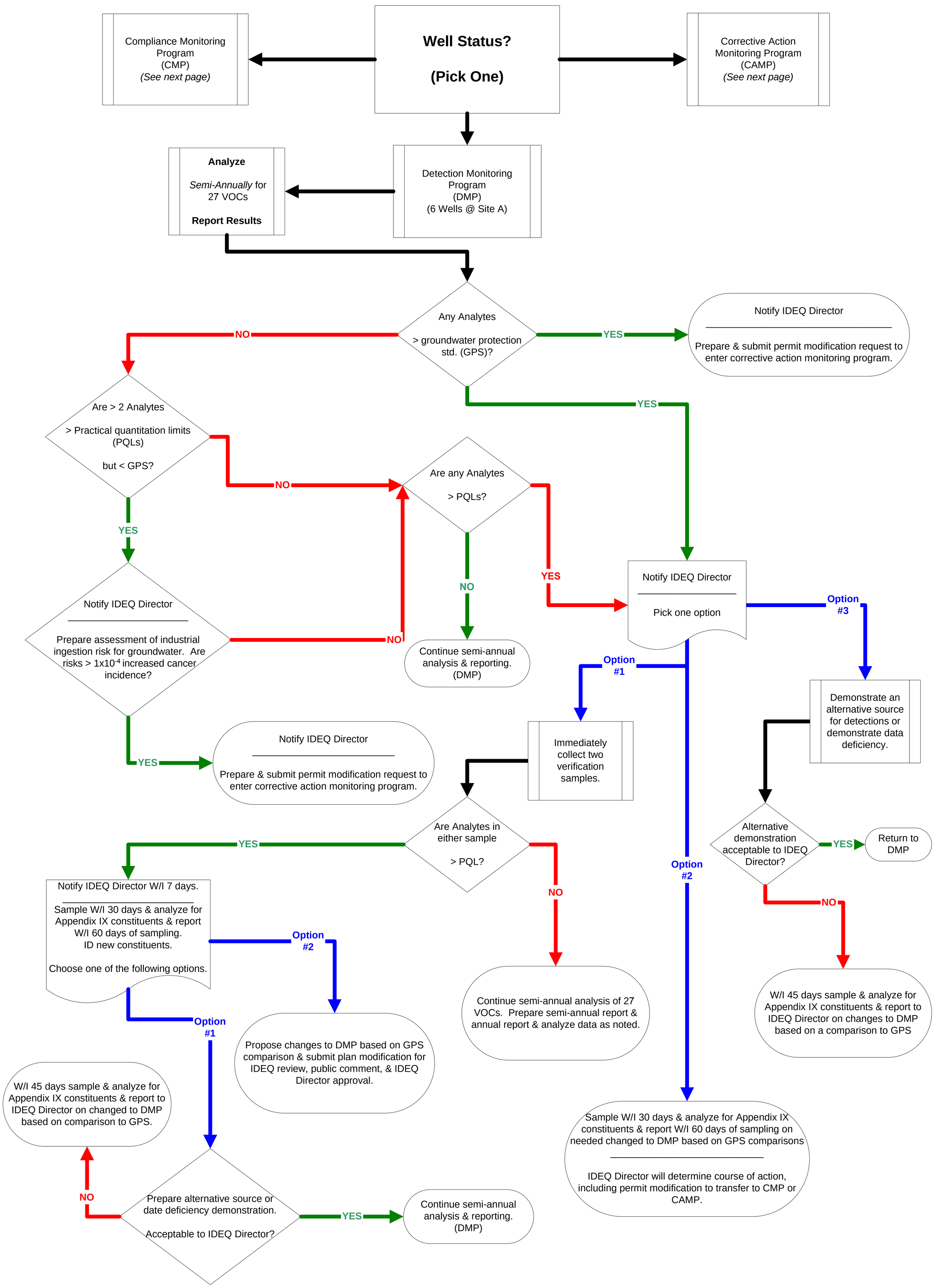
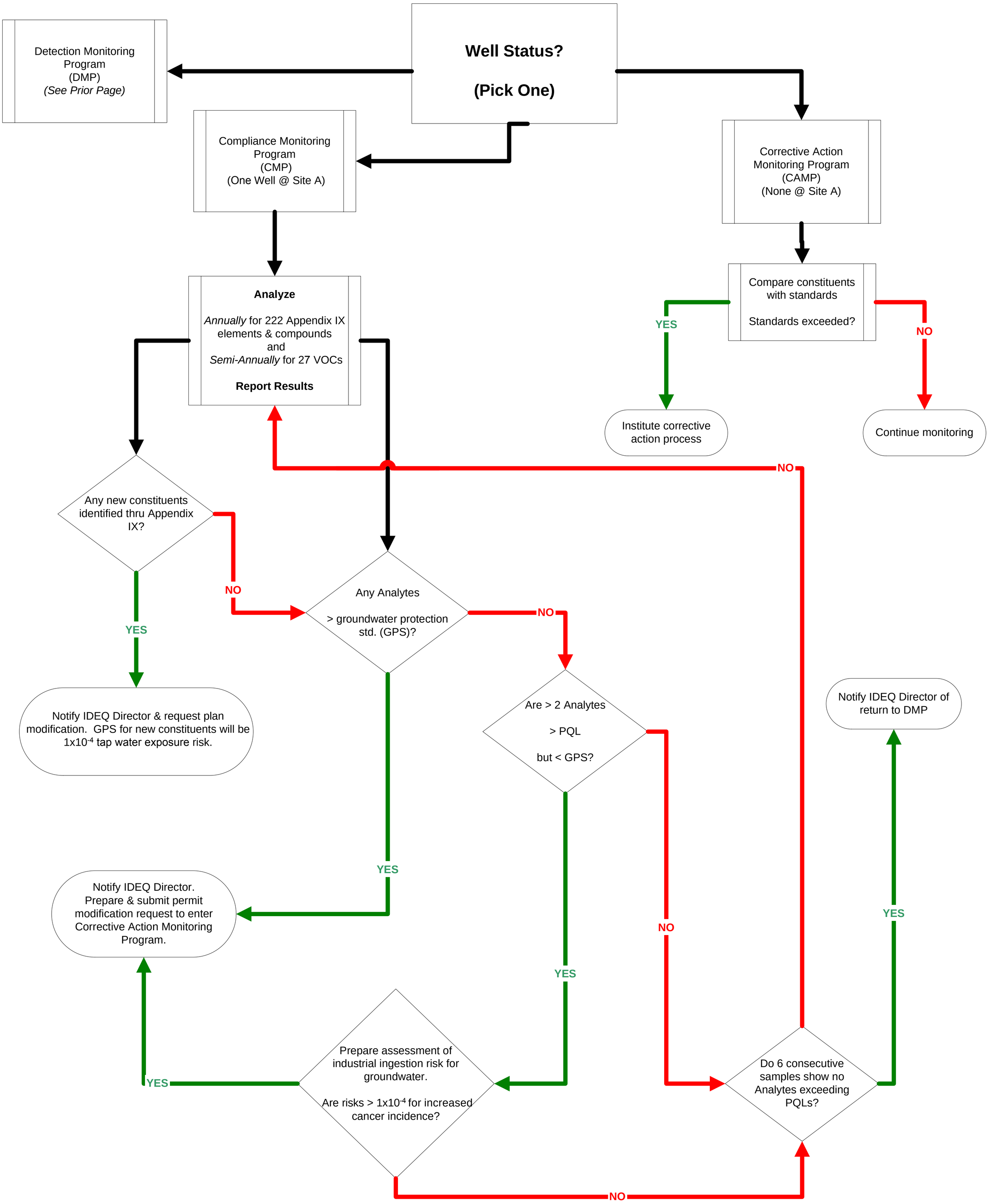


Figure 6-11 (continued)
Groundwater Monitoring Data Analysis
Site A

18 Miles South of Bruneau, Owyhee County, Idaho



6.7 GROUNDWATER MONITORING DATA

6.7.1 Pre-1995 Data

Data collected from a variety of sources provide an indication of site conditions prior to closure work. In many cases, these data sources are no longer available since they were plugged and abandoned in 1996/1997. Data tables presented in the 2002 permit update are reproduced in Appendix L and results are summarized below.

6.7.1.2 Test Well

A test well was drilled to a total depth of 2,502 feet below ground surface in December, 1959, and plugged and abandoned on August 8, 1978. The well was artesian. A sample collected in December, 1959 was analyzed for selected inorganics, total dissolved solids and alkalinity. The sample temperature was reported as 126 ^{o} F and pH was 9.2. The Fluoride concentration was 17.5 mg/L, and Fluoride consistently appears in all subsequent water samples in similar concentrations whenever it is included among the list of analytes.

6.7.1.3 Artesian Well

An artesian well was also drilled in December 1959 to a total depth of 2,250 feet, and sampled annually from 1981 until 1991. This well was plugged and abandoned during closure work in 1996/1997.

Parameters listed in 40 CFR 265, *Appendix III* (the 21 interim primary drinking water standards) were quantified from 1984 through 1989. The artesian well was monitored for parameters specified in 40 CFR 265.92(b)(2) (the five inorganics establishing groundwater quality) and 40 CFR 265.92(b)(3) (the four parameters used as indicators of groundwater contamination) from 1985 through 1991. Seventeen samples were collected from 1984 to 1991, and four of these were analyzed for a broader range of analytes including VOCs, pesticides, semi-volatiles, metals, or PCBs.

Analytical results from all sampling events showed parameters listed in *Appendix III* were below maximum levels allowed or were not detected, except for fluoride. Fluoride levels were

consistently in the 15 to 20 mg/L range. The maximum contaminant level goal for fluoride is 4.0 mg/L. Elevated fluoride is common to geothermal aquifer systems as indicated in data for the test well and artesian well. The artesian well data presents useful information concerning background concentrations of indicator parameters and inorganic constituents such as arsenic and fluoride.

6.7.1.4 Well AMW-3

Results are available for AMW-3 (now abandoned) from 1984 to 1994. This well was located adjacent to Missile Silo 1, and was developed in the primary aquifer. Analytical parameters were similar to those cited for the Artesian Well, and 28 samples were collected over a span of 10 years. Three of these samples included analytical results for, PCBs, volatile and semi-volatile organics, or pesticides. Except as noted below, results were negative for organic constituents and pesticides.

Results from 1985 show concentrations of two phthalates; bis(2-ethylhexyl) phthalate and Di-n-octyl phthlalate. Further sampling events at this well did not include sampling for these parameters, therefore the source of the two phthalates cannot be verified. Chloroform was detected at 3.2 ug/L in the same sample, and further sampling events at AMW-3 did not include analysis for chloroform. As noted above, this well has been abandoned.

6.7.1.5 Well AMW-7

AMW-7 was drilled and constructed to a total depth of 980 feet in June 1985 and deepened to 1,000 feet in October 1989. Groundwater from AMW-7 was sampled and analyzed in July 1985 to establish background values for indicator parameters and inorganics. This testing was broadened somewhat and repeated in 1991. AMW-7 was sampled and analyzed in August and October 1989 for volatile and semi-volatile organics, PCBs, pesticides, and certain indicators. Trace levels of an organophosphorus compound were detected in the October 1989 sample from AMW-7. In January 1990, AMW-7 was resampled and analyzed for organophosphorus pesticides. No organophosphorus pesticides were detected in the analyses completed by four different labs.

The 1989 samples did not show the presence of chloroform or BETX compounds at levels greater than 5 ug/L, which was the method detection limit at the time.

AMW-7 is now used as a piezometer.

6.7.1.6 Well APW-10

APW-10 was drilled and completed in September 1989 to a total depth of 1,053 feet, and sampled and analyzed four times from 1989 to 1991. Four samples were collected from 1989 to 1991. APW-10 continues in use as a downgradient monitoring well.

Initial sampling in September 1989 revealed no detectable concentrations of semi-volatiles. Trace levels of an organophosphorus compound were reported in an October 1989 sample. In January 1990, APW-10 was resampled (along with APW-7) and reanalyzed for organophosphorus pesticides. No organophosphorus pesticides were detected then, and none have been detected since.

In March 1990, at the conclusion of the 7-day pumping test, which purged 720,000 gallons of groundwater from the well, APW-10 was sampled and analyzed for PCBs, volatile and semi-volatile organics, pesticides and heavy metals. This sample and the sample from fall 1989 did not show the presence of chloroform or BETX compounds at levels greater than 5 ug/L, which was the method detection limit at the time.

6.7.2 Post-1995 Data

Site Groundwater monitoring from 1995 to 2006 concentrated on the analysis of 26 specified VOCs, with occasional sampling for the broader range of *Appendix IX* constituents (volatile and semi-volatile compounds, metals and inorganics, pesticides, herbicides, PCBs, dioxins and furans.). During the permit renewal in 2006, the list was increased to 27 constituents, which have been monitored since the permit was approved in 2007.

Table 6-6 presents analytical data concerning detection of VOCs from 1998 to present. The results demonstrate that VOCs occur sporadically at low concentrations at various locations. There is not currently enough data to delineate a groundwater contamination plume and, therefore, no groundwater contamination plume can be depicted in this permit application.

Analysis of the list of 27 constituents in Table 6-4 and the broad range of elements and compounds contained in U.S. EPA's *Appendix IX* list reveals the following:

- AMW-14; Appendix *IX* testing started in Fall 2001. Five detections of acetone, a common lab contaminant, were reported. Less than 15 µg/l of BTEX compounds were detected in one sample round; two measurements of chloroform were reported near the method detection limit (1 µg/L); and two measurements of 1,3,5 – trimethyl benzene (a petroleum fuel component) were reported at concentrations of 2.6µg/L and 1.8 µg/L. No additional detections of organic compounds have been reported since November 2004. AMW-15; one sample was analyzed for *Appendix IX* constituents in January 2003. Acetone was detected, however, benzene and toluene which were the basis for the *Appendix IX* analysis, were not detected. During the Fall 2011 groundwater sampling event cis-1,2-dichloroethylene and trichloroethylene were detected at 5.8 µg/L and 8.4 µg/L, respectively. Duplicate samples collected during the event showed no detections of any organic constituent. The well was re-sampled in November 2011; no organic compounds were detected during the resampling event. No other detections have been reported..
- AMW-16; three *Appendix IX* samples were analyzed prior to 2006. Each confirmed the presence of chloroform near the method detection limit (1 µg/L) and detected none of the other 221 elements and compounds included in the *Appendix IX* analysis. In November 2004, the permit was modified to place AMW-16 into the Compliance Monitoring Program, due to the continued presence of chloroform over the method detection limit. AMW-16 is in the Compliance Monitoring Program at this time and continues to have detections of chloroform >1 µg/L during most monitoring events.
- AOB-11; In October 2002, 1,1,1-trichloroethane was detected at a level of 1.0 µg/L. The well was re-sampled in December 2002; no organic constituents were detected. During the Spring 2016 sampling event benzene and toluene were detected at 1.3 µg/L and 1.5 µg/L, respectively. The confirmation sampling was performed in June 2016. The first confirmation sample collected contained benzene and toluene at 2.0 µg/L and 2.5 µg/L, respectively. There were no detections of VOCs in the second confirmation sample. Appendix IX sampling performed in July 2016 had detections of benzene and toluene at 1.5 µg/L and 1.5 µg/L, respectively. No other organic compounds were detected in the Appendix IX sample or duplicate sample. The pump motor is to be replaced as soon as possible and prior to the Spring 2017 sampling event.

Analytical results for inorganic constituents in Site A monitoring wells were addressed in several submittals; one in August 2002 concerning arsenic, chrome and lead in monitoring well AMW-14,

and one in 2004 which addressed arsenic in AMW-15 and AMW-16. See Appendix M and Appendix N. Based on U.S. EPA guidance, (Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, EPA 1989), a background concentration for arsenic in the groundwater at Site A was calculated as an Upper Tolerance Limit (95th percentile coverage level).[1] For background Monitoring Well AMW-15, the upper tolerance limit value is 0.038 mg/l.

The concentrations of arsenic in AMW-14 and AMW-16 during the Fall 2004 event were 0.033 and 0.030 mg/l respectively. These concentrations are less than the Upper Tolerance Limit of 0.038 mg/l, and within the range of reported data for AMW-15. The water chemistry data for Site A monitoring wells AMW-14, AMW-15 and AMW-16 shown on Table 6-5 indicates arsenic is present in these wells at about the same concentration. These concentrations are consistent with findings presented in the State of Idaho Groundwater Quality Monitoring report for 1993 for Snake River plain basalt aquifers, where arsenic concentrations are reported to range from <1 ug/L to 34 µg/L.

In addition, the US Geological Survey, (Hem, John D.; USGS Professional Paper 1473, *Study and Interpretation of the Chemical Characteristics of Natural Water, 2nd edition*, p.207), indicates that, "Arsenic is commonly present in water of thermal springs." and provides examples of natural arsenic concentrations of 1.3 to 4.0 mg/L (1,300 to 4,000 µg/L) in thermal aquifers in Oregon and Nevada.

In a report on "Geothermal Investigations in Idaho" for the U.S. Geological Service, Young and Whitehead include a survey of geothermal wells in Township 7S and ranges 4E through 6E, which are located approximately 9 to 12 miles north of Site A in Owyhee County. In this zone, wells surveyed averaged 1,166 feet deep. Arsenic values ranged from 3 to 78 micrograms per litre, with an average of 19 and a standard deviation of 14 ug/L. (See Table 3 in "Geothermal Investigations in Idaho" Part 2, An Evaluation of Thermal Water in the Bruneau-Grand View Area, Southwest Idaho, Young, H.W. and Whitehead, R.L., Idaho Department of Water Resources Information Bulletin 30, 1975.)

Values consistent with regional observations for similar geologic conditions indicate that the arsenic found in groundwater at Site A represents the natural variability in the geothermal aquifer beneath the site.

[1] EPA 1989, Section 5-3, pages 5-20 through 5-24

Table 6-5
Concentrations of Arsenic in Three Wells at USEI Site A

Arsenic Levels(µg/L)			
Date	**AMW-14**	**AMW-15**	**AMW-16**
Dec-01	36.0	Not sampled	Not sampled
May-02	37.0	36.0	Not sampled
Oct-02	34.0	33.0	Not sampled
Oct-02	34.0	33.0	Not sampled
May-03	35.0	31.0	Not sampled
May-03	34.0	31.0	Not sampled
Oct-03	34.0	33.0	Not sampled
Oct-03	33.0	33.0	Not sampled
May-04	35.0	35.0	Not sampled
May-04	35.0	35.0	Not sampled
Aug-04	Not sampled	Not sampled	33.0
Nov-05	35.0	Not sampled	32.0
Oct-06	35.0	Not sampled	31.0
Nov-07	Not sampled	Not sampled	32.0
Oct-08	Not sampled	Not sampled	33.0
Oct-09	Not sampled	Not sampled	31.0
Sep-10	Not sampled	Not sampled	32.0
Nov-11	Not sampled	Not sampled	30.0
Oct-14	Not sampled	Not sampled	33.0
Jun-16	Not sampled	Not sampled	Not sampled

Table 6-6
Site A Historical Summary of VOC's in Monitoring Wells; 1998-2016

Well		May-98	Sep-98	Oct-98	Dec-98	Jan-99	May-99	Jun-99	Oct-99	Jun-00	Oct-00	Dec-00	May-01	Dec-01	May-02	Oct-02	Dec-02	Dec-02 dup	Jan-03	Mar-03	May-03	Oct-03	Oct-03 dup	May-04	May-04 dup	Jul-04	Jul-04	Aug-04	Oct-04	Nov-04	Nov-04 dup	May-05	Oct-05	Nov-05	Jun-06	Oct-06	May-07	Oct-07	May-08
AMW-4																																							
	Acetone																					2.9																	
	Benzene	5.6	19.0		0.8																																		
	Ethylbenzene		0.7																																				
	Toluene	3.2	28.0		0.8	0.7																																	
AOB-11																																							
	Benzene																																						
	Toluene																																						
	1,1,1-Trichloroethane															1.0	ND																						
AMW-13																																							
	Benzene			0.7			0.7					2.4	2.3	2.8	1.8																								
	Toluene			0.6			0.6					1.2	2.4	1.5																									
AMW-14											NS																												
	Acetone																				2.5	13.0	10.0						2.8	2.8									
	Benzene																					5.0	3.7																
	Toluene																					7.9	5.0																
	Xylene (Total)																					2.1	1.3																
	Chloroform												0.9								1.1	1.0																	
	1,3,5-Trimethylbenzene																					2.6	1.8																
	Methyl Ethyl Ketone																												2.6										
AMW-15																																							
	Acetone																		18.0			5.0																	
	Benzene															8.5	1.0	1.5			1.3	3.2		2.9	2.8				18.0											
	cis-1,2-Dichloroethylene																																						
	Trichloroethylene																																						
	Toluene															2.5	1.0	1.1				3.1		2.1	2.0				24.0											
AMW-16																														*									
	Chloroform																							1.2		1.6	1.6	1.2	1.5	2.0		2.0				2.1	2.0	ND	
Trip Blanks																																							
	Acetone																		2.4		3.5																		
	Chloroform																																						
	1,2-Dichloropropane																																	6.6					
	1,1,2-Trichloroethane																																	1.9					
Equipment Blanks																																							
	Acetone																					11.0																	
	Methyl Ethyl Ketone																																						
Field Blanks																																							
	Acetone																		2.8					3.3															
	Bromodichloromethane																																		5.1				
	Chloroform																																		32.0				

* Permit modification submitted to move AMW-16 into the Compliance Monitoring Program based on chloroform concentrations.

Table 6-6
Site A Historical Summary of VOC's in Monitoring Wells; 1998-2016

Well		Oct-08	May-09	Oct-09	May-10	Oct-10	May-11	Oct-11	Oct-11 dup	Nov-11	May-12	Oct-12	May-13	Oct-13	May-14	Oct-14	May-15	Oct-15	May-16	Jun-16 Sample 1	Jun-16 Sample 2	Jul-16
AMW-4																						
	Acetone																					
	Benzene																					
	Ethylbenzene																					
	Toluene																					
AOB-11																						
	Benzene																		1.3	2.0	ND	1.5
	Toluene																		1.5	2.5	ND	1.5
	1,1,1-Trichloroethane																					
AMW-13																						
	Benzene																					
	Toluene																					
AMW-14																						
	Acetone																					
	Benzene																					
	Toluene																					
	Xylene (Total)																					
	Chloroform																					
	1,3,5-Trimethylbenzene																					
	Methyl Ethyl Ketone																					
AMW-15																						
	Acetone																					
	Benzene																					
	cis-1,2-Dichloroethylene							5.8	ND	ND												
	Trichloroethylene							8.4	ND	ND												
	Toluene																					
AMW-16																						
	Chloroform	ND	2.1	2.3	2.5	2.4	3.5	2.5	2.5		3.0	2.4	2.7	3.0	3.3	2.3	3.2	2.7	2.4			
Trip Blanks																						
	Acetone																					
	Chloroform	7.8																				
	1,2-Dichloropropane																					
	1,1,2-Trichloroethane																					
Equipment Blanks																						
	Acetone																					
	Methyl Ethyl Ketone																					
Field Blanks																						
	Acetone																					
	Bromodichloromethane																					
	Chloroform	6.5																				

* Permit modification submitted to move AMW-16

Technical Memorandum

To: Jim Hancock, US Ecology

From: Chuck Feast, Feast Geosciences, LLC

CC:

Date: February 2, 2003

Re: Hydraulic Conductivity, Effective Porosity and Groundwater Velocity Calculations, USEI Site A

Background and Purpose:

This memorandum uses previously submitted site characterization data and EPA guidance to propose representative values for hydraulic conductivity and effective porosity at USEI A Site A for the purposes of allowing consistent velocity calculations.

USEI Site is underlain by 1000's of feet of extrusive silicic volcanic rocks consisting of rhyolite, latite and tuffs. Groundwater levels are about 950 feet below land surface and the moves through complex fracture zones and open voids in the volcanic rocks. Based on hydraulic gradient patterns, Site A can be divided into two groundwater flow regimes. Beneath the southern portion of the site groundwater flows northerly under steep, uniform gradients. Beneath the northern portion of the site groundwater flows generally to the northwest under slight and variable gradients.

US Ecology Idaho, Inc.'s (USEI) RCRA permit requires that the velocity of groundwater be calculated every 6 months. Groundwater velocity is calculated by the formula:

Velocity = K * I / Ne; where:

K = Hydraulic conductivity
I = Hydraulic Gradient
Ne = Effective Porosity

Hydraulic conductivity is usually determined from analysis of aquifer tests and hydraulic gradient is determined by the difference in water levels across the site. However, effective porosity, expressed as a percentage of the aquifer through which water actually flows, in fractured and extrusive volcanic subsurface environment such as at USEI Site A is very difficult to determine.

Hydraulic Properties of Site A

The primary source of hydraulic properties for USEI is the aquifer test conducted by Morrison Knudson Engineering, Inc. (MKE) in 1990 as part of the site characterization efforts in support of the RCRA permit application (MKE, 1990). This test consisted of pumping well APW-10 (Figure 1) at 61 gpm for about 3000 minutes (approximately 2 days) at which point the pumping rate was increased to 75 gpm for approximately 7000 minutes (approximately 5 days). Water levels were measured in numerous wells at various distances from the pumped well. The analyses of this test resulted in a wide range of aquifer properties depending on the well and analytical method used. Table 1 summarizes the hydraulic properties MKE reported from this test. This information was summarized in the permit application for USEI Site A and that portion of the application containing the summary was included in the permit by reference as Appendix H of the permit.

MKE (MKE, 1990, page 5-65) noted that the aquifer at Site A is best described as a leaky artesian system and the aquifer properties determined using leaky artesian aquifer analysis methods are more representative of the aquifer than properties determined from other test methods. MKE (MKE 1990, page 5-65), citing log mean values, concluded that the aquifer at Site A has the following overall hydraulic properties:

- Transmissivity (T) – 11,400 gallons per day per ft (gpd/ft)
- Hydraulic conductivity (K) – 0.012 centimeters/second (cm/s)
- Storativity (S) – 0.037 (sic)

(Note, it appears that the storativity value cited by MKE should actually be 0.0037 as the values used to generate this number range from 0.0021 to 0.0093.)

Table 1 provides log mean values for various combinations of well groupings using only those values estimated from leaky artesian analytical methods. As can be seen, an exact match to the conclusions reached by MKE could not be duplicated. The closest match is for the 3 wells representing the northern side of the site nearest the pumping well. Log mean values for T, K and S (in appropriate units) for these wells were 12,409, .012 and .0041 respectively. This group matches the K value cited by MKE and would also match the T if the value in MKE's text was a typographic error (11,400 in text versus 12,400 in this grouping). The only grouping that matches MKE's value for S (assuming the note above is correct) is if all wells except AMW-5 are used, however, as shown on Table 1, without AMW-5 the values for T and S do not match MKE's summary of hydraulic properties. However, given the inherent uncertainty in the curve matching technique used by MKE to determine the individual properties, all of the groupings result in essentially the same set of properties.

The results from AMW-5 appear anomalous compared to the rest of the analyses, including all the values from other wells estimated by the various analytical methods MKE used to evaluate the aquifer test data. The well is located in the area of Site A with low gradients and suspected faulting and therefore intuitively, this area should have a high T because of abundant fracturing. However the results from the leaky artesian analysis for AMW-5 result in a the lowest T of all wells and the low T from the leaky artesian method stands in stark contrast to the high T's estimated for AMW-5 by the other analytical methods used for this well. MKE noted that the leaky artesian curve match method for AMW-5 did not produce a good fit which indicates the values are not reliable.

From this assessment of the MKE pumping test results, the representative overall aquifer properties for Site A, as shown in Table 1 (all wells without AMW-5), appear to be:

- T = 13,080 gpd/ft
- K = .017 cm/sec (49 feet/day)
- S = .0037

For the subsequent estimation of groundwater velocities, the K for the southern and northern portions of the site K were also estimated from the MKE data as shown on Table 1. For the reasons cited above the values for AMW-5 were not used for the northern grouping. The representative K values are therefore:

- K (southern) = .015 cm/sec (42 feet/day)
- K (northern) = .020 cm/sec (57 feet/day)

Effective Porosity

Effective porosity is a site specific property of the media through which groundwater flow is occurring and represents the percentage of the aquifer through which water actually flows. In porous media (sediments), most of the pore spaces between grains are interconnected and pore sizes do not vary greatly within the aquifer. Although not all pores are connected and therefore effective porosity is lower than total porosity in sedimentary aquifers, groundwater generally flow occurs across the entire aquifer thickness. For fractured flow systems like at Site A however, flow is occurring preferentially in open, persistent fractures and voids,

not at all in un-fractured portions of the aquifer and at highly variable rates as fractures open, close, dive and rise, and diverge and converge. Because of the complexities of fracture flow, it is necessary to use the bulk aquifer properties to approximate the hydraulic properties affecting groundwater flow as if the aquifer was behaving like a porous media. The more highly fractured the aquifer is, and the larger the volume of the aquifer being evaluated, the more closely the assumptions of behavior like a porous media are met.

The aquifer test conducted by MKE, discussed above, resulted in bulk aquifer properties for northwestern portion of the aquifer beneath Site A. The values presented on Table 1 from will be used in the following discussion to estimate the effective porosity for subsequent groundwater velocity calculations for Site A.

Methodology

EPA (1989) provides four approaches for estimating the effective porosity for the purposes of calculating groundwater velocity. These are:

- Literature values
- Default
- Typical Specific Yield
- Calculated from on-site testing

The preferred method cited by EPA is to calculate the site specific value by comparing the affected volume of the aquifer to the volume of water removed during a pumping test. This results in a ratio of the actual drained volume versus the theoretical volume within the "cone of depression" which is in essence effective porosity.

The aquifer test by MKE was used as the basis for this evaluation. The test by MKE resulted in the development of cone of depression in the aquifer approximately 300 feet in diameter as shown in Figures 2 and 3. The total volume of this cone was compared to the volume of water pumped to estimate the effective porosity for Site A. Two estimates were obtained, one for early time (1200 minutes) and one for later time (9840 minutes) in the pumping test.

Theoretical volume: To estimate the actual dimensions of the cone, it was necessary to predict the actual drawdown in the aquifer at the pumped well, as opposed to using the drawdown in the well itself. As noted in MKE, the drawdown in the pumped well was a combination of aquifer drawdown and well loss due to turbulent flow; turbulent flow predominated. To approximate the representative drawdown, the aquifer properties presented in Table 1 were used to estimate the aquifer transmissivity and storativity in the vicinity of the pumped well, again relying on the leaky artesian analyses for the purposes discussed previously. Table 2 shows the wells and values used for this analysis.

Using the T and S from Table 2, the drawdown in the pumped well was estimated by standard Theis drawdown calculations. For the early time evaluation a pumping rate of 61 gpm was used and for the later time a rate of 75 gpm was used. The calculated drawdown was then used to calculate the volume of the cone. The drawdown in the aquifer ranged from 7.3 to 10.2 feet depending on the time duration and pumping rate used.

The radius of the cone was scaled off the water level maps produced MKE (Figures 2 and 3 [MKE figures 5-3 and 5-9 respectively]). Radii of 300 and 350 feet were used for early and late time respectively.

Table 2 provides the values and resultant calculations for estimating the volume of the cones impacted by the aquifer tests.

Pumping volume: The volume of water removed was calculated by multiplying the flow rate times the pumping duration. Because the pumping rate was increased at about 3000 minutes into the test, it was necessary to add the two volumes (pre and post rate change) for the later time evaluation. The total volume of water removed for each test is shown on Table 2.

Calculated Effective Porosity

As shown on Table 2 the effective porosity for the early time test was about 6% and for the later test about 28%. The large difference between the early time and later time is attributed to the influx (recharge) of water coming from faults that effectively stopped the growth of the cone of depression as the test progressed. The early time value of 6% is considered more representative because it minimizes the potential influence of recharge. Although apparently impacted by recharge, the effective porosity from the later time data provides an upper limit for this analysis and is carried forward for that reason.

Comparison of Calculated Effective Porosity to Guidance Values

Total porosity for fractured basalt ranges from 5 to 50 % (Freeze and Cherry, 1979). Effective porosity is always less than total porosity. The effective porosity estimated for Site A is at the lower end of the total porosity range for basalt and therefore also appears reasonable compared to these typical porosity values.

The EPA document provides the following "typical" values for effective porosity for similar saturated media as exists at Site A:

- Default values for fractured rocks (in the absence of any other value) = .01%
- Specific Yield (young basalt) = 8%

The default value provided by EPA is unrealistically low compared to the aquifer characteristics at Site and using this effective porosity produces calculated velocities of over 9000 feet per day; such high velocities are not realistic. An effective porosity of .0001 implies that over a 50 foot thick section of the aquifer, flow is only occurring across a cumulative fracture aperture of .005 feet. The driller's logs and borehole TV surveys conducted at Site A indicate large open fractures exist in the aquifer and therefore the default value is not applicable.

The estimated effective porosity using the early data from the pumping test (6%) compares favorably with the Specific Yield for basalt provided by EPA guidance and therefore is considered a reasonable estimate for subsequent uses in Site A groundwater velocity calculations. The higher effective porosity from the later time test data provides an upper range of values for Site A but is probably not very representative because of recharge that occurred during the test.

Summary and Conclusions

This memorandum provides the background, approach and results of an evaluation of the available test data and subsequent conclusions regarding the hydraulic parameters for use in making groundwater velocity calculations for USEI Site A. Following EPA guidance, site specific aquifer testing was used to estimate hydraulic properties, including effective porosity for the aquifer at Site A.

The following representative aquifer properties are suggested by the available data:

Hydraulic Properties
USEI Site A

	T (gpd/ft)	K (cm/sec)	K (ft/day)	Storativity	Effective Porosity
Overall	13,080	0.017	49	0.0037	.06
Southern (high gradient regime)	9,343	0.015	42	0.0050	.06
Northern (low gradient regime)	18,310	0.020	57	0.0027	.06

Using the MKE test data a variety of other combinations of well groupings with more or less emphasis on specific aquifer test analytical methods can be used to produce hydraulic properties that will vary slightly from the above. However, the hydraulic properties provided above are recommended as representative values to be used for subsequent, routine groundwater velocity calculations at USEI Site A.

References:

EPA, 1979. Statistical *Analysis of Groundwater Monitoring Data at RCRA Facilities, Interim Final Guidance.*

Freeze, Allan R. and Cherry, John A.,1979. *Groundwater.* Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Morrison Knudson Engineers, Inc., 1990. *Geohydrological Characterization Report, Phase III, ESII Site A, Bruneau, Idaho.*

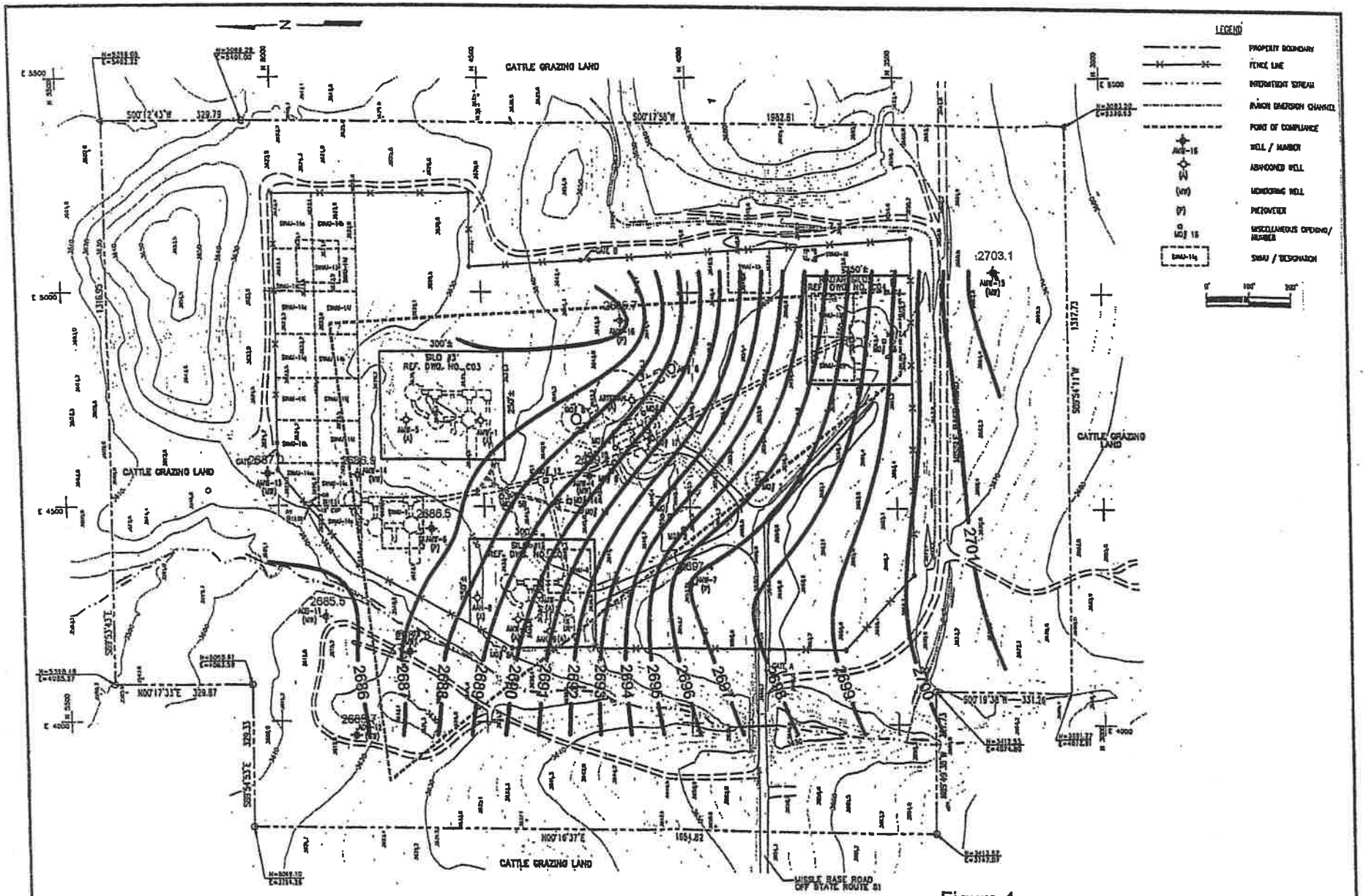


Figure 1
Potentiometric Surface, October 18, 2002
Site A - US Ecology Idaho, Inc

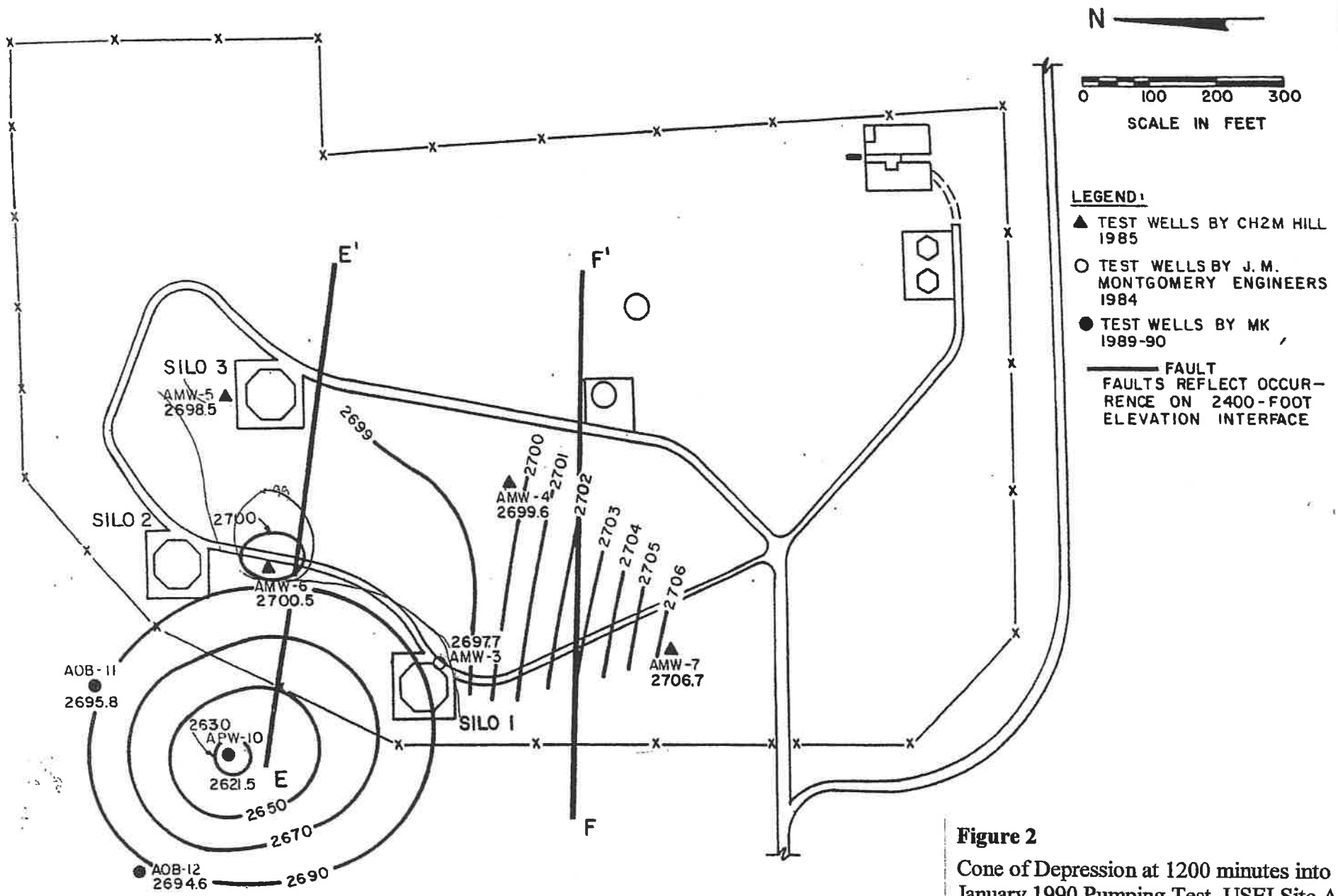


Figure 2

Cone of Depression at 1200 minutes into January 1990 Pumping Test, USEI Site A

Modified from MKE, 1990

FIGURE 5 - 9 Potentiometric Surface on March 8, 1990, 9840 Minutes After Pumping Test Start

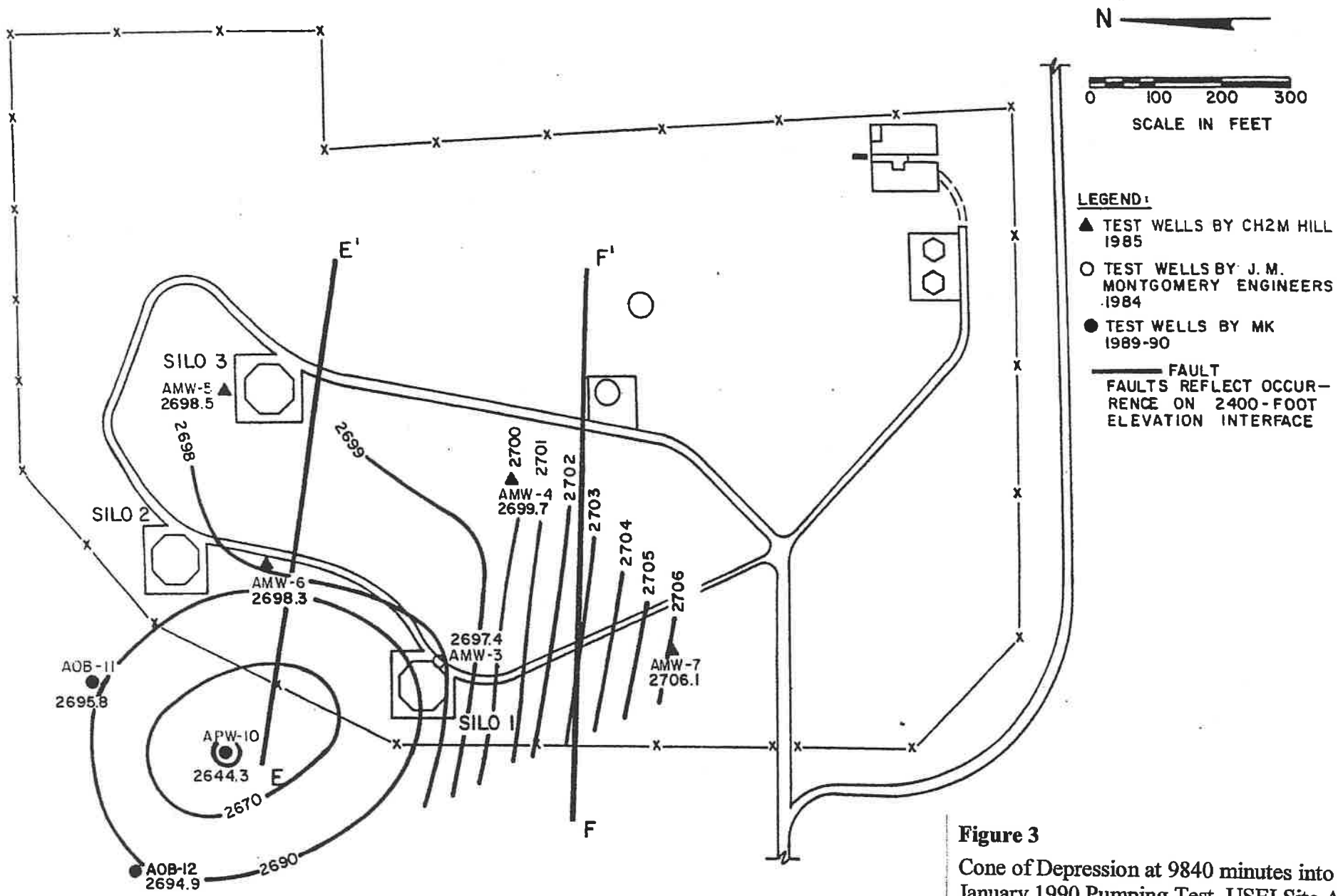


Figure 3

Cone of Depression at 9840 minutes into January 1990 Pumping Test, USEI Site A

Modified from MKE, 1990

FIGURE 5 - 3 Potentiometric Surface on March 2, 1990, 1200 Minutes After Pumping Test Start

Table 1
Summary of Hydraulic Properties
USEI Site A, Bruneau ID
(U.S. EPA ID No. IDD000773952)

Hydraulic Properties from long term aquifer test (January 1990) [a]

Well No.	b (ft)	T (gpd/ft)	K (cm/sec)	K (ft/day)	Storativity	Analysis type [b]
AMW-3	20	30,300	0.071	202.5	0.00063	S/L
AMW-3	20	17,600	0.042	117.6	0.0071	S/L
AMW-3	20	9,700	0.023	64.8	0.0028	Leaky
AMW-3	20	24,700	0.058	165.1	--	S/L
AMW-4	45	30,300	0.032	90.0	0.0044	S/L
AMW-4	45	20,400	0.021	60.6	0.0087	S/L
AMW-4	45	9,000	0.009	26.7	0.009	Leaky
AMW-7	31	13,400	0.020	57.8	0.018	L/L
AMW-5	61	69,900	0.054	153.2	0.00098	S/L
AMW-5	61	5,700	0.0044	12.5	0.0093	Leaky [c]
AMW-5	61	82,400	0.064	180.6	--	S/L
AMW-6	63	14,200	0.011	30.1	0.0015	S/L
AMW-6	63	12,900	0.010	27.4	0.0015	L/L
APW-10	90	4,700	0.0025	7.0	--	S/L
AOB-11	37	107,200	0.137	387.3	0.00026	S/L
AOB-11	37	27,400	0.035	99.0	0.055	Not reported
AOB-11	37	22,500	0.029	81.3	0.0035	Leaky
AOB-11	37	58,100	0.074	209.9	--	t/t'
AOB-12	52	23,600	0.021	60.7	0.0018	S/L
AOB-12	52	20,400	0.018	52.4	0.0085	S/L
AOB-12	52	14,900	0.014	38.3	0.0021	Leaky
AOB-12	52	19,200	0.017	49.4	--	t/t'
AOB-12	52	42,100	0.038	108.2	--	t/t'

Representative Hydraulic Properties for USEI Site A [a, c]

Properties for all wells using Leaky Artesian Analyical Method

	T (gpd/ft)	K (cm/sec)	K (ft/day)	Storativity
Log Mean	11,078	0.013	37	0.0044
Log mean (w/o AMW-5)	13,080	0.017	49	0.0037

Properties for Southern side of Site A (high gradient regime)

Well No.	b (ft)	T (gpd/ft)	K (cm/sec)	K (ft/day)	Storativity
AMW-3	20	9,700	0.023	65	0.0028
AMW-4	45	9,000	0.0094	27	0.0090
Log Mean		9,343	0.015	42	0.0050

Properties for Northern side of Site A (Low gradient regime)

Well No.	b (ft)	T (gpd/ft)	K (cm/sec)	K (ft/day)	Storativity
AMW-5	61	5,700	0.004	12	0.0093
AOB-11	37	22,500	0.029	82	0.0035
AOB-12	52	14,900	0.014	40	0.0021
Log Mean		12,409	0.012	34	0.0041
Log mean (w/o AMW-5)		18,310	0.020	57	0.0027

Notes: a Data presented on Table 4.1, February 1995 Corrective Action Management Unit Application, and incorporated into RCRA permit by reference (Attachment H); Source of data --- MK, 1990, Phase III Site Characterization Report, ESII Site A - Chapter 5.

b S/L semi log; Leaky - Log Log Leaky artesian; L/L - Log Log; t/t' Semi log recovery;

c MK, 1990, page 5-65, concluded that values from Leaky analyses were more representative of aquifer at Site A.

Shaded values are recommended K values for Site A velocity calculations.

Table 2
Summary of Hydralic Properties and Calculated Effective Porosity
USEI Site A, Bruneau ID
(U.S. EPA ID No. IDD000773952)

Calculated Effective Porosity
Based on Method in EPA(1989) [a]

Aquifer properties within cone of depression [b]

Well No.	b (ft)	T (gpd/ft)	K (cm/sec)	K (ft/day)	Storativity
AMW-3	20	9,700	0.023	65	0.0028
AOB-11	37	22,500	0.029	82	0.0035
AOB-12	52	14,900	0.014	40	0.0021
Log Mean		14,815	0.021	60	0.0027

At t = 1200 minutes

Q =	61 gpm	T =	14,815	gpd/ft
Radius =	300 ft [c]	S =	0.0027	
Time =	1200 min	Drawdown [d]	7.3	ft

Volume of cone of depression =	V_c =	1/3 pi r^2h =	1,286,576	gallons
Volume of water removed =	V_w =	Q x time =	73,200	gallons
Effective porosity =	V_w/V_c =	0.057	=	6%

At t = 9840 minutes

Q =	61, 75 gpm	T =	14,815	gpd/ft
Radius =	350 ft [c]	S =	0.0027	
Time =	9840 min	Drawdown [d]	10.2	ft

Volume of cone of depression =	V_c =	1/3 pi r^2h =	2,446,845	gallons
Volume of water removed =	V_w =	Q x time =	696,000	gallons *
Effective porosity =	V_w/V_c =	0.284	=	28%

* Volume = 61 gpm x 3000 mins. + 75 gpm x 6840 mins.

Notes: a EPA, 1989. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities, Interim Final Guidance, April 1989.

b MK, 1990. Phase III Site Characterization Report, ESII Site A - Chapter 5, as summarized on Table 1 of this memorandum.

c Radius of cone of depression illustrated on Figures 5-3 and 5-9, MK 1990.

d Calculated drawdown in the aquifer at the pumped well (APW 10) at a rate of 61 gpm for 1200 minutes based on aquifer properties determined from the pumping test. Actual pumping water level in well APW-10 was affected by high well loss due to turbulent flow.