



PDHonline Course C389 (3 PDH)

**Environmental Investigation and
Remediation of a Hazardous Waste
Site
Part 4 - Results and
Implications of Phase 1 Field**

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Environmental Investigation and Remediation of a Hazardous Waste Site Part 4 - Results and Implications of Phase 1 Field Investigations

Samir G. Khoury, Ph.D., P.G.

Course Content

Introduction

Starting in the 1960s a research institute (“Institute”) operated a small (0.65 acre) hazardous chemical and radioactive waste burial facility on its campus for about 20 years. All waste buried at the site resulted from the use of radioactive isotopes and chemicals in research experiments. Waste brought to the disposal site was in both solid and liquid form, and the liquids were in various types and sizes of containers. The waste was placed into narrow trenches dug into the soil at the burial site. The trenches were about 8 to 12 feet deep. Once waste reached about 4 feet from the surface, local dirt was used to fill the trench.

When the site was decommissioned and no longer used, it was fenced, posted and locked. Minimal ground maintenance was done until the State Radiation Protection Agency (State RPA) notified the Institute that they were to keep the fence clear of vegetation and the area within the fence mowed and free of trees. The following photo shows the waste disposal area after the site was decommissioned and the ground maintenance started:



Figure 1: Decommissioned waste disposal site at the Institute

Following decommissioning of the site, yearly testing of soil, surface water and vegetation by the State Radiation Protection Agency (State RPA) showed no evidence of significant radioactive contamination outside the burial area. In the late 1980s, the State RPA recommended that the Institute install a series

of monitoring wells to allow sampling and testing of the groundwater. In response, and under the guidance of the State Groundwater Protection Agency (State GPA), the Institute installed five monitoring wells around the waste disposal site. The location of the five wells is shown on the following figure.

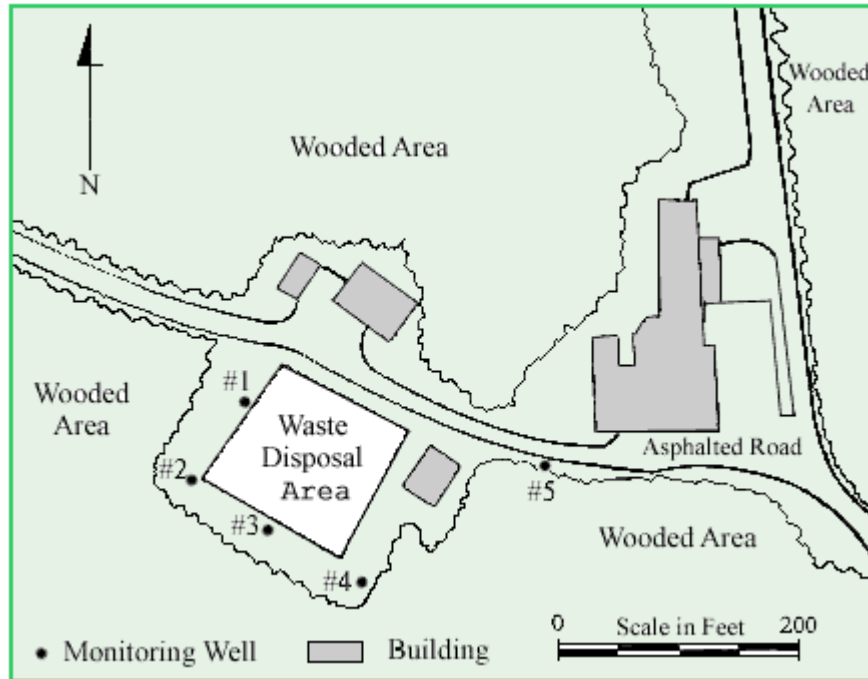


Figure 2: Location of Initial Monitoring Wells Installed around the Waste Disposal Site

About a month after installation, the State RPA collected groundwater samples from the five monitoring wells for radiological analysis. A year later, an additional groundwater sample was collected from Well No.3 for radiological and organic chemical analysis. The radiological analyses indicated that some of the groundwater samples in the immediate surroundings of the restricted area had elevated Tritium activities. It also appeared that organic chemical contamination might be present in the groundwater in the vicinity of the waste disposal area. Discovery of both chemical and radiological contamination outside the fenced burial area prompted the State RPA to require the Institute to design and implement an extensive investigation program. The Institute issued an RFP to environmental and engineering firms to retain the services of a technical services consultant (Consultant). The winning bidder reviewed existing information and developed an estimate of the inventory of the waste disposed of at the site and evaluated existing soil, vegetation, groundwater and surface water test results. The Consultant issued a Preliminary Site Condition Report summarizing the results of these initial studies. The State RPA and other State Regulatory Agencies then requested a characterization of the geology and hydrology of the area and the collection of additional soil, groundwater and surface water samples for analysis, including the installation of additional groundwater monitoring wells, in order to determine the size, extent, and characteristics of the down gradient contaminant plume.

Because the waste disposal site contained hazardous chemicals and radioactive isotopes, no additional field investigations could be started until a project-specific Health and Safety Plan was developed. A

project-specific Quality Assurance Plan was also created, and the technical requirements were developed as part of the Sampling and Testing Plan. A set of Project Procedures was written to guide the field sampling and analysis programs that incorporated the requirements of each of the project plans. The relationship of the various plans, procedures and the field and laboratory activities is shown on the following flowchart.

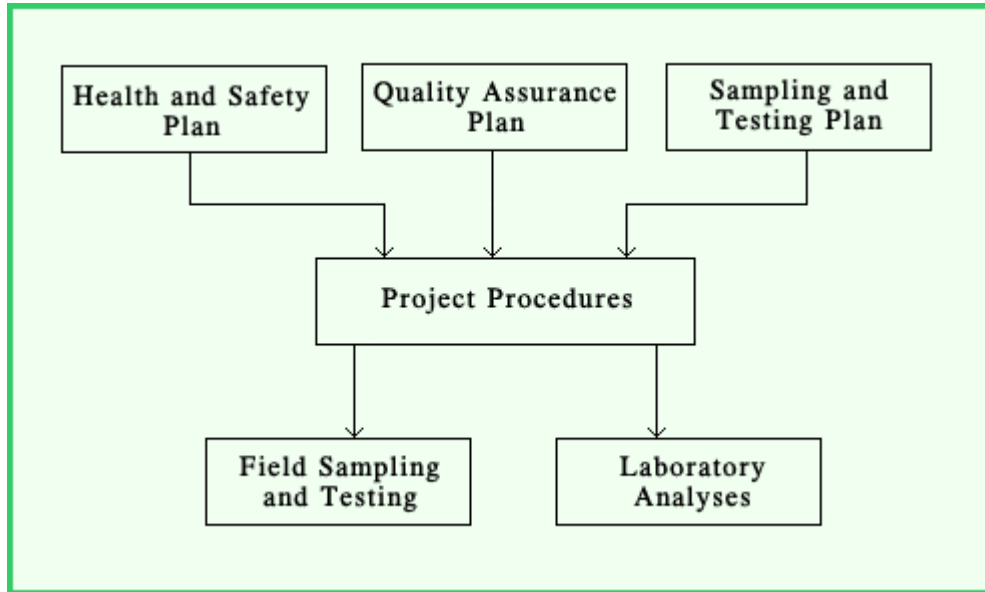


Figure 3: Relationship of the Various Project Plans, Procedures and Field and Laboratory Activities

These aspects of the project are covered in the first three parts of this course series, as follows: Part 1 – Background and History Leading to Contract Award, Part 2 - Analysis of Existing Information and Regulatory Concerns, and Part 3 – Preparation of Project Plans and Procedures.

This course (Part 4) examines the Phase 1 field activities and conclusions drawn from the results of these studies. Following the consideration of a change implemented in the project reporting structure, the technical studies that are presented and discussed include:

- Geologic Setting,
- Site Soils,
- Surface water conditions,
- Groundwater conditions,
- Chemical and radiological analyses of groundwater samples, and
- Chemical and radiological analyses of soil samples

The environmental impacts, conclusions and recommendations developed by the Consultant after this phase of work was completed are presented at the end of this course, as are questions from the regulatory agencies, the Consultant's responses and media coverage following issuance of the updated site condition report.

Regulatory Agencies/Institute/Consultant Relationship

At the start of the project, the Consultant reported directly to the Institute's Office of Legal Affairs on contractual issues and to a Senior Radiation Specialist on technical issues. The Institute, at that point, followed the directives of the State RPA and implemented its directives as they were formulated. Once the Preliminary Site Condition Report was issued and comments were received from several State Regulatory Agencies (discussed in Part 2 of this series of courses), the Institute realized that dealing with multiple regulatory agencies was likely to be a long, complicated and expensive process with no clear end in sight. Prior to the start of the Phase 1 field activities, therefore, the Institute added additional resources to the project team and adjusted the reporting structure.

First, all contacts and communications with the State Regulatory Agencies during the performance of the Phase 1 investigations and any follow-up work were to be conducted by the Institute's Office of Legal Affairs. In addition, the Institute retained the services of an Environmental Legal Counsel to advise them on procedural matters that needed to be considered in dealing with the State Regulatory Agencies. As a result of these changes, all recommendations by the Consultant in terms of technical approach, scope of work, scheduling and contents of written reports were all reviewed by the various legal entities involved. These changes resulted in approval delays, scope modifications and lengthy internal negotiations trying to balance the technical and legal needs of the project. As a consequence, the Consultant added additional time and resources to the subsequent phases of work to accommodate the changes created by this revised reporting structure.

Geologic Setting

Published geologic reports and United States Geological Survey (USGS) geologic quadrangle maps of the region were reviewed to determine the type of bedrock beneath the site. In addition, the distribution of soil types at the site and its vicinity were defined based on information provided by the US Department of Agriculture (USDA), Soil Conservation Service (SCS). In addition, particle size analyses were performed on two soil samples taken in the immediate vicinity of the waste disposal area to compare the results obtained with the generic descriptions given by the SCS. The results of these investigations are summarized in the following sections.

Site Geology

Bedrock at the site and in the surrounding region is granite thought to be about 300 million years old. From regional descriptions, the granite body is generally coarse-grained, massive, quartz rich, contains some thin layers of dark colored minerals and is typically non-foliated. In temperate climates, this type of bedrock tends to weather near the surface of the ground and yield a residual soil that is sandy, granular and permeable.

Site Soils

The soils at the site and its vicinity were mapped by the Soil Conservation Service as part of its national program of soil mapping and classification. Soil in the site area is classified into three types: type "A" clay loam, type "B" fine sandy loam, and type "C" loam. Based on the SCS mapping the distribution of soil types at the waste disposal site and its vicinity is shown on the following figure:

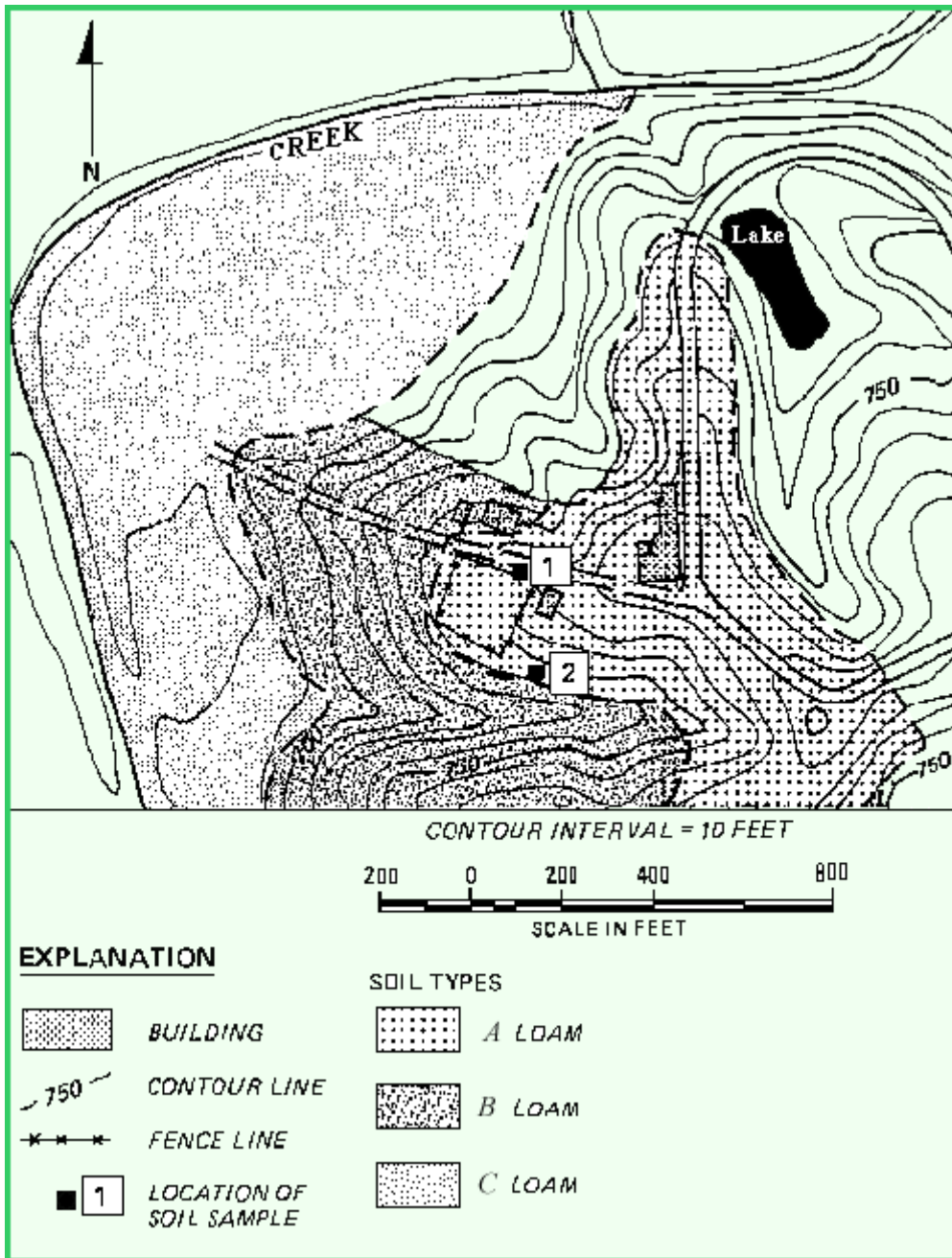


Figure 4: Map of Soil Types and Location of Soil Samples

The soil type in the upland areas of the site is shown on the SCS map as type “A” clay loam. The SCS description indicates that this is a well-drained soil typically found in slightly sloping upland areas. The surface layer is yellowish-red to dark brown clay loam 4 to 8 inches thick. The subsoil is red to yellowish-red clay to sandy clay loam 18 to 35 inches thick. Infiltration is slow, and surface runoff is rapid. The soil is very strongly acid to medium acid throughout. The SCS characterizes the type “A” clay loam as having a silt and clay content ranging between 65 to 80 percent of the total weight of the soil. Permeability of the typical type “A” clay loam ranges between 2.0 to 6.0 inches per hour (1.4 to

4.2 x 10⁻³ cm/sec) for the top six inches of soil, and between 2.0 to 0.6 inches per hour (1.4 x 10⁻³ to 4.2 x 10⁻⁴ cm/sec) from six inches to six feet in depth. The waste disposal trenches were excavated in the type “A” clay loam and these materials were also used to backfill and cap the waste trenches.

The soil type immediately down-drainage of the waste disposal site is classified by the SCS as a type “B” fine sandy loam. The SCS defines this as a well-drained soil typically found in upland areas with slopes ranging from 10 to 45 percent. The surface layer is yellowish-brown to grayish-brown fine sandy loam 4 to 8 inches thick. The subsoil is red to yellowish-red clay to sandy clay loam 20 to 30 inches thick. Infiltration is moderately slow, and surface runoff is very rapid. This soil is very strongly acid to medium acid throughout. The SCS characterizes the type “B” fine sandy loam as having silt and clay content ranging between 40 and 55 percent of the total weight of the soil. Typical permeabilities given are the same as those for the type “A” clay loam.

The soil type of the floodplain at the base of the slope west of the waste disposal area is mapped as a type “C” loam. The SCS defines the type “C” loam as a nearly level, somewhat poorly drained alluvial soil that occurs on stream flood plains. Infiltration is moderate, and surface runoff is slow. This soil is subject to frequent flooding for brief periods and is strongly acid or medium acid throughout.

Particle-Size Analysis of Site Soils

The purpose of the SCS mapping of soils throughout the US is to characterize their suitability for agricultural uses. Therefore, the SCS mapping can be used as a general guide, but local variability in soil properties makes site-specific testing important for any site assessment. As such, two samples of soil from around the waste disposal area, as shown on Figure 4, were collected for particle size analysis. Note that samples were from the area mapped by the SCS as the type “A” clay loam. Both samples were obtained from cut banks and are representative of the soil approximately one foot below the natural ground surface. As per the requirement of the project-specific Sampling and Testing Procedures, samples were analyzed using the method described in ASTM D-422. Table 1 and Figure 5, below, present the results of the analysis of soil sample No. 1.

TABLE 1 - Particle Size Analysis - Soil Sample No. 1

Sieve No.	Diameter (mm)	% Retained	% Passing
(63)	63	0	100
(31.5)	31.5	0	100
(A)	16	0	100
(B)	8	0	100
5	4	1.489	98.511
10	2	4.248	94.263
18	1	18.440	75.823
35	0.50	29.218	46.605
60	0.25	23.092	23.513
120	0.125	12.469	11.044
200	0.063	5.130	5.914
<200	pan	5.097	--

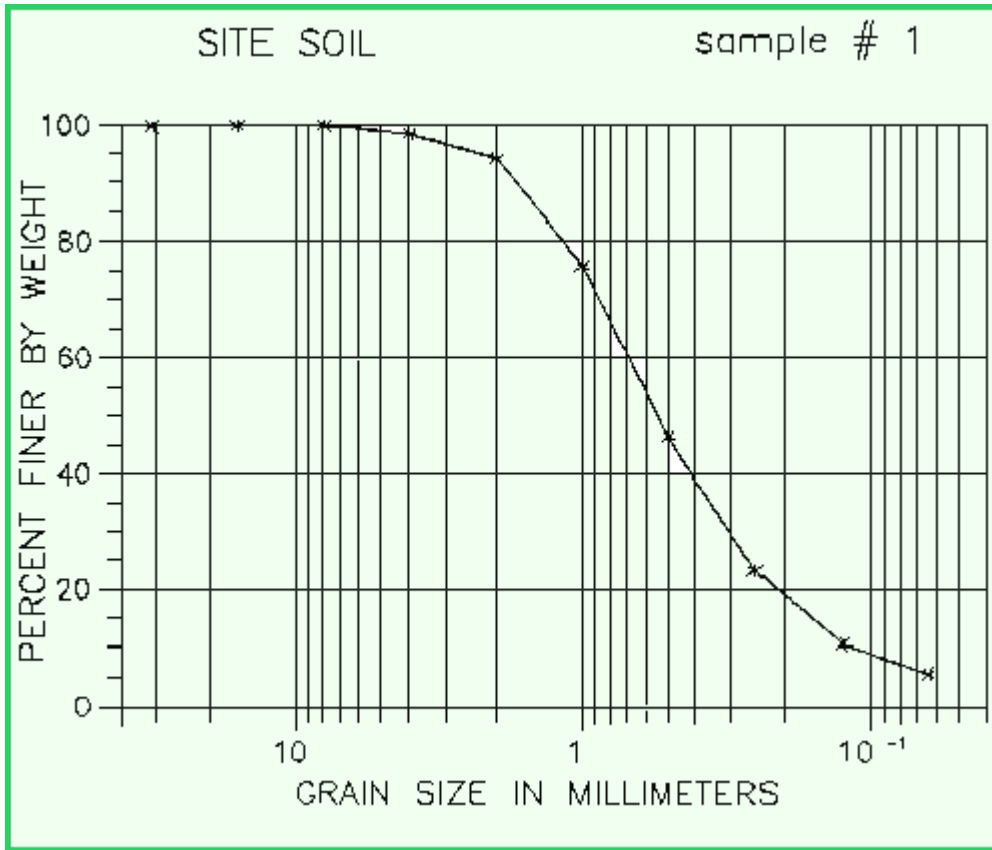


Figure 5: Grain Size Analysis Graph, Soil Sample No. 1

Based on the grain size distribution shown above, the soil would be classified as a well-graded, coarse-grained clayey-sand (using the Unified Soil Classification System). Note that the silt and clay content of this soil (defined as the amount passing through the number 200 sieve) is less than 6% by weight. Contrast this with the SCS definition of this soil (type “A” clay loam) indicating a silt and clay content of between 65% and 80% by weight.

Table 2 and Figure 6 present the results of the analysis of soil sample No. 2.

TABLE 2 - Particle Size Analysis - Soil Sample No. 2

Sieve No.	Diameter (mm)	% Retained	% Passing
(63)	63	0	100
(31.5)	31.5	0	100
(A)	16	0	100
(B)	8	0	100
5	4	0.181	99.819
10	2	10.002	89.817
18	1	30.856	58.961
35	0.50	26.095	32.866
60	0.25	16.236	16.630

120	0.125	8.617	8.013
200	0.063	4.056	3.957
<200	pan	3.956	--

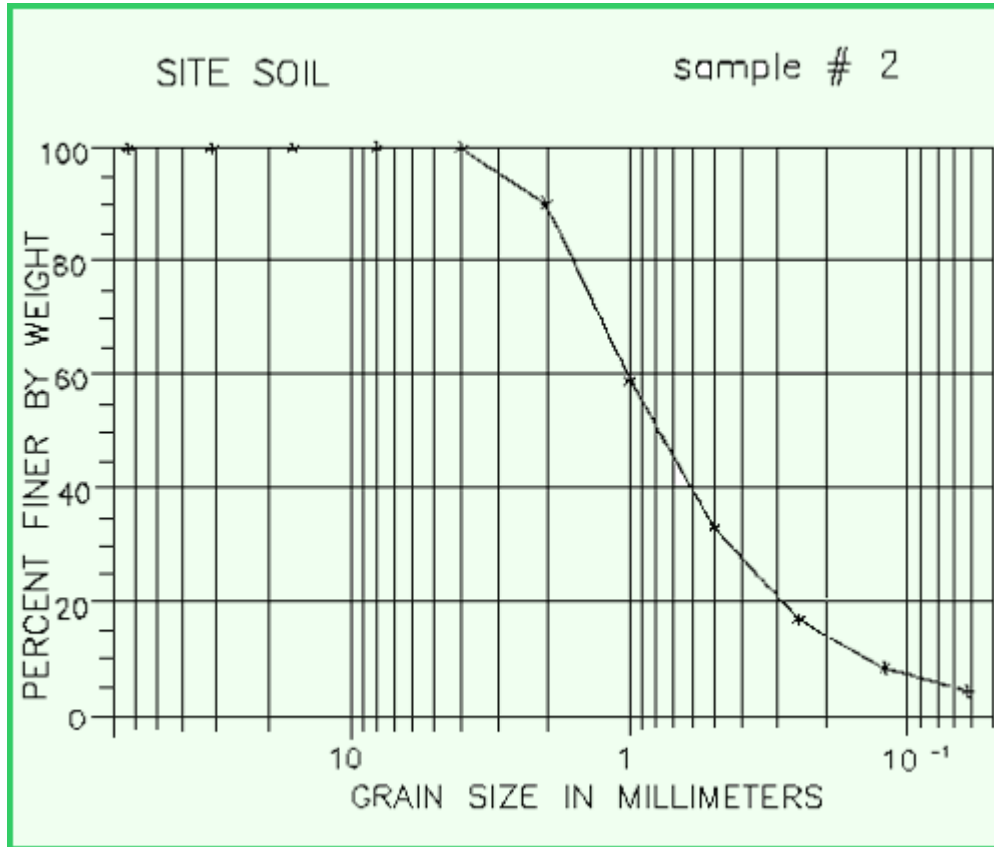


Figure 6: Grain Size Analysis Graph, Soil Sample No. 2

Using the Unified Soil Classification System, soil sample No. 2 is classified as well-graded, coarse sand, with little to no fines. Soil sample No. 2 has a silt and clay content of less than 4%, again in contrast to the SCS general description of 65% to 80% silt and clay.

The analyses of the two soil samples are consistent with the type of soil typically developed over quartz-rich granitic bedrock – sandy soil with little to no silt and clay. Contrary to the SCS mapping and general descriptions, this soil contains less than 10% clay and silt. It is therefore likely that the permeability of the waste disposal site soils is higher than the range given by the SCS. The site soils were used to backfill and cap the waste disposal trenches. The two analyses above suggest that this type of soil would be ineffective at preventing rain water from infiltrating into the trenches.

Surface Water

The location of the waste disposal site near the top of a hill indicates that precipitation and surface water are the primary mechanisms for recharging the groundwater system below the trenches. Since any water infiltrating into the trenches would likely become contaminated before moving down to the groundwater system, it is critical to assess the sources and characteristics of the surface water system in and around the site.

The meteorological conditions, site drainage characteristics, and an estimate of infiltration are presented in the following sections.

Meteorological Conditions

The Institute is located in a temperate part of the US. The average monthly year-round temperature is 59° F. The average relative humidity is 66 percent. The sun shines about half of the daylight hours in winter and nearly two thirds of the daylight hours in other seasons. Surface wind directions are variable during all seasons. However, northeasterly winds are more prevalent late in the summer and in autumn. Southwesterly winds are more prevalent in other seasons. The strongest winds often are northwesterly. The average surface wind speed is about eight miles per hour.

The average annual precipitation is approximately 42.5 inches of rain. There are no distinct wet and dry seasons. Most months average about three to five inches of rain. In only one year in ten the rain will exceed eight inches in any one month.

Site Drainage

The Institute's campus is drained by the Creek shown along the northern and western sides of Figure 7, below. This Creek joins a larger one about 2,500 feet south of the Institute's property boundary. The larger creek flows into a larger stream approximately 14 miles southwest of the Site.

The waste disposal area is located near the northern divide of a small local drainage basin. During periods of heavy precipitation, runoff in the basin follows the paths shown on Figure 7. The principal course of surface water within this basin is downhill into an east-west trending gully south of the waste disposal site. This gully carries most of the runoff to the Creek by way of a man made north-south trending drainage ditch cut into the floodplain, west of the Site (Figure 7).

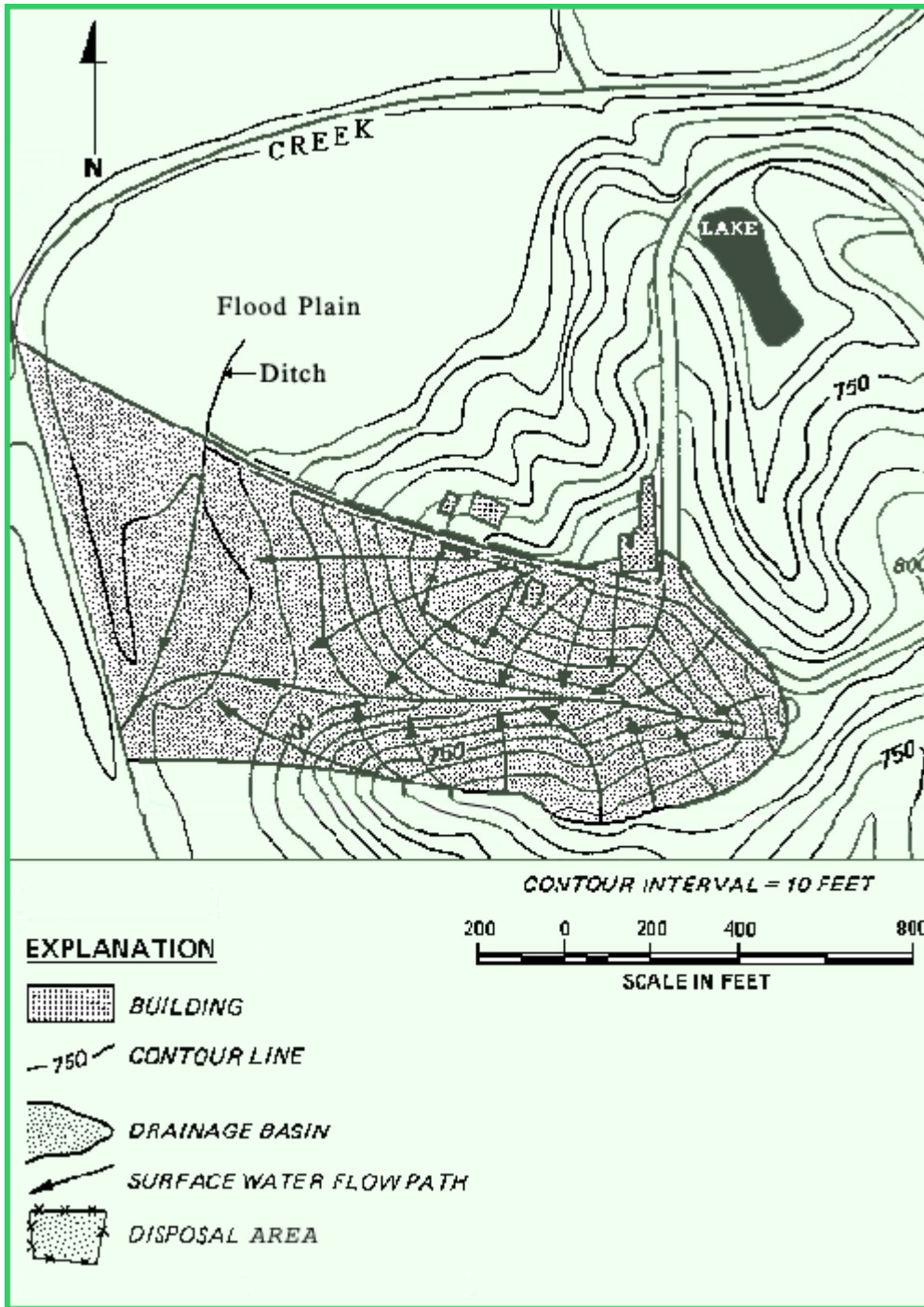


Figure 7: Map Showing Position of the Waste Disposal Area within Small Local Drainage Basin

Infiltration Estimates

In order to estimate the amount of water that infiltrates into the trenches and percolates to the groundwater below, a generalized site-specific water budget was determined. The components of this water budget are:

- precipitation
- runoff
- evapotranspiration
- infiltration

The annual precipitation in the site region is approximately 42.5 inches. The distribution of the rain is generally even throughout the year, with no especially wet or dry seasons. A portion of this water moves downhill off the upland areas as surface runoff and never infiltrates into the soil. In this part of the country, about 10% of the water in upland areas is lost to runoff.

Evapotranspiration is the process by which plants absorb water from the soil and release it back into the atmosphere. In this part of the country, a general rule of thumb is that 75% of the precipitation is consumed by evapotranspiration and never reaches the groundwater. The percentage changes with the seasons, as plants and grasses are much more active in the spring and summer than fall or winter. On average, however, 75% is considered a reasonable yearly estimate.

Since 10% of the water moves as runoff to surface water bodies, and 75% is trapped by plants, only about 15% of the precipitation is available to recharge the groundwater system by infiltration. Therefore, of the 42.5 inches of yearly rainfall, only about 6.4 inches (15% of 42.5) actually contributes to the recharge of the groundwater system.

The surface area of the fenced waste disposal area is about 28,790 square feet. A total of 6.4 inches of infiltration into this area yields a total yearly volume of about 15,000 cubic feet of recharge to the groundwater system. The distribution of trenches within the waste disposal area is shown on Figure 8, below. A reasonable worst-case estimate assumes that about 65% of the water that infiltrates within the waste disposal area infiltrates directly or moves laterally into trenches and becomes contaminated. Under this scenario, an estimated 10,000 cubic feet of contaminated water enters the groundwater system each year from the waste disposal area. Remember that no trenches were dug in the eastern one third of the waste disposal area.

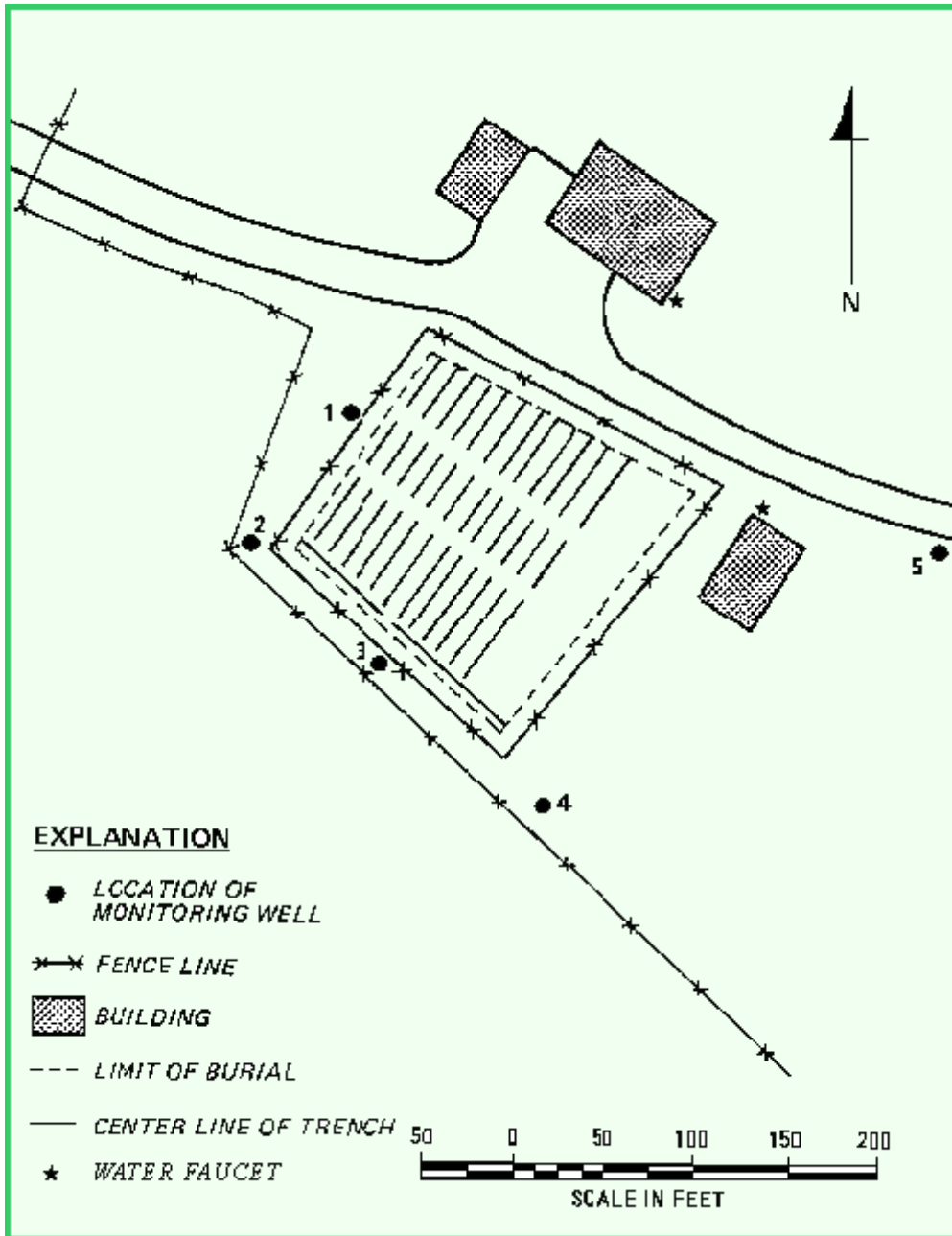


Figure 8: Map Showing the Inferred Layout of the Trenches within the Waste Disposal Area.

By comparison, the total surface area of the small drainage basin that contains the Site, shown on Figure 7, is approximately 1,157,000 square feet. Using 6.4 inches of annual infiltration yields a total of about 620,000 cubic feet of recharge to the groundwater system. Therefore, the contribution of contaminated water (10,000 cubic feet) is only about 1.6% of the total recharge to the groundwater from the local drainage basin. Therefore, the contaminated groundwater beneath the waste disposal area becomes quite diluted by clean groundwater as it moves down gradient towards the Creek.

Groundwater

As explained above, surface water that infiltrates from the waste disposal area into the trenches will leach the waste and carry contaminants to the groundwater. Therefore, determining the depth and configuration of the groundwater and its direction and rate of flow is a key to understanding the potential spread of contamination beyond the boundaries of the fenced waste disposal area.

Water Levels in Existing Monitoring Wells

Groundwater level measurements were obtained from the five on-site monitoring wells in June, September, and November. The measurements were obtained with an electronic water-sensing instrument. Groundwater elevations were calculated by subtracting the depth to water from the surface elevations. The results are presented in Table 3, below.

TABLE 3 - Groundwater Elevation (all measurements in feet)

Parameter	Well #1	Well #2	Well #3	Well #4	Well#5
Estimated Surface Elevation	756.6	747.0	749.6	740.2	779.0
Depth to Water in June	32.6	29.9	27.3	15.4	41.8
Groundwater Elevation	724.0	717.1	722.3	724.8	737.2
Depth to Water in September	33.7	31.7	29.0	17.1	42.9
Groundwater Elevation	722.0	715.3	720.6	723.1	736.1
Depth to Water in November	34.8	32.8	30.2	18.1	43.3
Groundwater Elevation	721.8	714.2	719.4	722.1	735.7
Change in Groundwater Elevation - June to November	-2.2	-2.9	-2.9	-2.7	-1.5

Over this six-month time period, the groundwater table at the site dropped an average of 2.4 feet. The changes in the elevation of the groundwater table were smallest in the up-gradient background Monitoring Well #5 (-1.5 feet) and greatest in the down-gradient wells 2 and 3 (-2.9 feet).

Groundwater Configuration

Figure 9 is a groundwater contour map showing the approximate elevation and configuration of the top of the water table using the June water level measurements. Note that the water table appears to slope gently towards the southwest.

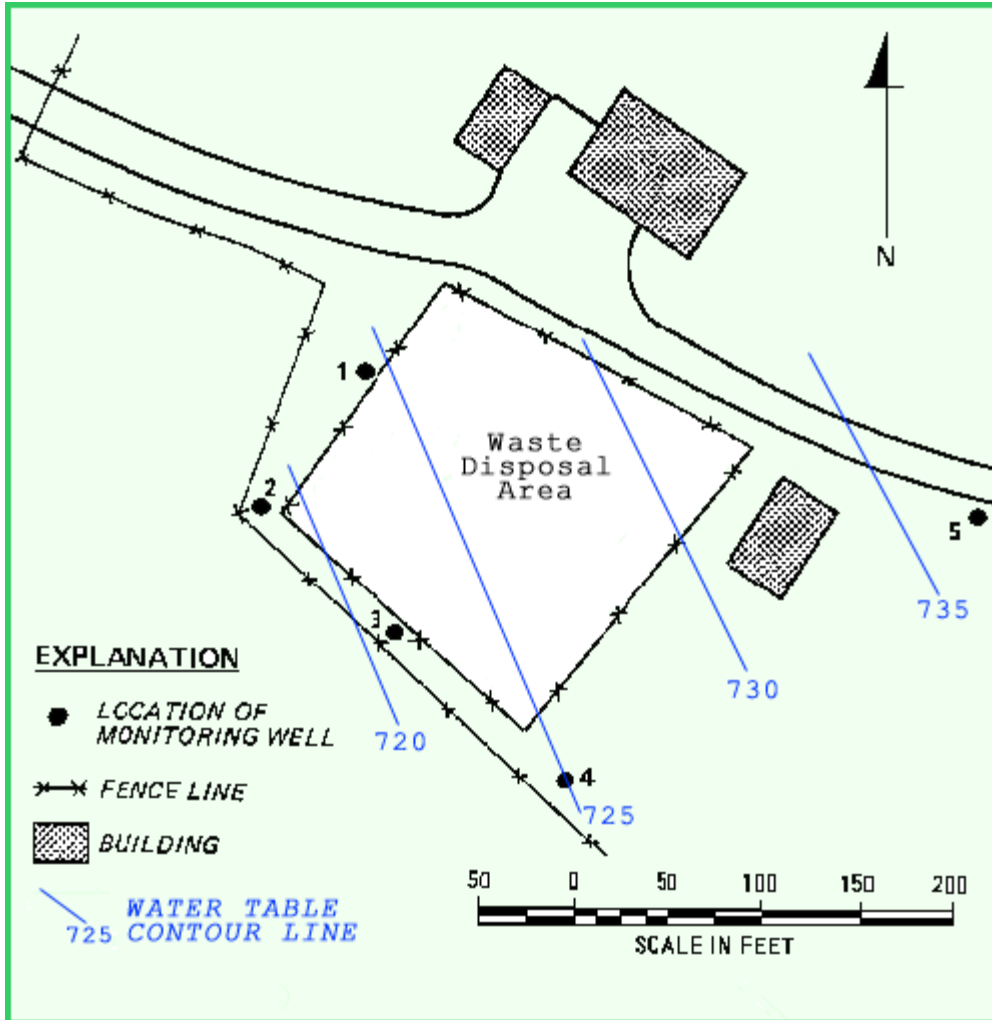


Figure 9: Configuration of the Groundwater Table under the Waste Disposal Site.

Figure 10 shows a profile drawn between monitoring wells Nos. 4 and 2, passing through monitoring well No. 3. This figure illustrates the relationship between the groundwater table and the bottom of the first two trenches that were dug parallel to the southern portion of the perimeter fence. It is evident from Table 3 and Figure 10 that the shortest distance between the bottom of the trenches and the top of the groundwater table is over 15 feet.

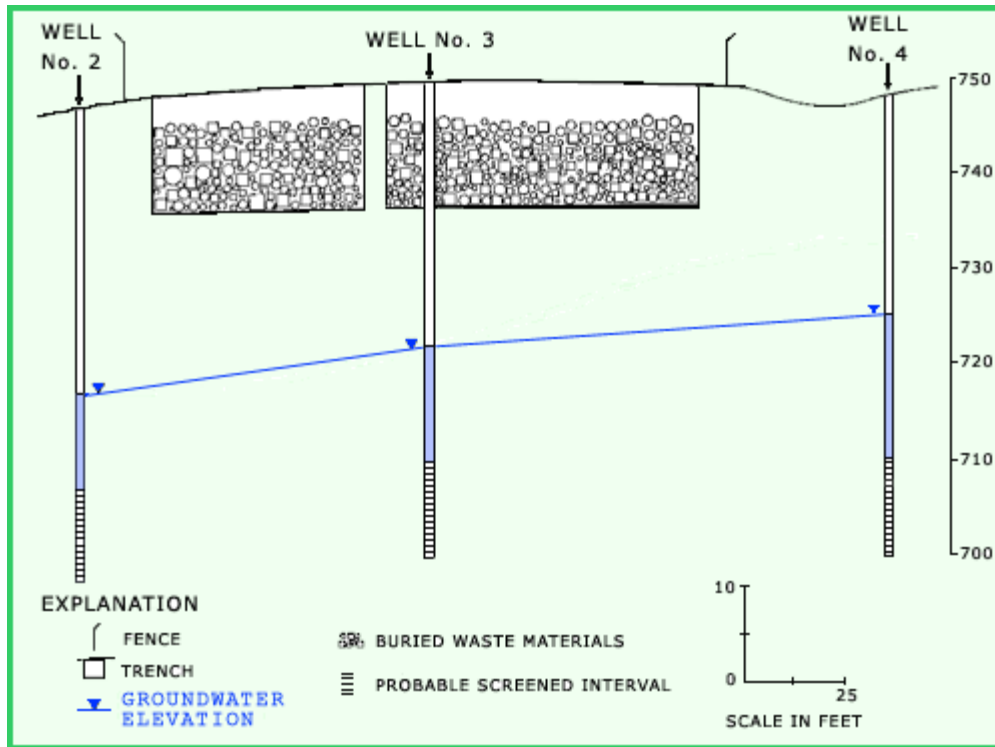


Figure 10: Cross Section through the Trenches Showing the Position of the Groundwater Table.

Figure 11 is a topographic cross section through the site area including the waste disposal site and the Creek to the west. The approximate configuration of the groundwater table is shown based on the readings from the monitoring wells. The cross section also illustrates the groundwater flow lines beneath the site area. As shown, any contaminated water from the trenches will seep downward to the groundwater table and will then travel westward towards the Creek.

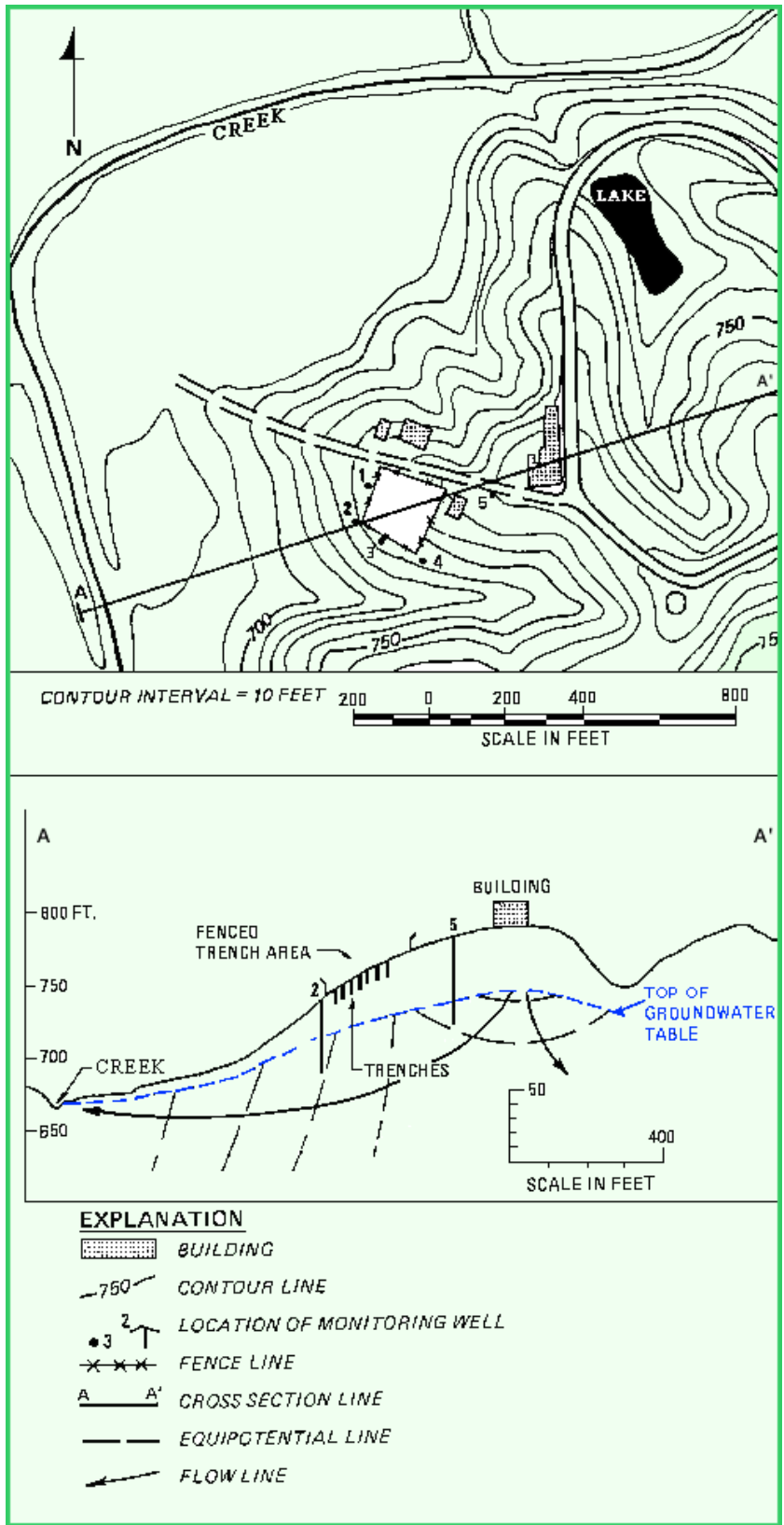


Figure 11: Map View and Cross Section through the Waste Disposal Site and surrounding Area

Groundwater Travel Time

A preliminary estimate of groundwater travel time from the disposal area to the creek can be calculated using Darcy’s law and an estimate of the effective porosity, as follows:

$$q = K * G; \text{ and } V = q / n$$

Where:

- q = Darcy velocity
- K = hydraulic conductivity
- G = groundwater gradient
- V = seepage velocity, and
- n = effective porosity

Two cases were examined, using a range of hydraulic conductivities. The parameters used for the travel time calculations are listed as follows:

Approximate distance from the waste disposal area to the eastern edge of floodplain = 500 feet,
 Approximate distance across the floodplain to the Creek = 500 feet,
 Case 1: Hydraulic conductivity = 1.0 x 10⁻³ cm/sec for silty sand,
 Case 2: Hydraulic conductivity = 1.0 x 10⁻⁴ cm/sec for clayey sand and silt,
 Groundwater gradient for Upland Area = 6% (0.06),
 Groundwater gradient for Floodplain = 0.5% (0.005), and
 Effective porosity (both areas) = 20%

Parameter	Case 1	Case 2
Hydraulic Conductivity (K):	1.0 x 10 ⁻³ cm/sec	1.0 x 10 ⁻⁴ cm/sec
Effective Porosity (n)	20%	20%
Groundwater Gradient – Upland	6% for 500 feet	6% for 500 feet
Travel time to edge of floodplain:	1.6 years	16 years
Groundwater Gradient – Floodplain	0.5% for 500 feet	0.5% for 500 feet
Travel time across the floodplain:	19.3 years	193 years
Total Groundwater Travel Time:	21 years	210 years

For Case 1, the total linear travel time for groundwater to reach the Creek from the waste disposal site is approximately 21 years. However, the travel time for the first 500 feet (the distance from the waste disposal site to the eastern margin of the floodplain) is only about 1.6 years. It should be noted at this point that surface water from the creek was analyzed yearly by the State Radiation Protection Agency in the mid to late 1980s and no contamination was detected. In Case 2, the travel time from the waste disposal area to the edge of the floodplain is about 16 years, and the travel time all the way to the creek is about 210 years.

Clearly, the travel time calculations are very sensitive to the groundwater gradient and the assumed hydraulic conductivity. As such, an accurate topographic survey and permeability testing in new wells,

planned for installation during the Phase 2 investigations, will be conducted to determine actual groundwater gradients and subsurface conductivities in the general waste disposal area.

Sample Collection and Analysis

Groundwater and soil samples were collected from the site following the methodologies listed in the written procedures developed for this work (See Part 3 of this course series – Preparation of Project Plans and Procedures). Groundwater samples were collected from each of the five existing monitoring wells located around the perimeter of the waste disposal site. A duplicate groundwater sample was collected from Monitoring Well #3 to provide a quality assurance check. Soil samples were collected with a hand auger from four locations down-gradient of the waste disposal area. The groundwater and soil sampling programs and the results of the tests are presented in the following subsections.

Groundwater Sampling

The following is a brief summary of the procedures used to collect the groundwater samples:

- The monitoring well cap was unlocked and removed. Air in the breathing zone and within the well casing was monitored with an organic vapor analyzer (OVA). Upon determining that the concentration of organic vapors in the breathing zone were at a safe level, the field investigators spread plastic sheeting on the ground around the monitoring well and set up the sampling equipment.
- The depth to the groundwater table and the total depth of the monitoring well were measured using an electronic water-sensing meter. The volume of water present in the monitoring well casing was computed and multiplied by 3 to determine the quantity of water that needed to be removed from the monitoring well before sampling to insure the collection of a high quality formational water sample.
- A laboratory decontaminated stainless steel bladder pump and fresh polyethylene tubing were used for the purging of the groundwater at each monitoring well. The bladder pump was operated by an air compressor powered by oil less propane motor.
- As a measure of groundwater stability, samples were collected periodically throughout the purging procedure and the pH, temperature, and specific conductivity were measured.
- The groundwater purged from each monitoring well was contained in a US-Department of Transportation (US-DOT) approved 55 gallon metal drum.
- The groundwater sample was obtained after the calculated purge volume had been removed and the field measurements indicated that the pH, temperature, and conductivity had stabilized.
- Sampling was performed with a laboratory decontaminated Teflon bailer and a fresh nylon cord. Sample bottles were filled for each type of analysis in the order presented in the following table:

Sample Type	Method of Analysis
Volatile Organics	EPA 601 and EPA 602
Volatile Organics	SW-846-8240
Semi-Volatile Organics	SW-846 8270
Priority Pollutants Metals	SW-846 6010

Cyanide (total)	EPA 335.2
Phenols (total)	SW-846 9065
Tritium	ASTM-2476
Carbon-14	ASTM-D3085
Gamma Scan	EPA 901.1

Immediately after sampling, the bottles were placed in coolers with ice to maintain a temperature of less than 4° centigrade. Custody of the samples was then transferred at the site to a person from the contracted EPA-approved analytical laboratory that was responsible for delivering the samples to the laboratory for analysis.

Groundwater samples were analyzed for chemical contamination and radioactivity. Chemical analyses included volatile organic compounds, 1,4-dioxane, di-isopropyl ether, semi-volatile organic compounds, priority pollutant metals, cyanide and phenols. The analysis for radioactivity included: Tritium, Carbon-14 and gamma emitting radio nuclides.

Radiological Analysis of Groundwater

The results of the radiological analyses of the groundwater samples are presented in Table 4.

Table 4 - Radiological Analysis of Groundwater

Radionuclide	Well #1	Well #2	Well #3	Well #3D	Well #4	Well #5	D.L.(*)
Ac-227	-	-	-	-	-	-	(*)
Ac-228	-	-	47	64	42	-	(*)
Bi-212	-	-	-	-	-	-	(*)
Bi-214	140	34	260	200	330	220	(*)
C-14	900	1000	1000	900	-	-	800
Co-60	-	-	-	-	-	-	(*)
Cs-134	-	-	-	-	-	-	(*)
Cs-137	-	-	-	-	-	-	(*)
H-3 (Tritium)	7500	7200	32000	32000	-	-	2000
K-40	880	900	1800	2100	2000	830	(*)
Pb-211	-	-	-	-	-	-	(*)
Pb-212	27	39	-	-	12	19	(*)
Pb-214	47	-	90	68	140	140	(*)
Ra-223	-	-	-	-	-	-	(*)
Ra-226	130	190	-	-	-	270	(*)
Rn-219	-	-	-	-	-	-	(*)
Th-227	-	-	-	-	-	-	(*)
Th-228	-	-	-	-	-	-	(*)
Th-231	-	-	-	-	-	-	(*)
Th-234	-	-	-	-	-	-	(*)
Tl-208	-	-	11	-	9	-	(*)

U-235	-	-	-	-	-	-	(*)
U-238	-	-	-	-	-	-	(*)

Notes: All measurements are given in pico-Curies/Liter.
All entries with a dash (-) were not detected.
The column labeled D.L. is the detection limit.
C-14 and Tritium were measured using a different methodology than the other radionuclides.
Those marked with (*) in the last column were identified based on a gamma scan, which is sensitive to extremely small quantities.
Well#3D is a duplicate sample from Well #3 analyzed for quality assurance purposes.

Only Tritium (H-3) and Carbon-14 are considered to be contaminants coming from the waste disposal trenches, based on the inventory of buried waste and half-lives discussed in Part 2 of this series of courses. Neither of these radionuclides was found in Well #5, the up gradient well, or Well #4. Tritium was the only radionuclide detected in activities above the National Primary Drinking Water Standard, which, at the time of testing, was 20,000 pCi/L. Activities above this level were found only in Well#3. A map depicting the activity of tritium in the groundwater is presented on Figure 12.

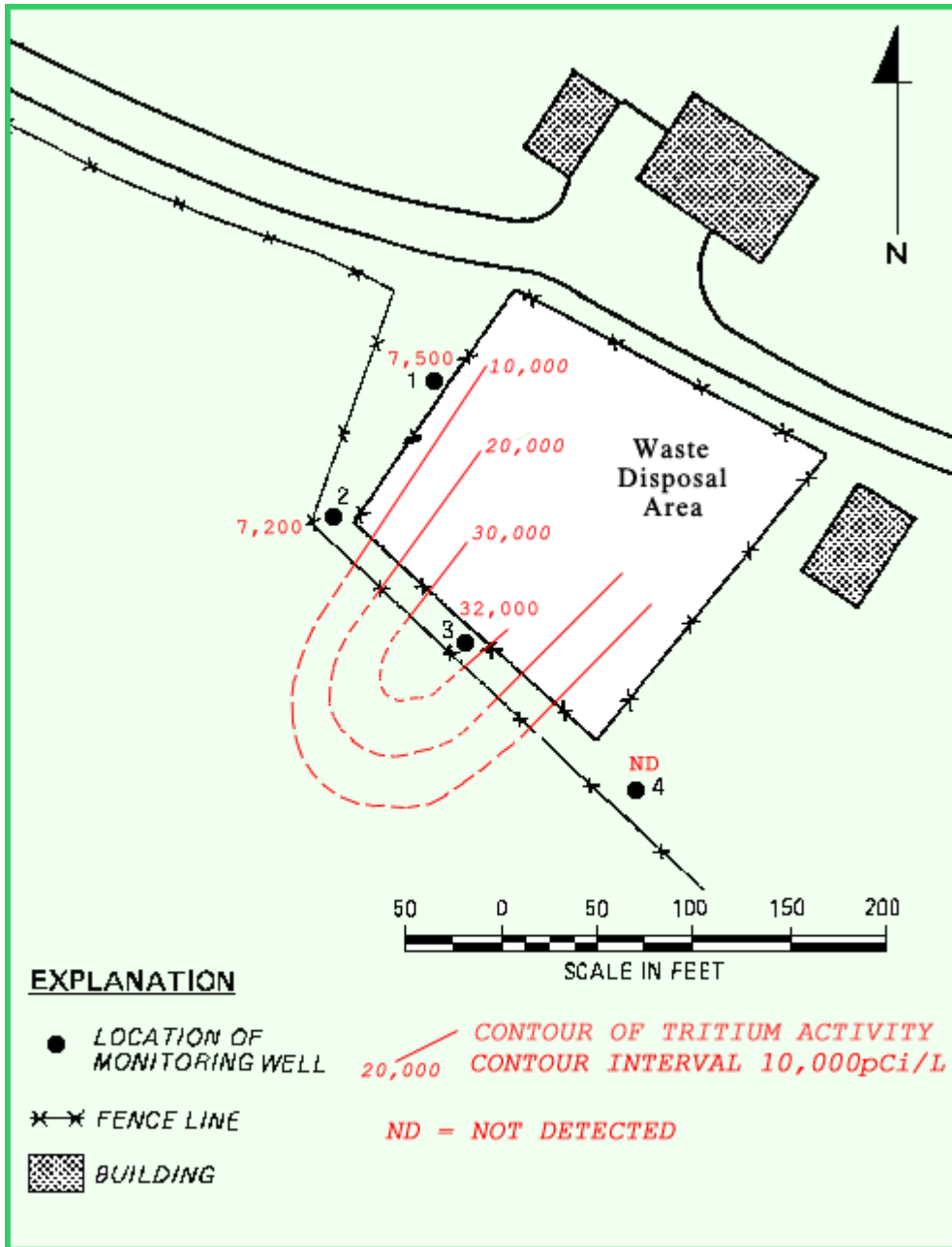


Figure 12: Map of Interpreted Tritium Activity

Carbon 14 activities were essentially the same in Wells #1 through #3, and barely above the detection limit. At the time of testing, the National Primary Drinking Water Standard for C-14 was 2,000 pCi/L. This standard was not exceeded in any of the sampled wells.

All of the other radionuclides detected can be attributed to natural sources. Radioactive potassium (K-40) is released into groundwater by the weathering of common rock minerals such as mica and feldspar. Potash fertilizer also contains K-40 and may have been used in the site area in the past.

Of the other radionuclides detected, Ac-228, Pb-212 and Tl-208 are intermediate products created during the radioactive decay of Thorium-232. Similarly, Bi-214, Pb-214 and Ra-226 are intermediate products created during the decay of Uranium- 238 and Uranium-234. Both Thorium and Uranium are naturally occurring radioactive elements that are especially common in granitic bedrock. None of these elements are related to the waste that was buried in the disposal area.

Organic Chemical Analyses of Groundwater

The results of the organic analysis of groundwater samples are presented in Table 5. In total, the organic chemical analyses tested for the presence of over 130 different compounds.

TABLE 5 - Organic Chemical Analysis of Groundwater (ppb)

Suite/Parameter	Well #1	Well #2	Well #3	Well #3D	Well #4	Well#5
Volatile Organic Compounds (EPA-601: 29 compounds listed)						
Chloroform	4,300	1,600	2,800	3,500	nd	nd
All other compounds:	nd	nd	nd	nd	nd	nd
Detection Limit	100	25	100	50	1.0	1.0
Volatile Organic Compounds (EPA-846-8240: 35 compounds listed)						
Chloroform	5,400	1300	3,000	3,000	nd	nd
Detection Limit	250	50	100	100	5	5
Volatile Organic Compounds (EPA-602: 8 compounds listed)						
All listed compounds:	nd	nd	nd	nd	nd	nd
Detection Limit	100	25	100	50	1.0	1.0
Additional compounds:						
Di-isopropyl ether	nd	nd	nd	nd	nd	nd
Detection Limit:	100	25	100	100	1.0	1.0
1,4-Dioxane	5,400	6,000	14,000	13,800	nd	nd
Detection Limit	500	5,000	10,000	10,000	500	500
Semi-Volatile Organic Compounds (EPA-846-8270: 65 compounds listed)						
All listed compounds:	nd	nd	nd	nd	nd	nd
Detection Limit	10 – 50	10 - 50	10 - 50	10 - 50	10-50	10 - 50
Notes:						
All concentrations given in ug/L (ppb) = microgram per liter (parts per billion)						
Well #3D = Duplicate Sample from Well #3						
nd = Not Detected						
Listed compounds for each test suite are presented in Appendix A, at the end of this course.						
Note: In some cases the detection limit is elevated due to sample dilution prior to analysis.						
Sample was diluted due to the high concentration of the target compounds present.						

Chloroform and 1,4-dioxane were the only volatile organic compounds detected in the groundwater samples. Samples from Wells 1, 2 and 3 showed chemical contamination, while samples from wells 4 and 5 did not. This is consistent with the pattern of radionuclide analyses from the same wells.

Chloroform concentrations in the groundwater samples from the three monitoring wells with detectable contamination ranged from a high 5,400 ug/L in Well #1 to a low 1,300 ug/L in Well #2. The concentration of chloroform in the sample from Well #3 was about 3,000 ug/L, roughly consistent with the concentration of 3,812 ug/L obtained by the State RPA. A map showing the interpreted concentration of chloroform in the groundwater is presented in Figure 13.

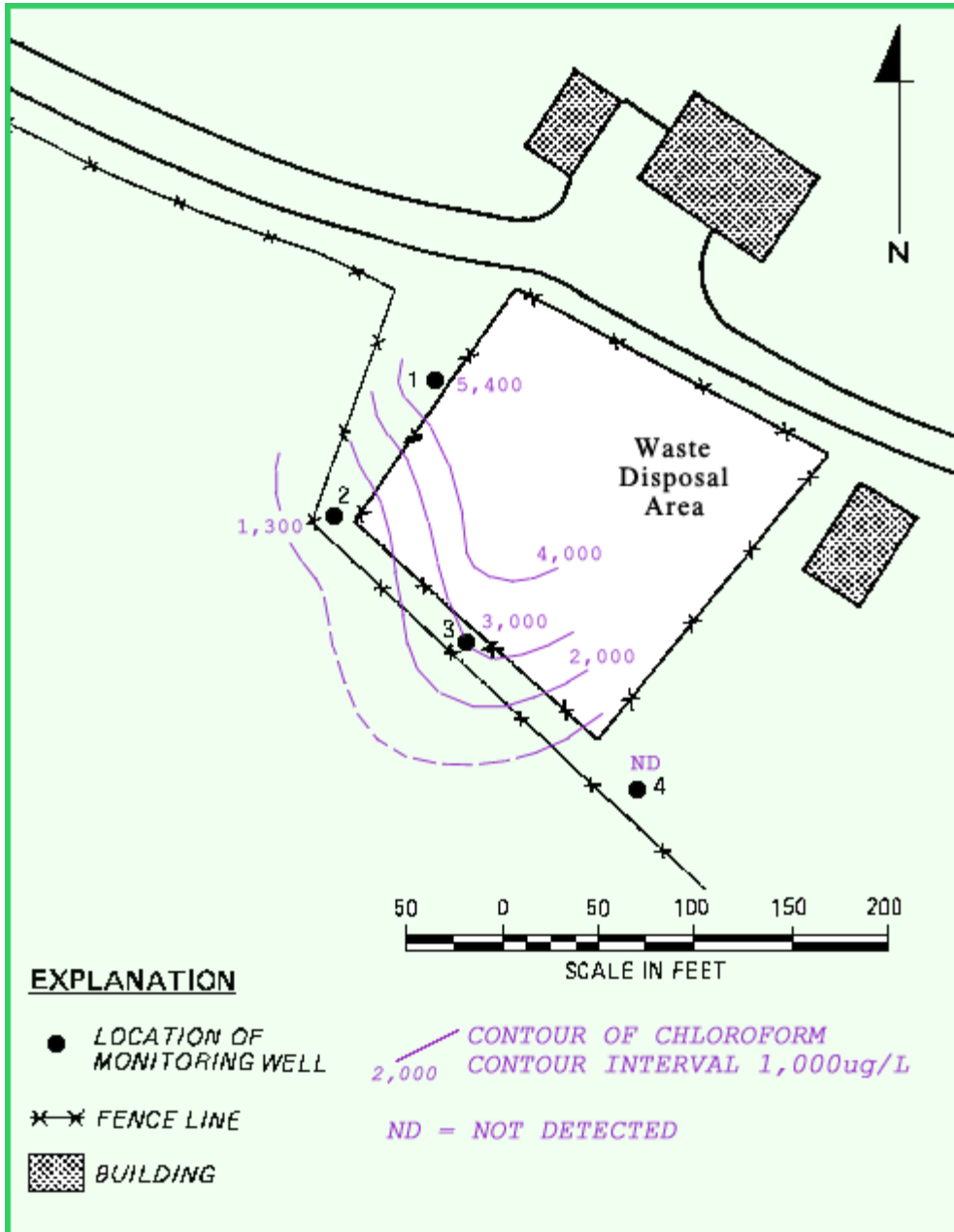


Figure 13: Map of Interpreted Chloroform Concentration

1,4-Dioxane concentrations in the groundwater samples from the three monitoring wells with detectable contamination ranged from 5,400 ug/L in monitoring well No. 1 to 14,000 ug/L in Well #3. The concentration in Well #3 is comparable to the 12,261 ug/L obtained by the State RPA. A map showing the interpreted concentration of 1,4-dioxane in the groundwater is presented in Figure 14.

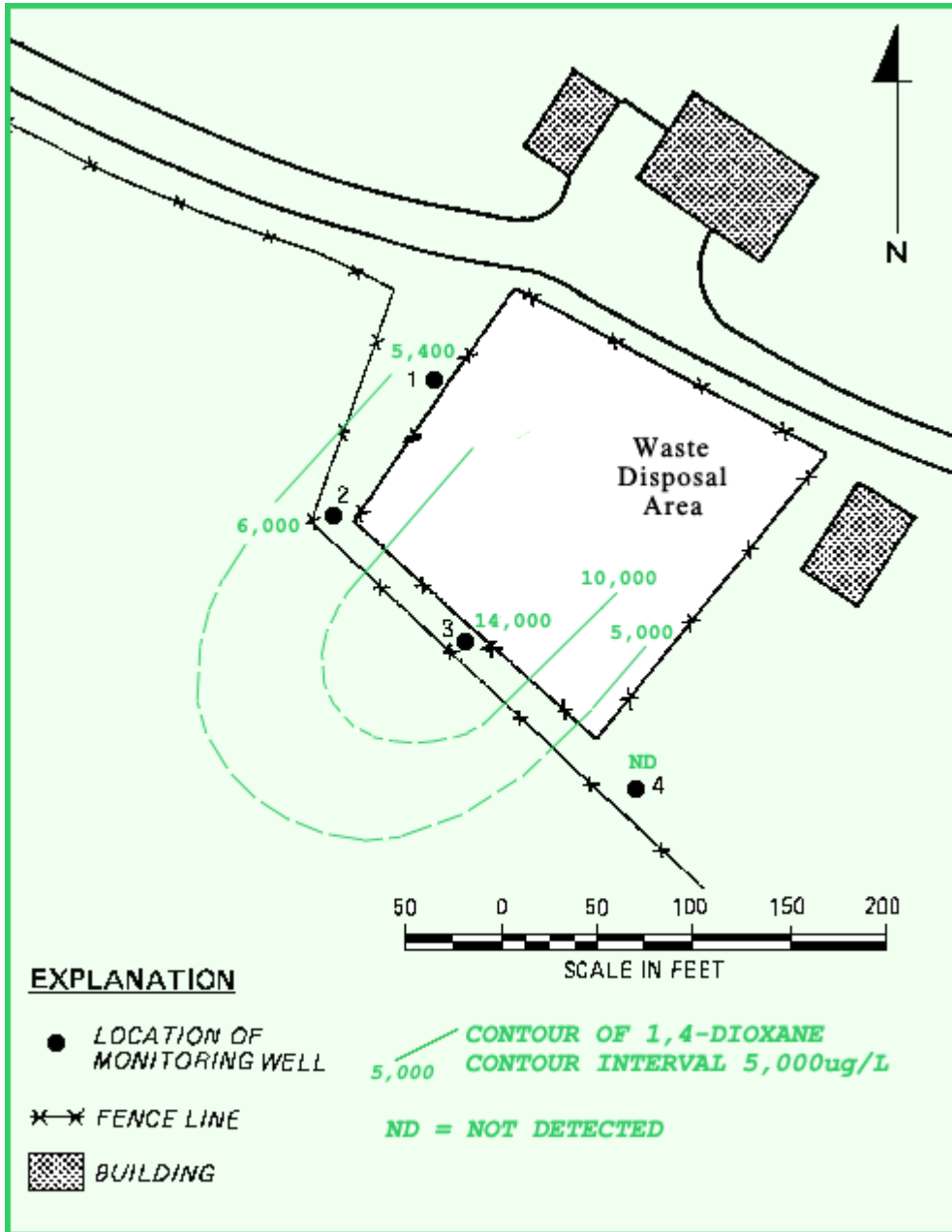


Figure 14: Map of Interpreted 1,4-Dioxane Concentration

Di-isopropyl ether, in a 166 ug/L concentration, was detected in earlier studies by the State RPA in a groundwater sample from monitoring well No. 3. Di-isopropyl ether was not detected in any of the samples analyzed during this Phase 1 study.

Inorganic Chemical Analysis of Groundwater

The testing of groundwater samples for inorganic constituents included the EPA Priority Pollutant metals, and total cyanide and phenols. The results of the inorganic analysis of groundwater samples are presented in Table 6.

TABLE 6 - Inorganic Analysis of Groundwater

Parameter	Well #1	Well #2	Well #3	Well #3D	Well #4	Well #5	D.L.
Antimony	-	-	-	-	-	-	0.20
Arsenic	-	-	-	-	-	-	0.005
Beryllium	-	-	-	-	-	-	0.01
Cadmium	-	-	-	-	-	-	0.01
Chromium	-	-	-	-	-	-	0.03
Copper	-	-	-	-	-	-	0.02
Lead	-	0.01	0.01	-	-	-	0.005
Mercury	-	-	-	-	-	-	0.0005
Nickel	-	-	-	-	-	-	0.03
Selenium	-	-	-	-	-	-	0.01
Silver	-	-	-	-	-	-	0.05
Thallium	-	-	-	-	-	-	0.005
Zinc	0.03	0.05	-	-	-	-	0.02
Cyanide	-	-	-	-	-	-	0.01
Phenols	-	-	-	-	-	-	0.005
Notes: All readings given in milligrams/Liter (parts per million) (mg/L, ppm) D.L. = detection limit. All entries with a dash (-) were not detected Well #3D is duplicate sample from Well #3 for quality assurance purposes.							

Of the thirteen Priority Pollutant Metals, only lead and zinc were present above their detection limit. The reported concentration of lead and zinc were below the state groundwater standards of 0.05 ppm and 5.0 ppm respectively. Concentrations of total cyanide and total phenols were below their respective detection limits of 0.01 and 0.005 ppm in all of the groundwater samples analyzed during the Phase 1 studies.

Measurement of Groundwater Field Parameters

Field measurements of specific conductivity and pH were obtained from each monitoring well prior to groundwater sampling. The pH of the groundwater samples from all the monitoring wells showed little variation, ranging from 5.56 to 5.86. Values for specific conductivity are listed in Table 7.

Table 7 – Specific Conductivity in Groundwater

Monitoring Well	Specific Conductivity
Well #1	279 uS/cm
Well #2	132 uS/cm
Well #3	114 uS/cm
Well #4	271 uS/cm
Well #5	359 uS/cm
Note: uS/cm = micro-Siemens per centimeter	

Specific conductivity is a general measure of the concentration of dissolved solids in the groundwater. The more dissolved solids (such as sodium or potassium) the higher the conductivity. This parameter can be used to compare the relative residence times of groundwater. In theory, the longer the water is in contact with the soil, the higher the specific conductivity, as it has had more time to dissolve elements from the soil.

As seen on Table 7, Well #5 had the highest specific conductivity (longest residence time), and wells #2 and #3 had the lowest (shortest residence time), with wells 1 and 4 intermediate. This pattern is consistent with the groundwater gradients observed and the likelihood of higher infiltration and recharge rates within the disposal area itself due to the excavation and backfill of the disposal trenches.

Summary of Groundwater Analyses

In summary, the laboratory data indicate that Tritium, C-14, chloroform, and 1,4-dioxane are the only detected contaminants interpreted to be migrating in the groundwater away from the immediate perimeter of the fenced waste disposal area. Contaminants appear to be moving in a west-southwest direction from the waste disposal area. The variation in the geometry of the various contaminant plumes (Figures 12, 13 and 14) is likely due to the variation in the location and timing of disposal of the various waste streams that were disposed of within the burial trenches.

Soil

Locations of the soil samples were selected after studying the site surface water and groundwater hydrology. These locations were chosen to maximize the possibility of intercepting any contamination that may have migrated in a down-gradient direction from the waste disposal area. The locations of the soil samples that were collected and analyzed during this phase of work are shown on Figure 15.

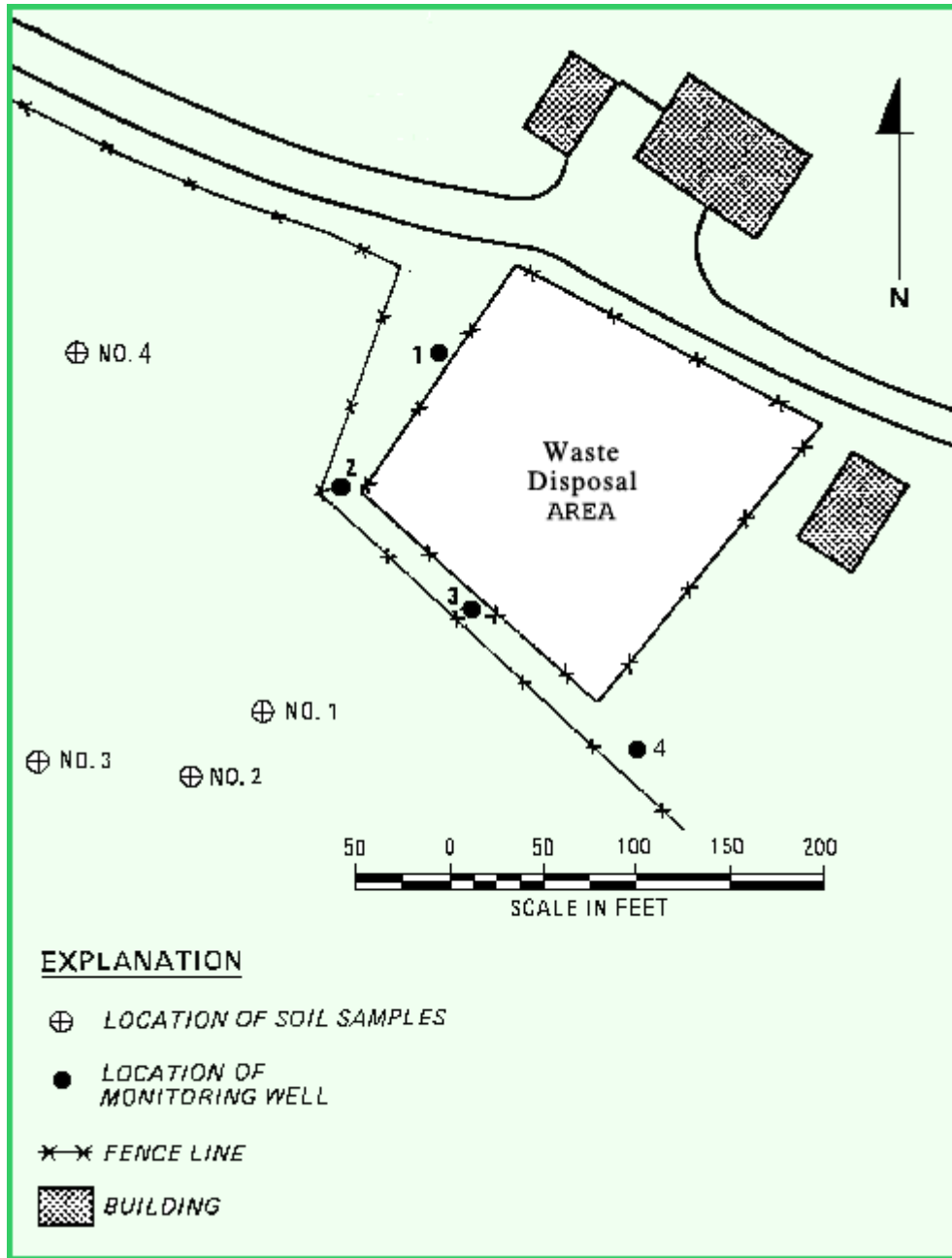


Figure 15: Locations of the Soil Samples that were collected and analyzed

Soil samples were collected from the interval 3.0 to 4.0 feet below the natural ground surface. These samples are located at the projected elevation of the bottom of the trenches (Sample No.1), and the approximate projected elevation of the top of the groundwater table beneath the site (Samples No.2, 3 and 4). These locations and elevations were selected to maximize the interception of any groundwater seeps that may have developed along the sides of the local drainage basin during periods of high groundwater stands. If such seeps occurred in the past they may have contaminated the soil. The samples were located in the field with reference to the perimeter fence around the waste disposal area by using a measuring tape and a brunton compass.

Soil Sampling

Following is a brief summary of the procedure used to collect the soil samples:

- Vegetation and surface debris were cleared from the sampling location and a sheet of plastic was placed on the ground.
- A laboratory decontaminated stainless steel auger was unwrapped and attached to a stainless steel soil auger handle
- Soil removed during augering was placed sequentially onto a plastic sheet in the order that represented the natural soil profile.
- Soil samples were collected from the interval of 3.0 to 4.0 feet below the natural ground surface.
- Two soil samples were collected from each location, one for each type of analysis presented in the following table:

Sample Type	Method of Analysis
Volatile Organic Compounds	EPA 601 and EPA 602
Tritium	ASTM 2476

- Immediately after sampling, the sample bottles were placed into coolers with ice to maintain a temperature of less than 4° centigrade. A sample custody form was completed and the samples were shipped to the analytical laboratory for analysis.
- After sampling, geologic descriptions of the soil profile were recorded.

Soil samples were analyzed for Tritium activity and volatile organic compounds. The results of these analyses are presented in Table 8.

TABLE 8 - Analysis of Soil Samples

Suite/Parameter	SS #1	SS #2	SS #3	SS #4	D.L.
Radiological Analysis:					
Tritium	nd	nd	nd	nd	0.78 pCi/gr
Volatile Organics - EPA Method 601 (29 compounds):					
All listed compounds	nd	nd	nd	nd	1.0 ug/kg
Volatile Organics - EPA Method 602 (8 compounds):					
All listed compounds	nd	nd	nd	nd	1.0 ug/kg
Additional compound:					
Di-isopropyl ether	nd	nd	nd	nd	1.0 ug/kg

Notes:

D.L. = detection limit

nd = not detected

pCi/gr = pico-Curie per gram

ug/kg = microgram per kilogram, equivalent to parts per billion

No evidence of contamination was detected in any of the soil samples. Tritium activities were below the detection limit (0.78 pCi/gr) in all soil samples. Volatile organic compounds were below the detection limit of 1 ug/kg in all soil samples.

Preparation of Updated Site Condition Report

At the close of this phase of work, all of the new groundwater and soil analyses were used to update the Preliminary Site Condition Report (discussed in Part 2 of this course series). The site history, waste inventory, and other sections of the Preliminary Report were carried forward to the updated report, so that the updated report would be a stand-alone document. The sections on groundwater chemistry and soil chemistry were augmented by the new analyses, the **Conclusion Section** was updated, and two additional sections were added: **Environmental Impacts** and **Recommendations**. The updated and the two new sections are presented below.

Conclusion Section

The waste disposal area is located in soils developed on the weathered upper portion of coarse grained, gray biotite granite bedrock. Field observations and data from two particle size analyses of soil samples, performed during this study, indicate that the soil in the vicinity of the waste disposal area has little silt or clay content. Hydraulic conductivity of the site soils is estimated to be in the range of 10-3 cm/sec to 10-4 cm/sec which is considered to be the representative range for silty to clayey sand.

The campus is drained by a creek that flows along an east-west trending course, north of the waste disposal area; and along a north-south trending course, west of the waste disposal area. This creek joins a larger one about 2,500 feet south of the Institute's property boundary. The larger creek joins a larger stream approximately 14 miles southwest of the research campus.

An estimate of the water budget for a portion of the site reveals that about 10,000 cubic feet of precipitation per year infiltrates into the area of the trenches and becomes contaminated. The waste disposal site comprises about 1.5% of the total area of the small drainage basin that contains it, so that we can infer that significant dilution occurs as the contaminated water heads downhill towards the flood plain.

Three rounds of groundwater level measurements were obtained between June and November. Based on these measurements, the distance between the bottoms of the trenches and the top of the groundwater table is estimated to be on the order of 15 feet.

Preliminary groundwater travel time estimates suggest that groundwater from the waste disposal area reaches the eastern edge of the floodplain in somewhere between 1.6 and 16 years, depending on the

assumed groundwater gradient and hydraulic conductivity of the soils. The time for groundwater to reach the creek across the floodplain ranges from 19.3 to 193 years, again depending on the assumed groundwater gradient and hydraulic conductivity of the soils.

Surface water from the Creek was analyzed on a yearly basis by the State Radiation Protection Agency in the mid- to late-1980s and no contamination was detected at that time.

Groundwater samples were collected from each of the five monitoring wells located around the perimeter of the waste disposal area. Samples were tested for 23 radionuclides and over 130 chemical compounds. Samples were analyzed for volatile organic compounds, semi-volatile organic compounds, priority pollutant metals, cyanide, phenols, Tritium, Carbon-14, and gamma emitting radionuclides. In addition, four soil samples were collected from the down-gradient hill slope, between the Site and the floodplain of the Creek. These soil samples were analyzed for volatile organic compounds and Tritium.

Tritium was the only radionuclide detected in the groundwater from Well #3 in activities above the National Primary Drinking Water Standard (20,000 pCi/L). Although groundwater in the area of the site is not used for drinking, the National Primary Drinking Water Standard is referred to in order to compare the level of contamination detected in the monitoring wells to the levels of allowable contaminants in drinking water. The results of gamma scan analyses of the groundwater samples indicated that the gamma emitting radionuclides are not elevated above natural background radiation.

The organic analysis of groundwater samples from the monitoring wells identified chloroform and 1,4-dioxane as the only volatile organic compounds that were detected above their respective allowable State Groundwater Standards. The organic analysis included a check for di-isopropyl ether and carbon tetrachloride, both of which were detected in the 1980s by the State RPA, but were not detected during this phase 1 investigation.

The groundwater samples were also analyzed for priority pollutant metals, cyanide and total phenols. All these elements and compounds were either not detected or were present in concentrations below the State Groundwater Standards.

No evidence of contamination was detected in any of the soil samples. Tritium activities and volatile organic compounds were below their respective detection limits in all soil samples.

Environmental Impacts

The environmental impacts discussion was limited to the areas down-gradient of the waste disposal site and down-stream of the southern property boundary of the facility, as per the guidelines of the State EPA. The primary pathways for contamination to reach the area outside the property boundary are through surface water and groundwater. The emphasis of this section, therefore, was towards identifying possible receptors from these potential pathways, as discussed below.

Nearest Downstream Surface Water Intake

The nearest downstream surface water intake is located on a large stream, approximately 14 miles southwest of the Site. This water intake serves 35,000 metered customers in a rural county. The second

nearest downstream surface water intake is located 29 miles south of the Site, on the same large stream. This second water intake serves approximately 9,500 metered customers also in a rural county. These intakes are at a considerable distance, and, because of attenuation and dilution, are not affected by any existing contamination at the Site.

Nearest Municipal Water Supply Well

There is no municipal water supply well within a 15-mile radius of the Site, which, again because of attenuation and dilution, precludes the possibility of any connection to existing contamination at the waste disposal site.

Nearest Private Water Well

Inspection of recent aerial photographs, maps and field reconnaissance found no down-gradient housing within a mile of the Site. At that distance considerable attenuation and dilution would have occurred, limiting any concern of contamination from conditions existing at the waste disposal site.

Nearest Agricultural Crop

A portion of the flood plain of the Creek, west of the waste disposal site, was cultivated by the owners of the farm which lies to the south of the Institute's southern property boundary. The corn crop is used as a feed for dairy cattle. Because of the possibility that contaminants may have migrated beneath the floodplain, the Consultant recommended that this practice be discontinued for the time being pending the development of additional information.

Recommendations

Based on the data collected and analyzed in this study, sufficient information has been developed to conclude that Tritium, chloroform and 1,4-dioxane have migrated in the groundwater past the perimeter fence that surrounds the waste disposal area. This condition led the Consultant to make the following recommendations to stabilize and improve existing conditions:

- Rainwater runoff in the up-gradient areas surrounding the waste disposal site should be controlled and redirected away from the area where the waste is buried.
- The waste disposal area should be re-graded and re-contoured to enhance runoff and avoid the local channeling and ponding of rain water.
- As work progresses, monitoring of groundwater levels should be carried out periodically to document a desired lowering of the water table beneath the disposal area.
- A precise topographic survey should be conducted at the Site to increase the level of confidence in the derived configuration of the groundwater table, the groundwater travel time calculations and to generate an accurate base map to guide future work at the site.
- A Feasibility Study should be performed to study the options for controlling the spread of contamination. One simple option may consist of placing a surface cover of low permeability over the waste disposal area to enhance the performance of the existing trench caps.
- The cultivation of corn in the down-gradient floodplain of the Creek should be discontinued at least until the groundwater beneath the floodplain is tested.

Regulatory Review

The updated Site Condition Report was submitted to the Institute. After review, the Institute transmitted copies to the State Radiation Protection Agency. The State RPA then transmitted copies to the State Groundwater Protection Agency (State GPA) and the State Waste Management Agency (State WMA), Superfund Section. Written comments were collected by the State RPA and sent to the Institute, with a directive that the agencies involved must have all their concerns addressed.

The State RPA provided no written comments. They verbally expressed to the Institute that they had no serious concerns relating to radiation exposure to the general public. They noted that the radioactive contamination exceeded drinking water standards at only one well at the edge of the disposal area, and they felt that dilution was likely to lower that value considerably by the time the groundwater reached the flood plain or property boundary. However, they would re-evaluate their position after the next round of field investigations.

The comments and responses from the State GPA and the State WMA are provided below.

State Groundwater Protection Agency Review

In a letter to the State RPA, the Chief of the State GPA expressed the view of one of his staff as follows:

- The study has still not adequately characterized the hydrogeology of the site. No information has been provided about the subsurface stratigraphy or the hydraulic properties of the soils. Estimates of travel times are based only on a range of assumed values.
- There was no recommendation to remove the source, even though contamination of groundwater had occurred and state groundwater quality standards had been exceeded. Should it be impractical to remove the source some plan for isolating the waste should be included to ensure that it will not continue to be a source of contamination.
- If it is the intent of the report to recommend that a passive remediation strategy be adopted we would suggest that much stronger evidence would be needed to support such a recommendation.
- This office also recommends that the waste be removed and disposed of in another waste facility or at least in a lined site on the Institute's property.
- Groundwater clean-up needs to be addressed as priority. Alternative proposals can certainly be considered. However, based on a site ranking performed by the staff member he concluded: "there are dozens of other sites with higher scores (priorities) that need urgent attention. This staff member will continue to follow development at this site proportionally".

The Consultant responded to these comments as follows:

Comment: The study has still not adequately characterized the hydrogeology of the site. No information has been provided about the subsurface stratigraphy or the hydraulic properties of the soils. Estimates of travel times are based only on a range of assumed values.

Response: The five monitoring wells at the site were installed prior to the Consultant's involvement in the study. No information such as drilling logs, monitoring well installation diagrams or geologic descriptions were recorded during the installation of these wells. This type of information will be generated during the follow-up investigations as new monitoring wells are installed and hydrologic testing is performed to determine the range of permeabilities at the site.

Comment: There was no recommendation to remove the source, even though contamination of groundwater had occurred and state groundwater quality standards had been exceeded. Should it be impractical to remove the source some plan for isolating the waste should be included to ensure that it will not continue to be a source of contamination.

Response: Studies to date have focused on defining the extent and magnitude of the problem, and not to the identification and evaluation of possible solutions. The workplan includes the performance of a conceptual engineering study to evaluate the methodologies that are best suited to control the source of contamination and propose the best-suited methodology for implementation once more information on the extent and nature of contamination has been developed.

It should be noted that source removal is always an attractive option to control the spread of contamination. However, because waste has been leaching from the disposal trenches and migrating vertically downward through at least 15 to 20 feet of soil before reaching the water table, the volume of waste and soil that may have to be removed greatly exceeds the original volume of the waste. Also, having all parties agree on a standard for "how clean is clean" to provide a limit to the amount of soil and waste to be excavated has proven very difficult at other sites nationwide. Nonetheless, source removal and other options will be evaluated in the conceptual engineering report (traditionally called the Feasibility Study).

Comment: If it is the intent of the report to recommend that a passive remediation strategy be adopted we would suggest that much stronger evidence would be needed to support such a recommendation.

Response: The report makes no recommendations with respect to remediation strategies, only that, as a first step, surface water should be diverted away from the waste disposal area. Remediation options will be evaluated as part of the Feasibility Study after additional site investigations are completed.

Comment: Groundwater clean-up needs to be addressed as priority. Alternative proposals can certainly be considered.

Response: To date, groundwater contamination has been investigated using monitoring wells along the perimeter of the waste disposal area. Before groundwater clean-up issues are addressed, more information on the hydraulic properties of the soil is needed, as are additional monitoring wells and groundwater testing further down-gradient towards the Creek and the southern property boundary. As your staff member has stated, the contamination levels found to date place this site relatively low on the ranking system used by the State EPA. No waste has been placed at this site in the past 20 years.

There does not appear to be a serious health risk to the public at this time. It would, therefore, be premature to address groundwater clean-up until more information is collected and analyzed during the next phase of field work.

State Waste Management Agency Review

This agency reviewed the Updated Site Condition Report and offered the following comments:

- Di-isopropyl ether may be present in Wells 1, 2 and 3 and not detected because of the necessary dilutions, which were conducted prior to analysis.
- Method 8240 has a broader list of volatile compounds than methods 601/602 but generally has higher detection limits. Method 8240 should be used to screen for additional volatile organic compounds in Well #4. Also, when future samples are analyzed by Method 8240, the laboratory should be instructed to also identify at least 10 percent of the largest peaks in an effort to identify compounds not listed in the method. If the Institute has already followed this procedure, this information should be specified in the report.
- The report shows agricultural land approximately 300 feet downgradient from the property boundary. Engineering controls to prevent any sedimentation or stormwater impact to this area during remediation should be included in any future remediation work plan. Also, the source of irrigation water should be determined.

The Consultant prepared the following responses to the comments that were received from the State Waste Management Agency:

Comment: Di-isopropyl ether may be present in Wells 1, 2 and 3 and not detected because of the necessary dilutions that were conducted prior to analysis.

Response: Detection limit for di-isopropyl ether for the groundwater samples from monitoring wells #1 and #3 was 100 ug/L. The detection limit for the groundwater sample from monitoring well #2 was 25 ug/L. The State Radiation Protection Agency previously sampled well #3 and detected di-isopropyl ether in a concentration of 166 ug/L. If di-isopropyl ether was present in the groundwater in a concentration similar to that detected by the State RPA, then it would have been detected and identified during the latest round of sampling and testing at the site.

Comment: Method 8240 has a broader list of volatile compounds than methods 601/602 but generally has higher detection limits. Method 8240 should be used to screen for additional volatile organic compounds in Well #4. Also, when future samples are analyzed by method 8240, the laboratory should be instructed to also identify at least 10 percent of the largest peaks in an effort to identify compounds not listed in the method. If the Institute has already followed this procedure, this information should be specified in the report.

Response: Analysis of groundwater samples from Well #4 did not detect any volatile organic compounds by method 601/602 at the low detection limit of 1.0 ug/L. Also, testing for radiological

parameters, priority pollutant metals, base/neutral/acid extractable semi-volatile compounds, cyanides, and total phenols did not detect the presence of any contamination. None of the tested analytical parameters indicated the presence of any contamination. In addition, Tritium is an excellent indicator of groundwater contamination at the site because of its presence throughout the waste material and its high mobility. If Tritium contamination is not present in the groundwater in Well #4 then it is likely that the less mobile constituents such as 1,4 dioxane and chloroform are not present either. This information, along with the knowledge gained about the groundwater flow pattern at the site, presented in the updated Preliminary Site Condition Report, was used to determine that Well #4 monitors background conditions and is not influenced by the waste buried at the site. This conclusion is additionally supported by the fact that there are no burial trenches in the eastern third of the waste disposal area, which is the section closest to Well #4. This is why analysis by the 8240 method was not completed on samples from that well.

1,4-dioxane and di-isopropylether were specifically requested for identification, outside of the target compounds listed by the 8240 method, because they were detected by the State RPA in their earlier sampling round. Identification of 10 percent of the largest spectral peaks of compounds not listed in the 8240 method was not performed. This suggestion will be considered and implemented when planning future sample analyses.

Comment: The report shows agricultural land approximately 300 feet down-gradient from the waste disposal site. Engineering controls to prevent any sedimentation or storm-water impact to this area during remediation should be included in any future remediation work plan. Also, the source of irrigation water should be determined.

Response: The small patch of agricultural land approximately 300 to 500 feet down-gradient of the waste disposal area, on the floodplain of the creek, does not seem to have been irrigated regularly by artificial means. The planting of this patch of land has been discontinued and will not be allowed until the groundwater in that area is tested.

Prior to implementing any remedial measures at the site the Consultant will generate the basic information that will be needed to develop an engineering plan to prevent sedimentation or storm-water impact to the floodplain located down-gradient of the site.

Media Reporting

Following the submittal of the Preliminary Site Condition Report, the press became aware of the work being conducted at the waste disposal site. An article appeared in the local daily newspaper and a summary of the article appeared on the TV morning news. Once the Updated Site Condition Report was issued, the same reporter conducted follow-up interviews with the State Radiation Protection Agency and the Institute. The reporter's updated story appeared in the local daily newspaper, and was picked up by other papers in the surrounding counties and cities. A summary was again aired on the local TV news.

The text of the article is presented below.

Contamination Leaking From Old Waste Dump

As we first reported several months ago, hazardous and low-level nuclear waste, buried more than 25 years ago, is moving towards a creek that flows through the property of the Research Institute. A recently released consultant report states that samples from wells near the waste dump on site found radioactive Tritium, chloroform and 1,4 dioxane – a hazardous chemical – in the groundwater. A representative of the State Radiation Protection Agency, who is overseeing the work at the site, said that there is “no threat to the community at this time.”

State officials from three agencies say that the waste - buried in 38 ditches up to 60 feet long and 12 feet deep - does not pose an immediate health threat, but they are directing the Institute to install more test wells closer to the creek and produce plans to block the waste plume or clean up the site. The official added: "They're working on plans to control the migration, and we're just waiting to see what they've got. If it starts moving off the property, then they could have to remove the materials."

The report notes that the creek is a tributary of a larger stream and that the contaminants, if not blocked or removed, could wind up in the drinking supplies of 44,500 households that are served by the counties and city suppliers.

But it adds, "These intakes are at a considerable distance and are not affected by any existing contamination at the site."

One of the water intakes is 14 miles southwest of the dump, and the other intake is 29 miles downstream.

No pollution from the dump has been detected in the stream, and five monitoring wells are being used to gauge the waste's movement, state officials say. The Consultant's report projects that the waste has spread 200 feet through ground water south of the dump site, to within 600 feet of the creek.

A representative of the Institute said: "We are proceeding as quickly as we think is prudent. Right now we are still assessing the extent of the contamination."

State records show that waste was buried at the site for a period of twenty years. It is believed that the dump may include waste that has come from other adjoining research institutions.

The waste - which originally included at least 23 different radioactive isotopes, most of which have decayed to non-threatening levels - were placed in cardboard boxes, plastic bags and 1- and 5-gallon metal cans, thrown into the ditches and covered with 4 feet of dirt. According to a representative from the Institute, this type of dumping was legal in the 60s and 70s, but is no longer allowed.

(End of article)

It is interesting to note that although the article can generally be characterized as fair, in that all agencies were contacted and quoted in context, the reporter could not avoid infusing a streak of sensationalism in his reporting. It is clear from a technical standpoint that his quotation "that the

contaminants, if not blocked or removed, could wind up in the drinking supplies of 44,500 households" was taken completely out of context. This statement is structured to unfairly exploit the anxiety of the reader. Also, the Consultant's report had not at this point delineated the extension of the contaminant plume "200 feet down gradient of the waste disposal site, and within 600 feet of the Creek". The extension and dimension of the contaminant plume were to be investigated during the Phase 2 field investigations.

Part 4 Summary

This course covered the results of the Phase 1 Field Investigations, where existing monitoring wells were re-sampled and analyzed for radionuclides and chemical contamination. The results were comparable to the results obtained by the State Radiation Protection Agency a number of years earlier, except that one compound (di-isopropyl ether) which was detected by the State RPA earlier, has not been detected during this phase of site work.

Four soil samples were also collected during the Phase 1 Field Investigations and tested for radionuclides and chemical compounds. None were detected.

Three rounds of water level measurements from the existing monitoring wells provided a first look at the depth and configuration of the groundwater beneath the waste disposal site. Based on published information the general site geology was evaluated. Two soil samples were collected for particle-size analysis, and preliminary infiltration rates and groundwater travel times were estimated.

The information obtained during this phase of work, combined with the review comments received from the State Regulatory Agencies were used to plan the Phase 2 field investigations, which consisted of installation of additional monitoring wells, sampling, analyzing and testing the new wells to determine the hydraulic properties of the soils. A detailed topographic survey of the entire site was implemented at the onset of the new phase of work to provide better control on well elevations and provide a base map for the evaluation of potential remedial options. This follow-up work is covered in Part 5 of this series of courses: Results and Implications of Phase 2 Investigations.

Glossary of Terms and Acronyms used in this Course Series

1,4-dioxane	para-dioxane (p-dioxane), a hazardous chemical
AEC	Atomic Energy Commission
adsorption coefficient	measure of adherence of ions in solution to the surface of solids with which they come in contact
alluvial soil	a young soil on flood plains that is being actively deposited
ASTM	American Society for Testing and Materials
bailer	cylindrical container designed to remove water from a well
biotite	a widely distributed rock forming mineral of the mica group
C-14	Carbon-14, a radioactive form of carbon
CFR	Code of Federal Regulations
cm/sec	centimeter/second
Curie	A unit of measurement of radioactivity, which is approximately equal to the decay rate of one gram of pure radium.
DOT	Department of Transportation
Down-gradient	A direction towards which groundwater is likely to flow
draw	A small natural watercourse or gully, also a dry streambed whose water results from periodic rainfall.
Effective porosity	The percent of the total volume of a given mass of soil or rock that consists of interconnecting interstices.
EPA	Environmental Protection Agency
ft.	feet
GC/MS	Gas Chromatograph/Mass Spectrometer
H&S	Health and Safety
HASP	Health and Safety Plan
H ₂ SO ₄	Chemical formula of sulfuric acid
H-3	Tritium, a radioactive form of hydrogen
HCL	Chemical formula of hydrochloric acid
HNO ₃	Chemical formula of nitric acid
in.	inches
mafic rock	igneous rock composed mainly of dark-colored minerals
mCi	milli-Curie, scale for the measurement of radioactivity
my	million years
NaOH	Chemical formula of sodium Hydroxide
OVA	organic vapor analyzer
pCi/L	pico-Curie/liter, scale for the measurement of radioactivity in liquids
pCi/gr	pico-Curie/gram, scale for the measurement of radioactivity in solids
permeability	capacity of a porous rock to transmit a fluid, ease of fluid flow
pH	hydrogen-ion activity in solution, a measure of acidity
pluton	A geologic igneous intrusion
potentiometric surface	a surface representing the total head of water in an aquifer
ppb	parts per billion
ppm	parts per million
purging	volume of water extracted from a well prior to sampling

QA/QC	Quality Assurance/Quality Control
Saprolite	A thoroughly decomposed rock, formed in place by the weathering of igneous, sedimentary or metamorphic rocks.
SCS	Soil Conservation Service
State RPA	State Radiation Protection Agency
State EPA	State Environmental Protection Agency
State GPA	State Groundwater Protection Agency
State WMA	State Waste Management Agency
Superfund	Acronym referring to the resources allocated by Federal or State Agencies for the clean-up of decommissioned waste disposal sites. The funds are disbursed by priority based on the degree of hazard
total head	the height of a column of water above a datum plane
ug/L	micro-gram/Liter
ug/kg	micro-gram/kilogram
uS/cm	microsiemens per centimeter, a measure of specific conductivity
Up-gradient	A direction opposite to that in which groundwater is likely to flow
USDA	United States Department of Agriculture
US-DOT	United States Department of Transportation
USEPA	United States Environmental Protection Agency
USNRC	United States Nuclear Regulatory Commission
USGS	United States Geological Survey
well screen	section of well casing perforated or slotted to allow water inflow

APPENDIX A – Lists of Compounds Tested For in Chemical Analyses

Volatile Organics- EPA 601 Compound List (Purgeable Halocarbons)	
Chloromethane	1,2-Dichloropropane
Bromomethane	cis-1,3-Dichloropropene
Vinyl Chloride	Trichloroethene
Dichlorodifluoromethane	trans-1,3-Dichloropropene
Chloroethane	1,1,2-Trichloroethane
Methylene Chloride	Dibromochloromethane
Trichlorofluoromethane	2-Chloroethylvinyl ether
1,1-Dichloroethene	Bromoform
1,1-Dichloroethane	Tetrachloroethene
1,2-Dichloroethene (total)	1,1,2,2-Tetrachloroethane
Chloroform	Chlorobenzene
1,2-Dichloroethane	1,3-Dichlorobenzene
1,1,1-Trichloroethane	1,2-Dichlorobenzene
Carbon Tetrachloride	1,4-Dichlorobenzene
Bromodichloromethane	

Volatile Organics - EPA 602 Compound List (Purgeable Aromatics)	
Benzene	1,4-Dichlorobenzene
Chlorobenzene	Ethylbenzene
1,2-Dichlorobenzene	Toluene
1,3-Dichlorobenzene	Xylenes (total)

Volatile Organics - EPA SW-846 Method 8240 Compound List	
Acetone	1,2-Dichloropropane
Benzene	cis-1,3-Dichloropropene
Bromodichloromethane	trans-1,3-Dichloropropene
Bromoform	Ethylbenzene
Bromoethane	2-Hexanone
2-Butanone	Methylene chloride
Carbon disulfide	4-Methyl-2-pentanone
Carbon tetrachloride	Styrene
Chlorobenzene	1,1,2,2-Tetrachloroethane
Dibromochloromethane	Tetrachloroethene
Chloroethane	Toluene
2-Chloroethylvinyl ether	1,1,1-Trichloroethane
Chloroform	1,1,2-Trichloroethane
Chloromethane	Trichloroethene
1,1-Dichloroethane	Vinyl acetate
1,2-Dichloroethane	Vinyl chloride
1,1-Dichloroethene	Xylenes (total)
1,2-Dichloroethene (total)	

Semi-Volatile Organics - EPA SW-846 Method 8270 Compound List	
Acenaphtene	4,6-Dinitro-2-methylphenol
Acenaphthylene	2,4-Dinitrophenol
Anthracene	2,4-Dinitrotoluene
Benzoic acid	2,6-Dinitrotoluene
Benzo (a) anthracene	Di-n-octylphthalate
Benzo (b) fluoranthene	Fluoranthene
Benzo (k) fluoranthene	Fluorene
Benzo (g,h,i) perylene	Hexachlorobenzene
Benzo (a) pyrene	Hexachlorobutadene
Benzyl alcohol	Hexachlorocyclopentadene
bis (2-Chloroethoxy) methane	Hexachloroethane
bis (2-Chloroethyl) ether	Indeno (1,2,3-cd) pyrene
bis (2-Chloroisopropyl) ether	Isophorone
bis (2-Ethylhexyl) phthalate	2-Methylnaphthalene
4-Bromophenyl phenyl ether	2-Methylphenol (o-cresol)
Benzyl butyl phthalate	4-Methylphenol (p-cresol)
4-Chloroaniline	Naphthalene
2-Chloronaphthalene	2-Nitroaniline
4-Chloro-3-methylphenol	3-Nitroaniline
2-Chlorophenol	4-Nitroaniline
4-Chlorophenyl phenyl ether	Nitrobenzene
Chrysene	2-Nitrophenol
Dibenzo (a,h) anthracene	4-Nitrophenol
Dibenzofuran	N-Nitroso-di-n-propylamine
Di-n-butylphthalate	N-Nitrosodiphenylamine
1,3-Dichlorobenzene	Pentachlorophenol
1,4-Dichlorobenzene	Phenanthrene
1,2-Dichlorobenzene	Phenol
3,3'-Dichlorobenzidine	Pyrene
2,4-Dichlorophenol	1,2,4-Trichlorobenzene
Diethyl phthalate	2,4,5-Trichlorophenol
2,4-Dimethylphenol	2,4,6-Trichlorophenol
Dimethyl phthalate	