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MARTIN MARIETTA

Characterization Plan for the Old Hydrofracture Facility

C. W. Francis
R. G. Stansfield

ENVIRONMENTAL SCIENCES DIVISION
PUBLICATION NO. 2701

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C. W. Francis
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Environmental Sciences Division
Publication No. 2701

NUCLEAR AND CHEMICAL WASTE PROGRAM
(Activity No. AR 05 10 10 0; ONL-WD20)

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ABSTRACT

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U. S. Department of Energy (DOE) facilities are required to comply fully with all federal and state regulations. In response to this requirement, the Oak Ridge National Laboratory (ORNL) has established the remedial action program, to provide comprehensive management of areas where past research, development, and waste management activities have been conducted and have resulted in residual contamination of facilities or the environment. One of the objectives of this program is to define the extent of contamination at these sites. The intent is to document the known environmental characteristics of the sites and identify the additional actions, such as sampling, analytical measurements, and modeling, necessary to confirm contamination and the possible migration of contaminants from the sites. One of these sites is the Old Hydrofracture Facility (OHF).

The OHF was used for the permanent disposal of liquid radioactive waste in impermeable shale formations at depths ranging from about 230 to 300 m (750 to 1000 ft), from 1964 to 1979. The liquid waste was blended into a pumpable grout by mixing it with cement and special clays used to immobilize radionuclides against groundwater transport.

This report summarizes the results of several studies at ORNL that have measured the concentration of radionuclides and, to some extent, concentrations of hazardous chemicals in the sediment of the impoundment, as well as the concentrations in soils and groundwater

near the facility. The report addresses only the contamination of and the potential releases to the environment that might result from the facility per se and makes no attempt to address potential releases that might result from permanent disposal of wastes (i.e., the grout sheets) during its operation. Outlined in the report are the additional actions needed to obtain the information required to confirm the extent of contamination within the facility. The major efforts include the measurement of radionuclides and potentially hazardous chemicals contained in the five underground waste storage tanks at the facility and determining of the lateral and vertical contamination due to seepage of waste from the impoundment.

1. INTRODUCTION

U. S. Department of Energy (DOE) facilities are required to comply fully with all federal and state regulations. In response to an application to the U. S. Environmental Protection Agency (USEPA) by the Oak Ridge National Laboratory (ORNL) for a permit to operate a hazardous waste storage facility, the USEPA has required ORNL to comply with the 3004 (u) provision of the 1984 Hazardous and Solid Waste Amendment of the reauthorization of the Resource Conservation and Recovery Act (RCRA). Under these regulations the Permittee is required to identify and characterize all solid waste management units currently or previously located within ORNL's boundary. The intent of this regulation is to determine whether a prior or continuing release of hazardous waste or hazardous constituents have occurred and/or to characterize the nature and extent of the releases.

One of the facilities that may pose an undue risk to health, safety, and environment as a result of the migration of hazardous substances to groundwater is the Old Hydrofacture Facility (OHF).

This report documents the existing environmental information on the OHF and defines additional actions, such as the installation of monitoring wells, collection of samples, and analytical measurements, required to confirm contamination and possible migration of contaminants from the site. Also included are descriptions of activities required to collect additional geologic and hydrologic information necessary to model the site performance.

2. DESCRIPTION OF THE FACILITY

The old hydrofracture facility (OHF) was used for the permanent disposal of liquid radioactive waste in impermeable shale formations at depths ranging from approximately 229 to 300 m (750 to 1000 ft) from 1964 to 1979 (Weeren 1976 and Weeren 1980). The liquid waste was formed into a pumpable grout by blending with cement and special clays used to immobilize radionuclides against groundwater transport. The grout was injected through a slotted well casing into the shale where it solidified into nearly horizontally thin sheets, depending on the orientation of the shale formation, around the injection well in a generally elliptical pattern. The average concentration of radionuclides in the grout mixture prior to injection was approximately 10 MBq/mL (0.26 mCi/mL) or less for beta-gamma-emitting radionuclides and 370 Bq/g (10 nCi/g) or less for transuranic alpha-emitting radionuclides. For a single injection, as much as 7.6×10^6 L (2×10^6 gal) of waste grout containing as much as 2.2×10^4 GBq (6.0×10^5 Ci) were disposed of.

The OHF is located approximately 1.1 miles southwest of the main complex of the Oak Ridge National Laboratory at the confluence of Melton Branch and White Oak creeks (see Fig. 1). Immediately to the east of the OHF is the western fenced boundary of the Solid Waste Storage Area 5 (SWSA 5), where low-level radioactive solid wastes were

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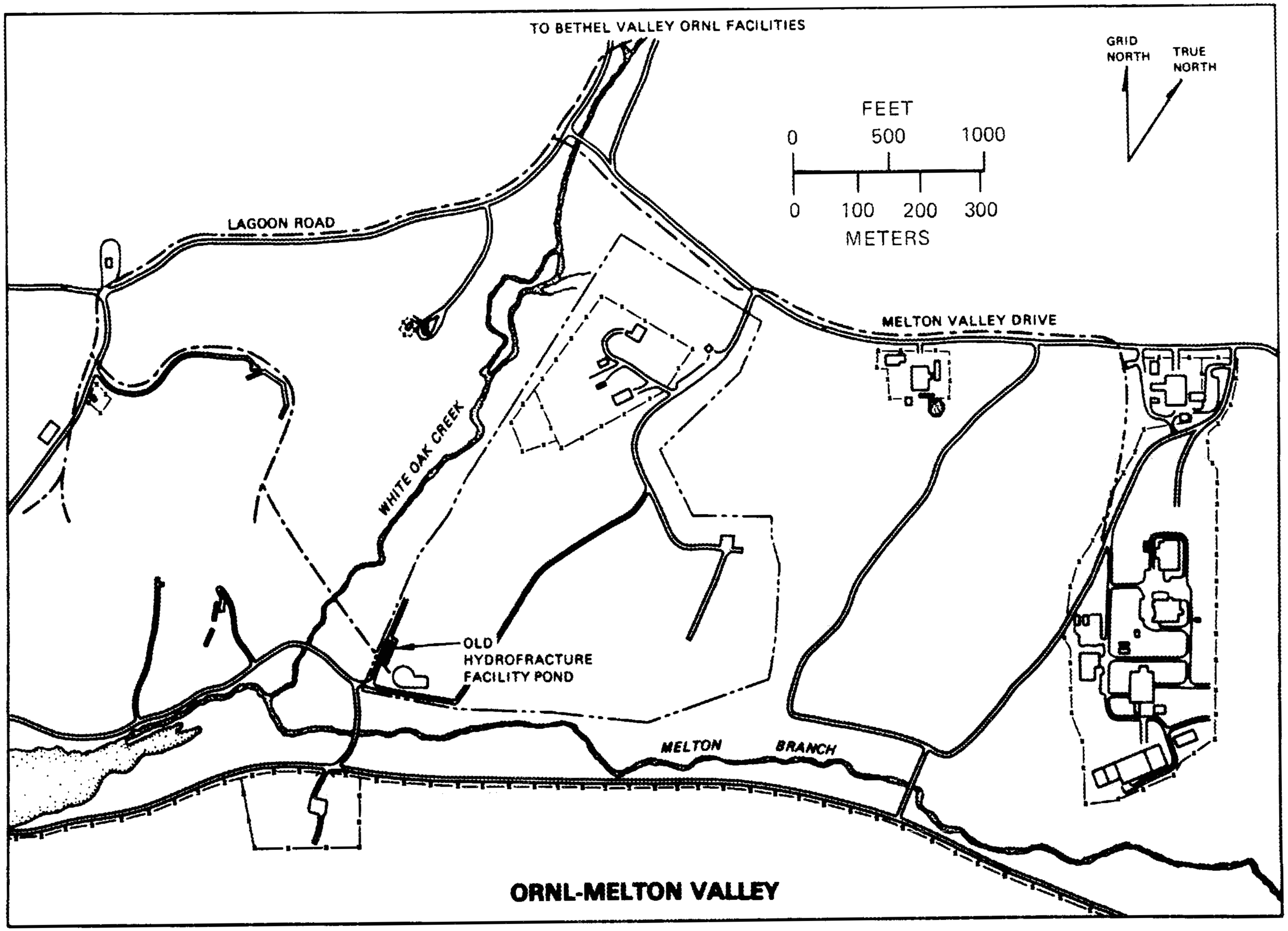

Fig. 1. Location of old hydrofracture facility at the Oak Ridge National Laboratory.

buried between 1958 and 1973. The facility is approximately 120 m (400 ft) east of White Oak Creek and approximately the same distance north of the Melton Branch. White Oak Creek flows into White Oak Lake and hence into the Clinch River.

The OHF site consists of three buildings (Buildings 7852, 7853, and a pump house) and some waste related containment facilities (waste pits, tanks, and an impoundment that was constructed to serve as an emergency containment basin in the event of a spill from the radioactive grout injections. The site plan and a photograph of the OHF are illustrated in Figs. 2 and 3, respectively.

The focus of this plan is limited to the buildings, equipment, and waste related facilities near surface, such as the waste pits, waste tanks and the waste impoundment. It does not address the characterization of disposed waste injected during the facility's lifetime.

2.1. BUILDINGS

2.1.1. Building 7852

Building 7852 contains a mixing cell, a pump cell for the head end of the injection pump, a well cell, a transit-roof-covered engine pad (at the south end), and a control room (at the north end). The three cells, which were used for the mixing, pumping, and injection of the grout, have a 30-cm (12-in) thick concrete walls and are covered with a metal roof (triple-layered steel, two 1/4-in. plates on either side of a steel grating). The walls, however, are only painted and are not lined with metal as is the ceiling. The hot cells have windows

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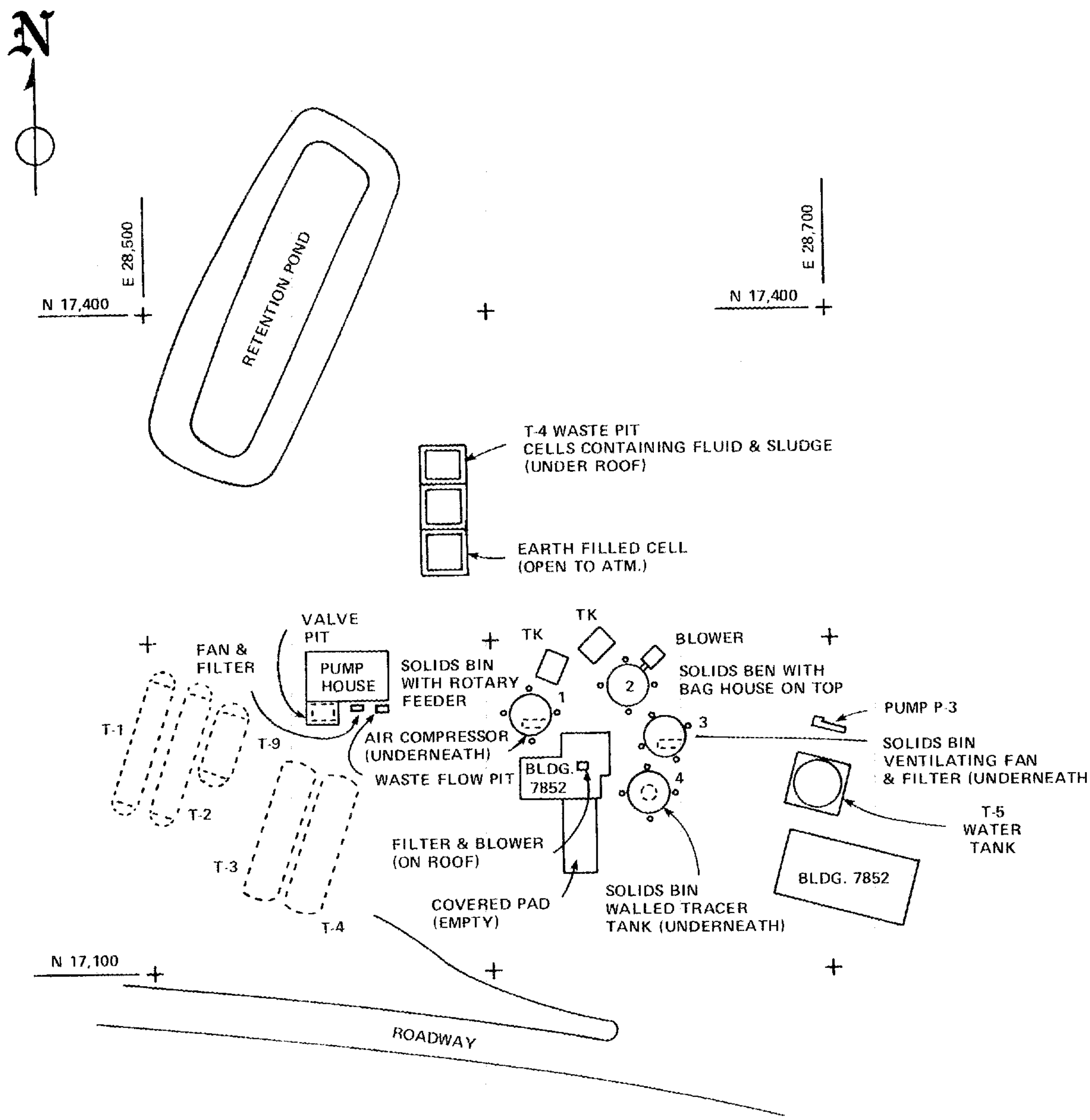

Fig. 2. Site plan of the old hydrofracture facility.

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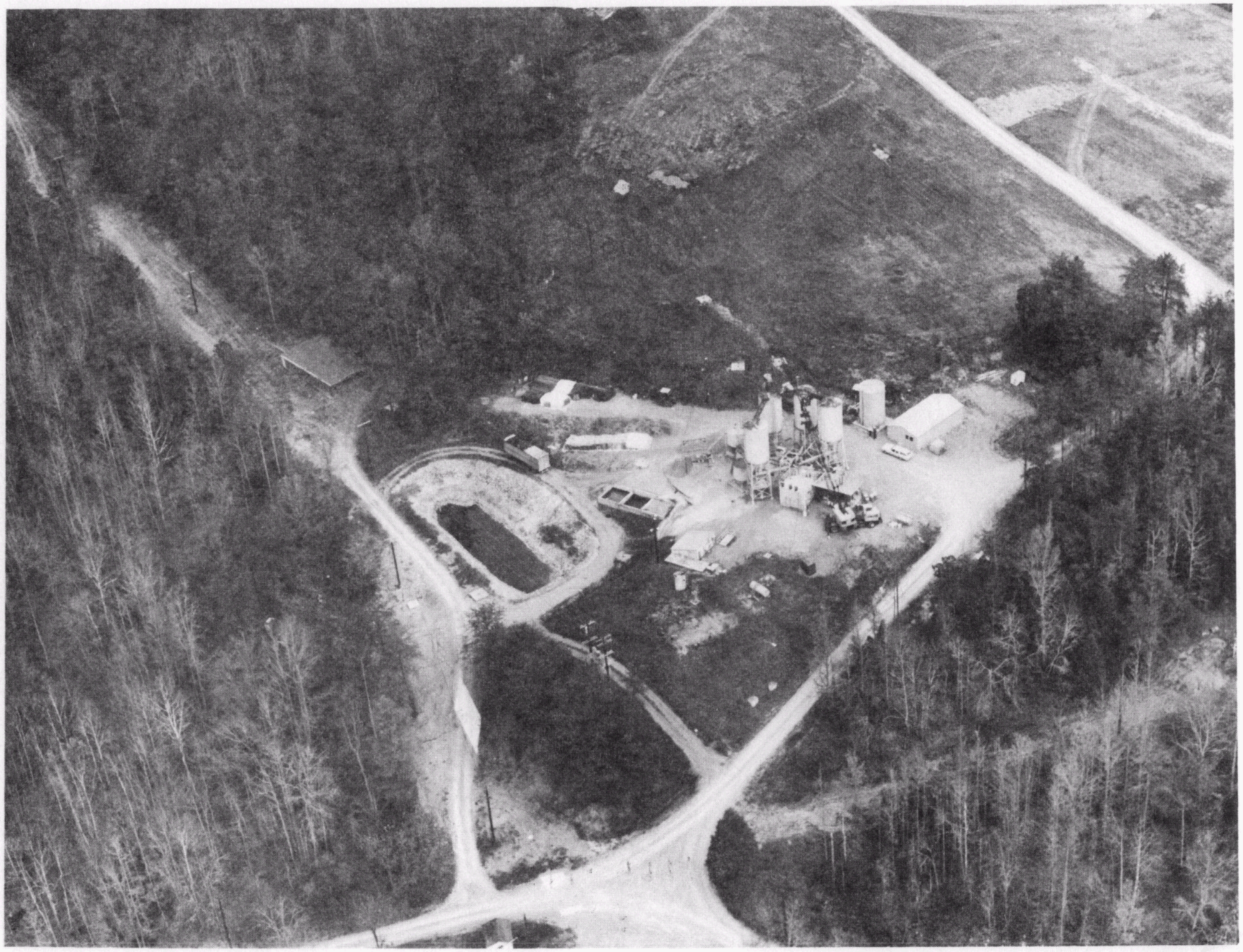

Fig. 3. Photograph of the old hydrofracture facility.

constructed of bulletproof glass. The roof of the mixing cell is fixed in place, but the roofs of the pump cell and the well cell can be removed. The control room roof is metal decking. On the roof of building 7852 are a hoist, an air filter and blower, and three disconnected solids conveyers used to transport solids from the adjacent bulk storage bins. Listed in Table 1 are the dimensions for building 7852.

Within the mixing cell are located a mixer assembly and a grout mix "tub." The mixer assembly is approximately 2.7 m (9 ft) high and has the shape of a cone that is 1.5 m (5 ft) in diameter at the top. The grout "tub" is approximately 1 m (3 ft) in diameter and 2 m (6.5 ft) high. The tops of both of these vessels and the motor for the agitation of the grout mix extend through the roof of the mixing cell. The cell also contains valves and piping.

The well cell contains a small drum-sized tank, piping, valves, and the top of the injection well. The pump cell also contains some equipment, namely, hoses, piping, and valves.

Around building 7852 are located four cylindrical bulk storage bins with conical bottoms (see Fig. 2). These are elevated to permit gravity flow of the solids (cement, fly ash, clay, and other additives used during the process) through air slides to building 7852. Only one air slide is now connected to the mix hopper in building 7852. Each bin is 3.6 m (12 ft) in diameter by 6 m (20 ft) high. The bins are interconnected by piping and by a catwalk. Under bin 4 is a small vessel once used to contain a short-lived radioactive tracer fluid; concrete shielding blocks surround this vessel. Directly to the east

Table 1. Dimensions for rooms in building 7852

Room	Length (m)	Width (m)	Height (m)
Mixing cell	3.8	3.5	2.4
Pump cell	3.0	2.3	2.4
Well cell	3.3	3.4	3.0
Control room	4.4	3.3	3.1
Engine pad	9.1	3.0	2.7-3.0

of building 7852 is a 97,000-L (25,000-gal) water tank and pump for delivering water to the facility during mixing and injection.

2.1.2. Building 7853

This building was used as a change room for operators of the OHF during grout injections. It is now used for storage.

2.1.3. Pump House

The pump house, located to the northwest of building 7852, contains two 30-hp progressive-cavity-type pumps that were used to feed waste from the nearby buried storage tanks, via underground piping, to building 7852. This 33-m^2 (360-ft^2) concrete block house was built in an excavation with only the roof and southeast corner (at the door) being fully exposed. A valve pit [6 ft 4 in. by 21 ft (1.9 by 6.4 m)] is located at the southwest corner of the pump house. This pit is covered with metal plates through which valve handles extend for opening and closing valves.

2.2. WASTE PITS

Approximately 6.2 m (20 ft) to the northeast of the pump house are the waste pits that are composed of three separate concrete-walled cells (12 by 12 ft wide and approximately 9 ft deep, 3.7 x 3.7 x 2.7 m). These pits were used to allow maximum recycle of contaminated water during slotting and wash-up, minimizing the need to inject waste water. The original pit, the southern cell, was filled with grout during an experimental injection, and two additional cells were built to the north. These two pits now contain water-covered sludge. The two northern cells are covered with a corrugated plastic roof, while the south cell remains uncovered.

2.3. WASTE TANKS

Five buried carbon steel tanks were used for storing liquid radioactive waste prior to injection by the OHF. These tanks are located about 18 m (60 ft) directly west of building 7852. These buried storage tanks, which were placed horizontally, are still connected to the Intermediate-Level Waste (ILW) transfer line, allowing the tanks to serve as a possible emergency storage site. There remains in each of the tanks approximately a foot (30 cm) of residual ILW, amounting to less than 10% of the total volume in the tanks. The tanks were installed on concrete pads in open pits that were equipped with concrete dividing walls to separate the tanks and allow for monitoring of possible leakage. The tanks, which are covered with approximately 1.2 m (4 ft) of soil, are under cathodic protection and vented through a HEPA filter to the atmosphere. The voltage/amperage applied to the cathodic protection system and the general radiation background of the storage tank dry well systems (monitoring wells located within the concrete enclosure built to contain each of the tanks) are monitored daily. The ventilation system is also checked daily, and any accumulated liquids in the storage tank dry well systems are sampled and analyzed for radioactivity.

2.4. WASTE IMPOUNDMENT

2.4.1. Impoundment Construction

The impoundment was constructed as part of the hydrofracture operation in 1963, by excavating a rectangular basin into the base of the valley wall. Construction dimensions of the bottom of the basin are 6 m (20 ft) in width by 30 m (100 ft) in length, with sides sloping at 1 vertical on 1.5 horizontal. The depth of the impoundment is slightly greater than 1.5 m (5 ft) at the low (west) side. The sides are lined with limestone rip-rap. Design capacity was 379,000 L (100,000 gal). Inflow was to the south end of the impoundment via a buried 46-cm (18-in.) diam line from the injection well cell. A 20-cm (8-in.) diam line from the waste pits upslope from the impoundment is also shown on drawings as entering the impoundment at the same location. Construction drawings specified that the impoundment bottom be sprayed with liquid asphalt to control erosion, and a plastic liner was placed in the impoundment prior to experimental injections. However, no evidence of either of these treatments was observed by Stansfield and Francis (1986) while sampling the sediment. A 1.5-m (5-ft) high, concrete standpipe was provided as an emergency outflow at the north end of the impoundment. ORNL drawing S-10,916 EA 001 D shows this vertical standpipe connected to an 8-in (20-cm) vitrified clay, pipeline. The drawing also shows this line extending to the west for a distance of approximately 15 m (50 ft) where it empties into a shallow, natural swale at an approximate elevation of 233 m (763 ft). Probings made by Stansfield and Francis (1986) indicate that the bottom of the impoundment is at an approximate elevation of 231.1 m (764.6 ft).

2.4.2. Impoundment Operation

The impoundment was constructed to serve as an emergency containment basin in the event of a spill from the radioactive grout injections, for example, one caused by back-flow of grout. Due to malfunction of pumping equipment or piping, the impoundment did receive radioactive grout from injections made in 1965 (de Laguna et al. 1971) and 1977 (L. C Lasher, Operations Division, personal communication). Prior to a grout injection at the facility, the water level in the impoundment was required to be low enough that there would be sufficient capacity in the impoundment to hold the radioactive grout should an emergency arise that required such action during the operation. Prior to some injections, depending on the water level, this necessitated decanting the water from the impoundment. Before contamination of the impoundment by radioactive waste, the pond water was siphoned to the White Oak Creek flood plain. Subsequent to contamination of the impoundment, the water was pumped to the low-level waste system for processing (L. C Lasher, oral communication, 1985).

Operation of the OHF facility ceased by 1980 (Myrick 1984). In the winter of 1984-85, the impoundment received drilling fluid and drill cuttings from an exploratory core boring (5.7-cm-diam core and 8.6-cm-diam hole) through the radioactive grout sheets underlying the OHF site. Probings made by Stansfield and Francis (1986) indicate that the thickness of the sediment in the impoundment averages 27 cm (0.9 ft). This amounts to approximately 55,000 L (14,500 gal) of sediment.

3. CURRENT STATUS OF INFORMATION ON SITE

Considerable site specific, environmental information on the facility exists in published reports (McMaster and Waller 1965; Stansfield and Francis 1986). In addition, S. F. Huang [Environmental and Occupational Safety Division (EOSD), personal communication, September 1984] has conducted considerable radiological and chemical analysis at the facility.

3.1. CONTAMINANT INVENTORY

3.1.1. Buildings

A preliminary radiological survey was completed on the buildings by S. F. Huang (EOSD, personal communication, September 1984). Standard ORNL radiation survey instruments were used for all surveys. Beta-gamma readings were made with a GM meter, a Victoreen 440 (a low-range air ionization chamber), or a Cutie Pie (Gupton 1961). Smear samples were taken over areas of approximately 100 cm^2 and counted in alpha and beta-gamma sample counters or with a portable survey instrument for the samples with high levels of contamination.

3.1.1.1. Building 7852

Radiation and contamination levels in the interiors of the control room, mixing cell, pump cell, well cell, and pump room were measured. To measure the high levels of transferable contamination on the rough surfaces of the interior walls, wet paper towel smears were used. These smears were surveyed with a portable instrument rather than with smear counters to prevent contamination of the smear counters.

In the control room, the absorbed dose rates ranged from 0.75 to 6 mGy/h (75 to 600 mrad/h). Smearable activity per 100 cm^2 varied from 330 to 820 Bq (8.9 to 22.3 nCi) of beta-gamma and from 0.3 to 0.7 Bq (8 to 22 pCi) of alpha (see Fig. 4). High levels of direct beta-gamma readings ranging from 1.5 to 40 mGy/h (150 to 4000 mrad/h) were observed in the mixing, pump, and well cells. Removable beta-gamma activity measured from 0.05 to 0.35 mGy (5 to 35 mrad). For the most part, removable alpha activity was less than 1.7 Bq/100 cm^2 (<50 pCi/100 cm^2) in these rooms (see Figs. 5, 6 and 7). At 10 cm above the engine pad, dose rates ranged from 0.2 to 3 mGy/h (20 to 300 mrad/h). Removable beta-gamma activity on the engine pad, using the wet towel smear technique previously described, varied from 5 to 10 μGy/h (0.5 to 1 mrad/h) per 100 cm^2. Alpha activity, using the same smear technique, was usually less than 0.5 Bq (14 pCi) per 100 cm^2 (see Fig. 8).

It is not clear how thoroughly S. F. Huang (EOSD, personal communication, September 1984) surveyed the four bulk storage bins or their connecting air slides, catwalk, etc. For example, it was stated in the S. F. Huang (EOSD, personal communication, September 1984) that these bins and the water tank were "considered to be relatively uncontaminated, with no serious radiological impacts expected."

3.1.1.2. Building 7853

This building, which was used as a change room during OHF operations, was also "considered to be relatively uncontaminated, with no serious radiological impacts expected."

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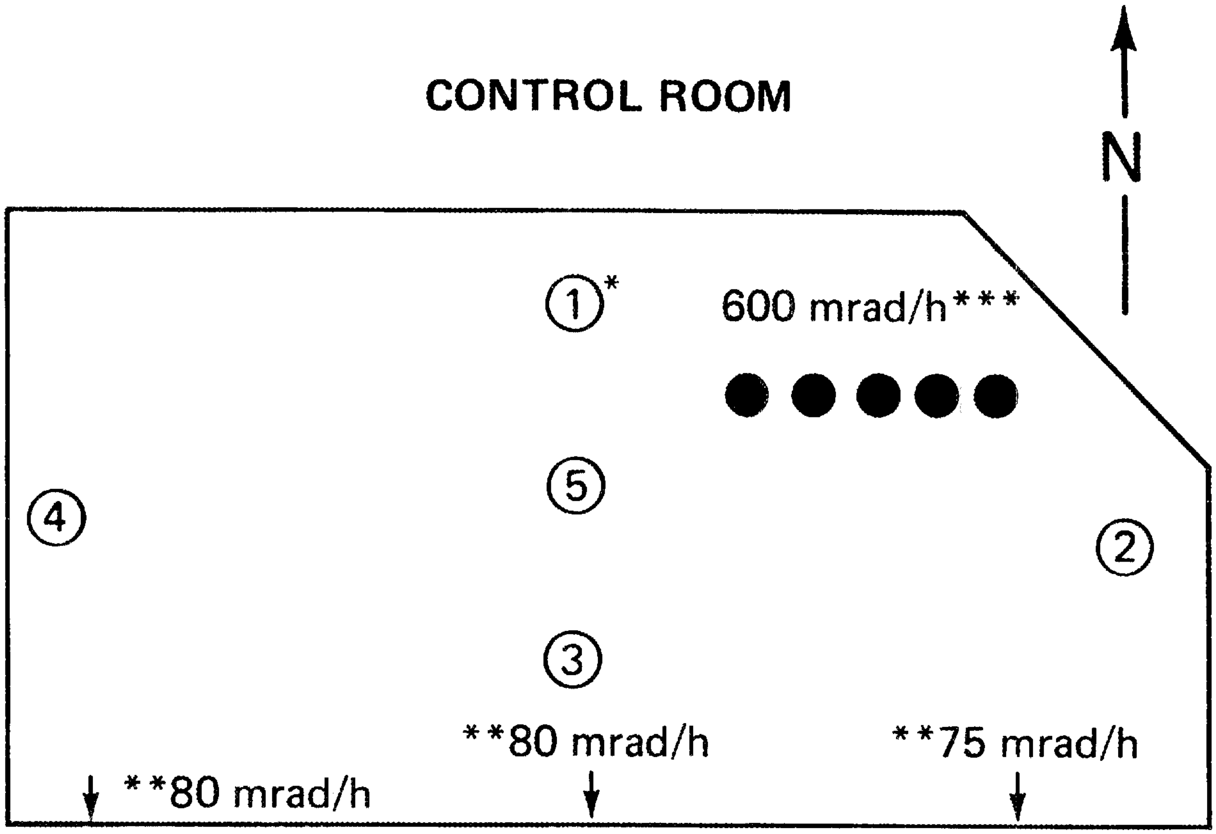
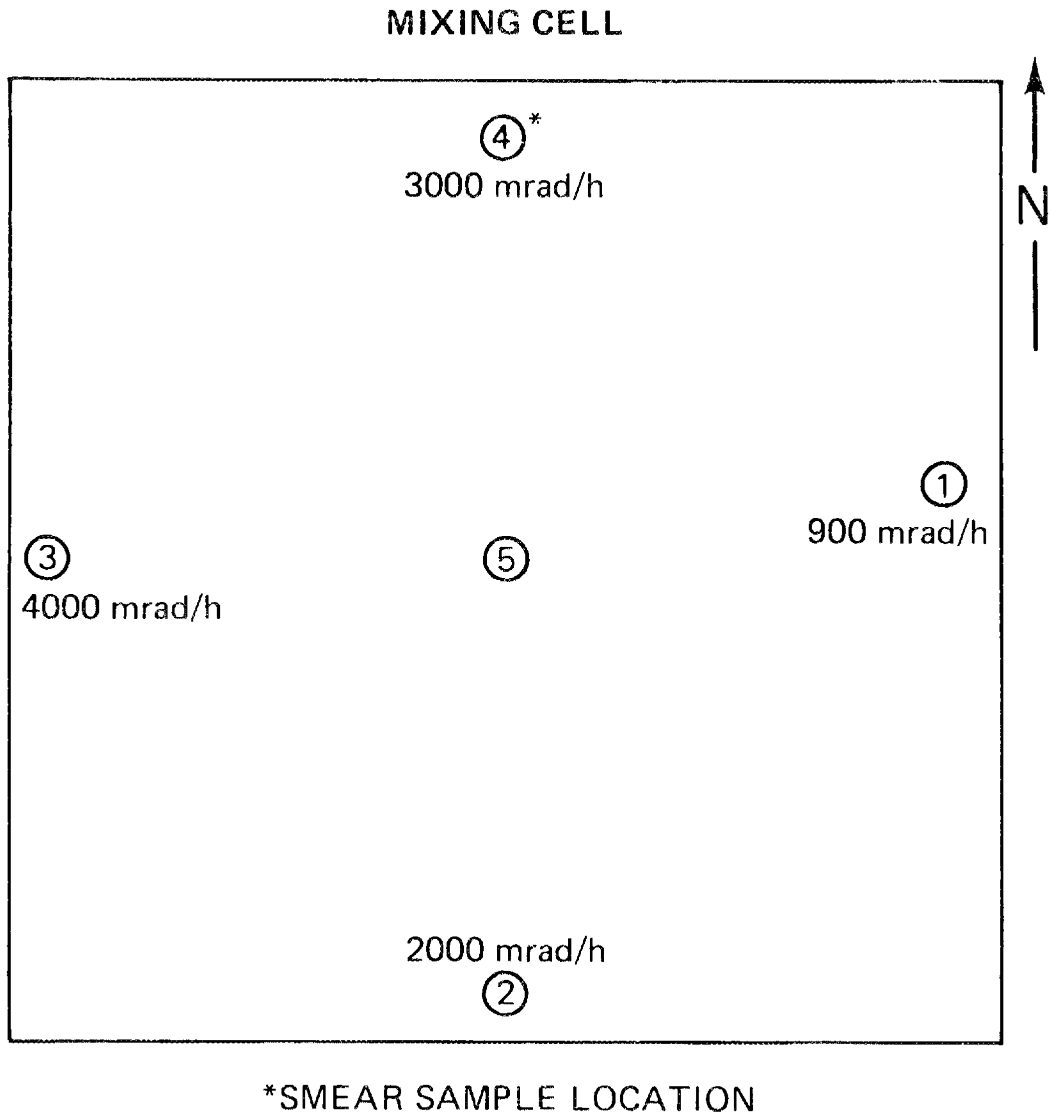


*SMEAR SAMPLE LOCATION
**READING AGAINST THE WALL
***READING FROM FIVE STORED ITEMS

	SMEARABLE ACTIVITY PER 100 cm^2	
LOCATION	BETA-GAMMA	ALPHA
1	49,200 dpm	< 20 dpm
2	32,200 dpm	< 20 dpm
3	63,320 dpm	30 dpm
4	27,600 dpm	21 dpm
5	20,650 dpm	36 dpm

Fig. 4. Radiological survey results of the control room (1 mrad = 10µGy). Direct beta-gamma readings are marked.

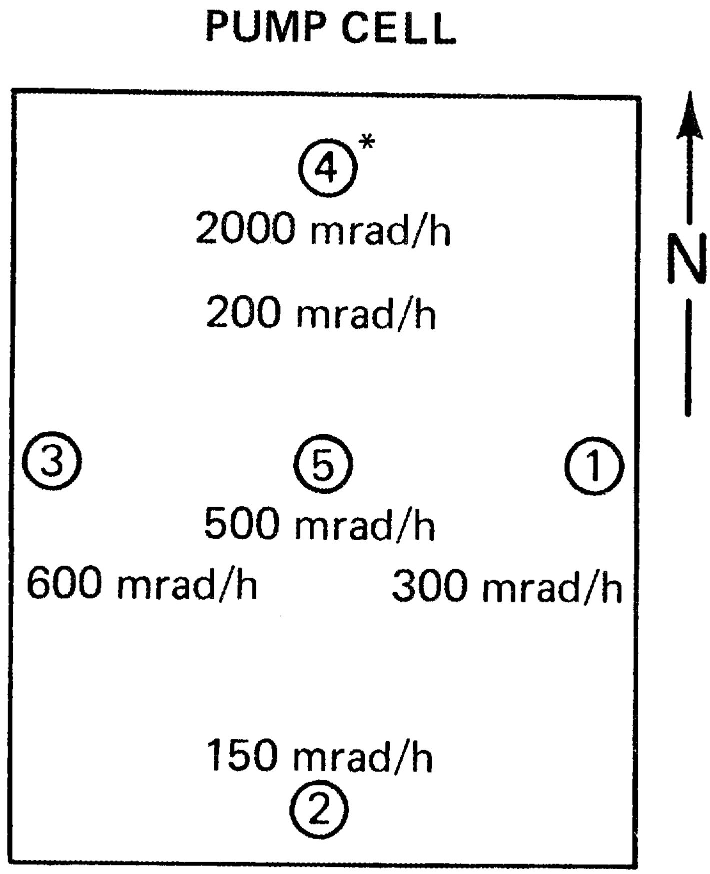
ORNL-DWG 84-12880



	SMEARABLE ACTIVITY PER 100 cm^2	
LOCATION	BETA-GAMMA	ALPHA
1	15 mrad/h	102 dpm
2	15 mrad/h	$<$ 20 dpm
3	15 mrad/h	$<$ 20 dpm
4	5 mrad/h	$<$ 20 dpm
5	30 mrad/h	$<$ 20 dpm

Fig. 5. Radiological survey results of the mixing cell (1 mrad = 10 µGy). Direct beta-gamma readings are marked.

ORNL–DWG 84-12879

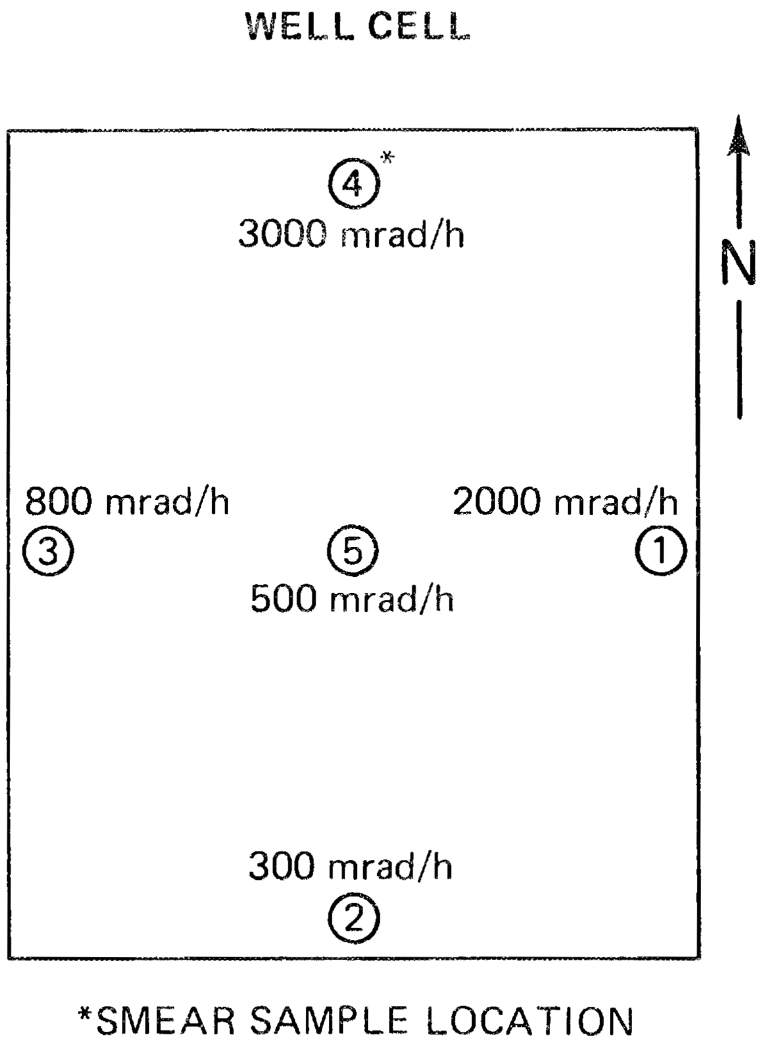


*SMEAR SAMPLE LOCATION

	SMEARABLE ACTIVITY PER 100 cm^2	
LOCATION	BETA-GAMMA	ALPHA
1	2 mrad/h	< 20 dpm
2	4 mrad/h	< 20 dpm
3	3 mrad/h	< 20 dpm
4	3 mrad/h	< 20 dpm
5	5 mrad/h	< 20 dpm

Fig. 6. Radiological survey results of the pump cell (1 mrad = µGy). Direct beta-gamma readings are marked.

ORNL–DWG 84-12878

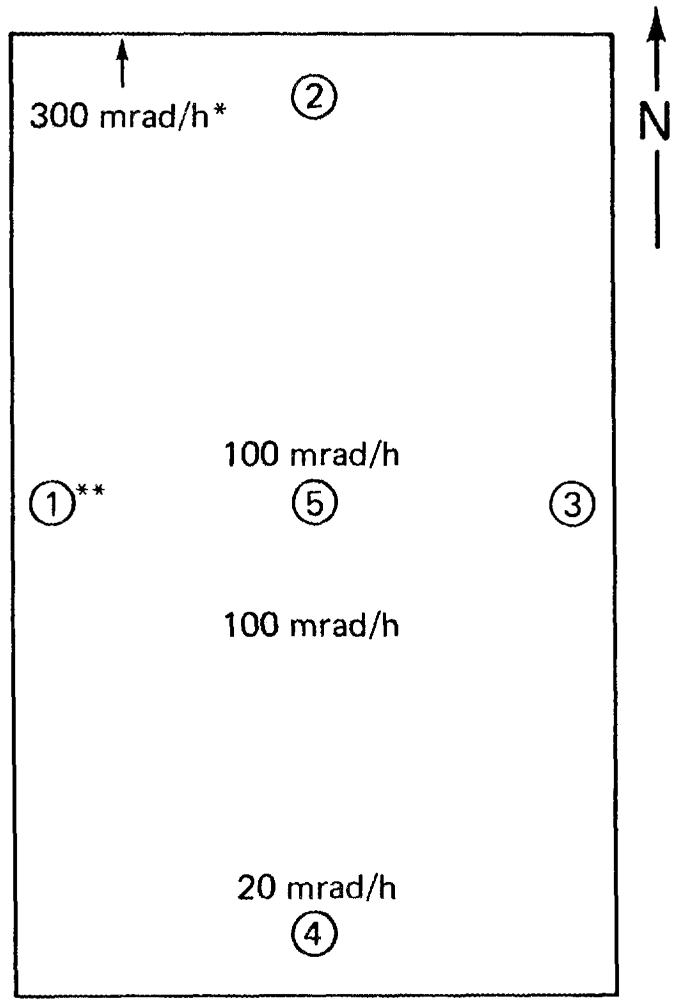


	SMEARABLE ACTIVITY PER 100 cm^2	
LOCATION	BETA-GAMMA	ALPHA
1	35 mrad/h	$<$ 20 dpm
2	35 mrad/h	$<$ 20 dpm
3	15 mrad/h	$<$ 20 dpm
4	20 mrad/h	$<$ 20 dpm
5	10 mrad/h	$<$ 20 dpm

Fig. 7. Radiological survey results of the well cell (1 mrad = 10 µGy). Direct beta-gamma readings are marked.

ORNL–DWG 84-12876

ENGINE PAD



*READING AGAINST THE WALL
**SMEAR SAMPLE LOCATION

	SMEARABLE ACTIVITY PER 100 cm^2	
LOCATION	BETA-GAMMA	ALPHA
1	0.75 mrad/h	< 20 dpm
2	0.5 mrad/h	< 20 dpm
3	1.0 mrad/h	27 dpm
4	1.0 mrad/h	< 20 dpm
5	1.0 mrad/h	< 20 dpm

Fig. 8. Radiological survey results of the engine pad (1 mrad = 10 µGy). Smear sample locations and direct beta-gamma dose rates are marked.

3.1.1.3. Pump House

The interior surfaces of the pump house were contaminated with fixed and removable activity from 0.2 to 80 mGy/h (20 to 8000 mrad/h) and 5 to 150 µGy/h (0.5 to 15 mrad/h), respectively (Fig. 9). A radiation reading of 50 µGy/h (5 mrad/h) was measured directly above the sheet metal covering the concrete blocks of the valve pit. The interior of the pit was considered likely to be contaminated with fixed and removable activity.

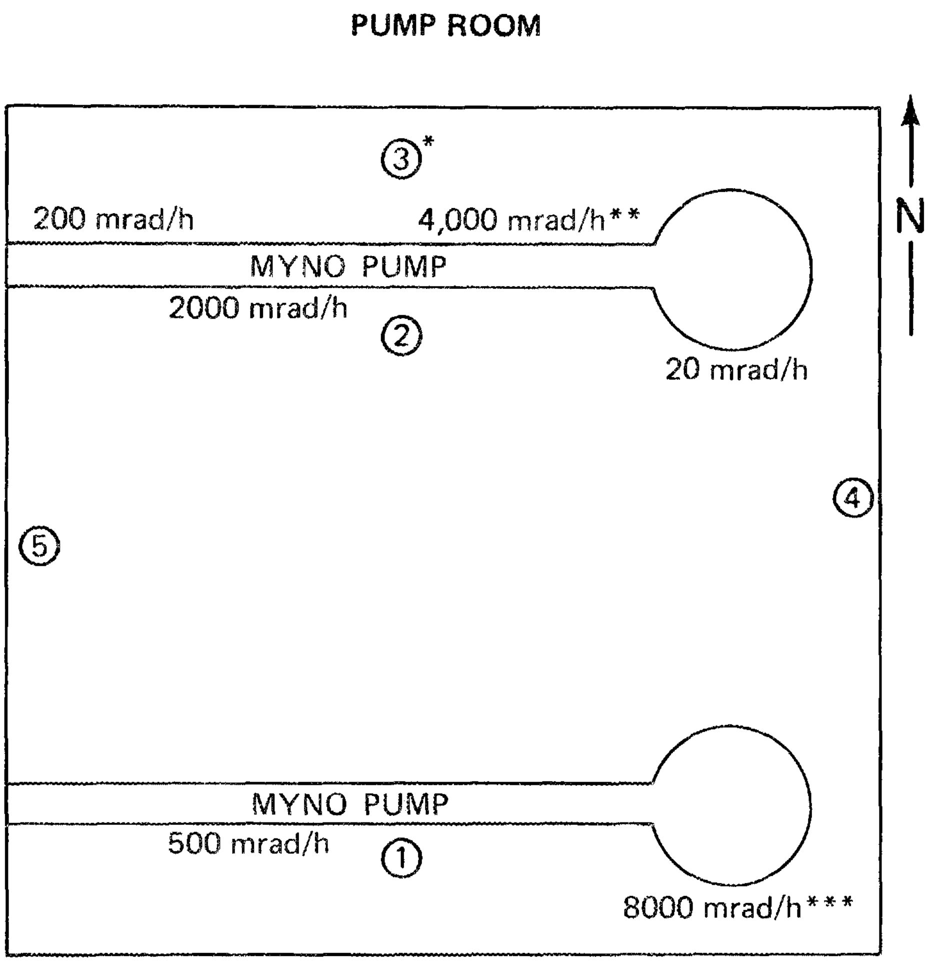
3.1.2. Soils

S. F. Huang (EOSD, personal communication, September 1984) made direct beta-gamma readings on 6- by 6-m grids covering a 96- by 60-m area that encompassed the OHF (see Fig. 10 for readings in excess of 3 µGy at 1 to 3 cm above the soil surface). Also illustrated in Fig. 10 are the locations of 17 deep soil cores taken near potential radiation hazards. Sections of these soil cores, of varying soil depths, were counted on a 15- x 15-cm NaI(Tl) detector for 5 min, from which the gamma-ray spectrum (and total integral counts) over the energy range of 100 to 1500 keV was obtained. The activity in cps/kg is presented in Table 2.

3.1.3. Waste Pits

In January of 1984 S. F. Huang (EOSD, personal communication, September 1984) measured the absorbed dose rates under the roof of the waste pit ranging from 0.1 to 0.4 mGy/h (10 to 40 mrad/h). In the south pit, 45 cm of water covered a 10-cm layer of sediment. In the north pit, approximately twice as much water (90 cm) covered a 10-cm

ORNL–DWG 84-12877



*SMEAR SAMPLE LOCATION
**READING AGAINST THE PUMP
***READING FROM UNDERNEATH A LEAD SHIELD

	SMEARABLE ACTIVITY PER 100 cm^2	
LOCATION	BETA-GAMMA	ALPHA
1	0.5 mrad/h	< 20 dpm
2	15.0 mrad/h	< 20 dpm
3	10.0 mrad/h	< 20 dpm
4	10.0 mrad/h	< 20 dpm
5	8.0 mrad/h	< 20 dpm

Fig. 9. Radiological survey results of the pump room (1 mrad = 10 μGy). Direct beta-gamma readings are marked.

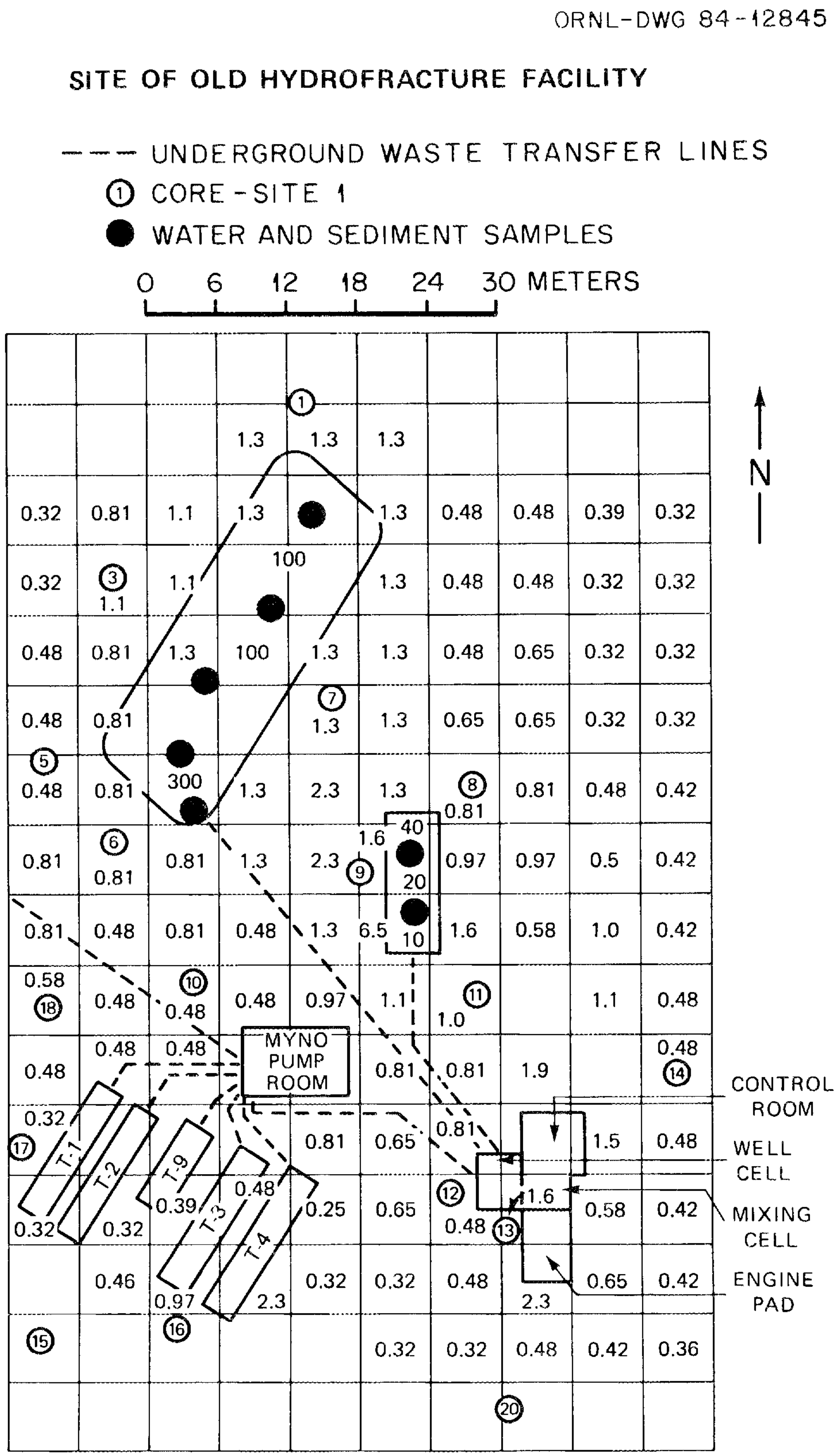


Fig. 10. Beta-gamma direct readings exceeding 0.3 mrad/h (1 mrad = 10 µGy) at 1 to 3 cm above the surface.

Table 2. Gamma screening of deep soil cores

	Deep soil core sites																
	1	3	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20
Soil depth in meters	(cps/kg)[a]																
0.0-0.3	<80	66	35	41	96	NS	<30	470	NS[b]	NS	NS	NS	51	88	29	43	<30
0.3-0.6	33	29	41	32	38	NS	28	120	NS	NS	NS	NS	43	43	29	32	20
0.6-1.2	44	55	30	34	38	44	60	240	35	36	130	81	40	36	30	41	27
1.2-1.8	44	420	28	37	31	24	31	34	36	39	68	84	33	42	32	33	36
1.8-2.4	34	65	32	29	32	34	37	38	38	34	70	43	40	53	40	30	31
2.4-3.1	42	45	33	45	34	28	35	25	38	34	46	45	31	54	NS	34	31
3.1-3.7	NS	32	31	46	34	53	37	32	34	81	69	37	64	NS	NS	31	37
3.7-4.3	NS	34	NS	NS	NS	26	35	38	30	240	260	41	41	33	NS	31	39
4.3-4.9	NS	NS	NS	NS	NS	37	28	66	30	NS	40	34	42	32	NS	34	41
4.9-5.5	NS	NS	NS	NS	NS	35	NS	46	29	NS	50	53	35	67	NS	NS	NS
Mean concentrations	39	93	33	38	43	35	36	111	34	77	92	52	42	50	32	34	33
Coordinates in meters																	
North	5298	5273	5262	5256	5268	5262	5255	5246	5244	5229	5225	5236	5223	5217	5232	5246	5202
East	8708	8690	8682	8690	8711	8717	8708	8697	8720	8717	8722	8737	8681	8697	8678	8623	8723

[a]Gamma activity is in counts per second per kilogram of moist soil (cps/kg). Natural background was approximately 20 to 40 cps/kg on the 15- by 15-cm NaI (Tl) detector over the energy span of 100 to 1500 keV (S. F. Huang, EOSD, personal communication, September 1984).

[b]NS = not sampled.

Table 3. Waste pit inventories of radionuclides[a]

	Average depth and volume	Radio-nuclide	Concentration (Bq/mL or Bq/g)	Inventory[b] (GBq)	Inventory[b] (mCi)
South cell water	45 cm	^{135}Cs	1.2×10^2	0.8	20.0
	6.3×10^3 L	^{239}Pu	1.1	0.007	0.2
		^{238}Pu	2.2	0.01	0.4
		^{241}Am	1.0	0.006	0.2
		^{244}Cm	1.0	0.006	0.2
		^{90}Sr	15.0	0.09	3.0
South cell sediment	10 cm	^{137}Cs	4.0×10^3	6.0	200.0
	1.4×10^3 L	^{60}Co	31.0	0.04	1.0
		^{239}Pu	97.0	0.1	4.0
		^{238}Pu	30.0	0.04	1.0
		^{241}Am	17.0	0.02	0.6
		^{244}Cm	54.0	0.08	2.0
		^{90}Sr	7.8×10^2	1.0	30.0
North cell water	90 cm	^{137}Cs	2.1×10^2	3.0	80.0
	1.3×10^4 L	^{239}Pu	1.0	0.01	0.4
		^{238}Pu	1.5	0.02	0.5
		^{241}Am	1.0	0.01	0.4
		^{244}Cm	1.0	0.01	0.4
		^{90}Sr	16.0	0.2	6.0
North cell sediment	10 cm	^{137}Cs	3.1×10^3	4.0	100.0
	1.4×10^3 L	^{60}Co	14.0	0.02	0.6
		^{239}Pu	42.0	0.06	2.0
		^{238}Pu	17.0	0.02	0.6
		^{241}Am	13.0	0.02	0.6
		^{244}Cm	6.0×10^2	0.8	20.0
		^{90}Sr	4.0×10^2	0.6	20.0

[a]Taken from S. F. Huang (EOSD, personal communication, September 1984).

[b]Inventory in the sediment was estimated by assuming that the total volume was equal to the total dry weight.

layer of sediment. The total radioactivity in the water and sediment was estimated to be 5 GBq (0.1 Ci) and 10 GBq (0.3 Ci), respectively The concentrations and inventories of the various radionuclides measured in the water and sediment taken from these pits are listed in Table 3.

3.1.4. Waste Tanks

S. F. Huang (EOSD, personal communication, September 1984) estimated the radioactivity in each tank to be between 22 and 37 TBq (600 to 1000 Ci). The total quantity of sludge in the tanks was estimated to be 2×10^6 L, containing on the order of 170 TBq (4.6 kCi). An estimate of the activity in each of the tanks, and the assumptions used in making the estimates are presented in Table 4. Water taken from the "dry wells" (monitoring wells located within the concrete enclosure built to contain each of the tanks) have shown slightly elevated levels of beta activity (maximum of 1.2 Bq/mL). Also, the soil core taken directly to the southwest of tank T-4 (soil core 16) showed some elevated levels of gamma activity at soil depths of approximately 5 m (see Table 2). The possibility (or likelihood) has to be taken into consideration that the carbon steel tanks, which are inclined to rust (although cathodically protected), may have developed leaks over the years.

3.1.5. Waste Impoundment

3.1.5.1. <u>Pond Water</u>

Pond water from the OHF impoundment was sampled in May of 1985 by Stansfield and Francis (1986). The sample was taken from the center of the impoundment when the depth of water was approximately 1 m (3 ft). The sample, which was not filtered, was analyzed for heavy metals,

Table 4. Estimate of residual radioactivity in waste tanks at the old hydrofracture facility[a]

Tank	Tank capacity (L)	Tank diameter (m)	Tank length (m)	Sludge volume (L)	Sludge activities (TBq)	Sludge activities (kCi)
T-1	5.9×10^4	2.4	13.0	4.2×10^3	40	1.0
T-2	5.9×10^4	2.4	13.0	4.2×10^3	40	1.0
T-9	4.4×10^4	3.1	5.9	2.2×10^3	30	0.6
T-3	1.1×10^5	3.2	13.0	4.9×10^3	40	1.0
T-4	1.1×10^5	3.2	13.0	4.9×10^3	40	1.0

[a]From S. F. Huang (EOSD, personal communication, September 1984). The estimate was based on the assumption of 30 cm thickness of residual sludge (a rough estimate from operational experience) at a concentration of 0.26 Ci/L.

Table 5. Concentration and inventory of nonradioactive contaminants in OHF pond water[a]

Constituent	Concentration (mg/L): Pond	Concentration (mg/L): NIPDWS	Inventory[b] (g)
Metals			
Antimony	<0.3	ND[c]	<74
Arsenic	<0.001	0.05	<1
Barium	0.539	1	132
Beryllium	0.0021	ND	1
Boron	<0.1	ND	<25
Cadmium	0.0015	0.01	<1
Calcium	26.3	ND	6444
Chromium	0.0219	0.05	5
Cobalt	<0.02	ND	<5
Copper	<0.02	ND	<5
Iron	9.25	ND	2266
Lead	<0.001	0.05	<1
Lithium	<0.2	ND	<49
Magnesium	8.99	ND	2203
Manganese	0.2	ND	49
Mercury	0.0001	0.002	<1
Molybdenum	<0.02	ND	<5
Nickel	<0.06	ND	<15
Potassium	6.5	ND	1593
Selenium	0.016	0.01	4
Silver	<0.07	0.05	<17
Sodium	<0.5	ND	<123
Strontium	0.316	ND	77
Titanium	<0.02	ND	<5
Vanadium	<0.03	ND	<7
Zinc	0.134	ND	33
Anions			
Chloride	64	ND	15680
Fluoride	1	1.2–2.4	245
Nitrate-N	<1	10	<245
Phosphate	<0.93	ND	<228
Sulfate	19	ND	4655

[a]Data taken from R. G. Stansfield and C. W. Francis, 1986, Characterization of the Old Hydrofracture Facility (OHF) Impoundment, ORNL/TM-9990, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[b]Inventory based on pond water volume of 2.45×10^5 L.

[c]ND = level not defined by NIPDWS (National Interim Primary Drinking Water Standards).

Table 6. Concentration and inventory of organic chemicals in OHF pond water[a]

Constituent	Concentration: Pond (mg/L)	Concentration: NIPDWS (mg/L)	Inventory[b] (g)
Herbicides/pesticides			
Endrin	<0.0001	0.002	<0.1
Lindane	<0.0001	0.004	<0.1
Methoxychlor	<0.0002	0.1	<0.1
Toxaphene	<0.002	ND[c]	<0.5
Organic compounds[d]			
PCBs	0.0001	ND	<0.1
Phenols	<0.0001	ND	<0.1
TOC	16.5	ND	4043
TOX	0.132	ND	32

[a]Data taken from R. G. Stansfield and C. W. Francis, 1986, Characterization of the Old Hydrofracture Facility (OHF) Impoundment, ORNL/TM-9990, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[b]Inventory base on pond water volume of 2.45×10^5 L.

[c]ND = limit not defined by NIPDWS (National Interim Primary Drinking Water Standards).

[d]PCB = polychlorinated biphenyls, TOC = total organic carbon, TOX = total organic halides.

Table 7. Concentration and inventory of radionuclides in OHF pond water*

Radionuclide	Stansfield and Francis (1986)[a] Concentration (Bq/L)	Stansfield and Francis (1986)[a] Inventory (MBq)	Stansfield and Francis (1986)[a] Inventory (mCi)	S. F. Huang[b] Concentration (Bq/L)	S. F. Huang[b] Inventory (MBq)	S. F. Huang[b] Inventory (mCi)
Gross alpha	11	2.7	0.07	NR[c]	NR	NR
Gross beta	9400	2303	63	NR	NR	NR
Americium-241	0.24	0.1	<0.01	NR	NR	NR
Cesium-137	3900	956	26	29000	2100	57
Cobalt-60	27	6.6	0.18	27	2	0.05
Curium-244	6.8	1.7	0.05	NR	NR	NR
Plutonium-238	0.17	<0.1	<0.01	NR	NR	NR
Plutonium-239	0.052	<0.1	<0.01	NR	NR	NR
Radium-226	0.015	<0.1	<0.01	NR	NR	NR
Strontium-90	4400	1080	29	7100	514	14
Uranium-234	1.5	0.4	0.01	NR	NR	NR
Uranium-238	0.375	0.1	<0.01	NR	NR	NR

[a]Value used for pond volume, 2.45×10^5 L (R. G. Stansfield and C. W. Francis, 1986, Characterization of the Old Hydrofracture Facility (OHF) Impoundment, ORNL/TM-9990, Oak Ridge National Laboratory, Oak Ridge, Tennessee).

[b]Value used for pond volume, 7.24×10^4 L (S. F. Huang, EOSD, personal communication, September 1984).

[c]NR = not reported.

herbicides/pesticides, PCBs, and radionuclides (Tables 5, 6, and 7). The pH of the pond water was neutral (7.05) with specific conductance of 224 µS/cm. The analyses indicated that arsenic, barium, cadmium, chromium, fluoride, mercury, lead, and nitrate, as well as the pesticides and herbicides, were below the maximum allowable NIPDWS (National Interim Primary Drinking Water Standards). The measured concentration of selenium (0.016 mg/L), slightly over the NIPDWS level (0.01 mg/L), and the detection limit of silver (0.07 mg/L) determined in the pond water were the only indications that chemical constituents exceeded the allowable NIPDWS levels. Detectable concentrations of PCBs were observed in the pond water (0.0001 mg/L) and counts of coliform bacteria (8 counts per 100 mL) were in excess of the NIPDWS. The concentration of total organic halides (TOX) was 0.13 mg/L, and the total organic carbon content (TOC) was 16 mg/L. Other than the radionuclide concentrations, which are discussed below, the water quality of pond water from the impoundment (based on these chemical analyses) was surprisingly high.

The principal radionuclides measured in the pond water were cesium-137 and strontium-90 (Table 7). Stansfield and Francis (1986) observed similar concentrations of the two radionuclides [approximately 4000 Bq/L (equivalent to 109 pCi/mL)], while S. F. Huang (EOSD, personal communication, September 1984), who sampled the impoundment in September 1983, observed approximately four times more cesium-137 than strontium-90 [29000 and 7100 Bq/L, respectively (equivalent to 800 and 193 pCi/mL). The concentrations of these two radionuclides measured by Huang et al. were two to seven times that measured by Stansfield and

Francis (see Table 7). On the other hand, cobalt-60 concentrations in the pond water were identical. Stansfield and Francis (1986) also measured gross alpha and gross beta activity in the pond water. Gross beta activity was approximately twice the activity of strontium-90, implying that the gross beta activity resulted largely from the decay of strontium-90 and yttrium-90. Gross alpha activity was less than 1% of the gross beta and cesium-137 activities combined. Curium-244 appeared to be the dominant transuranic radionuclide measured (6.8 Bq/L or <0.2 pCi/mL). The volume of pond water retained in the impoundment was estimated by Stansfield and Francis to be approximately three times that estimated by S. F. Huang (EOSD, personal communication, September 1984). The difference between time of the year in sampling, May for Stansfield and Francis and September for S. F. Huang (EOSD, personal communication, September 1984), is likely the major cause for the differences in estimates of pond water volumes. As a consequence, there was not a major difference in estimates of the radionuclide inventory between the two studies. For example, the total inventory of strontium-90 and cesium-137 (approximately 1 GBq or 0.03 Ci for each radionuclide) was not substantially different from the estimate by Huang et al. (2.1 and 0.5 GBq, for cesium-137 and strontium-90, respectively).

3.1.5.2. Impoundment Sediment

S. F. Huang (EOSD, personal communication, September 1984) and Stansfield and Francis (1986) have measured concentrations of potential contaminants in the sediment of the OHF impoundment. The principal purpose of the latter study was to determine if the sediment would be classified as a hazardous waste under RCRA regulations. Thus, the emphasis in this study was centered more along the analyses of sediment for nonradioactive contaminants, whereas the earlier study was principally concerned about the radiological characteristics of the impoundment in support of decontamination and decommissioning (D&D) activities. In the federal regulation 40 CFR 261 promulgated under RCRA (USEPA 1980), a solid waste is hazardous if it exhibits any of the defined characteristics of ignitability, corrosivity, reactivity, or extraction procedure (EP) toxicity. The EP toxicity is of primary concern because the inherent physical and chemical characteristics of the sediment rule out classification as a hazardous waste based on ignitability or reactivity. Since the pH of the sediment was 5.2, the waste will not be classified as having the characteristic of corrosivity as defined under the regulations. The EP toxicity characteristic is based on measured concentrations of eight elements of the National Interim Primary Drinking Water Standard (NIPDWS) and six herbicides and pesticides in the filtrate of a 24-hr solid waste extraction test (USEPA 1982). If the levels of these constituents exceed established maximum permissible concentrations, then the waste is considered hazardous based on the characteristic of toxicity.

The sediment was thoroughly tested for its toxicity characteristics by replicate samplings and extractions of the sediment by the EP. For example, the sediment was tested for concentrations of metals in its EP extracts a total of six times (sediment collected from three sample locations at two dates). Analyses for the herbicides/pesticides in the extracts were conducted three times (sediment collected from three sample locations in the impoundment at a single sampling date).

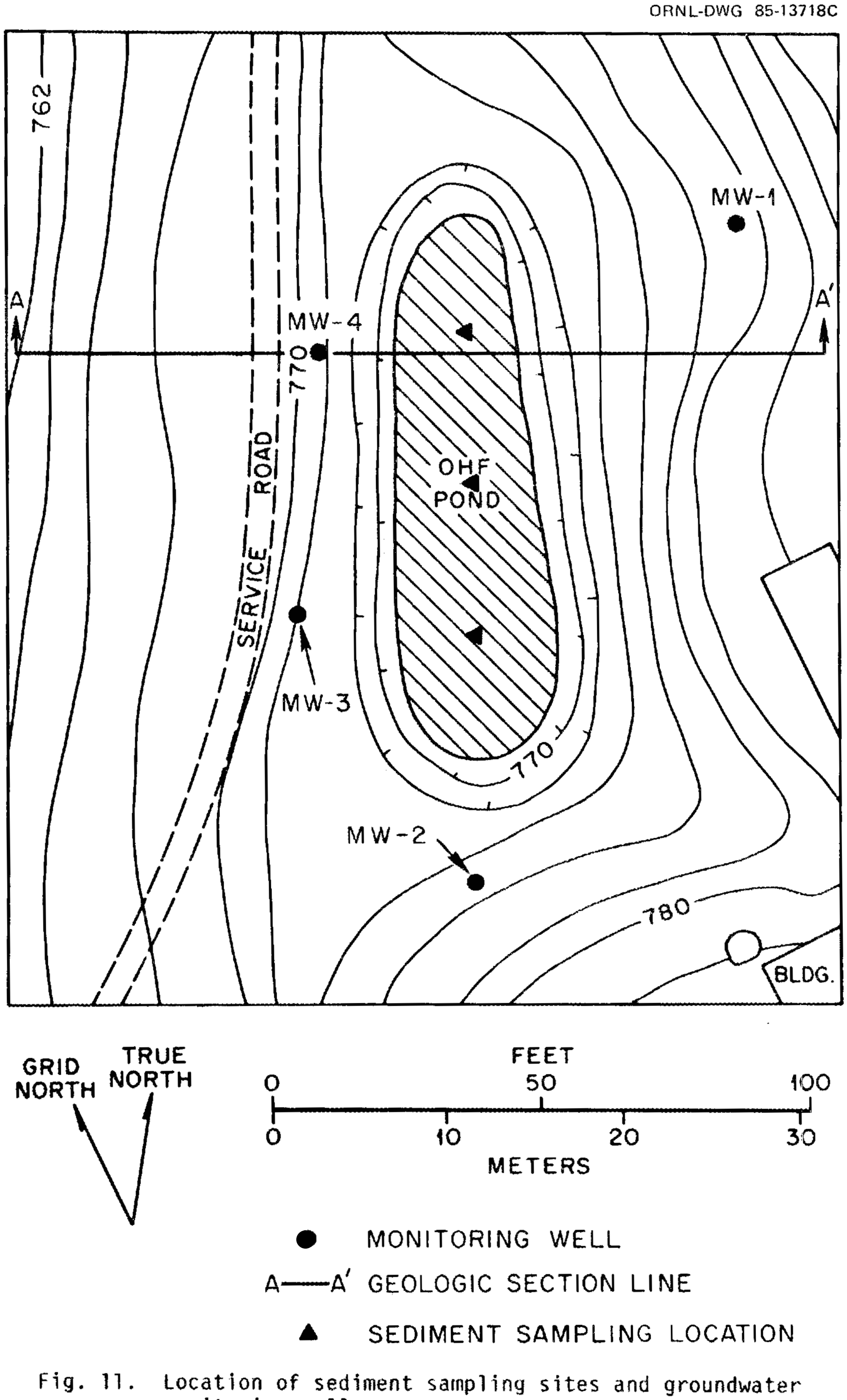


Fig. 11. Location of sediment sampling sites and groundwater monitoring wells.

Table 8. Concentration of RCRA regulated constituents in EP extracts of sediment from the OHF impoundment

Constituent	Maximum allowable concentration (mg/L)	Measured concentration[a] (mg/L)
Arsenic	5	<0.60
Barium	100	0.307
Cadmium	1	0.0092
Chromium	5	0.0492
Lead	5	<0.0232
Mercury	0.2	0.065
Selenium	1	<1.2
Silver	5	<0.2
Endrin	0.02	<0.0001
Lindane	0.04	0.0001
Methoxychlor	10	<0.0002
Toxaphene	0.5	<0.002
2,4-D	10	<0.005
2,4,5-DTP	1	<0.005

[a]Taken from R. G. Stansfield and C. W. Francis, 1986, Characterization of the Old Hydrofracture Facility (OHF) Impoundment, ORNL/TM-9990, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Means concentrations from six replicated EP extracts for metals (sediment from three sample locations at two dates). For the herbicides/pesticides, the concentrations are mean concentrations from three replicated EP extracts (sediment from three sample locations at a single date).

Sediment sampling locations are illustrated in Fig. 11. Sampling was conducted in November 1984 and February 1985. A summary of these measurements are presented in Table 8.

Where analytical detection limits were low enough, the concentrations of the RCRA regulated constituents measured in the EP extracts were well below the RCRA maximum allowable concentrations. Selenium concentrations in the EP extracts of the sediment samples collected in November 1984 were determined by inductively coupled plasma (ICP) spectroscopy. For these samples, the detection limit was 2.4 mg/L, 1.4 mg/L in excess of the RCRA limit. The EP extracts of sediment samples taken in February 1985 were analyzed for selenium by atomic absorption spectroscopy (AA) in which the detection limit was 0.01, well below the maximum allowable RCRA concentration. In all six EP extracts, the selenium concentrations were below detection by the particular analytical technique used. The mean of the two detection limits (2.4 and 0.01) is 1.2 mg/L. Thus, the mean selenium concentration reported in Table 8 (1.2 mg/L) is an artifact in reporting the detection limits of the analytical procedure, and should not imply that the concentrations of selenium in the EP extracts are in excess of the maximum allowable RCRA concentration.

Total concentrations of nonradioactive contaminants in sediment samples of the OHF impoundment were determined by both S. F. Huang (EOSD, personal communication, September 1984) and Stansfield and Francis (1986). The method of expressing their concentration, however, differed. Stansfield and Francis expressed the concentrations on the dry weight basis, while S. F. Huang (EOSD, personal communication,

Table 9. Concentration and inventory of nonradioactive contaminants in sediment from the OHF impoundment

Contaminant	Stansfield and Francis (1986)[a]		S. F. Huang[b]	
	Concentration (mg/kg)	Inventory (kg)	Concentration (mg/kg)	Inventory (kg)
Antimony	<194	<3.69	<1.0	<0.08
Arsenic	<120	<2.28	1.1	0.09
Barium	320	6.07	NR[c]	NR
Boron	132	25	NR	NR
Cadmium	<6.1	<0.12	<2.0	<1.60
Chromium	342	6.50	17.0	1.30
Cobalt	22.4	0.43	NR	NR
Copper	140	2.66	18.0	1.40
Iron	11200	403	NR	NR
Lead	<156	<2.97	6.0	0.48
Manganese	370	7.03	NR	NR
Mercury	NR	NR	<2.3	<0.18
Molybdenum	<15.5	<0.29	NR	NR
Nickel	149	2.84	NR	NR
PCB	2.9	0.05	3.5	2.80
Selenium	<240	<4.55	<0.8	<0.06
Silver	<40.9	<0.78	NR	NR
Vanadium	79.1	1.50	NR	NR
Zinc	162	3.07	16.0	1.20

[a]Sediment concentrations by R. G. Stansfield and C. W. Francis [1986, Characterization of the Old Hydrofracture Facility (OHF) Impoundment, ORNL/TM-9990, Oak Ridge National Laboratory, Oak Ridge, Tennessee].

[b]Sediment concentrations by S. F. Huang (EOSD, personal communication, September 1984) are on dry weight basis and represent a mean of three sediment samples taken from the north, center, and south sections of the impoundment. Inventory calculated by Stansfield and Francis was based on a total volume of sediment equal to 5.5×10^4 L, a wet bulk density of 1.2 kg/L, and a moisture content of 71%.

[b]Sediment concentrations by Huang et al. are on a wet weight basis and represent a mean of five sediment samples taken from the center of the pond from a southwest to northeast direction. Inventory calculated by Huang et al. was based on a total volume of sediment equal to 3.7×10^4 L and a wet bulk density of 2.16 kg/L.

[c]NR = not reported.

September 1984) expressed the concentrations on a wet weight basis (Table 9). All things considered equal, the concentrations expressed on a dry weight basis should be higher than those on the same sediment on a wet weight basis. This is generally the case except for the case of PCBs in the sediment. Here, the concentrations determined by S. F. Huang (EOSD, personal communication, September 1984) are higher than those determined by Stansfield and Francis. S. F. Huang (EOSD, personal communication, September 1984) sampled the sediment in September 1983, while Stansfield and Francis sampled in February 1985, which should not be a major factor assuming the degradation rates of PCBs to be relatively slow. Different volumes of sediment and bulk densities of the sediment were also used by each study to determine the total inventory. The basis of calculation for each of the studies is footnoted at the bottom of Table 9. Generally speaking, there was not a profound difference in the contaminant inventory between the two studies. The exception was the major difference in the estimated inventory of PCBs. S. F. Huang (EOSD, personal communication, September 1984) estimated the PCB inventory to be close to 3 kg, while that calculated by Stansfield and Francis was approximately 50 grams.

A similar trend in the concentrations of radionuclides in sediment taken from the OHF impoundment was noted between the two studies. For example, measurements by S. F. Huang (EOSD, personal communication, September 1984) were generally higher than those determined by Stansfield and Francis, even though S. F. Huang (EOSD, personal communication, September 1984) expressed the concentration on the wet weight basis and Stansfield and Francis on a dry weight basis (see Table 10). The major

Table 10. Concentration and inventory of radionuclides in sediment from the OHF impoundment

Radionuclide	Stansfield and Francis (1986)[a]			S. F. Huang[b]		
	Concentration (Bq/g)	Inventory (GBq)	Inventory (Ci)	Concentration (Bq/g)	Inventory (GBq)	Inventory (Ci)
Gross alpha	102	1.93	0.05	NR[c]	NR	NR
Gross beta	92700	1761	48	NR	NR	NR
Cesium-134	<20	<0.38	0.01	100	8.1	0.22
Cesium-137	125000	2370	64	180000	14000	388
Europium-154	<22.7	<0.43	<0.01	390	31	1
Uranium-234	<33.3	<0.63	<0.01	NR	NR	NR
Uranium-238	<612	<11.6	<1	0.23	0.0055	<0.01
Americium-241	<20.0	<0.38	<0.01	2.8	0.22	<0.01
Cobalt-60	608	11.6	0.31	740	60	1.6
Strontium-90	38800	737	20	9700	770	21

[a]Sediment concentrations by R. G. Stansfield and C. W. Francis, [1986, Characterization of the Old Hydrofracture Facility (OHF) Impoundment, ORNL/TM-9990, Oak Ridge National Laboratory, Oak Ridge, Tennessee] are on dry weight basis and represent a mean of three sediment samples taken from the north, center, and south sections of the impoundment. Inventory calculated by Stansfield and Francis was based on a total volume of sediment equal to 5.5×10^4 L, a wet bulk density of 1.2 kg/L, and a moisture content of 71%.

[b]Sediment concentrations by S. F. Huang (EOSD, personal communication, September 1984) are on a wet weight basis and represent a mean of five sediment samples (except the Europium-154 analysis which is from a single sediment sample) taken from the center of the pond from a southwest to northeast direction. Inventory calculated by Huang was based on a total volume of sediment equal to 3.7×10^4 L and a wet bulk density of 2.16 kg/L.

[c]NR = not reported.

exception was the measurements for strontium-90. In this case, concentrations determined by S. F. Huang (EOSD, personal communication, September 1984) were four times smaller than those determined by Stansfield and Francis. Ironically, the inventories of strontium-90 in the sediment by both studies were very close (737 and 770 GBq or 20 and 21 Ci). The basis for calculation of the inventories also differed with respect to volume of sediment, density, etc. (see footnotes at bottom of Table 10 for an explanation for the basis of calculation). As in the pond water, the bulk of the radioactivity is due to cesium-137 and strontium-90, and only a small but detectable fraction (<0.05%) is transuranic related.

3.1.5.3. Groundwater

An indication that groundwater in the vicinity of the OHF is possibly contaminated are the strontium-90 measurements in samples of shallow groundwater taken immediately down-slope southeast of the OHF in the floodplain along Melton Branch (Spalding and Munro 1984). Strontium-90 concentrations (determined by a Cherenkov counting technique) in groundwater samples taken in early spring of 1980 from shallow bore holes (3.2 cm diam and 45 cm deep) were quite high (on the order of 10 kBq/L) and were thought to be related to past operations of the facility. It was impossible to ascertain whether contamination resulted from subsurface contamination (e.g., from the migration of radionuclides from the waste impoundment or leaking waste storage tanks) or from surface contamination of this area by spillage of liquid waste during testing and injection processes. For example, in the late summer and fall of 1968, two curies of strontium-90 was diverted "into a small channel draining toward Melton Creek" from a test well approximately 6 m (20 ft) from Melton Branch that experienced considerable "bleed back" (unpublished January 7, 1969 correspondence to A. M. Weinberg from a committee to investigate the release). Test wells were used to investigate the grouting characteristics of certain injections. This particular test well was made following an injection by the hydrofracture unit into a fracture that contained approximately 130,000 L (35,000 gal) of residual water. Considerable pressure remained on the fracture, and a "bleed back" of contaminated water came up the test well, which was diverted to Melton Branch.

To determine the status of groundwater quality around the OHF impoundment, Stansfield and Francis (1986) installed four groundwater monitoring wells at the OHF site. One well was located to sample groundwater upgradient of the impoundment, and the other three were located to the west and south of the impoundment to sample groundwater downgradient to the impoundment (see Fig. 11). The initial boring for the wells ranged in depth from 7.3 to 10.4 m (24 to 34 ft). In each of the borings, monitoring wells were constructed of 3-in (7.6-cm) diam fiberglass well screen and casing. A summary of the construction details and measured groundwater elevations, as well as surveyed locations and elevation, is listed in Table 11.

Monitoring well 1 (MW-1) was located to provide a groundwater sampling point positioned upgradient (i.e., in the direction of increasing hydrostatic head of the groundwater table) of the impoundment. Its position, however, is only 27 m (95 ft) downgradient from the nearest waste trench in a formerly used low-level radioactive waste burial ground (SWSA 5, solid wastes storage area number 5).

Table 11. Summary of monitoring well location, construction data, and water levels at the OHF impoundment*

	MW-1	MW-2	MW-3	MW-4
North grid coordinate, ft	17325.24	17236.06	17298.86	17339.13
East grid coordinate, ft	28600.38	28504.80	28496.78	28519.01
Top of well casing elevation, ft	782.11	776.89	773.46	773.50
Height of casing above ground, ft	2.80	2.70	2.90	2.90
Ground surface elevation, ft	779.30	774.20	770.60	770.60
Top of well screen elevation, ft	760.10	761.20	760.40	760.50
Bottom of well screen elevation, ft	750.10	751.90	750.40	750.50
Top of sand pack elevation, ft	769.80	768.20	764.60	762.60
Bottom of well hole elevation, ft	744.30	750.20	746.60	746.60
Diameter of well pipe/screen, in.	3.00	3.00	3.00	3.00
Type material of pipe/screen	Fiber-glass	Fiber-glass	Fiber-glass	Fiber-glass
Width of screen opening, in.	0.02	0.02	0.02	0.02
Water level elevation, ft, 4-8-85	770.92	756.58	757.38	760.87
Water level elevation, ft, 5-23-85	769.41	755.86	756.79	759.82
Water level elevation, ft, 6-4-85	768.92	755.37	756.14	759.36
Water level elevation, ft, 7-1-85	768.23	755.34	756.30	759.46
Water level elevation, ft, 7-30-85	768.04	755.47	756.50	759.66

*Taken from R. G. Stansfield and C. W. Francis, 1986, Characterization of the Old Hydrofracture Facility (OHF) Impoundment, ORNL/TM-9990, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

The location of the other three monitoring wells were selected to determine if contaminants from the impoundment had migrated into the groundwater. The wells comply with the regulations promulgated in accordance with RCRA that specify that there be at least three hydraulically downgradient wells (i.e., in the direction of decreasing static head of the groundwater table). These downgradient wells were located at the boundary of the impoundment facility, which is described in the RCRA Permit Writer's Manual Groundwater Protection 40 CFR, Part 264, Subpart E, Draft (USEPA 1983) to be no more distant than the outside toe of any containment dike that may exist, plus 9.14 m (30 ft), for physically selecting an appropriate drill site.

The primary goal in analyzing groundwater samples taken from the monitoring wells was to determine whether the groundwater had been contaminated. To do this, samples were analyzed for those 30 constituents promulgated under RCRA regulations (USEPA 1980). The mean concentrations determined in groundwater sampled the first two quarters of 1985 from the three downgradient wells are presented in 2. The mean concentrations of all RCRA regulated constituents were below maximum allowable levels except those for gross alpha, gross beta, and coliform bacteria. Radioactivity as well as PCBs were detected in the upgradient well, indicating potential contamination by either leakage from the waste pits or from the many underground pipes in the OHF area. Many of the underground pipes lead to the waste pits located uphill and slightly to the southeast of the impoundment. Activity in this well could also have been caused by the leaching of radionuclides from wastes previously disposed of in the abandoned SWSA 5 burial ground. Counts of coliform bacteria in groundwater upgradient as well as downgradient were in excess of the NIPDWS. These counts may result from wildlife habitat such as waterfowl and terrestrial animals known to be in the area. Radioactivity was detected in all monitoring wells; however, well number 4 contained the highest concentration of cesium-137 and strontium-90.

Table 12. Groundwater concentrations in wells downgradient from the OHF impoundment[a]

	Maximum level	Measured mean
National Interim Primary Drinking Water Standards (NIPDWS)		
Arsenic	0.05	<0.0017
Barium	1	0.3907
Cadmium	0.01	<0.0037
Chromium	0.05	<0.0456
Fluoride	1.4-2.4	<1
Lead	0.05	0.0267
Mercury	0.002	<0.0001
Nitrate-N	10	3.83
Selenium	0.01	<0.0023
Silver	0.05	<0.07
Endrin	0.0002	<0.0001
Lindane	0.004	<0.0001
Methoxychlor	0.1	<0.0002
Toxaphene	0.005	<0.002
2,4-D	0.1	0.005
2,4,5-TP Silvex	0.01	0.005
Radium-226, Bq/L	0.19	0.104
Gross alpha, Bq/L	0.556	<3.08
Gross beta, mR/yr	4	382
Coliform bacteria, counts per 100 mL)	1	12.7
Parameters establishing groundwater quality		
Chloride	ND[b]	14.7
Iron	ND	12.1
Manganese	ND	2.37
Phenols	ND	<0.001
Sodium	ND	22.8
Sulfate	ND	17
Parameters used as indicators of groundwater contamination		
pH	ND	6.49
Specific conductance, µS/cm	ND	376
Total organic carbon	ND	6.37
Total organic halogen	ND	0.03
Nonregulated parameters		
PCBs	ND	0.0001
Tritium, Bq/L	ND	94333
Cesium-137, Bq/L	ND	1.71
Strontium-90, Bq/L	ND	223

[a]Mean concentrations [in mg/L, unless otherwise noted (gross beta is in Bq/L)] taken from three monitoring wells the first two quarters of 1985 (total of six analyses). Data taken from R. G. Stansfield and C. W. Francis, 1986, Characterization of the Old Hydrofracture Facility (OHF) Impoundment, ORNL/TM-9990, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[b]ND = not determined.

3.2. GEOLOGY AND SOILS

3.2.1. Regional Geology

Oak Ridge National Laboratory lies in the Ridge and Valley Physiographic Province. In Tennessee, the province consists of northeast-southwest striking rock strata of limestone, sandstone, and shale extending from the Virginia border on the north to the Georgia-Alabama border on the south. The strata is tilted to angles of 30 degrees and greater throughout its length, resulting in the erosion-resistant beds forming parallel ridges, and those less resistant beds becoming intervening valley floors.

3.2.2. Site Geology

3.2.2.1. Bedrock

The OHF site lies in Melton Valley approximately 1200 m (4000 ft) southeast of the Copper Creek fault. As shown on the geologic map of Fig. 12, the site is underlain by unit "Ccb" of the Conasauga Group. The lithology of this unit is described by Mc Master and Waller (1965) as follows:

> Variable lithology, ranging from shale and siltstone to limestone. Limestone is characteristically pebble conglomerate or edgewise conglomerate having irregular bedding surfaces coated with thin film of dark grey clay and marked by abundant ropy 'worm trails'. Limestone occurs in zones of shale and siltstone. Siltstone in this unit is commonly calcareous and white or light grey when fresh. Shale is thinly bedded, colored brown, olive, and tan, and locally maroon. In places the unit is deformed by very small, sharp folds and faults of small displacement.

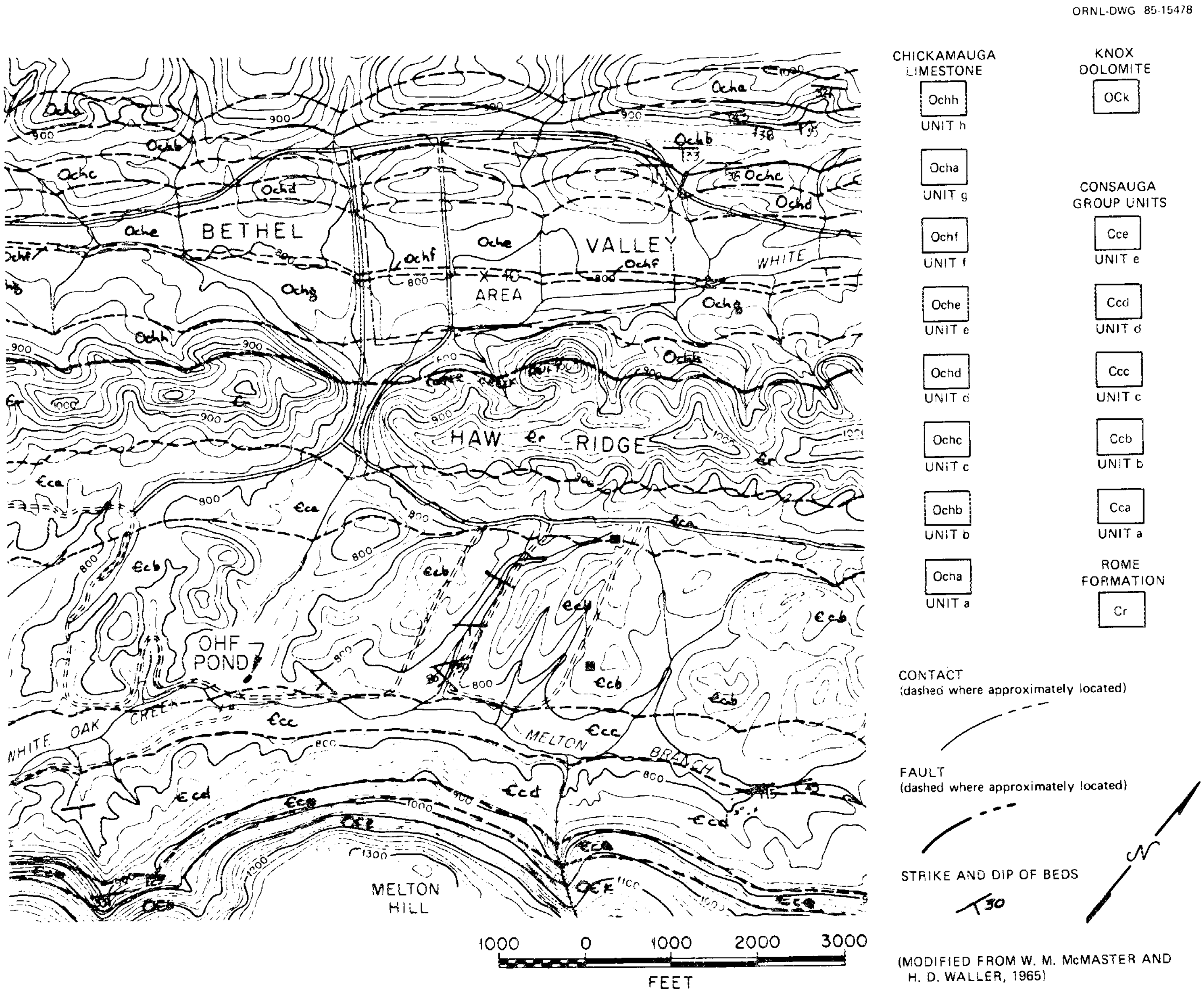


Fig. 12. Geologic map of the ORNL area including the old hydrofracture facility.

They describe the residual material as follows:

> Unit weathers to a bedded shale appearance, leaving little or no indication of original calcareous nature. Limestone weathers to porous brown siltstone or to a light orange-yellow illitic clay. Residuum is generally light tan to yellow-brown but local variations include maroon and green bands. Black manganese oxide stains common on joint surfaces.

OHF was constructed in the upper beds of the Ccb unit as mapped by McMaster and Waller (1965). From later work in the area by others (Haase et al. 1985; Davis et al. 1984; and Rothschild et al. 1984) the upper beds of this mapped unit can be correlated with the upper portion of the Maryville Limestone Formation of the Conasauga Group. Davis and Stansfield (1984) reported on the excavation and construction for a French drain in the Maryville Formation at Solid Waste Storage Area (SWSA) 6, approximately 1200 m (4000 ft) southwest of the OHF site and along geologic strike. They found that the attitude of the beds vary locally from horizontal to dipping to the southeast as steep as 60 degrees due to folding of the strata. They also found two, near-vertical joint sets in the weathered rock. Slides into the French drain, along bedding planes, indicate that either a third joint system or bedding plane faults existed along those surfaces. Both vertical joint systems were very closely spaced (approximately 1 cm) in the weathered rock. At the location that was subsequently the site of the OHF facility, Cowser et al. (1961) mapped the bedrock strata as striking approximately north 43 degrees east, and dipping 15 degrees to the southeast.

A geologic section through the impoundment is shown in Fig. 13. The elevation of the sediment and bottom of the impoundment, as shown in the figure, is from Stansfield and Francis (1986).

3.2.2.2. Soils

The soil depth around the impoundment ranges from approximately 1.5 to 2.7 m (5 to 9 ft). The soil consists of material which classifies as clay under the Unified Soil Classification System (Stansfield and Francis 1986). This clay soil overburden is the residuum of the underlying bedrock. Soils derived from the Conasauga Group contain illite and vermiculite as the predominant clay minerals (McMaster and Waller 1965).

3.3. HYDROLOGY

From 1948 through 1983, the mean annual precipitation at Oak Ridge was 138.71 cm (54.61 in). In this region, the heaviest precipitation normally occurs during winter and early spring, with the monthly maximum normally occurring during the period January to March. However, during some years the monthly maximum has occurred in July because of thunderstorms. September and October are usually the driest months. According to the Climatic Atlas of the United States (U.S Department of Commerce 1979), mean annual lake evaporation in the Oak Ridge area is 89 cm (33 in). From the above data it can be estimated that the net annual precipitation input to the OHF impoundment is 56 cm (22 in). Multiplying this amount by the surface area of the impoundment yields an average yearly retained precipitation contribution of approximately 140,000 L (37,000 gal). In late summer of 1985, the water surface of

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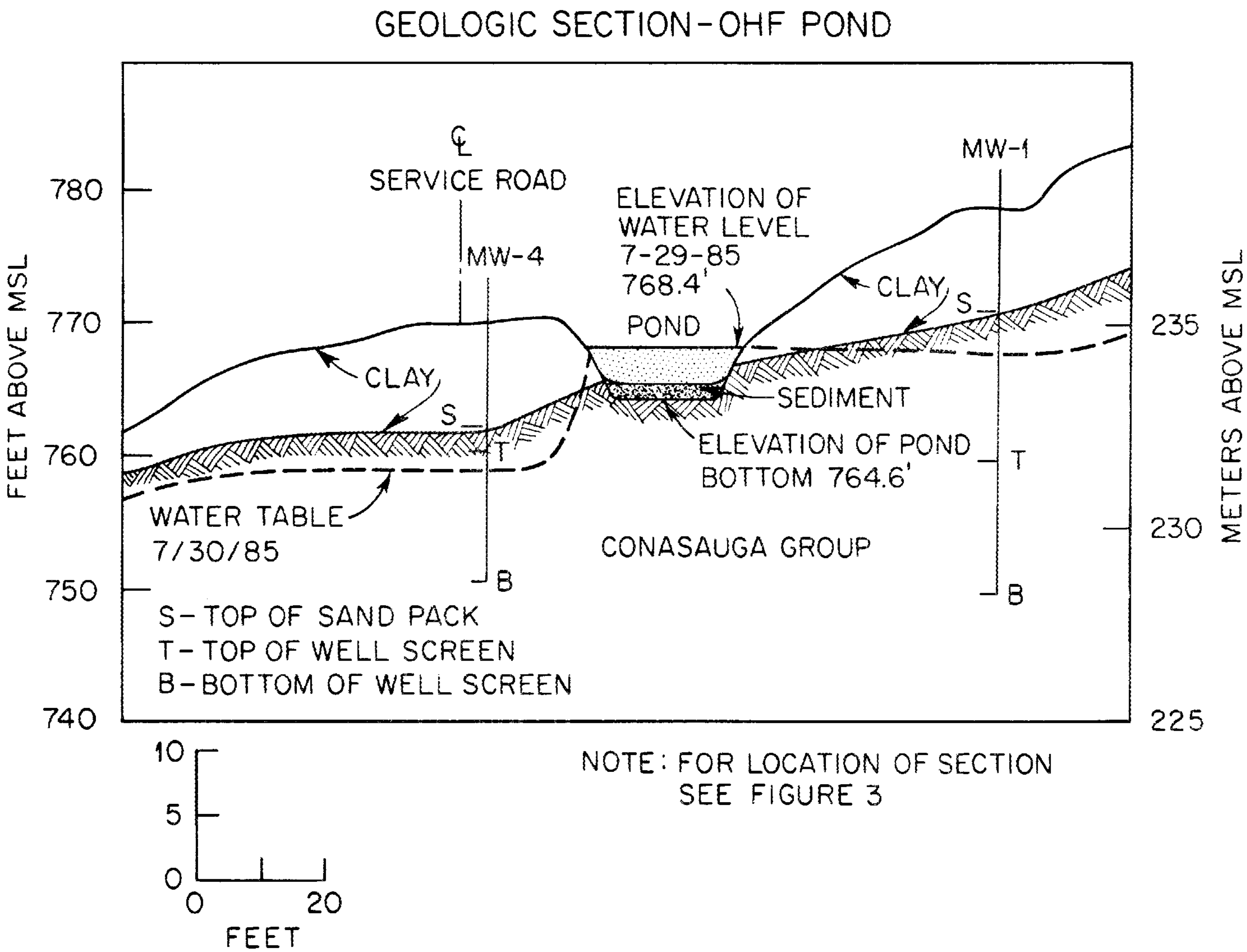

Fig. 13. Geologic section through the old hydrofracture facility impoundment.

the impoundment was measured at elevation 234.2 m (768.4 ft) above msl. At this elevation, the capacity of the impoundment is approximately 300,000 L (77,000 gal). Therefore, the average net annual precipitation input amounts to slightly less than one-half the capacity of the impoundment at this level. The only design outflow system appears to be by the vertical standpipe, and this overflow system does not come into operation until slightly below the elevation at which overflow of the west wall of the impoundment occurs. As there have been no withdrawals of water from the impoundment since operation of the facility ceased, it appears that on a annual basis a net volume of approximately 140,000 L (37,000 gal) is leaking from the impoundment and entering the groundwater.

3.3.1. Groundwater Movement

Two water-table maps are shown in Figs. 14 and 15. The map in Fig. 14, from a report by Cowser et al (1961), depicts the water table for SWSA 5 prior to the construction of the OHF impoundment on the western border of the area. Figure 15 is based on water level observations from the four monitoring wells constructed in 1985 (Stansfield and Francis 1986) and is limited to the immediate site of the OHF impoundment. Water level observations upon which Fig. 15 is based are provided in Table 11. Both Figs. 14 and 15 show the hydraulic gradient at the impoundment to be generally towards White Oak Creek, which is also the general direction of geologic strike of the bedrock strata. At the impoundment, as shown in Fig. 15, the gradient also has a component in the direction of Melton Branch, which is in the general direction of the geologic dip of the bedrock strata.

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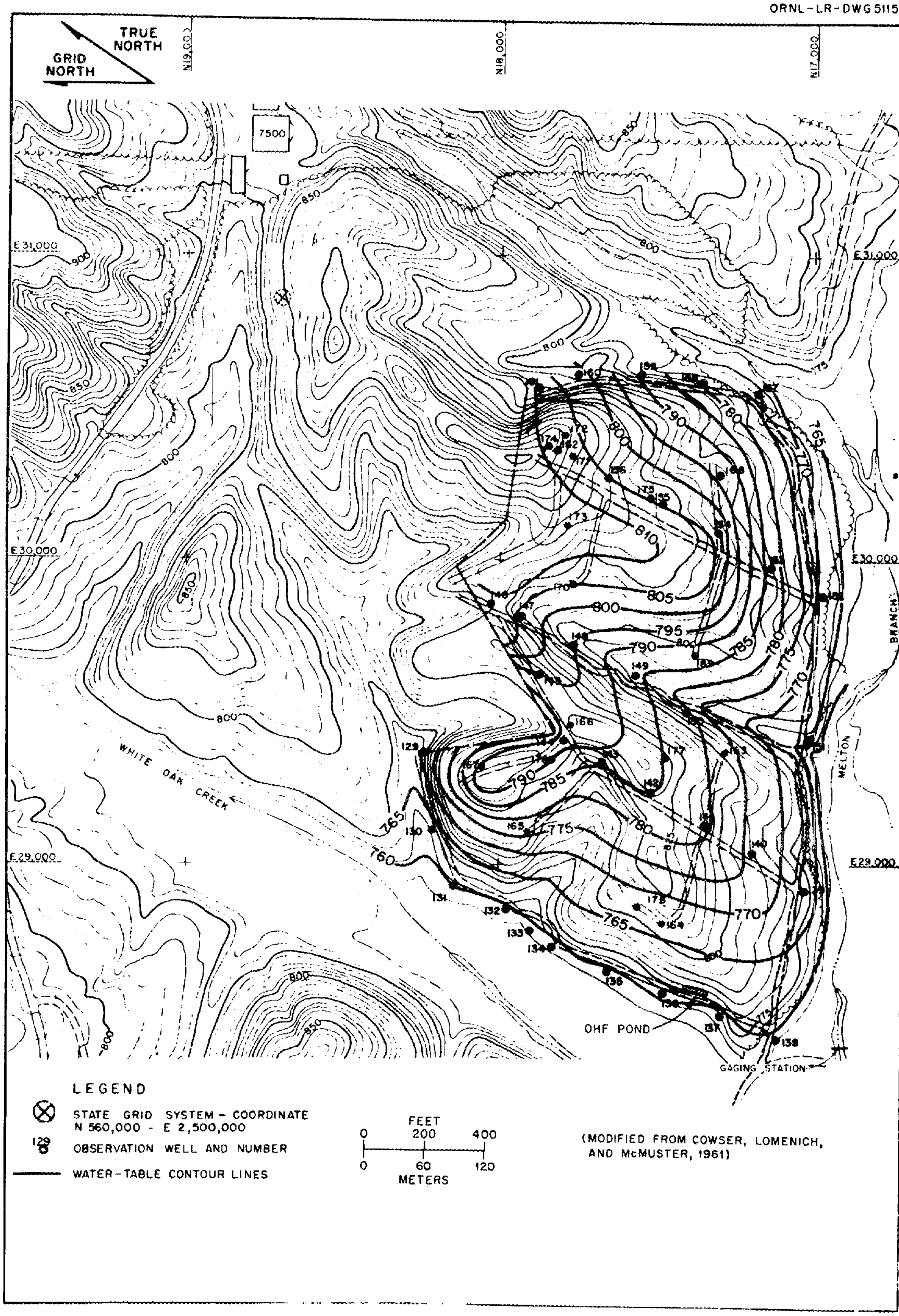

Fig. 14. General water-table map of the area upgradient from the old hydrofracture facility.

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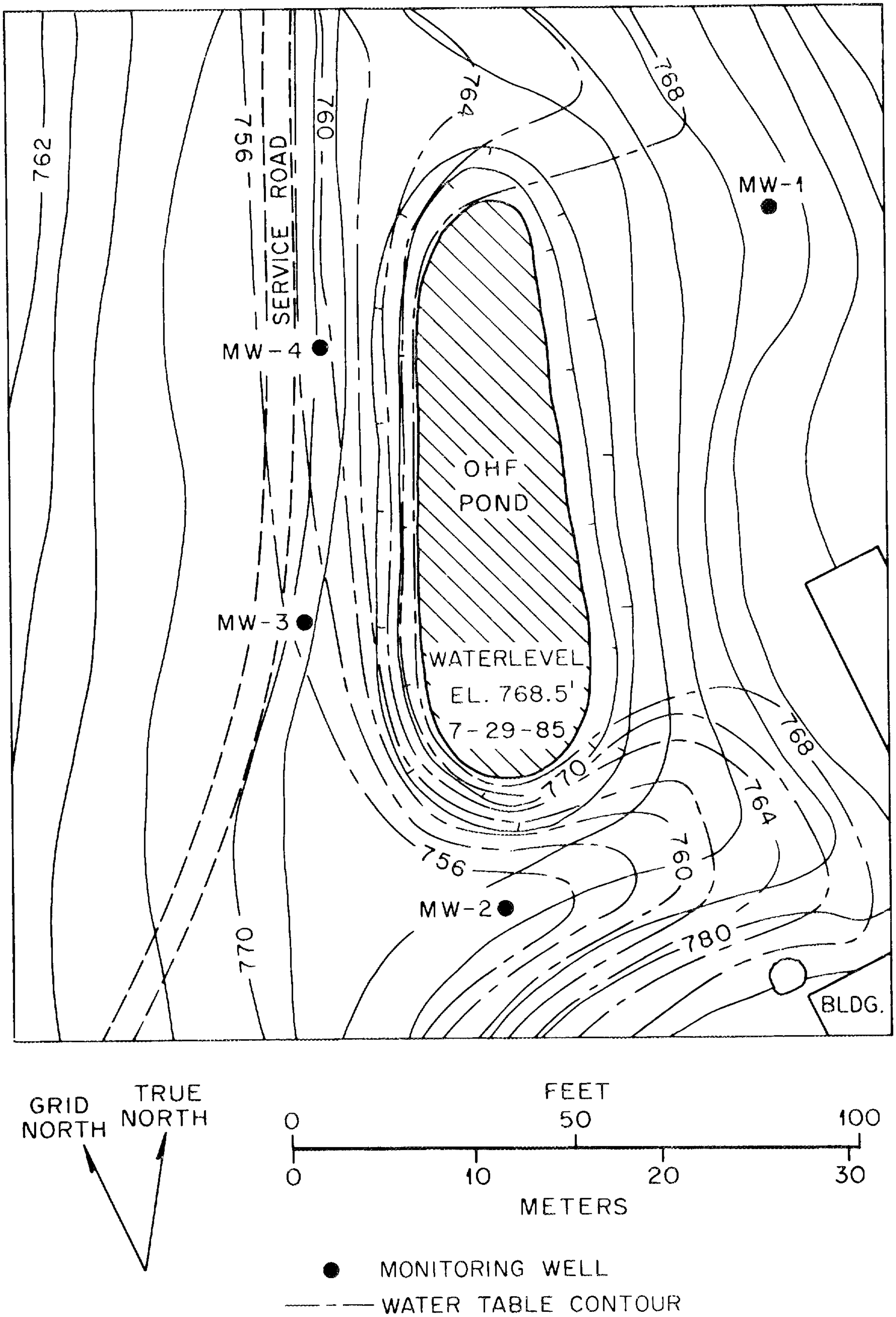

Fig. 15. Water-table map of the old hydrofracture facility impoundment.

As shown in the geologic section through the impoundment (Fig. 13), and the impoundment's water-table map (Fig. 15), the water table is below the bottom of the impoundment on the downgradient (west and south) sides. The water level on the upgradient side is several feet above the bottom of the impoundment. In the summer of 1985, the water surface of the impoundment was approximately at the same elevation as the upgradient monitoring well. Studies on the ORNL reservation (Webster 1976; Davis et al. 1984) show that in the bedrock, the direction of groundwater movement is greatly affected by the directional permeability of the strata. Therefore, the overall groundwater movement through the bedrock is often in a direction at some acute angle to the groundwater contours. The Conasauga strata is anisotropic in respect to hydraulic conductivity with conductivities parallel to the direction of geologic strike being reported as 3 to 20 times greater than in a direction normal to the strike. Such movement would not normally be expected to be in a straight line of flow, but rather would follow irregular pathways along joints and bedding planes because the bedrock strata has very low primary permeability.

3.3.2. Uppermost Aquifer

The soil at the impoundment consists of material that has been visually classified as clay (according to the Unified Soils Classification System), which categorically has a low hydraulic conductivity. However, as shown in Fig. 13, the water table is below the soil, except at the edge of the impoundment. Therefore, the uppermost aquifer at the site is the "Ccb" unit (probably the

Maryville Limestone Formation). Davis et al. (1984) conducted hydraulic conductivity tests in 36 monitoring wells in the Maryville Limestone. Conductivities ranged from 1×10^{-5} to 238×10^{-5} cm/s with a geometrical mean of 6.31×10^{-5} cm/s, and the effective porosity was estimated to be 0.03. These aquifer characteristics are believed to be representative of the OHF site.

3.4. ECOLOGY

The OHF impoundment has not been a site for intensive radioecology studies such as those conducted at the 3513 impoundment (Garten 1982, Kaye and Dunaway 1962, and Trabalka et al. in press). However, the flora and fauna occupying the OHF impoundment are generally considered similar to those in the 3513 impoundment. The major difference is that the OHF impoundment is considerably smaller than the 3513 impoundment. The OHF impoundment is located on a northwestern slope, surrounded by some trees, whereas the 3513 impoundment is located at the bottom of a small floodplain, making for some differences in the quantity and intensity of sunlight striking the impoundments. S. F. Huang (EOSD, personal communication, September 1984) remarked that the impoundment contained large quantities of filamentous algae and measured the level of cesium-137 in the algae to be approximately 60 kBq/g (2 uCi/g) on the dry weight basis.

4. ADDITIONAL INFORMATION NEEDED

In future phases of the ORNL remedial action program, the intent is to evaluate the transport and dose pathways for hazardous substances from each of the considered to pose an undue rish to health, safety, and environment facilities, using standard as well as state-of-the-art mathematical models to provide adequate assessment of the site conditions. This pertains especially to the assessment of potential impacts on groundwater quality, which are difficult to determine using conventional analytical procedures. One purpose of this report is to identify the necessary data requirements to be used as input to drive such models. This pathway analysis assessment will then be utilized to determine the proper course of action required for future remedial actions.

4.1. CONTAMINANT INVENTORY

4.1.1. Buildings

4.1.1.1. Building 7852

Additional radiological survey in this building offers little benefit. Radiation levels in the control room, mixing cells, pump cell, well cell, pump room, and engine pad are high; therefore, additional readings offer little new information. The radiation "shine" due to scatter would easily mask any moderate variations in levels of contaminants in the areas. Similarly, the transferable levels of radioactive contamination are high, and additional efforts at sampling would likely only redistribute the contamination within the area. Core samples of walls and floors could be obtained to determine the depth of penetration of radio-contaminants; however, the high levels of contamination on the surfaces could cause cross-contamination problems, making the interpretation difficult and casting doubts on any results that indicated penetration.

Some equipment remains in the cells and is presumably contaminated. For example, the Moyno pump in the pump room was observed to be contaminated. In the other cells, specific equipment was not identified as being contaminated. Thus, an additional survey in each of the cells should be conducted in an attempt to determine levels of contamination associated with particular pieces of equipment. Such a survey should be conducted only after initial decontamination work is completed. The high levels of transferable contamination observed in the initial survey indicate that a relatively simple cleaning of the surfaces of walls, floors, and equipment would greatly reduce radiation levels. At that time additional survey work could be done to determine areas of residual contamination as well as to measure radiation levels on the equipment in the rooms. Verification of the isotopes involved needs to be undertaken, and it is especially important to determine if levels exceed TRU limits.

Outside building 7852, a radiological survey needs to be conducted to determine if the bulk storage bins are contaminated. The objective of this survey would be to determine if these bins, and their associated equipment, can be "green tagged" and thus released to salvage operations. The 97,000-L (25,000-gal) water tank and pump directly to the east of building 7852 should also be included in this survey to determine if these items can be salvaged.

4.1.1.2. Building 7853

This building as well as the equipment stored in the building needs to be surveyed to verify perceived noncontamination.

4.1.1.3. Pump House

In the initial survey made by S. F. Huang (EOSD, personal communication, September 1984), only a cursory survey was made of the valve pit. Therefore, an additional survey is required of this area. This would involve removing the sheet metal covering the valve pit and making radiation readings and taking smear samples from the interior of the pit. No surveys were made of the piping system of the OHF. Thus, the valve pit area would be a good place to disconnect some of the piping and determine the levels of contamination on the interior surfaces of the pipe. A complete survey of the OHF piping system would require a great deal of excavation and expense; on the other hand, analyzing the contamination present on the outside as well on the interior of the pipes in the valve pit area would be much more practical than the extensive excavation of the pipelines. To determine whether extensive leakage from pipes has occurred, however, soil cores need to be taken to depths below the pipes and analyzed for radioactivity. Perhaps pressure tests on specific pipelines could be used to determine suspected leakage.

4.1.2. Waste Pits

Additional analyses, both radiological and for RCRA hazardous constituents (using the RCRA-EP leach test), need to be conducted on the solidified material at the bottom of the compartments already surveyed by S. F. Huang (EOSD, personal communication, September 1984) and on the contents of the sealed third compartment. This will involve taking drilled core samples from the concrete-like material. Sections of these cores will be analyzed and estimates made as to total inventory of radionuclides and hazardous constituents. Radiological analyses will also include analyses for transuranics to determine if these materials contain TRU levels in excess of the TRU waste handling limits.

4.1.3. Waste Tanks

These tanks were not surveyed directly in the S. F. Huang (EOSD, personal communication, September 1984) survey. For example, the estimated inventories of up to 37 TBq (1 kCi) per tank were made based on past operating experience of how much and the character of waste left in the tank. Thus, detailed characterization of the sludge as to quantity and activity levels is needed prior to removal of the tanks. To do this, the soil covering the tanks would need to be removed so that access to the tank could be made to measure the quantity of sludge remaining and to take samples for radiological and RCRA analyses. It is not clear from the available documentation if portals on top of the tank exist so that such sampling can be conducted. Additional soil cores adjacent these tank also need to be taken, as there was an indication of elevated levels of gamma activity in the core sample (number 16, directly southwest of tank T-4) taken by S. F. Huang (EOSD, personal communication, September 1984) from around the tanks. Further characterization of soil around the tanks is addressed in Sect. 5.2.2.

4.1.4. Waste Impoundment

The studies of S. F. Huang (EOSD, personal communication, September 1984) and Stansfield and Francis (1986) provided an adequate data base to determine the inventory of both radionuclides and nonradioactive contaminants for the pond water and sediment. However, additional samples of subsurface soils need to be taken from the berm as well as from underneath the impoundment to determine the extent of contamination, both in terms of concentration and soil depth. Also, if the modeling predictions associated with remedial action are truly dependent on being able to model the extent of the contamination under existing conditions, then leaching studies on the sediment need to be conducted. The leaching should be conducted with pond water from the impoundment, and any subsequent attenuation of the transported contaminants by the soil underlying the impoundment and subsurface surrounding soils should also be determined. Sediment samples need to be taken to assure that any engineering approaches to the remedial actions, such as stabilizing the sediment, can be completed.

4.2. GEOLOGY AND SOILS

4.2.1. Site Geology

The first step in further characterization will be coring at depths ranging from 20 to 40 m (65 to 130 ft) to determine if deep soils and bedrock are contaminated. For example, core sections will be analyzed for radioactive as well as nonradioactive contamination (using the RCRA EP leach test). Cores of this type serve as excellent integrators of past contamination. One core will be taken between the impoundment and the waste tanks, and another in a southwesterly direction downgradient to the facility.

If the bedrock is found to be contaminated, further efforts will be needed to determine the bedding plane characteristics and their frequencies so that the extent of contamination can be modeled. To observe bedding plane characteristics and frequency in the Conasauga, three exploratory borings of approximately a 33-m (100-ft) depth would be needed. As a major proportion of the joint sets are believed to be in the near vertical attitude, the jointing frequency of the major proportion of joint sets will not be obtained from a vertical core hole. Therefore, two of the exploratory borings will be inclined from the vertical at 30 degrees or more and at right angles to each other. A likely location of the core holes would be at the southwest corner of the impoundment. Selected core samples should be prepared for geochemical analysis including stable isotope and fluid inclusion analysis. These actions, however, are dependent on verification of contamination in the bedrock.

4.2.2. Soils

Soil samples need to be taken so that sorption/desorption of known contaminants in the pond water and sediment on the subsoils below and around the impoundment can be determined. To validate modeling of existing conditions, detailed spatial concentrations in soils near-field the impoundment will be needed. For example, the possibility of seepage from the impoundment having occurred in the subsurface, along the 8-in (20-cm) diam drain line installed at the northwest corner of the impoundment to act as an emergency overflow, needs to be investigated. This will require coring along the pipeline and analyses of soil to check for contamination. The same pattern of soil coring needs to be conducted along pipe lines from the waste storage tanks to building 7852, and from building 7852 to the impoundment and waste pits (see Fig. 10).

In the surveying of the waste tanks, soil excavated to reach the tanks needs to be sampled and analyzed for radioactivity and RCRA constituents (via use of the RCRA EP leach test). In addition, soil cores from between the tanks should be taken and analyzed to determine the extent of contamination.

4.3. HYDROLOGY

The results of analyses and groundwater-level measurements from the monitoring wells constructed in the fall of 1985 need to be evaluated in concert with the several piezometer wells that are scheduled for completion in the area of the impoundment in 1986. A potentiometric map for the area will be prepared by using data from all wells.

4.3.1. Surface Water

To model the impoundment, at least monthly water level observations of the impoundment and monitoring wells should be recorded for one year. A water budget will need to be made for the impoundment to determine the leakage from the impoundment.

4.3.2. Groundwater

Groundwater samples, from the OHF impoundment monitoring wells, have been taken and analyzed four times during the period starting in February 1985 and ending in September 1985. These results need to be evaluated to determine whether contaminants other than radionuclides from the impoundment have significantly affected the groundwater. Pollution from chemical hazardous waste is assumed if an analysis by a statistical procedure such as Cochran's Approximation to the Behrens-Fisher Student's t test indicates a significant increase (decrease in the case of pH) in the water quality parameters listed in Table 12 between the upgradient and downgradient wells.

If contamination has been verified deep into the weathered bedrock by the 20- to 40-m (60- to 130-ft) corings (see Sect. 4.2.1.), additional data on the aquifer properties (hydraulic conductivity, effective porosity, and degree of anisotropism) will be needed for constructing models of the groundwater flow system and contaminant transport. Hydraulic conductivity tests, using slug-test procedures, will be conducted and analyzed for the existing monitoring wells at the impoundment. A pump test with several observation wells will be necessary to study the anisotropic nature of the hydraulic conductivity and transmissivity. The well to be pumped in the test will need to be at least 10 cm in diameter so that a submersible pump can be installed. Because of this relatively large diameter, rather than drill the well using coring techniques, normal well drilling methods will be used. The strata in the well will be examined and logged by the use of a down-the-hole camera.

Additional shallow-groundwater monitoring wells will be needed on the west side of the OHF impoundment to define the limits of contamination. Wells will have to be sufficient in number and depth to determine the lateral extent of the contamination. At present, the groundwater adjacent to the concrete block pits and carbon steel waste tanks is not monitored. It will therefore be necessary to construct additional shallow-groundwater monitoring wells for this purpose [depths of wells up to approximately 10 m (32 ft)]. This will require three wells downgradient in a semicircle surrounding the southwest corner of the facility, but at further distances than the wells presently surrounding the impoundment. Two wells will also be constructed upgradient to the impoundment and waste pits to differentiate any contamination being released from SWSA 5 burial ground immediately to the northeast. The drill cuttings will need to be monitored for radioactivity during the well drilling.

The monitoring of groundwater at depths greater than 10 m (32 ft) is presently being conducted by the U.S. Geological Survey (Webster 1982). One of the monitoring stations is approximately 15 m (48 ft) to the northwest of the facility. If analysis of deep cores indicate contamination (see Sect. 4.2.1.), then one or more deep-groundwater monitoring wells will be constructed.

4.4. ECOLOGY

Before implementation of any remedial action, a biological survey documenting the flora and fauna present in the OHF impoundment should be conducted. The intent here is to determine if the aquatic communities in the pond are similar to those found in the 3513 impoundment where extensive radioecological studies have been conducted (see Sect. 4.4).

5. MONITORING AND TESTING PLAN

5.1. RECOMMENDED TASKS

The following is a list of specific tasks that need to be accomplished to determine the remedial actions needed:

1. Conduct a Radiological Survey of Equipment in Building 7852

   After washing, with a strong cleaning solution, surfaces of walls and floors of rooms in building 7852 that showed high surface contamination, a radiological survey of equipment in building 7852 will be conducted.

2. Collect and Analyze Materials Stored in Waste Pits

   Samples of waste from the three waste pits will be taken and analyzed for radionuclide and RCRA hazardous waste concentrations to estimate total inventory of these constituents.

3. Measure Concentrations of Radionuclides and RCRA Hazardous Waste in Waste Tanks

   Representative samples of waste will be taken from all five steel waste tanks and the quantity of waste in each measured. The purpose is to determine concentrations as well as total inventory of radionuclides and RCRA hazardous waste constituents in each of the tanks. To do this, the soil overlying these tanks must be excavated.

4. Conduct a Radiological Survey of Valve Pit and Associated OHF Piping

   The valve pit, adjacent to the pump house, has never been thoroughly surveyed for radioactive contaminants. The covering of the valve pit needs to be removed and a radiological survey conducted. In addition, piping in this pit needs to be disassembled and activity on the interior of the piping determined to evaluate the potential activity related to the underground piping throughout the OHF. Soil cores will be taken and analyzed down to and along known areas of underground piping to determine if leakage has occurred. This includes the emergency overflow pipeline from the impoundment, the two influent pipelines to the impoundment, as well as other pipelinesfrom the waste tanks and waste pit. For soil samples that show contamination with radionuclides (indicating a pipeline leak), the EP leach test will be used to assess the soil's RCRA hazard characteristic.

5. Perform Statistical Analysis of Groundwater Monitoring Data

   Using an adequate statistical analysis procedure, one year of groundwater monitoring data will be evaluated (samples collected over four quarters and analyzed for the parameters established by the U.S. Environmental Protection Agency as indicators of significant groundwater contamination by chemical hazardous waste).

6. Conduct Sediment Leaching and Soil Attenuation Studies

   Studies to determine the leaching rates of contaminated sediment by pond water in conjunction with sorption/desorption attenuation studies of the leached contaminants on berm soils and soil samples taken from below the pond sediment are needed.

7. Determine Impoundment Leakage

A water budget for the impoundment will be determined by monitoring pond water and groundwater elevations on a monthly basis. Rainfall and free water evaporation rates will be determined at the site. Dye and or short-lived radionuclide tracer tests will also be conducted. For example, the loss from the impoundment will be estimated by comparing the concentration of the tracer in the impoundment over time. Also, the direction of flow and leakage to White Oak creek can likely be determined.

8. Determine Lateral Limits of Shallow-Groundwater Contamination

Additional groundwater monitoring wells will be required to determine the lateral limits of shallow-groundwater contamination. This includes three additional wells that encompass the southern and western boundaries of the OHF impoundment and two wells upgradient between the facility and SWSA 5. The 2-in-diam wells will be constructed of stainless steel.

9. Determine Vertical Limits of Contamination

Vertical contamination deep into the partially weathered bedrock (30 m or more) will be determined by extracting two corings from the site. Tentatively, the location of one core will be at the southwest corner of the impoundment but close to the waste tanks. The other core should be taken downgradient in a southwesterly direction. Sections of these cores will be surveyed for radionuclides, and samples will be taken and extracted using the RCRA EP leaching test to determine the presence of RCRA hazardous chemicals.

10. Collect and Analyze Data from New Monitoring Wells

Sampling and analyses of the new wells for gross alpha, gross beta, Sr-90, and H-3 is planned. Also, if the statistical analyses indicates significant pollution by chemical waste, then all groundwater samples for all RCRA constituents will be analyzed.

11. Conduct Single-Well Hydraulic Conductivity Tests

Single-well hydraulic conductivity tests (slug tests) will be conducted in all monitoring wells and the respective hydraulic conductivities of the surrounding geologic media will be calculated.

12. Conduct an Ecological Survey of OHF Impoundment

A survey will be conducted to determine the major biological fauna and flora living in the OHF impoundment.

13. Prepare Pathway Analysis

Data from the presently available characterization information and from that obtained from the above actions will be used to prepare a pathway analysis of contaminants from the facility using documented models.

14. Coordinate Project and Prepare Report

This action includes the overall coordination role to complete the above tasks, as well as to take the information obtained from the above tasks and to document them in a report

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