



Prepared by
Oak Ridge Associated
Universities

Prepared for
U.S. Nuclear
Regulatory
Commission's
Region III Office

Supported by
Safeguards and
Materials Program
Branch;
Division of
Inspection Programs;
Office of
Inspection and
Enforcement

RADIOLOGICAL SURVEY
OF THE
FORMER DOW CHEMICAL CORPORATION SITE
BAY CITY, MICHIGAN

L. L. SOWELL

Radiological Site Assessment Program
Manpower Education, Research, and Training Division

DRAFT REPORT
February 1983

8507310024 850617
PDR ADDCK 04000017
C PDR

MAR 11 1985

RADIOLOGICAL SURVEY
OF THE
FORMER DOW CHEMICAL CORPORATION SITE
BAY CITY, MICHIGAN

Prepared for

Safeguards and Materials Program Branch
Division of Inspection Programs
U. S. Nuclear Regulatory Commission
Region III Office

L. L. SOWELL*

Project Staff

J. D. Berger	T. J. Sowell
R. D. Condra	C. F. Weaver
D. A. Gibson	B. C. Williams

Prepared by
Radiological Site Assessment Program
Manpower Education, Research, and Training Division
Oak Ridge Associated Universities
Oak Ridge, TN 37831-0117

DRAFT REPORT

February 1985

This report is based on work performed under Interagency Agreement DOE No. 40-816-83 NRC Fin. No. A-9076 between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy. Oak Ridge Associated Universities performs complementary work under contract number DE-AC05-76OR00033 with the U.S. Department of Energy.

This draft report has not been given full review and patent clearance, and the dissemination of its information is only for official use. No release to the public shall be made without the approval of the Office of Information Services, Oak Ridge Associated Universities.

*Presently with Energetics, Inc., Philadelphia, PA.

DRAFT

TABLE OF CONTENTS

	<u>Page</u>
List of Figures	ii
List of Tables	iii
Introduction	1
Site Description	1
Survey Procedures	2
Results	4
Comparison of Survey Results with Guidelines	8
Summary	9
References	41
Appendices	
Appendix A: Major Analytical Equipment	
Appendix B: Analytical Procedures	
Appendix C: Nuclear Regulatory Commission Guidelines For Residual Concentrations of Thorium and Uranium Wastes in Soil	

DRAFT

LIST OF FIGURES

	<u>Page</u>
FIGURE 1: Map of Michigan and Bay City Showing the Location of the Former DOW Chemical Site	10
FIGURE 2: Plan View of the Former DOW Chemical Site	11
FIGURE 3: Grid System Established for Survey Reference - Processing Area	12
FIGURE 4: Grid System Established for Survey Reference - Field Area	13
FIGURE 5: Locations of Boreholes - Processing Area	14
FIGURE 6: Locations of Boreholes - Field Area	15
FIGURE 7: Locations of Sediment Samples - Processing Area	16
FIGURE 8: Locations of Water Samples - Processing Area	17
FIGURE 9: Locations of Background Measurements and Baseline Samples in the Bay City Area	18
FIGURE 10: Locations of Elevated Contact Radiation Levels - Processing Area	19
FIGURE 11: Locations of Elevated Contact Radiation Levels - Field Area	20

LIST OF TABLES

	<u>Page</u>
TABLE 1A: Direct Radiation Levels Measured at Baseline Sample Locations, Former Dow Chemical Site - Bay City, Michigan	21
TABLE 1B: Radionuclide Concentrations Measured in Baseline Soil and Sediment Samples, Former Dow Chemical Site - Bay City, Michigan	22
TABLE 1C: Radionuclide Concentrations Measured in Baseline Water Samples, Former Dow Chemical Site - Bay City, Michigan	23
TABLE 2: Direct Radiation Levels Measured at Grid Line Intersections - Processing Area	24
TABLE 3: Surface Radiation Levels Measured at Locations Identified by the Walkover Scan-Processing Area	27
TABLE 4: Radionuclide Concentrations Measured in Surface Soil Samples Collected at Grid Line Intersections - Processing Area	28
TABLE 5: Radionuclide Concentrations Measured in Surface Soil Samples Collected from Selected Locations of Elevated Contact Radiation Levels - Processing Area	30
TABLE 6: Radionuclide Concentrations Measured in Soil Samples Collected After Decontamination - Processing Area	31
TABLE 7: Radionuclide Concentrations Measured in Soil Samples Collected from Boreholes - Processing Area	32
TABLE 8: Radionuclide Concentrations Measured in Sediment Samples - Processing Area	33
TABLE 9: Radionuclide Concentrations Measured in Water Samples- Processing Area	34
TABLE 10: Direct Radiation Levels Measured at Grid Line Intersections - Field Area	35
TABLE 11: Surface Radiation Levels Measured at Locations Identified by the Walkover Scan - Field Area	36
TABLE 12: Radionuclide Concentrations Measured in Surface Soil Samples Collected at Grid Line Intersections - Field Area	37

LIST OF TABLES (Continued)

	<u>Page</u>
TABLE 13: Radionuclide Concentrations Measured in Surface Soil Samples Collected from Selected Locations of Elevated Contact Radiation Levels - Field Area	38
TABLE 14: Radionuclide Concentrations Measured in Soil Samples Collected After Decontamination - Field Area	39
TABLE 15: Radionuclide Concentrations Measured in Soil Samples Collected from Boreholes - Field Area	40

RADIOLOGICAL SURVEY
OF THE
FORMER DOW CHEMICAL CORPORATION SITE
BAY CITY, MICHIGAN

INTRODUCTION

Beginning in the early 1950's, DOW Chemical Corporation operated an alloy casting plant in Bay City, Michigan. One of the products was a magnesium-thorium alloy containing up to four percent thorium by weight. Residues from the production of the alloy were contaminated with licensable concentrations of the natural thorium decay series; low concentrations of radionuclides from the natural uranium decay series were also present. These residues, primarily in the form of slag, were used on portions of the property as construction fill. Some of this slag was also used at a chemical disposal landfill north of Bay City. In 1961, the DOW plant was leased to Wellman Bronze and Aluminum Company (later changed to Wellman Dynamics Corporation). Wellman's operations also included casting and finishing of magnesium-thorium alloys. Wellman discontinued operations in 1972 and the site reverted to DOW. The property was decontaminated in 1974 and sold to Dore Wrecking Company (now Dore Enterprises, Inc.) - the present owner.

Surveys conducted by NRC in 1982 indicated the presence of residual radioactive material exceeding NRC guidelines for decommissioning. DOW Chemical further decontaminated the facility, and a report, dated October 8, 1982, submitted to the NRC, indicated that the site meets the release criteria.¹ Oak Ridge Associated Universities (ORAU), at the request of the NRC, Region III, conducted a confirmatory survey during August 1984 to provide data necessary to evaluate radiological conditions relative to release for unrestricted use.

SITE DESCRIPTION

The former DOW Chemical site is located on Andre St. in Bay City, Michigan, (see Figures 1 and 2). The site contains two areas of potential contamination (1) the main processing area and (2) a nearby open field, previously used for storage of the process slag. The main processing area is 140 m x 260 m and covers approximately 3.6 hectares.

There are five buildings on the property; with the exception of Building 15, which is owned and occupied by General Housing Corporation, the buildings are in use by Dore Enterprises. Buildings 2, 4, and 7, previously used in the foundry operations have been demolished, and piles of rubble remain on the site. The former slag storage area is located on Marquette Avenue. It occupies approximately 0.5 hectares (about 80 m x 50 m). The southeastern portion of the site is covered by a swampy area; there are no structures and the property is currently not being used.

SURVEY PROCEDURES

Objective

The objective of this survey was to provide an assessment of the radiological conditions of the two areas of interest. Activities included the following:

1. measurement of direct radiation levels;
2. determination of locations and depths of radioactive material;
3. measurement of radionuclide concentrations in surface and subsurface soil and water; and
4. measurement of radionuclide concentrations in sediment and water from site drainage systems.

Procedures

1. Twenty meter grid systems were established for survey reference in both the processing and field areas. These grid systems are shown on Figures 3 and 4.
2. A walkover surface scan using portable NaI(Tl) gamma scintillation detectors was conducted at 1-2 m grid intervals over the gridded areas. Locations of elevated contact radiation levels were noted.
3. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at each grid line intersection, and at locations of

DRAFT

elevated contact radiation levels identified by the walkover surface scan. These measurements were performed using portable NaI(Tl) gamma scintillation detectors and ratemeters, cross calibrated onsite with a pressurized ionization chamber.

4. Soil samples were collected from the surface (0-15 cm) at grid line intersections, and at various depths from selected locations of elevated contact radiation levels identified by the walkover surface scan.
5. Seven boreholes were drilled in the processing area and two boreholes were drilled in the field area. Two of these boreholes were drilled at locations of elevated contact radiation levels; the remainder were spaced to provide representative coverage of the area. Locations of these boreholes are indicated on Figures 5 and 6.

Radiation profiles of the boreholes were determined by measuring gamma radiation at 30 cm intervals from the surface to the bottom of the hole, using a collimated NaI(Tl) gamma scintillation detector and a portable scaler.

Soil samples were collected at the surface (0-15 cm), at 1 m to 1.5 m, and at 2.5 to 3.0 m in each borehole using a split spoon sampler driven through the center of a hollow stem auger. Water samples were collected from four boreholes, where available.

6. Sediment samples were collected from drains and conveyor pits. These sampling locations are shown on Figure 7.
7. Water samples were collected from drains and conveyor pits, where available. These locations are shown on Figure 8.
8. Four surface soil and water samples and two sediment samples were collected from the Bay City area (but not on or near the former DOW property) to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were measured

DRAFT

at the locations where baseline samples were collected. These locations are shown on Figure 9.

Sample Analysis and Interpretation of Results

Soil samples and sediment samples were analyzed by gamma spectrometry. Radionuclides of primary interest included Th-232, Th-228, U-238, and Ra-226; however, spectra were reviewed for other identifiable photopeaks. Water samples were analyzed for gross alpha and beta concentrations. Radium analyses were performed on selected water samples having elevated gross alpha concentrations. Additional information concerning analytical equipment and procedures is contained in Appendices A and B.

Results of this survey were compared to NRC guidelines for residual thorium and uranium in soil. These guidelines are presented in Appendix C.

RESULTS

Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil, sediment, and water for locations in the Bay City area are presented in Tables 1A, 1B, and 1C. Exposure rates ranged from 7 to 9 μ R/h, both at contact and at 1 m above the surface.

Radionuclide concentrations in soil were: Th-232, 0.28 to 0.85 pCi/g (picocuries per gram); Th-228, 0.10 to 0.47 pCi/g; U-238, <0.74 to 1.41 pCi/g; and Ra-226, 0.37 to 0.80 pCi/g. Radionuclide concentrations in sediment were: Th-232, 0.57 and 0.96 pCi/g; Th-228, 0.26 and 0.89 pCi/g; U-238, <0.49 and 1.35 pCi/g; and Ra-226, <0.55 and 0.35 pCi/g. Gross alpha and gross beta concentrations in water ranged from 0.21 to 8.02 pCi/l (picocuries per liter) and 5.77 to 14.8 pCi/l, respectively.

DRAFT

Processing Area

Direct Measurements

Direct radiation levels measured at grid line intersections are presented in Table 2. The gamma exposure rates measured at 1 m above the surface ranged from 7 to 13 $\mu\text{R/h}$ (average 8 $\mu\text{R/h}$). At surface contact, the exposure rates ranged from 7 to 15 $\mu\text{R/h}$ (average 9 $\mu\text{R/h}$).

The walkover survey identified nineteen isolated locations with elevated surface radiation levels. These locations are indicated on Figure 10, and associated direct radiation levels are presented in Table 3. Contact gamma exposure rates ranged from 33 to 430 $\mu\text{R/h}$. DOW personnel promptly removed surface material from these areas, until the radiation levels at 1 m above the surface were less than 20 $\mu\text{R/h}$. The gamma exposure rates after cleanup ranged from 9 to 15 $\mu\text{R/h}$ at 1 m above the surface and from 11 to 42 $\mu\text{R/h}$ at contact (see Table 3).

Radionuclide Concentrations in Soil

Table 4 lists the concentrations of radionuclides measured in surface soil collected at grid line intersections. These samples contained Th-232 concentrations ranging from <0.09 to 44.0 pCi/g. The highest level was in the sample collected from grid coordinate 100N,60E. Thorium-228 concentrations ranged from 0.15 to 42.3 pCi/g, with the highest level also found in the sample collected from coordinate 100N,60E. Concentrations of U-238 and Ra-226 ranged from <0.35 to 9.77 pCi/g and <0.09 to 2.32 pCi/g, respectively. Radionuclide concentrations in the majority of the samples were within the range encountered in baseline samples.

Table 5 lists the concentrations of radionuclides measured in surface soil samples collected at four locations of elevated contact radiation levels. All of these samples contained elevated concentrations of Th-232 and Th-228. The Th-232 levels ranged from 85.3 to 149 pCi/g; Th-228 levels ranged from 82.2 to 153 pCi/g. The sample from coordinate 65N,197E contained the maximum concentration of each of the thorium isotopes. Radium-226 concentrations were also elevated (up to 9.16 pCi/g) in three of the four samples.

After excavation of surface areas identified by the gamma scan, additional samples were collected. The radionuclide concentrations in these samples are presented in Table 6. Thorium-232 concentrations ranged from 0.52 pCi/g to 264 pCi/g with the highest value measured in the sample collected at 53N,253E. Thorium-228 concentrations ranged from 0.48 to 256 pCi/g with the highest level also in the sample from 53N,253E. Radium-226 was also elevated in several of the samples; the sample from 53N,253E contained the highest level - 30.4 pCi/g.

Table 7 presents the radionuclide concentrations measured in samples collected from boreholes. The surface sample from borehole B5 contained 90.5 pCi/g of Th-232 and 92.4 pCi/g of Th-228. Cleanup efforts by DOW subsequently removed the contaminated residues from this location. The other boreholes contained radionuclide concentrations which were much lower. Borehole B7 had surface Th-232 and Th-228 concentrations of 2.51 and 2.46 pCi/g, respectively; all other borehole samples were in the range of baseline concentrations. Borehole gross gamma logging measurements did not identify any subsurface contamination, and were thus in agreement with the subsurface sampling results.

Radionuclide Concentrations in Sediment Samples

Radionuclide concentrations in sediment samples collected from drains and conveyor pits are presented in Table 8. Thorium-232 and Th-228 concentrations were elevated in samples 5, 8, and 10. The maximum concentrations of Th-232 and Th-228 were 28.0 pCi/g and 27.1 pCi/g, respectively, measured in sample 8 from a drain at 36N,255E.

Radionuclide Concentrations in Water

Concentrations of gross alpha and gross beta activity in water samples are presented in Table 9. Concentrations in many of the samples were elevated above those encountered in baseline samples. Gross alpha concentrations in samples from conveyor pits ranged from 1.63 to 5.36 pCi/l; gross beta ranged from 33.2 to 40.0 pCi/l. Drain water samples contained gross alpha and gross beta concentrations ranging from <0.75 to 11.9 pCi/l and from 5.82 to

186 pCi/l, respectively. Borehole samples ranged from 5.06 to 30.6 pCi/l gross alpha and from 6.36 to 179 pCi/l gross beta. Radium-226 and Ra-228 concentrations were measured in the four samples with gross alpha activity exceeding 10 pCi/l. The highest Ra-226 was 0.72 pCi/l; the highest Ra-228 was 3.38 pCi/l in the sample from borehole B6.

Field Area

Direct Measurements

Direct radiation levels measured at grid line intersections are presented in Table 10. The gamma exposure rates measured at 1 m above the surface ranged from 8 to 13 μ R/h (average 9 μ R/h). At surface contact, the exposure rates ranged from 8 to 13 μ R/h (average 9 μ R/h).

The walkover survey identified fifteen locations with elevated surface radiation levels. These locations are indicated on Figure 11 and associated direct radiation levels are presented in Table 11. Contact gamma exposure rates ranged from 30 to 600 μ R/h; at 1 m above the surface the exposure rates ranged from 18 to 45 μ R/h. DOW personnel removed surface material to reduce exposure rates at 1 m to less than 20 μ R/h. After cleanup, the surface and 1 m gamma exposure rate ranges were 15 to 40 μ R/h and 10 to 15 μ R/h, respectively.

Radionuclide Concentrations in Soil

Table 12 lists the concentrations of radionuclides measured in surface soil collected at grid line intersections. These samples contained Th-232 concentrations ranging from 0.31 to 2.32 pCi/g. The highest level was in the sample collected from grid point 60N,0E. Thorium-228 concentrations ranged from 0.36 to 2.46 pCi/g, with the highest level also found in the sample collected from grid point 60N,0E. Concentrations of U-238 and Ra-226 ranged from <0.61 to 2.76 pCi/g and <0.09 to 0.97 pCi/g, respectively. Radionuclide concentrations in the majority of the samples were within the range encountered in baseline samples.

DRAFT

Table 13 lists the concentrations of radionuclides measured in surface soil samples collected at six locations of elevated contact radiation levels. Thorium-232 and Th-228 concentrations were elevated in all of the samples. The maximum concentration of Th-232 was 274 pCi/g, measured in the sample from grid coordinate 77N,30E; the maximum concentration of Th-228 was 272 pCi/g, from the same location. The Ra-226 concentration was also elevated (25.2 pCi/g) in the sample from 77N,30E.

After excavation of surface material from locations of elevated contact radiation, followup samples were collected. The radionuclide concentrations in these samples are presented in Table 14. The maximum concentrations of Th-232 and Th-228 were 8.25 pCi/g and 8.19 pCi/g respectively, at coordinate 34N,16E.

Table 15 presents the radionuclide concentrations measured in samples from two boreholes. The surface sample at coordinate 31N,4E (borehole B8) contained 10.4 pCi/g of Th-232 and 10.6 pCi/g of Th-228. This material was excavated by DOW. No other significant radionuclide concentrations were noted in samples from the boreholes in this area. These soil results are in agreement with the gross gamma logging measurements, which indicated positive results only at the surface in borehole B8.

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The soil guidelines applicable to this site are presented in Appendix C. The guideline for total thorium (Th-232 plus Th-228) contamination in soil is 10 pCi/g for unrestricted use (Option 1). The acceptable exposure rate at one meter above the surface is 10 μ R/h above background or 19 μ R/h total for this site.

Numerous locations exceeded 19 μ R/h at 1 m above the surface prior to further decontamination by DOW; after decontamination, all locations were less than 19 μ R/h.

After excavations, 15 of the samples from the processing area and four of the samples from the field area exceeded the 10 pCi/g thorium guideline. Five of the processing area samples also exceeded 50 pCi/g (Option 2) and one, at 53N,253E, exceeded 500 pCi/g (Option 4).

DRAFT

The sediment sample collected from a processing area drain located at 56N,255E exceeds the thorium Option 2 guideline of 50 pCi/g.

Two water samples collected from boreholes exceed the EPA Drinking Water Standard of 15 pCi/g gross alpha, and two water samples - one from a drain and one from a borehole - exceed 50 pCi/g gross beta.² It should be noted that the EPA standards are used here for comparison purposes only, because this water does not represent a source of drinking water.

SUMMARY

A survey of the former DOW Chemical Corporation site, Bay City, Michigan, was conducted during August 1984. The survey included surface radiation scans, measurements of direct radiation levels, and analyses of radionuclide concentrations in soil, sediment, and water samples.

Locations of elevated direct surface radiation levels were detected. Most of these locations were removed by excavation of the soil. Exposure rates at one meter above the surface were reduced to 15 μ R/h or less by this excavation. Although the direct radiation levels were reduced, isolated areas still contain thorium concentrations which exceed the NRC guidelines for unrestricted release. Additional small areas of subsurface thorium residues, which were not detectable by this survey because of overlying noncontaminated soil, are likely.

The thorium contaminated residues constitute a very small fraction of the total property soil. The radionuclides are of low solubility and off-site migration is not occurring. Under present conditions of property use, the thorium contaminated residues do not pose any danger to site occupants or the general public.

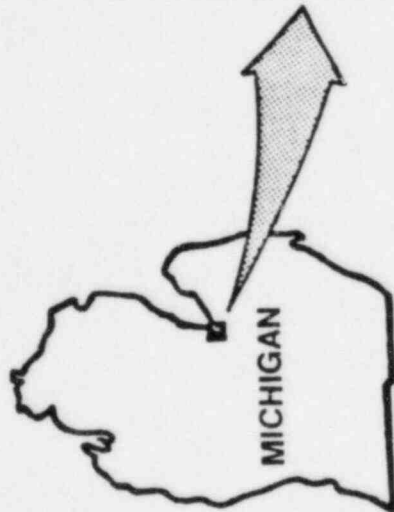
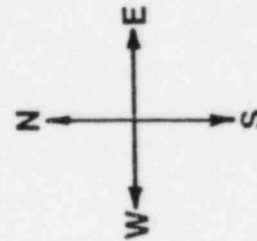
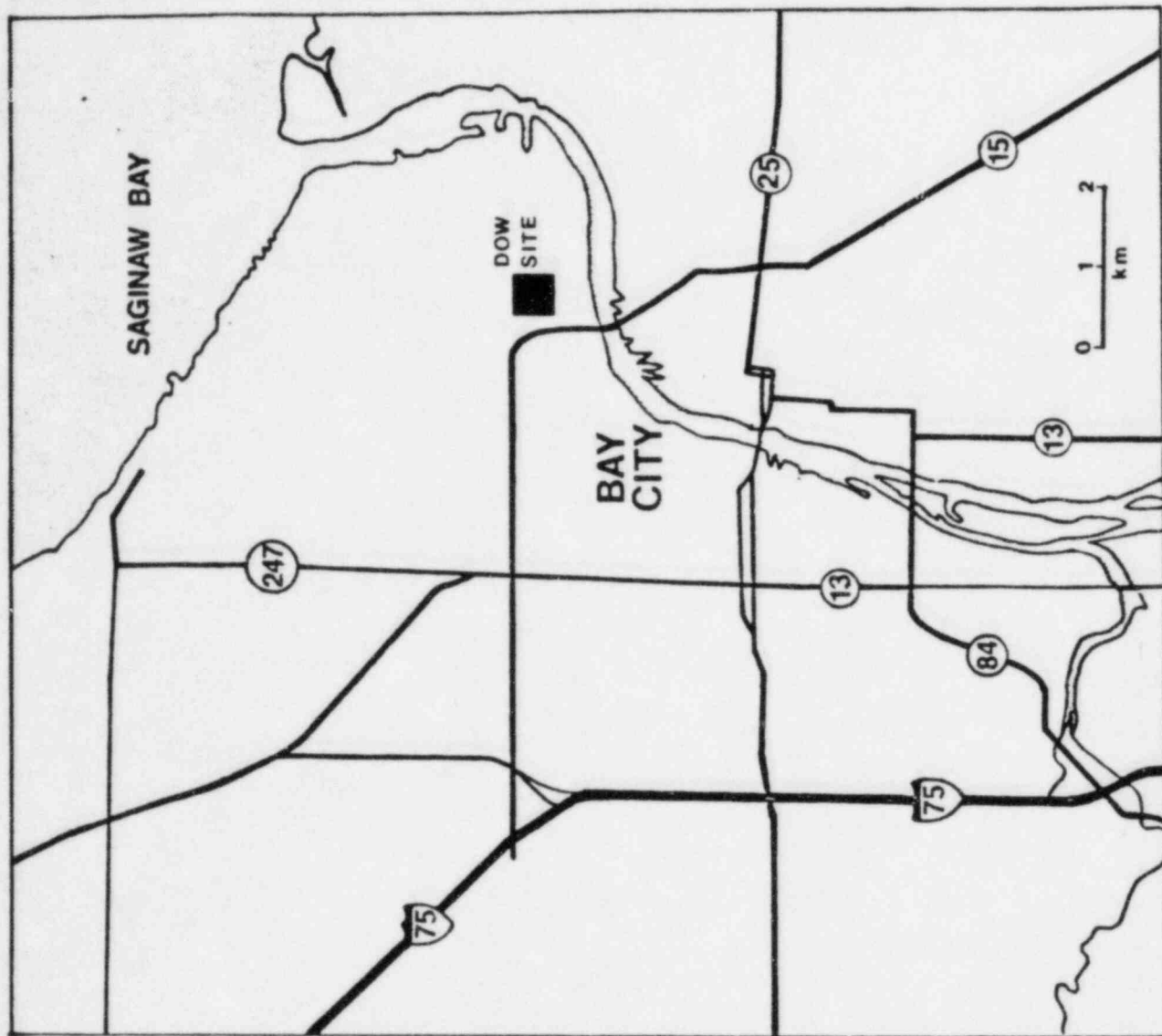


FIGURE 1: Map of Michigan and Bay City Showing the Location of the Former DOW Chemical Site.

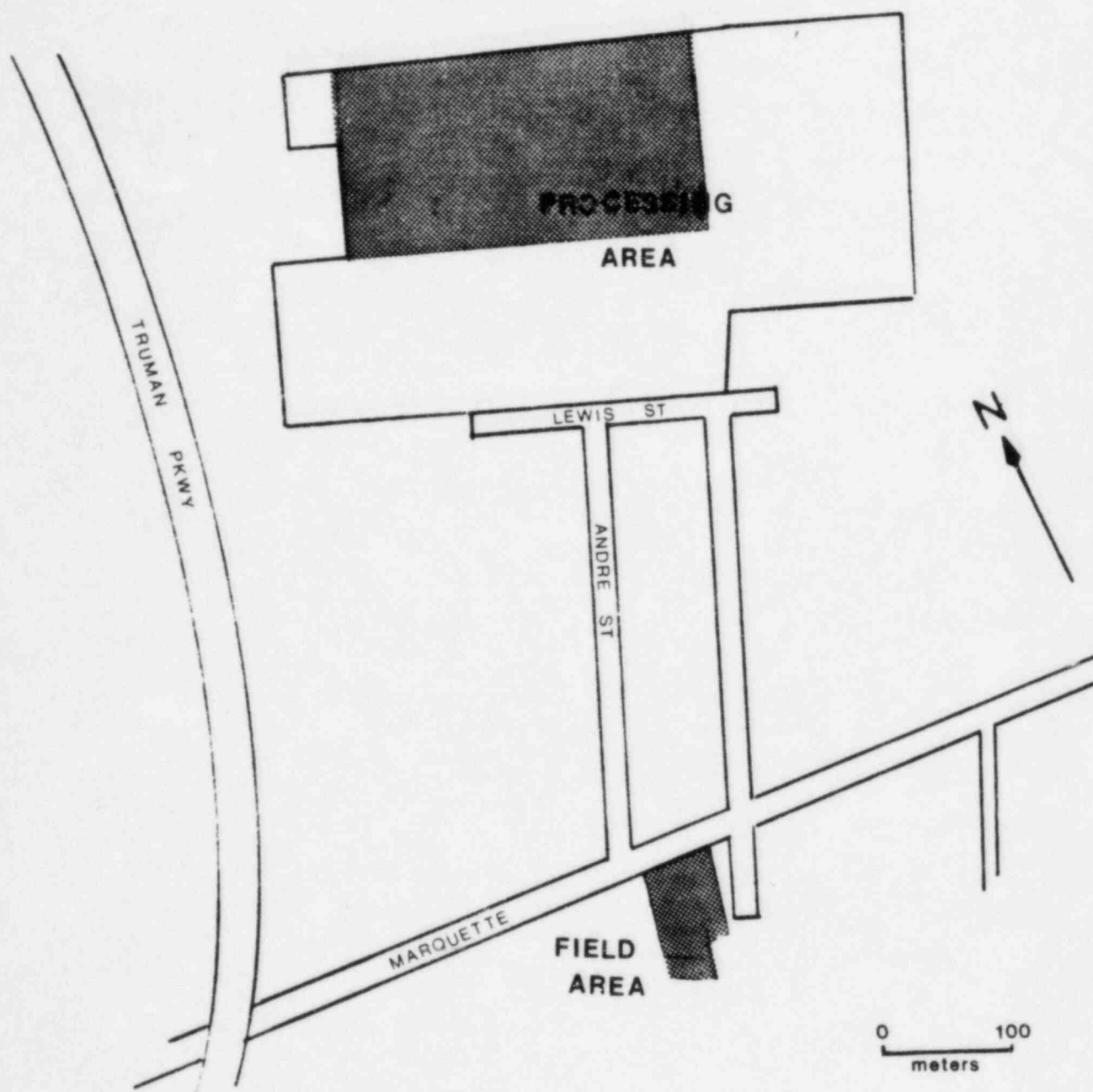


FIGURE 2: Plan View of the Former DOW Chemical Site (shading indicates areas surveyed).

DRAFT

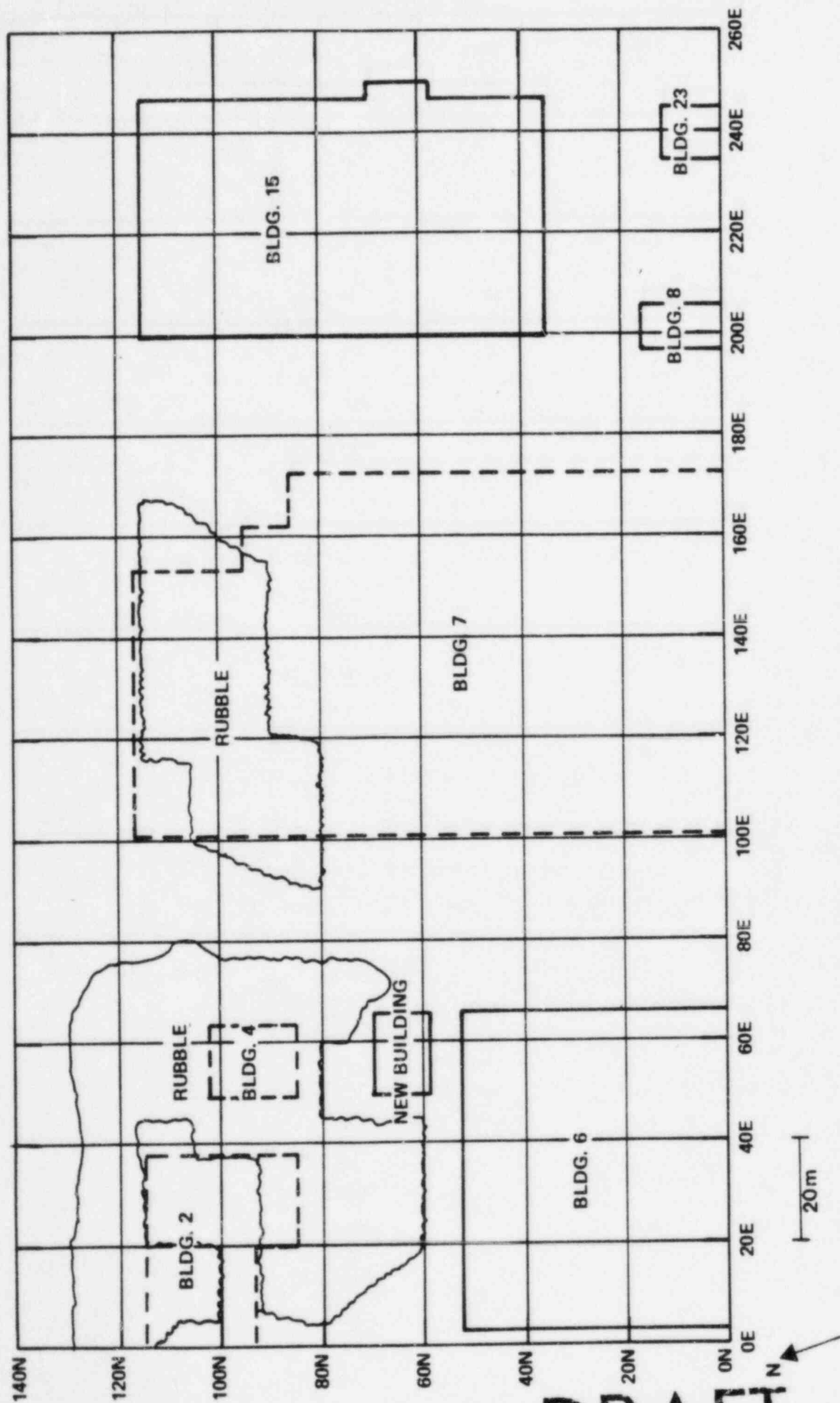


FIGURE 3: Grid System Established for Survey Reference - Processing Area (dashed areas indicate previous building locations).

DRAFT

13

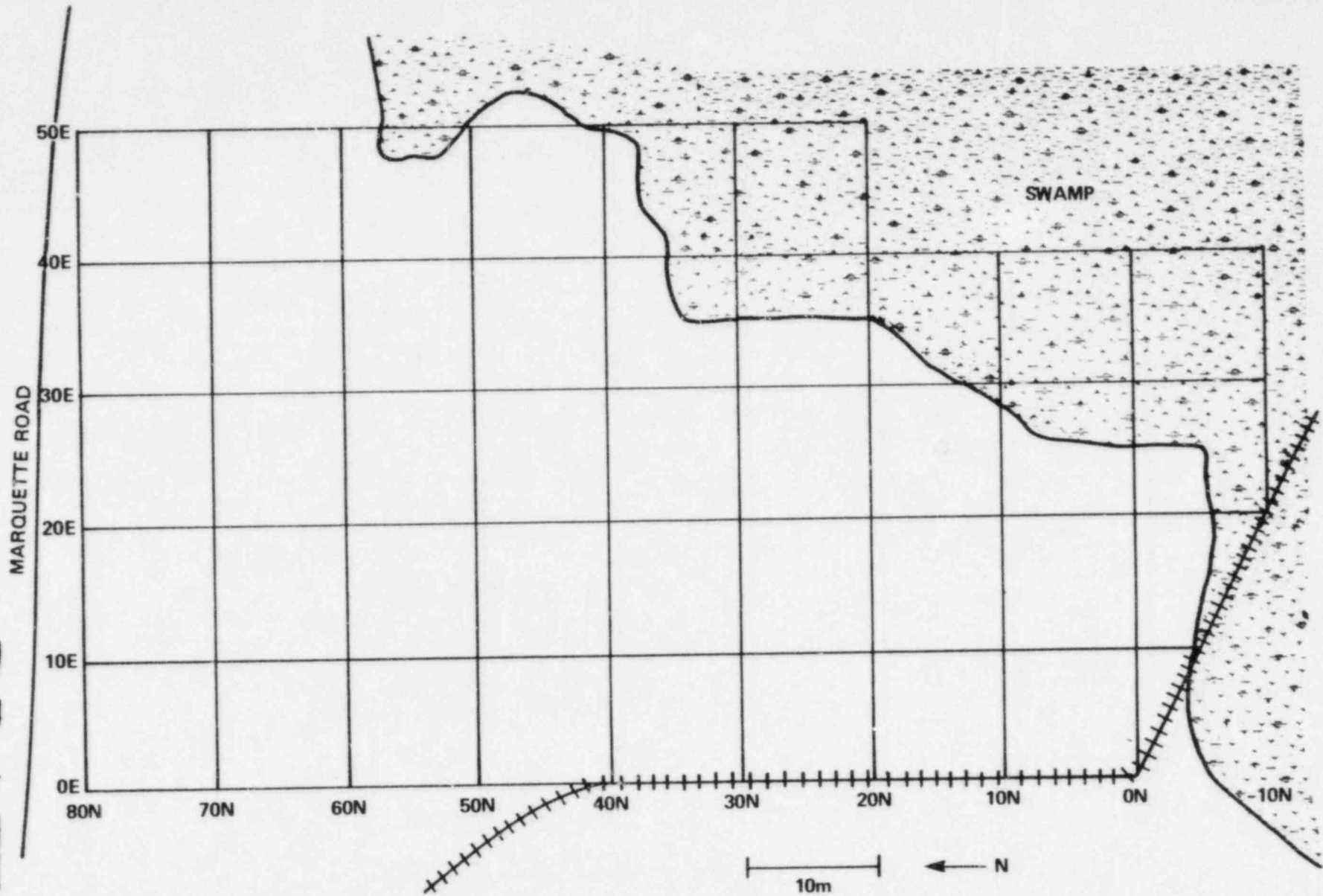


FIGURE 4: Grid System Established for Survey Reference - Field Area.

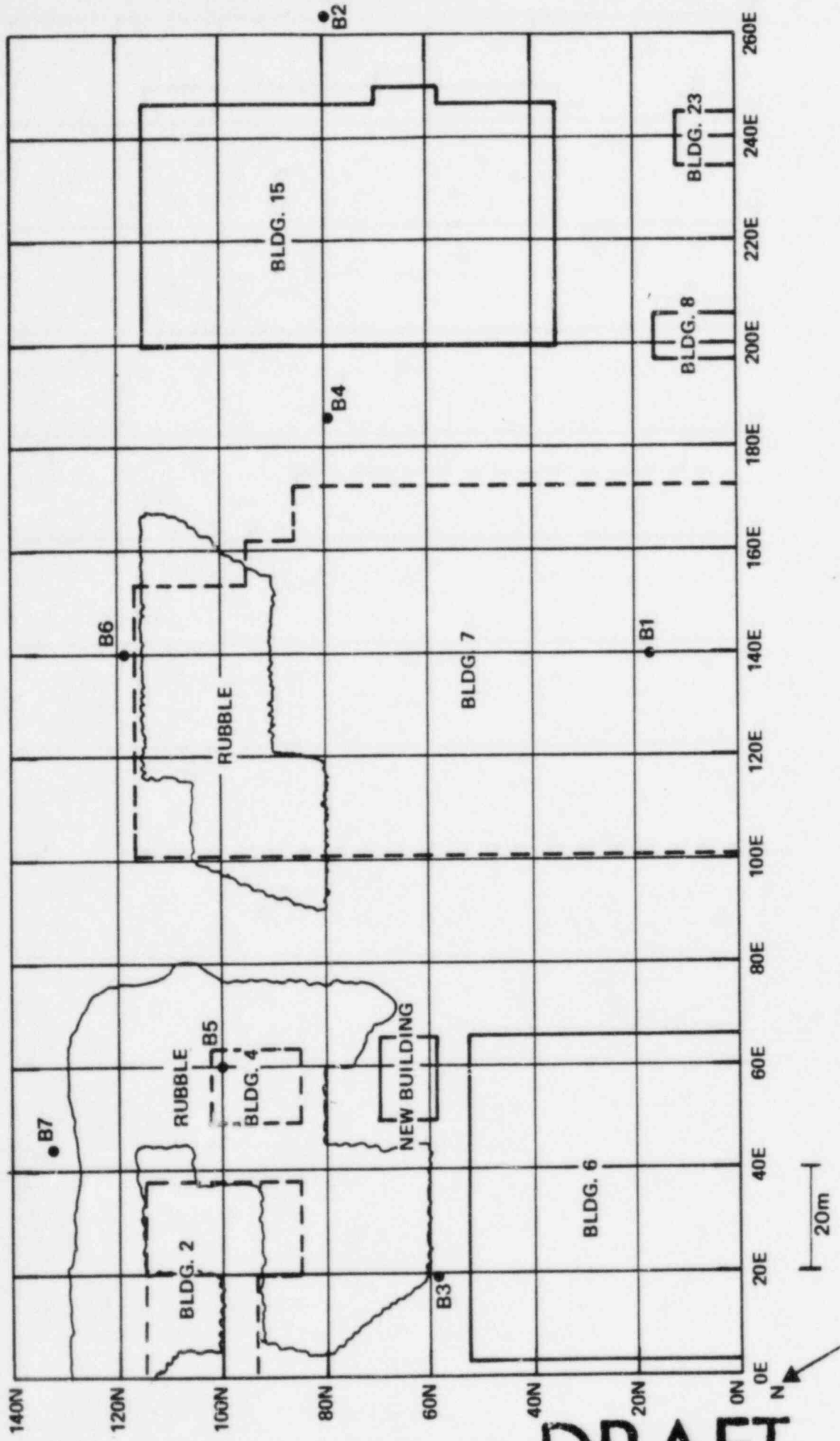


FIGURE 5: Locations of Boreholes - Processing Area.

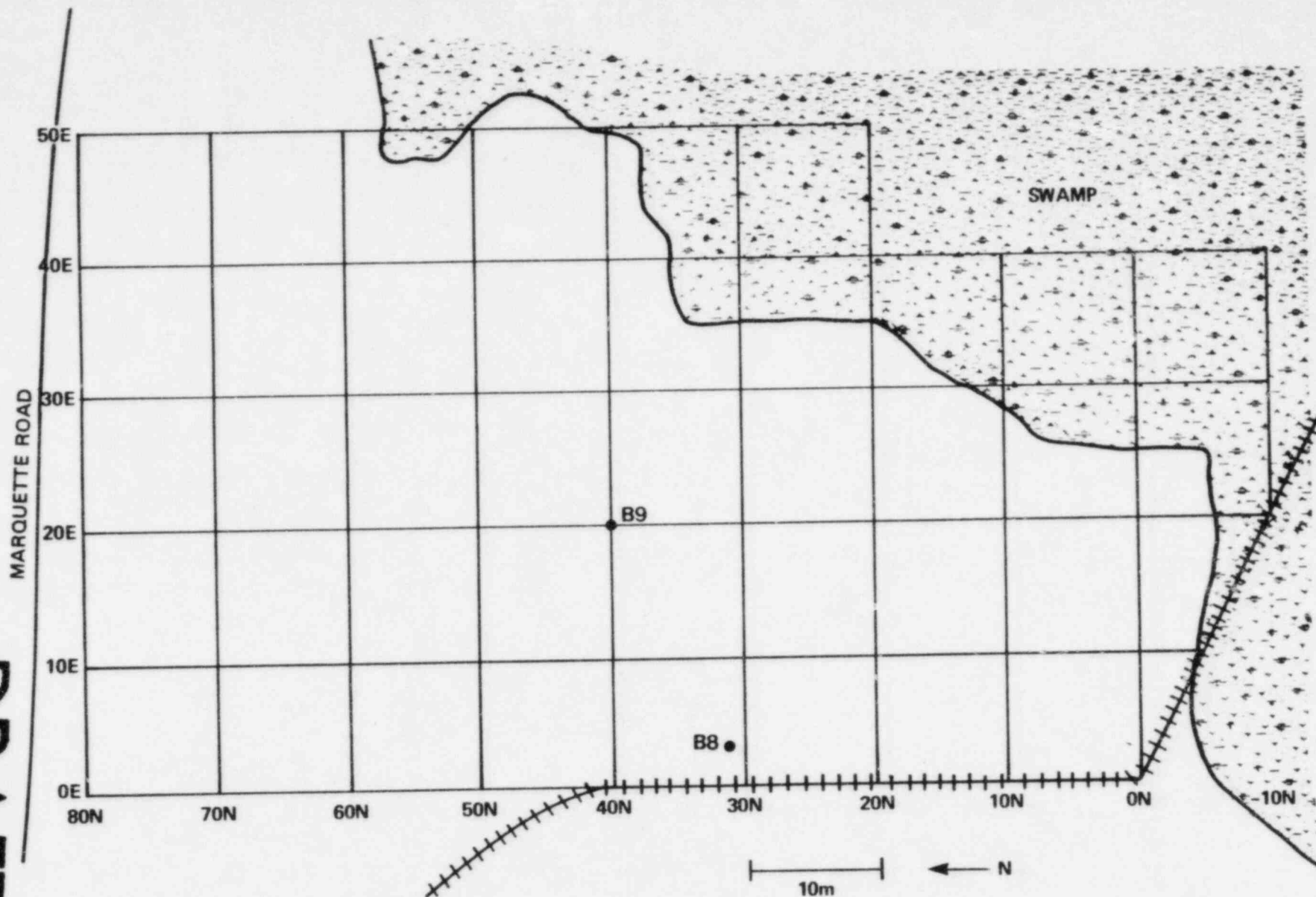


FIGURE 6: Locations of Boreholes - Field Area.

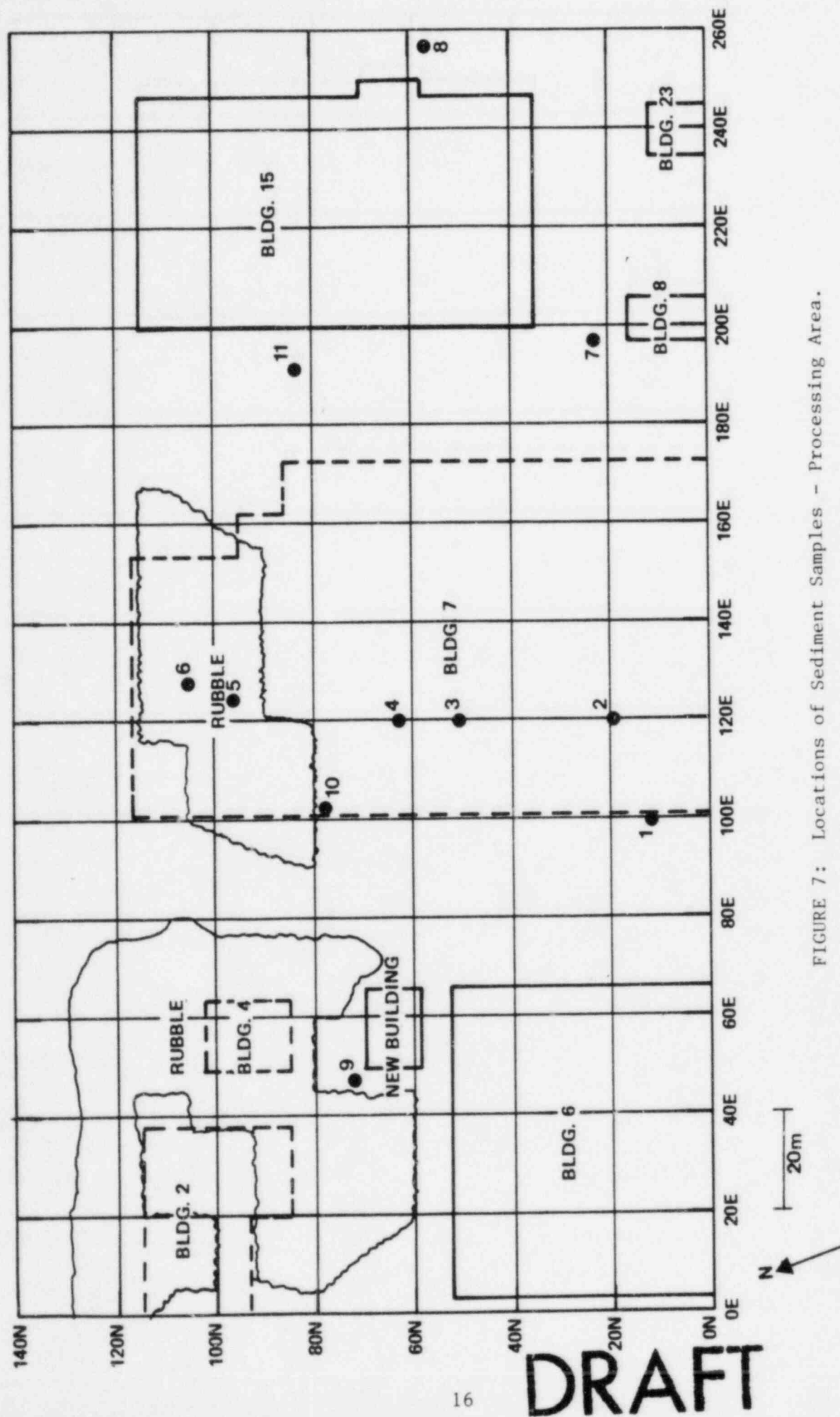


FIGURE 7: Locations of Sediment Samples - Processing Area.

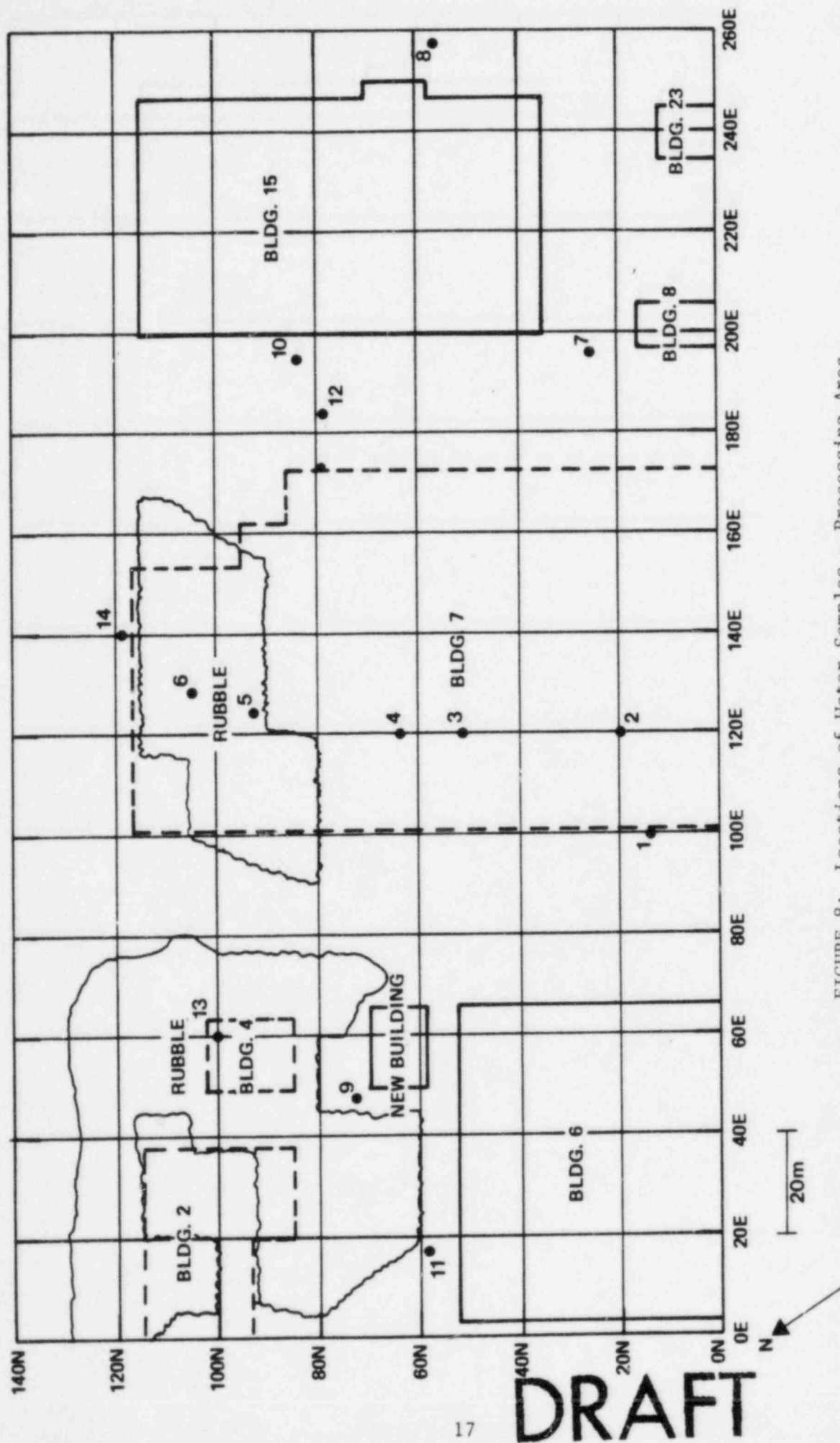


FIGURE 8: Locations of Water Samples - Processing Area.

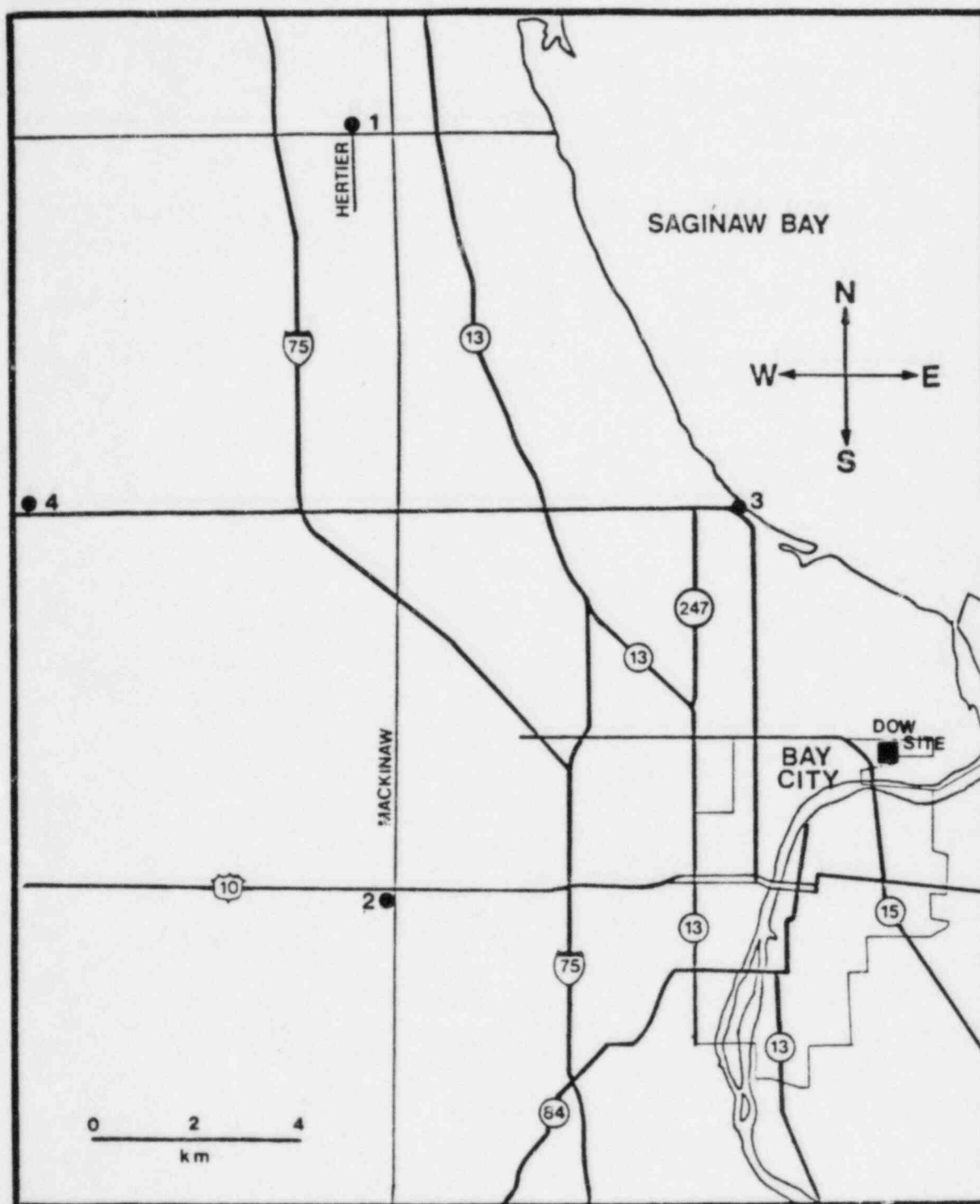


FIGURE 9: Locations of Background Measurements and Baseline Samples in the Bay City Area.

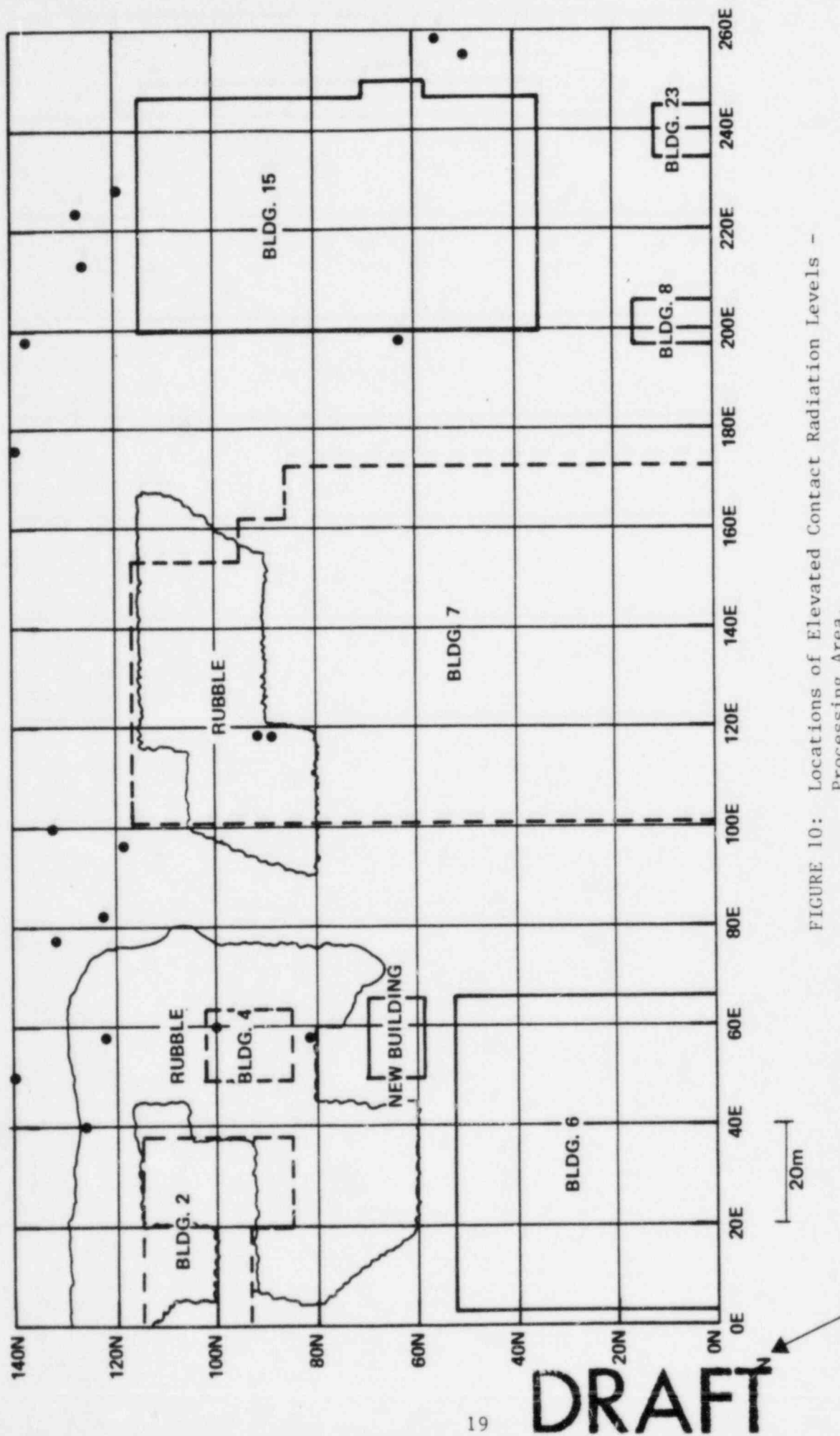


FIGURE 10: Locations of Elevated Contact Radiation Levels - Processing Area.

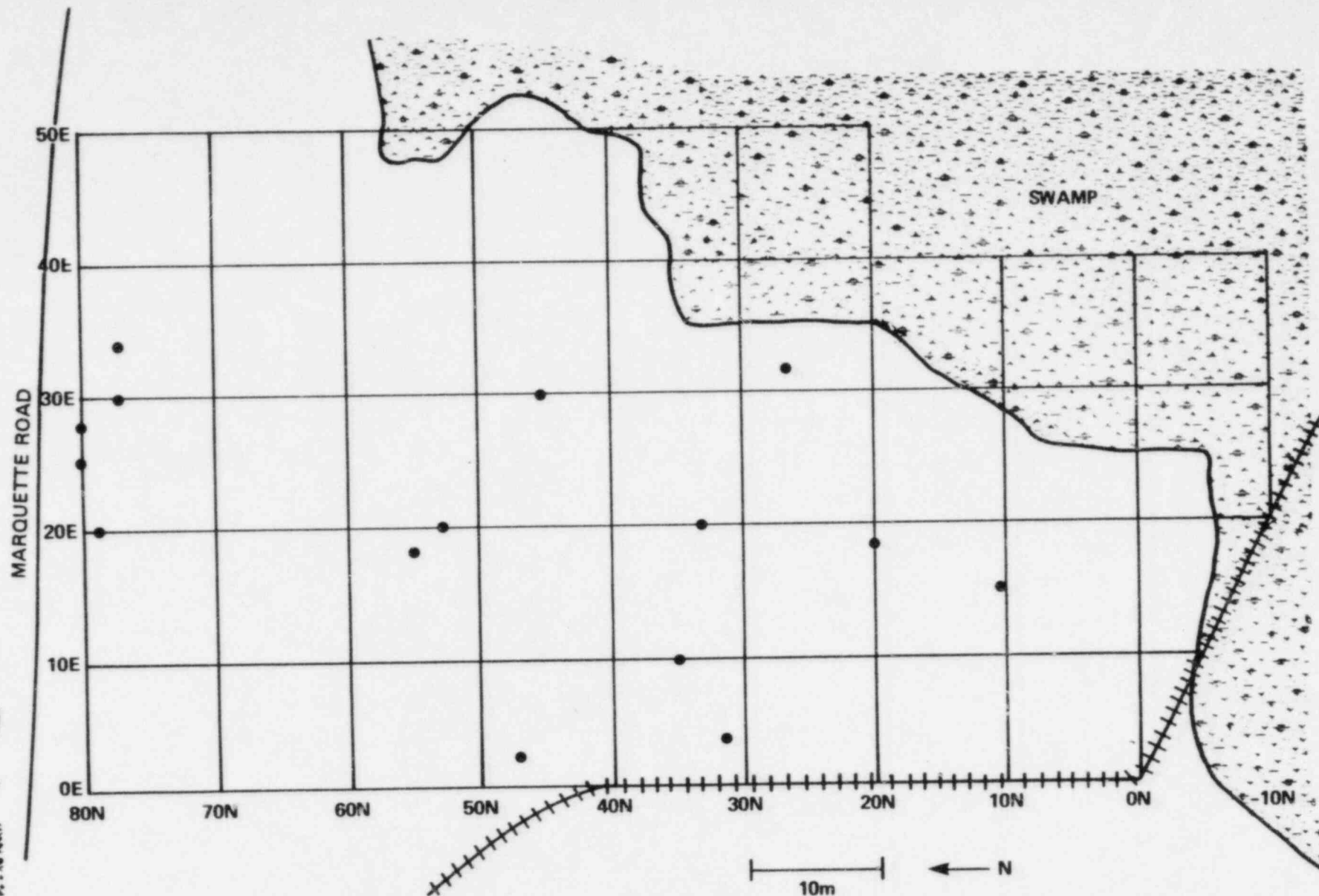


FIGURE 11: Locations of Elevated Contact Radiation Levels - Field Area.

TABLE 1A

DIRECT RADIATION LEVELS MEASURED
AT BASELINE SAMPLE LOCATIONS
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Sample ^a Location	Exposure Rate (μ R/h)	
	Contact	1 m Above Surface
1	8	8
2	9	9
3	7	7
4	9	9

^a See Figure 9.

TABLE 1B

RADIONUCLIDE CONCENTRATIONS MEASURED IN BASELINE
SOIL AND SEDIMENT SAMPLES
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Sample ^a Location	Sample Type	Radionuclide Concentrations (pCi/g)			
		Th-232	Th-228	U-238	Ra-226
1	Soil	0.50 \pm 0.31 ^b	0.28 \pm 0.26	1.05 \pm 1.15	0.48 \pm 0.20
2	Soil	0.57 \pm 0.27	0.10 \pm 0.09	<0.74	0.80 \pm 0.19
3	Soil	0.85 \pm 0.35	0.47 \pm 0.31	1.41 \pm 1.19	0.59 \pm 0.15
3	Sediment	0.57 \pm 0.20	0.26 \pm 0.39	<0.49	<0.55
4	Soil	0.28 \pm 0.17	0.42 \pm 0.23	0.81 \pm 1.09	0.37 \pm 0.15
4	Sediment	0.96 \pm 0.34	0.89 \pm 0.29	1.35 \pm 1.79	0.35 \pm 0.33

^a See Figure 9.

^b Errors are 2 σ based on counting statistics.

TABLE 1C

RADIONUCLIDE CONCENTRATIONS MEASURED IN
BASELINE WATER SAMPLES
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Sample ^a Location	Radionuclide Concentrations (pCi/l or $\times 10^{-9}$ μ Ci/ml)	
	Gross Alpha	Gross Beta
1	3.19 \pm 1.27 ^b	9.81 \pm 1.55
2	8.02 \pm 1.80	14.8 \pm 1.9
3	0.21 \pm 0.61	5.77 \pm 1.12
4	2.13 \pm 0.97	6.25 \pm 1.72

^a See Figure 9.

^b Errors are 2 σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS MEASURED AT GRID LINE
INTERSECTIONS - PROCESSING AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

<u>Grid Location</u> ^a		Gamma Exposure Rates at 1 m Above the Surface (μ R/h)	Gamma Exposure Rates at the Surface (μ R/h)
0N	0E	8	8
20N	0E	8	8
40N	0E	8	8
60N	0E	8	8
80N	0E	10	11
100N	0E	8	8
120N	0E	8	8
140N	0E	8	8
60N	20E	8	8
80N	20E	8	8
100N	20E	8	8
120N	20E	8	8
140N	20E	9	10
60N	40E	7	8
80N	40E	8	8
100N	40E	8	8
120N	40E	8	8
140N	40E	13	15
80N	60E	8	8
100N	60E	12	14
120N	60E	9	9
140N	60E	9	9
0N	80E	7	8
20N	80E	7	7
40N	80E	8	7
60N	80E	7	8
80N	80E	7	8
100N	80E	8	8
120N	80E	10	11
140N	80E	12	12
0N	100E	8	8
20N	100E	8	9
40N	100E	8	8
60N	100E	9	10
80N	100E	8	8
100N	100E	10	10
120N	100E	10	9
140N	100E	13	15
0N	120E	7	7
20N	120E	8	8
40N	120E	7	8
60N	120E	7	8

DRAFT

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE
INTERSECTIONS - PROCESSING AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

<u>Grid Location</u>		Gamma Exposure Rates at 1 m Above the Surface ($\mu\text{R/h}$)	Gamma Exposure Rates at the Surface ($\mu\text{R/h}$)
80N	120E	7	7
100N	120E	8	8
120N	120E	8	8
140N	120E	10	11
0N	140E	8	8
20N	140E	8	7
40N	140E	8	8
60N	140E	8	7
80N	140E	7	8
100N	140E	7	7
120N	140E	8	8
140N	140E	9	11
0N	160E	8	8
20N	160E	7	7
40N	160E	7	7
60N	160E	8	8
80N	160E	8	8
100N	160E	8	8
120N	160E	8	8
140N	160E	10	13
0N	180E	8	8
20N	180E	8	9
40N	180E	8	8
60N	180E	9	9
80N	180E	8	9
100N	180E	8	9
120N	180E	9	9
140N	180E	10	9
20N	200E	8	8
120N	200E	10	10
140N	200E	11	15
0N	220E	9	10
20N	220E	7	8
120N	220E	9	11
140N	220E	10	9
20N	240E	8	8
120N	240E	10	9
140N	240E	9	9
0N	260E	8	8
20N	260E	9	9
40N	260E	9	9
60N	260E	9	9
80N	260E	9	10

DRAFT

TABLE 2 (Continued)

DIRECT RADIATION LEVELS MEASURED AT GRID LINE
INTERSECTIONS - PROCESSING AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

<u>Grid Location</u>		Gamma Exposure Rates at 1 m Above the Surface ($\mu\text{R/h}$)	Gamma Exposure Rates at the Surface ($\mu\text{R/h}$)
100N	260E	10	10
120N	260E	9	9
140N	260E	9	9

^aRefer to Figure 3.

TABLE 3

SURFACE RADIATION LEVELS MEASURED AT
LOCATIONS IDENTIFIED BY THE
WALKOVER SCAN - PROCESSING AREA
FORMER DOW CHEMICAL SITE
BAY CITY, MICHIGAN

Grid Location ^a		Gamma Exposure Rates			
N	E	Prior to Decontamination (μ R/h)		After Decontamination (μ R/h)	
		At 1 m Above The Surface	At the Surface	At 1 m Above The Surface	At the Surface
53	253	21	175	14	42
57	257	17	105	13	32
65	197	14	175	10	13
82	58	* ^b	51	9	15
89	119	*	175	14	30
92	119	*	84	14	30
100	60	*	105	13	11
118	94	*	47	10	11
118	226	15	105	14	15
121	58	*	33	14	30
122	82	*	71	13	*
126	40	*	33	13	15
126	212	*	430	14	17
127	222	*	175	14	47
130	78	*	88	13	33
132	100	*	37	11	13
137	197	*	71	14	17
138	50	*	40	13	18
138	176	*	140	15	21

^a Refer to Figure 10.

^b*Indicates no measurement was made.

DRAFT

TABLE 4

RADIONUCLIDE CONCENTRATIONS MEASURED IN
SURFACE SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS-
PROCESSING AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Grid ^a Location N E		Radionuclide Concentrations (pCi/g)			
		Th-232	Th-228	U-238	Ra-226
80	0	2.55 + 0.59 ^b	2.52 + 0.57	3.69 + 1.87	1.76 + 0.36
140	0	1.18 + 0.43	0.72 + 0.45	1.49 + 1.24	0.59 + 0.27
80	50	0.78 + 0.41	0.84 + 0.33	2.12 + 1.02	0.59 + 0.23
80	60	2.80 + 0.81	2.13 + 0.66	1.58 + 3.21	0.56 + 0.36
100	60	44.0 + 1.8	42.3 + 1.7	9.77 + 2.66	2.23 + 0.54
120	60	0.39 + 0.17	0.51 + 0.15	<0.39	0.11 + 0.07
140	60	5.23 + 0.95	5.16 + 0.93	4.02 + 2.94	1.21 + 0.52
100	80	0.40 + 0.15	0.45 + 0.21	<0.51	0.36 + 0.17
120	80	1.84 + 0.51	1.77 + 0.36	2.11 + 0.85	0.49 + 0.19
140	80	0.85 + 0.35	0.90 + 0.39	2.39 + 1.26	0.72 + 0.19
0	100	0.65 + 0.31	0.60 + 0.30	<0.52	0.52 + 0.13
20	100	0.84 + 0.30	0.93 + 0.24	0.81 + 1.47	0.65 + 0.14
40	100	0.66 + 0.38	0.54 + 0.24	0.51 + 1.05	0.44 + 0.15
60	100	1.50 + 0.30	1.08 + 0.27	1.98 + 1.63	0.96 + 0.19
80	100	0.76 + 0.24	0.93 + 0.21	<0.50	0.44 + 0.17
100	100	1.62 + 0.32	1.53 + 0.27	<0.86	0.89 + 0.17
120	100	0.75 + 0.24	1.08 + 0.24	<0.58	0.60 + 0.17
140	100	2.82 + 0.57	3.00 + 0.51	2.97 + 1.46	1.07 + 0.28
0	120	0.52 + 0.24	0.78 + 0.24	0.95 + 0.94	0.52 + 0.13
20	120	1.77 + 0.47	2.40 + 0.48	<1.10	0.47 + 0.27
40	120	1.02 + 0.62	1.29 + 0.42	<1.25	0.70 + 0.24
60	120	1.07 + 0.35	0.47 + 0.21	0.91 + 1.22	0.45 + 0.21
80	120	1.01 + 0.33	1.20 + 0.30	<0.67	0.95 + 0.18
100	120	1.82 + 0.40	1.32 + 0.41	2.30 + 1.15	0.85 + 0.21
120	120	0.79 + 0.49	0.96 + 0.30	0.86 + 1.25	0.68 + 0.26
140	120	5.48 + 0.65	5.07 + 0.60	5.56 + 1.95	0.90 + 0.25
0	140	0.88 + 0.27	0.48 + 0.24	<0.53	0.42 + 0.16
20	140	0.40 + 0.37	0.63 + 0.21	<0.69	0.36 + 0.11
40	140	0.55 + 0.22	0.93 + 0.27	<0.55	0.81 + 0.17
60	140	0.76 + 0.31	0.81 + 0.24	0.93 + 1.08	0.76 + 0.20
80	140	1.48 + 0.43	0.87 + 0.30	<0.67	0.74 + 0.23
100	140	0.80 + 0.33	0.87 + 0.30	<0.79	0.69 + 0.18
120	140	1.02 + 0.40	1.11 + 0.36	1.53 + 1.27	0.76 + 0.23
140	140	4.73 +	4.65 + 0.54	<1.46	0.94 + 0.26
0	160	0.34 + 0.22	0.51 + 0.27	<0.54	0.51 + 0.17
20	160	0.47 + 0.23	0.63 + 0.21	<0.60	0.57 + 0.12
80	160	0.85 + 0.38	0.78 + 0.39	<0.75	0.67 + 0.29
120	160	1.69 + 0.43	1.92 + 0.36	2.44 + 2.23	0.69 + 0.21
140	160	3.49 + 0.64	3.54 + 0.60	1.23 + 1.12	0.76 + 0.32
0	180	0.40 + 0.23	0.30 + 0.21	<0.52	0.46 + 0.12
20	180	0.23 + 0.17	0.24 + 0.15	<0.35	0.37 + 0.10

TABLE 4 (Continued)

RADIONUCLIDE CONCENTRATIONS MEASURED IN
SURFACE SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS-
PROCESSING AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Grid ^a		Radionuclide Concentrations (pCi/g)			
Location		Th-232	Th-228	U-238	Ra-226
N	E				
40	180	<0.10	0.18 ± 0.15	<0.48	0.56 ± 0.11
60	180	0.97 ± 0.27	0.78 ± 0.27	<0.53	0.61 ± 0.21
80	180	0.46 ± 0.17	0.39 ± 0.15	<0.47	0.48 ± 0.11
100	180	0.74 ± 0.28	0.48 ± 0.24	<0.48	0.40 ± 0.16
120	180	1.31 ± 0.22	1.35 ± 0.18	1.33 ± 1.07	0.39 ± 0.09
140	180	7.32 ± 0.92	7.92 ± 0.84	7.65 ± 1.82	0.63 ± 0.28
40	200	0.66 ± 0.26	0.69 ± 0.21	<0.80	0.49 ± 0.17
80	200	0.83 ± 0.29	1.14 ± 0.42	1.60 ± 1.52	0.76 ± 0.25
120	200	1.72 ± 0.37	1.08 ± 0.30	2.50 ± 0.95	0.46 ± 0.13
140	200	2.53 ± 0.50	2.76 ± 0.54	<0.95	0.40 ± 0.27
0	220	1.72 ± 0.44	1.23 ± 0.36	<1.02	0.95 ± 0.19
20	220	<0.09	0.15 ± 0.12	0.48 ± 0.63	0.39 ± 0.12
120	220	1.17 ± 0.28	1.14 ± 0.27	2.03 ± 1.21	0.52 ± 0.15
140	220	0.41 ± 0.23	0.42 ± 0.30	<0.40	0.14 ± 0.07
20	240	0.73 ± 0.27	0.78 ± 0.21	<0.64	0.42 ± 0.15
120	240	0.43 ± 0.28	0.60 ± 0.36	1.10 ± 0.96	0.50 ± 0.13
140	240	<0.18	0.30 ± 0.15	<0.66	0.43 ± 0.15
0	260	0.94 ± 0.32	0.69 ± 0.27	<0.44	0.31 ± 0.11
20	260	1.35 ± 0.32	0.88 ± 0.24	<0.73	0.31 ± 0.13
40	260	1.01 ± 0.34	0.72 ± 0.18	1.01 ± 0.99	0.36 ± 0.17
60	260	0.83 ± 0.27	0.93 ± 0.27	<0.71	0.52 ± 0.17
80	260	1.10 ± 0.45	1.37 ± 0.39	0.69 ± 1.61	0.80 ± 0.25
100	260	1.21 ± 0.46	0.84 ± 0.33	2.10 ± 1.62	0.50 ± 0.19
120	260	0.41 ± 0.20	0.63 ± 0.18	<0.36	<0.09
140	260	0.46 ± 0.25	0.60 ± 0.21	<0.66	0.63 ± 0.13

^a Refer to Figure 3.

^b Errors are 2σ based on counting statistics.

TABLE 5

RADIONUCLIDE CONCENTRATIONS MEASURED IN SURFACE SOIL SAMPLES
COLLECTED FROM SELECTED LOCATIONS OF ELEVATED CONTACT RADIATION LEVELS
PROCESSING AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Grid ^a Coordinate		Radionuclide Concentrations (pCi/g)			
N	E	Th-232	Th-228	U-238 ^c	Ra-226
65	197	149 \pm 4 ^b	153 \pm 4	<22.2	1.79 \pm 1.08
100	60	90.5 \pm 2.8	92.4 \pm 2.4	<15.4	4.14 \pm 0.83
118	226	85.3 \pm 2.7	82.2 \pm 2.5	<17.8	<0.48
137	197	123 \pm 3	120 \pm 3	<8.04	9.16 \pm 1.03

^a Refer to Figure 10.

^b Errors are 2σ based on counting statistics.

^c Large minimum detectable values are due to interference from high thorium concentrations.

TABLE 6

RADIONUCLIDE CONCENTRATIONS MEASURED IN SOIL SAMPLES
COLLECTED AFTER DECONTAMINATION - PROCESSING AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Grid ^a Coordinate		Depth Below Original Surface (cm)	Radionuclide Concentrations (pCi/g)			
N	E		Th-232	Th-228	U-238	Ra-226
53	253	30 - 45	264 + 5 ^b	256 + 5	<33.3	30.4 + 1.6
57	257	30 - 45	1.57 + 0.50	2.64 + 0.54	<0.94	0.68 + 0.21
82	58	10 ^c	35.5 + 1.7	38.4 + 1.7	<9.34	1.10 + 0.48
92	119	65 ^c	73.3 + 2.8	74.7 + 2.7	<15.2	3.73 + 0.90
100	90	30 - 45	13.8 + 1.2	13.9 + 1.2	<5.55	1.11 + 0.42
106	91	15 - 30	10.0 + 0.6	11.7 + 0.7	<10.2	1.09 + 0.25
118	68	45 - 60	11.6 + 0.8	11.8 + 0.8	<6.57	0.57 + 0.29
118	94	30 - 45	2.75 + 0.48	2.40 + 0.36	1.42 + 1.53	0.58 + 0.14
121	58	15 ^c	55.3 + 2.8	53.7 + 2.4	<17.1	2.56 + 0.77
122	79	30 - 45	7.36 + 0.68	6.30 + 0.69	<1.80	1.11 + 0.29
126	40	15 - 30	7.09 + 0.69	7.14 + 0.60	4.93 + 1.41	1.17 + 0.29
126	208	45 - 60	7.93 + 0.73	7.83 + 0.57	5.17 + 2.52	0.97 + 0.29
126	212	45 - 60	3.04 + 0.68	2.94 + 0.60	2.23 + 2.27	1.50 + 0.30
126	216	45 - 60	1.08 + 0.39	1.32 + 0.27	4.52 + 1.36	1.03 + 0.19
126	220	80 - 95	22.1 + 1.6	22.4 + 1.4	<6.97	0.91 + 0.50
127	222	60 - 75	45.5 + 1.8	42.6 + 1.7	<10.2	1.38 + 0.56
127	232	30 - 45	2.44 + 0.49	2.16 + 0.36	3.17 + 1.41	1.05 + 0.22
130	78	30 - 45	17.6 + 1.5	18.3 + 1.4	<6.79	0.98 + 0.47
132	36	15 - 30	5.00 + 0.69	4.50 + 0.57	<1.63	1.05 + 0.24
136	43	15 - 30	1.75 + 0.42	1.92 + 0.39	<0.66	0.27 + 0.25
136	173	55 - 70	0.64 + 0.33	0.54 + 0.18	1.29 + 0.76	0.52 + 0.14
136	180	55 - 70	7.15 + 0.76	6.48 + 0.72	3.42 + 1.50	0.87 + 0.20
136	184	55 - 70	0.91 + 0.33	0.48 + 0.33	<0.69	0.27 + 0.18
136	189	55 - 70	0.52 + 0.33	0.63 + 0.36	1.14 + 1.07	0.37 + 0.17
137	24	30 - 45	6.02 + 0.62	5.34 + 0.54	<4.50	1.04 + 0.30
137	30	15 - 30	4.00 + 0.61	4.26 + 0.60	<1.36	0.88 + 0.30
138	50	15 - 30	1.40 + 0.39	1.71 + 0.30	<1.01	0.52 + 0.14

a Refer to Figure 3.

b Errors are 2 σ based on counting statistics.

c Over subsurface concrete or metal structure.

TABLE 7

RADIONUCLIDE CONCENTRATIONS MEASURED IN SOIL SAMPLES
COLLECTED FROM BOREHOLES - PROCESSING AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Borehole ^a Location	Grid Coordinate		Depth (m)	Radionuclide Concentrations (pCi/g)			
	N	E		Th-232	Th-228	U-238	Ra-226
B1	17	140	0 - 0.15	0.16 \pm 0.28 ^b	0.18 \pm 0.12	<0.37	0.19 \pm 0.17
			1 - 1.5	0.91 \pm 0.33	0.60 \pm 0.30	1.43 \pm 1.28	0.57 \pm 0.19
B2	58	262	0 - 0.15	0.80 \pm 0.30	1.35 \pm 0.36	<0.97	0.50 \pm 0.19
			1 - 1.5	0.82 \pm 0.35	0.81 \pm 0.24	1.91 \pm 1.24	0.48 \pm 0.14
			2.5 - 3.0	1.05 \pm 0.61	0.57 \pm 0.30	<0.68	0.51 \pm 0.18
B3	59	19	0 - 0.15	0.92 \pm 0.32	0.66 \pm 0.33	0.47 \pm 1.30	0.56 \pm 0.16
			1 - 1.5	0.47 \pm 0.29	0.44 \pm 0.28	0.51 \pm 1.45	0.43 \pm 0.16
			2.5 - 3.0	0.82 \pm 0.39	0.65 \pm 0.31	0.89 \pm 1.10	0.54 \pm 0.18
B4	79	183	0 - 0.15	0.62 \pm 0.25	0.81 \pm 0.24	2.11 \pm 0.93	0.75 \pm 0.18
			1 - 1.5	0.37 \pm 0.20	0.57 \pm 0.19	0.69 \pm 0.99	0.44 \pm 0.20
			2.5 - 3.0	1.03 \pm 0.29	0.75 \pm 0.21	<0.83	0.51 \pm 0.14
B5	100	60	0 - 0.15	90.5 \pm 2.8	92.4 \pm 2.4	<15.4	4.14 \pm 0.83
			1 - 1.5	0.25 \pm 0.24	0.48 \pm 0.21	<0.56	0.31 \pm 0.18
			2.5 - 3.0	0.59 \pm 0.39	0.60 \pm 0.24	<0.69	0.52 \pm 0.18
B6	119	140	0 - 0.15	0.40 \pm 0.25	0.29 \pm 0.18	0.74 \pm 0.86	0.16 \pm 0.10
			1 - 1.5	1.23 \pm 0.40	0.60 \pm 0.21	<0.46	0.41 \pm 0.17
			2.5 - 3.0	0.97 \pm 0.38	0.96 \pm 0.24	<0.82	0.63 \pm 0.21
B7	130	43	0 - 0.15	2.51 \pm 0.42	2.46 \pm 0.39	2.21 \pm 1.17	0.97 \pm 0.26
			1 - 1.5	0.62 \pm 0.32	0.60 \pm 0.21	1.05 \pm 0.60	0.52 \pm 0.17
			2.5 - 3.0	0.76 \pm 0.37	0.51 \pm 0.24	<0.75	<0.11

^a See Figure 5.

^b Errors are 2 σ based on counting statistics.

TABLE 8

RADIONUCLIDE CONCENTRATIONS MEASURED IN
SEDIMENT SAMPLES
PROCESSING AREA - FORMER DOW CHEMICAL SITE
BAY CITY, MICHIGAN

Sample Identification Number	Location ^a of Sample	Grid Location		Radionuclide Concentrations (pCi/g)			
		N	E	Th-232	Th-228	U-238	Ka-226
1	Conveyor Pit	13	100	0.82 ± 0.27^b	1.20 ± 0.33	<0.89	0.61 ± 0.20
2	Conveyor Pit	20	120	0.80 ± 0.40	0.96 ± 0.94	<0.65	0.55 ± 0.24
3	Conveyor Pit	50	120	1.06 ± 0.32	0.93 ± 0.36	<0.79	0.73 ± 0.18
4	Conveyor Pit	62	120	0.68 ± 0.44	1.02 ± 0.36	0.67 ± 1.73	0.61 ± 0.23
5	Conveyor Pit	92	125	2.90 ± 0.57	3.12 ± 0.63	2.58 ± 2.44	0.79 ± 0.22
6	Conveyor Pit	105	128	0.75 ± 0.59	0.57 ± 0.36	<0.60	0.52 ± 0.16
7	Drain	25	196	1.02 ± 0.43	1.26 ± 0.45	<0.76	0.60 ± 0.23
8	Drain	56	255	28.0 ± 1.7	27.1 ± 1.7	<12.0	3.34 ± 0.65
9	Drain	72	49	1.42 ± 0.38	1.08 ± 0.36	0.96 ± 1.33	0.47 ± 0.19
10	Drain	77	103	4.50 ± 0.63	4.53 ± 0.54	2.63 ± 1.88	0.41 ± 0.25
11	Drain	82	193	1.00 ± 0.26	0.99 ± 0.27	<0.84	0.67 ± 0.18

^a Refer to Figure 7.

^b Errors are 2 σ based on counting statistics.

TABLE 9

RADIONUCLIDE CONCENTRATIONS MEASURED IN
WATER SAMPLES - PROCESSING AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Sample Identification Number	Location ^a of Sample	Grid Coordinate		Radionuclide Concentrations (pCi/l or $\times 10^{-9}$ μ Ci/ml)			
		N	E	Gross Alpha	Gross Beta	Ra-226	Ra-228
1	Conveyor Pit	13	100	4.54 ± 1.26^b	40.0 ± 2.1	--- ^c	---
2	Conveyor Pit	20	120	5.36 ± 1.33	38.2 ± 2.1	---	---
3	Conveyor Pit	50	120	1.63 ± 0.97	36.7 ± 2.1	---	---
4	Conveyor Pit	62	120	2.30 ± 1.08	36.9 ± 2.1	---	---
5	Conveyor Pit	92	125	2.23 ± 1.08	34.0 ± 2.0	---	---
6	Conveyor Pit	105	128	3.36 ± 2.00	33.2 ± 3.6	---	---
7	Drain	25	196	<0.75	5.82 ± 1.47	---	---
8	Drain	56	255	1.61 ± 0.78	14.6 ± 1.5	---	---
9	Drain	72	49	11.9 ± 5.2	186 ± 10	0.17 ± 0.05	1.04 ± 0.43
10	Drain	82	193	4.41 ± 2.22	33.6 ± 3.5	---	---
11	Borehole B3	59	19	13.2 ± 2.5	6.36 ± 2.28	0.10 ± 0.05	2.46 ± 0.51
12	Borehole B4	79	183	30.6 ± 7.3	16.1 ± 7.1	0.72 ± 0.22	1.54 ± 1.79
13	Borehole B5	100	60	5.06 ± 3.02	179 ± 8	---	---
14	Borehole B6	119	140	20.7 ± 3.8	13.3 ± 3.1	<0.12	3.38 ± 1.48

^a See Figure 5 and 8.

^b Errors are 2 σ based on counting statistics.

^c Dash indicates analyses not performed.

TABLE 10

DIRECT RADIATION LEVELS MEASURED AT GRID LINE
INTERSECTIONS - FIELD AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

<u>Grid Location</u> ^a		Gamma Exposure Rates at 1 m Above the Surface ($\mu\text{R/h}$)	Gamma Exposure Rates at the Surface ($\mu\text{R/h}$)
0N	0E	8	8
20N	0E	9	9
40N	0E	9	10
60N	0E	13	13
80N	0E	8	9
-10N	20E	9	8
0N	20E	10	10
20N	20E	10	10
40N	20E	9	9
60N	20E	10	10
80N	20E	10	10
-10N	40E	9	9
0N	40E	9	9
20N	40E	9	9
40N	40E	9	9
60N	40E	9	9
80N	40E	9	9
20N	50E	9	9
40N	50E	9	9
60N	50E	9	9
80N	50E	9	9

^aRefer to Figure 4.

TABLE 11

SURFACE RADIATION LEVELS MEASURED AT
LOCATIONS IDENTIFIED BY THE
WALKOVER SCAN - FIELD AREA
FORMER DOW CHEMICAL SITE
BAY CITY, MICHIGAN

Grid Location ^a		Gamma Exposure Rates			
N	E	Prior to Decontamination (μ R/h)		After Decontamination (μ R/h)	
		At 1 m Above The Surface	At The Surface	At 1 m Above The Surface	At The Surface
11	15	18	40	13	15
20	17	* ^b	51	11	21
26	32	*	37	15	18
31	4	*	140	13	27
33	20	*	51	13	37
35	10	*	30	10	21
45	30	*	105	11	30
46	3	*	63	14	15
53	20	*	30	13	18
55	18	*	63	13	40
77	30	*	105	13	18
77	34	21	175	13	18
79	20	21	279	13	18
80	25	30	314	13	18
80	27	45	600	13	18

^a Refer to Figure 11.

^b* Indicates no measurement was made.

TABLE 12

RADIONUCLIDE CONCENTRATIONS MEASURED IN
SURFACE SOIL SAMPLES COLLECTED AT GRID LINE INTERSECTIONS - FIELD AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Sample ^a Location		Radionuclide Concentrations (pCi/g)			
N	E	Th-232	Th-228	U-238	Ra-226
0	0	0.35 \pm 0.29 ^b	0.36 \pm 0.21	<0.61	0.38 \pm 0.18
20	0	0.66 \pm 0.07	0.66 \pm 0.06	2.76 \pm 0.32	0.44 \pm 0.04
40	0	1.49 \pm 0.51	1.56 \pm 0.42	0.93 \pm 1.37	0.37 \pm 0.20
60	0	2.32 \pm 0.60	2.46 \pm 0.60	0.89 \pm 1.87	0.56 \pm 0.24
80	0	0.57 \pm 0.51	0.51 \pm 0.30	<0.86	0.97 \pm 0.25
-10	20	0.58 \pm 0.26	0.45 \pm 0.27	<0.77	0.39 \pm 0.18
0	20	1.45 \pm 0.78	2.34 \pm 0.51	1.75 \pm 1.00	0.31 \pm 0.23
20	20	0.31 \pm 0.37	0.69 \pm 0.21	<0.61	0.28 \pm 0.12
40	20	0.55 \pm 0.37	0.39 \pm 0.33	<0.46	0.19 \pm 0.09
60	20	1.14 \pm 0.54	0.78 \pm 0.54	0.68 \pm 2.50	0.70 \pm 0.17
80	20	0.55 \pm 0.05	0.45 \pm 0.03	0.44 \pm 0.21	0.41 \pm 0.03
140	20	1.06 \pm 0.50	0.72 \pm 0.42	<1.02	0.49 \pm 0.37
-10	40	0.78 \pm 0.44	0.90 \pm 0.42	<0.82	0.40 \pm 0.33
0	40	0.51 \pm 0.64	0.69 \pm 0.42	<6.47	0.49 \pm 0.30
20	40	0.57 \pm 0.41	0.36 \pm 0.27	<6.19	0.27 \pm 0.14
40	40	0.66 \pm 0.34	0.75 \pm 0.30	<3.62	0.27 \pm 0.10
60	40	0.51 \pm 0.51	0.39 \pm 0.45	<0.71	0.51 \pm 0.19
80	40	0.86 \pm 0.54	1.14 \pm 0.27	<0.87	0.67 \pm 0.19
100	40	1.00 \pm 0.43	0.96 \pm 0.39	<0.68	0.57 \pm 0.27
140	40	0.91 \pm 0.38	0.84 \pm 0.27	<0.67	0.33 \pm 0.12
20	50	0.51 \pm 0.34	0.65 \pm 0.27	1.02 \pm 2.25	0.33 \pm 0.22
40	50	0.74 \pm 0.28	0.90 \pm 0.27	<0.77	<0.09
60	50	0.57 \pm 0.43	0.57 \pm 0.36	<0.71	0.52 \pm 0.25

^a Refer to Figure 4.

^b Errors are 2 σ based on counting statistics.

DRAFT

TABLE 13

RADIONUCLIDE CONCENTRATIONS MEASURED IN SURFACE SOIL SAMPLES
COLLECTED FROM SELECTED LOCATIONS OF ELEVATED CONTACT RADIATION LEVELS - FIELD AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Grid ^a Coordinate		Radionuclide Concentrations (pCi/g)			
N	E	Th-232	Th-228	U-238 ^c	Ra-226
11	15	0.77 \pm 0.25 ^b	0.60 \pm 0.27	0.77 \pm 0.9	0.23 \pm 0.12
21	16	34.5 \pm 1.8	34.2 \pm 1.8	<9.33	<0.26
33	20	41.1 \pm 1.8	40.5 \pm 1.8	<10.4	0.99 \pm 0.50
45	30	43.0 \pm 2.0	42.0 \pm 1.9	<8.69	0.52 \pm 0.47
53	20	15.2 \pm 1.5	14.8 \pm 1.3	<7.80	0.65 \pm 0.34
77	30	274 \pm 5	272 \pm 5	<33.8	25.2 \pm 1.5

^a Refer to Figure 4.

^b Errors are 2 σ based on counting statistics.

^c Large minimum detectable values are due to interference from high thorium concentrations.

TABLE 14

RADIONUCLIDE CONCENTRATIONS MEASURED IN SOIL SAMPLES
COLLECTED AFTER DECONTAMINATION - FIELD AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Grid ^a		Depth Below Original Surface (cm)	Radionuclide Concentrations (pCi/g)			
Coordinate N	E		Th-232	Th-228	U-238	Ra-226
11	15	80 - 95	6.51 \pm 0.78 ^b	6.75 \pm 0.78	<3.80	<0.14
26	14	15 - 30	7.67 \pm 0.83	7.83 \pm 0.78	<4.52	0.36 \pm 0.32
26	32	15 - 30	6.81 \pm 0.92	7.26 \pm 0.81	<5.09	0.19 \pm 0.17
34	16	15 - 30	8.25 \pm 0.74	8.19 \pm 0.81	<7.10	0.48 \pm 0.20
35	10	15 - 20	1.98 \pm 0.40	1.62 \pm 0.42	1.24 \pm 1.53	0.35 \pm 0.13
46	3	15 - 30	1.09 \pm 0.32	1.17 \pm 0.27	<0.81	0.28 \pm 0.15
55	18	15 - 30	1.65 \pm 0.58	1.74 \pm 0.36	<1.23	0.39 \pm 0.15
55	21	60 - 75	1.77 \pm 0.48	2.01 \pm 0.45	3.81 \pm 1.35	0.61 \pm 0.18

^a Refer to Figure 4.

^b Errors are 2 σ based on counting statistics.

DRAFT

TABLE 15

RADIONUCLIDE CONCENTRATIONS MEASURED IN SOIL SAMPLES
COLLECTED FROM BOREHOLES - FIELD AREA
FORMER DOW CHEMICAL SITE - BAY CITY, MICHIGAN

Sample ^a Location	Grid Coordinate		Depth (m)	Radionuclide Concentrations (pCi/g)			
	N	E		Th-232	Th-228	U-238	Ra-226
B8	31	4	0 - 0.15	10.4 \pm 1.0 ^b	10.6 \pm 0.8	<2.12	0.28 \pm 0.25
			1 - 1.5	0.48 \pm 0.22	0.51 \pm 0.30	<0.52	0.35 \pm 0.16
B9	40	20	0 - 0.15	1.16 \pm 0.30	0.43 \pm 0.20	<0.59	0.37 \pm 0.12
			1 - 1.5	0.45 \pm 0.24	0.39 \pm 0.30	<0.57	0.50 \pm 0.18
			2.5 - 3.0	0.91 \pm 0.31	0.66 \pm 0.33	0.46 \pm 1.28	0.55 \pm 0.16

^a Refer to Figure 6.

^b Errors are 2 σ based on counting statistics.

REFERENCES

1. Decommissioning of the DOW/Wellman Foundry Site in Bay City, Michigan. Letter from R.A. Olson (DOW) to M. Schumacher (NRC), October 8, 1982.
2. Title 40, Code of Federal Regulations, Part 141, Interim Primary Drinking Water Standards, Federal Register, July, 1976.

APPENDIX A

MAJOR ANALYTICAL EQUIPMENT

DRAFT

APPENDIX A

Major Analytical Equipment

The display or description of a specific product is not to be construed as an endorsement of that product or its manufacturer by the authors or their employer.

A. Direct Radiation Measurements

Eberline PRM-6
Portable Ratemeter
(Eberline, Sante Fe, NM)

Victoreen Gamma Scintillator (NaI) Probe
Model 489-55
(Victoreen, Inc., Cleveland, OH)

Reuter-Stokes Pressurized Ionization Chamber
Model RSS-111
(Reuter-Stokes, Cleveland, OH)

B. Laboratory Analyses

Ge(Li) Detector
Model LGCC2220-SD, 23% efficiency
(Princeton Gamma-Tech, Princeton, NJ)

Used in conjunction with:
Lead Shield, SPG-16
(Applied Physical Technology, Smyrna, GA)

Pulse Height Analyzer, ND680
Model 88-0629
(Nuclear Data, Inc., Schaumburg, IL)

High-Purity Germanium Detector
Model GMX-23195-S, 23% efficiency
(EG&G ORTEC, Oak Ridge, TN)

Used in conjunction with:
Lead Shield, G-16
(Gamma Products Inc., Palos Hills, IL)

Low Background Alpha-Beta Counter
Model LB5100-2080
(Tennelec, Inc., Oak Ridge, TN)

APPENDIX B
ANALYTICAL PROCEDURES

DRAFT

APPENDIX B

Analytical Procedures

Gamma Scintillation Measurements

Walkover surface scans and measurements of gamma exposure rates were performed using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm x 3.8 cm NaI(Tl) crystals. Count rates were converted to exposure rates ($\mu\text{R/h}$) using factors determined by cross calibration of the scintillation detectors with a Reuter Stokes model RSS-111 pressurized ionization chamber, at several locations on the surveyed property.

Soil and Sediment Sample Analysis

Soil and sediment samples were dried, mixed, and a portion sealed in a 0.5-liter Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 400 to 800 g of soil. Net soil weights were determined and the samples counted using Ge(Li) and intrinsic germanium detectors coupled to a Nuclear Data model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Th-232 - 0.911 MeV from Ac-228*
Th-228 - 0.583 MeV from Tl-208*
U-238 - 0.094 MeV from Th-234 or 1.001 MeV from Pa-234m*
Ra-226 - 0.609 MeV from Bi-214*

*Secular equilibrium was assumed

Water Sample Analysis

Water samples were rough-filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by subsequent filtration through 0.45 μm membrane filters. The filtrate was acidified by addition of 10 ml of concentrated nitric acid. Aliquots were then evaporated to dryness and counted

DRAFT

for gross alpha and gross beta using a Tennelec Model LB 5100 low-background proportional counter.

Samples were analyzed for Ra-226 and 228 using the standard technique EPA 600/4-75-008 (Revised).

Calibration and Quality Assurance

All survey and laboratory instruments were calibrated with NBS-traceable standards. Quality control procedures on all instruments included daily background and check-source measurements to confirm acceptable equipment operations. The ORAU laboratory participates in the EPA Quality Assurance Program.

DRAFT

APPENDIX C

NUCLEAR REGULATORY COMMISSION
GUIDELINES FOR RESIDUAL CONCENTRATIONS
OF THORIUM AND URANIUM WASTE IN SOIL

DRAFT

Guidelines for Residual Concentrations of Thorium and Uranium Wastes in Soil

On October 23, 1981, the Nuclear Regulatory Commission published in the Federal Register a notice of Branch Technical Position on "Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations." This document establishes guidelines for concentrations of uranium and thorium in soil, that will limit maximum radiation received by the public under various conditions of future land usage. These concentrations are as follows:

Material	Maximum Concentrations (pCi/g) for various options			
	1 ^a	2 ^b	3 ^c	4 ^d
Natural Thorium (Th-232 + Th-228) with daughters present and in equilibrium	10	50	--	500
Natural Uranium (U-238 + U-234) with daughters present and in equilibrium	10	--	40	200
Depleted Uranium:				
Soluble	35	100	--	1,000
Insoluble	35	300	--	3,000
Enriched Uranium:				
Soluble	30	100	--	1,000
Insoluble	30	250	--	2,500

^aBased on EPA cleanup standards which limit radiation to 1 mrad/yr to lung and 3 mrad/yr to bone from ingestion and inhalation and 10 μ R/h above background from direct external exposure.

^bBased on limiting individual doses to 170 mrem/yr.

^cBased on limiting equivalent exposure to 0.02 working level or less.

^dBased on limiting individual doses to 500 mrem/yr and in case of natural uranium, limiting exposure to 0.02 working level or less.

Option 1 concentrations permit unrestricted use of the property and is the guideline applicable to surface soils. Options 2, 3, and 4 apply to buried wastes and assume that intrusions into the burial sites may occur. Regardless of the concentrations in the buried materials, surface soil must meet the Option 1 concentration guidelines.