



**Consumers  
Power  
Company**

**David J VandeWalle**  
Director of  
Nuclear Licensing

General Offices: 1945 West Parnall Road, Jackson, MI 49201 • (517) 788-1636

August 16, 1985

Director,  
Nuclear Reactor Regulation  
US Nuclear Regulatory Commission  
Washington, DC 20555

DOCKET 50-155 - LICENSE DPR-6 - BIG ROCK POINT PLANT -  
REQUEST TO RETAIN CONTAMINATED SOIL ON-SITE IN ACCORDANCE WITH 10CFR20.302

The Code of Federal Regulations, Title 10, section 20.302 allows for approval of proposed procedures to dispose of licensed material in a manner not otherwise authorized in the regulations. As a result of water leakage from an underground line, approximately 5300 cubic feet of soil was contaminated below grade. The occurrence of this event was reported to the NRC in informational LER 84-03 dated October 19, 1984. Consumers Power Company requests NRC approval to retain the contaminated soil in place in accordance with 10CFR20.302. Justification for this request is in the attachment to this letter. Retaining the contaminated soil on-site would result in no discernable impact on either the environment or on occupational or public health. The total activity is expected to be undetectable within seven years.

Pursuant to 10CFR170.12(c) a check in the amount of \$150 is attached.

David J VandeWalle  
Director, Nuclear Licensing

CC Administrator, Region III, USNRC  
NRC Resident Inspector - Big Rock Point

Attachment

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PDR ADOCK 05000155  
P PDR

OC0885-0001B-NL02

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1/39*

ATTACHMENT

Consumers Power Company  
Big Rock Point Plant  
Docket 50-155

"JUSTIFICATION FOR RETAINING  
CONTAMINATED SOIL ON-SITE"

August 16, 1985

64 Pages

## EVALUATION OF UNMONITORED LIQUID RELEASE TO SOIL

A volume of contaminated earth located adjacent to the below grade wall of the radwaste pump room and extending under the turbine generator building floor has been evaluated for possible retention at its present location. The source of this contamination has been addressed in previous reports to the NRC. The evaluation consists of the following studies:

- 1) Core samples were taken in the vicinity of the affected area to determine the extent of the leak.
- 2) The hydrology of the area as described in our Final Hazard Summary Report (FHSR) and the report by James H Zumberge (attached) was reviewed. Core samples indicate the hydrology has not changed since the above reports were written.
- 3) Alternatives to retaining the earth on-site were evaluated.

Based on the results of this evaluation and the commitments made herein, Consumers Power Company hereby requests authority under 10 CFR 20.302 to retain this earth at its present location. It is felt there will be no discernible impact on either the environment or on occupational and public health.

## DISCUSSION

Big Rock Point was shut down on May 30, 1984 after samples taken of water leakage through the below grade wall of the radwaste pump room indicated the presence of tritium and iodine-131. The tritium concentration of these samples closely matched that of the main condensate. Evaluation and testing of underground lines indicated a leak in a two-inch diameter aluminum pipe. This pipe carries water from the demineralized water supply and condensate process monitor line to the condensate storage tank (see Figure 1 of Attachment II). The pipe was removed, the line was capped and a temporary line was installed.

From an increase in makeup water usage, it was estimated that 20,000 gallons of water had leaked into the soil. Analysis was conducted on samples taken from the primary system, condensate storage tank and water puddled at the base of the leaking pipe.

The isotopic distribution of the puddled water is very similar to that of the main condensate. The puddled water sample was chosen as the source term because of the greater concentrations present. This will yield the most conservative estimate of probable dose consequences.

Only the four longer lived isotopes were used in the dose calculations. I-131 was not included since by the time the sample was taken (July 11), the concentration was already two orders of magnitude less than the concentration calculated to have been released (May 30). The Cs-134 concentration of the source term was increased to 70% of the Cs-137 concentration on the basis of

results of 7 out of 11 soil samples. The resulting source term used in the calculations is as follows:

Table I: Source Term

| Nuclide | Activity Level ( $\mu\text{Ci}$ )* |
|---------|------------------------------------|
| Co-60   | 238.46                             |
| Mn-54   | 132.48                             |
| Cs-137  | 1,741.10                           |
| Cs-134  | 1,218.77                           |

\*Total activity in 20,000 gallons

On July 11, 1984, soil samples were taken near the area of the line failure. Samples were taken at three depths, just below the turbine building concrete, at one foot below the concrete and at four feet below the concrete. Five samples were taken at each depth. These samples were analyzed for radionuclide concentration. The location and total activity of each soil sample are indicated on Figure 2 of Attachment II. A listing of the results of the samples is presented in Table 3 of Attachment II.

Additional soil samples were taken to determine the spread of contamination resulting from the condensate makeup line leak. Nine sampling locations were chosen (Figures 3 and 4 of Attachment II). Samples were taken at approximately one-foot intervals to a depth of about ten feet as measured from the track alley floor (including the two locations outside the building). The activity of individual isotopes in each sample and the location of maximum activity of each isotope are listed in Tables 4 and 5 of Attachment II. The total concentration in each sample is recorded in Table II below:

Table II: Total Concentration\* ( $\mu\text{Ci}/\text{gram}$ ) of Samples

| Depth<br>(Ft) | Sampling Location |         |         |         |         |         |         |         |         |
|---------------|-------------------|---------|---------|---------|---------|---------|---------|---------|---------|
|               | 1                 | 2       | 3       | 4       | 5       | 6       | 7       | 8       | 9       |
| 0- 1          |                   | 3.4E-07 |         |         |         |         |         |         |         |
| 1- 2          | 1.3E-07           |         | 8.8E-07 | 1.4E-07 | 3.2E-07 | 5.6E-07 | 2.3E-07 | <MDA    | <MDA    |
| 2- 3          |                   | 6.7E-07 | 3.4E-06 | <MDA    | 8.4E-07 | 2.0E-06 | 1.2E-06 | <MDA    | <MDA    |
| 3- 4          | 9.2E-08           |         | 6.6E-06 | 7.3E-07 | 2.4E-06 | 2.6E-06 | 1.1E-06 | 9.5E-07 | 7.8E-08 |
| 4- 5          |                   | 1.1E-06 | 3.2E-06 | <MDA    | <MDA    | 1.2E-06 | 9.6E-07 | 1.9E-06 | <MDA    |
| 5- 6          | <MDA              |         |         | 7.4E-07 | 4.4E-08 | 1.8E-07 | 4.4E-07 | <MDA    | <MDA    |
| 6- 7          |                   | 7.7E-08 |         |         |         |         |         | 2.2E-07 | 3.2E-07 |
| 7- 8          |                   |         |         |         |         |         |         | <MDA    |         |
| 8- 9          |                   | 1.6E-07 |         |         |         |         |         |         |         |
| 9-10          |                   |         |         |         |         |         |         |         |         |
| 10-11         |                   | 1.1E-07 |         |         |         |         |         |         |         |

\* Background concentrations not corrected for.



The Cs-137 concentrations are important when looking at the transport through the soil since Cs-137, having the greatest solubility in water, has the highest likelihood of reaching the lake. Also, Cs-137 is expected to be the most concentrated isotope after transport through the soil. Cs-137 has the longest half-life and presents the greatest radiological hazard of the four isotopes. The Cs-137 distribution as determined by the sampling described above is presented in Figure 5 of Attachment II.

Eight 55-gallon drums of contaminated soil were removed by excavation from the area (shown in Figure 5 of Attachment II). This soil will be shipped as low level waste to a licensed burial ground. This application applies to the remaining contaminated soil. The total amount of activity which remained in the soil is estimated to have been 37  $\mu$ Ci. This was determined using data from soil samples, #3 through #9 (Figures 3 and 4 of Attachment II). A copy of this estimation is enclosed (Attachment III). The average isotopic concentrations are given below:

| <u>Nuclide</u> | <u>Average<br/>Concentration* [nCi/gm]</u> |
|----------------|--|
| Mn-54          | 1.512E-05                                  |
| Co-60          | 2.884E-05                                  |
| Cs-137         | 3.807E-05                                  |
| Cs-134         | 5.776E-05                                  |
| <u>Total</u>   | <u>1.398E-04</u>                           |

\* The average was calculated only using samples showing >MDA, therefore, it is very conservative.

Based on a total of 62 soil samples collected throughout the area (and analyzed using gamma isotopic techniques), the total estimated activity present was 37  $\mu$ Ci. The total volume of earth contaminated is approximately 5300 cubic feet. Based on a soil density of  $4.99\text{E}+04$  gm/ft<sup>3</sup>, the average concentration of contaminated soil estimated to be in the soil at the time of excavation was  $1.4\text{E}-04$  nCi/gm (and at present is  $1.1\text{E}-04$  nCi/gm). Cs-134 is the most predominant isotope present comprising approximately 37.32% of the total activity; while Cs-137, Mn-54 and Co-60 comprise approximately 33.69%, 6.09% and 22.90% (respectively) of the remaining activity.

#### MIGRATION ANALYSIS AND ENVIRONMENTAL IMPACT

An analysis of the migration of isotopes through the soil towards Lake Michigan was performed using methods described in ANSI/ANS-2.17-1980: "Evaluation Of Radionuclide Transport In Groundwater For Nuclear Power Sites" and using groundwater data obtained from the Big Rock Point FHSR. The ANSI model employs geohydraulic and geometrical parameters as a function of

radioactive decay to account for retardation of radionuclides by sorption onto/into the soil. The results reveal the leak will reach the lake in seven years. The isotopic concentrations at that time are expected to be:

| <u>Nuclide</u> | <u>Concentration* [<math>\mu\text{Ci/ml}</math>]</u> |
|----------------|--|
| Mn-54          | 2.50E-10   |
| Co-60          | 5.64E-09   |
| Cs-137         | 9.00E-08   |
| Cs-134         | 1.92E-08   |

\* These values were calculated assuming all the contaminants were left in the soil (ie, as if no excavation took place).

Based on the characterization discussed above, the potential for migration of the contaminants presents a negligible impact to the environment for the following reasons:

- 1) The contaminated layer is above the water table (soil layer is about 4 feet thick). The ground in the site area is composed of sand, gravel and weathered limestone, which is well drained. The contaminated water from the leak seeps into the water table then towards Lake Michigan. Upward migration of contaminants through the soil is highly improbable.
- 2) The minimum distance between the contaminated soil and the lake is 89 m. Using the rate of flow of 0.035 m/day, the contaminants will not reach the lake for seven years. Some of the contaminants may find their way to the lake sooner due to flowing along underground piping. Taking dilution, dispersion and sorption factors into account, it is conservatively estimated that the activity when the contaminants reach Lake Michigan will be much less than 1% of the source activity.
- 3) All the contaminated soil is contained within the radiologically controlled area. Of 62 soil samples outside the excavated area, all reveal concentrations within the limits of 10 CFR 20.106 (Radioactive Effluents To Unrestricted Areas) and within the limits of 10 CFR 30.14 (Exempt Concentrations). These concentrations will continue to decrease with time due to radioactive decay, dispersion, dilution, ion exchange and sorption.
- 4) The general area radiation levels, both at the surface of the contaminated area (above the turbine building floor) and one meter above the surface, are background, as determined in Attachment III. The dose rate to a person digging in the area is estimated to be 2.0E-04 mr/hr.
- 5) The radionuclide concentrations at the time of sampling and the total activity released are given above. The concentrations and activity remaining in the contaminated soil at present and in seven years are expected to be as given in Table III. After seven years, all the contaminants will have migrated to Lake Michigan, thereafter it is

assumed that the concentrations and activities of these isotopes remaining in the soil will be reduced to their natural levels.

#### OCCUPATIONAL AND PUBLIC HEALTH IMPACT OF RETAINING CONTAMINATED SOIL ON-SITE

The potential doses to workers and to the general public due to leaving the contaminated soil in place were determined assuming no excavation of the soil took place. The exposure pathways considered were direct exposure to the contaminated soil, exposure from inhalation of particles suspended in air during removal of concrete from the turbine building floor and exposure to radionuclides transported to Lake Michigan through ground water flow. The activity in the remaining contaminated soil at the present is determined to be 0.88% of the total activity released. The doses to workers and the general public due to leaving the remaining contaminated soil in place can be taken as 0.88% of the doses calculated when assuming no soil was excavated. The calculated doses for each exposure pathway are summarized in Table IV.

#### EXCAVATING, PACKAGING AND SHIPPING TO A FEDERALLY APPROVED DISPOSAL SITE

The estimated cost for excavation and disposal of the remaining contaminated soil is well over \$100,000. The estimated volume of soil to be removed is approximately 5300 cubic feet. This would require ~ 720 55-gallon drums. The average total activity per drum, based on a concentration of  $1.4\text{E}-04$  nCi/gm and a soil density of  $4.99\text{E}+04$  gm/ft<sup>3</sup> would be about  $5.13\text{E}-02$  µCi. The average concentration of radioactive material in these containers is less than 1% of the concentration that would require regulations for transport under Department of Transportation (DOT) criteria set forth in 49 CFR 173.389 as it defines "Radioactive Material".

Based on the present conditions of radioactive material disposal sites, shipping barrels with such low concentrations would result in inefficient use of the current limited available burial space.

#### SUMMARY

The estimated total cost of excavation, packaging and transporting the contaminated soil to an approved disposal facility is estimated to be much greater than \$100,000. The packages would contain radioactive concentrations much less than that necessary to be considered "radioactive material" as defined in Department of Transportation Regulations and would result in inefficient use of limited available burial space.

Retaining the contaminated soil on-site with approximately 8 inches of concrete covering (the turbine building floor), would result in no discernable impact on either the environment or on occupational and public health. The total activity is expected to be undetectable within seven years.

Any migration of the contaminants would be in the direction of Lake Michigan and would not reach the lake for at least seven years. This leakage would contribute minimally to the concentration of naturally occurring radioactivity and permissible plant releases already present.

Table III: Radioactivity [ $\mu\text{Ci}$ ] And Isotope Concentrations [ $\text{nCi/gm}$ ] Remaining In Soil vs Time

| Isotope | Half Life<br>$t_{1/2}$ In Days | Total Activity<br>Released | After Excavation |               | Present (1 year) |               | 7 Years After Leak |               |
|---------|--------------------------------|----------------------------|------------------|---------------|------------------|---------------|--------------------|---------------|
|         |                                |                            | Activity         | Concentration | Activity         | Concentration | Activity           | Concentration |
| Co-60   | 1920                           | 238.46                     | 7.63             | 2.884E-05     | 6.69             | 2.529E-05     | 3.03               | 1.145E-05     |
| Mn-54   | 312                            | 132.48                     | 4.00             | 1.512E-05     | 1.78             | 6.729E-06     | 0.01               | 3.780E-08     |
| Cs-137  | 10950                          | 1741.10                    | 10.07            | 3.807E-05     | 9.84             | 3.720E-05     | 8.57               | 3.238E-05     |
| Cs-134  | 748                            | 1218.77                    | 15.28            | 5.776E-05     | 10.90            | 4.120E-05     | 1.43               | 5.406E-06     |
| Totals  |                                | 3330.81                    | 36.98            | 1.398E-04     | 29.21            | 1.104E-04     | 13.04              | 5.232E-05     |

NOTES: Total activity released is based on total gallons estimated to have leaked and isotopic concentrations found in a puddled water sample.

Activities and concentrations after excavation were determined using soil samples taken outside the excavated area.

Present and seven year activities and concentrations are estimated by taking radioactive decay into account for one and seven years (respectively) since the excavation using the following equations:

$$\text{Activity At Time, } t = (\text{Activity After Excavation}) \exp \frac{-\ln^2 t}{t_{1/2}}$$

$$\text{Concentration } \frac{\text{nCi}}{\text{gm}} = \frac{\text{Activity } [\mu\text{Ci}]}{5301.44 [\text{ft}^3]} \frac{1 \text{ ft}^3}{4.99\text{E}+04 \text{ gm}} \frac{10^3 \text{ nCi}}{1 \mu\text{Ci}}$$

Where 5301.44  $\text{ft}^3$  is estimated volume of contaminated soil and 4.99E+04  $\text{gm/ft}^3$  is used as soil density.

Table IV: Summary of Occupational and General Population Doses

| Exposure Pathways   |                  | Occupational<br>Doses                          | General<br>Population<br>Doses                           |
|---|------------------|--|--|
| Direct exposure and shine   |                  | $1.9\text{E}-06 \frac{\text{mrem}}{\text{hr}}$ | $9.99\text{E}-10 \frac{\text{mrem}}{\text{hr}}$          |
| Direct exposure to person digging at site   |                  | $2.0\text{E}-04 \frac{\text{mrem}}{\text{hr}}$ | -  |
| Nuclides transported to Lake Michigan<br>through groundwater                        |                  |  |  |
| Single batch release  | Adult Total Body | -  | $7.65\text{E}-05 \frac{\text{mrem}}{\text{year intake}}$ |
|   | Teen Liver       | -  | $1.11\text{E}-04 \frac{\text{mrem}}{\text{year intake}}$ |
| Released over 7 years   | Adult Total Body | -  | $1.10\text{E}-05 \frac{\text{mrem}}{\text{year intake}}$ |
|   | Teen Liver       | -  | $1.57\text{E}-05 \frac{\text{mrem}}{\text{year intake}}$ |
| Single release after 7 years<br>(retardation and sorption by soil<br>accounted for) |                  | -  | $9.70\text{E}-08 \frac{\text{mrem}}{\text{year intake}}$ |
| Inhalation of resuspended particles   |                  | $.03 \frac{\text{mrem}}{8 \text{ hours}}$      | $4.02\text{E}-12 \frac{\text{mrem}}{\text{year intake}}$ |

\* The activity of the suspended source term does not exceed the amount necessary to deliver a 40 MPC-hour burden.

CONCLUSION

We request to retain the contaminated soil on-site for the above mentioned reasons. The impact on both the environment and occupational and public health would be negligible. The potential of recontaminating this region is negligible based on the inspection of other piping in the area for proper corrosion protection (See Licensee Event Report 84-03, revision 2, dated October 19, 1984).



LIST OF ATTACHMENTS

Attachment I : Geology and Hydrology of the Proposed Reactor  
Site at Big Rock Point, Near Charlevoix, Michigan  
by James H. Zumberge

Attachment II : Resolution of AIR:BRP-84-20 "Disposition of  
Contaminated Soil"

Attachment III : Radioactivity Remaining in Soil from Condensate  
Tank Leak

## ATTACHMENT I

### GEOLOGY AND HYDROLOGY OF THE PROPOSED REACTOR SITE AT BIG ROCK POINT, NEAR CHARLEVOIX, MICHIGAN

James H. Zumberge  
Geologist  
Ann Arbor, Michigan

### TOPOGRAPHIC SETTING

#### Terrain

The proposed site lies in the NE Quarter of Section 7, in Township 34 N, Range 7 W, Charlevoix County, Michigan, near the shore of Lake Michigan. The lake shore consists of scattered limestone outcrops alternating with short stretches of beach containing granular materials ranging in size from sand to coarse boulders and limestone rubble. The land rises from a mean lake elevation to 580 feet A.T. to about 700 A.T. a mile or so inland.

Topographically, the region within a five-mile radius of the site location can be divided into two categories. The first is more or less parallel to the lake shore and is a zone of low relief which was once submerged beneath the waters of ancestral Lake Michigan. Locally, swampy conditions prevail between low ridges of stabilized beach deposits.

The second zone is the upland surface which rises from an elevation of about 700 A.T. to over 900 feet A.T. five miles south-east of the site. The upland surface is a constructional terrain consisting of till plain containing NW-SE oriented drumlins which rise 40 to 60 feet above the general till plain surface.

### Drainage

Surface drainage flows either northward directly into Lake Michigan or southward into Lake Charlevoix and thence into Lake Michigan via Round Lake and Pine River at the town of Charlevoix. The divide between these two watersheds extends in a northwesterly direction from a point just south of Susan Lake in Section 29, thence northward into Section 20, northwesterly into the SE corner of Section 18, and finally northward into Lake Michigan.

The surface drainage area in which the proposed site is located is bounded on the south and west by the divide just described, on the north by Lake Michigan, and on the east by Susan Creek which originates in Susan Lake and flows northward into Lake Michigan which it enters at a point about one mile east of Big Rock Point. The total area of this watershed is between 3 and 4 square miles.



# GEOLOGICAL MAP OF MICHIGAN

By

HELEN M. MARTIN

1957 Revision of Pub. 39

## THE CENTENNIAL GEOLOGICAL MAP OF MICHIGAN

Data for revision was obtained from oil and water well logs, from core cut data generally supplied by several oil companies and from field notes of geologists working in the Northern Peninsula.

### PENNSYLVANIAN

Pgr Grand River  
Ps Saginaw

### MISSISSIPPIAN

Mib Bayport  
Min Aukagon  
Mmm Napoleon-Marshall  
Mic Coldwater  
Mbb Berea-Bedford  
Me Elsworth-Antrim

### MISSISSIPPIAN DEVONIAN

M Da Antrim

### DEVONIAN

Dtr Traverse  
Drc Rogers City  
Dd Dundee  
Ddr Detroit River  
Dbb Bois Blanc

### DEVONIAN-SILURIAN

D Sm Mackinac breccia

### SILURIAN

Sbi Bois Island  
Ssi St. Ignace  
Ssp Point Aux Chenes  
Sse Engadine  
Sim Manistique  
Sbb Burnt Bluff  
Sme Mayville

## GEOLOGIC SETTING

### Bedrock Geology

Bedrock Topography. The site lies in a belt of limestone of lower Paleozoic age. The rocks exposed along the lake shore are part of the Traverse Group of Devonian age. Near the shore the bedrock surface is either at the ground or covered by thin unconsolidated glacial and lacustrine deposits. Farther inland, the bedrock surface is buried beneath the till plain.

At the city of Charlevoix, the log of the city well reveals 230 feet of Pleistocene sand and gravel over the Traverse limestone. This situation is common place along the entire eastern shore of Lake Michigan and indicates that the streams entering the lake were deeply entrenched into bedrock during a time when the lake level was several hundred feet lower, about 5,000 years ago. Thus, the maximum relief of the bedrock topography is much greater than one would expect from an examination of outcrops along the shore of Lake Michigan.

Bedrock Lithology. Borings at the site were made by the Raymond Concrete Pile Company to a depth of 40 feet. Two borings 400 feet apart and 500 feet from shore penetrated a grey to black fossiliferous limestone with thin shale partings. Core recovery ranged from a low of 24% in the 8 to 9 foot levels of Boring No. 2 to a high of 100%. Generally, the core recovery was greater than 60% and many sections of two-foot lengths showed 100% recovery. Poor core recovery seems to be related to weathered sections of the limestone sections with closely

spaced shale partings, or a highly jointed rock, rather than cavernous conditions. Some of the cores are reported as having low porosity.

The limestone bedding planes are nearly horizontal and the regional dip is to the southeast toward the center of the Michigan Basin. The log of the Charlevoix water well shows no salt or anhydrite beds down to a depth of 482 feet.

Log of City Well, Charlevoix, Michigan

Location: Section 26, T 34 N, R 8 W.

Elevation: 600 feet above sea level.

Drilled before 1901

|   | Thickness<br>(feet) | Depth<br>(feet) |
|---|---------------------|-----------------|
| Pleistocene:  |                     |                 |
| Sand  | 6                   | 6               |
| Gravel  | 9                   | 15              |
| Fine sand   | 155                 | 170             |
| Gravel  | 6                   | 176             |
| Sand, quicksand at 214 feet   | 54                  | 230             |
| Devonian:   |                     |                 |
| Traverse:   |                     |                 |
| Limestone, fine grained earthy  | 10                  | 240             |
| Limestone, gray   | 10                  | 250             |
| Limestone, earthy or chalky, brownish, porous, much oxidized shaly, with a strong shale odor, being in fact in large part shale   | 10                  | 260             |
| Limestone, dark gray argillaceous and somewhat shaly  | 10                  | 270             |
| Shale, finely stratified. Compact in texture  | 10                  | 280             |
| Limestone, fossiliferous whitish, containing <i>Atrypa reticularis</i> and other fossils  | 10                  | 290             |
| Limestone, white crystalline, containing considerable crystalline calcite. It carried fragments of <i>Acervularia davidsoni</i> . Some portions of the samples are compact and argillaceous | 10                  | 300             |



|   | <u>Thickness</u><br>(feet) | <u>Depth</u><br>(feet) |
|---|----------------------------|------------------------|
| Limestone, white chalky, non-argillaceous, fossiliferous  | 15                         | 315                    |
| Limestone, brownish, earthy and argillaceous with a strong shale odor, Bryozoa and other fossils have been observed                           | 7                          | 322                    |
| Shale, gray calcareous, of very uniform texture, partially oxidized   | 8                          | 330                    |
| Shale, gray compact calcareous rock, but of massive character   | 5                          | 335                    |
| Fragments of <i>Acervularia davidsoni</i> with the calices free from matrix, and evidently embedded in shale. No shale, however, is retained. | 10                         | 345                    |
| Shale, gray calcareous, mixed with pure white limestone, the latter containing <i>Favosites</i> and <i>Acervularia</i>                        | 5                          | 350                    |
| Limestone, gray argillaceous, and some white limestone, with fragments of <i>Spirifer</i> and <i>Acervularia</i>                              | 5                          | 355                    |
| Limestone, gray, <i>Acervularia davidsoni</i> is abundant. <i>Favosites</i> and <i>Atrypa reticularis</i> also occur                          | 5                          | 360                    |
| Limestone, gray, compact, and semi-argillaceous crinoid stems; much shale is mixed with the limestone   | 7                          | 367                    |
| Fragments of <i>Acervularia davidsoni</i> and <i>Favosites</i>  | 3                          | 370                    |
| Limestone, compact, gray, argillaceous  | 5                          | 375                    |
| Rock, fine grained, compact, argillaceous   | 12                         | 387                    |
| Limestone and black shale   | 3                          | 390                    |
| Limestone, gray argillaceous with whiter limestone containing <i>Acervularia</i>  | 10                         | 400                    |
| Shale, chalky; crumbles and soils fingers, cream colored  | 2                          | 402                    |
| Shale, bluish gray, slightly calcareous   | 8                          | 410                    |
| Limestone, compact, brown to gray, weathering earthy  | 5                          | 415                    |
| Shale, cream colored calcareous, identical with rock at 400 feet  | 5                          | 420                    |
| Limestone, compact, brown   | 10                         | 430                    |
| Shale, cream colored earthy, calcareous   | 13                         | 443                    |
| Limestone, brown banded, mingles with black and gray shale containing <i>Atrypa reticularis</i> , etc.  | 4                          | 447                    |
| Bell formation:   |                            |                        |
| Shale, bluish   | 35                         | 482                    |

### Surficial Deposits

Glacial Drift. The site area lies within the boundaries of the Late Wisconsin drift deposits of Pleistocene age. A narrow belt parallel to the shore of Lake Michigan contains thin lacustrine deposits and beach sands and gravels associated with former higher stages of Lake Michigan which prevailed at various times since the last retreat of the Lake Michigan glacial lobe. These deposits range from fine sands to coarse gravel and weathered limestone bedrock.

The upper surface is the product of the last ice advance which deposited a stony till of variable thickness over the entire area. In the site area the till is very thin or wholly lacking due to the many episodes of lake history. The ancestral lakes removed much of the till by wave erosion, and in places, replaced it with beach deposits or lacustrine sediments.

Soils. Generally, the soils in the immediate site area have weakly developed Podzol profiles, are very well drained, and extremely poor from the agricultural point of view. The major soil in the area is the Eastport Series which is commonly developed on low sand ridges and dry sand benches, but can also occur on bedrock flats, stony wet clays, and shingle and cobbly beaches.

The upland soils, developed on the drumlin-till surface, belong to the Emmet-Rosclawn Association. The soil textures are mostly sandy loams of medium fertility. Their well drained character reflects the generally high permeability of the morainic materials on which they are developed.

### GROUND WATER

The general geologic setting, topography, and climatic conditions of the region provide a basis for a general evaluation of the ground water conditions.

The water table at the site area was at 579 feet in May, 1959, as shown by the notes accompanying Boring No. 1 of the Raymond Concrete Pile Company report dated May 8, 1959. This shows that water table rather than artesian conditions prevail.

It can be assumed that the water table rises gradually from Lake Michigan back to the drainage divide described under surface drainage in this report. It cannot be stated definitely that this surface drainage divide is coincident with the ground water divide because even though the surface drainage on either side is graded to either Lake Michigan or Lake Charlevoix, both of which have the same mean surface elevation, the slope of the land on the Lake Charlevoix side of the divide is much steeper than on the Lake Michigan side. Steeper water table gradients, therefore, may result in a water table divide that is closer to the Lake Michigan base level than the surface drainage divide would indicate. Nevertheless, the water table divide is most likely not much different than the surface drainage divide between the two lakes.

The eastern margin of the watershed is Susan Creek which forms a very definite boundary insofar as both surface and subsurface water movement is concerned. The preliminary copy of the U.S.G.S. topographic map directly east of the Charlevoix Quadrangle shows Susan

Creek to be a permanent stream. Even though a good portion of the base flow undoubtedly comes from Susan Lake, Susan Creek itself is undoubtedly effluent in character and draws on ground water storage to sustain its base flow, however small, during periods of drought.

Ground Water Movement. Ground water that originates as infiltration from rainfall which falls on land west of Susan Creek, south of Lake Michigan, and north or east of the divide between Lakes Michigan and Charlevoix, will eventually reach Lake Michigan, either directly by normal ground water movement toward the lake or by ground water flow into Susan Creek and thence to Lake Michigan as surface run-off.

In terms of vagrant ground water released at the proposed site itself, such water would flow to the lake very quickly except in times of a rapid rise in lake level during a seiche, in which case some delay would result because of a reduced hydraulic gradient between the site and the lake. Locally, where the water table causes swampy conditions because of its proximity to the surface swales between old beach ridges, the movement toward the lake would be retarded.

## PUMP TEST ANALYSIS

There is little doubt that any ground water that originates as infiltration from rainfall which falls on land west of Susan Creek, south of Lake Michigan, and north or east of the divide between Lakes Michigan and Charlevoix, will eventually reach Lake Michigan, either directly by normal ground water movement toward the lake or by ground water flow into Susan Creek and thence to Lake Michigan as surface runoff.

In terms of vagrant ground water released at the proposed site itself, such water would flow to the lake very quickly except in times of a rapid rise in lake level during a seiche, in which case some delay would result because of a reduced hydraulic gradient between the site and the lake. Locally, where the water table causes swampy conditions because of its proximity to the surface swales between old beach ridges, the movement toward the lake would be retarded.

On December 9, 10, 1959, pump tests were run to determine the coefficients of Transmissibility (T) and Storage (S). The tests were run on Borings #5, 6, and 7. On December 19, 1959, a slug test was run on Boring #3. This test was designed to measure the infiltration capacity of the clay on the site area.

Aquifer Selection. The initial evaluation of the subsurface geology indicated that a thick sequence of Traverse limestone is overlain by about 50 feet of compact clay till. The upper 10 feet of limestone is badly fractured, indicating higher velocities of

ground water compared to the surrounding geologic materials. It was, therefore, decided to drill three borings (see sketch map of boring locations) using #5 as the pump well and #6 and #7 as observation wells. These borings were completed to depths of 59' 11", 64' 3", and 59' 9", respectively, and penetrated up to 13' of fractured limestone. These borings essentially penetrate the fractured zone which averages about 10 feet in thickness. Water levels in the wells indicated artesian conditions as would be expected.

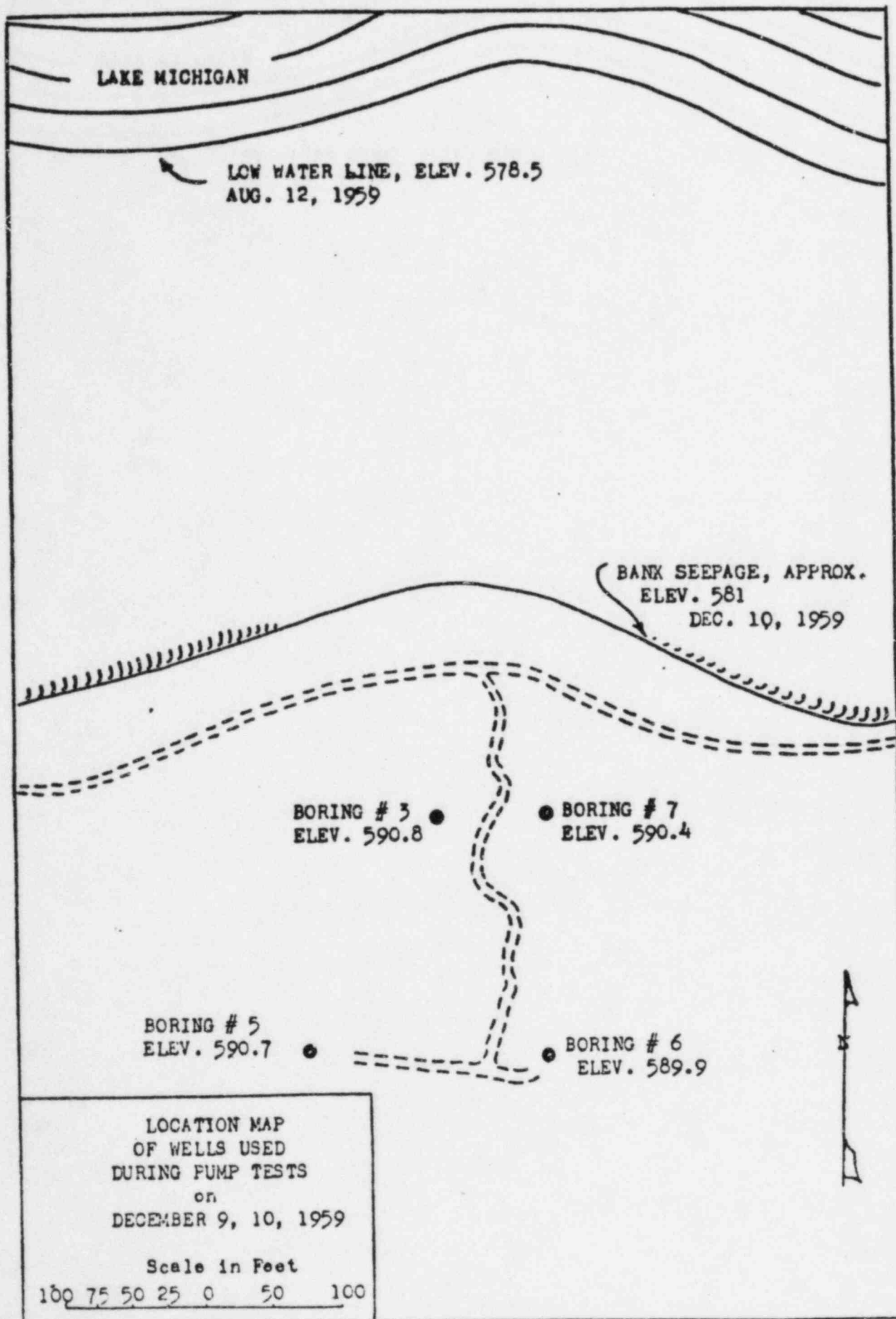
Boring #5 showed a sand zone from 23' 5" to 29' 5" which produced a flow of 0.33 gallon/minute. The static level of the sand was 1.33 feet above the ground surface or at an elevation of 591.98. This zone will be discussed on Page 14.

A slug test was run on Boring #3 at a depth of 8.5 - 20 feet. The well was entirely in clay, and the test shows the capacity of the capping clay to transmit water.

Pump Test. Upon completion of the wells, static water levels were taken, and a short test run to determine the approximate well capacity for an eight-hour pump test which would utilize the maximum amount of drawdown allowable.

On December 9, test #1 was commenced, pumping at a rate of 5.2 gpm. A standard 5/8 inch Badger water meter was used with a stop watch to regulate the discharge. An electrical contact water level recorder was used on Boring #5 and tape readings were taken on Borings #6 and 7. Readings were taken according to a prearranged schedule with each observer using a synchronized watch. Between 60 and 90





minutes, the water level in Boring #5 dropped 10 feet indicating a rapid change in transmissibility. The suction head produced was too large for the pump and, therefore, test #1 was suspended.

On December 10, after allowing the static level to recover, test #2 was begun with a discharge of 4.0 gpm. The pressure cone was not reduced sufficiently during this test to allow dewatering of the aquifer which essentially occurred during the first test. After 8 hours of drawdown, 5-1/2 hours of recovery were measured.

Results. The drawdown vs time and recovery vs time relationships allow the determination of the coefficient of transmissibility, T, defined as the flow of water in gallons/day (under a hydraulic gradient of one) through a rock cross section with a width of one foot and a depth equal to the thickness of the water bearing formation. Also, it permits the determination of, S, the coefficient of storage which is defined as the volume of water released from storage per unit surface area of aquifer per unit change in the component of head normal to that surface. Under artesian conditions in a vertical column one foot by one foot, the storage coefficient equals the volume of water in cubic feet released from an aquifer when the piezometric surface declines one foot.

Calculation for the Big Rock Point Plant was made by use of the Theis, Jacob and Theim methods\*. These methods are well known and standard in well hydraulics. For the slug test, a standard slug formula of  $T = \frac{114.6 V (1/tm)}{s}$  was used where: V equals volume of the slug in gallons, tm equals time since slug injection in minutes, and s equals the residual head above the static.

\*See Appendix B for drawdown and recovery data from all wells.

The pump test formulae are based on the assumptions that (1) the aquifer is uniform in thickness, (2) that the aquifer is both homogeneous and isotropic, and (3) of infinite areal extent. These conditions are never realized in nature and especially so in bedrock aquifers. However, the test formulae represent the best approach that is economically feasible. Therefore, departures of the results can be attributed directly to departures of the rock.

Table 1 shows the values of T and S for both tests, and the three different methods. Even with so many departures from the ideal conditions, there is good conformity between the average values of the three methods.

| Well No.       | JACOB |                       | THEIS |                       | THEIM |     |
|----------------|-------|-----------------------|-------|-----------------------|-------|-----|
|                | T     | S                     | T     | S                     | T     |     |
| <u>TEST #1</u> |       |                       |       |                       |       |     |
| 6 dd           | 337   | $1.8 \times 10^{-5}$  |       |                       |       |     |
| 7 dd           | 818   | $7.8 \times 10^{-6}$  |       |                       |       |     |
| <u>TEST #2</u> |       |                       |       |                       |       |     |
| 5 rec          | 528   |                       |       |                       | 834   | 7   |
| 6 dd           | 464   |                       |       |                       | 1     | 637 |
| 6 rec          | 352   | $4.2 \times 10^{-6}$  | 491   | $3.86 \times 10^{-5}$ | 109   |     |
| 7 dd           | 754   |                       |       |                       |       |     |
| 7 rec          | 880   | $1.75 \times 10^{-5}$ | 668   | $2.11 \times 10^{-5}$ |       |     |
| AVERAGE        | 590   | $1.19 \times 10^{-5}$ | 590   | $2.99 \times 10^{-5}$ | 527   |     |

TABLE #1

Transmissibility (T) and Storage (S)

As transmissibility (T) is in gpd/ft of aquifer, and permeability is in gpd/ft<sup>2</sup>, the average value of T is divided by the thickness of the fractured zone to arrive at the permeability. The average permeability is then seen to be somewhere between 52.7 gal./day/ft<sup>2</sup> and 59 gal./day/ft<sup>2</sup>.

The slug test yielded a transmissibility of 4.0 gal./day/ft. Since the amount of open hole was 11.5 feet, the permeability of the clay is 0.35 gal./day/ft<sup>2</sup>.

Conclusions on ground water flow under existing conditions:

(1) The static water levels in the three wells in the test area show that the fractured rock zone is under artesian conditions. The elevation of the static levels indicates that there is a pressure drop towards Lake Michigan. The elevations also indicate that there is leakage from the clay into the fractured limestone. Taking the average value of (T) equal to 590 gal./day/ft, and the approximate thickness of the fractured zone as 10 feet, the flow velocity under existing hydraulic gradients equals 0.05 ft/day. This value is very low compared to most sand and gravel aquifers.

(2) The drawdown and recovery vs time relationships indicate a direct connection between the fractured bedrock and Lake Michigan. Using the recovery data from Boring #7, and the drawdown data from #6, positive boundary conditions, i.e., recharge to the aquifer system, were established as being approximately 820 and 850 feet from the pumping well. Lake Michigan is 500 feet away at its closest point. Recharge would not be expected to show appreciably

until the pressure cone had intersected a sizeable section of the lake.

(3) The overlying clay till has an exceptionally low transmissibility, and gives flow velocities of about 0.002 ft/day. This rate is largely dependent on the hydraulic gradient which fluctuates. However, even if the velocity were doubled it would still be low. note

(4) The artesian sand in Boring #5 is believed to represent a beach sand, deposited during the interval elapsed during the deposition of the underlying and overlying till. The overlying till shows an average penetration of about 57 blows/12 inches while the underlying till has an average penetration of 109 blows/12 inches. Well drillers in the area report that artesian sand pockets are hit within 50 feet of the present lake level. The static of the sand indicates that the source area is probably 1000 feet south of the test area. Examination by the writer of the area immediately south showed surface expressions of old beaches with back shore swamps. One of these back shore swamp areas is pictured by the writer as being connected to the subsurface sand by a sand smear similar to those now present on the surface. Buried beach deposits may be expected in the area, where they will be of limited areal extent, with small yields such that they could only be suitable for small scale domestic purposes. The high static indicates that these sand bodies are under high pressure and will not permit water to enter them, but to the contrary leak water to the surrounding area. In this respect, the sand acts as a boundary to the passage of water.

(5) Existing wells in the area are of two types. The shallow wells which are less than 70 feet deep and the deep wells of generally over 150 feet and up to 350 feet in depth. Just north of Charlevoix Lake and in a band approximately one-half mile wide, stretching NW-SE parallel to the lake, are found many shallow type wells. These wells are located in permeable sands or gravels lying above a tight clay till whose upper surface is thought to be depressed in the immediate area of Lake Charlevoix.

Wells of Type #2 are generally found elsewhere in the area. They are in the Traverse limestone, at considerable depth, and under artesian conditions for the most part. These wells yield up to 50 gpm, but are mostly in the 15-20 gpm range. No heavy producing wells are known of within 2 miles of the site area.

#### Lake Levels

The Lake Survey Division of the U.S. Corps of Engineers issues monthly bulletins of levels of the Great Lakes. The period of record for Lakes Michigan and Huron is from 1860 to the present.

Lake level fluctuations are of two types, long-range and short-range. The long-range variations are those related to variations in precipitation over the years, whereas the short-range fluctuations are caused by seasonal variances in regional precipitation, or very short changes in lake levels due to seiches.

Long-Term Fluctuations. The level of Lake Michigan has varied from a low of 577.35 feet A.T. which occurred in February, 1926, to a high of 583.68 feet A.T. in June of 1886. This amounts to a maximum difference in level of 6.33 feet during the period of record (1860-1959).



Short-Term Fluctuations. Seasonal variation in precipitation produces a seasonal variation in levels of the Great Lakes. The average difference in the level of Lake Michigan between July (high water) and February (low water) is about one foot, but differences of as much as two feet and as little as 0 feet have been recorded between these two months for any one water year.

Both the long-term and short-term seasonal fluctuations have the same effect on the water table which rises and falls with the level of the lake, at least in the vicinity of the shore.

Seiches. Short-term water level fluctuations with periods of a few hours are called seiches. They are produced by some meteorological force such as high winds or rapid changes in atmospheric pressure. In either case, lake levels fluctuate two to three feet in less than a day. Such rapid changes in the lake level have some affect on the near shore ground water because the water table is graded to the water plane of Lake Michigan. High levels reduce the hydraulic gradient of the water table and result in sluggish movement in the near shore area. Such changes are only temporary, however.

#### Lake Currents

The site lies on the south side of Little Traverse Bay, an east-west embayment opening into the northern end of Lake Michigan.

Investigations of the currents of Lake Michigan by the Great Lakes Research Institute of the University of Michigan suggest that two directions of currents exist in Little Traverse Bay. They are both apparently controlled by wind conditions in the area centered

around the Straits of Mackinac. When the prevailing westerly or northwesterly winds are blowing, a clockwise current moves in the bay which gives rise to a westward moving longshore current on the southern shore of the bay, as demonstrated in the Synoptic Cruises IV and V on June 28 and 29, respectively, in 1955. However, when the winds come from the north or northeast quadrant, the current changes to a counterclockwise direction, thereby reversing the longshore movement on the south shore of the bay so that it moves in an easterly direction from the site area toward the head of the bay, as shown in Synoptic Cruises VI and VII on August 9 and 10, respectively, in 1955.

The question naturally arises as to which condition prevails most frequently, the eastern or western direction of flow. The answer is based on both meteorological and geological evidence. Wind direction data obtained from the U.S. Coast Guard Lifeboat Station at Charlevoix indicates that the wind is from the northeast quadrant less than 20% of the time. It follows that the westward moving shore current near the site area is the normal situation.

Evidence in support of this conclusion also comes from the presence of a mile-long spit extending into Little Traverse Bay from the north shore at Harbor Springs. This spit curves eastward toward the head of the bay. It is inconceivable that this spit could maintain its orientation with any current other than the clockwise current which prevails when the westerly winds are blowing.

Actually, the pattern of currents in the bay may be more complicated than indicated by the synoptic cruises of the Great Lakes Research Institute. Also, the proposed site area is some 15 miles

from Petoskey at the head of the bay, and it has not been proved with certainty that water entering Lake Michigan at Big Rock Point would, in fact, move all the way to Petoskey at the head of the bay.

## REFERENCES

1. Abrams Aerial Survey Corporation, Aerial Photos of the site area flown November 1957, (scale 1:6000).
2. Department of Conservation, Michigan Geological Survey:
  - a. An Index of Michigan Geology, by Helen Martin and Muriel Straight, 1956. Page 228 gives location of bedrock outcrops on the south shore of Little Traverse Bay.
  - b. Map of surface formations of Michigan, by Helen Martin, 1957.
  - c. Centennial Geological Map of Michigan (revised, 1957), by Helen Martin.
3. Great Lakes Research Institute, Currents and Water Masses of Lake Michigan, by John C. Ayers, et. al., 1958. Figures 13 (p. 30), 24 (p. 53), 38 (p. 79), and 51 (p. 104).
4. Melhorn, W.N., Valders Glaciation of the Southern Peninsula of Michigan, 1954, unpublished Ph. D. thesis, Univ. of Michigan, Dept. of Geology.
5. Michigan Geological Society Annual Guidebook, The Traverse Group of the Northern Part of the Southern Peninsula of Michigan, 1949, by William Kelley. Map No. 4 shows aerial map of the Traverse formation for Charlevoix and Emmet Counties, Michigan.
6. Raymond Concrete Pile Company, Gow Division, Test Boring Report, Borings No. 1 and No. 2 at Big Rock Point, Michigan, May 8, 1959.
7. Spurr, S.H. and Zumberge, J.H., Late Pleistocene Features of Cheboygan and Emmet Counties, Michigan, 1956, Amer. Jour. Sci., vol. 254, p. 96-109.
8. U.S. Army Corps of Engineers, Lake Survey Division, Monthly Bulletin of Lake Levels for August 1959.
9. U.S. Dept. of Agriculture:
  - a. Photo Index Mosaic of Charlevoix County, Michigan, 1938, (sheet 1 of 3).
  - b. Photo Index Mosaic of Emmet County, Michigan, 1938, (sheet 2 of 2).
 Both of these include the area surrounding Little Traverse Bay.
10. U.S. Geological Survey, Topographic Branch, Charlevoix and Charlevoix Lake 15-minute Quadrangle topographic maps.

11. Wilson, J.T., Zumberge, J.H., and Marshall, E.W., A Study of Ice on an Inland Lake, 1954, Snow Ice and Permafrost Research Establishment, U.S. Corps of Engineers, Report 5.
12. Veatch, J.O., Soils and Lands of Michigan, 1953, Michigan State College Press.
13. Zumberge, J.H., Effects of Ice on Shore Development, 1954, Proceedings of the 4th Conference on Coastal Engineers, p. 201-205.
14. Zumberge, J.H., Guidebook for the Friends of the Pleistocene Midwest Section, 1956.

## APPENDIX A

### WELL \*LOGS OF BORINGS USED DURING PUMP TEST

#### Boring #5, Elevation 590.7

|                |   |
|----------------|---|
| 0' - 1'        | Sandy loam and organic matter.  |
| 1' - 7'5"      | Clayey brown sand and broken limestone.                                   |
| 7'5" - 23'5"   | Hard sandy and gravelly brown clay, few limestone fragments.              |
| 23'5" - 29'5"  | Compact medium brown sand, some gravel.                                   |
| 29'5" - 48'±   | Hard sandy brown clay, some gravel, few boulders and limestone fragments. |
| 48'± - 49'7"   | Compact clayey brown sand, gravel and broken limestone.                   |
| 49'7" - 59'11" | Limestone, poor recovery.   |

#### Boring #6, Elevation 589.9

|               |  |
|---------------|--|
| 0' - 2'10"    | Broken limestone, some clayey sand.                          |
| 2'10" - 14'±  | Sandy medium to medium hard brown clay, some gravel.         |
| 14'± - 41'5"  | Hard sandy and gravelly brown clay, few limestone fragments. |
| 41'5" - 46'±  | Sandy medium brown clay, little gravel.                      |
| 46'± - 55'3"  | Hard sandy and gravelly brown clay, some broken limestone.   |
| 55'3" - 64'3" | Limestone, good to poor recovery.                            |

#### Boring #7, Elevation 590.4

|                 |   |
|-----------------|---|
| 0' - 3'8"       | Loose brown sand, some limestone.                             |
| 3'8" - 7'0"     | Compact clayey brown sand, and broken limestone.              |
| 7'0" - 16'10"   | Hard sandy brown clay, some gravel and broken limestone.      |
| 16'10" - 22'10" | Boulders and hard brown clay.                                 |
| 22'10" - 46'11" | Hard sandy and gravelly brown clay, some limestone fragments. |
| 46'11" - 59'9"  | Limestone, recovery fair.                                     |

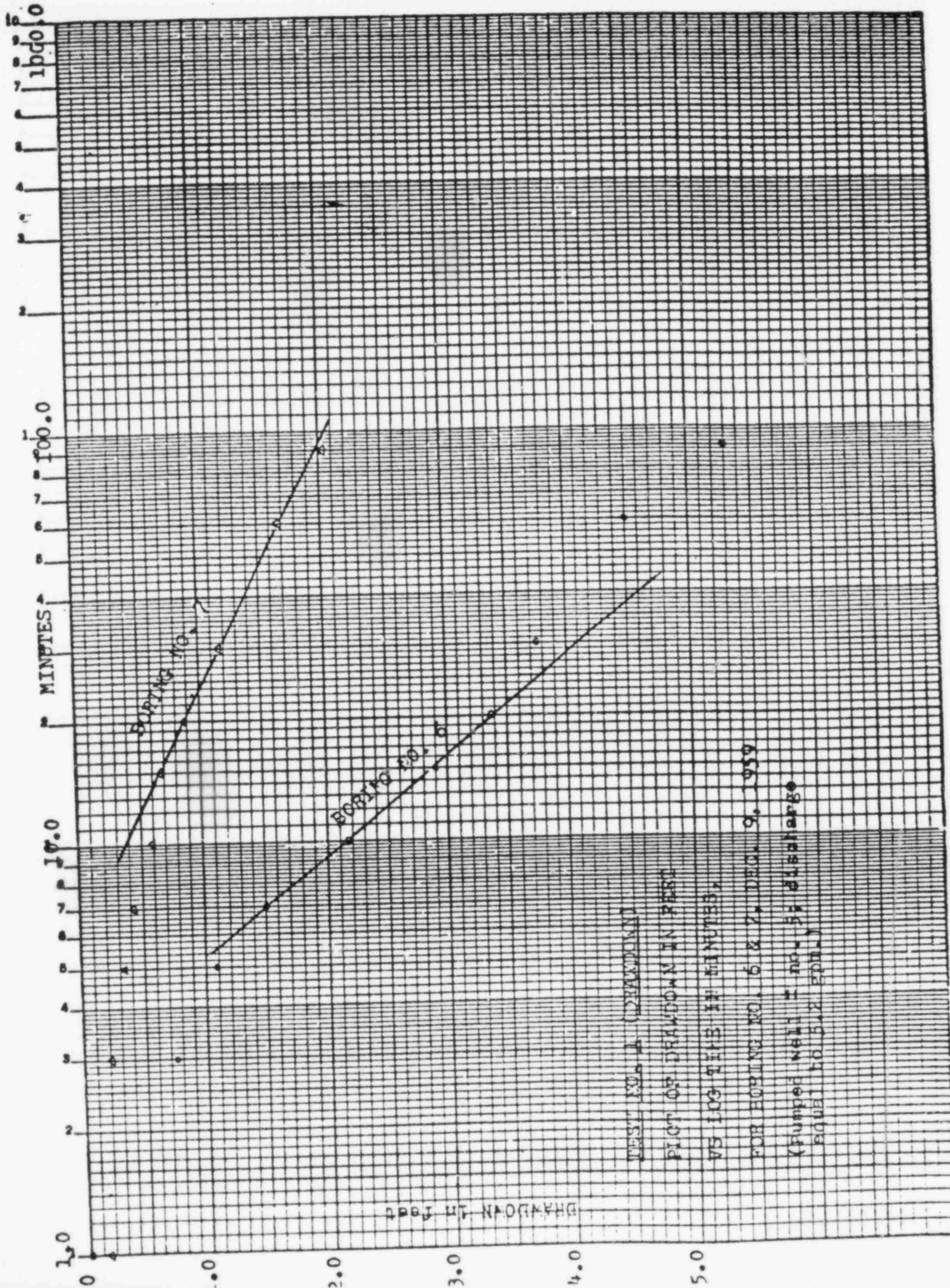
#### Boring #3, Elevation 590.8

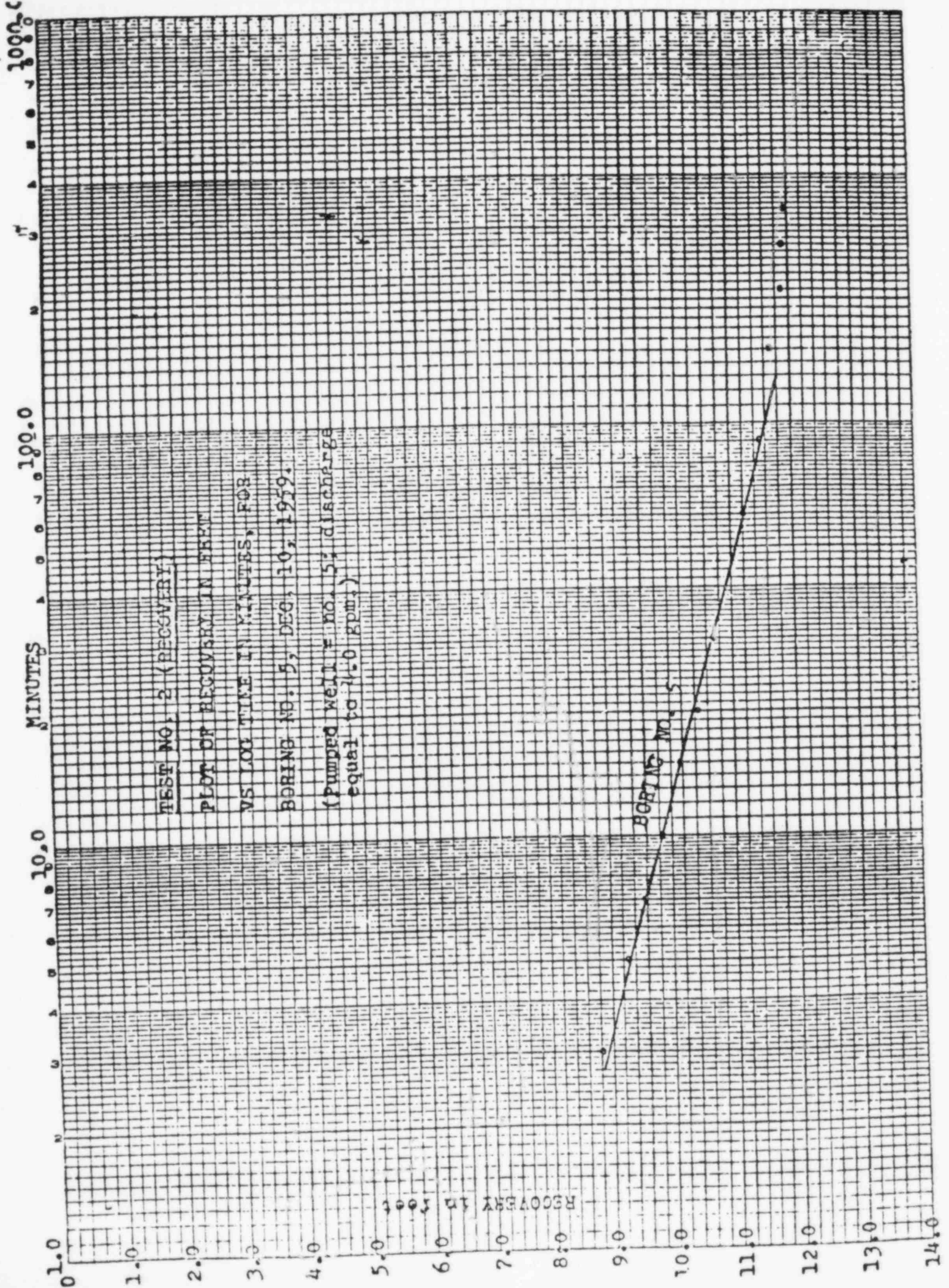
(No log)

\*These logs are from Raymond Concrete Pile Company preliminary reports.

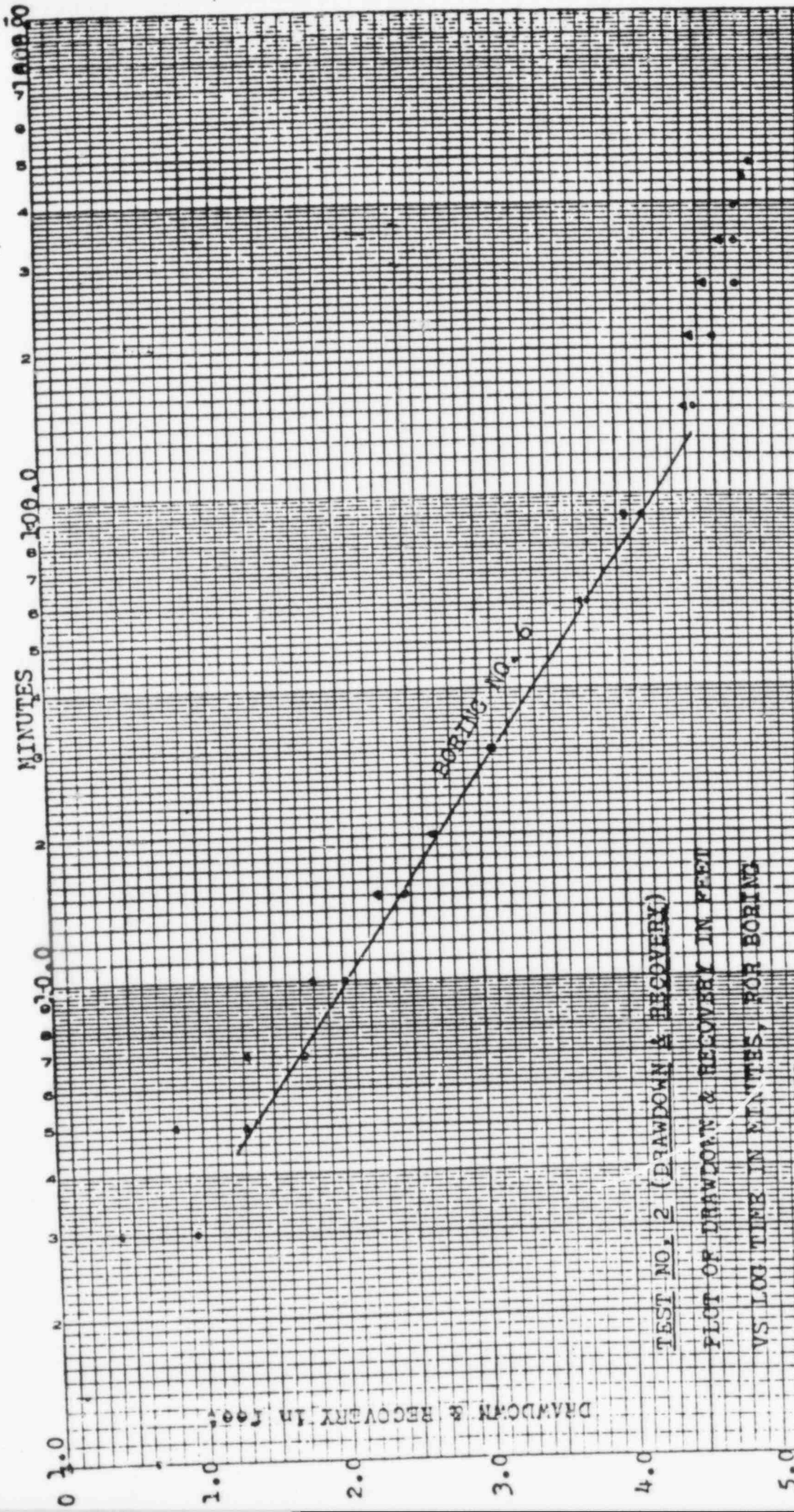


## APPENDIX B









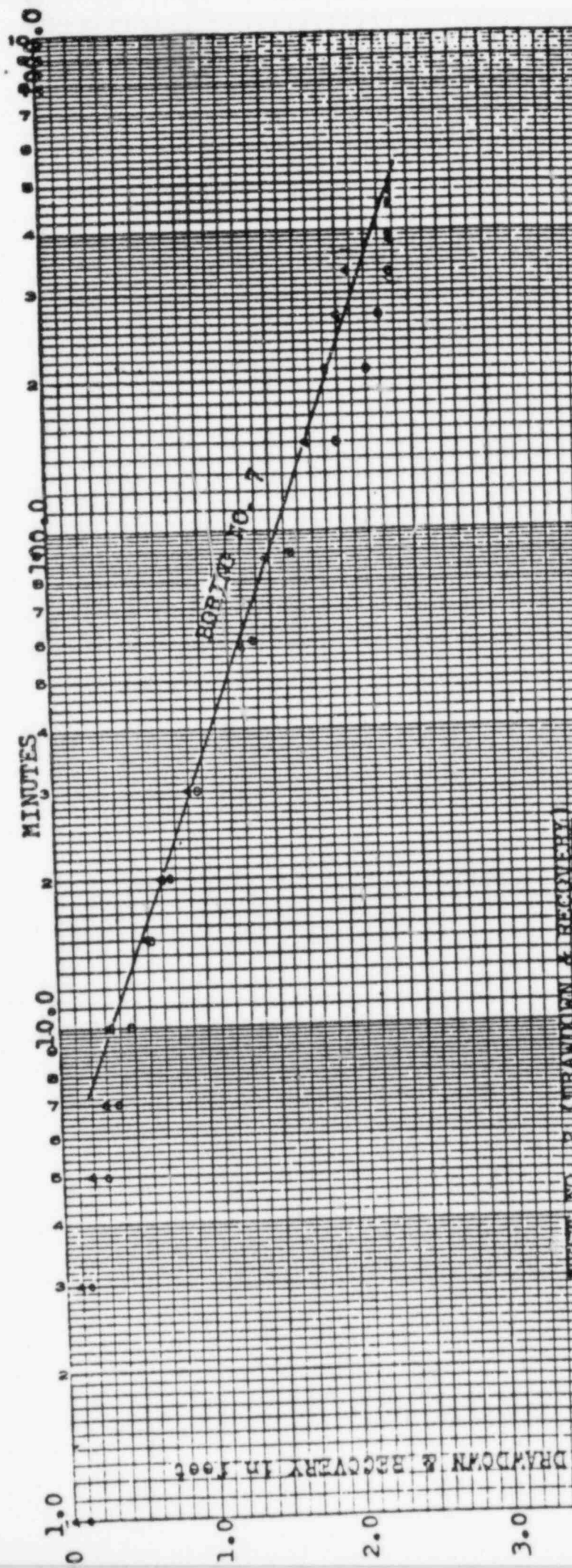
TEST NO. 2 (DRAWDOWN & RECOVERY)

PLOT OF DRAWDOWN & RECOVERY IN FEET

VS LOG TIME IN MINUTES, FOR BORING

NO. 6, DEC. 10, 1959.

(PUMPED WELL - NO. 5; DISCHARGE  
equal to 4.0 gpm.)



# TEST NO. 2 (DRAWDOWN & RECOVERY)

PLOT OF DRAWDOWN & RECOVERY IN FEET  
VS LOG TIME IN MINUTES FOR BORING

NO. 7, DECEMBER, 1919

(Pumped well = no. 5; discharge  
equal to 4.0 GPM.)

## ATTACHMENT II

RESOLUTION OF AIR: BRP-84-20

"DISPOSITION OF CONTAMINATED SOIL"

DECEMBER 20, 1984

prepared by TAHancock



### Discussion and Analysis

Big Rock Point was shut down on May 30, 1984 after samples taken of water leakage into the below grade wall of the radwaste pump room indicated the presence of tritium and iodine-131. The tritium concentration of these samples closely matched that of the main condensate. Evaluation and testing of underground lines indicated a leak in a two-inch diameter aluminum pipe. This pipe carries water from the demineralized water supply and condensate process monitor line to the condensate storage tank (see Figure 1). The pipe was removed, line capped and a temporary line installed.

From an increase in makeup water usage, it was estimated that 20,000 gallons of water were leaked. Analysis was conducted on samples taken from the primary system, condensate storage tank and water puddled at the base of the leaking pipe. A partition factor of 1000 (from NUREG-0016) was applied to the primary sample to account for activity loss across the steam drum before entering the condensate process monitor line. On May 30, a sample of the condensate storage tank was taken and analyzed using gamma spectroscopy (GeLi detector). The samples of the puddled water were taken on July 11, and back decayed to May 30. The concentrations ( $\mu\text{Ci/ml}$ ) and the percentages of total activity of each isotope in the samples are compared below:

Table 1: Source Term Determination

| Nuclide | Primary System |        | Main Condensate Storage Tank |        | Puddled Water From Leak |        |
|---------|----------------|--------|------------------------------|--------|-------------------------|--------|
|         |                |        |                              |        |                         |        |
| Mn-54   | -              | -      | 2.11E-07                     | 1.2%   | 1.74E-06                | 0.8%   |
| Co-60   | 1.94E-07       | 16.6%  | 2.80E-07                     | 1.6%   | 3.16E-06                | 1.5%   |
| I-131   | -              | -      | 1.57E-05                     | 92.1%  | 1.70E-04                | 80.4%  |
| Cs-137  | 5.12E-07       | 43.9%  | 5.85E-07                     | 3.4%   | 2.35E-05                | 11.1%  |
| Cs-134  | 4.61E-07       | 39.5%  | 2.64E-07                     | 1.7%   | 1.30E-05                | 6.2%   |
| Total   | 1.167E-06      | 100.0% | 1.704E-05                    | 100.0% | 2.114E-04               | 100.0% |

The isotopic distribution of the puddled water is very similar to that of the main condensate. The puddled water sample was chosen as the source term because of the greater concentrations present. This will yield the most conservative dose consequences.

Only the four longer lived isotopes were used in the dose calculations. I-131 was not included since by the time the sample was taken (July 11), the concentration was already two orders of magnitude less than the concentration calculated to have been released (May 30). The Cs-134 concentration of the source term was increased to 70% of the Cs-137 concentration on the basis of results of 7 out of 11 soil samples. The resulting source term used in the calculations is as follows:

Table 2: Source Term

| <u>Nuclide</u> | <u>Activity Level (<math>\mu\text{Ci}</math>)*</u> |
|----------------|--|
| Co-60          | 238.46   |
| Mn-54          | 132.48   |
| Cs-137         | 1,741.10   |
| Cs-134         | 1,218.77   |

\*Total activity in 20,000 gallons

On July 11, 1984, soil samples were taken near the area of the line failure. Samples were taken at three depths, just below the turbine building concrete, at one foot below the concrete and at four feet below the concrete. Five samples were taken at each depth. These samples were analyzed for radionuclide concentration. Just below the turbine building floor, maximum total soil contamination was  $1.3\text{E-}03 \mu\text{Ci/gram}$ . At a depth of one foot below the turbine building floor, maximum total soil contamination was  $1.7\text{E-}02 \mu\text{Ci/gram}$ . At a depth of four feet below the turbine building floor, maximum total soil contamination was  $1.2\text{E-}03 \mu\text{Ci/gram}$ . Also, at the four-foot depth, water samples were taken. Analysis of the unfiltered water sample resulted in a total contamination of  $8.5\text{E-}05 \mu\text{Ci/ml}$ . The location and total activity of each soil sample are indicated on Figure 2. A listing of the results of the samples is presented in Table 3.

Additional soil samples were taken to determine the spread of contamination resulting from the condensate makeup line leak. Nine sampling locations were chosen (Figures 3 and 4). Samples were taken at approximately one-foot intervals to a depth of about ten feet, when possible, as measured from the track alley floor (including the two locations outside the building). The activity of individual isotopes in each sample and the location of maximum activity of each isotope are listed in Tables 4 and 5. The total concentration in each sample is recorded below:

Table 6: Total Concentration\* ( $\mu\text{Ci}/\text{gram}$ ) of Samples

| Depth<br>(Ft) | Sampling Location |         |         |         |         |         |         |         |         |
|---------------|-------------------|---------|---------|---------|---------|---------|---------|---------|---------|
|               | 1                 | 2       | 3       | 4       | 5       | 6       | 7       | 8       | 9       |
| 0- 1          |                   | 3.4E-07 |         |         |         |         |         |         |         |
| 1- 2          | 1.3E-07           |         | 8.8E-07 | 1.4E-07 | 3.2E-07 | 5.6E-07 | 2.3E-07 | <MDA    | <MDA    |
| 2- 3          |                   | 6.7E-07 | 3.4E-06 | <MDA    | 8.4E-07 | 2.0E-06 | 1.2E-06 | <MDA    | <MDA    |
| 3- 4          | 9.2E-08           |         | 6.6E-06 | 7.3E-07 | 2.4E-06 | 2.6E-06 | 1.1E-06 | 9.5E-07 | 7.8E-08 |
| 4- 5          |                   | 1.1E-06 | 3.2E-06 | <MDA    | <MDA    | 1.2E-06 | 9.6E-07 | 1.9E-06 | <MDA    |
| 5- 6          | <MDA              |         |         | 7.4E-07 | 4.4E-08 | 1.8E-07 | 4.4E-07 | <MDA    | <MDA    |
| 6- 7          |                   | 7.7E-08 |         |         |         |         |         | 2.2E-07 | 3.2E-07 |
| 7- 8          |                   |         |         |         |         |         |         | <MDA    |         |
| 8- 9          |                   | 1.6E-07 |         |         |         |         |         |         |         |
| 9-10          |                   |         |         |         |         |         |         |         |         |
| 10-11         |                   | 1.1E-07 |         |         |         |         |         |         |         |

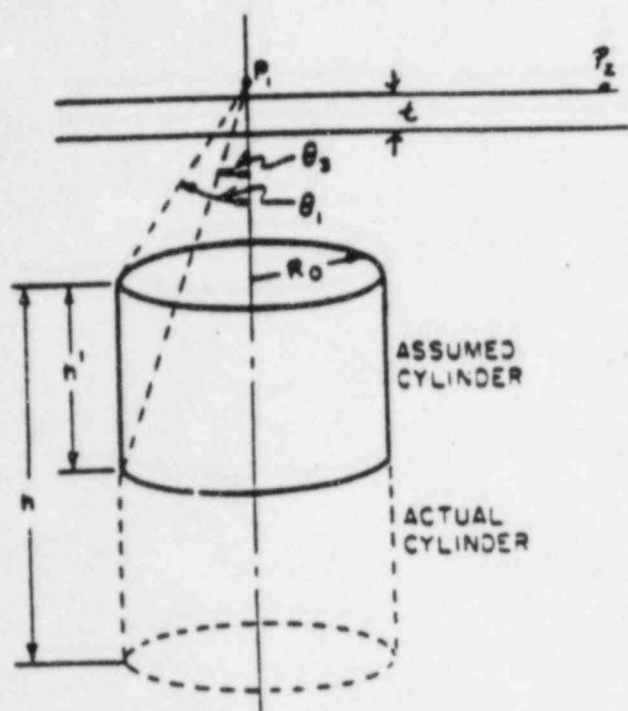
\*Background concentrations not corrected for.

The Cs-137 concentrations are important when looking at the transport through the soil since it has a long half-life and is most likely to reach the lake. The Cs-137 distribution as determined by the sampling described above is presented in Figure 5.

#### Calculations

In order to determine the potential doses to workers and to the general population due to leaving the contaminated soil in place, calculations of direct exposure to the contaminated soil, of exposure from inhalation of resuspended particles, and of exposure to radionuclides transported to the lake through groundwater were performed.

The dose rate to workers due to direct exposure was calculated by modeling the contaminated soil as a cylinder shielded by eight inches of concrete (the turbine building floor). The method of calculation was derived from Theodore Rockwell's Reactor Shielding Design Manual, (p 364).



$$R_0 = 4.45 \text{ m}$$

$$h = 1.22 \text{ m}$$

$$t = 8'' = 0.203 \text{ m}$$

$$\phi = \frac{BSv}{2\mu_s} [E_2(b_1) - \frac{E_2(b_1 \sec \theta_1)}{\sec \theta_1}]$$

where  $S_v$  = Volume Source Strength  
 $B$  = buildup factor  
 $\mu_s$  = attenuation coefficient of source material  
 $b_1 = \sum_i N_i t_i$   
 $t$  = thickness of shield

$$E_2(b) = b \int_b^{\infty} \frac{e^{-t}}{t^2} dt$$

$$\dot{D} = \frac{\phi}{\phi \text{ to give } 1R/hr}$$

Figure 6: Dose to Workers

The source is modeled assuming an isotropic distribution to a depth where the groundwater is believed to begin. This assumption will yield conservative results, as in reality, the source will sink to a greater depth where it will merge with the water table and be diluted. Also, the total source strength is taken as 1 MeV gammas again contributing to conservative results since most of the isotopes yield gammas of lower energy. This method results in a dose rate of  $9.28E-04$  mrem/hr to the workers (refer to calculation folder for details).

The dose rate to the general population at the site boundary, due to direct exposure to the contaminated soil, could be calculated as the dose at Point 2 (as labeled in Figure 6); this dose rate is expected to be negligible. For conservatism, and ease of calculation, it is assumed the cylinder is directed toward the site boundary.

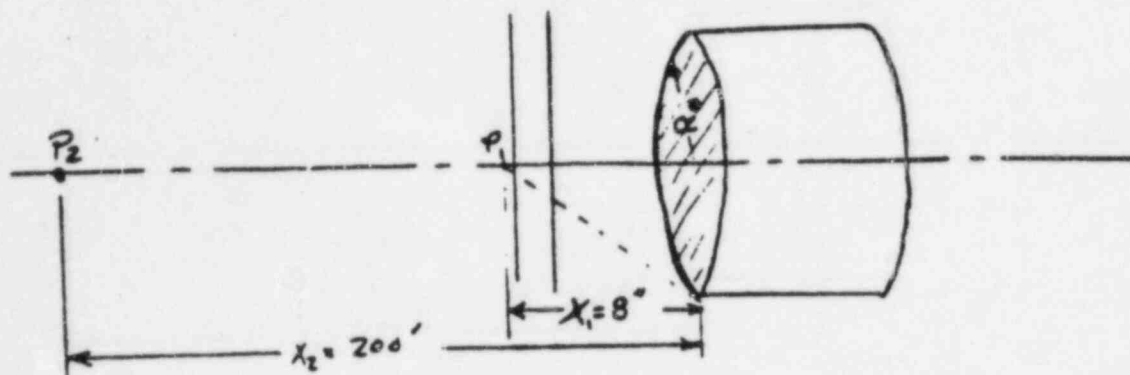


Figure 7: Dose to Population at the Site Boundary

To a point at the site boundary, the source can be taken as a disk source and the dose rate can be quickly determined.

$$\dot{D} = \frac{S}{4\pi R/\text{hr}} \ln \left( 1 + \frac{R_0^2}{X^2} \right) \text{ for a disk source}$$

$$\dot{D} (\text{Point 2}) = \frac{\dot{D} (\text{Point 1}) \ln \left( 1 + \frac{R_0^2}{X_2^2} \right)}{\ln \left( 1 + \frac{R_0^2}{X_1^2} \right)}$$

Using this method, the dose rate to population at the site boundary was found to be  $1.03\text{E-}07$  mrem/hr.

The doses due to inhalation of resuspended particles were calculated to determine the effect of removing the concrete slab above the contaminated soil. A volume fraction of concrete to contaminated soil of  $4\text{E-}05$  was used to determine the source term in air. To determine if this activity posed a hazard during concrete removal, the amount of activity required to produce (by acute exposure) 40 MPC-hours was calculated assuming an employee works in the general vicinity 40 hours per week. This amount of activity was then ratioed with the suspended source term, the results of which show no MPC burdens were exceeded.

The population dose from atmospheric dispersion of this contaminated concrete dust was also investigated. The maximum doses to the total body were calculated using the GASPAR computer code. The doses are reported in mrem using a population of  $1.54\text{E-}05$  spanning a 50-mile radius. The total body dose from all radionuclides in the source term is  $6.36\text{E-}08$  mrem. This yields a



dose of  $4.14\text{E-}10$  mrem per average person in a 50-mile radius. The dose contributions of the individual isotopes are presented below:

#### Determination of Doses Due to Inhalations

| Nuclide | Activity<br>[ $\mu\text{Ci}$ ] | Occupational                     |                      | Population                                      |
|---------|--------------------------------|----------------------------------|----------------------|---|
|         |                                | $A_{40}^*$<br>[ $\mu\text{Ci}$ ] | Activity<br>$A_{40}$ | Manrem Total Body<br>Population Within 50 Miles |
| Mn-54   | $5.30\text{E-}03$              | 1.34                             | $4.0\text{E-}03$     | $2.64\text{E-}10$                               |
| Co-60   | $9.50\text{E-}03$              | 5.76                             | $1.6\text{E-}03$     | $7.26\text{E-}09$                               |
| Cs-137  | $6.96\text{E-}02$              | 0.144                            | $4.8\text{E-}01$     | $3.43\text{E-}08$                               |
| Cs-134  | $4.88\text{E-}02$              | 0.096                            | $5.1\text{E-}01$     | $2.18\text{E-}08$                               |

\* $A_{40}$  is the amount of activity required to produce 40 MPC-hours burden.

NOTE: Biological data taken from ICRP 2;  $\text{MPC}_{\text{air}}$  taken from 10 CFR 20, Appendix B, Table 1, Column 1.

Two cases were considered for the dose due to migration of radionuclides into Lake Michigan. Case 1, a worse case situation, examines the dose consequences as if the 20,000 gallon source term (Table 2) were to be released into Lake Michigan as a liquid batch release. Case 2 examines the consequences from the release after traversing approximately 89 meters of soil to the lake by groundwater flow. This case was calculated by using ANSI/ANS-2.17-1980: "Evaluation of Radionuclide Transport in Groundwater for Nuclear Power Sites." This model employs geohydraulic and geometrical parameters as a function of radioactive decay to account for retardation of radionuclides by sorption onto/into soil. The following equation was used:

$$c = \frac{m'}{4 R_d N \sqrt{\pi E_x t}} \exp \left[ - \left( \frac{(x - Vt)^2}{4 E_x t} + \lambda t \right) \right] \times \left[ \operatorname{erf} \frac{y + F/2}{2 \sqrt{E_y t}} - \operatorname{erf} \frac{y - F/2}{2 \sqrt{E_y t}} \right] \frac{\mu\text{Ci}}{\text{m}^3}$$

- c concentration of radioisotope
- m activity per unit area of source
- n Porosity of soil (void fraction of the medium equal to 0.2)
- t time since release
- x distance away from source (down lake in the direction of groundwater flow)
- $\lambda$  radioactive decay constant
- y radius of source
- f width of source
- $K_d$  distribution coefficient (a measure of the reaction between the contaminant, the fluid, and the medium, taken equal to 0.0)
- $R_d$  retardation coefficient (a measure of the capability of the porous medium to impede, by sorption, the movement of a particular radionuclide carried by the fluid =  $1 + \rho(K_d/N)$  taken as 1.0)
- $\rho_b$  bulk density of the soil



- $D_i$  dispersion coefficient (relates the concentration of a contaminant to the flux of contaminant)  
 $a_L$  longitudinal dispersivity (radius of source)  
 $V_x$  hydraulic velocity of groundwater, equal to 0.015 m/d

$$E_i = \frac{D_i}{R_d} \quad D_i = A_L \frac{V_x}{n} \quad V = \frac{V_x}{nR_d}$$

Numerical values for the parameters are given in the calculation folder. The expected concentrations of individual radionuclides were calculated for various times and distances from the source. Note that the time of release was taken as May 30, 1984. This was the day the condensate pumps were shut down and the leak was stopped. It is believed the leak began earlier; however, due to lack of an exact date May 30 was used. The rate of groundwater flow to the lake is 0.035 m/day. This results in a seven-year travel time for the radionuclides to reach the lake (89 meters). Using the above equation to account for retardation in the soil, the concentrations of each isotope reaching the lake were calculated ( $x = 89$  m,  $t = 2,500$  days).

Table 7: Concentrations at Lake

| Nuclide | Concentration [ $\mu\text{Ci/ml}$ ] |
|---------|-------------------------------------|
| Mn-54   | 2.50E-10                            |
| Co-60   | 5.64E-09                            |
| Cs-137  | 9.00E-08                            |
| Cs-134  | 1.92E-08                            |

The dose rate to the general population due to a liquid batch release (Case 1) was determined using the LADTAP Code (Liquid Annual Dose To All Persons). The code was run for two cases - the total source release at once and the total source released over seven years time. The resultant dose consequences for the adult total body and limiting age group critical organ for both Cases 1 and 2 are presented in Table 8.

Table 8: Release to Lake

| Case | Dose Consequences | mrem<br>Yr Intake |
|------|-------------------|-------------------|
| 1    | Adult Total Body  | 7.89E-03          |
|      | Teen Liver        | 1.14E-02          |
| 2    | Adult Total Body  | 1.13E-03          |
|      | Teen Liver        | 1.62E-03          |

The dose calculation of Case 1 uses a Cs-137 concentration of  $1.74\text{E-}03$  Ci/yr. The concentration actually reaching the lake is  $6.8\text{E-}06$  Ci/yr (ie,  $9.00\text{E-}08$   $\mu\text{Ci/ml} \times 20,000$  gal  $\times 3,785$  ml/gal  $\times 10^{-6}$  Ci/ $\mu\text{Ci}$  in a single release)

∴ the actual dose to the population will be on the order of 1E-05 mrem, much less than the five millirem annual dose limit defined in 10 CFR 50 Appendix I.

### Summary of Results

The quantities of radionuclides released onsite and into Lake Michigan have been estimated and found not to exceed the limits defined by 10 CFR 20.106 (Radioactive Effluents to Unrestricted Areas) or by 10 CFR 30.14 (Exempt Concentrations).

Table 9: Summary of Releases

| Nuclide | May 30<br>Leak Concentration<br>[μCi/ml] | Concentration <sup>1</sup><br>Released to<br>Lake [μCi/ml] | Concentration <sup>2</sup><br>Released to<br>Lake [μCi/ml] | 10 CFR 20.106*<br>MPC<br>[μCi/ml] | 10 CFR 30.14*<br>[μCi/ml] |
|---------|--|--|--|-----------------------------------|---------------------------|
| Co-60   | 3.15E-06                                 | 1.26E-06   | 5.64E-09   | 5E-05                             | 5E-05                     |
| Mn-54   | 1.75E-06                                 | 6.22E-09   | 2.50E-10   | 1E-04                             | 1E-03                     |
| Cs-137  | 2.30E-05                                 | 1.96E-05   | 4.00E-08   | 2E-05                             | Not Listed                |
| Cs-134  | 1.61E-05                                 | 1.54E-06   | 1.92E-08   | 9E-06                             | 9E-05                     |

<sup>1</sup>Radioactive decay (7 years) taken into account

<sup>2</sup>Radioactive decay as well as sorption and retardation in the soil considered for X = 89 meters and t = 2,500 days

\*From 10 CFR 20, Appendix B, Table II, Column 2, Soluble Concentrations

†From 10 CFR 30.70, Column II

In addition to the limits on quantities of individual isotopes released to unrestricted areas, limits for combinations are defined in 10 CFR 20.106 and 10 CFR 30.14.

10 CFR 30.14 as per § 30.70

$$\text{limit for combination} = \sum \frac{\text{concentration of isotope}}{\text{exempt concentration}} \leq 1$$

$$\text{At Lake}^1 = \frac{1.26\text{E-}06}{5\text{E-}05} + \frac{6.22\text{E-}09}{1\text{E-}03} + \frac{1.54\text{E-}06}{9\text{E-}05} = 0.042$$

10 CFR 20.106 as per § 20, App B

$$\text{limit for combination} = \sum \frac{\text{concentration of isotope}}{\text{MPC isotope}} \leq 1$$

$$\text{At Lake}^1 = \frac{1.26\text{E-}06}{5\text{E-}05} + \frac{6.22\text{E-}09}{1\text{E-}04} + \frac{1.96\text{E-}05}{2\text{E-}05} + \frac{1.54\text{E-}06}{9\text{E-}06} = 1.18$$

But, taking sorption and retardation of the isotopes during transport through the soil into account:

$$\text{At Lake}^2 = \frac{5.64\text{E-}09}{5\text{E-}05} + \frac{2.5\text{E-}10}{1\text{E-}04} + \frac{9.0\text{E-}08}{2\text{E-}05} + \frac{1.92\text{E-}08}{9\text{E-}06} = 0.007$$

Since the release of radioactivity in this case is well within the limits of 10 CFR 20.106, the requirements of 10 CFR 20.302 (Method for Obtaining Approval of Proposed Disposal Procedures) do not apply.

The potential doses to workers and to the general population due to leaving the contaminated soil in place have been determined. The results are presented below:

Table 10: Summary of Occupational and General Population Doses

| Exposure Pathways   |                  | Occupational<br>Doses                    | General<br>Population<br>Doses                    |
|---|------------------|--|---|
| Direct exposure and shine   |                  | 9.28E-04 $\frac{\text{mrem}}{\text{hr}}$ | 1.03E-07 $\frac{\text{mrem}}{\text{hr}}$          |
| Nuclides transported to Lake Michigan<br>through groundwater                        |                  |  |   |
| Single batch release  | Adult Total Body | -  | 7.89E-03 $\frac{\text{mrem}}{\text{year intake}}$ |
|   | Teen Liver       | -  | 1.14E-02 $\frac{\text{mrem}}{\text{year intake}}$ |
| Released over 7 years   | Adult Total Body | -  | 1.13E-03 $\frac{\text{mrem}}{\text{year intake}}$ |
|   | Teen Liver       | -  | 1.62E-03 $\frac{\text{mrem}}{\text{year intake}}$ |
| Single release after 7 years<br>(retardation and sorption by soil<br>accounted for) |                  | -  | 1E-05 $\frac{\text{mrem}}{\text{year intake}}$    |
| Inhalation of resuspended particles   |                  | *  | 4.14E-10 mrem                                     |

\*The activity of the suspended source term does not exceed the amount necessary to deliver a 40 MPC-hour burden.

10 CFR 20.101(a) states that no occupationally exposed individual shall receive in any calendar quarter a dose to the "whole body, head and trunk, active blood forming organs, lens of the eye or gonads" in excess of 1.25 rem. As shown above the dose at the surface of the turbine floor would be 9.28E-4 mrem/hr. Thus, even if a worker was to lay on the turbine floor

continuously for the quarter a dose of only 2.03 mrem would be given and the federal limit would not be exceeded.

10 CFR 20.103(a) references occupational exposure by inhalation. It is recognized that the inhalation potential proposed previously is highly unlikely and very conservative in its approach; however, for purposes of doing a complete analysis it was undertaken. Calculations show no worker will be or has been exposed to airborne concentrations required to exceed 40 MPC hours.

10 CFR 20.105(b)(1) and (2) concerns direct exposure of the general public in an unrestricted area. As shown earlier, a person would be able to stand at the site boundary fence and conservatively receive a dose of  $1.03\text{E-}07$  mrem/hr thus not exceeding the federal limits of 2 mrem/hr or 100 mrem in seven consecutive days.

10 CFR 20.106(d) is concerned with concentrations of radioactive material released through a pipe, stack or other conduit at the boundary of the restricted area. As stated, these concentrations "may be determined by applying appropriate factors for dilution, dispersion or decay between the point of discharge and the boundary." The source term for liquid effluent release to Lake Michigan is below Appendix B limits at the source. The results using the LADTAP code show that dose consequences to the general public using worse case assumptions are negligible.

10 CFR 50, Appendix I states that "the calculated annual total quantity of all radioactive material from all light-water-cooled nuclear power reactors at a site should not result in an annual dose or dose commitment to the total body or to any organ of an individual in an unrestricted area from all pathways of exposure in excess of 5 millirems." As shown in Table 10, if a teenager were to stand at the site boundary and in the lake for a full year, the total dose received would be  $1.23\text{E-}02$  mrem (ie,  $1.03\text{E-}07$  mrem/hr direct exposure  $\times$  8,760 hours/year +  $1.14\text{E-}02$  mrem/year intake).

Table 3: Soil and Unfiltered Water Samples Near Line Failure

| Depth<br>(ft) | Concentrations [μCi/gram] 7/10/84 |         |        |         |         |        |        |        |        |         |         |        | Total  |
|---------------|-----------------------------------|---------|--------|---------|---------|--------|--------|--------|--------|---------|---------|--------|--------|
|               | Mn-54                             | Co-58   | Fe-59  | Co-60   | Zn-65   | Ag-110 | I-131  | Cs-134 | Cs-136 | Cs-137  | Nb-95   | La-140 |        |
| Location A    |                                   |         |        |         |         |        |        |        |        |         |         |        |        |
| 0             | 1.32E-4                           | 6.3E-6  | 7.8E-5 | 7.6E-05 | -       | 1.2E-5 | 7.4E-4 | 3.8E-4 | 2.0E-5 | 5.4E-4  | 1.7E-05 | 6.2E-5 | 1.3E-3 |
| 1             | 8.7E-6                            | -       | 3.7E-6 | 6.6E-6  | -       | 2.2E-6 | 1.3E-4 | 6.7E-5 | 3.3E-6 | 1.0E-4  | 1.8E-6  | -      | 3.3E-4 |
| 4             | 4.1E-5                            | 2.2E-6  | 2.4E-5 | 3.2E-5  | -       | 8.4E-6 | 1.2E-4 | 4.1E-4 | 1.8E-5 | 5.6E-4  | -       | 8.6E-6 | 1.2E-3 |
| Location B    |                                   |         |        |         |         |        |        |        |        |         |         |        |        |
| 0             | 1.95E-6                           | 1.95E-6 | 1.2E-5 | 1.8E-5  | -       | -      | 2.8E-4 | 1.6E-4 | 8.8E-6 | 2.2E-4  | 2.5E-6  | 8.2E-6 | 7.3E-4 |
| 1             | 4.5E-4                            | 4.8E-6  | 2.4E-4 | 3.6E-4  | -       | 8.6E-5 | 3.2E-4 | 6.0E-4 | 3.1E-4 | 8.7E-3  | -       | 9.7E-5 | 1.7E-2 |
| 4             | 1.9E-5                            | 1.5E-6  | 1.2E-5 | 1.7E-5  | -       | 6.3E-6 | 1.6E-4 | 1.7E-4 | 1.1E-5 | 2.4E-4  | 1.2E-6  | -      | 6.3E-4 |
| Location C    |                                   |         |        |         |         |        |        |        |        |         |         |        |        |
| 0             | 3.9E-5                            | 3.1E-6  | 1.9E-5 | 2.9E-5  | -       | 4.3E-6 | 3.3E-4 | 8.6E-5 | 6.4E-6 | 1.3E-4  | 2.9E-6  | 9.8E-6 | 6.6E-4 |
| 1             | 1.2E-4                            | 9.1E-6  | 6.4E-5 | 8.2E-5  | 4.9E-6  | 2.3E-5 | 9.9E-5 | 3.7E-4 | 2.1E-5 | 5.3E-4  | 1.5E-5  | -      | 1.4E-3 |
| 4             | 2.7E-5                            | 1.9E-6  | 1.7E-5 | 2.1E-5  | -       | 4.2E-6 | 5.6E-5 | 1.1E-4 | 5.2E-6 | 1.5E-4  | 2.4E-6  | -      | 3.9E-4 |
| Location D    |                                   |         |        |         |         |        |        |        |        |         |         |        |        |
| 0             | 1.0E-5                            | 1.0E-6  | 7.9E-6 | 7.1E-6  | -       | -      | 1.3E-5 | 5.3E-5 | 3.1E-6 | 7.1E-5  | -       | -      | 1.7E-4 |
| 1             | 8.5E-6                            | 4.1E-7  | 4.1E-6 | 5.4E-6  | -       | 2.1E-6 | 6.6E-5 | 5.1E-5 | 2.2E-6 | 7.7E-5  | -       | -      | 2.2E-4 |
| 4             | 2.0E-5                            | 1.8E-7  | 1.1E-5 | 1.5E-5  | -       | 3.1E-6 | 7.5E-5 | 9.9E-5 | 2.2E-6 | 1.4E-4  | 1.2E-6  | -      | 3.7E-4 |
| Location E    |                                   |         |        |         |         |        |        |        |        |         |         |        |        |
| 0             | 1.1E-5                            | 6.0E-7  | 6.3E-6 | 1.2E-5  | -       | -      | 1.3E-5 | 3.1E-5 | 2.0E-6 | 4.2E-5  | 9.2E-7  | -      | 1.2E-4 |
| 1             | 3.4E-6                            | -       | 1.7E-6 | 3.0E-6  | -       | 1.6E-6 | 1.9E-5 | 1.6E-5 | -      | 2.5E-5  | -       | -      | 6.9E-5 |
| 4             | 5.0E-6                            | -       | 1.8E-6 | 3.9E-6  | 3.1E-6* | 1.5E-6 | 2.2E-5 | 3.0E-5 | 1.7E-6 | 4.32E-5 | -       | -      | 1.1E-4 |

\*From unfiltered water sample

| Unfiltered Water Sample |        |   |   |        |   |   |         |         |   |         |   |   |         |
|-------------------------|--------|---|---|--------|---|---|---------|---------|---|---------|---|---|---------|
| 4                       | 3.4E-6 | - | - | 2.6E-6 | - | - | 1.0E-05 | 1.2E-05 | - | 1.5E-05 | - | - | 4.3E-05 |



Table 4: Activity in Soil Samples

| Depth<br>(ft) | Grams              | Mn-54   | Concentrations [ $\mu\text{Ci/gm}$ ] |         |         |         |
|---------------|--------------------|---------|--------------------------------------|---------|---------|---------|
|               |                    |         | Co-60                                | Cs-137  | Cs-134  | I-131   |
| Location No 1 |                    |         |                                      |         |         |         |
| 1-2           | 792                | 1.3E-07 |                                      |         |         |         |
| 2-4           | 780                | 9.2E-08 |                                      |         |         |         |
| 4-6           | 833                | <MDA    |                                      |         |         |         |
| Location No 2 |                    |         |                                      |         |         |         |
| BKG           |                    |         |                                      |         |         |         |
| 0-1           | 606                |         | 3.4E-07 (3.2-7)                      |         |         |         |
| 1-3           | 623                |         | 5.2E-07 (3.1-7)                      | 1.5E-07 |         |         |
| 3-5           | 456                |         | 6.4E-07 (4.2-7)                      | 4.2E-07 |         |         |
| 5-7           | 1141               | 4.6E-08 |                                      | 3.1E-08 |         |         |
| 7-9           | 1196               |         | 1.6E-07 (1.6-7)                      |         |         |         |
| 9-11          | 1570               |         | 1.1E-07 (1.2-7)                      |         |         |         |
| Location No 3 |                    |         |                                      |         |         |         |
| 1-2           | 617                | 1.2E-07 | 4.9E-7 (3.1-7)                       | 2.6E-07 |         |         |
| 2-3           | 645                | 1.4E-07 | 4.8E-7 (3.6-7)                       | 1.7E-06 | 1.1E-06 |         |
| 3-4           | 668                | 2.8E-07 | 6.7E-07 (2.9-7)                      | 3.2E-06 | 1.7E-06 | 1.5E-07 |
|               | (Ag 110 m 5.5E-07) |         |                                      |         |         |         |
| 4-5           |                    |         | 1.2E-06                              | 1.2E-06 | 8.3E-07 |         |
| Location No 4 |                    |         |                                      |         |         |         |
| 1-2           | 704                | 1.4E-07 |                                      |         |         |         |
| 2-3           | 654                | <MDA    |                                      |         |         |         |
| 3-4           | 746                |         | 4.5E-7 (2.6-7)                       | 2.8E-07 |         |         |
| 4-5           | 844                | <MDA    |                                      |         |         |         |
| 5-6           | 671                |         | 4.3E-7 (2.9E-7)                      | 3.1E-07 |         |         |
| Location No 5 |                    |         |                                      |         |         |         |
| 1-2           | 500                | 1.3E-07 |                                      | 1.9E-07 |         |         |
| 2-3           | 481                |         | 3.8E-7 (4E-7)                        | 4.6E-7  |         |         |
| 3-4           | 718                |         |                                      | 1.8E-07 | 5.6E-08 |         |
| 4-5           | 950                | <MDA    |                                      |         |         |         |
| 5-6           | 994                |         | 4.4E-08                              |         |         |         |
| Location No 6 |                    |         |                                      |         |         |         |
| 1-2           | 780                |         | 3.6E-7 (2.5-7)                       | 2.0E-07 |         |         |
| 2-3           | 696                | 7.4E-08 | 3.2E-7 (2.8-7)                       | 8.8E-07 | 6.7E-07 | 5.8E-08 |
| 3-4           | 628                | 4.1E-07 | 5.8E-7 (3.1-7)                       | 9.9E-07 | 6.1E-07 |         |
| 4-5           | 609                | 6.1E-07 | 5.1E-07                              | 9.8E-08 |         |         |
| 5-6           | 916                | 9.3E-08 | 8.6E-8                               |         |         |         |
| Location No 7 |                    |         |                                      |         |         |         |
| 1-2           | 816                |         |                                      | 2.3E-07 |         |         |
| 2-3           | 536                | 1.7E-07 | 5.7E-07                              | 4.5E-07 |         |         |
| 3-4           | 653                |         | 7.9E-07                              | 3.1E-07 |         |         |
| 4-5           | 599                |         | 6.5E-07                              | 3.1E-07 |         |         |
| 5-6           | 1353               |         | 3.4E-07                              | 9.7E-08 |         |         |

(Continued)



Table 4: Activity in Soil Samples (Contd)

| Depth<br>(ft) | Grams | Concentrations [ $\mu\text{Ci/gm}$ ] |         |         |        | I-131 |
|---------------|-------|--------------------------------------|---------|---------|--------|-------|
|               |       | Mn-54                                | Co-60   | Cs-137  | Cs-134 |       |
| Location No 8 |       |                                      |         |         |        |       |
| 1-2           | <MDA  |                                      |         |         |        |       |
| 2-3           | <MDA  |                                      |         |         |        |       |
| 3-4           | 610   |                                      | 6.8E-07 | 2.7E-07 |        |       |
| 4-5           | 392   |                                      | 1.3E-06 | 5.7E-07 |        |       |
| 5-6           | 803   |                                      | <MDA    |         |        |       |
| 6-7           | 1191  |                                      | <MDA    | 2.2E-07 |        |       |
| 7-8           | 992   |                                      | <MDA    |         |        |       |
| Location No 9 |       |                                      |         |         |        |       |
| 1-2           | 542   | <MDA                                 |         |         |        |       |
| 2-3           | 529   | <MDA                                 |         |         |        |       |
| 3-4           | 562   |                                      |         | 7.8E-08 |        |       |
| 4-5           | 681   | <MDA                                 |         |         |        |       |
| 5-6           | 962   | <MDA                                 |         |         |        |       |
| 6-7           | 1191  |                                      | 2.5E-07 | 6.5E-08 |        |       |

Table 5: Location of Maximum Concentration

| Sample<br>Location | Depth | Maximum Concentration [ $\mu\text{Ci/gm}$ ] |         |         |         |         |
|--------------------|-------|---|---------|---------|---------|---------|
|                    |       | Mn-54                                       | Co-60   | Cs-137  | Cs-134  | I-131   |
| 6                  | 4'-5' | 6.1E-07                                     |         |         |         |         |
| 8                  | 4'-5' |   | 1.3E-06 |         |         |         |
| 3                  | 3'-4' |   |         | 3.2E-06 |         |         |
| 3                  | 3'-4' |   |         |         | 1.7E-06 |         |
| 3                  | 3'-4' |   |         |         |         | 1.5E-07 |

Figure 1

BIG ROCK POINT PLANT DWG. 0740G44011 SHEET 2, REVISION 3  
INFORMATION COPY

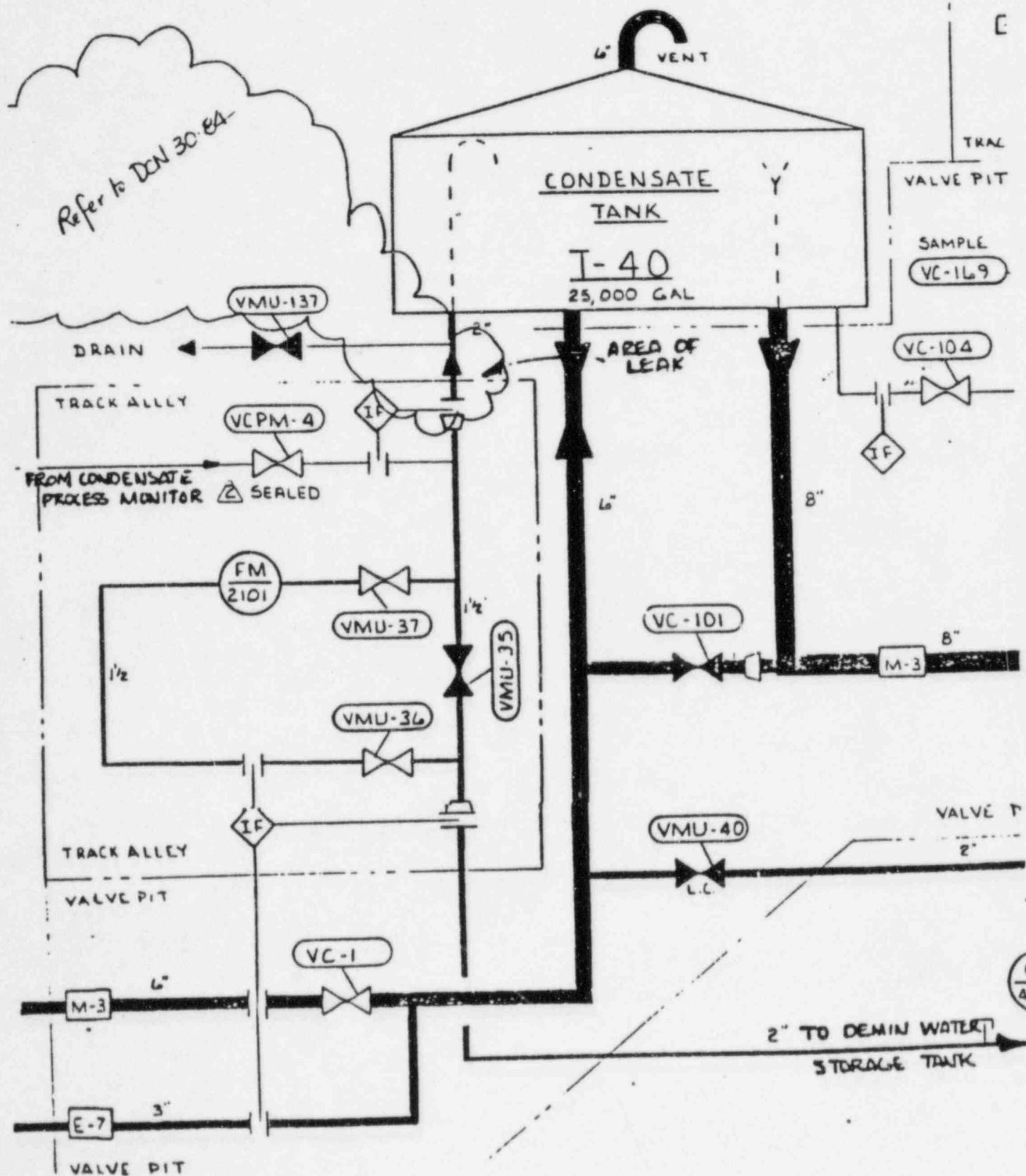
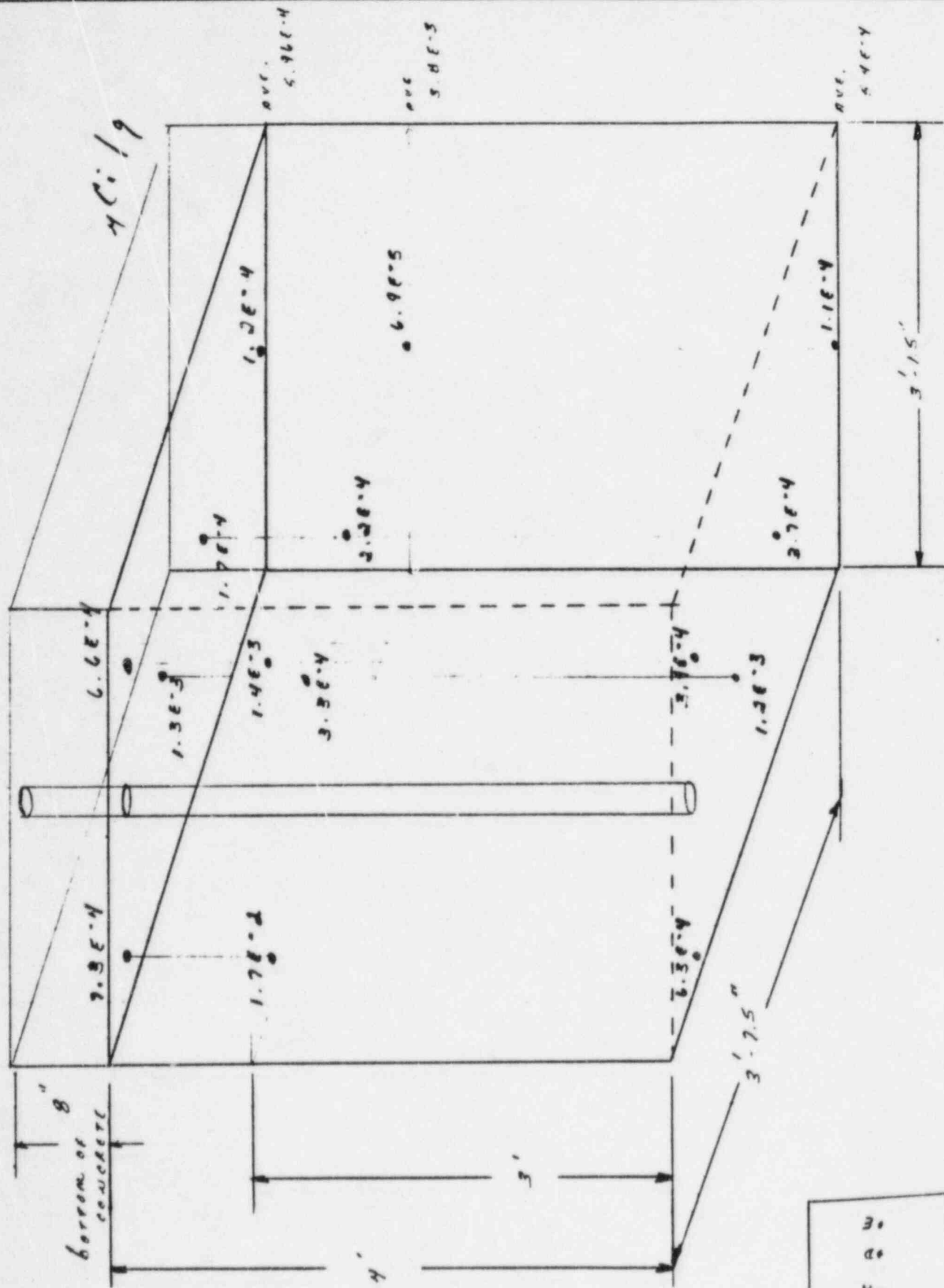
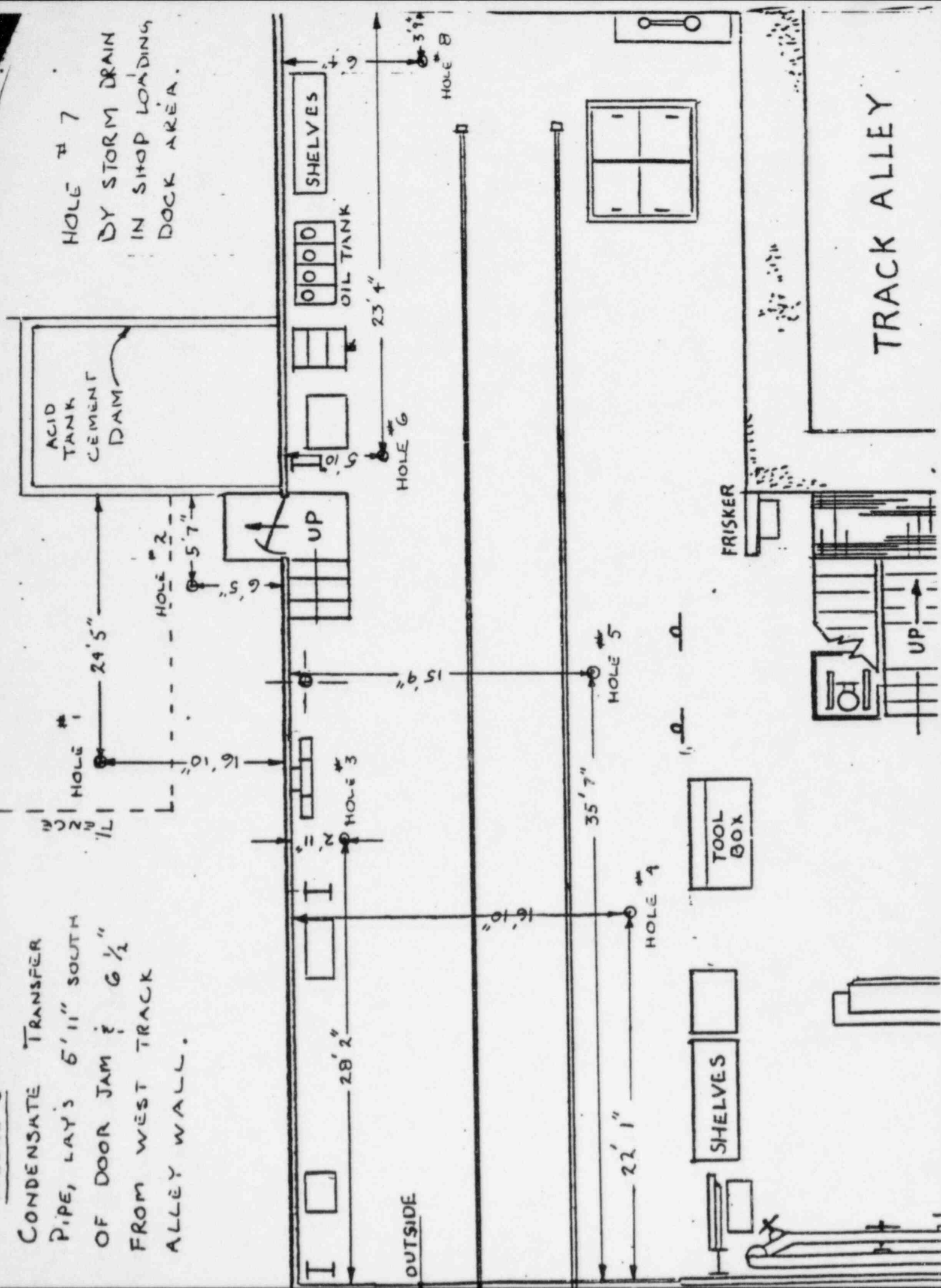


Figure 2: Soil Samples Near Line Failure



CONDENSATE TRANSFER  
PIPE, LAYS 5' 11" SOUTH  
OF DOOR JAM & 6 1/2"  
FROM WEST TRACK  
ALLEY WALL.

BY STORM DRAIN  
IN SHIP LOADING  
DOCK AREA.



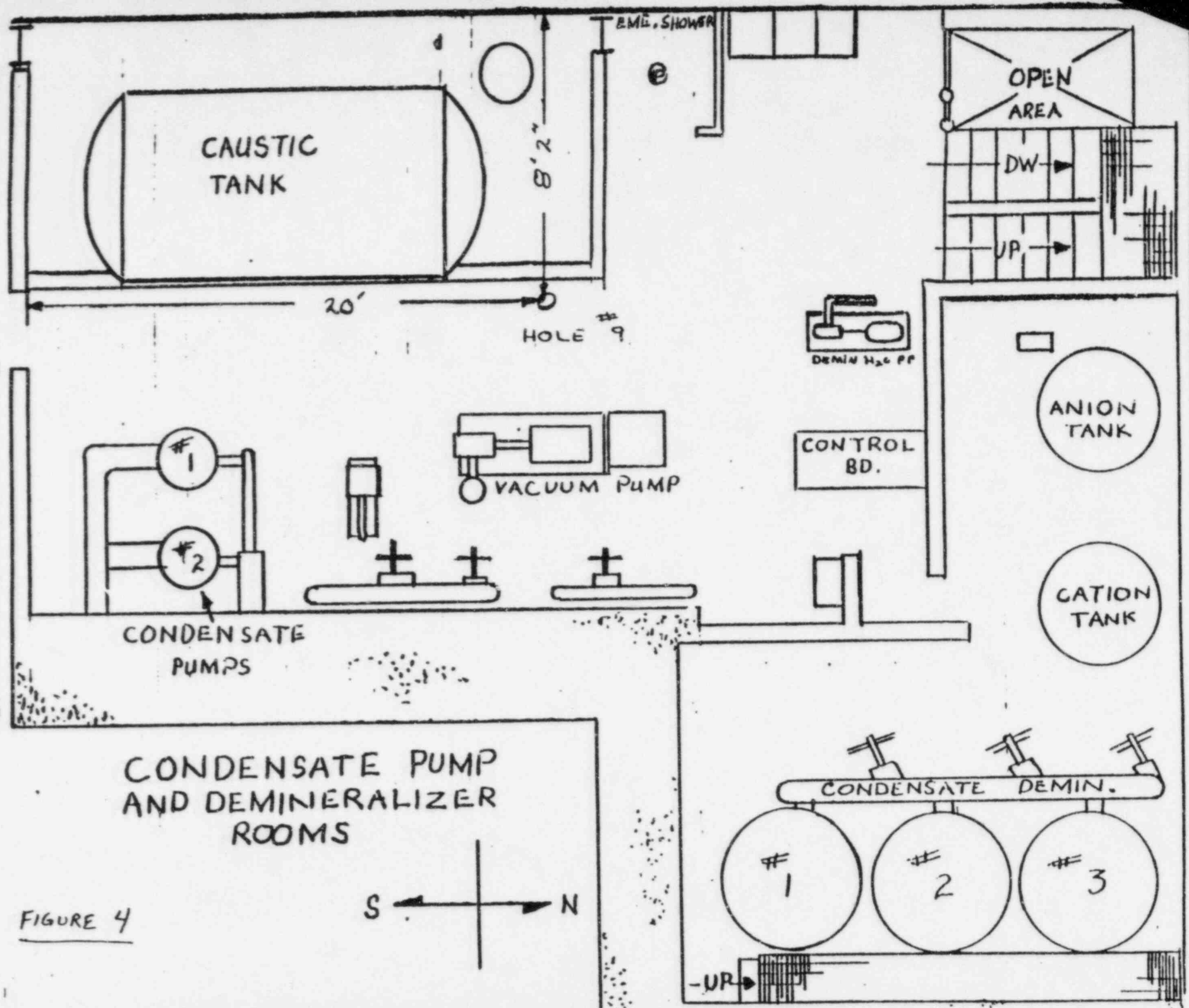


FIGURE 4

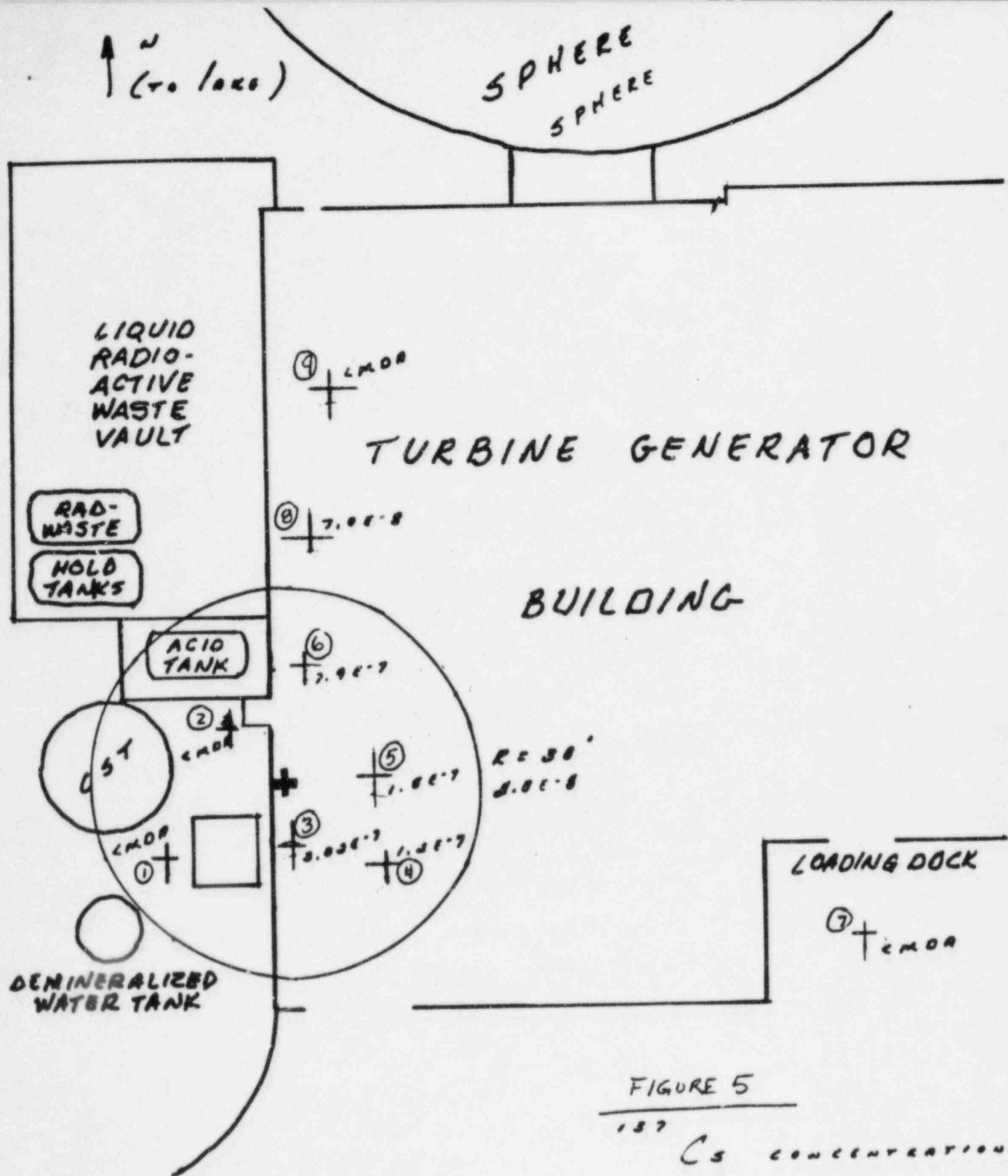


FIGURE 5

137

$^{137}\text{Cs}$  concentration.  
( $\mu\text{Ci/m}^3$ )



ATTACHMENT III

RADIOACTIVITY REMAINING IN SOIL DUE TO CONDENSATE TANK LEAK

EA-TAH-85-06

Performed By: TAHancock

Technical Review By: JLBeer

Administrative Review By: DPHoffman

July 8, 1985

### Problem Statement

Describe the present conditions of the remaining contaminated soil in the area of the main condensate leak. Include an estimate of the amount of contaminated soil remaining, the total activity and concentrations of radioisotopes in the soil, and dose rates expected to result from leaving the soil in place.

### Input Data

- Isotopic concentrations based on soil samples taken near the area of the line failure (Tables 3 and 4 and Figures 2 and 5 of Reference 1).
- Amount of soil excavated = eight 55-gallon drums
- Estimated total activity released = 3330.8  $\mu\text{Ci}$
- Rate of groundwater flow = 0.035 m/day (as per the FHSR).

### Assumptions

- Assumptions made in the "disposition" report calculations (Reference 1) are carried through.
- The total amount of soil removed by excavation was contaminated and contained the bulk of the contaminants released.

### References

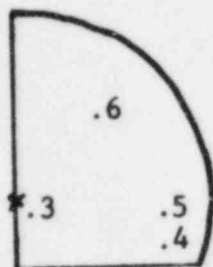
1. Disposition of contaminated soil calculations summarized in report titled Revised Resolution of AIR-BRP-84-20 "Disposition of Contaminated Soil".
2. Rockwell, Theodore III; Reactor Shielding Design Manual

### Calculations

#### Estimate of the Amount of Contaminated Soil Remaining

Based on the ground water flow of 0.035 m/day, the distance the contaminants traveled through the soil in 41 days (believed to be the duration of the leak) is 4.7 feet. The excavation removed a volume corresponding to a travel distance of 3.6 feet. Assuming the width and depth of the excavation were sufficient to contain the vertical and horizontal (perpendicular to the direction to the lake) spread of contaminants, the volume remaining is 4 feet deep, 3.125 feet wide and 1.1 feet long (ie, 13.75 cubic feet). There are supply and drain lines in the area of the leak providing pathways of "least resistance" in which the contaminants can spread. Detectable levels of the radioisotopes have been found in samples out to a distance of 30 feet from the leak site and down to a depth of 5 feet, verifying that this has occurred.

The minimum volume of soil which would have to be removed is determined from Figure 5 of Reference 1.



$$r = 30 \text{ feet}$$

$$\text{area} \approx 3/8 \pi r^2 = 1060.29 \text{ ft}^2$$

$$\text{volume} = 5 \text{ ft} (1060.29 \text{ ft}^2) = 5301 \text{ ft}^3$$

To remove all the contaminated soil would require much tunnelling resulting in a large cost for soil removal. The soil would be disposed of in 55-gallon drums (volume = 7.35 ft<sup>3</sup>). This would require the use and disposal of an estimated 721 drums.

#### Activity And Concentration Of Radioisotopes In Soil

The average concentrations of each isotope left in the soil were calculated by averaging the concentrations in soil samples #3 through #9 taken in the area beneath the turbine building floor. The average includes only those samples showing results greater than MDA which greatly overestimates the true average concentration and activity in the soil. The activity of each isotope is determined from the sample concentration using the following equation:

Activity [ $\mu\text{Ci}$ ] =

$$\text{Concentration} \left[ \frac{\mu\text{Ci}}{\text{ml}} \right] 20,000 \text{ gallons} \left( \frac{10 \text{ days}}{41 \text{ days}} \right) \left( \frac{1 \text{ ft}^3}{7.481 \text{ gallons}} \right) \left( \frac{28316.8 \text{ ml}}{\text{ft}^3} \right)$$

Where: 20,000 gallons is the estimated volume of the leak

$\frac{10 \text{ days}}{41 \text{ days}}$  is the fraction of total leak spreading beyond the excavated area (ie, excavated to 3.6 feet; ground water flow = 0.035 m/day which indicates 31 days worth of spread was excavated, therefore, 10 days worth of the leak remains). The leak is believed to have begun 41 days prior to sampling.

Assuming the isotopes are distributed uniformly in the soil, the concentration [ $\text{nCi/gm}$ ] of each isotope can be determined as follows:

Concentration [ $\text{nCi/gm}$ ] =

$$\frac{\text{Activity} [\mu\text{Ci}] 1000 [\text{nCi}/\mu\text{Ci}]}{V [\text{ft}^3] \rho [\text{gm}/\text{ft}^3]} = 3.78\text{E-}06 (\text{Activity} [\mu\text{Ci}])$$

Where  $V = 5301 \text{ ft}^3$   
 $\rho = 4.99\text{E}+04 \text{ gm/ft}^3$

\* This is a conservative assumption since the soil would act as a filtering media with the largest concentration being closest to the source and decreasing with distance.

The activity in the soil at present can be estimated by taking radioactive decay into account for one year. The resulting activities and concentrations in the soil are given below:

Table 1: Total Activities and Average Concentrations In Soil

| Nuclide | Half Life [Days] | Sample Concentration [ $\mu\text{Ci/ml}$ ] | <u>At Excavation</u>        |                                   | <u>At Present</u>           |                                   |
|---------|------------------|--|-----------------------------|-----------------------------------|-----------------------------|-----------------------------------|
|         |                  |  | Activity [ $\mu\text{Ci}$ ] | Concentration [ $\text{nCi/gm}$ ] | Activity [ $\mu\text{Ci}$ ] | Concentration [ $\text{nCi/gm}$ ] |
| Mn-54   | 312              | 2.167E-07                                  | 4.00                        | 1.512E-05                         | 1.78                        | 2.529E-05                         |
| Co-60   | 1920             | 4.132E-07                                  | 7.63                        | 2.884E-05                         | 6.69                        | 6.729E-06                         |
| Cs-137  | 10950            | 5.456E-07                                  | 10.07                       | 3.807E-05                         | 9.84                        | 3.720E-05                         |
| Cs-134  | 748              | 8.276E-07                                  | 15.28                       | 5.776E-05                         | 10.90                       | 4.120E-05                         |
| Totals  |                  | 2.003E-06                                  | 36.98                       | 1.398E-04                         | 29.21                       | 1.104E-04                         |

The percentage of the total activity released to the soil which still remains is:  

$$\frac{29.21}{3330.8} \times 100 = 0.88\%$$

#### Dose Rates Expected To Result From Leaving The Soil In Place

The contaminants will eventually reach Lake Michigan resulting in a dose rate to the public of less than

$$1.0\text{E}-05 \frac{\text{mrem}}{\text{year intake}} (0.88\%) = 8.8\text{E}-08 \frac{\text{mrem}}{\text{year intake}}$$

Where  $1.0\text{E}-05 \frac{\text{mrem}}{\text{year intake}}$  is the dose rate previously calculated using the LADTAP code (Liquid Annual Dose To All Persons) assuming all the activity released went directly into Lake Michigan (ie, removal of activity by excavation was neglected).

Doses to people working in the area will result mostly from direct shine. The dose rate at the surface of the turbine building floor over the contaminated soil and one meter above can be determined using methods described in the Rockwell Reactor Shielding Design Manual.

## Dose Rate At Surface:

$$\phi = \frac{BS_V}{2\mu_s} E_2(b_1) - \frac{E_2(b_1 \sec \theta_1)}{\sec \theta_1}$$

$$R_0 = 30 \text{ ft} = 914.4 \text{ cm}$$

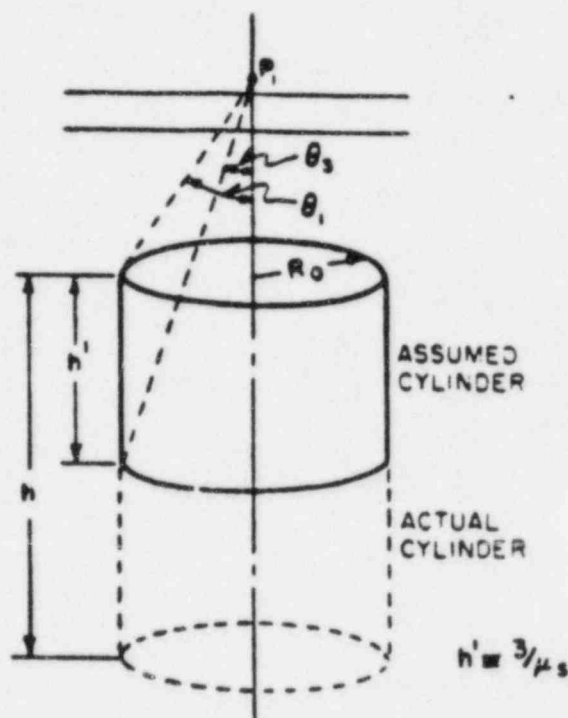
$$h = 5 \text{ ft} = 152.4 \text{ cm}$$

$$t = 8'' = 20.32 \text{ cm}$$

Assuming uniform concentration throughout the volume.

$$\text{Activity At Excavation} = 36.98 \text{ } \mu\text{Ci}$$

$$\text{Activity At Present} = 29.21 \text{ } \mu\text{Ci}$$



The values of the remaining parameters can quickly be determined.

$$SV \equiv \frac{\text{Activity}}{\text{Volume}} = 3.43\text{E-}03 \text{ sec}^{-1} \text{ cm}^{-3}$$

$$\mu_s \cong \text{attenuation coefficient in soil (taken as concrete)} = 0.1249 \text{ cm}^{-1}$$

$$h^1 = 24.019 \text{ cm}$$

$$\bar{E}_\gamma = \Sigma (\text{fraction of activity due to isotope } i) \bar{E}_{\gamma i} \sim 0.8 \text{ Mev}$$

$$B \equiv \text{buildup through concrete} = 5.09$$

$$b_1 = \Sigma \mu x \text{ of shielding} = 2.538$$

$$\sec \theta = 45.01$$

$$E_2(b_1) = 1.85\text{E-}02$$

$$E_2(b_1 \sec \theta) = 0$$

$$\text{The resulting flux is } \phi = 1.29\text{E-}03 \text{ sec}^{-1} \text{ cm}^{-2}$$

The dose rate can be determined by dividing the calculated flux by the flux of 0.8 MeV gammas which would result in a dose rate of 1 R/hr.

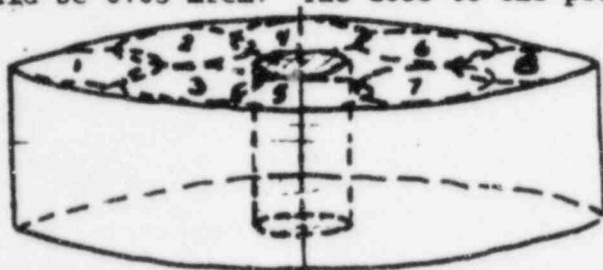
$$D = \frac{\phi}{\phi \text{ to give 1R/hr}} = 1.9\text{E-}09 \frac{\text{R}}{\text{hr}} = 1.9\text{E-}06 \frac{\text{mR}}{\text{hr}}$$

$$\text{Where } \phi \text{ to give 1R/hr} = 6.8\text{E+}05 \text{ sec}^{-1} \text{ cm}^{-2}$$



This dose rate, as well as the dose rate which would be calculated at 1 meter above the surface, will not be detectable above background.

The dose to a person digging in the area includes dose from inhalation of resuspended particles and dose from direct exposure in the center of the area. The dose due to inhalation of suspended particles was previously investigated and show that the maximum occupational dose commitment in an eight hour day would be 0.03 mrem. The dose to the person digging is calculated below:



Let the contaminated volume be modeled as eight cylindrical sources. Assume the volume removed by the person (in which he stands) is a cylinder of 1.5 ft radius.

$$V \text{ of the cylinder} = 1/8 [V \text{ of the contaminated soil} - h\pi r^2] = 658.2 \text{ ft}^3$$

$$\text{Then, } R_0 \text{ of the cylinder} = 6.4732 \text{ ft} = 197.3 \text{ cm}$$

Using Rockwell methods, the dose rate from one cylinder is calculated.

At  $P_2$

$$\phi = \frac{BS_V R_0^2}{2(a+z)} F(\theta, b_2) \quad \theta_1 = \theta_2 = \theta$$

$$h = 5 \text{ ft} = 152.4 \text{ cm}$$

$$a = 1.5 \text{ ft} = 45.72 \text{ cm}$$

$$S_V = 3.43\text{E-}03 \text{ sec}^{-1} \text{ cm}^{-3}$$

The remaining parameters are easily evaluated:

$$B = 1.007$$

$$Z = 27.49 \text{ cm}$$

$$\theta = 59^\circ$$

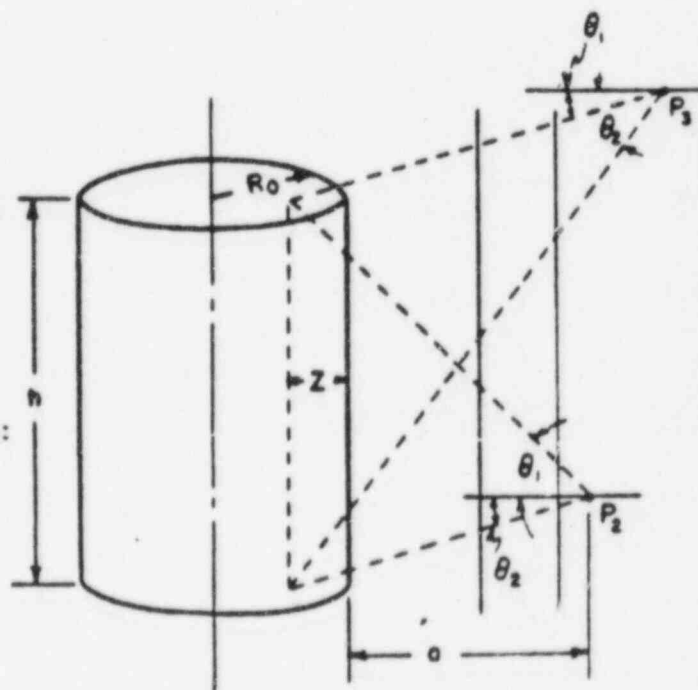
$$b_2 = 3.44$$

$$F(\theta, b_2) = 1.9\text{E-}02$$

$$\text{The resulting flux is } \phi = 1.74\text{E-}02 \text{ sec}^{-1} \text{ cm}^{-2}$$

$$\text{and the corresponding dose rate is } D_0 = 2.6\text{E-}08 \text{ R/hr} = 2.6\text{E-}05 \text{ mr/hr}$$

$$\text{The total dose rate to the person digging is then } D = 8D_0 = 2.0\text{E-}04 \text{ mr/hr}$$



### Summary of Results

Based on the analysis above, the amount of contaminated soil is approximately 5300 ft<sup>3</sup> which would result in the disposal of about 720 55-gallon drums. The total activity in this soil is estimated to have been 36.98  $\mu$ Ci at the time of excavation and is estimated to be 29.21  $\mu$ Ci at the present time. This is 0.83% of the total activity believed to have been released into the soil. The average concentration in the soil is estimated as 1.1E-04 nCi/gm. Dose rates at the surface of the turbine building floor, one meter above the turbine building floor, and to a person digging in the area are not expected to be detectable above the background levels. Dose rates to members of the public as a result of release to Lake Michigan are also negligible.