System development: Crandon Project waste disposal system: project report 8. v. 8 1983

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SYSTEM DEVELOPMENT

CRANDON PROJECT

WASTE DISPOSAL SYSTE[M]

PROJECT REPORT 8

Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

Report on

SYSTEM DEVELOPMENT
CRANDON PROJECT
WASTE DISPOSAL SYSTEM
PROJECT REPORT 8

Submitted to:

Exxon Minerals Company
P. O. Box 813
Rhinelander, WI 54501

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January 1983 786085

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Golder Associates
CONSULTING GEOTECHNICAL AND MINING ENGINEERS

January 12, 1983

786085/MA/480
F/N 179.9

Exxon Minerals Company
P. O. Box 813
Rhinelander, Wisconsin 54501

Attn: Mr. C. E. Fowler

RE: EXXON CRANDON PROJECT
MINE WASTE DISPOSAL SYSTEM
CRANDON, WISCONSIN

Gentlemen:

We are pleased to present the final draft of our report "System Development, Crandon Project Waste Disposal System, Project Report 8." This report summarizes the studies and alternative mine waste disposal facility site designs leading to the design considered to be the most acceptable.

We appreciate the continuing opportunity to provide services to Exxon Minerals Company for the Crandon Project and extend our thanks to you and the Exxon staff for their excellent cooperation.

Very truly yours,

GOLDER ASSOCIATES

Gary H. Collison, P.E.
Principal

GHC:dap

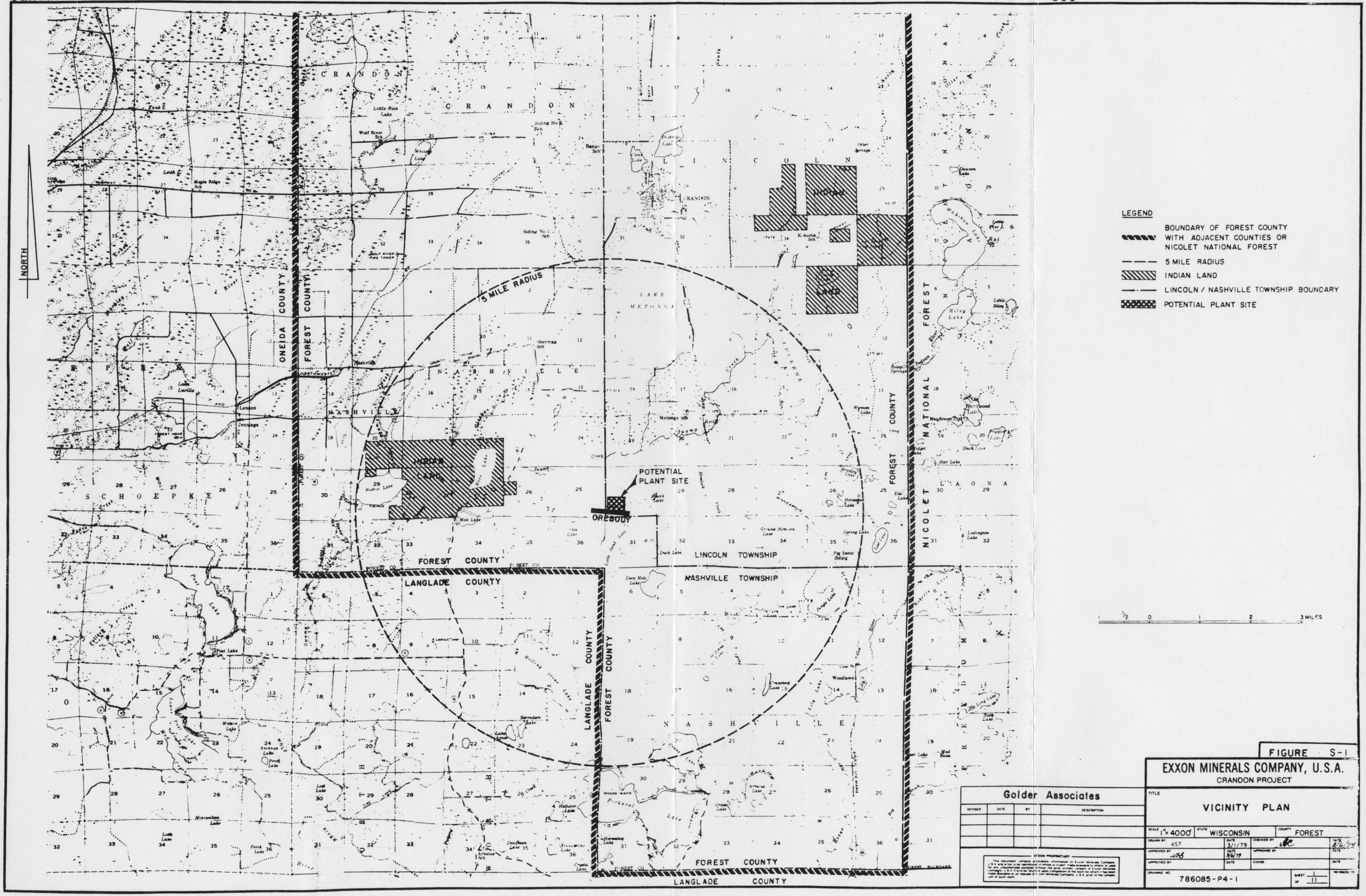
EXECUTIVE SUMMARY

Exxon Minerals Company retained Golder Associates to provide preliminary engineering design for permitting the mine waste disposal system for their Crandon Mining Project in Forest County, Wisconsin. The purpose of this Site Development report is to review the various technical aspects, studies, and analyses considered in evaluating the alternative site designs, and to present the site design considered to be most acceptable.

Golder Associates has been working with Exxon on this project since October, 1978. Numerous engineering reports have been prepared by Golder Associates which present in detail the data, analyses, results, and evaluations made during the course of the work. Many of these studies are briefly reviewed or referenced in this report and a listing of Golder Associates' reports are presented as References 9 through 22. The Preliminary Geohydrologic Screening Analyses (Section 8) and the Recommended Slurry System (Section 9) are not covered by other Golder Associates' reports.

In the more than four years Golder Associates has been working on this project with Exxon, many changes have been made because of refinements in the available information. This has led to an evolving preliminary engineering design process in which some of the studies, design guidelines and alternative mine waste disposal systems discussed in this report and prior reports are outdated. However, results of many of these studies and proposed design alternatives were used as the basis for later work. Some are presented in this report in order to provide a complete understanding of the development of the selected mine waste dispoal site and system selection.

Dames & Moore prepared a siting report (Ref. 4) providing a general overview of the characteristics of an area within a 12-mile (19 km) radius of the orebody. This study indicated that the land within this radius was generally similar to that beyond this radius. Golder Associates prepared an additional siting study (Ref. 9) with the area of primary concern reduced to a radius of 5 miles (8 km) from the orebody (see Figure S-1). This report described the methodology by which thirteen areas potentially suited to development of a mine waste disposal system were identified. This study, recognizing regulatory trends toward discouraging the use of wetlands as disposal sites, noted the large wetlands, particularly those contiguous with lakes or major streams, as being predominantly below elevation 1600 feet (487 m) and noted the presence of numerous small, upland wetlands more isolated from the streams, lakes, and groundwater. In addition to the wetlands, the siting aspects of certain ecological features (such as endangered species nests), topography, regional hydrology, land use, political boundaries, and facilities requirements were also considered. During the course of this study four of the potential siting areas were inspected by Exxon and representatives of the Public Intervenor's staff and were found to contain numerous meadow type wetlands which did not appear on the USGS quadrangle maps being used as the base maps for the study. These wetlands made these areas less attractive for mine waste facilities siting and they were subsequently eliminated from future consideration. It was also found during the course of the study that some of the areas were too small to contain an entire waste disposal system of the size anticipated. In one of these areas, because of size and the necessity to divert the drainage of Oak Lake, it was decided by Exxon to incorporate land in

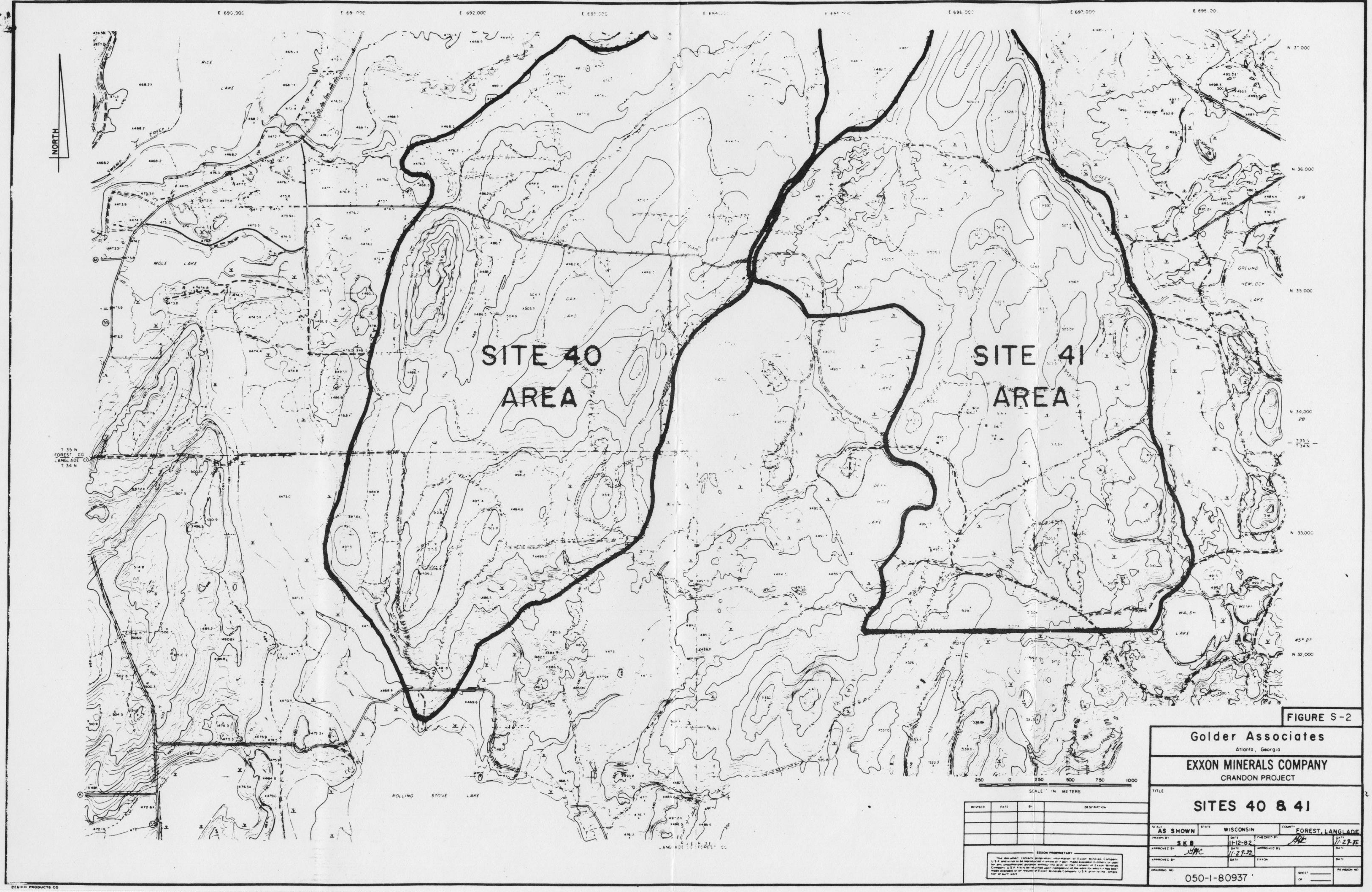

NORTH
LEGEND
BOUNDARY OF FOREST COUNTY WITH ADJACENT COUNTIES OR NICOLET NATIONAL FOREST
5 MILE RADIUS
INDIAN LAND
LINCOLN / NASHVILLE TOWNSHIP BOUNDARY
POTENTIAL PLANT SITE
5 MILE RADIUS
POTENTIAL PLANT SITE
OREBODY
INDIAN LAND
ONEIDA COUNTY
FOREST COUNTY
LANGLADE COUNTY
NICOLET NATIONAL FOREST
LINCOLN TOWNSHIP
NASHVILLE TOWNSHIP
C R A N D O N
L I N C O L N
N A S H V I L L E
S C H O E P K E
L A O N A
1/2 0 1 2 3 MILES
FIGURE S-1
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
Golder Associates
VICINITY PLAN
1" = 4000'
WISCONSIN
FOREST
AST
3/1/79
786085-P4-1

the extreme northeast corner of Langlade County in future studies.

The three most attractive disposal areas delineated by the Golder Associates Siting Report (Ref. 9) were studied in more detail. With Exxon's revised estimates of waste product tonnages and volume estimates available, several factors were noted which suggested revision to the land areas previously designated as being most attractive. The result of this evaluation led to the selection of two primary areas considered by Exxon and Golder Associates to be the most suitable for mine waste disposal system sites. These two areas are known as the Site 40 and Site 41 areas (see Figure S-2) and were two of the general areas included in the earlier Dames & Moore siting study (Ref. 4).

Detailed investigations of the geology and hydrology of the Site 40 and Site 41 areas have been made (Ref. 11, 14, 18, and 22) to provide data for evaluation of the effects a mine waste disposal facility might have on the groundwater system and to provide data for preliminary engineering design of the facilities. These studies were made over a period of more than three years while siting and trial designs were being performed.

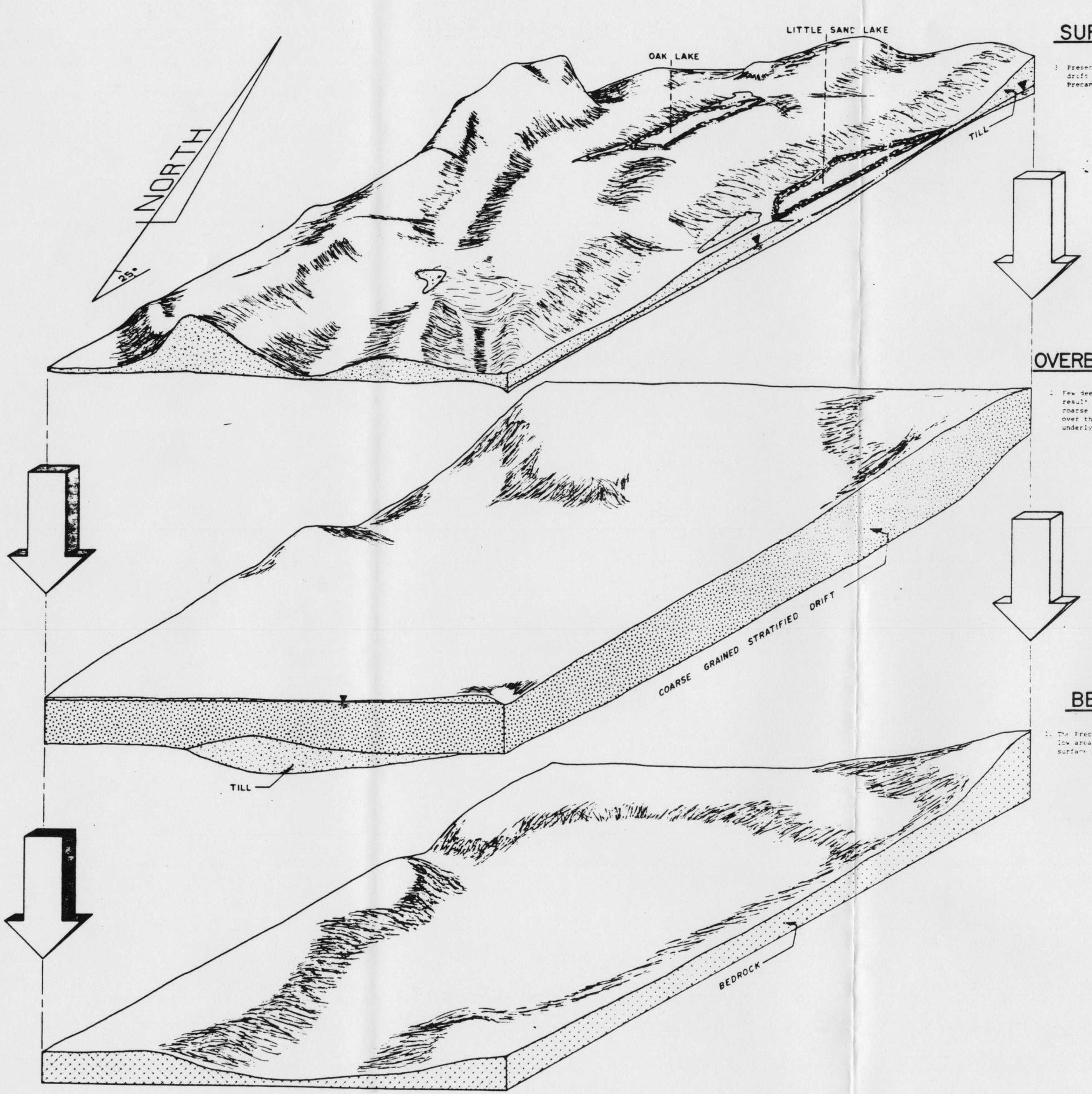
The geology of the Site 40 and Site 41 areas has been found to generally consist of a surface deposit of glacial till (heterogeneous mixture of silt, sand, gravel, some cobbles and boulders, and traces of clay) underlain by coarse grained stratified drift (sand and fine gravel with traces of silt). The coarse grained stratified drift is underlain in most areas by an additional layer of till or a layer of fine grained stratified drift which, in turn, are underlain by igneous and metamorphic bedrock. Lacustrine


NORTH
SITE 40 AREA
SITE 41 AREA
RICE LAKE
MOLE LAKE
ROLLING STONE LAKE
GROUND HEMLOCK LAKE
WALSH LAKE
SCALE IN METERS
250 0 250 500 750 1000
FIGURE S-2
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
SITES 40 & 41
AS SHOWN
WISCONSIN
FOREST, LANGLADE
SKB
11-12-82
050-1-80937
DESIGN PRODUCTS CO

deposits of mostly silts and clays have been found predominantly beneath and surrounding the present day lakes and major wetlands. Uniformly graded outwash deposits have been mapped at the surface but not encountered at depth. Figures S-3 and S-4 are block diagrams of the Site 40 and Site 41 areas providing an overall three dimensional view of the subsurface materials. They are intended to provide an overall understanding of the terrain, bedrock, and glacial materials.

The Crandon Project area lies within the Swamp Creek and Pickerel Creek surface water drainage basins of the Wolf River drainage basin. Average annual precipitation in the regional areas is 30.77 inches (781.6 mm). Groundwater recharge occurs readily in the upland areas and flows essentially vertically in an unsaturated mode to the groundwater table. After water percolates to the aquifer (primarily the coarse grained stratified drift) it flows essentially horizontally towards areas of lower groundwater levels. The flood potential for the area is low because of the high infiltration rates of the upland areas and storage capacities of the lakes and wetlands. In general, the Project Area is bounded by Ground Hemlock Lake, Hemlock Creek and associated wetlands to the east, by Swamp Creek and Rice Lake to the north, and by the chain of lakes and wetlands from Mole Lake to Rolling Stone Lake, Pickerel Lake and Crane Lake to the west and south. This series of wetlands, lakes and creeks comprise the surface and groundwater discharge boundaries for the project area.

The glacial deposits constitute the main water bearing unit within the Project Area. The coarse drift is the primary transmissive unit in the project area and although it laterally pinches out or grades into till in some areas



SURFACE TOPOGRAPHY

1. Present day topography is composed of till uplands and drift lowlands. A topographic high occurs over a Precambrian valley at the north-west block boundary.

OVERBURDEN STRATIGRAPHY

1. Few deep boreholes were drilled at Site 40 and as a result the deep stratigraphy is not well defined. The coarse grained stratified drift appears to be continuous over the entire Site area with a possible extensive underlying till layer.

BEDROCK SURFACE

1. The Precambrian relief is generally subdued with a broad low area lying in the center of the Site. The bedrock surface rises steeply to the north-east.

VERTICAL SCALE IN METERS: 0 25 50 100
HORIZONTAL SCALE IN METERS: 0 250 500 1000

NOTE:

This expanded block diagram is intended to show the relationship between the bedrock topography and the various overlying glacial deposits. It allows for better understanding of the terrain and geological conditions at the site. It does not represent the exact geological strata at a given point and should be viewed in conjunction with the geologic sections.

FIGURE S-3

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SITE 40 GLACIAL STRATIGRAPHY BLOCK DIAGRAM

SCALE	STATE	COUNTY
AS SHOWN	WISCONSIN	FOREST, LANGLADE

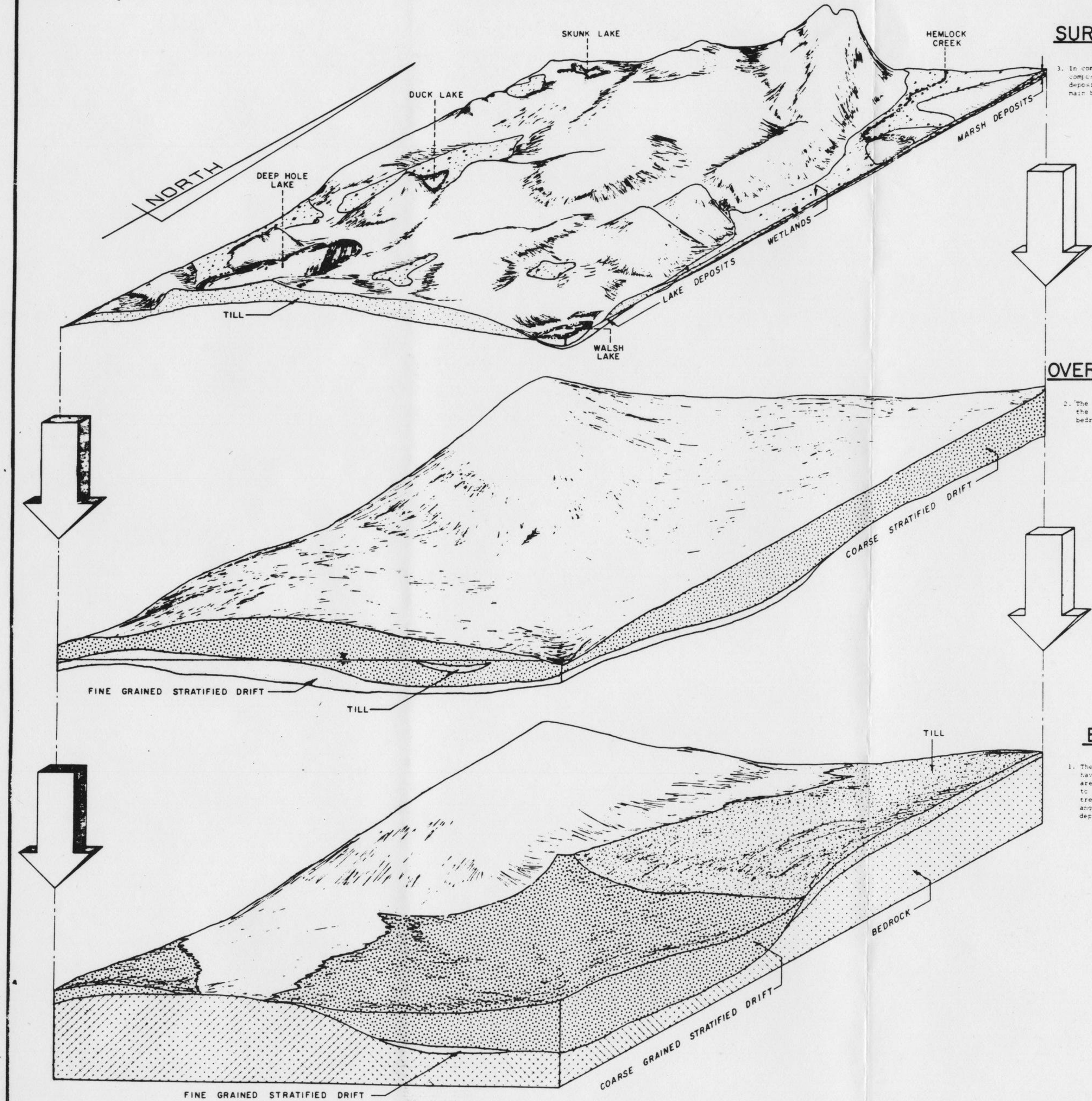
DRAWN BY	DATE	CHECKED BY	DATE
SKB	10-9-81		10/21
APPROVED BY	DATE 10-22-81	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE

DRAWING NO. 050-1-80923 SHEET ___ OF ___ REVISION NO.

REVISED	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

DESIGN PRODUCTS CO.



SURFACE TOPOGRAPHY

3. In common with Site 40, the drumlin topography is composed of the youngest till deposits. The thickest deposits of till appear to have accumulated along the main bedrock valley.

OVERBURDEN STRATIGRAPHY

2. The coarse grained stratified drift is shown to cover the entire site area, still reflecting the underlying bedrock relief.

BEDROCK SURFACE

1. The earliest glacial materials deposited appear to have been confined mainly to the low-lying bedrock areas. This sketch shows the bedrock under Site 41 to have a valley running from the south-east then trending northwards across the Site. At right angles to this valley is a broader east-west bedrock depression.

NOTE:

This expanded block diagram is intended to show the relationship between the bedrock topography and the various overlying glacial deposits. It allows for better understanding of the terrain and geological conditions at the site. It does not represent the exact geological strata at a given point and should be viewed in conjunction with the geologic sections.

VERTICAL SCALE IN METERS: 0 25 50 100
HORIZONTAL SCALE IN METERS: 0 250 500 1000

REVISED	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

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FIGURE S-4

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE **SITE 41 GLACIAL STRATIGRAPHY BLOCK DIAGRAM**

SCALE	STATE		COUNTY	
AS SHOWN	WISCONSIN		FOREST, LANGLADE	
DRAWN BY: SKB	DATE: 10-9-81	CHECKED BY: JK		DATE:
APPROVED BY: Gac	DATE: 10-22-81	APPROVED BY		DATE
APPROVED BY	DATE	EXXON		DATE
DRAWING NO. 050-1-80924		SHEET ___ OF ___		REVISION NO

and exhibits vertical variation, over the Project Area as a whole these effects become minimal. The coarse drift behaves essentially as an unconfined aquifer that is locally semi-unconfined where it is overlain by till. The upland portion of the Project Area is a groundwater recharge area with groundwater discharging to the surrounding lowlying streams, lakes, and wetlands. The groundwater potentiometric surface contours, based primarily on water level measurements made in February 1982, are shown on Figure S-5.

Alternative slurry mine waste disposal system designs were prepared for Site 40 and Site 41. In addition, slurry mine waste disposal system designs were prepared so that the facilities did not cover any wetlands. To accomplish this criteria the facilities had to be located in both the Site 40 and Site 41 areas. This approach was termed the Site 50 area. For each of these site areas numerous slurry mine waste disposal facility layouts were prepared incorporating several of the waste product mix variations for an estimated 100 million DMT (Dry Metric Ton = 2205 pounds) orebody. Three prospective alternatives, one for each site area, were presented for comparison of the three site areas (Ref. 10). The results of this comparison led Exxon and Golder Associates to recommend Site 41 for disposal of the mine wastes. It was believed a Site 41 system could be designed to have the least adverse environmental impact on the area and be feasible to construct and operate.

In evaluating these three site alternatives, it became apparent that although a particular upland wetland may not be covered by the facilities, it could be impacted because the facilities may cover the land within the surface watershed of the wetland. A wetland was considered to be poten-


LEGEND
—480— GROUNDWATER CONTOURS IN METERS ABOVE MSL.
--480-- GROUNDWATER CONTOURS IN METERS ABOVE MSL, INTERPRETED FROM LIMITED DATA
CRANDON FORMATION
NORTH
PLANT SITE
RICE LAKE
OAK LAKE
LITTLE SAND LAKE
DUCK LAKE
DEEP HOLE LAKE
ROLLING STONE LAKE
ST JOHN LAKE
WALSH LAKE
HEMLOCK LAKE
FOREST LANGLADE CO.
NOTE ELEVATIONS IN METERS ABOVE MSL
SCALE IN METERS
FIGURE S-5
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
GROUNDWATER POTENTIOMETRIC CONTOURS PROJECT AREA
AS SHOWN
WISCONSIN
FOREST, LANGLADE
CAB
4-12-82
050-1-81118 A

tially impacted if 50 percent or more of its watershed were covered by the facilities. The primary advantage of Site 40 over Site 41 was that fewer acres of wetland were covered and/or impacted. Although no wetlands were covered by the Site 50 alternate, it covered wetland watersheds and could potentially impact nearly as many acres of wetland as the Site 41 alternate. Within the overall area surrounding the Crandon orebody, there appears to be no viable site which would exclude incorporation of wetlands or wetland watersheds within the facility area. Considering the results of this study, Exxon in consultation with Golder Associates decided to proceed with more detailed slurry system designs in the Site 41 area.

At the same time the slurry system designs were being studied, alternative methods of mine waste handling were being considered. Exxon studied the possibility of reducing the water content of the tailings to the point where they could be handled as a solid material instead of a slurry. This possibility led to studies on solid mine waste disposal options. Two primary methods were studied by Golder Associates. One was termed a landfill type operation and the other a cut-and-cover operation.

In the landfill operation the tailings would be hauled to the disposal site in trucks and distributed in relatively thin layers with bulldozers, or hauled and spread with earthmoving scrapers. After a layer was begun, it could be covered with glacial soil so that the area of exposed tailings could be minimized. Eventually, the entire area would be covered with soil for final reclamation.

The cut-and-cover operation consisted of excavating a series of parallel trenches with a dragline. The tailings would be transported from the mine and placed in the trenches by conveyor. The dragline would cover the tailings in one trench with soil excavated from the adjacent trench. The final surface would be shaped by bulldozers. In this operation the tailings would be exposed for a very short period of time and the entire excavation, disposal, and reclamation portions of the system would be occurring essentially simultaneously.

The technology for dewatering the tailings and handling them as a solid is not new, but has never been applied to fine grained tailings on a large production basis. Because of this uncertainty, Exxon elected not to pursue this approach as an alternative for mine waste disposal permitting. The results of Golder Associates' studies have not been submitted in a formal report.

As more detailed designs for a slurry mine waste disposal system were being prepared, many changes were made in the waste product mix and tonnages. These changes were the result of continuing work by Exxon and other consultants. The most significant change was a reduction in the reserve estimate from a 100 million DMT orebody to a 77 million DMT orebody. This latter estimate is based on a 62.3 million DMT orebody with an approximate 25 percent contingency.

Various mine waste disposal facility layouts have been prepared for the Site 41 area for the 77 million DMT orebody. Five of these systems are presented and discussed in detail in Section 7 of this report. These five systems have the following significant common features:

1. Lakes are not employed as disposal areas.
2. Offset of more than 300 feet (91.4 m) from navigable streams.

3. Ponds excluded from areas below elevation 1600 feet (487.7 m) MSL.

4. Outside floodplains.

5. Offset more than 1,000 feet (305 m) from the right-of-way of the following:
   a) state trunk highway,
   b) interstate or federal primary highway,
   c) boundary of any state of federal park,
   d) boundary of a scenic easement purchased by the Wisconsin DNR or DOT,
   e) boundary of a designated scenic or wild river,
   f) a scenic overlook designated by the Wisconsin DNR by rule,
   g) a bike or hiking trail designated by the United States Congress or the State Legislature.

6. More than 1,200 feet (366 m) from any public or private water supply well (except wells drilled by Exxon).

7. More than 0.25 miles (0.4 km) from osprey or eagle nests.

8. Outside the area containing a known mineral resource likely to be mineable in the future and which lies within 1,000 feet (305 m) of the surface.

9. All tailings ponds to include a low permeability liner and underdrain above the liner.

10. Reclaim water ponds to include two low permeability liners.

11. All ponds to have a minimum of 3 feet (0.91 m) of freeboard.

12. Pond crests to be able to carry at least one-way traffic for periodic inspection.

13. All pond crests sloped to drain into the pond.

14. Exterior embankment slopes 3.0 horizontal to 1.0 vertical.

15. Interior embankment slopes 4.0 horizontal to 1.0 vertical.

16. Service road to be provided around the perimeter of the system at the toe of embankment slopes.

17. Drainage swales or other drainage grading to be provided around the perimeter of the system.

18. All tailings ponds to be covered, graded to drain, and vegetated at reclamation.

19. Reclaim ponds to be dismantled, with lining materials placed in final tailings pond, and area regraded and vegetated at reclamation.

One of the location criteria of proposed NR 182 is that the facilities be more than 1,000 feet (305 m) from navigable lakes. In preparing the facility layouts, it was found that there were topographic and groundwater features which could warrant infringing on this offset around Duck and Deep Hole lakes. Rather than ignore these possibilities, some layouts were developed which would require a variance from this location criteria.

In comparing these five alternates, it is apparent no one design will minimize all environmental impacts and at the same time provide least cost for construction. Those systems trending toward least cost, as measured by earthwork and land area, are also those which cover the most wetland acreage, are closer to the groundwater table, are closer to the lakes, or provide least opportunity for staged reclamation. One of the five is located in the southwestern portion of Site 41 and although potentially has the least groundwater effects, it covers the large wetland just east of Deep Hole Lake.

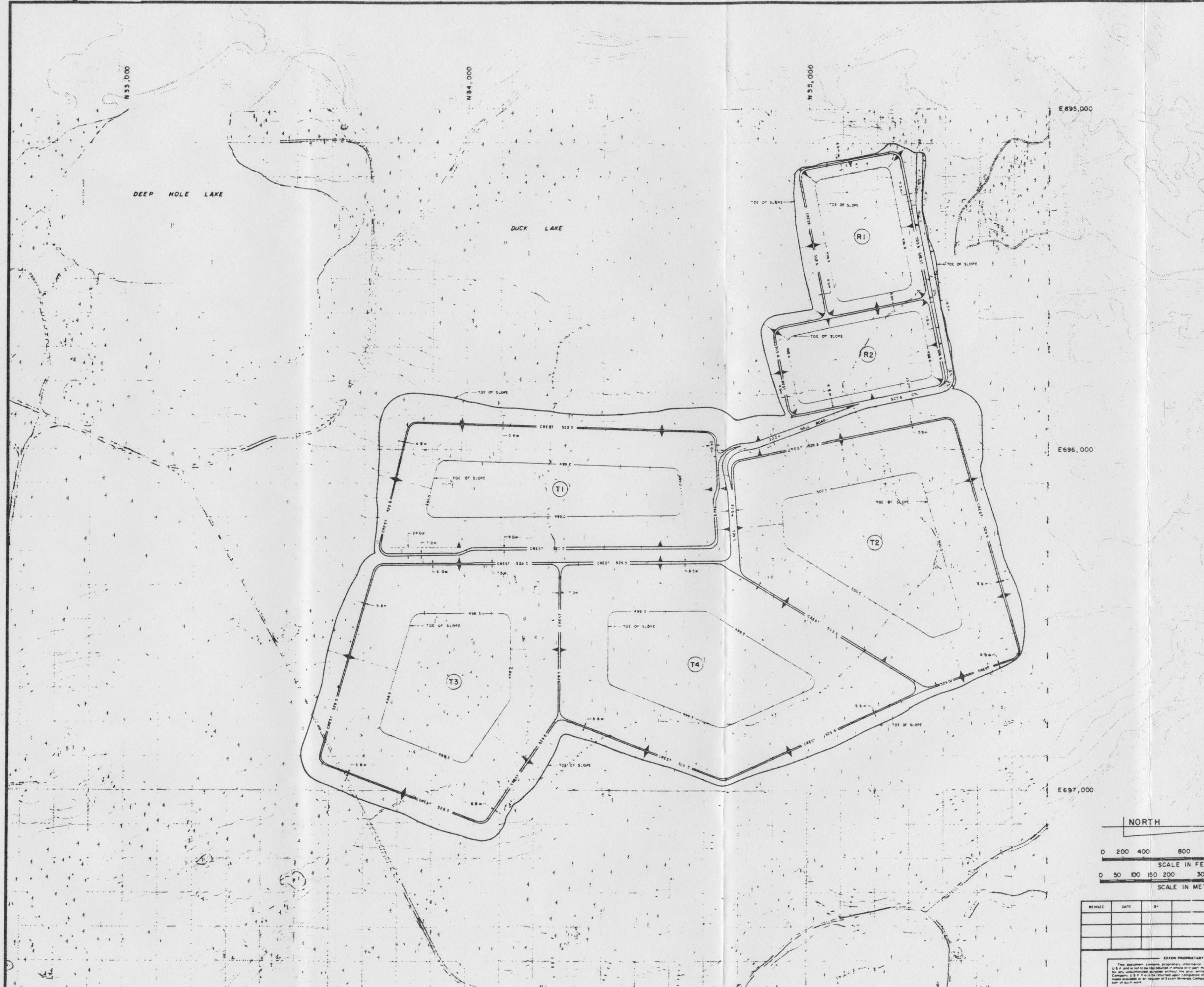
The effect of a potential mine waste disposal site on the geohydrologic system was considered a major factor in the overall site evaluation process. This consideration was studied and evalauted during the time the 77 million DMT layouts were being prepared. In the site selection process it was necessary to screen many disposal sites and different seepage control systems over the life of the mine and many years after reclamation. The methodology selected for this preliminary screening process was a computer model to simulate the groundwater flows and movement of seepage from the mine waste disposal facility with the groundwater.

The preliminary screening study pointed out that mine waste disposal facilities in the Site 41 area could be designed to provide a lesser overall environmental effect on the groundwater and surface water system than facilities in the Site 40 area. Also, till/bentonite lined tailings ponds with an underdrain system above the liner provide lower seepage rates during operation than systems with till/bentonite liners only, even if these liners are as much as 5 feet (1.5 m) thick. Furthermore, the long term steady-state seepage from the system is more dependent on the final cover than the liner system. Of the Site 41 alternative system layouts studied, the one in the south-western portion of the site provides the least groundwater effect on the Hemlock Creek/Swamp Creek surface water system. However, is has some potential disadvantage because the lack of thick till cover over the coarse grained stratified drift over part of the layout may decrease vertical flow time and hence reduce the potential for chemical attenuation. This, coupled with covering of the large wetland just east of Deep Hole Lake made this system less attractive from an overall environmental impact standpoint than other systems in the Site 41 area.

From the results of the various alternative Site 41 system layouts compared and the preliminary groundwater effect screening study, it is Exxon's and Golder Associates' collective opinion that system 41-114B is the most viable mine waste disposal system. System 41-114B is a four pond system which maintains the 1,000 foot (305 m) lake offset required by NR 182. The potential groundwater effects of this system are directed primarily toward Rolling Stone Lake with a long flow path within the groundwater system and, to a lesser degree, toward Hemlock Creek.

The system 41-114B layout is shown on Figure S-6 and a typical cross section is shown on Figure S-7. These drawings reflect the waste disposal system plan which has been developed to provide for permanent storage of the mine/mill waste products based on an estimated 77 million DMT orebody. The system has been designed so that waste rock is included in the embankments or used as rock slope protection. Cover material for reclamation will be obtained from material excavated within the tailings pond areas. Benches have been added to the interior slope of tailings pond embankments to facilitate construction and to permit vertical staged construction of the liner, underdrain, and rock slope protection. Two reclaim ponds are included in the system with different normal water levels and a mixing box between them so that chemicals can be added as the water flows from one pond to the other. Seepage control liners will be included in the reclaim ponds and tailings ponds with an underdrain system installed above the tailings pond liners. A groundwater monitoring system is also provided around the system.

The seepage control measures for the tailings ponds will consist of a 6 inch (150 mm) thick till/bentonite lin-



WASTE DISPOSAL SYSTEM AND RECLAIM POND DATA

Tailings and Reclaim Pond Area (ha) (1)	233.6	Abandonment Cover Seal Thickness (m)	0.15
Tailings Pond Abandonment Area (ha) (2)	202.2	Minimum Abandonment Cover Thickness (m)	1.7
Wetlands Covered (ha) (3)	22.7	Underdrain Drain Layer Thickness (m)	0.46
Pond Excavation ($x 10^6 m^3$)	13.579	Minimum Underdrain Filter Layer Thickness (Note 1) (m)	0.46
Till and Waste Rock Embankment Fill ($x 10^6 m^3$)	6.566	Minimum Rock Slope Protection Thickness (Note 2) (m)	1.0
Waste Rock Embankment Fill ($x 10^6 m^3$)	1.04	Reclaim Pond Synthetic Liner Thickness (mm)	0.91
Minimum Crest Width (Note 3) (m)	4.9	Reclaim Pond Till/Bentonite Liner Thickness (m)	0.15
Processed Till For Mine Backfill Makeup ($x 10^6 m^3$)	1.605	Sand Cushion Above Synthetic Liner Thickness (m)	0.46
Tailings Slope (%)	0.5	Sand Cushion Below Synthetic Liner Thickness (m)	0.30
Minimum Abandonment Cover Slope (%)	2.0	Protective Cushion Above Synthetic Liner Thickness (m)	0.46
Till/Bentonite Tailings Pond Liner Thickness (m)	0.15	Transition Below Reclaim Pond Rock Slope Protection Thickness (m)	0.30

WASTE DISPOSAL SYSTEM AND RECLAIM POND DATA NOTES

POND DATA \ POND NUMBER	R1	R2	T1 (See Note 11)	T2	T3	T4	Σ
Period of Use (yrs) (4)	0-30	0-30	4-9	10-16	17-23	24-30	—
Area Inside Crest (ha)	12.70	11.65	33.08	43.86	40.29	39.98	181.56
Bottom Area (ha)	8.14	8.13	11.11	15.32	12.92	14.10	69.72
Lined Slope Area (ha)	4.74	3.81	20.39	32.64	26.09	27.22	114.89
Maximum Interior Depth (m)	8.7	7.0	23.5	29.0	31.0	30.0	—
Maximum Exterior Fill Height (m)	13.1	13.0	29.0	32.5	21.7	13.6	—
Crest Elevation (m) (5)	505.6	505.6	522.5	529.5	529.5	529.5	—
Lowest Bottom Elevation (m)	496.9	498.6	499.0	500.5	498.5	499.5	—
Struck Storage Volume ($x 10^6 m^3$) (6)	0.59	0.59	5.00	7.56	7.24	7.67	27.47
Tailings Storage Volume ($x 10^6 m^3$)	—	—	4.34	6.57	6.29	6.67	23.87
Till Excavation ($x 10^6 m^3$)	0.369	0.308	2.346	3.755	2.867	3.934	13.579
Till Embankment ($x 10^6 m^3$)	0.245	0.156	1.869	1.324	1.759	0.173	5.526
Synthetic Liner Area (ha)	13.64	12.47	—	—	—	—	26.11
Till/Bentonite Liner Volume ($x 10^6 m^3$) (10)	0.020	0.018	0.073	0.077	0.063	0.069	0.320
Underdrain Drain Material Volume ($x 10^6 m^3$)	—	—	0.221	0.226	0.179	0.202	0.828
Underdrain Filter Material Volume ($x 10^6 m^3$) (7)	—	—	0.214	0.351	0.273	0.293	1.131
Rock Slope Protection Volume ($x 10^6 m^3$) (8)	0.021	0.012	0.270	0.243	0.170	0.181	0.897
Abandonment Cover Volume ($x 10^6 m^3$) (9)	—	—	0.885	1.514	1.260	1.903	5.562
Till/Bentonite Abandonment Cover Seal ($x 10^6 m^3$) (10)	—	—	0.051	0.066	0.060	0.110	0.287
Sand Cushion Above Synthetic Liner ($x 10^6 m^3$)	0.014	0.008	—	—	—	—	0.022
Sand Cushion Below Synthetic Liner ($x 10^6 m^3$)	0.039	0.035	—	—	—	—	0.074
Protective Cushion Above Synthetic Liner ($x 10^6 m^3$)	0.048	0.047	—	—	—	—	0.095
Transition Below Reclaim Pond Rock Slope Protection ($x 10^6 m^3$)	0.008	0.004	—	—	—	—	0.012
Underdrain Collector Pipe Length (m)	—	—	1760	1610	1380	1545	6295
Sump Discharge Pipe Length (m)	—	—	345	410	435	425	1615

WASTE DISPOSAL SYSTEM DATA AND RECLAIM POND DATA NOTES

1. Measured to outside toe of slope
2. Includes tailings ponds only.
3. Represents wetland areas within limits of construction
4. Start of construction for Crandon Project at beginning of year one.
5. Crest width varies from 4.9 meters to 9.0 meters depending on number of pipelines along crest
6. Measured below a level surface below freeboard height. Freeboard for R1 is 2.59 meters. Freeboard for all other ponds is 0.91 meters. Σ for tailings ponds only.
7. Underdrain filter 1.0 meter thick beneath rock slope protection on tailings ponds T2, T3, and T4
8. Rock slope protection 2.0 meters thick on tailings pond T1.
9. Includes working mat and material for grading below top seal and 1.0 meter till cover over top seal.
10. Volume is 13% higher than till required to provide allowance for bentonite.
11. Excavation, fill, and underdrain material volume for grading below waste rock embankment and storage area included with tailings pond T1 volume.

GENERAL NOTES

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. SITE AREA MAPPING AT 1.0 METER CONTOUR INTERVAL. ADDITIONAL AREA TO THE NORTH AND WEST WAS ADDED AT THE AVAILABLE 2.0 METER CONTOUR INTERVAL TO PROVIDE ADDITIONAL COVERAGE.
4. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.

0 200 400 800 1200 1600
SCALE IN FEET

0 50 100 150 200 300 400 500
SCALE IN METERS

REVISED	DATE	BY	DESCRIPTION

FIGURE S-6

Golder Associates

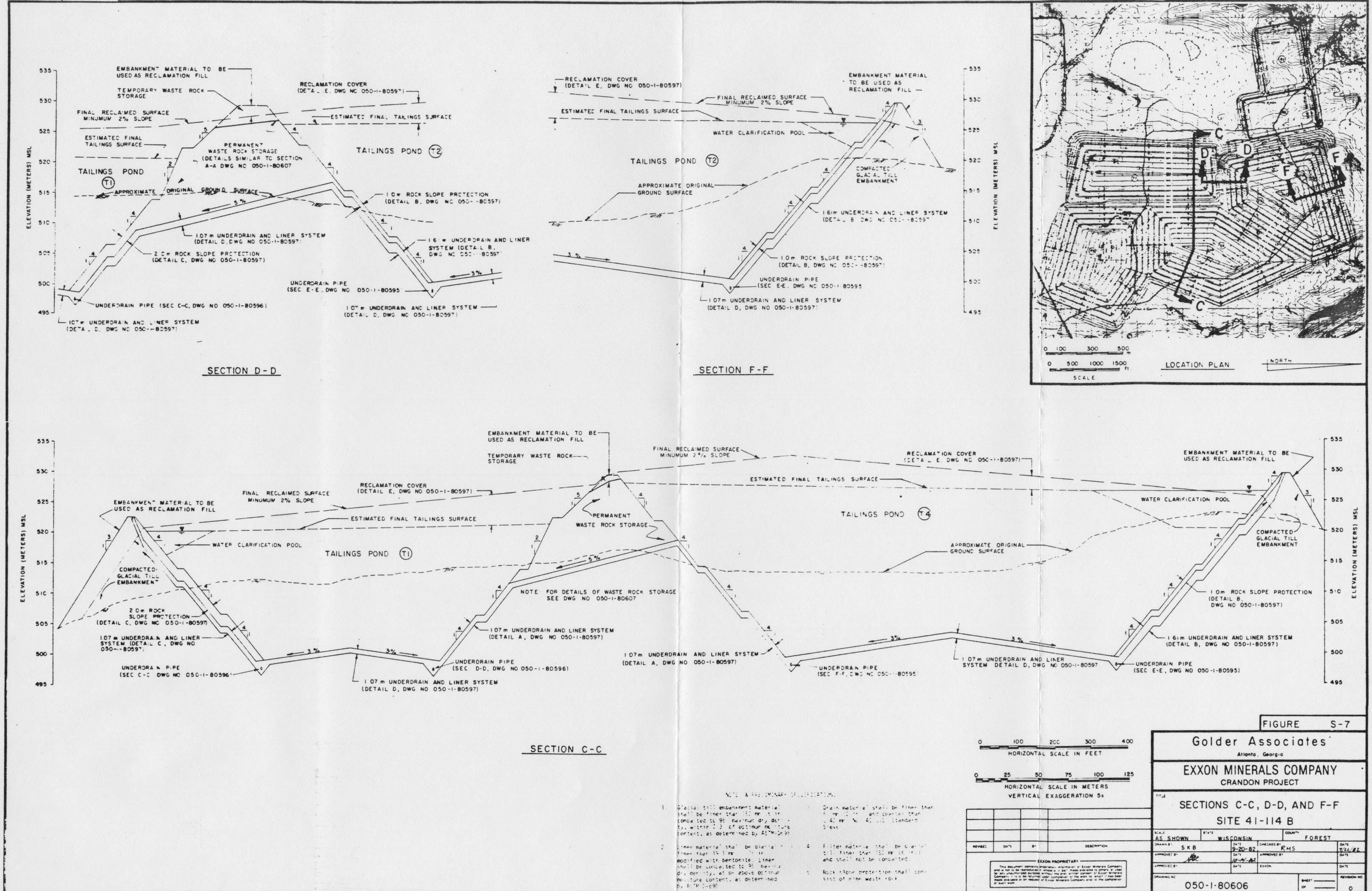
Atlanta, Georgia

EXXON MINERALS COMPANY

CRANDON PROJECT

TITLE WASTE DISPOSAL SYSTEM SITE 41-114B

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY SKB	DATE 9-22-82	CHECKED BY [signature]		DATE 12-10-82
APPROVED BY [signature]	DATE 12-10-82	APPROVED BY		DATE
APPROVED BY	DATE	EXXON		DATE
DRAWING NO. 050-1-80631			SHEET ___ OF ___	REVISION NO.



SECTION D-D
SECTION F-F
SECTION C-C
LOCATION PLAN
NORTH
SCALE
0 100 300 500
0 500 1000 1500
ELEVATION (METERS) MSL
TAILINGS POND T1
TAILINGS POND T2
TAILINGS POND T4
EMBANKMENT MATERIAL TO BE USED AS RECLAMATION FILL
TEMPORARY WASTE ROCK STORAGE
RECLAMATION COVER (DETAIL E, DWG NO 050-1-80597)
FINAL RECLAIMED SURFACE MINUMUM 2% SLOPE
ESTIMATED FINAL TAILINGS SURFACE
PERMANENT WASTE ROCK STORAGE (DETAILS SIMILAR TO SECTION A-A DWG NO 050-1-80607)
APPROXIMATE ORIGINAL GROUND SURFACE
1.0m ROCK SLOPE PROTECTION (DETAIL B, DWG NO 050-1-80597)
1.07m UNDERDRAIN AND LINER SYSTEM (DETAIL D, DWG NO 050-1-80597)
1.6m UNDERDRAIN AND LINER SYSTEM (DETAIL B, DWG NO 050-1-80597)
2.0m ROCK SLOPE PROTECTION (DETAIL C, DWG NO 050-1-80597)
UNDERDRAIN PIPE (SEC E-E, DWG NO 050-1-80595)
UNDERDRAIN PIPE (SEC C-C, DWG NO 050-1-80596)
UNDERDRAIN PIPE (SEC D-D, DWG NO 050-1-80596)
UNDERDRAIN PIPE (SEC F-F, DWG NO 050-1-80595)
1.07m UNDERDRAIN AND LINER SYSTEM (DETAIL A, DWG NO 050-1-80597)
1.07m UNDERDRAIN AND LINER SYSTEM (DETAIL C, DWG NO 050-1-80597)
WATER CLARIFICATION POOL
COMPACTED GLACIAL TILL EMBANKMENT
NOTE: FOR DETAILS OF WASTE ROCK STORAGE SEE DWG NO 050-1-80607
HORIZONTAL SCALE IN FEET
0 100 200 300 400
HORIZONTAL SCALE IN METERS
0 25 50 75 100 125
VERTICAL EXAGGERATION 5x
FIGURE S-7
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
SECTIONS C-C, D-D, AND F-F
SITE 41-114 B
AS SHOWN
WISCONSIN
FOREST
SKB
9-20-82
RMS
050-1-80606
0

er overlain by a two layer blanket underdrain system placed in two 18 inch (450 mm) thick lifts. The pond bottoms will be sloped toward the embankments to direct the seepage in the underdrain to collection pipes placed around the perimeter. Discharge pipes will extend down the embankments to the collection pipes and pumps will be placed in the discharge pipes to lift the collected seepage to the surface where it will be piped to the reclaim ponds. The maximum seepage rate through the liner for each tailings pond is estimated to be 4.0 gallons per minute ($2.55x10^{-4}$ m^3/s), or less, with the underdrain pumping system operating. Maximum seepage rates after reclamation and shutdown of the underdrain pumping system are estimated to be less than 30 gallons per minute ($1.9x10^{-3}$ m^3/s) per pond and 92.4 gallons per minute ($5.8x10^{-3}$ m^3/s) for the four pond system.

The two reclaim ponds will be lined with a till/bentonite liner overlain by a synthetic liner. These two ponds provide for retention of two months of process water at normal operating levels which is a depth of approximately 20 feet (6.1 m). The freeboard above the operating water level is sufficient to provide storage for the 24 hour-100 year design storm plus two weeks of water from the mine in the event of a shut-down of the excess water treatment plant, and protect against overtopping from waves.

The pond crests will be used as access/haul roads. Also, the tailings pipelines and water return pipelines from the underdrain system and the floating decant systems will be routed along the tailings pond crests. A perimeter access road and fence will also be provided outside the toe of slope of the embankments.

System 41-114B is designed to provide for staged construction on an individual pond basis. The timing of construction has been set to match the time at which the various ponds are anticipated to be needed based on mine/mill production. Some of the embankments will be constructed earlier than required by the tailings production schedule because they are made of waste rock and their timing is established by the waste rock production schedule. The soil used in embankment construction and the soil required for liner and underdrain materials will come from the tailings pond excavations.

The mine waste disposal system is designed so that reclamation can be done in stages. After each tailings pond is filled and taken out of service, the ponded water will be pumped to the reclaim ponds or, in the case of the last tailings pond, to the treatment facility for discharge. A working mat above the tailings can be constructed in the winter months when the tailings surface is frozen to insure adequate trafficability for construction equipment. The remainder of the grading, seal construction, and final cover will follow. The liner materials from the reclaim ponds and rock slope protection materials will be palced in the last tailings pond prior to its final cover being placed. The reclaim pond area will be regraded with the glacial till embankment soils.

The recommended slurry system design provides structurally sound tailings and reclaim water ponds. The system has sufficient flexibility to alter the details of later tailings ponds as may be dictated by actual tailings production and by actual experience in operating the first pond. This flexibility is also available to accommodate experience gained in reclaiming the first tailings pond and applying it to the later ponds.

Golder Associates has worked closely with Exxon in performing their studies and preparing their design recommendations for this system. Exxon and Golder Associates collectively believe that the Site 41-114B system is the most viable mine waste disposal system for the Crandon Project.

SECTION PAGE

1.0 INTRODUCTION

Exxon Minerals Company has retained Golder Associates to provide the preliminary engineering design for use in permitting the mine waste disposal system for their Crandon Mining Project in Forest County, Wisconsin. The purpose of this report is to present alternative mine waste disposal facility site designs and recommend a site design considered to be the most acceptable.

A brief discussion of the history of the preliminary engineering design studies is presented to provide an overview of the project and an understanding of some of the changes in the project because of refinements in the available information. It is because of this evolving design study process that some of the studies, design guidelines, and alternative mine waste disposal systems discussed in this report are outdated. However, results of some of these studies and proposed design alternatives were used as the basis for later work. Thus, they need to be presented in order to provide a complete understanding of the development of the selected waste disposal system.

The report reviews the waste product tonnages and mine waste product mixes which were used during most of the work. A brief description of the general relationship between the mine/mill complex and the mine waste disposal system outlining the various mine waste product flows and general system operations is also included.

Previous siting studies are summarized to provide a framework for the reasoning behind selecting site areas in which more detailed site specific information has been obtained and for which more detailed mine waste disposal system siting has been studied. This summary is primarily directed to discussion of the potential siting areas within about a 5 mile (13 km) radius of the orebody.

Topographic, geologic, and hydrologic conditions of the primary siting areas (encompassing Sites 40 and 41) are summarized. This summary provides a general review of the surface and subsurface geologic conditions and groundwater conditions. The physical properties of the geologic materials are presented.

Three mine waste disposal system alternatives sized for an estimated 100 million DMT (dry metric ton) (one dry metric ton = 1000 kg = 2205 pounds) orebody are reviewed. Description of the waste products and estimated tonnages is presented along with the design parameters for the embankments. Consideration of wetlands in the site alternatives is discussed. The three alternatives are compared on the basis of environmental, construction, and operational factors which were the basis for selecting the system in the Site 41 area.

Because of major changes in the waste product mix and refinement of the estimated orebody size to 77 million DMT, an additional series of five alternatives within the Site 41 area were prepared. The waste product mix and estimated tonnages for these alternatives are described. These five alternatives are compared using environmental, construction, operational, and reclamation factors.

A groundwater model was used to assess the movement of potential seepage from several of the proposed waste site alternatives. The model, algorithms, input parameters and calibration are briefly reviewed. Seepage histories used in the assessments are provided. Various seepage control measures for an example mine waste disposal site were studied to assess their relative effects on seepage movement. In addition, alternative waste disposal sites within the Site 40 and 41 areas were evaluated. The results of these evaluations are presented and their relative differences discussed.

As a result of this continually refining study, alternative 41-114 has been recommended as the preferred alternative. This system design has been completed to a more detailed level and is designated as 41-114B. The preliminary engineering design for this mine waste disposal system is presented and descriptions provided for an understanding of its major design, construction, and reclamation features.

2.0 MINE WASTE DISPOSAL FACILITY ALTERNATIVES EVOLUTION

Golder Associates began work on the preliminary engineering designs of the mine waste disposal facilities for permitting in October, 1978. Since that time, numerous changes have occurred which have affected these designs and the guidelines used in their preparation. The following paragraphs present a brief review of the chronology of waste disposal preliminary engineering design work highlighting the major factors which impacted the work.

Golder Associates began their work with preliminary mine waste disposal layouts within the Site 40 and Site 41 areas. These layouts were sized for a 100 million DMT (dry metric ton) orebody with only two waste products, tailings and reclaim water. These layouts were done to ascertain an estimate of the land area which would be needed to develop the facilities so that subsurface investigation programs and other studies could be developed.

Golder Associates was then asked by Exxon to briefly review the siting work by Dames & Moore and to provide an independent review with regard to siting. Golder Associates concluded that the Site 40 and Site 41 areas were the most advantageous sites available and continued working on preliminary waste facilities designs while completing the Siting Report (Ref. 9).

As the design progressed, many changes were made in the mine waste product mix and tonnages. These changes were the result of continuing work by Exxon and other consultants. These changes were made simultaneously and as such, waste disposal layouts at the Site 40 and 41 areas were prepared for almost every change. The changes prior to January, 1981 are as follows:

1. Prepare the waste facility layouts for a potential 100 million DMT orebody with a 10 percent by weight tailings slurry.

2. Provide for temporary storage of mine backfill sand.

3. Restrict the depth of the reclaim pond to approximately 20 feet (6.1 m).

4. Prepare layouts for both of the following cases:
   a. Separation of pyrite from the tailings with the high pyrite tailings stored in a separate pond with a liner and the low pyrite tailings stored in ponds without liners.
   b. Storage of combined tailings (100 million DMT orebody with a 10 percent by weight tailings slurry) in lined ponds.

5. Accommodate waste rock into the facility.

6. Accommodate excess water treatment sludge into the facility in a separate pond.

Since January, 1981 the following refinements in the waste product mix and tonnages have been made:

1. Prepare the waste facility layouts for a 77 million DMT orebody with a 50 percent by weight tailings slurry.

2. Delete mine backfill sand storage area.

3. Reduce size of reclaim pond and provide two separate ponds.

4. Provide for storage of combined tailings in lined ponds (underdrains also added).

5. Delete separate excess water treatment sludge pond.

6. Provide reclamation cover soil from within the pond areas.

Many of these changes were incorporated into the waste facility designs along with changes necessitated by other studies. To date, over 200 alternative mine waste facility layouts have been prepared.

Regulatory trends toward limiting the use of wetlands as waste disposal areas has been a major consideration in the siting and alternative design process. Large wetlands, particularly those groundwater fed wetlands contiguous with lakes and streams, were excluded from consideration as potential waste disposal areas during the siting study process. The concern regarding wetlands led to the waste disposal facility Site 50 area which included layouts that did not cover any wetland areas. The Site 50 area covered portions of the Site 40 and 41 areas. Numerous facility alternatives were prepared for this area incorporating several of the waste product mix variations for the 100 million DMT orebody. The concept of providing a mine waste facility design alternative which covers no wetlands was not carried through for the 77 million DMT orebody because it is apparent that although a facility may not cover any wetlands, it would impact wetlands by covering the watershed area which drains to them.

As the design of the mine waste facilities progressed, studies were continually being performed and updated on the Project area geology, surface water and groundwater hydrology, groundwater modeling, tailings materials properties, liners, and reclamation concepts. As results of these studies became available, they were integrated into the facility designs and carried forward. With each input of additional information the previous work was reviewed and if the changes were significant (such as revising the orebody size or waste product mix) revisions were made to prior work. In most cases, however, it was considered unnecessary to repeat prior studies on the basis of new information since some of the prior studies were completely outdated or decisions made on a comparison basis (such as comparing one site layout to another) would not change because of the later information. An example of such a comparison is the screening analyses made with the groundwater model. One of the comparative analyses was done with one facility layout in the Site 41 area where the thickness of the pond liner was altered. This study was done with an estimated permeability of $1x10^{-10}$ m/s ($3.3x10^{-10}$ ft./sec.) for the bentonite clay admixture liner. Later information from laboratory studies indicated that a slightly higher permeability of $5x10^{-10}$ m/s ($1.6x10^{-9}$ ft./sec.) (Ref. 15) would be more prudent for these preliminary studies. However, since the comparative analyses was done to assess general trends with respect to changes in liner thickness at a given permeability, the results of the comparison would not change with this revision in estimated liner permeability.

In addition to the many revisions in the preliminary engineering design process brought about by the continuing studies being performed, this work was being done while legislation regarding mining and mine waste disposal, NR 182 in particular, was being developed. Thus, there was little consistent guidance from the regulations with respect to some of the detailed requirements for some of the studies. Portions of the work were designed in anticipation of the legislative requirements.

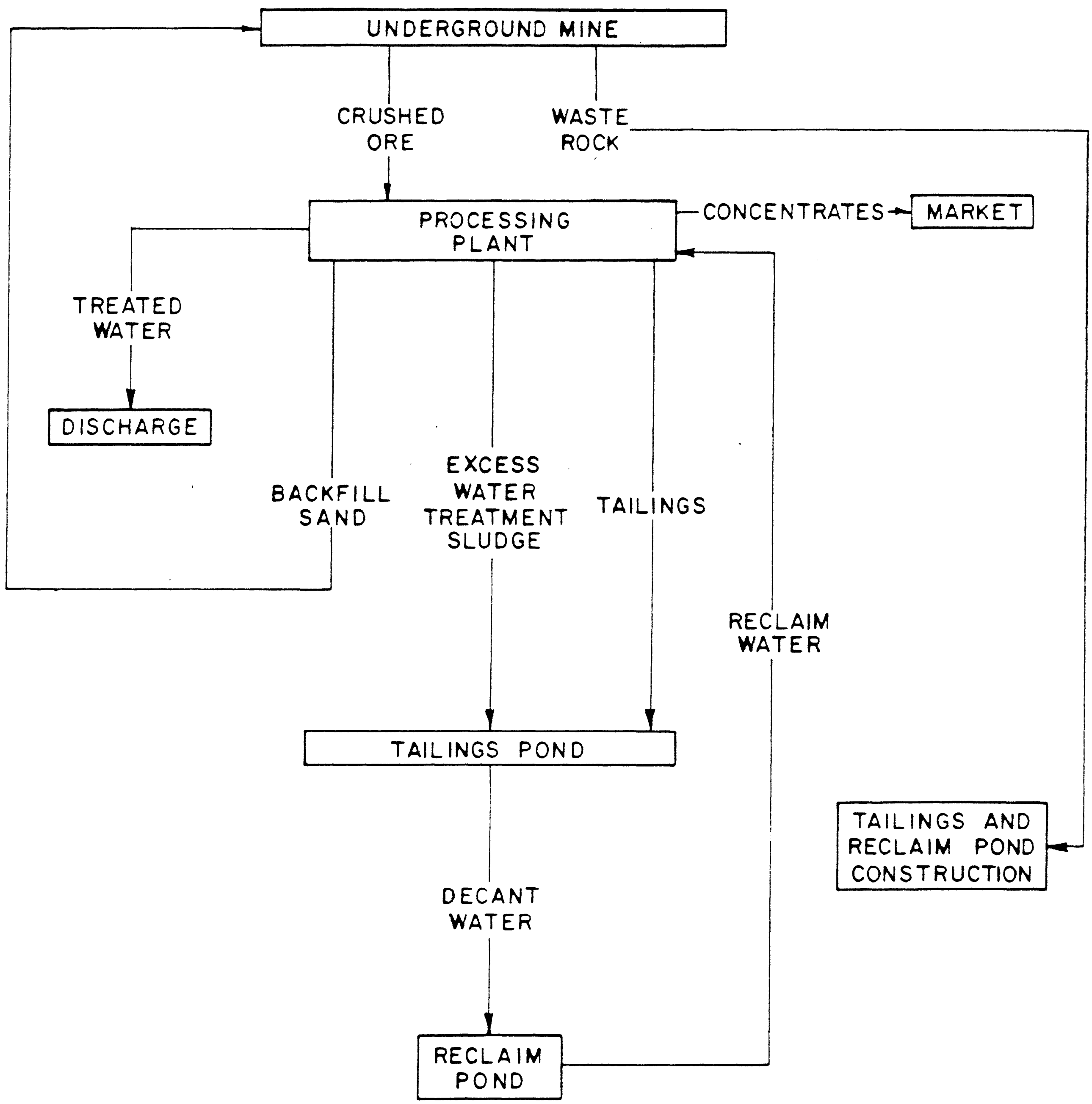
The preliminary waste facility design process was one of adaptation to continuous refinements in the available information and design guidelines. Many of the changes evolving from this process are discussed in this report with the recommended mine waste facility site being the outcome of this process.

3.0 WASTE PRODUCTS

3.1 General System Operation

The mine waste disposal system for the Crandon Project will provide for surface disposal of materials generated directly by mining and milling and the sludge from treatment of excess water for discharge. The products from mining and milling will be generated from the orebody and are essentially crushed or ground rock of varying grain size. The water treatment sludge will include minerals from the ground rock and precipitates from the treatment process. The disposal system will also serve as a water retention and recycle system. The products for storage or disposal in the mine waste disposal area are: waste rock, tailings, reclaim water, and excess water treatment sludge. A simplified flow diagram of the system is shown on Figure 3.1, and a brief description of this system follows.

In the underground mining operation, rock is excavated by blasting, crushed to about 6 inches (152 mm) and less in size, and lifted to the surface. The excavated rock includes both mineralized rock (ore) and non-mineralized rock (waste rock). The crushed ore brought to the surface is the raw feed material for the processing plant. When possible, the waste rock is kept underground and used to fill previously mined areas. At times during the mining operation, there are no openings requiring filling with the waste rock. At these times the waste rock will be crushed and lifted to the surface for use in construction of the waste disposal ponds or for disposal with the tailings. This waste rock will be transported to the mine waste disposal area by truck.



JOB NO. 786085	SCALE NOT TO SCALE	MINE WASTE DISPOSAL SYSTEM FLOW DIAGRAM
DRAWN SKB	DATE 10-21-82	
CHECKED	DWG NO. —	
Golder Associates	EXXON MINERALS COMPANY	FIGURE 3.1

The ore fed to the mill is further reduced by grinding to sizes less than about one millimeter and the concentrates (merchantable products) are extracted. The Crandon orebody contains two major ore types which have been termed "massive ore" and "stringer ore." The massive ore includes copper, lead, and zinc in a mostly pyritic (sulfide mineral) rock. The stringer ore contains copper and a small amount of zinc in a mostly quartz rock and has some "stringers," or veinlets, of sulfide minerals within the rock. The two ore types occur in such a fashion that they can usually be mined and milled separately.

The material remaining after extraction of the concentrates will be split (separated by size) at 20 microns (0.02 mm = 0.0008 in.). The coarser fraction will be primarily sand size material and will be returned to the underground mine as backfill. When sand backfill is not needed in the mine, the sand will be temporarily stored in the plant area.

The finer fraction of mill waste is the tailings. This material is primarily silt sized and will be pumped at a 50 percent (by weight) slurry concentration to the tailings pond. The tailings solids will settle in the tailings pond and clarified water (decant water) will be piped to the reclaim water pond. Water from the reclaim pond will be reused in the mill as process water.

It is presently anticipated that the mine/mill complex will have excess water in the system which will have to be treated and discharged. Details of the volumes, treatment processes, and discharge methods and locations are beyond the scope of this report. The treatment process is expected to produce a sludge which, if it cannot be marketed, will be pumped to the tailings pond. The volume of this sludge is small in comparison to the volume of tailings and does not markedly affect the size of the waste disposal system.

This brief description of the materials flow is by no means complete in all details. However, it is sufficient for use as a basis for understanding the system and how the flow system affects the overall facilities layout.

3.2 Tonnage and Volume Estimates

The present estimate of reserves for the Crandon orebody is 77 million DMT based on data obtained as of January, 1981. This estimate is based on a 62.3 million DMT orebody with an approximate 25 percent contingency. This reserve estimate is presently being used to estimate the amount of tailings and hence determine the waste facility capacity. Estimated tonnage and waste volumes for the 77 million DMT orebody are provided in Table 3.1.

Prior to 1981, the reserve estimate used to determine the amount of tailings was 100 million DMT. Although capacity estimates based on this size orebody are of little value to the design of the final system, they were used to establish pond volumes for some of the waste facility layouts presented in Section 6 of this report. Therefore, the estimated tonnages and volumes of waste products for the 100 million DMT orebody are provided in Table 3.2.

In addition to changes in the waste facility design necessitated by the revised reserve estimate, Exxon decided on four other changes in the waste product mix. First, the tailings would not be separated as sulfide and non-sulfide

TABLE 3.1

77 Million DMT Orebody
Mine Waste Product Tonnage

Product	Tonnage		Dry Density		Volume	
	10^6 DMT	10^9 lbs.	kg/m^3	lbs./cu. ft.	10^6 m^3	Ac.-Ft.
Tailings	34.81	76.76	1522	95	22.88	18,548
Waste Rock	3.24	7.14	1689	105	1.93	1,565
Reclaim Water Pond(1)	N/A	N/A	N/A	N/A	1.18	954
Excess Water Treatment Sludge(2)	N/A	N/A	N/A	N/A	0.99	800

Notes:

(1) Reclaim Pond sized to accommodate 3,600 gpm for 60 days retention time.

(2) To be included in tailings pond.

TABLE 3.2

100 Million DMT Orebody
Mine Waste Product Tonnage and Volume Estimates

Product	Tonnage		Dry Density		Volume	
	10^6 DMT	10^9 lbs.	kg/m^3	lbs./cu. ft.	10^6 m^3	Ac.-Ft.
Sulfide Tailings	14.67	32.35	2083	130	7.05	5,713
Non-sulfide Tailings	28.09	61.93	1362	85	20.63	16,726
Waste Rock	6.40	14.11	1682	105	3.81	3,085
Reclaim Water Pond(1)	N/A	N/A	N/A	N/A	2.22	1,799
Excess Water Treatment Sludge(2)	N/A	N/A	N/A	N/A	1.97	1,600
Backfill Sand(3)	43.80	96.58	1762	110	24.86	20,156

Notes:

(1) Reclaim pond sized to accommodate 6670 gpm for 60 days retention time.

(2) Volume is an allowance. More accurate estimate to be made after further study.

(3) Temporary surface storage to be provided for 3 million DMT (1381 Ac.-Ft. = 1.70x10^6 m^3).

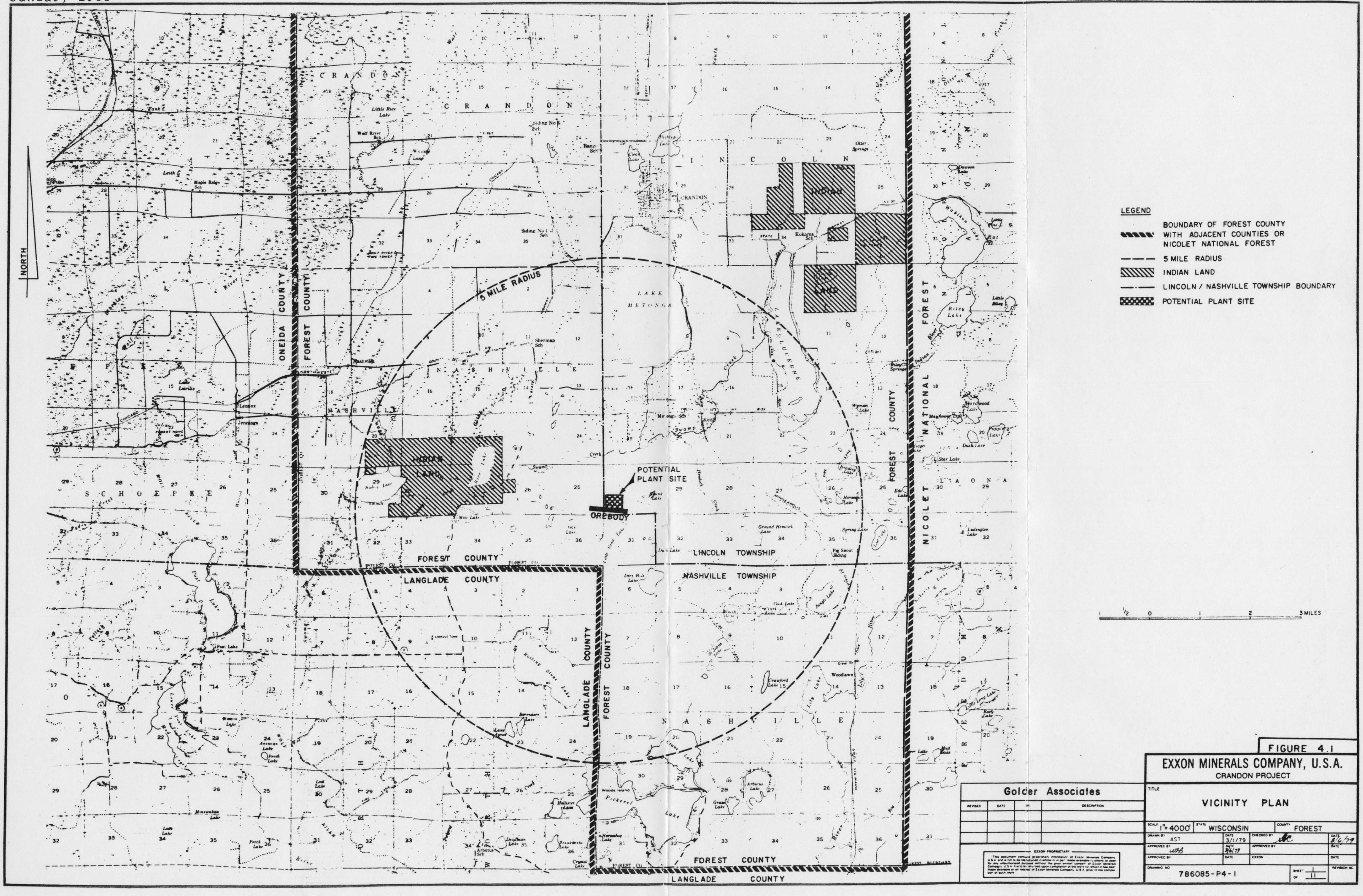
tailings. Thus, the sulfide and non-sulfide tailings noted as separate products in Table 3.2 are listed as one product in Table 3.1. For the 100 million DMT orebody both separated and combined tailings disposal were studied. For the 77 million DMT orebody only combined tailings have been considered. Second, the tailings would be pumped as a slurry at 50 percent solids content (by weight) and not 10 percent solids content as it was for the earlier studies. Third, backfill sand would be temporarily stored, if needed, in a special storage area near the mine/mill complex, not in the waste disposal area. Fourth, the excess water treatment sludge would be mixed with the tailings for disposal instead of being placed in a separate pond. These changes, along with those resulting from the revised reserve estimate are reflected in the estimated waste product tonnages and volumes in Table 3.1.

4.0 SITING STUDY REVIEW

4.1 General Siting Criteria

Dames & Moore prepared a siting study report (Ref. 4) for Exxon Minerals Company which was submitted to the Wisconsin DNR in January, 1979. This report provided a general overview of the characteristics of an area within a 12-mile (19 km) radius of the Crandon orebody. It indicated that the land beyond this radius did not reveal physiographic features significantly different than those within the study area.

Golder Associates prepared an additional Siting Report (Ref. 9) in April, 1979, supplementing the previous study and presenting another perspective of the tailings siting question. In performing the study, Golder Associates made maximum utilization of the data and reports existing at that time. In the study, the region of primary consideration was reduced to the approximate area within a radius of 5 miles (8 km) from the orebody. The major political boundaries within the study area included the Forest-Langlade County line and the Lincoln-Nashville Township lines within Forest County. The orebody is located in both the Lincoln and Nashville Townships of Forest County. The Siting Report described the methodology by which certain broad areas were excluded from consideration as disposal areas and by which 13 potential disposal areas were identified and evaluated with respect to their viability as disposal sites. Figure 4.1, Vicinity Plan, shows the orebody location and area of about 5 miles (8 km) from the orebody. The remainder of Section 4 of this report reviews the Golder Associates Siting Study (Ref. 9).


NORTH
CRANDON
LINCOLN
NASHVILLE
SCHOEPKE
5 MILE RADIUS
INDIAN LAND
LAKE METONGA
LAKE LUCERNE
POTENTIAL PLANT SITE
OREBODY
ONEIDA COUNTY
FOREST COUNTY
LANGLADE COUNTY
LINCOLN TOWNSHIP
NASHVILLE TOWNSHIP
NICOLET NATIONAL FOREST
LAONA
LEGEND
BOUNDARY OF FOREST COUNTY WITH ADJACENT COUNTIES OR NICOLET NATIONAL FOREST
5 MILE RADIUS
INDIAN LAND
LINCOLN / NASHVILLE TOWNSHIP BOUNDARY
POTENTIAL PLANT SITE
1/2 0 1 2 3 MILES
FIGURE 4.1
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
Golder Associates
TITLE
VICINITY PLAN
SCALE 1" = 4000'
STATE WISCONSIN
COUNTY FOREST
DRAWN BY AST
DATE 3/1/79
DATE 3/6/79
DRAWING NO 786085-P4-1
SHEET 1 OF 11

The land within the study boundary was evaluated for consideration of potential disposal areas. Consideration was given to the location of lakes and wetlands, presence of certain ecological features (such as endangered species nests), land topography, overall regional hydrology, land use, political boundaries, and facilities requirements. In the siting analysis, some of the various environmental factors were considered in a qualitative manner rather than quantitative. Each item was discussed with its relative importance to mine waste disposal system siting noted.

State law precludes the use of lakes as potential waste disposal sites. In addition, Wisconsin Administrative Code, Section NR 151.12 regarding Solid Waste Management, requires an offset of 1000 feet (305 m) from lake shores for waste disposal areas. Thus, the lakes within the study area and the land within 1000 feet (305 m) of the lakes were eliminated from consideration as disposal areas.

Regulatory trends towards limiting the use of wetlands discourages consideration of these features as disposal sites. For this reason, the large wetlands, particularly those contiguous with lakes or major streams, were not considered potentially viable disposal areas. In the study area, these large wetlands are predominantly below elevation 1600 feet (487 m). Above elevation 1600 feet (487 m) the wetlands are relatively small and more isolated from surface streams, lakes, and groundwater. In most cases these areas are simply small topographic depressions. The existence of these scattered upland wetlands did not eliminate general areas from further consideration as potential disposal sites.

The study area included certain important ecological features such as endangered species nests and unique habitats. It was generally considered that if a potential disposal area contained one of these features it would be excluded from further consideration. Singular features, such as eagle or osprey nests were avoided from the standpoint of actual destruction. However, since deer yards encompass fairly large land areas, consideration was given to using part of a deer yard if other factors strongly favored such a particular area. The necessity to cross a deer yard, wetland, or stream with a pipeline corridor to transport the waste products was also considered.

The topography of the entire area is characterized by rolling terrain at higher elevations, above about elevation 1600 feet (487 m), and with relatively little relief at elevations below about 1600 feet (487 m). The lakes, most wetlands, and most of the sensitive habitat areas such as deer yards, trout streams, osprey nests, etc., are found below elevation 1600 feet (487 m). Because of these factors, most of the land below elevation 1600 feet (487 m) was considered as probably not containing an area suitable for the siting of major waste disposal facilities. Within the higher ground, natural depressions would be desirable topographic features since they could tend to minimize the amount of earthwork necessary for waste facility development.

Primary land use in the study area from an economic viewpoint is for the timber and pulpwood industry with a small amount used for agricultural purposes and private dwellings. The overall area is attractive from the standpoint of recreation, hunting, and fishing. The broad land use of recreation, hunting, and fishing was not considered as a major siting factor except for unique habitats. Since timber and pulpwood lands cover a large area, it was believed that the amount of land used for waste facility siting would not impact the industry. More populated areas such as the town of Crandon were eliminated from consideration, as was the Mole Lake Indian Reservation. Agricultural land and private dwellings in rural areas were not considered as reason to exclude an area.

From a surface water standpoint, it was considered preferable to keep all facilities within the same surface watershed. Because of the nature of the glacial soils in the area, particularly in the upland areas, it was anticipated that permeabilities and surface water infiltration rates would be very similar from one area to another. Thus, a slight modification or straddling of surface watershed boundaries was not considered a major siting feature. The upland areas are groundwater recharge areas and were considered to have similar reactions to waste disposal siting. Thus, no one upland area was considered to be markedly different than any other upland area in this regard.

In assessing potential waste disposal areas the broad requirements of the facilities were included as siting parameters. The areas considered had to be large enough to accommodate a series of tailings ponds with storage volumes in the 2000 to 7000 acre-foot (2.5×10^6 to 8.6×10^6 m^3) range covering surface areas ranging from about 25 to 200 acres (10 to 81 ha) per pond. Topographic features and proximity to the orebody were also considered important to the facility design. Pipeline corridors and adjacent service roads should be as short as possible to reduce the overall costs and to reduce the amount of land disturbed.

Figure 4.2, Composite Site Plan with Selected Siting Features, shows the study area with highlighted topography, political boundaries, and other physical and ecological features considered as siting criteria.

4.2 Potential Disposal Areas

The methodology used to identify potential disposal areas was to screen the entire study area in order to delineate those portions considered not suitable for siting of mine/mill waste disposal facilities. The area remaining was that in which there might be potentially viable tailings disposal sites. This remaining area was divided into smaller areas based on topography and location, and these smaller areas were considered in more detail.

To establish those areas which were not considered potentially viable as disposal areas, the land in the vicinity of the orebody was screened by plotting various siting criteria on base maps. These criteria included land below elevation 1600 feet (487 m), locations of endangered species nesting sites, unique habitats, lakes, land within 1000 feet (305 m) of lake shores, wetlands, and political boundaries. Figure 4.2 is a composite map showing these features. With the exception of the textured areas delineating zones above elevation 1700 feet (518 m), the various shaded portions of Figure 4.2 represent those areas judged not to be viable disposal locations. About one half the area around the orebody within the five mile radius is thus excluded from being considered potentially viable for waste disposal. The orebody is nearly surrounded by an area comprised of low ground with major lakes, streams, and lowland wetlands. Only a small corridor of high land to the east and southeast of the orebody prevents the mine area from being completely surrounded by excluded lands.

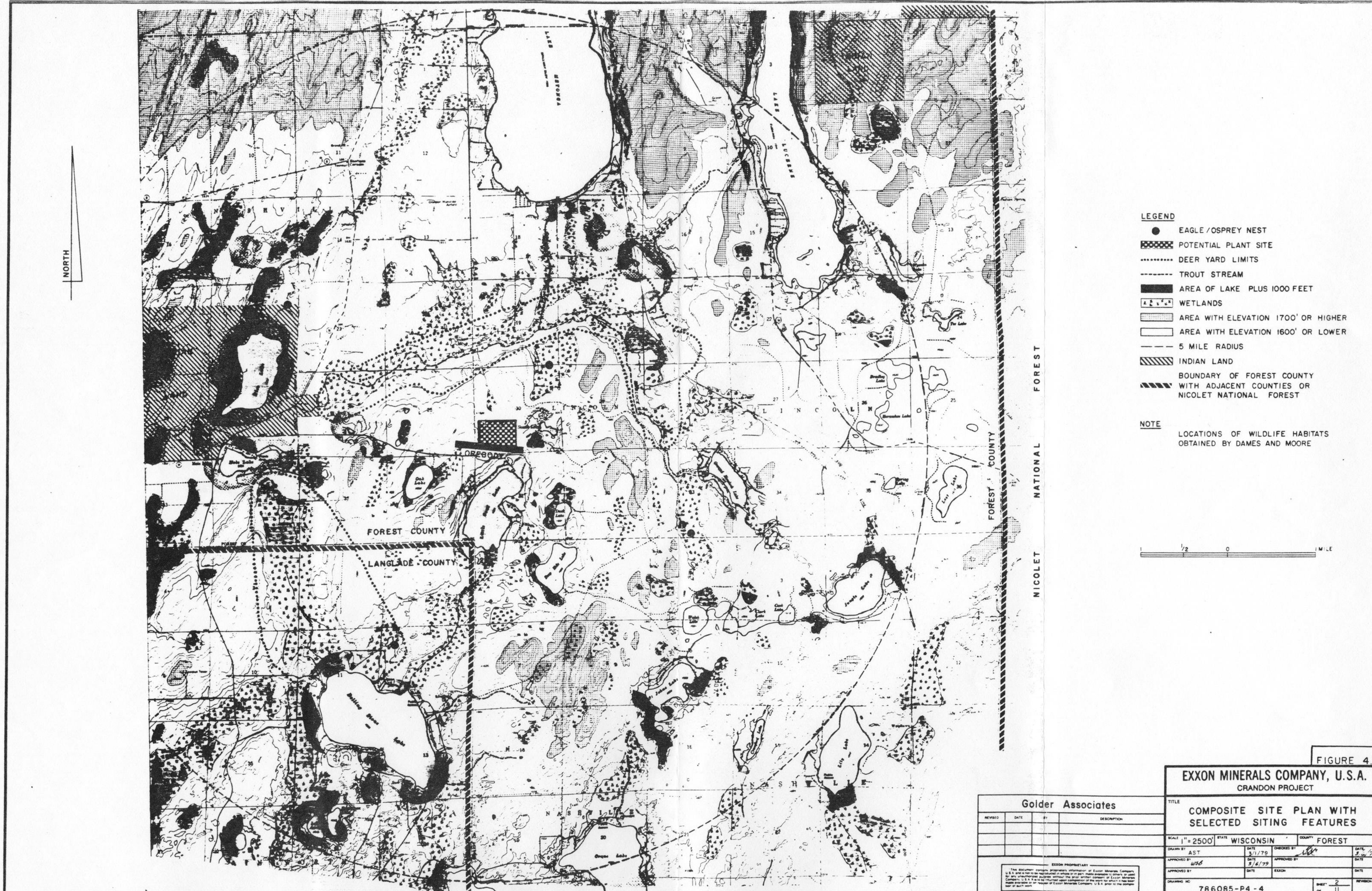
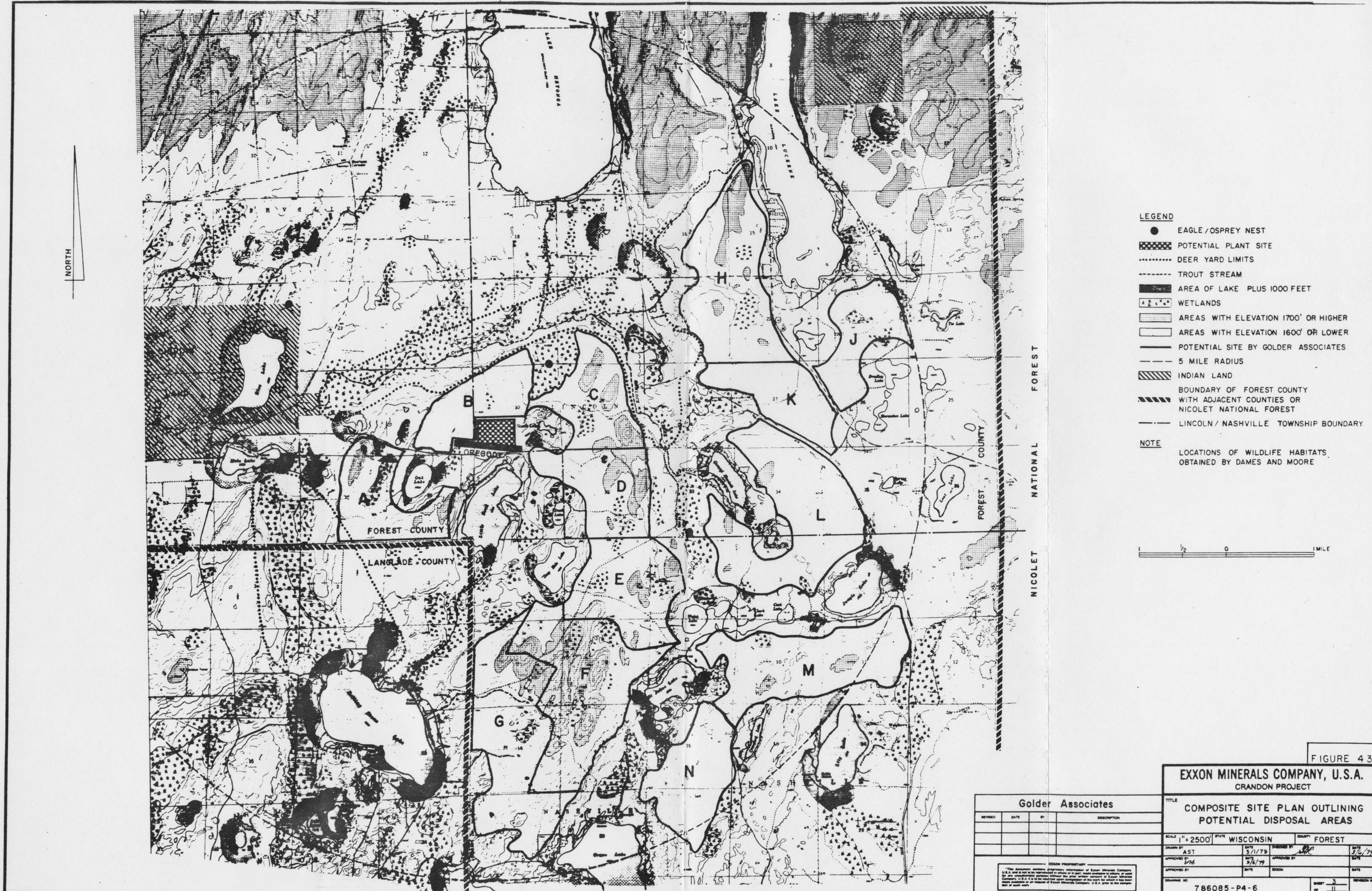

NORTH
FOREST COUNTY
LANGLADE COUNTY
OREBODY
LINCOLN
NASHVILLE
NICOLET NATIONAL FOREST
FOREST COUNTY
LEGEND
EAGLE / OSPREY NEST
POTENTIAL PLANT SITE
DEER YARD LIMITS
TROUT STREAM
AREA OF LAKE PLUS 1000 FEET
WETLANDS
AREA WITH ELEVATION 1700' OR HIGHER
AREA WITH ELEVATION 1600' OR LOWER
5 MILE RADIUS
INDIAN LAND
BOUNDARY OF FOREST COUNTY WITH ADJACENT COUNTIES OR NICOLET NATIONAL FOREST
NOTE
LOCATIONS OF WILDLIFE HABITATS OBTAINED BY DAMES AND MOORE
1/2
0
1 MILE
Golder Associates
REVISED
DATE
BY
DESCRIPTION
EXXON PROPRIETARY
FIGURE 4.2
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
TITLE
COMPOSITE SITE PLAN WITH SELECTED SITING FEATURES
SCALE 1" = 2500'
STATE WISCONSIN
COUNTY FOREST
DRAWN BY AST
DATE 3/1/79
CHECKED BY
DATE 3/6/79
APPROVED BY
DATE 3/6/79
APPROVED BY
DATE
EXXON
DRAWING NO 786085-P4-4
SHEET 2 OF 11
REVISION NO

Figure 4.3, Composite Site Plan Outlining Potential Disposal Areas, shows 13 potential sites which were identified and considered in detail. There are also some areas within the study boundary which were not within the exclusion screening and which were not considered as potential disposal areas. These areas include the land in the northwest portion of the study boundary, the land between Lake Lucerne and Lake Metonga, and the land within Langlade County. These areas were excluded because of their proximity to major lakes, residential areas, the Crandon airport, and the necessity of crossing major wetlands and streams with the waste product transportation system. Only the land in the extreme northeast corner of Langlade County (north of Rolling Stone Lake) appeared viable for waste facilities siting but it was considered too small by itself and it was considered desirable not to have the facilities in more than one county.

4.3 Selected Siting Areas

Of the 13 potential siting areas identified, the most attractive siting areas included combinations of Areas A, B, C, D, E, and F. The principal advantages of these areas were topographic features which could be incorporated into the facility design, shorter pipeline corridor length, and not needing to cross major wetlands and streams with the pipelines. Area G is approximately four miles from the orebody and includes two trout streams with their headwaters. Areas H, J, K, and L all have the disadvantage that the pipelines would have to cross Swamp and/or Hemlock Creeks and their associated wetlands, or the pipeline would have to be routed south of the Hemlock Creek wetland which would increase its length markedly. The Soo Line Railroad would also have to be crossed to reach either Area H, J or K. Areas K and L are relatively flat and the probability exists that borrow material would have to be obtained from


NORTH
LEGEND
EAGLE / OSPREY NEST
POTENTIAL PLANT SITE
DEER YARD LIMITS
TROUT STREAM
AREA OF LAKE PLUS 1000 FEET
WETLANDS
AREAS WITH ELEVATION 1700' OR HIGHER
AREAS WITH ELEVATION 1600' OR LOWER
POTENTIAL SITE BY GOLDER ASSOCIATES
5 MILE RADIUS
INDIAN LAND
BOUNDARY OF FOREST COUNTY WITH ADJACENT COUNTIES OR NICOLET NATIONAL FOREST
LINCOLN / NASHVILLE TOWNSHIP BOUNDARY
NOTE
LOCATIONS OF WILDLIFE HABITATS OBTAINED BY DAMES AND MOORE
1 1/2 0 1 MILE
A B C D E F G H J K L M N
OREBODY
FOREST COUNTY
LANGLADE COUNTY
NICOLET NATIONAL FOREST
FOREST COUNTY
Golder Associates
REVISED DATE BY DESCRIPTION
EXXON PROPRIETARY
FIGURE 43
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
TITLE
COMPOSITE SITE PLAN OUTLINING POTENTIAL DISPOSAL AREAS
SCALE 1" = 2500' STATE WISCONSIN COUNTY FOREST
DRAWN BY AST DATE 3/1/79 DATE 3/6/79
APPROVED BY DATE 3/6/79
DRAWING NO. 786085-P4-6
SHEET 3 OF 11

one of the adjacent areas. Areas M and N both exhibit erratic topography, may require borrow to be obtained from other areas, and are two to three times farther from the orebody than the more attractive siting areas.

Of the most attractive sites, Area D with the southern portion of Area C and possibly the northern portion of Area E appeared to be the best site. The second most attractive site was Area A with possibly some or all of Area B depending on the surface land area required. The third choice was a combination of Areas E and F. Flexibility was noted for each of these choices depending on more detailed design parameters and other factors as they developed.

During the time the Golder Associates Siting Report (Ref. 9) was being reviewed by the Wisconsin DNR and the Public Intervenor's staff, it appeared from the maps in the report that there were almost no wetlands within Areas K and L and the southern parts of H and J. This region was then inspected by Exxon with representatives from the Public Intervenor. It was found to contain numerous small wetlands and large meadow type wetlands. These features did not appear on the USGS quadrangle maps which were used as base maps for the Golder Associates Siting Report (Ref. 9). The presence of these wetlands makes these areas even less attractive for facilities siting.

During the course of facilities layout studies, it became apparent that Area A, by itself, was not large enough to accomodate all waste products within the framework of the guidelines for the layouts. Also, it was believed that using the large wetland west of Oak Lake, which would require re-routing the drainage path of Oak Lake, would not be favorably considered because of the size of the wetland and the proximity of this area to Swamp Creek. It was then decided by Exxon to include the land in the extreme northeast corner of Langlade County, just south of Area A and north of Rolling Stone Lake, for the facilities layout studies.

5.0 SELECTED DISPOSAL AREA CONDITIONS

5.1 Disposal Site Locations

The three most attractive disposal areas as delineated in the Golder Associates Siting Report (Ref. 9) were the targets for specific data collection and trial facility layouts. On closer examination of these areas, and with more detailed estimates of waste product tonnages and volume estimates (previously discussed in Section 3), several factors were noted which suggested revision to the land areas designated as being the most attractive areas for waste disposal siting.

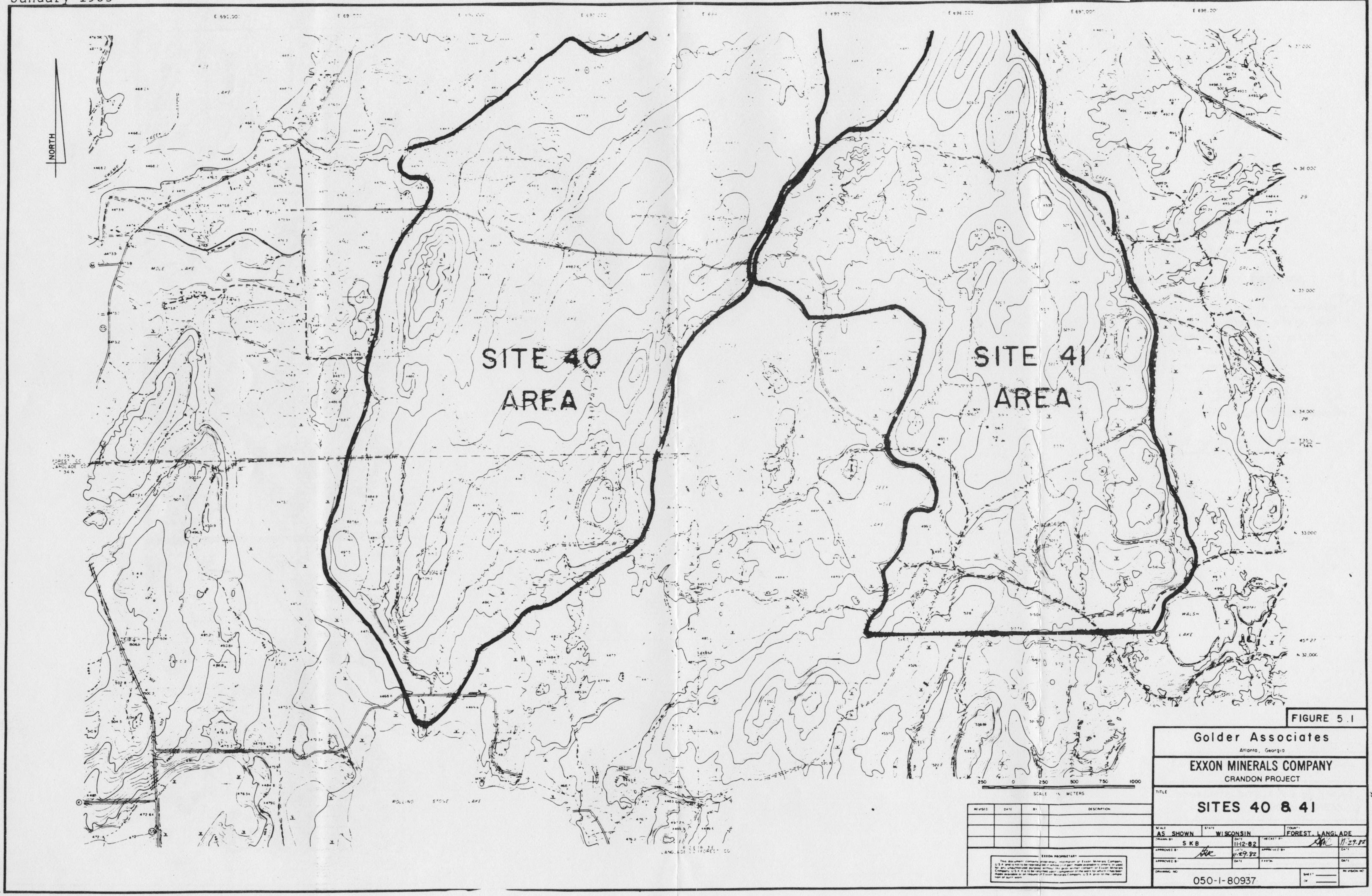
Area B, northwest of the orebody, was considered an attractive siting area when used in combination with one of the other areas. Area B, by itself, is too small to contain all required facilities. Much of Area B is below elevation 1600 feet (487 m) and relatively close to groundwater levels. All of Area B is within the Swamp Creek surface watershed. Compared to most other areas, Area B is closest to Swamp Creek and has the shortest hydraulic connection to the environmentally sensitive Swamp Creek wetland and Rice Lake. As trial facility layouts were being developed, it became evident that Area B would be best suited for storage of small volume products which would not need a great deal of earthwork to develop, and for products which would only be stored while the mine/mill complex is operational. Products such as pre-production ore, backfill sand, reclaim water, and possibly pre-production waste rock could be stored in this area. This area is generally not suited for permanent waste disposal of tailings.

It became apparent with initial facility layout work that Area A, by itself, would be too small to develop a multiple pond waste facility system for the various waste products. Also, much of the land usable for disposal included fairly large wetlands adjacent to, and part of, the drainage path of Oak Lake. In consideration of the regulatory trends concerning disturbance of wetlands, and considering that the Oak Lake drainage path would have to be relocated, it was concluded that this land area should not be viewed as a favorable site. Focus was then shifted to combining the southern portion of Area A and the highland area within the northeast corner of Langlade County immediately south of Area A and north of Rolling Stone Lake. It was found that this combination of land areas would be large enough to develop the required waste facility system. Also, it did not include large, lowland wetlands contiguous with streams or lakes and, for the most part, was within the Pickerel Creek surface watershed.

For convenience, Area A, Area B, and the land in the northeast portion of Langlade County were combined into one siting area for additional data development and study. This siting area is designated as Site 40. Earlier work by Dames & Moore designated this general area as Site 40-A.

With trial layout development, it was found that Area D, by itself, was too small to contain a multiple cell system for the various waste products. As anticipated during the siting study, layouts in this area included extensions into the southern portion of Area C and into much of Area E. This siting area is designated as Site 41 (earlier work by Dames & Moore also designated this general area as Site 41).

The location of Sites 40 and 41 are shown on Figure 5.1. The location boundaries shown are approximate and are intended to show the general location of each site for


NORTH
SITE 40
AREA
SITE 41
AREA
250 0 250 500 750 1000
SCALE IN METERS
FIGURE 5.1
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
SITES 40 & 41
AS SHOWN
WISCONSIN
FOREST, LANGLADE
SKB
11-12-82
050-1-80937

discussion reference purposes. The boundaries shown are not precise limits of a recommended waste disposal site.

A combination of Areas E and F was the third most attractive disposal site identified in the Golder Associates Siting Report (Ref. 9). A brief review of Area F suggests it has no distinct advantages over Area D. Area F contains numerous small wetlands and the surface watershed divide for Little Sand Lake passes almost through the center of Area F. Area F is less attractive than Area D because of its distance from the orebody. Since development of a disposal system would include a combination of Areas F and E and since Area E is required in combination with Area D, there appeared to be little advantage to considering the Area E-F combination over the D-E combination. Therefore, no further consideration has been given to Area F.

5.2 Geology

5.2.1 Background Information

Golder Associates have prepared a report "Geotechnical Review, Crandon Project Waste Disposal System, Project Report 2," October, 1981 (Ref. 11), presenting the results of field and laboratory investigations and the interpretation of this data. The report provides a description of the geologic and hydrologic conditions and the physical properties of the glacial materials in the Site 40 and Site 41 areas. The specific subsurface conditions have been investigated by test borings, test pits, borehole permeability tests, and laboratory tests on samples obtained from the borings and test pits. In addition, a pumping test was conducted at Site 41 (Ref. 14). These data along with the surface geologic mapping, geophysical investigation in the area surrounding the proposed waste disposal sites, and published and unpublished geological and soil information have been used to assess the specific site conditions and material properties. Data which is not included in the three volumes of Project Report 2 but which were used in the study are referenced. Figure 5.2 is a plan of the project area showing the borehole and test pit locations.

Test borings for investigation of the subsurface conditions (not specifically related to exploration of the orebody) at the proposed waste disposal sites and surrounding areas were a result of programs designed and supervised by Golder Associates and Dames & Moore. These programs were implemented over a period of several years to investigate different areas around the project site, for specific purposes (such as groundwater monitoring or definition of the glacial stratigraphy) and for increased level of stratigraphic detail in some areas, particularly in Site 41. A detailed discussion of the test boring programs designed by Golder Associates is presented in Reference 11. Detailed logs and discussion of the test boring programs designed by Dames & Moore are presented in Reference 5.

A brief summary of the geologic history, geologic material types, and physical properties of those geologic materials of consequence to the Crandon Project waste disposal system design are summarized in the following sections of this report. Detailed information is provided in Golder Associates' Project Report 2 (Ref. 11).

5.2.2 Geologic Setting

The glacial events which deposited and shaped the overburden materials within the Crandon Project area and

LEGEND

- TEST BORING LOCATION
- TEST BORING INCLUDING GROUNDWATER OBSERVATION WELL
- TEST BORING INCLUDING MULTIPLE GROUNDWATER OBSERVATION WELL
- WELL DATA PROVIDED BY USGS
- GOLDER ASSOCIATES TEST PIT LOCATION
- GOLDER ASSOCIATES TEST WELL LOCATION
- DAMES & MOORE TEST WELL LOCATION
- CRANDON FORMATION

NOTE

SUPERVISION OF BORINGS AND GROUNDWATER OBSERVATION WELL INSTALLATION DETERMINED BY THE FOLLOWING DESIGNATION PREFIXES

G	GOLDER ASSOCIATES
DM	DAMES & MOORE
DW	DAMES & MOORE
BE	BRAUN ENGINEERING TESTING
X	EXXON MINERALS COMPANY
STS	SOIL TESTING SERVICES OF WISCONSIN, INC
AR,RR	SOIL TESTING SERVICES OF WISCONSIN, INC
CDM	CAMP DRESSER & McKEE, INC

FIGURE 5.2

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
BORING LOCATION PLAN PROJECT AREA

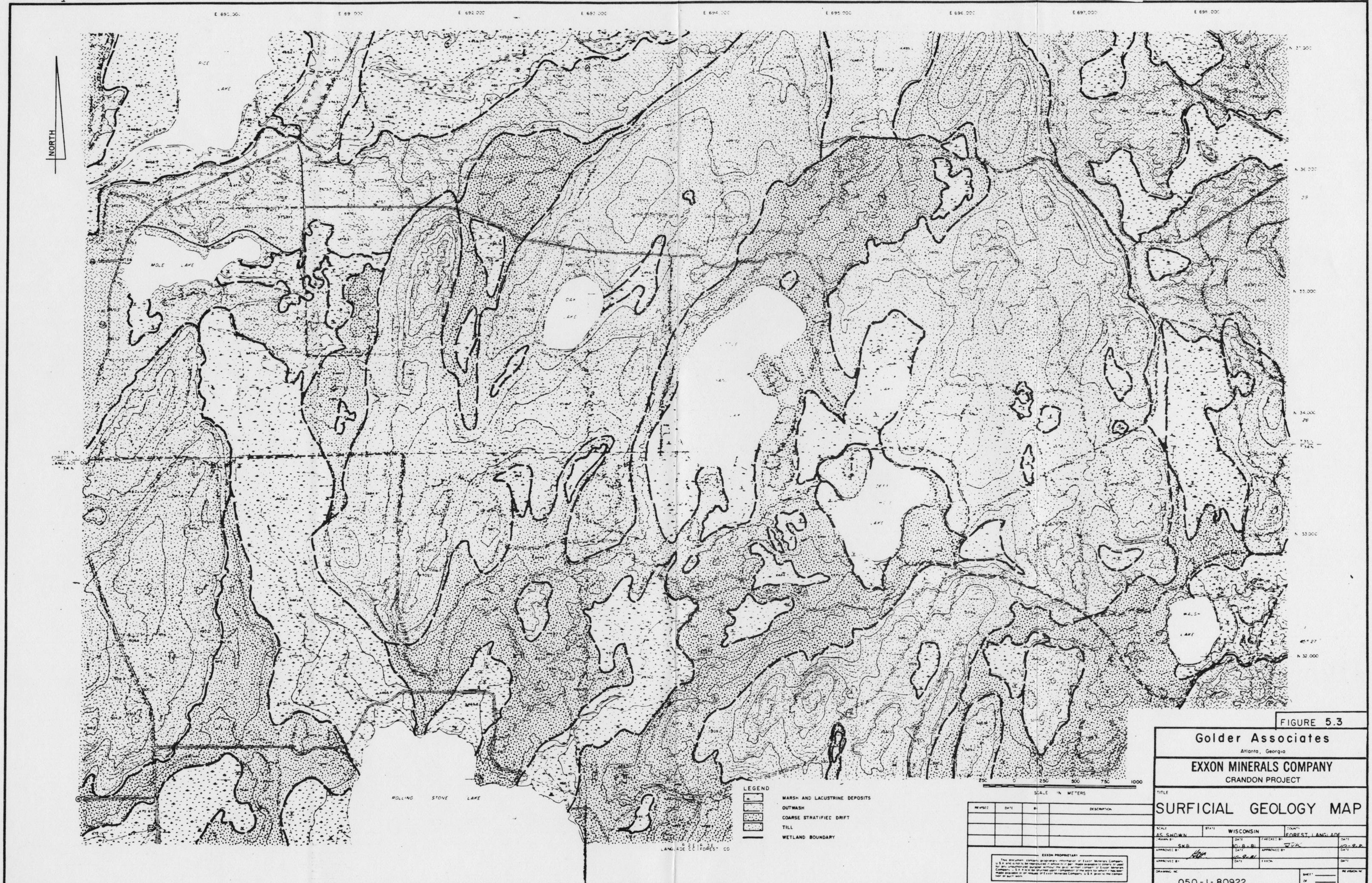
SCALE AS SHOWN | STATE WISCONSIN | COUNTY FOREST
DRAWN BY CAB | DATE 4-2-82
DRAWING NO 050-1-81333

the surrounding region occurred primarily during the Wisconsin stage of glaciation. The bulk of the drift in the Crandon Project area is most likely from the Green Bay and Langlade lobes of the Woodfordian advance. Mickelson, et. al., (Ref. 23) provide a more detailed discussion of the glacial events of northern Wisconsin.

Mapping of the surficial materials and glacial landforms within the Crandon Project area has been completed by Dames & Moore (Ref. 5), the U.S. Department of Agriculture Soil Conservation Service (Ref. 3), and the Wisconsin Geological and Natural History Survey (Ref. 24). Each group approached the work with a different purpose and accomplished it with different mapping techniques. These different approaches in combination with the interpretive nature of the mapping resulted in three slightly different surface material maps.

The surficial geologic mapping done by Dames & Moore was the result of site specific test boring data and reconnaissance work within the Crandon Project area. This map has been slightly modified by Golder Associates to reflect the additional data obtained by Golder Associates' test boring program. This modified map is shown as Figure 5.3. Revisions to Dames & Moore's surficial geology map were restricted to the northeast corner of Langlade County where a more extensive surface deposit of glacial till was further defined by the additional investigation.

Although the various mapping techniques and personnel involved have produced somewhat different interpretations of the geologic origin of the surficial materials, these differences are relatively minor. These differences are not anticipated to affect the overall design of the proposed waste disposal system.


NORTH
RICE LAKE
MOLE LAKE
OAK LAKE
DEEP HOLE LAKE
WALSH LAKE
ROLLING STONE LAKE
LEGEND
MARSH AND LACUSTRINE DEPOSITS
OUTWASH
COARSE STRATIFIED DRIFT
TILL
WETLAND BOUNDARY
250 0 250 500 750 1000
SCALE IN METERS
FIGURE 5.3
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
SURFICIAL GEOLOGY MAP
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST, LANGLADE
DRAWN BY SKB
DATE 10-8-81
CHECKED BY JPK
EXXON PROPRIETARY
DRAWING NO 050-1-80922

The bedrock of northern Wisconsin is an extension of the Canadian Shield. The Canadian Shield is a continental block of the earth's crust which has been relatively stable over a long period of time. The rock types present in the region are Precambrian igneous and metamorphic rocks which were formed approximately 1.9 billion to 1.5 billion years ago. Igenous rocks are formed by the cooling and crystallization of molten rock material, while metamorphic rocks represent sedimentary or igneous rocks modified by changes in temperature and pressure. Within the Crandon Project Area, the bedrock is primarily a metamorphosed volcanic tuff.

The regional trend of the bedrock surface in north-central Wisconsin is downward to the east and southeast at approximately 7 to 10 feet per mile (Ref. 24) (1.3 to 1.9 m/km). Within Forest County the bedrock surface is irregular (Ref. 24). Detailed work in the Crandon Project area has also defined an irregular bedrock surface. The interpreted bedrock surface for the Crandon Project area is shown on Figure 5.4, Bedrock Contour Map.

The Bedrock Contour Map is the result of the synthesis and interpretation of data from various sources. The area shown on Figure 5.4 is a portion of a larger geographical area for which bedrock contours have been interpreted. A map of the larger area with the data locations shown is presented in Golder Associates' Project Report 2 (Ref. 11, App. D) along with a discussion of the map construction.

The methods of glacial deposition and the various time periods of deposition in the Crandon Project area have created a variable distribution of soil materials at the ground surface and with depth. The specific types of gla-

FIGURE 5.4

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

BEDROCK CONTOURS
PROJECT AREA

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: CAB	DATE: 4-12-82		
DRAWING NO. 050-1-80927			

cial deposition of the materials mapped at the surface are not necessarily indicative of the method of deposition of the materials at depth at the same location. Based on the test boring and laboratory data, and the understanding of general glacial deposition processes, the primary materials found throughout the depth of the glacial deposits at the proposed waste Sites 40 and 41 are till and coarse grained stratified drift. Lesser amounts of fine grained stratified drift and lacustrine deposits were also identified. Outwash materials were found surrounding the sites (as shown on the Surface Geology Map, Figure 5.3) but not directly identified beneath the two proposed waste disposal sites. A brief description of each of the glacial materials follows:

Till - A well graded (poorly sorted) heterogeneous mixture of silt, sand, gravel, some cobbles and boulders, and traces of clay. This material was directly deposited by a glacier.

Coarse Grained Stratified Drift - Moderately uniformly graded (well sorted) sand and fine gravel with traces of silt. This is a water deposited, glaciofluvial material.

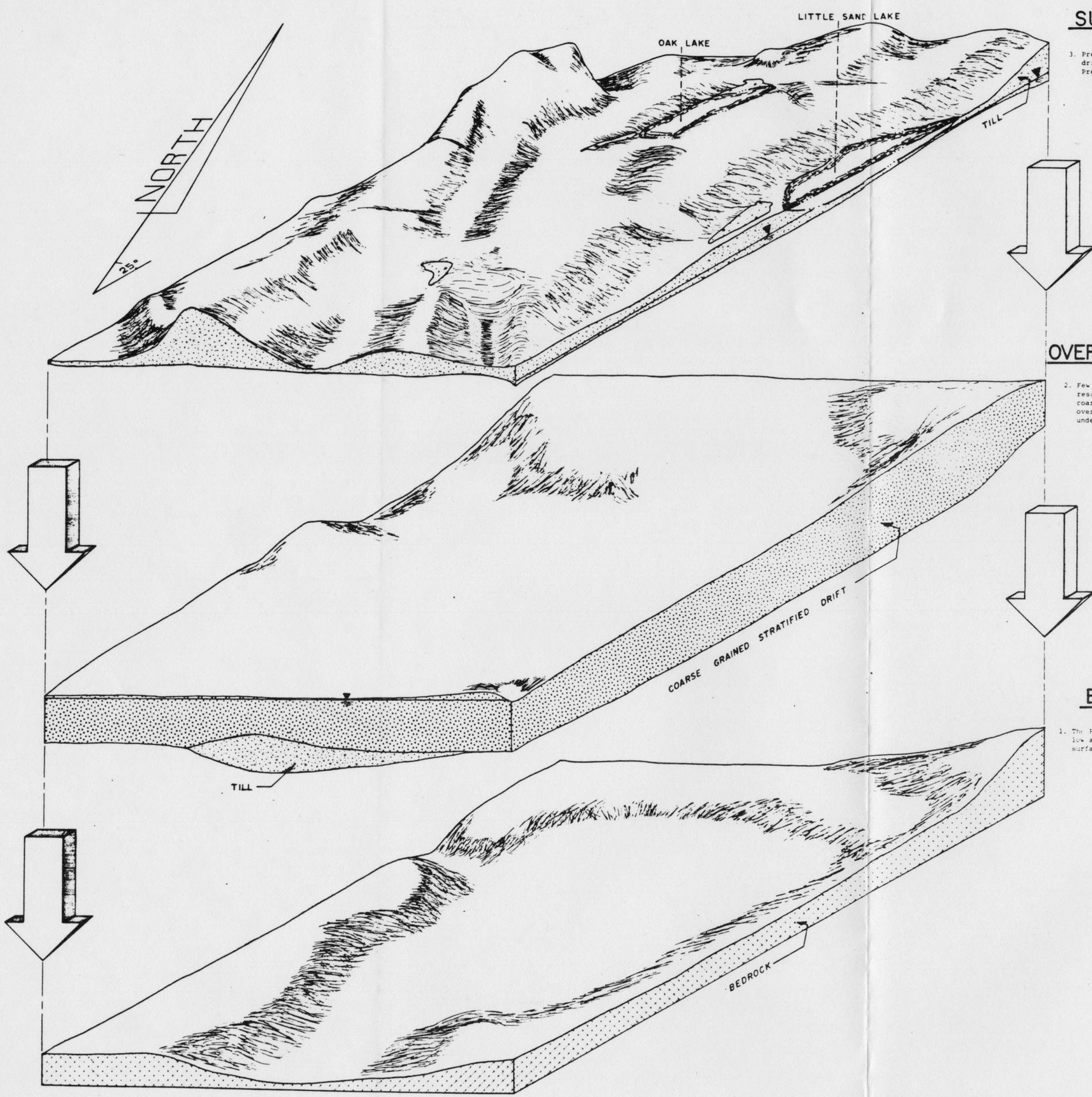
Fine Grained Stratified Drift - Moderately uniformly graded (well sorted) silt and/or fine sand, often layered and including clay and/or coarse sand. This material appears to be a glaciolacustrine sediment deposited in a glacial lake or other body of still water in front of a glacier.

Lacustrine Deposits - Deposits of fine grained soils, mostly silts and clays. Predominantly found surrounding and beneath present day lakes and major wetlands. These materials are deposited from still bodies of water. They are similar to the silt and clay layers found in the fine grained stratified drift. These deposits do not constitute a single mappable unit.

Outwash - Uniformly graded (well sorted) sand and gravel usually containing very little to no silt. This material has been mapped at the surface, but has not been encountered at depth beneath the proposed waste disposal areas.

As a visual aid in perceiving the distribution of the various glacial materials at Sites 40 and 41, the block diagrams shown on Figures 5.5 and 5.6 were prepared. The diagrams give an overall three dimensional view of the proposed disposal sites. They are intended to provide a overall understanding of the terrain, bedrock, and major glacial formations. They are not a precise duplication of the borehole data, but this data was used in their construction.

Each diagram was constructed by outlining the area to be drawn on a topographic map of the area. A block of this rectangular area was then drawn in what is known as 'cabinet' projection. In this particular block diagram, the sides of the block are projected at an angle of 30° from the front side of the block. With this projection, measurements in direction parallel to all the edges are on the same scale. This allows borehole locations and other data points to be easily transposed from the base map to the block. Both block diagrams were oriented approximately north-south. To obtain the various geologic formation's surface features, such as the bedrock surface and the coarse grained stratified drift surface, boreholes were located on the block and then depths to the various strata



SURFACE TOPOGRAPHY

3. Present day topography is composed of till uplands and drift lowlands. A topographic high occurs over a Precambrian valley at the north-west block boundary.

OVERBURDEN STRATIGRAPHY

2. Few deep boreholes were drilled at Site 41 and as a result the deep stratigraphy is not well defined. The coarse grained stratified drift appears to be continuous over the entire Site area with a possible extensive underlying till layer.

BEDROCK SURFACE

1. The Precambrian relief is generally subdued with a broad low area lying in the center of the Site. The bedrock surface rises steeply to the north-east.

VERTICAL SCALE IN METERS: 0 25 50 100
HORIZONTAL SCALE IN METERS: 0 250 500 1000

NOTE:

This expanded block diagram is intended to show the relationship between the bedrock topography and the various overlying glacial deposits. It allows for better understanding of the terrain and geological conditions at the site. It does not represent the exact geological strata at a given point and should be viewed in conjunction with the geologic sections.

REVISED	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

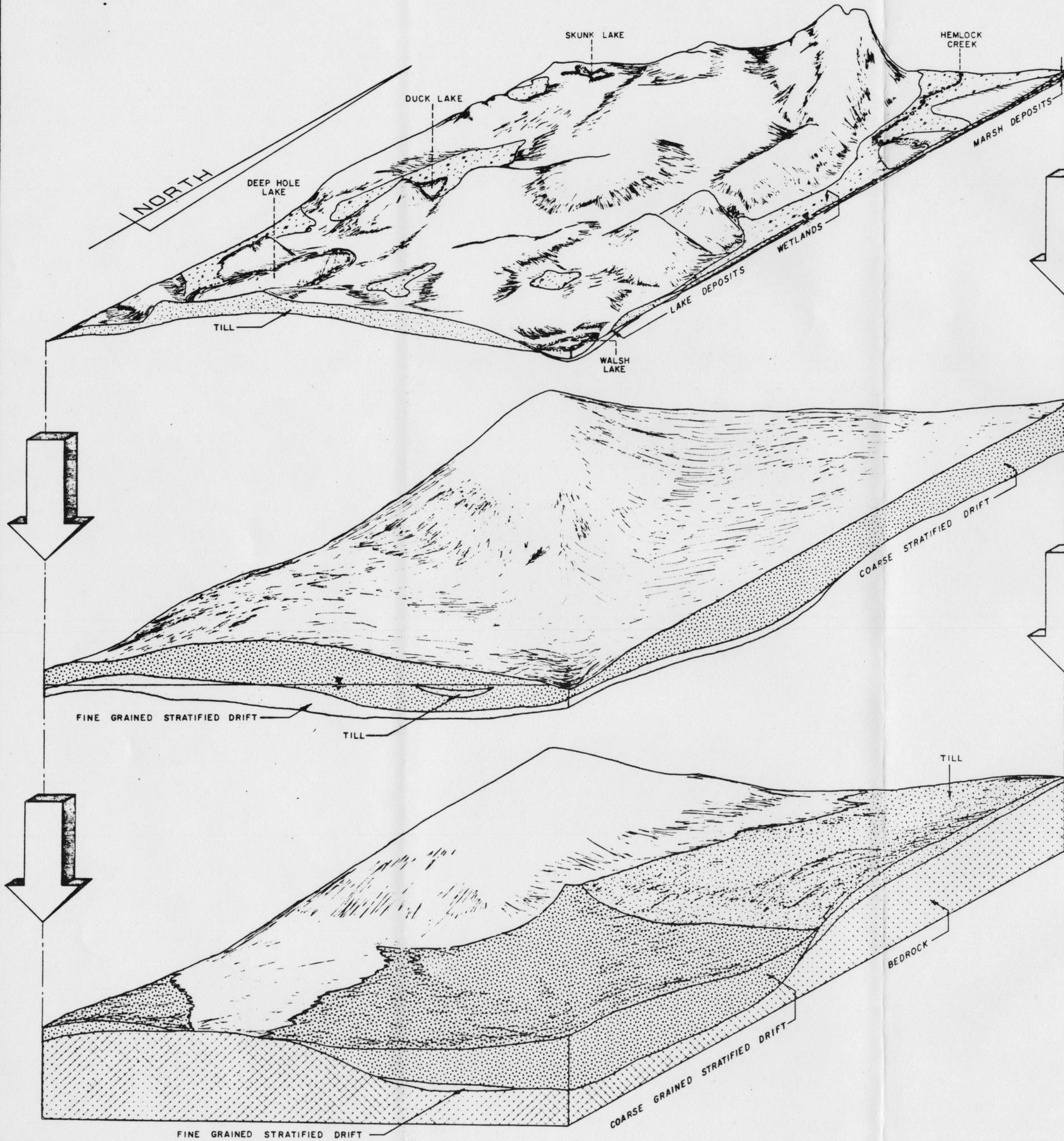
FIGURE 5.5

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SITE 40 GLACIAL STRATIGRAPHY BLOCK DIAGRAM

SCALE: AS SHOWN	STATE: WISCONSIN		COUNTY: FOREST, LANGLADE
DRAWN BY: SKB	DATE: 10-9-81	CHECKED BY: JK	DATE: 10/21
APPROVED BY: [signature]	DATE: 10-22-81	APPROVED BY:	DATE:
APPROVED BY:	DATE:	EXXON:	DATE:
DRAWING NO: 050-1-80923		SHEET ___ OF ___	REVISION NO:



SURFACE TOPOGRAPHY

3. In common with Site 40, the drumlin topography is composed of the youngest till deposits. The thickest deposits of till appear to have accumulated along the main bedrock valley.

OVERBURDEN STRATIGRAPHY

2. The coarse grained stratified drift is shown to cover the entire site area still reflecting the underlying bedrock relief.

BEDROCK SURFACE

1. The earliest glacial materials deposited appear to have been confined mainly to the low-lying bedrock areas. This sketch shows the bedrock under Site 41 to have a valley running from the south-east then trending northwards across the Site. At right angles to this valley is a broader east-west bedrock depression.

NOTE:

This expanded block diagram is intended to show the relationship between the bedrock topography and the various overlying glacial deposits. It allows for better understanding of the terrain and geological conditions at the site. It does not represent the exact geological strata at a given point and should be viewed in conjunction with the geologic sections.

VERTICAL SCALE IN METERS: 0, 25, 50, 100
HORIZONTAL SCALE IN METERS: 0, 250, 500, 1000

REVISED	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

FIGURE 5.6

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SITE 41 GLACIAL STRATIGRAPHY BLOCK DIAGRAM

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST, LANGLADE	
DRAWN BY: SKB	DATE: 10-9-81	CHECKED BY: [signature]	DATE: 9/21
APPROVED BY: [signature]	DATE: 10-22-81	APPROVED BY:	DATE:
APPROVED BY:	DATE:	EXXON:	DATE:
DRAWING NO: 050-1-80924	SHEET ___ OF ___	REVISION NO:	

plotted. The surface for a given deposit was then constructed by drawing a network of lines between the various borings that intersect that given surface. The trend of the surface shape is interpreted and shading is used to illustrate that trend. The diagrams were constructed using horizontal scales of 1:1250 and a ten times exaggeration along the vertical axis. The front and side faces of the block are essentially geological sections along those faces.

These diagrams show how the bedrock surface has influenced the subsequent deposition of glacial materials. The coarse grained stratified drift is noted to be continuous over both sites as is the overlying till deposit. Site 41 has a till and/or fine grained stratified drift underlying the coarse drift. These deposits may be similarly present at Site 40 but there is insufficient deep borehole information to confirm the continuous presence of the lower till/fine grained stratified drift.

5.2.3 Glacial Material Properties

The majority of the glacial materials encountered in the project area are till and stratified drift which are granular soils; combinations of sand and gravel with varying amounts of silt and often containing cobbles and boulders. Traces (up to 10 percent) of clay were encountered but represent only a very small fraction of the till and stratified drift materials. The predominantly fine grained soils, silt and clay, were mostly associated with lacustrine deposits around the present day wetlands, as layers within the fine grained stratified drift, or residual soil. These fine grained soils represent only a small fraction of the glacial overburden. From the test boring data and results of field and laboratory tests, pertinent physical properties for the various glacial strata are summarized on Table 5.1.

From the glacial history and results of the penetration tests taken during the boring program, it is evident that the till and stratified drift materials are medium dense to dense (Standard Penetration results between 10 and 50 blows per foot) in the upper 15 to 20 feet (4.5 to 6.1 m) and very dense (Standard Penetration tests above 50 blows per foot) below this level (Ref. 11). The individual grains of the granular materials are rounded to sub-angular. The high density of these materials, their grain angularity and their grain size ranges make them excellent materials for embankment construction and foundation support. These materials will not undergo long term settlement due to consolidation to an amount which will be preceptively significant to waste disposal facilities. Although these granular soils may range from sand, gravel, and cobbles with little fines (silt and clay size particles) to sand or sand and gravel with up to 40 percent fines (predominantly silt), their overall engineering strength characteristics will be similar, having high friction angles and little to no cohesion.

Glacial till is differentiated from stratified drift deposits by not only the gradation of the materials, but by the shape of the grain size curves. The till is not water sorted material and therefore tends to have particles throughout the range of silt, sand, and gravel sizes. The stratified drift materials are water sorted and tend to have a large percentage of single sized, or closely sized, particles. The coarse grained stratified drift soils are predominantly sand sized with less than 10 percent fines (material passing the No. 200, 0.074 mm, sieve). The fine

TABLE 5.1

SUMMARY OF GLACIAL MATERIAL PROPERTIES

Material Type	Unified Soil Classification Symbol	Atterberg Limits			Shear Strength Parameters		Permeability k m/s (ft./sec.)	Density - Moisture: In situ	Density - Moisture: Compacted		Remarks
		L.L. %	P.L. %	P.I. %	c' N/m^2	ø' deg		Dry Unit Wt. kg/m^3 (pcf)	Max. Dry Density kg/m^3 (pcf)	Optimum Moisture Content %	
Glacial Till	Predominantly SM and SP-SM	Predominantly non-plastic			0	34 to 40	1×10^{-6} to 1×10^{-8} (3×10^{-6} to 3×10^{-8})	1762 to 2211 (110 to 138)	1986 to 2195 (124 to 137)	7.2 to 12.5	Primary construction material
Coarse Grained Stratified Drift	Predominantly SP and SP-SM	Non-plastic			0	35	1×10^{-3} to 1×10^{-5} (3×10^{-3} to 3×10^{-5})	1602 to 2083 (100 to 130)	-	-	May be used as construction material
Fine Grained Stratified Drift	Ranges from ML to SP	Varies			-	-	1×10^{-4} to 1×10^{-8} (3×10^{-4} to 3×10^{-8})	-	-	-	Not anticipated for use in construction
Outwash	SP Only one sample tested	Non-plastic			-	-	1×10^{-3} to 1×10^{-5} (3×10^{-3} to 3×10^{-5})	-	-	-	Not anticipated for use in construction
Lacustrine	Ranges from OL to SM	Varies			-	-	1×10^{-5} to 1×10^{-8} (3×10^{-5} to 3×10^{-8})	-	-	-	Not anticipated for use in construction

NOTES:

1. Unified Soil Classification System designations are representative of the majority of the materials of the deposit.
2. Permeability ranges are representative of the majority of the materials of the deposit. See Appendix C of Reference 11 for evaluation of permeability tests and estimates from Hazen's approximation. See Reference 14 for details of pump test and analysis.
3. Cohesion measured in triaxial tests believed to be a result of test procedure. Cohesion considered to be zero for effective stress analyses. Zero cohesion inconsequential to facility design analyses.
4. See Reference 11 for individual laboratory test results.
5. (-) in table indicates no testing performed.

grained stratified drift grain size curves have a shape similar to the coarse grained stratified drift, but are usually finer in overall grain size.

The predominantly fine grained soils, silts and clay combinations, were most always associated with the larger, existing wetlands. The proposed mine waste disposal facilities are anticipated to be constructed in, and with, the granular glacial materials. There is presently no intention to utilize the fine grained wetland deposits for construction purposes. Therefore, the engineering properties of these fine grained materials as applicable to construction considerations are not addressed in detail. Similarly, the outwash soils, fine grained stratified drift, residual materials, and rock are not proposed as materials for construction so their engineering properties are not addressed in detail.

Strength parameters are of importance for those materials anticipated to be used in, or providing foundations for, construction of waste disposal facilities. These materials are the till and, possibly, the coarse grained stratified drift. Of these two materials, only the till has been subjected to laboratory triaxial shear testing. The till soil was sampled in bulk in test pits and triaxial tests were performed on laboratory compacted samples. Undisturbed samples of dense granular soils (till or coarse grained stratified drift) were not obtained from the test borings. Estimates of the friction angle for the coarse grained stratified drift are provided on the basis of grain size distribution of the samples tested and estimated density of these materials from the borehole penetration tests.

A great deal of emphasis has been placed on determining the hydraulic characteristics of the glacial soils. Aquifer characteristics were directly investigated by a pumping test at Site 41. Permeability testing was performed in some of the test borings and laboratory measurements were made on compacted samples from the test pits. Also, soil permeability was estimated from the grain size data using Hazen's approximation. The permeability test data was evaluated in detail in Golder Associates' Project Report 2 (Ref. 11).

5.3 Hydrology

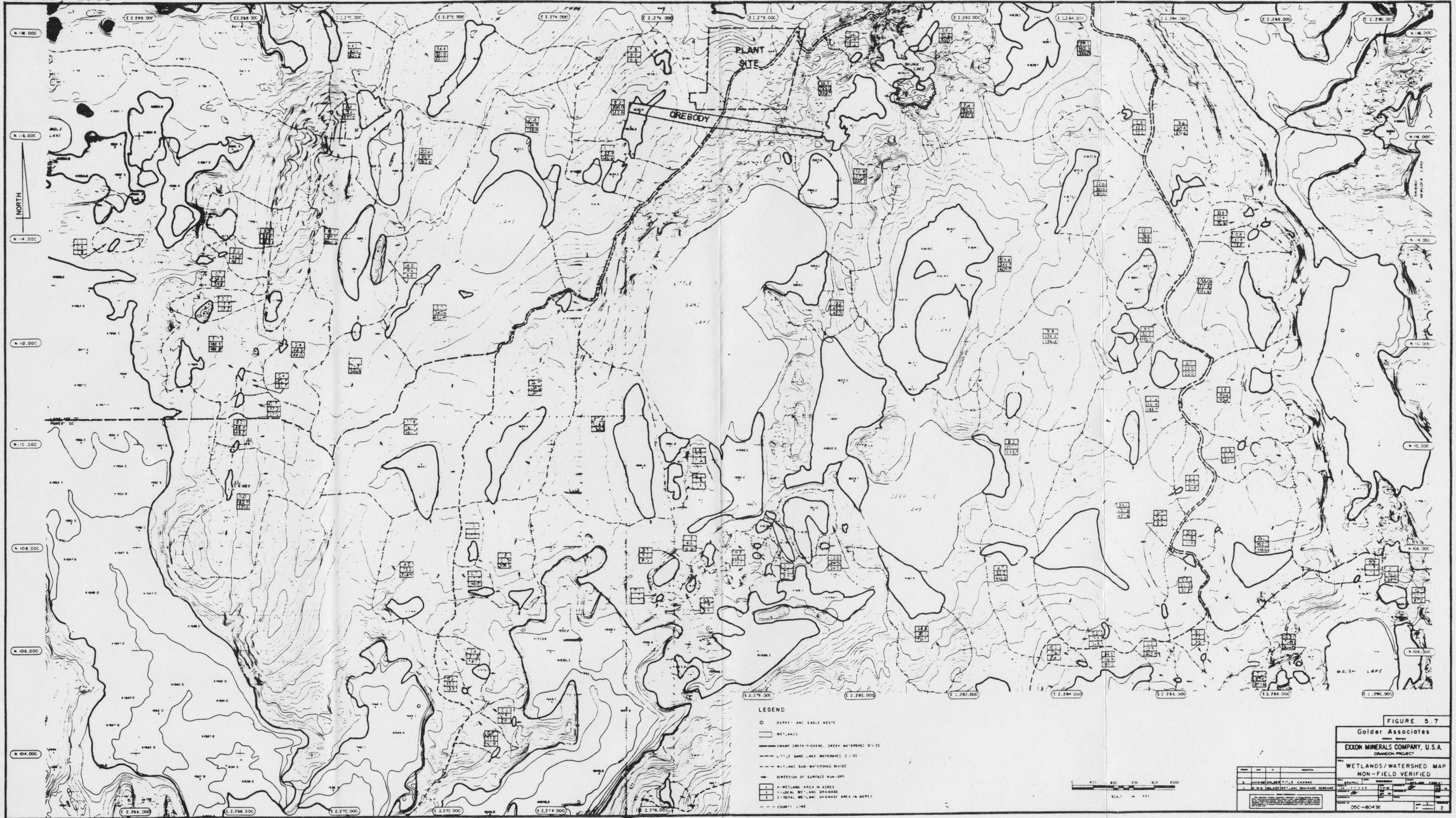
5.3.1 Surface Water System

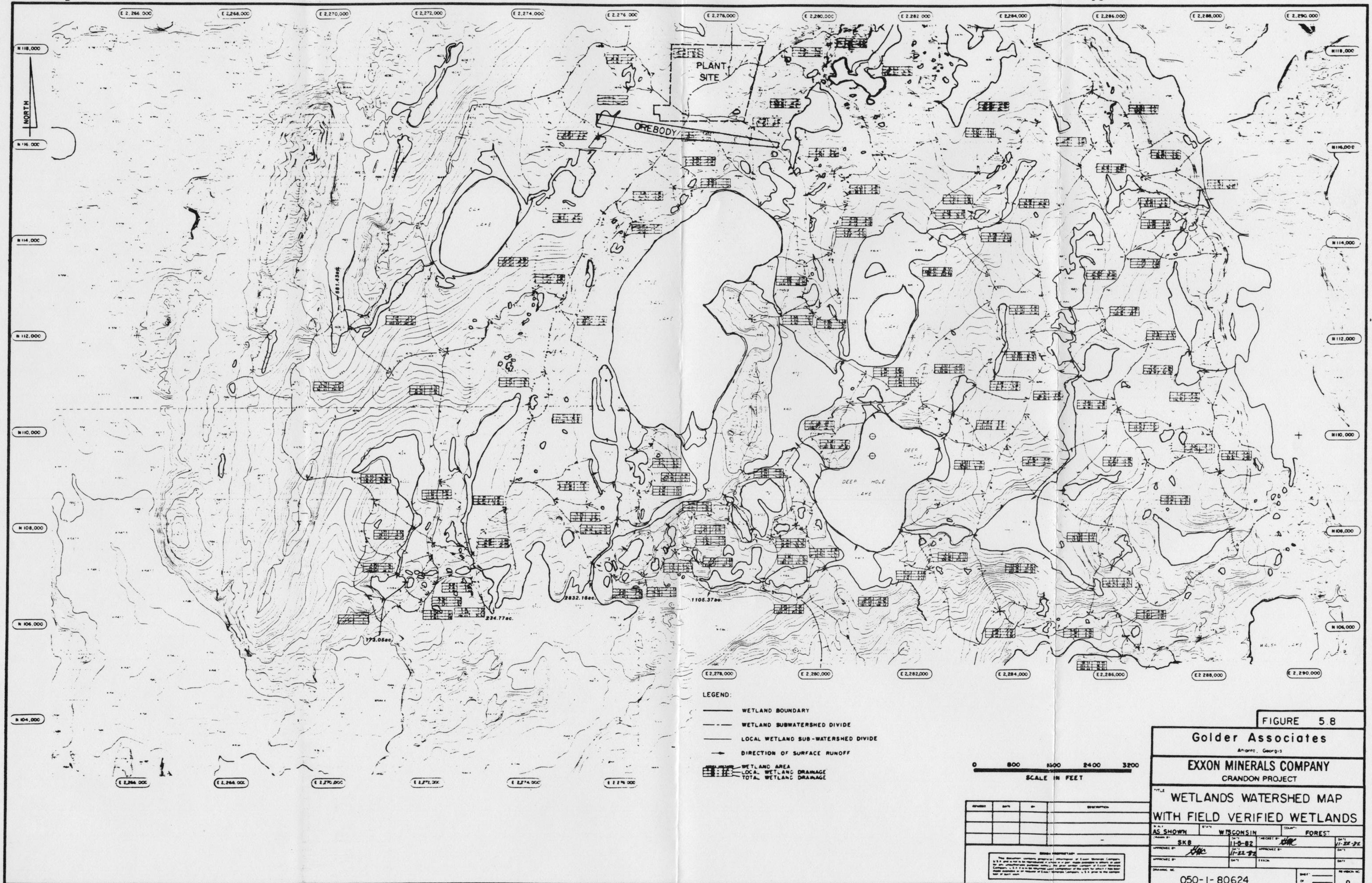
The Crandon Project site lies within the Swamp Creek and Pickerel Creek surface water drainage basins of the Wolf River drainage basin. The drainage basins are characterized by forested land, lakes, and wetlands. Most of the larger wetlands are contiguous with the lakes and streams of the area. The streams and some of the lakes with their contiguous wetlands are areas of groundwater discharge. Some of the lakes and wetlands are perched above the regional groundwater levels and tend to inhibit or retard infiltration of surface water.

The flood potential for the Project area is low because of the large infiltration rates of the upland areas and the storage capacities of the lakes and wetlands. Many lakes and wetlands can store large volumes of water without appreciably affecting their water levels. Average annual precipitation in the regional area is 30.77 inches (781.6 mm) with approximately 16.9 inches (429 mm) percent returning to the atmosphere as evapotranspiration. A study of subbasins in the Project area indicates evapotransportation ranges from 40 to 67 percent of total precipitation (Ref. 7).

A wetlands watershed map has been prepared for a large portion of the potential siting areas. This map is presented as Figure 5.7. This map indicates the wetlands as shaded areas and shows the surface watershed boundary for each wetland and the major surface watershed boundaries for the area. Tabulated within each wetland watershed on the map is the surface acreage of the wetland, the surface acreage of the local watershed to that wetland and the total acreage of watershed which is contributory to that wetland. The areas and watersheds for the large wetlands adjacent to the streams and lakes have not been shown since most of these wetlands are suspected of being at least partially fed by groundwater. The wetland boundaries shown on Figure 5.7 are based on interpretations from the topographic map obtained by aerial photography. At the time this Wetlands Watershed Map was drawn, the precise boundaries of all wetlands had not been field verified. Even with this imprecision, the map clearly shows that there are a large number of wetlands and that a large portion of the surface drainage is through these wetlands.

The wetland boundaries in the Crandon Project area were field verified in 1981. These field verified wetland boundaries are shown on the wetlands watershed map presented in Figure 5.8. As can be seen by comparison with the wetlands watershed map on Figure 5.7, the major differences in the wetland boundaries arise in the wetland connections. In general, the overall amount of wetland area is nearly equal.


PLANT SITE
OREBODY
NORTH
WALSH LAKE
LEGEND
OSPREY AND EAGLE NESTS
WETLANDS
SWAMP CREEK/PICKEREL CREEK WATERSHED DIVIDE
LITTLE SAND LAKE WATERSHED DIVIDE
WETLAND SUB-WATERSHED DIVIDE
DIRECTION OF SURFACE RUN-OFF
X-WETLAND AREA IN ACRES
Y-LOCAL WETLAND DRAINAGE
Z-TOTAL WETLAND DRAINAGE AREA IN ACRES
COUNTY LINE
SCALE IN FEET
TITLE CHANGE
WETLAND DRAINAGE ACREAGE
FIGURE 5.7
Golder Associates
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
WETLANDS/WATERSHED MAP
NON-FIELD VERIFIED
05C-80438

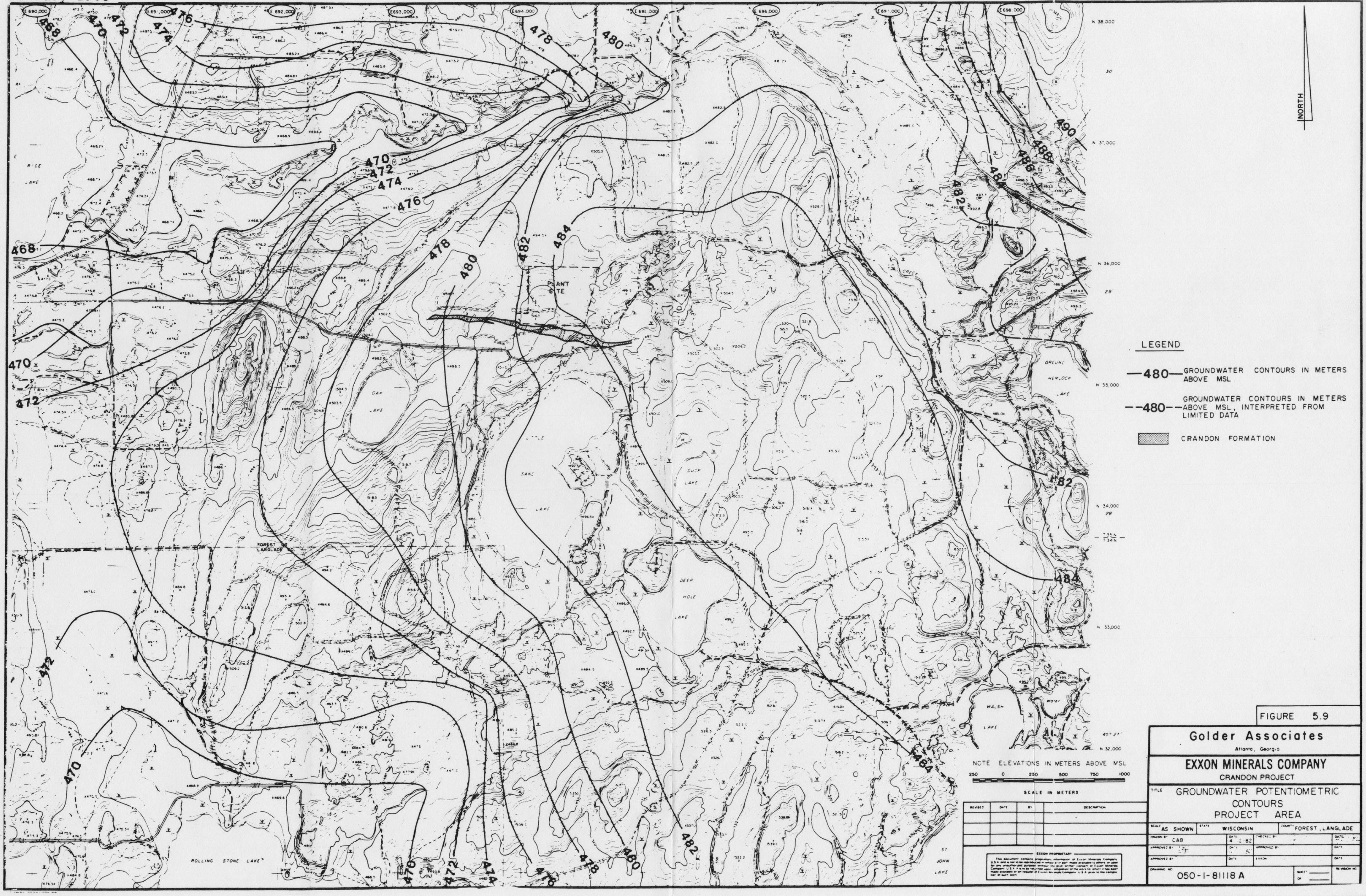

NORTH
PLANT SITE
OREBODY
DEEP HOLE LAKE
E 2,278,000
E 2,280,000
E 2,282,000
E 2,284,000
E 2,286,000
E 2 288,000
E 2,290,000
N 118,000
N 116,000
N 114,000
N 112,000
N 110,000
N 108,000
N 106,000
N 104,000
LEGEND:
WETLAND BOUNDARY
WETLAND SUBWATERSHED DIVIDE
LOCAL WETLAND SUB-WATERSHED DIVIDE
DIRECTION OF SURFACE RUNOFF
WETLAND AREA
LOCAL WETLAND DRAINAGE
TOTAL WETLAND DRAINAGE
0 800 1600 2400 3200
SCALE IN FEET
FIGURE 5.8
Golder Associates
EXXON MINERALS COMPANY
CRANDON PROJECT
WETLANDS WATERSHED MAP
WITH FIELD VERIFIED WETLANDS
AS SHOWN
WISCONSIN
FOREST
SKB
11-5-82
11-22-82
050-1-80624
0

5.3.2 Groundwater

Groundwater occurs within the glacial overburden and in the bedrock. The principal aquifers are within the glacial overburden, occurring under unconfined (water table) and semi-unconfined conditions. Locally perched groundwater conditions occur within the surficial glacial deposits above the main aquifers. These zones of perched water appear to be of limited areal extent (Ref. 6) and none were found beneath the proposed waste disposal site areas 40 and 41.

Groundwater recharge occurs readily in the upland areas of the site and flows essentially vertically in an unsaturated mode to the groundwater table. After water percolates to the aquifer, it flows essentially horizontally toward the areas of lower groundwater levels; directions normal to the groundwater contour lines.

Groundwater levels over the Crandon Project site have been primarily determined by measurements in observation wells installed in test borings. Groundwater observation wells have been installed at various times over the past 3 years under the supervision of Golder Associates and Dames & Moore. The observation wells have been installed at various depths and locations to evaluate the groundwater conditions at the site. Many of the observation wells have been monitored over long periods to measure fluctuations in groundwater levels and groundwater chemistry. The results of the activities have been assembled by Dames & Moore (Ref. 6). An evaluation of the potentiometric conditions in the glacial material has been made in order to define the groundwater conditions. The resulting potentiometric contour map is shown on Figure 5.9. This groundwater potentiometric contour map was constructed through joint efforts by Golder Associates and Dames & Moore for the pur-


NORTH
LEGEND
—480— GROUNDWATER CONTOURS IN METERS ABOVE MSL
--480-- GROUNDWATER CONTOURS IN METERS ABOVE MSL, INTERPRETED FROM LIMITED DATA
CRANDON FORMATION
NOTE ELEVATIONS IN METERS ABOVE MSL
250 0 250 500 750 1000
SCALE IN METERS
PLANT SITE
ROLLING STONE LAKE
DEEP HOLE LAKE
FIGURE 5.9
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
GROUNDWATER POTENTIOMETRIC CONTOURS PROJECT AREA
AS SHOWN
WISCONSIN
FOREST, LANGLADE
CAB
050-1-81118 A

pose of providing a single, acceptable representation of the potentiometric groundwater elevations for the area. This contour map is based on water level measurements in the accessable observation wells obtained in February, 1982, plus well data obtained at various times as provided by the United States Geological Survey. A complete listing of the data used in the map's construction are presented in Golder Associates' Geohydrologic Characterization Report (Ref. 22) and a description of the methods used to derive the map is presented in Golder Associates' Project Report 7 (Ref. 18).

Principal areas of groundwater discharge surrounding the Project site are along the major drainages: Swamp Creek, Ground Hemlock Creek, Upper Pickerel Creek; Rice Lake, Rolling Stone Lake, Ground Hemlock Lake, and the wetlands associated and contiguous with these features. All of these bodies of water and wetlands are below approximately elevation 1600 feet (487 m). Around the Crandon orebody and proposed waste disposal areas are numerous lakes and wetlands which are perched above the main water table aquifer. These lakes and wetlands receive little to no groundwater recharge. They are fed by surface water runoff and probably inhibit percolation of the surface water to the main groundwater aquifer. Around the orebody, Skunk, Oak, Little Sand, Duck and Deep Hole Lakes are perched partially or completely above the main groundwater aquifer. These perched conditions are discussed in more detail in the following section of this report.

5.3.3 Perched Conditions

Potentiometric head elevations may differ from groundwater surface elevations in that the potentiometric head represents the elevation of zero pressure head associated with a particular stratum or water body. In many areas across the site there exist wetlands and lakes where the potential head (surface of standing water) is well above the groundwater surface. If an observation well were sealed just at the bottom of such a lake or wetland, it would measure a water level equal in elevation to that of the free standing water in the lake or wetland. However, if the ground beneath the lake or wetland bottom was not completely saturated, and the groundwater system not mounded to the lake or wetland bottom, then a second observation well sealed below the main groundwater system surface would show a lower water level which is coincident with the main groundwater system. In such instances, the potential head in the lake or wetland is higher than the potential head of the main groundwater system. Such conditions in the context of this report are termed perched conditions.

Based on water level and water chemistry data, some of the lakes in the area are independent of the groundwater and can be described as being perched (Ref. 7). These lakes are recharged by surface water flow (overland or interflow) and discharge to surface flow. A small portion of the lake water seeps from these lakes into the groundwater system. The extent to which complete mounding beneath these lakes has developed is not known, but it is suspected to be minimal for lakes with bottoms above the main body of the groundwater system. Where mounding is fully developed the radius of influence of this mounding is very small in relationship to the area covered by the groundwater map. In either case, mounded or not, lake levels higher than surrounding groundwater levels indicate that water flows out of these lakes into the groundwater system. Table 5.2 lists those lakes which are around the Crandon orebody and indicates which are believed to be

TABLE 5.2

LAKE RELATIONSHIP TO GROUNDWATER SYSTEM

Lake	Relationship	Comments
Duck Lake	Perched	Contains very soft to soft and neutral to acidic water. Wells DMA-4, G41-C15B, and G41-C15 show groundwater about 15 to 20 feet (4.6 to 6.1 m) below the lake surface.
Deep Hole Lake	Perched	Contains very soft to soft and neutral to acidic water. Wells upgradient (DMA-4, DMB-27, etc.) show groundwater about 15 feet (4.6 m) below the lake surface.
Little Sand Lake	Perched	Contains very soft to soft and slightly acidic to slightly alkaline water. Wells located adjacent to the lake (DMP-2, DMP-3, DMA-10) show groundwater levels 6 to 16 feet (1.8 to 4.9 m) below the lake surface.
Oak Lake	Perched	Contains very soft to soft and neutral to slightly acidic water. Wells G40-M15, DMA-15, and DMA-3 show groundwater levels at least 49 to 63 feet (14.9 to 19.2 m) below the lake surface.
Skunk Lake	Perched	Contains very soft to soft and slightly acidic to acidic water. Well DMA-12 shows groundwater about 5 to 10 feet (1.5 to 3.0 m) below the lake surface.
Ground Hemlock Lake	Groundwater Discharge	Contains moderately hard to hard and neutral to alkaline water. Well DMC-1 on the bank of the lake shows groundwater about 7 feet (2.1 m) above the lake surface.
Lake Metonga	Groundwater Discharge	Contains medium hard and slightly alkaline water. The lake is in a topographic valley.

TABLE 5.2 (Continued)

LAKE RELATIONSHIP TO GROUNDWATER SYSTEM

Lake	Relationship	Comments
Rice Lake	Groundwater Discharge	Contains moderately hard to hard and neutral to alkaline water. U.S.G.S. wells show groundwater at or above the level of the lake surface.
Mole Lake	Inconclusive	Contains soft and neutral water. Data inconclusive to determine whether primary recharge is from groundwater or surface water.
Rolling Stone Lake	Groundwater Discharge	Contains moderately or medium hard and neutral to slightly alkaline water. Well DMB-24 about 500 feet away (152 m) shows groundwater about 5 feet (1.5 m) below the lake surface.
Pickerel Lake	Groundwater Discharge	Contains moderately or medium hard and neutral to alkaline water.
Crane Lake	Groundwater Discharge	Contains hard and slightly alkaline water.
St. John's Lake	Perched	Contains very soft to soft and neutral to slightly acidic water. Well DMB-29 located upgradient has groundwater about 1 foot (0.3 m) below the surface.
Walsh Lake	Perched	Contains very soft to soft and neutral to slightly acidic water. Wells located around the lake (DMB-7, DMB-29, DMC-3, G41-P24) show groundwater about 10 to 13 feet (3.0 to 4.0 m) below the lake surface.
Lake Lucerne	Perched	Contains soft and slightly acidic water.
Bishop Lake	Groundwater Discharge	Contains medium hard and slightly alkaline water. Surrounding U.S.G.S. wells show groundwater levels near the lake surface.

primarily groundwater fed (groundwater discharge areas) and which are believed to be perched and hence primarily surface water fed (groundwater recharge areas).

6.0 REVIEW OF 100 MILLION DMT OREBODY SYSTEMS

6.1 Background

Golder Associates prepared an Interim Report (Ref. 10) for waste facility siting in October 1980. This Interim Report presented the finding of studies to provide alternative waste disposal facility layouts for disposal of mining waste which were considered to be the most feasible for the guidelines proposed for their design and operation at that time. Several studies, including hydrological modeling, detailed wetland evaluations, and evaluation of pond liner materials were either being planned or in progress but not complete at the time the Interim Report was prepared. The Interim Report presented three prospective waste disposal site areas, Sites 40, 41, and 50, for consideration. In addition to evaluating the proposed site areas for broad siting criteria, many alternative site pond layouts for disposal facilities were prepared for each site area. Of these, the most feasible alternative for each site area was presented and was employed in comparing the three site areas. A brief review of this study is presented in the remainder of this Section.

6.2 Design Guidelines

6.2.1 Waste Products and Design Volumes

It was proposed that the mining and milling waste materials would be separated for storage or disposal. These products were: waste rock, combined backfill sand (temporary storage), sulfide tailings, non-sulfide tailings, reclaim water, and water treatment sludge. The waste facilities were sized for estimated ore reserves of 100 million dry metric tons (110 million short tons). A more detailed discussion of the waste products and tonnages is presented in Section 3 of this report. Exxon directed the separation of sulfide and non-sulfide tailings to concentrate the sulfide minerals for disposal because of their acid producing potential. Although the waste rock could be used in construction of the facilities or disposed of with the tailings, it had been assumed for this study that it would require a separate disposal area. Also, it had not yet been determined whether there would be a surplus of water and, if so, what provisions would be made for its treatment and disposal. However, two of the proposed layouts included provision for a water treatment sludge disposal area. At the time, data suggested a low potential for acid leachate generation in the non-sulfide tailings ponds and their designs did not have provisions for special lining materials. The other ponds had provisions for special liners.

The estimates of storage volumes which were used for the facility layouts are presented in Table 6.1. The water treatment sludge was given an estimated allowance of 1600 ac. ft. (1.97 Mm^3) of storage volume. The reclaim water volume for reclaim pond sizing was based on the estimated volume of process water flow with a retention time of 2 months. After about 15 years of operation the combined backfill sand would have been removed and the pond would be available for disposal of sulfide tailings. Therefore, sulfide tailings disposal would be in two ponds with a combined storage capacity of 7000 ac. ft. (8.64 Mm^3).

The difference between the minimum volume of storage and the design volume of storage for the various waste products shown in Table 6.1 is a reflection of the estimated accuracy of densities and the storage efficiencies

TABLE 6.1

100 MILLION DMT OREBODY
ESTIMATED WASTE POND STORAGE VOLUMES

Waste Product	Specific Gravity	Estimated Dry Density		Min. Req'd. Volume		Design Volume	
		(pcf)	(Kg/m^3)	(ac. ft.)	(Mm^3)	(ac. ft.)	(Mm^3)
Waste Rock	--	105	1680	3,085	3.80	3,200	3.95
Comb. backfill sand	3.55	110	1760	1,381	1.70	1,550	1.91
Sulfide tailings	4.30	130	2080	5,713	7.05	7,000	8.64
Non-sulfide tailings	2.74	85	1360	16,726	20.64	20,000	24.68
Treatment sludge	N/A	N/A	N/A	--	--	1,600	1.97
Reclaim water	N/A	N/A	N/A	1,799	2.22	1,850	2.28
	TOTALS			28,704	35.41	35,200	43.43

at which the facilities might operate. Since the reclaim water density and quantity was known and the storage of water is very efficient, there is little difference between the minimum and design volume estimates. Waste rock storage is also relatively efficient so little excess volume was provided. The combined backfill sand, sulfide tailings and non-sulfide tailings volumes are the most difficult to estimate because variations in density will yield variations in volume and the efficiency with which these materials can be stored is dependent on the method of disposal. Therefore, design volumes for these waste products provided allowance for these uncertainties.

6.2.2 Hydrology and Topography

All selected siting areas have similar groundwater hydrologic features since each is a groundwater recharge area and their geologic materials are similar. At this stage of the project, simple hydrologic parameters were considered. The greater the distance between the groundwater and pond bottoms the greater the potential for attenuation of any leachate which might escape from a waste pond. The greater the distance from the site to a groundwater discharge area, the greater the opportunity for dispersion and attenuation of leachate. From a surface water standpoint, it was considered preferable to keep all facilities within the same surface watershed. The surface watersheds which were employed for this study are shown on Figure 5.7, Wetlands Watershed Map, in Section 5 of this report.

The topography of a site profoundly affects the specific facilities layout. The topography affects the earthwork required to construct the facility more than most any other feature. Valleys or surface depressions are key target areas for creating ponds with a minimum amount of earthwork. Because the lakes and large low-lying wetlands were excluded as potential siting areas, there are few major topographic depressions or valleys which are available for pond sites. However, the topographic features were used as much as possible in developing the potential waste disposal facility layouts.

6.2.3 Wetland Considerations

In addition to the site topography, and predominantly as a result of the site topography, wetlands locations were an important siting consideration. As previously noted, the large wetlands and those contiguous with streams and lakes were excluded from consideration during the siting phase of the project. Most of these wetland areas are below elevation 1600 feet (487.8 m). However, the topography of the land above elevation 1600 feet (487.8 m) includes numerous localized depressions which have developed into wetlands. These wetlands are not groundwater discharge areas and are believed to be only associated with the surface drainage system.

In addition to the area of wetlands actually covered by the layouts, consideration was also given to the potential impact of covering the surface watershed to a wetland when not covering the wetland itself. In this regard, it was assumed that if 50 percent of the total surface watershed to a wetland (the local watershed and the contributing watersheds) was covered by the facilities, then the wetland could be potentially impacted.

6.2.4 Embankment Design Parameters

The embankment design parameters which were of primary concern at this stage of the facilities layouts were those which have the greatest affect on earthwork and hence overall size of the facilities. These factors were slope configuration, freeboard height, and crest width. Other features, such as filter material design, slope protection details, and drainage and grading details would not control the overall layout concepts.

From an aesthetic, erosion control and maintenance standpoint, 3.0 horizontal to 1.0 vertical slopes were selected for the downstream (outside) sides of all embankments. Vegetative cover can be established on these slopes and they can be readily maintained.

For the upstream (inside) slopes of the embankments, two slope angles were used. Where pond linings were envisioned for water retention and/or leachate control, 4.0 horizontal to 1.0 vertical slopes were used. This slope is sufficiently flat for placement of synthetic membrane or other types of liner materials. The 4.0 horizontal to 1.0 vertical slopes were used to size the reclaim, combined backfill sand, sulfide tailings, and water treatment sludge ponds.

At the time, data suggested that the non-sulfide ponds would not contain sufficient quantities of acid producing materials to generate acid leachate and otherwise unacceptable water quality to warrant installation of special pond linings. On this basis, the non-sulfide tailings ponds were designed with upstream (inside) slopes of 2.0 horizontal to 1.0 vertical. These slopes are satisfactory from a stability and surface erosion standpoint.

For this project, with the nominal embankment heights envisioned, a 20-foot (6.1 m) crest width was established for perimeter embankments and a 16-foot (4.9 m) crest width for interior (between ponds) embankments. These crest widths were used for the facility layouts except where wider crests were needed for pipeline or rock haul corridors.

The crests of all ponds would be sloped to drain into the ponds. All ponds were designed to have a minimum freeboard height of 3 feet (0.9 m). This freeboard height is adequate for the pond sizes considered based on the 100-year, one-hour wind velocity of 90 miles per hour (145 km/h). A service road would be provided around the outside perimeter of the pond embankments. The service road and a perimeter ditch would also be constructed around the waste rock disposal area.

6.2.5 Earthwork and Stage Construction

The cost of the earthwork will be a major portion of the overall expense of the waste disposal facility. Thus, the approximate amount of earthwork required for the various layouts is an important factor in the layout process. At the time of the study, earthwork estimates were not detailed and did not differentiate the different types of materials which may be incorporated in the final design. Although the cost of the earthwork for construction had not been estimated, the relative costs of various layouts were compared based on their relative earthwork quantities.

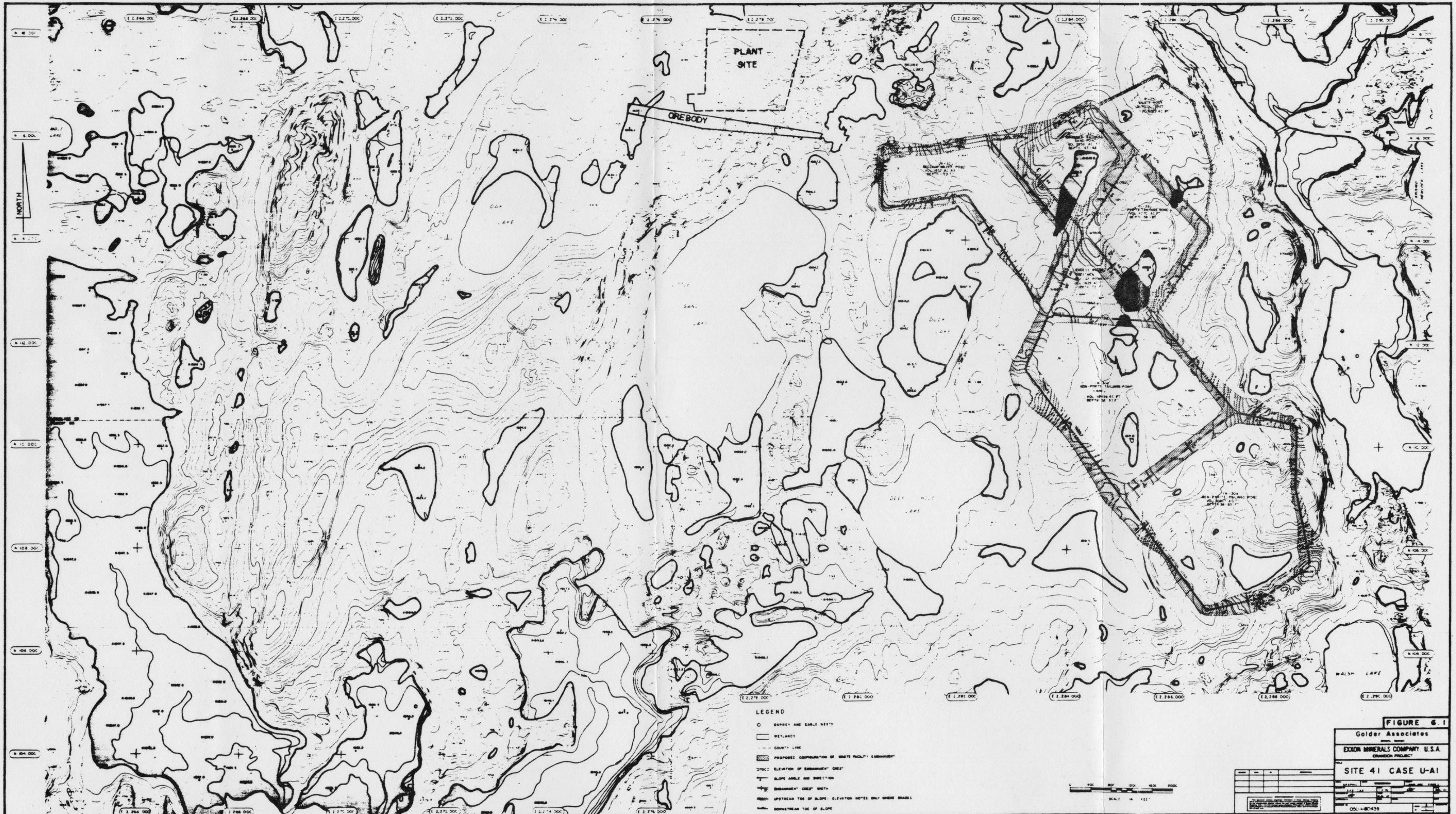
In addition to the total volume of earthwork for a waste disposal site, planning for staged construction activity was also a factor in the facilities layouts. The aspects of staged construction included time factors of when various ponds would be constructed as well as the approximate location of the excavated material (borrow) and the approximate location of the embankment construction. To the degree possible, borrow areas would be close to required fill areas since long haul distances markedly increase the cost of earthwork.

Preliminary earthwork estimates were prepared for each layout included in the report. Consideration was given to staged construction timing and haul distances in a generalized manner. The specific layouts were not studied extensively to provide highly accurate earthwork volume estimates. However, sufficient work had been done to provide an estimate of the overall magnitude of the earthwork involved and to be able to compare the relative amount of earthwork for the various layouts.

6.3 Evaluation of Site Systems

6.3.1 Overall Environmental Factors

The three site layouts presented on Figures 6.1, 6.2 and 6.3 were designed to meet the more readily identifiable environmental criteria which were anticipated to be required of such facilities. All facilities for the three layouts are outside of floodplain areas, more than 300 feet (91.4 m) from navigable rivers or streams, and more than 1000 feet (305 m) from lakes or ponds. They are more than 1000 feet (305 m) from interstate and federal or state trunk highways, and more than 1000 feet (305 m) from any public park. No active private or public water supply wells are known to be within 1200 feet (366 m) of the facilities. The proposed sites are not known to cover mineral resources within 1000 feet (305 m) of the surface. None of the sites require destruction or moving of either osprey or eagle nests, and each is more than approximately one-quarter mile (0.4 km) from the closest osprey nest. Sites 40 and 50 infringe slightly on the deer yard associ-


PLANT SITE
OREBODY
NORTH
WALSH LAKE
LEGEND
OSPREY AND EAGLE NESTS
WETLANDS
COUNTY LINE
PROPOSED CONFIGURATION OF WASTE FACILITY EMBANKMENT
ELEVATION OF EMBANKMENT CREST
SLOPE ANGLE AND DIRECTION
EMBANKMENT CREST WIDTH
UPSTREAM TOE OF SLOPE: ELEVATION NOTED ONLY WHERE GRADED
DOWNSTREAM TOE OF SLOPE
SCALE IN FEET
FIGURE 6.1
Golder Associates
EXXON MINERALS COMPANY U.S.A.
CRANDON PROJECT
SITE 41 CASE U-A1
050-4-80439


PLANT SITE
OREBODY
NORTH
WALSH LAKE
LEGEND
SCALE IN FEET
FIGURE 6.2
Golder Associates
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
SITE 40 CASE U-AI


PLANT SITE
OREBODY
NORTH
OAK LAKE
WALSH LAKE
LEGEND
FIGURE 6.3
Golder Associates
EXXON MINERALS COMPANY, U.S.A.
SITE 50 CASE U-A2

ated with the wetland between Mole and Rolling Stone Lakes, but since deer yard locations and areas change continuously this is not considered a major environmental factor.

The amount of land actually covered by each of the three layouts, excluding pipeline corridors and access roads, is approximately the same: 850 acres (344 ha) for Site 40, 917 (371 ha) for Site 41, and 1073 (434 ha) for Site 50. Sites 41 and 40 are compact layouts, keeping all facilities within the same general area. Site 50 is spread over a much larger area than the 1073 acres (434 ha) the facilities actually cover. Sites 41 and 40 are believed to be preferable to Site 50 from the standpoint of overall area required.

None of the sites cover or infringe on any wetlands which are contiguous with lakes or streams. Such wetland areas were strictly avoided in selecting the sites. Sites 40 and 41 cover 39 and 63 acres (16 and 25 ha) of upland wetlands, respectively. Site 50 covers no wetlands since this criteria was the primary intent of the layout.

For purposes of the report, the potentially impacted upland wetlands were those where half or more of the wetland's watershed is covered by the facilities. All three site layouts presented include potentially impacted wetlands according to this criteria. The wetland areas directly covered and wetland areas potentially impacted by having 50% of their watershed covered are 85 acres (34 ha) for Site 50, 96 acres (39 ha) for Site 41, and 50 acres (20 ha) for Site 40. Thus, all three sites have the potential of impacting upland wetlands even through one layout, Site 50, covers no wetlands directly.

Since all sites are in upland areas, they are all above the groundwater levels. The facilities of Site 40 are nominally 35 to 70 feet (10.7 to 21.3 m) above groundwater while those at Sites 41 and 50 are nominally 50 to 95 feet (15.2 to 29.0 m) above groundwater. With increased height above groundwater, there is increased opportunity for attenuation of any leachate which may seep from the system. Thus, Sites 41 and 50 may provide additional safeguards compared to Site 40 in this regard.

From a surface watershed viewpoint, Site 41 has the advantage of being able to contain the facilities within one watershed except for the downstream slopes of the embankments along the east side of the site. The Site 40 facilities straddle the Swamp Creek/Pickerel Creek watershed divide and the Little Sand Lake sub-watershed divide within the Pickerel Creek watershed. Site 50, because it is spread over parts of both the Site 40 and 41 land areas, has facilities in all of these watersheds. The overall potential impact of the facilities will probably be reduced when they can be contained in fewer surface watersheds such as the Site 41 layout.

It is generally safe to assume that the farther a potential source of leachate is from a groundwater discharge area, the greater the potential for attenuation and dilution. Of particular importance in this regard are the groundwater discharge areas of the wetlands associated with Ground Hemlock Creek, Swamp Creek, Rice Lake, Mole Lake and Rolling Stone Lake. These creeks, lakes and wetlands form a continuous band around the southwest, west, north, and east sides of the combined Site areas 40 and 41.

From the standpoint of proximity to groundwater discharge areas, Site 40 is the closest and Site 41 the farthest, with Site 50 having its facilities located in both Site 40 and 41 areas. The Site 40 layout is within about 400 feet (122 m) of the wetland between Mole Lake and Rolling Stone Lake. This wetland drains both north to Mole Lake and south to Rolling Stone Lake. On the south side of Site 40, the wetlands contiguous to Rolling Stone Lake are groundwater discharge areas and drain directly to Rolling Stone Lake. Groundwater contours at Site 40 suggest that groundwater flows across the site from essentially northeast to southwest with a gradient of about 0.3%. Thus, any seepage which enters this groundwater system would tend to flow in this same direction.

Site 41 is located above a groundwater high. From the central portion of Site 41 the groundwater level contours tend to become lower in all directions, but there is preference for the majority of the groundwater flow to be toward the east and southwest. The groundwater gradient from the center of Site 41 to the wetland contiguous with Hemlock Creek is 0.3%, but steepens to about 1% between the edge of Site 41 and this wetland. The groundwater gradient from the center of Site 41 to the wetland northeast of Rolling Stone Lake is about 0.3%. At its closest point the Site 41 layout is about 600 feet (183 m) from the wetland contiguous with Hemlock Creek, but over most of its eastern edge is more than 1000 feet (305 m) from this wetland. It is also more than 10,000 feet (3050 m) from the wetland northeast of Rolling Stone Lake.

Site 50, because of being spread over the land areas of both Site 40 and 41, includes the groundwater features of these two sites. Those facilities on the east side of

Little Sand Lake are over the groundwater high. Those facilities on the west side of Little Sand Lake are over the lower groundwater areas but located such that the down gradient direction is across the site from northeast to southwest.

6.3.2 Construction and Operational Factors

The primary factors in evaluation of the sites from a construction veiwpoint is the overall earthwork volume, staged construction considerations, waste rock haul road length, and pipeline lengths. For these three sites, most all other construction related factors are equal. There are no major construction problems related to the foundation conditions, material availability or groundwater which are anticipated at this time for either of the three sites. From an operational standpoint the method of decant water removal, pipeline lengths and haul distances are the primary factors. Other operational factors not related to these items are essentially the same for the three sites or have a lesser impact to the total system operation.

The earthwork volume estimates for the three sites indicate that Site 41 will require less earthwork than Site 40 and much less than Site 50. If balanced, the earthwork for Site 41 could be two-thirds that of Site 40 and half that of Site 50. These differences represent substantial costs since earthwork alone could be more than half of the total construction cost of the facility.

From a staged construction standpoint, it appeared that Site 41 could be developed in stages which correspond reasonably well with the need of the various facilities. Vertical staging would be possible, for the unlined tailings ponds. Since detailed excavation and fill volumes were not compiled for Site 40, it was assumed that it could also be similarily developed. Although Site 50 could be constructed in stages, the stages themselves would probably have to be large units. Since each pond would have to have nearly a balanced earthwork by itself, the excavated material would be obtained from the pond bottom. Therefore, a pond would have to be completely constructed to its full size before it could become operational. This leaves little possibility for constructing an individual pond in successive vertical stages while in operation.

The pipeline corridor and waste rock haul road from the mine/mill area to the disposal area would be more than four times longer for Site 40 than for Site 41. Thus, four times the land area would be covered and probably about four times the expense would be involved in construction. For Site 50 this length is essentially the total of both Sites 40 and 41. Distribution lengths around the ponds, once the disposal area is reached, would be about the same for Site 40 and 41. The Site 50 system would be longer than either of these because the ponds are spread over such a large area. In addition, duplicate standby lines and additional piping to the water reclaim pond would be required for Site 50.

The problems and costs associated with operating this waste transport system are approximately directly related to the length of the pipelines and haul road. With approximately equal grade change, the longer the lengths, the greater the pump sizes and energy costs of operation, and a greater area is impacted. Maintenance costs are higher because there is more length to the system. There are no benefits, from a cost or environmental view, in having a long waste product transfer system.

The decant system design and operation is primarily a function of the proximity of the waste ponds to the reclaim pond and their relative elevations. A simple, short gravity flow system is most advantageous with respect to cost and operations. Of the three sites, the Site 41 system will allow for gravity flow decanting from all but one non-sulfide pond. The Site 40 system will also allow for gravity decanting from most ponds with some pumping required from the non-sulfide ponds. The Site 50 system will require pumping from all ponds except the combined backfill sand pond.

6.3.3 Summary and Conclusions

Based on the studies performed and the information regarding the volumes and characteristics of the various waste products, the Site 41 system was recommended for disposal of the waste products from the Crandon mining and milling process. A Site 41 system can be designed to have the least adverse environmental impact on the area, and be feasible to construct and operate. A summary of the features of each of the three site layouts is presented in Table 6.2.

Site 41 is more acceptable than Site 40 for a number of reasons. Site 41 is predominantly contained in one surface watershed and its location, in that watershed, is such that there is not a direct, short drainage path to the waters and wetlands of Swamp Creek and Rolling Stone Lake. Site 40 straddles three surface watersheds which drain directly to the wetlands contiguous to Mole and Rolling Stone Lakes. The groundwater surface beneath Site 40 has a preferencial gradient toward, and discharges into, the wetland around Rolling Stone Lake and the wetland between Mole and

TABLE 6.2

COMPARISON OF SITE FEATURES

(* Notes advantage over the other sites)

FEATURES	SITE 40 CASE U-A1	SITE 41 CASE U-A1	SITE 50 CASE U-A2
1. Land area covered	*1. 850 acres (344 ha)	1. 917 acres (371 ha)	1. 1073 acres (434 ha), but is spread over a much larger area
2. Upland wetlands covered	2. 8 wetlands @ 39 acres (16 ha)	2. 13 wetlands @ 63 acres (25 ha) total	*2. None - "no wetland" layout
3. Upland wetlands potentially impacted	*3. 3 wetlands @ 11 acres (4 ha)	3. 3 wetlands @ 33 acres (13 ha) total	3. 14 wetlands @ 85 acres (34 ha)
4. Distance from pond bottoms to groundwater table	4. 35 to 70 feet (10.7 to 21.3 m)	*4. 50 to 95 feet (15.2 to 27.4 m)	*4. 50 to 95 feet (15.2 to 27.4 m)
5. Surface watersheds in which site is located	5. 3 - Swamp Creek and Pickerel Creek watersheds and Little Sand Lake subwatershed	*5. 2 - Ponds in Little Sand Lake subwatershed, small area of downstream embankments in the Hemlock Creek/Swamp Creek watershed	5. 5 - All watersheds of Sites 40 and 41
6. Proximity to groundwater discharge areas	6. Closest to discharge area	*6. Farthest from discharge area	6. Combination of Sites 40 and 41
7. Estimated earthwork volume	7. 13 million cu.yds. (9.9 Mm^3)	*7. 9.3 million cu.yds (7.1 Mm^3)	7. 19.2 million cu.yds. (14.7 Mm^3)
8. Staged construction considerations	*8. Probably could be developed in stages similar to Site 41	*8. Could be constructed in stages which correspond reasonably well to needs.	8. Full size pond units only; nearly no possibility for constructing an individual pond in stages
9. Pipeline corridor/haul roads	9. About 4 times longer than Site 41	*9. Shortest corridor/haul road from the mine/mill complex to disposal area	9. Total of both Sites 40 and 41
10. Decant systems	10. Some gravity flow, some pumping	*10. Mostly gravity flow, some pumping	10. Mostly all pumping
11. Relative costs	11. Probable cost significantly higher than Site 41, but less than Site 50	*11. Lowest probable capital and operating cost	11. Probably twice the cost of Site 41.

Features common to all three sites:

1. Outside flood plain areas
2. More than 300 ft. (91 m) from navigable rivers or streams
3. More than 1000 ft. (305 m) from lakes or ponds
4. More than 1000 ft. (305 m) from state and federal highways
5. More than 1000 ft. (305 m) from public park
6. More than 1200 ft. (366 m) from known active water supply well
7. More than 1000 ft. (305 m) above any known mineral resource likely to be minable in the future
8. Do not include a major wetland contiguous with a lake or stream
9. More than one-quarter mile (0.40 km) from existing osprey/eagle nest

Rolling Stone Lakes. The groundwater surface beneath Site 41 forms a northwest to southeast trending ridge so that the gradient has some preference toward the east and southwest. The groundwater levels are farther below the pond bottoms at Site 41 than at Site 40, thereby affording a greater potential for leachate attenuation. Site 41 is closer to the mill, thus keeping all surface facilities in a more compact geographical area. The pipeline corridor and haul road length from the mine/mill complex to the disposal area is shortest for Site 41, thus reducing the amount of land required and reducing potential environmental impact. In addition to these environmental advantages of Site 41, the waste disposal system can be developed and operated at this Site for a lesser cost than the Site 40 system. Pipeline and haul distances are shorter, more decanting can be done by gravity and the overall earthwork is substantially less for Site 41 than for Site 40. The primary advantage of Site 40 over Site 41 is that the facility layout at Site 40 covers and potentially impacts fewer acres of upland wetlands than does the Site 41 layout.

Recent regulatory trends towards limiting the incorporation of wetlands in a disposal facilities system led to the development of the Site 50 design which does not cover a wetland. Although no wetlands are covered by this facilities layout, it does cover wetland watersheds and could potentially impact nearly as many acres of wetland as does Site 41. Through work completed to date, the potential for adverse environmental impact is considered greater for the Site 50 layout than for either Site 40 or 41. Although the advantages of Site 41 apply to the eastern portion of the Site 50 layout, the disadvantages of Site 40 apply to the western portion of the Site 50 layout. In addition, the

Site 50 layout impacts nearly twice the overall land area as either Site 40 or 41, even though it only covers slightly more area. From a cost standpoint, Site 50 could easily be twice as expensive to construct and operate as the Site 41 system.

In consideration of the overall area surrounding the Crandon orebody, there appears to be no viable site which would exclude incorporation of wetlands. The three site layouts presented herein are believed to have a minimum overall environmental impact for the general design constraints placed on each system. The Site 41 and Site 40 layouts were designed to minimize wetland usage. Of these sites, Site 41 is considered to provide a functional waste disposal facility which minimizes the potential wetland impacts and has the least overall adverse impact to the environment.

7.0 SLURRY SYSTEM LAYOUTS FOR 77 MILLION DMT OREBODY

7.1 Design Pond Volumes

After determining Site 41 to be the preferred waste disposal facility location, various alternative facility layouts in Site 41 were studied. The waste products and product volumes used as the basis for sizing the waste disposal system facilities were presented in Section 3 of this report. Those volumes are an estimate of the amounts of materials to be stored, but do not include any allowance for the efficiency of tailings storage nor any allowance for water in the reclaim pond above that required for return to processing. Additional capacity must be provided within the system to account for these allowances. Table 7.1 is a summary of the waste product volumes estimated from mine/mill production tonnages and the total volume for which the system will be designed from a storage viewpoint. The reasoning of these differing volumes is discussed below.

The reclaim ponds (it is presently envisioned that there will be two separate ponds although early designs were based on one pond) must store the required process water volume of 954 acre-feet ($1.18x10^6$ m^3) plus the design storm water volume of 28 acre-feet ($0.035x10^6$ m^3). The design storm is the 24-hour, 100-year event which equals 5.1 inches (130 mm) of precipitation. Also, storage will be provided for 14 days storage of 2,500 gallons per minute (0.158 m^3/s) of mine water handling from excess water treatment facility shut-down. This is equivalent to 154 acre-feet ($0.19x10^6$ m^3). The early pond systems designed with one reclaim pond were sized for the process reclaim water plus 3 feet (0.91 m) of freeboard. This freeboard height is sufficient for retaining the 24-hour,

TABLE 7.1

DESIGN WASTE PRODUCT VOLUMES
FOR THE 77 MILLION DMT OREBODY

Product	Production Volume		Design Storage Volume		Percent of Storage Volume above Production Volume
	$10^6 m^3$	Ac. Ft.	$10^6 m^3$	Ac. Ft.	
Tailings and Excess Water Treatment Sludge	23.87	19,348	27.45	22,250	15%
Waste Rock	1.93	1,565	1.93	1,565	0%
Reclaim Water (see Note 1)	1.18	954	1.59	1,288	35%

Note 1. Reclaim pond design storage includes storm precipitation and an allowance for mine water handling due to shut-down of the excess water treatment plant.

100-year storm water plus waves. The requirement, by Exxon, to store the mine water from the excess water treatment plant shut-down was applied along with their request to have two reclaim ponds in lieu of one. In addition, capacity was added to contain the Probable Maximum Precipitation (PMP) Volume from the largest tailings pond. Thus, the total volume of the two reclaim pond options is larger than the single reclaim pond options.

The tailings ponds will hold the slurried tailings, waste water treatment sludge, and waste rock. Most of the waste rock will be incorporated into the construction of the ponds or will be used to re-grade the ponds beneath the reclamation cover. Thus, its total volume is not treated as required storage volume at this stage in the preliminary design process.

In addition to the solids within the pond and the water retained within the pores of the tailings after it settles, the tailings ponds will also pond water for final clarification prior to its decanting to the reclaim ponds. Along with a volume for water ponding, the tailings pond volume must account for the slope of the tailings surface. The surface of the tailings beach in a pond slopes downward from the input point to the ponded water area. Slopes generally range from 0.5 to 1.0 percent for similar mine tailings ponds. Because of the fine particle size of the tailings for this project, a 0.5 percent slope is estimated for preliminary design. Experience indicates the slope of the tailings below the ponded water will be nearly horizontal, except for a steep slope (which may range from 5 to 50 percent) right at the water's edge against the tailings beach. This steeply sloped area, however, is usually found to be limited in height to about 10 to 20 feet (3 to 6 m). The difference in pond volume between the anticipated tailings surface configuration and a level surface at the highest point of the tailings (at the input point) is termed the inefficiency of the pond. Typical inefficiencies for similar tailings ponds ranges from 10 to 20 percent of the storage volume based on production tonnages. As shown on Table 7.1, a 15 percent inefficiency has been used for preliminary design for the tailings and sludge. No inefficiency was assumed for the waste rock since it will be used as construction material.

The waste production volumes and design storage volumes included in Table 7.1 are based on the latest tonnage estimates available from Exxon at the time of this writing. Prior to having these tonnages, many estimates were made and subsequently refined for the 77 million DMT orebody. As revised tonnages were received and revised volume estimates made, they were incorporated into tailings facility layouts. Details of the various tonnage estimate refinements are not presented herein since they were fairly minor and would lend little to the overall purpose of this report. Although there are slight differences in the design volumes of some of the layouts because of these changes, any one of the system layouts presented could be modified to accomodate the latest waste product tonnage and volume estimates.

7.2 Common Design Features

All facility layouts developed have several common features regardless of differences in size, shape, location, or number of ponds in each system. Some features cannot be shown on the drawings because they are beyond the level of detail required at this stage of project development. However, allowances have been made, or could be made, to incorporate each of the features. The significant common features of these systems are as follows:

1. Lakes are not employed as disposal areas.

2. Offset of more than 300 feet (91.4 m) from navigable streams.

3. Ponds excluded from areas below elevation 1600 feet (487.7 m) MSL.

4. Outside floodplains.

5. Offset more than 1,000 feet (305 m) from the right-of-way of the following:
   a) state trunk highway,
   b) interstate or federal primary highway,
   c) boundary of any state or federal park,
   d) boundary of a scenic easement purchased by the Wisconsin DNR or DOT,
   e) boundary of a designated scenic or wild river,
   f) a scenic overlook designated by the Wisconsin DNR by rule,
   g) a bike or hiking trail designated by the United States Congress or the State Legislature.

6. More than 1,200 feet (366 m) from any public or private water supply well (except wells drilled by Exxon).

7. More than 0.25 miles (0.4 km) from osprey or eagle nests.

8. Outside the area containing a known mineral resource likely to be mineable in the future and which lies within 1,000 feet (305 m) of the surface.

9. All tailings ponds to include a low permeability liner and underdrain above the liner.

10. Reclaim water ponds to include two low permeability liners.

11. All ponds to have a minimum of 3 feet (0.91 m) of freeboard.

12. Pond crests to be able to carry at least one-way traffic for periodic inspection.

13. All pond crests sloped to drain into the pond.

14. Exterior embankment slopes 3.0 horizontal to 1.0 vertical.

15. Interior pond side slopes 4.0 horizontal to 1.0 vertical.

16. Service road to be provided around the perimeter of the system at the toe of embankment slopes.

17. Drainage swales or other drainage grading to be provided around the perimeter of the system.

18. All tailings ponds to be covered, graded to drain, and vegetated at reclamation.

19. Reclaim ponds to be dismantled, with lining materials placed in final tailings pond, and area regraded and vegetated at reclamation.

One of the location criteria of proposed NR 182 is that the facilities be more than 1,000 feet (305 m) from navigable lakes. In preparing the facility layouts, it was found that there were topographic and groundwater features which could warrant infringing on this offset around Duck and Deep Hole lakes. Rather than ignore these possibilities, some layouts were developed which would require a variance from this location criteria.

Another location criteria listed in proposed NR 182 is that the facilities not be within 200 feet (61 m) of the property line. At this time, it is understood that Exxon is still in the process of acquiring certain portions of land. It is therefore considered inappropriate to show certain property boundaries. In preparing the layouts, it has been assumed that this location criteria would not present a restriction.

There are many other features to be incorporated into the design of a tailings facility beyond those listed above. However, for purposes of preparing the alternate layouts which follow, these additional features are considered as details or would not have a bearing on selecting a system from the alternatives provided.

7.3 Alternative System Layouts and Comparison

In working with the Site 41 area, numerous pond configuration layouts have been developed. To date, over 100 different layouts have been prepared within the Site 41 area over a period of about 3.5 years. With the many changes and refinements in orebody size estimates, waste product tonnage estimates, number of waste products, waste production schedules, and waste product properties, most of these layouts are now out dated. As discussed in Section 3 of this report, the most significant change in waste product volume estimates was applied to the waste facilities design in January, 1981 when the orebody reserve estimate was revised from 100 million DMT to 77 million DMT. Since that time about 25 layout alternatives have been prepared for the Site 41 area.

Since the adoption of the 77 million DMT reserve estimate for waste facility design, the most significant changes in waste product volume and scheduling have been for the waste rock and reclaim pond. The waste rock volume and production schedule has been refined based on newer mine planning concepts. The reclaim pond design has been altered by Exxon's request that this water be retained in two ponds rather than one, so that they have the option of chemically treating the reclaim water as it flows between these two ponds, and their requirement that the reclaim ponds be large enough to hold mine water in the event of a short shut-down of the excess water treatment facility.

The alternative Site 41 layouts presented herein were selected to illustrate the range of viable variations possible. Although the available storage within each system differs slightly, any one could be altered to provide the latest estimated storage volume and still maintain its overall characteristics. The five alternatives shown cover an average of (measured within the outside toe of embankment slope) 515 acres (209 ha) (±6 percent) of land and have an average storage capacity of 21,100 acre-feet ($26.0 \times 10^6 m^3$) (±1 percent).

In terms of overall environmental impact, those items considered of most significance are wetlands, groundwater, and distance from lakes. Less significant items are total land area, embankment height, and crest elevation. The impact of mine waste facilities on the groundwater system is discussed in detail in the following Section of the report. The other items listed above are summarized on Table 7.2 from the drawings of the five alternatives shown on Figures 7.1 through 7.5. Other environmental impact considerations and design features common to each of these alternatives were listed in Section 7.2.

From a construction cost standpoint, the volume of earthwork required to develop the configurations shown and the area inside the crests are the most significant. The area inside the crests represents the area of pond bottoms and inside slopes requiring liners or liners and underdrains, and also the area requiring cover for reclamation. Since the location of each of the systems presented rela-

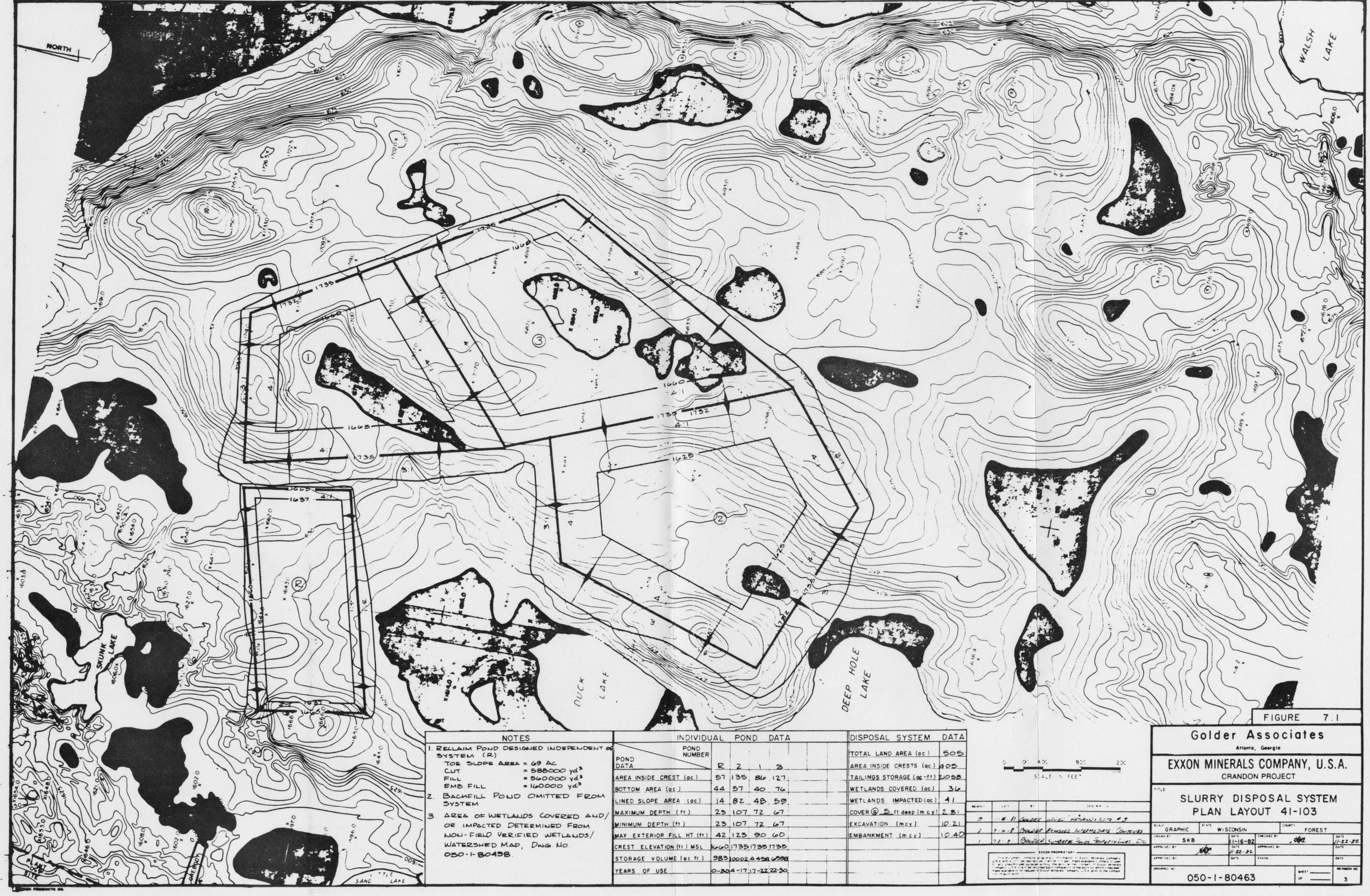
TABLE 7.2

SUMMARY OF COMPARATIVE FEATURES

COMPARATIVE FEATURE	41-103	41-106	ALTERNATIVE SYSTEM DESIGNATION 41-109	41-114	41-121
Number of tailings ponds	3	4	3	4	2
Distance from lakes, feet (m)	170 (51.8)	450 (137.2)	1,050 (320.0)	1,050 (320.0)	200 (61.0)
Wetlands covered, acres (ha)	36 (14.6)	47 (19.0)	54 (21.9)	49 (19.8)	62 (23.1)
Wetlands impacted, acres (ha)	41 (16.6)	53 (21.4)	54 (21.9)	49 (19.8)	62 (25.1)
Total land area, acres (ha)	505 (204.4)	537 (217.3)	503 (203.6)	538 (217.7)	485 (196.3)
Area inside crests, acres (ha)	405 (163.9)	423 (171.2)	386 (156.2)	421 (170.4)	406 (164.3)
Height above groundwater, feet (m) (Note 1)	30-66 (9.1-20.1)	34-59 (10.4-18.0)	54-59 (16.5-18.0)	44-60 (13.4-18.3)	30-55 (9.1-16.8)
Maximum crest elevation, feet MSL (m)	1,735 (528.8)	1,740 (530.4)	1,745 (531.9)	1,745 (531.9)	1,723 (525.2)
Max. pond depth, feet (m)	90 (27.4)	90 (27.4)	95 (29.0)	95 (29.0)	98 (29.9)
Max. exterior fill height, feet (m)	123 (37.5)	95 (29.0)	102 (31.1)	100 (30.5)	108 (32.9)
Approximate earthwork, millions of cubic yards ($10^6 m^3$)	11.71 (8.95)	13.15 (10.05)	12.03 (9.20)	12.49 (9.55)	9.26 (7.08)

(1) Heights given are for tailings pond bottoms only. Reclaim pond bottoms for all five alternatives range from 35 to 45 feet (10.7 to 13.7 m) above groundwater.

786085



NOTES

1. RECLAIM POND DESIGNED INDEPENDENT OF SYSTEM (R)
   TOE SLOPE AREA = 69 AC
   CUT = 588000 yd^3
   FILL = 560000 yd^3
   EMB. FILL = 160000 yd^3
2. BACKFILL POND OMITTED FROM SYSTEM
3. AREA OF WETLANDS COVERED AND/OR IMPACTED DETERMINED FROM NON-FIELD VERIFIED WETLANDS/WATERSHED MAP, DWG. NO. 050-1-80458.

INDIVIDUAL POND DATA

POND DATA \ POND NUMBER	R	2	1	3
AREA INSIDE CREST (ac)	57	135	86	127
BOTTOM AREA (ac)	44	57	40	76
LINED SLOPE AREA (ac)	14	82	48	59
MAXIMUM DEPTH (ft)	23	107	72	67
MINIMUM DEPTH (ft)	23	107	72	67
MAX EXTERIOR FILL HT (ft)	42	123	90	60
CREST ELEVATION (ft) MSL	1660	1735	1735	1735
STORAGE VOLUME (ac ft)	983	10002	4458	6598
YEARS OF USE	0-30	4-17	17-22	22-30

DISPOSAL SYSTEM DATA

TOTAL LAND AREA (ac)	505
AREA INSIDE CRESTS (ac)	405
TAILINGS STORAGE (ac-ft)	21058
WETLANDS COVERED (ac)	36
WETLANDS IMPACTED (ac)	41
COVER @ 5 ft deep (mcy)	2.81
EXCAVATION (mcy)	10.21
EMBANKMENT (mcy)	10.40

REVISION	DATE	BY	DESCRIPTION
3	11-15-82	GOLDER	ADDED WETLANDS NOTE #3
2	7-6-8	GOLDER	REMOVED INTERMEDIATE CONTOURS
1	[illegible]	GOLDER	NUMBERED PONDS, PROPERTY LINES, ETC

EXXON PROPRIETARY

FIGURE 7.1

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE
SLURRY DISPOSAL SYSTEM
PLAN LAYOUT 41-103

SCALE: GRAPHIC	STATE: WISCONSIN	COUNTY: FOREST
DRAWN BY: SKB	DATE: 11-16-82	CHECKED BY: [signature] DATE: 11-22-82
APPROVED BY: [signature]	DATE: 11-22-82	APPROVED BY: DATE:
APPROVED BY:	DATE:	EXXON DATE:
DRAWING NO. 050-1-80463	SHEET ___ OF ___	REVISION NO. 3

NOTES

1. RECLAIM PONDS (R1 & R2) DESIGNED INDEPENDENT OF SYSTEM.
   - TOE SLOPE AREA = 77 ACRES
   - CUT VOLUME = 717,000 yd^3
   - FILL VOLUME = 676,000 yd^3
2. BACKFILL POND OMITTED FROM SYSTEM
3. POND 1 DESIGNED WITH EXCESS CUT.
   - TOE SLOPE AREA = 101 ACRES
   - CUT VOLUME = 2.25 mcy
   - FILL VOLUME = 1.53 mcy
4. CREST WIDTH = 25 FT
5. AREA OF WETLANDS COVERED AND FOR IMPACTED DETERMINED FROM NON-FIELD VERIFIED WETLANDS WATERSHED MAP, DWG. NO 050-1-80438

INDIVIDUAL POND DATA

POND DATA \ POND NUMBER	1	2	3	4	R_1	R_2
AREA INSIDE CREST (ac)	79	99	94	90	31	29
BOTTOM AREA (ac)	37	38	41	31	20	20
LINED SLOPE AREA (ac)	42	62	53	59	11	9
MAXIMUM DEPTH (ft)	70	90	90	90	23	23
MINIMUM DEPTH (ft)	70	90	90	90	23	23
MAX EXTERIOR FILL HT. (ft.)	80	95	55	70	37	34
CREST ELEVATION (ft.) MSL	1700	1740	1740	1740	1657	1654
STORAGE VOLUME (ac ft.)	3828	5830	5798	5879	485	483
YEARS OF USE (INCLUSIVE)	5-10	11-17	18-23	24-30	0-30	0-30

DISPOSAL SYSTEM DATA

DISPOSAL SYSTEM	DATA
TOTAL LAND AREA (ac)	537
AREA INSIDE CRESTS (ac)	423
TAILINGS STORAGE (ac-ft)	21,335
WETLANDS COVERED (ac)	47
WETLANDS IMPACTED (ac)	53
COVER @ 5 ft deep (m cy)	2.92
EXCAVATION (mcy)	13.62
EMBANKMENT (m cy)	9.75

REVISION	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

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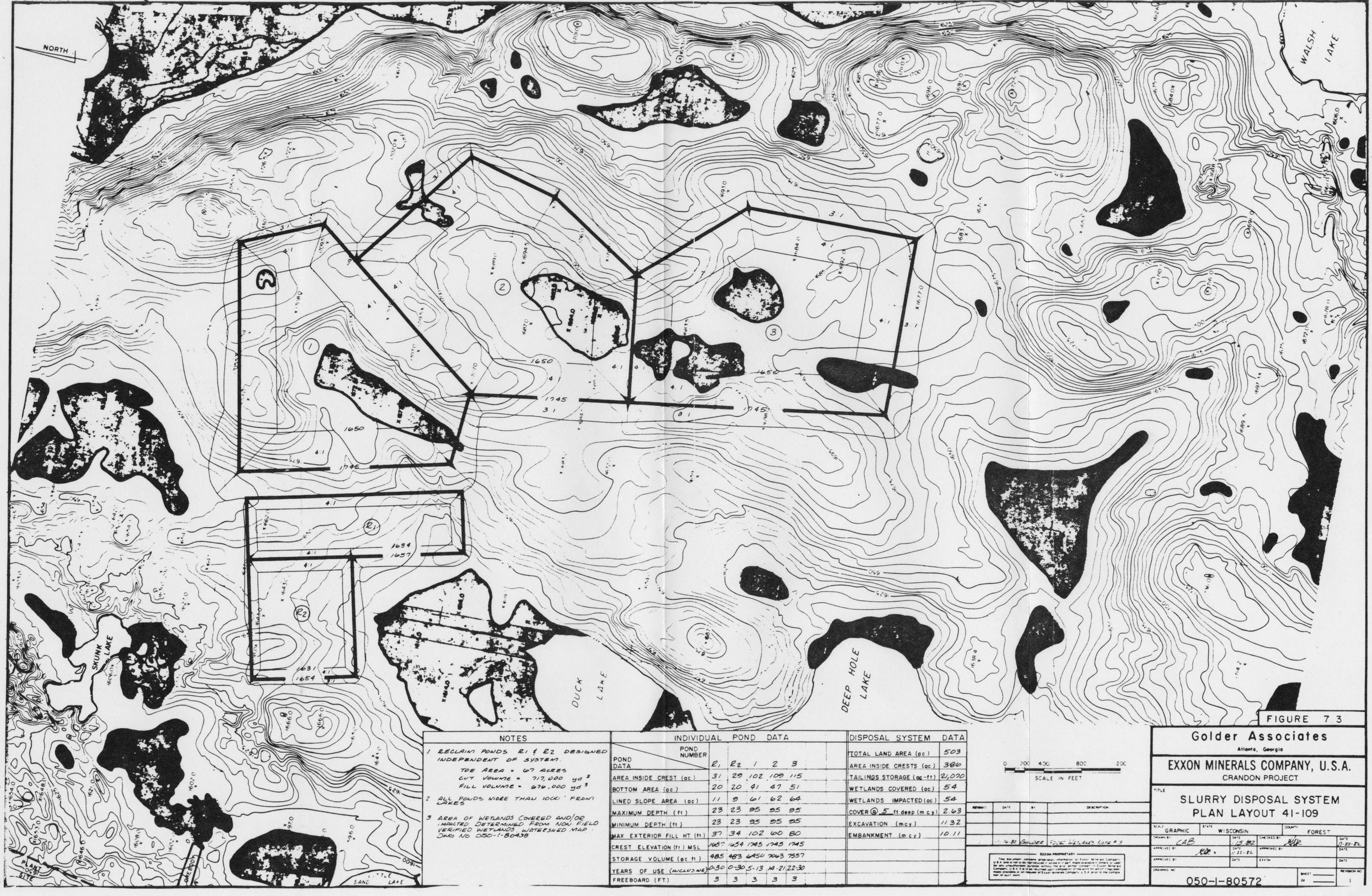
FIGURE 7.2

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE: SLURRY DISPOSAL SYSTEM PLAN LAYOUT 41 - 106

SCALE: GRAPHIC	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: SKB	DATE: 11-16-82	CHECKED BY: [signature]	DATE: 11-22-82
APPROVED BY: [signature]	DATE: 11-22-82	APPROVED BY:	DATE:
APPROVED BY:	DATE:	EXXON:	DATE:
DRAWING NO: 050-1-80639		SHEET: ___ OF ___	REVISION NO.



NOTES

1 RECLAIM PONDS R1 & R2 DESIGNED INDEPENDENT OF SYSTEM.

TOE AREA = 67 ACRES
CUT VOLUME = 717,000 yd^3
FILL VOLUME = 676,000 yd^3

2 ALL PONDS MORE THAN 1000' FROM LAKES

3 AREA OF WETLANDS COVERED AND/OR IMPACTED DETERMINED FROM NON FIELD VERIFIED WETLANDS WATERSHED MAP DWG NO 050-1-80438

INDIVIDUAL POND DATA

POND DATA \ POND NUMBER	R1	R2	1	2	3		
AREA INSIDE CREST (ac)	31	29	102	109	115		
BOTTOM AREA (ac)	20	20	41	47	51		
LINED SLOPE AREA (ac)	11	9	61	62	64		
MAXIMUM DEPTH (ft)	23	23	95	95	95		
MINIMUM DEPTH (ft)	23	23	95	95	95		
MAX EXTERIOR FILL HT (ft.)	37	34	102	60	80		
CREST ELEVATION (ft) MSL	1657	1654	1745	1745	1745		
STORAGE VOLUME (ac ft)	485	483	6450	7063	7557		
YEARS OF USE (INCLUSIVE)	0-30	0-30	5-13	14-21	22-30		
FREEBOARD (FT)	3	3	3	3	3		

DISPOSAL SYSTEM	DATA
TOTAL LAND AREA (ac)	503
AREA INSIDE CRESTS (ac)	386
TAILINGS STORAGE (ac-ft)	21,070
WETLANDS COVERED (ac)	54
WETLANDS IMPACTED (ac)	54
COVER @ 5 ft. deep (m cy)	2.63
EXCAVATION (m cy)	11.32
EMBANKMENT (m cy)	10.11

0 200 400 800 1200
SCALE IN FEET

REVISED	DATE	BY	DESCRIPTION
	11-16-82	GOLDER	[illegible] WETLANDS NOTE # 3

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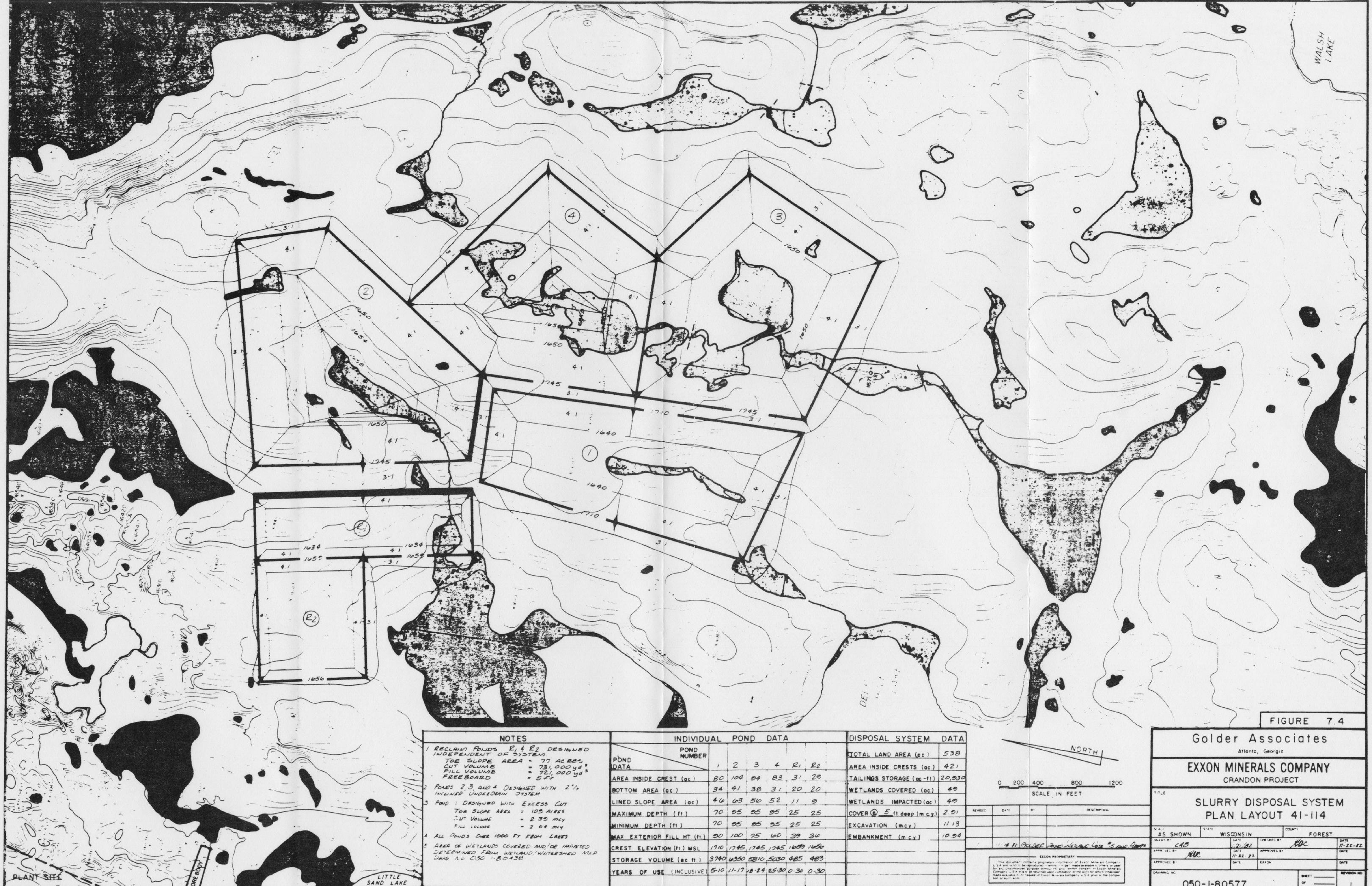
FIGURE 7.3

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE
SLURRY DISPOSAL SYSTEM
PLAN LAYOUT 41-109

SCALE GRAPHIC	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY CAB	DATE 11-15-82	CHECKED BY [signature]	DATE 11-22-82
APPROVED BY [signature]	DATE 11-22-82	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO 050-1-80572		SHEET ___ OF ___	REVISION NO 1



NOTES

1. RECLAIM PONDS R_1 & R_2 DESIGNED INDEPENDENT OF SYSTEM.
   - TOE SLOPE AREA = 77 ACRES
   - CUT VOLUME = 731,000 yd^3
   - FILL VOLUME = 721,000 yd^3
   - FREEBOARD = 5 Ft
2. PONDS 2, 3, AND 4 DESIGNED WITH 2% INCLINED UNDERDRAIN SYSTEM
3. POND 1 DESIGNED WITH EXCESS CUT
   - TOE SLOPE AREA = 109 ACRES
   - CUT VOLUME = 2.39 mcy
   - FILL VOLUME = 2.04 mcy
4. ALL PONDS OVER 1000 FT FROM LAKES
5. AREA OF WETLANDS COVERED AND/OR IMPACTED DETERMINED FROM WETLAND/WATERSHED MAP DWG. NO. 050-1-80438

INDIVIDUAL POND DATA

POND DATA \ POND NUMBER	1	2	3	4	R_1	R_2
AREA INSIDE CREST (ac)	80	104	94	83	31	29
BOTTOM AREA (ac)	34	41	38	31	20	20
LINED SLOPE AREA (ac)	46	63	56	52	11	9
MAXIMUM DEPTH (ft)	70	95	95	95	25	25
MINIMUM DEPTH (ft)	70	95	95	95	25	25
MAX EXTERIOR FILL HT (ft.)	90	100	75	60	39	36
CREST ELEVATION (ft.) MSL	1710	1745	1745	1745	1659	1656
STORAGE VOLUME (ac ft.)	3740	6350	5810	5030	485	483
YEARS OF USE (INCLUSIVE)	5-10	11-17	18-24	25-30	0-30	0-30

DISPOSAL SYSTEM DATA

TOTAL LAND AREA (ac)	538
AREA INSIDE CRESTS (ac)	421
TAILINGS STORAGE (ac-ft)	20,930
WETLANDS COVERED (ac)	49
WETLANDS IMPACTED (ac)	49
COVER @ 5 ft deep (m.c.y.)	2.91
EXCAVATION (mcy)	11.13
EMBANKMENT (m.c.y.)	10.94

REVISED	DATE	BY	DESCRIPTION
1	11-18-82	GOLDER	[illegible]

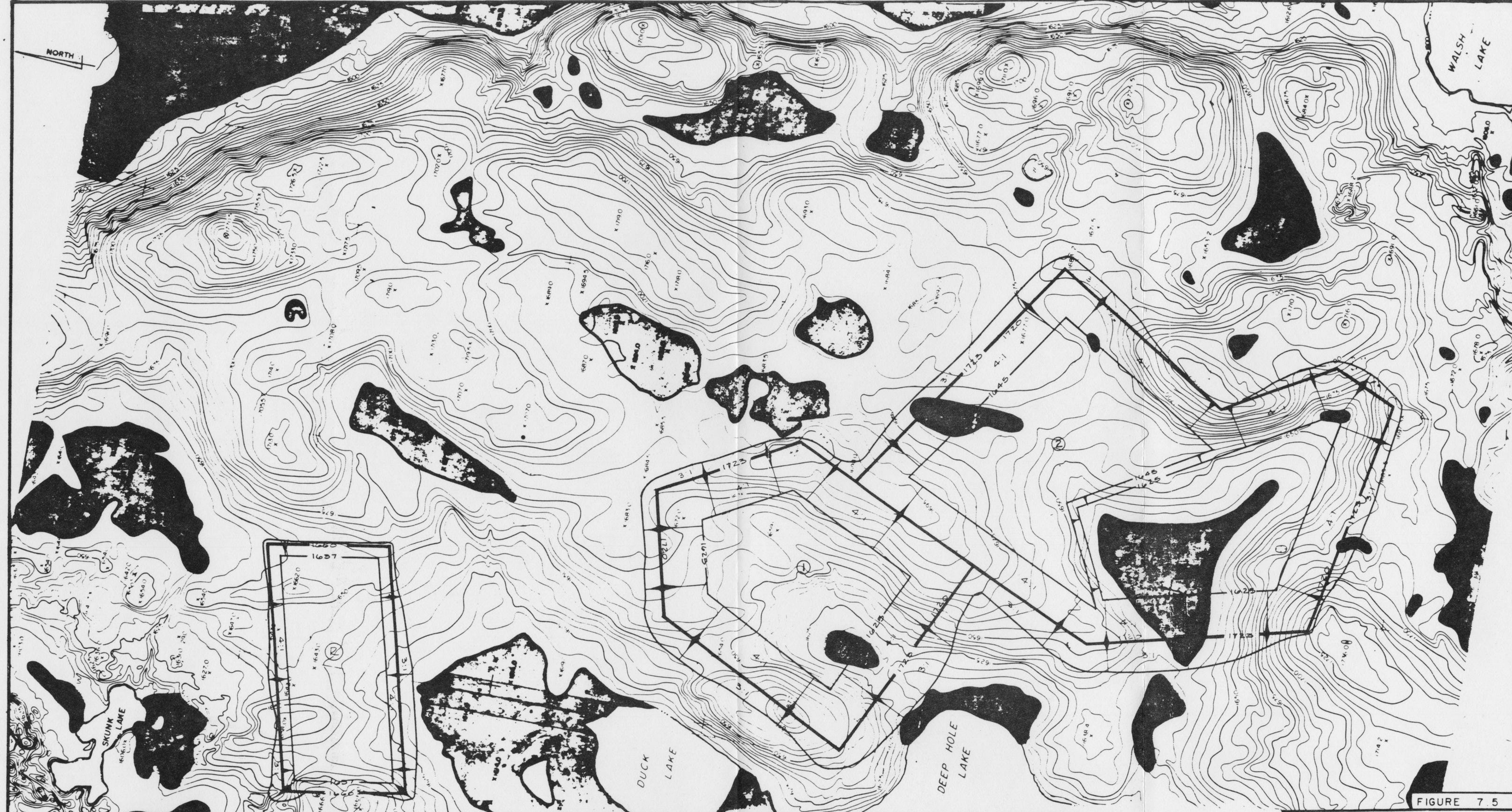
FIGURE 7.4

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SLURRY DISPOSAL SYSTEM PLAN LAYOUT 41-114

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST
DRAWN BY: CAB	DATE: [illegible]/21/82	CHECKED BY: [illegible] DATE: 11-22-82
APPROVED BY: [illegible]	DATE: 11-22-82	APPROVED BY: DATE:
APPROVED BY:	DATE:	EXXON: DATE:
DRAWING NO. 050-1-80577	SHEET ___ OF ___	REVISION NO. 1



NOTES

1. RECLAIM POND DESIGNED INDEPENDENT OF SYSTEM (R)
   TOE SLOPE AREA = 69 AC
   CUT = 588000 yd^3
   FILL = 560000 yd^3
   EMB FILL = 160000 yd^3
2. BACKFILL POND OMITTED FROM SYSTEM
3. AREA OF WETLANDS COVERED AND/OR IMPACTED DETERMINED FROM NON-FIELD VERIFIED WETLANDS/WATERSHED MAP DWG NO 050-1-80438

INDIVIDUAL POND DATA

POND DATA \ POND NUMBER	R	1	2
AREA INSIDE CREST (ac)	57	119	230
BOTTOM AREA (ac)	44	47	130
LINED SLOPE AREA (ac)	14	66	98
MAXIMUM DEPTH (ft)	23	98	98
MINIMUM DEPTH (ft)	23	98	78
MAX EXTERIOR FILL HT (ft)	42	108	98
CREST ELEVATION (ft) MSL	1660	1723	1723
STORAGE VOLUME (ac ft)	983	7298	13675
YEARS OF USE	0-30	4-14	14-30

DISPOSAL SYSTEM DATA

TOTAL LAND AREA (ac)	485
AREA INSIDE CRESTS (ac)	406
TAILINGS STORAGE (ac-ft)	20,973
WETLANDS COVERED (ac)	57
WETLANDS IMPACTED (ac)	62
COVER @ 5 ft deep (m cy)	2.82
EXCAVATION (m cy)	8.63
EMBANKMENT (m cy)	7.07

0 200 400 800 1200
SCALE IN FEET

REVISION	DATE	BY	DESCRIPTION
2	11-16-82	GOLDER	ADDED WETLAND NOTE # 3
1	7-6-8	GOLDER	REMOVE INTERMEDIATE CONTOURS

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FIGURE 7.5

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

TITLE
SLURRY DISPOSAL SYSTEM PLAN LAYOUT 41-121

SCALE: GRAPHIC | STATE: WISCONSIN | COUNTY: FOREST
DRAWN BY: CZL, JFC | DATE: 6-19-81 | CHECKED BY: ADC | DATE: 11-22-82
APPROVED BY: AWC | DATE: 11-22-82 | APPROVED BY: | DATE:
APPROVED BY: | DATE: | EXXON | DATE:
DRAWING NO. 050-1-80464 | SHEET ___ OF ___ | REVISION NO. 2

tive to the mine/mill complex location is about the same for four of the five systems, the cost of the waste materials handling facilities will be about equal for these four and slightly higher for the fifth (layout 41-121).

Staging the construction and reclamation over time is advantageous from a cost standpoint and from an environmental standpoint since part of the area can be reclaimed at an earlier date. The environmental advantages include a reduction of any impact related directly to pond size, a small improvement in overall system water balance, and, that on an average, the tailings areas are reclaimed faster. Also, with a staged system there is the ability to refine and improve designs for the latter ponds. This consideration makes a four tailings pond system more attractive than a three pond system and a three pond system more attractive than a two pond system. However, staging by increasing the number of ponds usually requires more total earthwork and, all other things being equal, more land area. Construction staging can also be done vertically by increasing the height of an embankment in stages as an individual pond is being filled. However, these facilities have been designed to keep earthwork for an individual pond in fairly good balance, thus keeping haul distances and stockpile requirements to a minimum. Thus, because the embankment materials for the individual ponds will be primarily obtained from excavation of the pond bottoms, these systems are ameniable to very little vertical staging.

One factor which cannot be compared on a one-to-one basis for the alternative systems presented concerns wetlands. As the project progressed, a revised wetlands map was prepared. The initial wetlands boundaries (see

Figure 5.7 in Section 5) were defined by photographs and maps and were later better defined by field survey (see Figure 5.8 in Section 5). Timing was such that these later wetland boundary definitions have only been incorporated on the basemap for the 41-114 layout. This difference is fairly small as noted by comparing the wetland acreage covered by layout 41-109 versus 41-114. Even though 41-114 covers more individual wetlands than 41-109, the acreage of wetlands covered by 41-114 is less, by about 10 percent, than 41-109. Considering the relatively small wetland acreages covered by these alternative systems, any comparison made with respect to wetlands impact would essentially be the same regardless of which wetland basemap is used. Only the large wetland southeast of Deep Hole Lake was considered to be of more relative importance than the others covered by any one of the alternative layouts because of its size and because it is a large segment of the surface drainage area to Deep Hole Lake. None of the wetlands covered by the alternative layouts are groundwater discharge wetlands; they are all well above the regional groundwater level.

In one wetland area, northeast of Duck Lake, the differences in the wetland boundaries between the two basemaps would cause a shift in pond layouts to some of the alternatives. Any dual reclaim pond system finally developed could, and would, be located outside this wetland. The dual reclaim pond configuration for 41-114 shows a small portion of this wetland beneath one of the reclaim ponds. This reclaim pond configuration was subsequently altered to avoid this wetland and is shown later in Section 9 of this report. This same altered configuration of reclaim ponds could be applied to any one of the other systems having two reclaim ponds in this general location.

Alternative layouts 41-103, 106, and 121 are within 1,000 feet (305 m) of either, or both, Duck or Deep Hole Lakes. These layouts were located so that the topographic mound just east of Duck Lake could be incorporated into an embankment, making use of the surrounding low ground for tailings storage. Also, as will be discussed in the following Section of this report, these layouts tend to stay toward the western side of the groundwater mound beneath Site 41 to the degree possible. Layouts 41-109 and 41-114 maintain more than 1,000 feet (305 m) from the lake shores to the outside toe of embankment slope.

Earthwork volumes estimated for the alternative systems presented are approximate (probably within ±15 percent, but not verified) and the layouts were not adjusted so that the excavation balanced with the combined fill volume needed for embankment and cover material. Furthermore, the waste rock volume has not been accounted for in those earthwork quantities. The total earthwork volume shown on Table 7.2 was obtained by averaging the total excavation and total fill (embankment plus cover volume). In comparing the estimated earthwork volumes, it is apparent that the greater the number of tailings ponds, the greater the total earthwork. The three pond systems 41-103 and 109 will require about 11.7 to 12.0 million cubic yards ($9.0x10^6$ and $9.2x10^6 m^3$) of earthwork while the four pond systems 41-106 and 114 will require about 12.5 to 13.2 million cubic yards ($9.6x10^6$ and $10.1x10^6 m^3$) of earthwork. Two pond system 41-121 will require substantially less earthwork, about 9.3 million cubic yards ($7.1x10^6 m^3$).

Earthwork volume comparison also points out that there is some saving to be gained by incorporating the topographic hill adjacent to Duck and Deep Hole Lakes, but only by placing embankment very close to these lakes as shown for systems 41-103 and 41-121. Earthwork for 41-103 is about 0.3 million cubic yards ($0.2x10^6m^3$) less than for 41-109, both being three tailings pond systems. Although System 41-106 also utilizes the hill adjacent to Deep Hole Lake it makes less advantageous use of the other topography in this area resulting in greater earthwork than required by system 41-114, both being four tailings pond systems.

The depths of the tailings ponds and maximum embankment heights (measured as the difference in elevation between the pond crest and point where the outside toe of slope intersects the natural ground surface) for the five alternatives presented are not significantly different. The tailings pond depths range from 90 to 98 feet (27.4 to 29.9 m) and the maximum embankment fill heights range from 95 to 123 feet (29.0 to 37.5 m). Similarly, the highest embankment crest elevations for the five alternatives are nearly the same, ranging from elevation 1723 feet to 1745 feet MSL (525.2 m to 531.9 m). Thus, regardless of the number or location of the individual tailings ponds, there is no advantage of one alternative over another in significantly reducing these pond depths, embankment fill heights, or crest elevations.

The height of the tailings pond bottoms above the groundwater levels ranges from 30 to 66 feet (9.1 to 20.1 m). The range in height above groundwater for the reclaim ponds is from 35 to 45 feet (10.7 to 13.7 m). Since the reclaim ponds need to be shallow, 20 feet (6.1 m) for reagent decay, their location from system to system is essentially the same to make use of the relatively flat area north of Duck Lake. The tailings pond bottom levels vary widely because of their location with respect to the topographic low areas around Deep Hole Lake. Those alternatives with pond bottoms closest to the groundwater are 41-103, 106, and 121. These same alternatives are also closer than 1,000 feet (305 m) to either, or both, Duck and Deep Hole Lakes. Alternatives 41-109 and 114, more centrally located in the Site 41 area, have tailings pond bottoms ranging from 44 to 60 feet (13.4 to 18.3 m) above groundwater.

7.4 Summary of Layout Comparisons

Comparison of the various environmental impact features of the five alternative waste disposal system layouts presented may be viewed as a system of trade-offs. As will be discussed in the following Section of this report, potential groundwater effects are nearly equivalent for systems 41-103, 106, 109, and 114 to the degree considered in the screening analysis. As the next Section of the report will show, System 41-121 has a different effect on the groundwater system than the other four. Keeping this in mind, comparison of other aspects of the alternative system layouts is best made between 41-103, 106, 109, and 114 and then between these four and system 41-121.

Systems 41-103 and 109 are three tailings pond systems and 41-106 and 114 are four tailings pond systems. The advantage of a four pond system over a three pond system is the ability to better stage construction and to begin reclamation earlier. The disadvantages are that the four pond systems cover more surface area and require more earthwork. The stage construction cost advantages of the four pond systems are offset by the total cost advantage of lesser earthwork for the three pond systems. At this point in the design process, these items are considered equal. The advantage of being able to begin reclamation earlier in the life of the system, offset by its cost disadvantage can be weighed against the need for the larger surface area of the four pond systems versus the three pond systems. This trade-off comparison is subjective but the advantages of early, better staged reclamation are considered to outweigh the increase in land area required by the four pond systems.

Crest elevations, pond depths, and maximum fill heights for the three and four tailings pond system alternatives are approximately equal. No one system is viewed as having a significant advantage over any other system.

Although alternatives 41-103, 106, 109, and 114 cover and impact (impact being defined as over 50 percent of a wetland's surface drainage area being covered by the waste facilities) about the same wetland acreage, ranging from 41 to 62 acres (16.6 to 25.1 ha), there is a regulatory trend favoring minimizing the acreage of wetlands incorporated into a waste facility. There are, however, significant trade-offs associated with covering wetlands for the three and four pond alternative systems. The primary trade-offs are in the distance from Duck and Deep Hole Lakes and the distance between the tailings pond bottoms and the groundwater.

Alternatives 41-103 (3 ponds) and 41-106 (4 ponds) cover fewer wetlands than alternatives 41-109 (3 ponds) and 114 (4 ponds). However, both 41-103 and 106 are closer than 1,000 feet (305 m) to Duck Lake and 41-103 is also closer than 1,000 feet (305 m) to Deep Hole Lake. In taking advantage of the slightly lesser earthwork provided by the topography around these two lakes, the tailings pond bottoms are also the closest to the groundwater table, 30 feet (9.1 m) for 41-103 and 34 feet (10.4 m) for 41-106. This is because the topography is low on the east side of the hill just north of Deep Hole Lake. Even though the four pond systems 41-106 and 114 take more land area than the three pond systems 41-103 and 109, system 109 covers the most wetland acreage. Thus, the minimization of wetland acreage is at the expense of reduced offset from the lakes and closer distance from the lowest pond bottom to the groundwater table. Alternatives 41-109 and 41-114 adhere to the location criteria in NR 182 of maintaining a minimum of 1,000 feet (305 m) between the lakes and the waste facility, although they require the taking of more wetland acreage than systems 41-103 and 41-106.

In comparing 41-109 and 41-114, the four pond 41-114 system covers less wetland acreage than the three pond 41-109 system. However, as previously discussed, 41-114 is shown on the latest wetland basemap while 41-109 is shown on an earlier wetland basemap. Without preparing each layout on the latest wetland base map it is fair to consider that alternatives 41-106, 109, and 114 cover about equal wetland areas.

Alternative system 41-121 is significantly different from the other four alternatives presented. The reason for the difference is that its two tailings ponds are located in the southwestern portion of the Site 41 area. As will be discussed further in the following Section of this report, this location was selected based on reduced potential groundwater effects. This alternative has two distinct advantages over the other four systems. It requires about 25 percent less earthwork, and covers the least amount of land area. Although with only two ponds there is less opportunity for construction staging of individual ponds, the stepped bottom of pond number 2 does allow for vertical staging. Some disadvantages of this system compared to the other four is that there is little opportunity for staged reclamation, the pond bottoms are fairly close to the groundwater table, it is closer than 1,000 feet (305 m) to Duck and Deep Hole lakes, it covers the largest wetland acreage, and it covers the single largest wetland which is a major surface feature in the Deep Hole Lake drainage area. Also, the geologic conditions around the wetland east of Deep Hole Lake are less favorable than the general geologic conditions beneath the remainder of the Site 41 area. In the vicinity of this wetland the surface glacial till strata is very thin and the coarse grained stratified drift extends well above the groundwater level (see Geologic Section C-C in Section 3 of Ref. 11). The coarse grained stratified drift would allow leachate which may leak from the pond bottom to reach the groundwater much faster than would glacial till, thus providing less time for attenuation.

As can be seen from the layouts and discussions presented, there is no one waste disposal system alternative which minimizes all environmental impacts and at the same time provides the least cost for construction. Those systems trending toward lowest cost as measured by earthwork and land area, are also those which may cover the most wetland acreage, are closer to the groundwater table, are closer to the lakes, or provide least opportunity for staged reclamation. If minimizing wetland acreage coverage is viewed as being of primary importance, system 41-103 is the best choice. If it is desirable to adhere to the location criteria of proposed NR 182 with respect to the lake offsets while also minimizing wetland coverage, system

41-114 is the best selection. To minimize earthwork and land area covered, system 41-121 is most advantageous, but it covers the largest wetland acreage and includes the largest wetland, is close to the lakes, and has a fairly short distance between the groundwater table and pond bottoms. There are no obvious single answers.

8.0 PRELIMINARY GEOHYDROLOGIC SCREENING ANALYSIS

8.1 Purpose and Model Section

The effect of a potential mine waste disposal site on the geohydrologic system was considered a major factor in the overall site evaluation process. Groundwater is the primary water resource in the Project area and was therefore the prime target of this screening investigation.

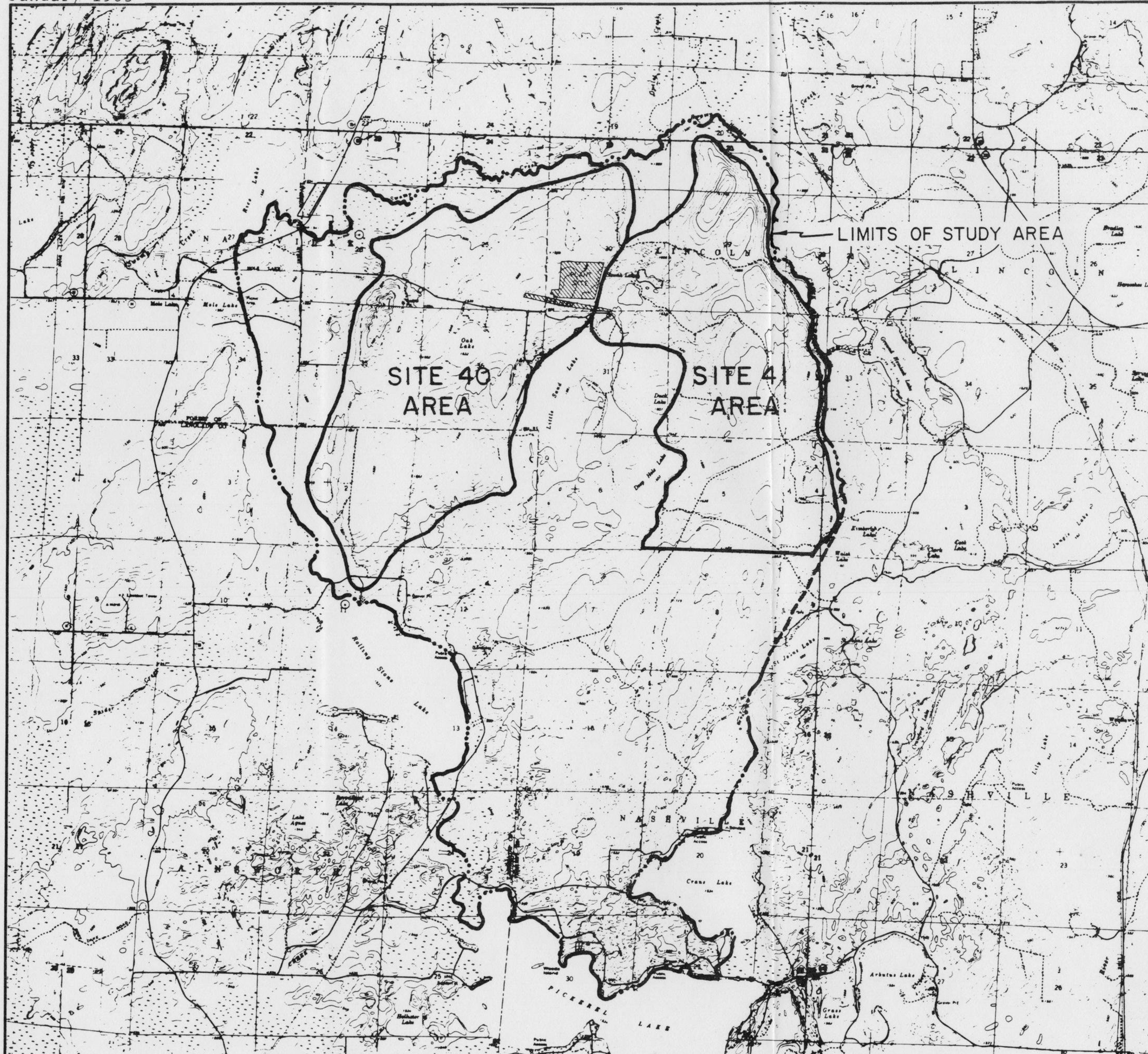
In the site selection process it was necessary to screen many mine waste disposal sites and different seepage control systems over the life of the mine and many years after reclamation. The methodology selected for this preliminary screening process was use of a computer model to simulate the groundwater flows and movement of seepage from the mine waste disposal facility with the groundwater. The model had to be suited to the hydrogeology of the study area, allow easy simulation of mine waste disposal system seepage, and be relatively inexpensive to operate. It was determined that these requirements could best be met by combining a groundwater flow model with a seepage transport model and developing input and output capabilities specifically oriented toward this study.

The model which was developed for this preliminary screening study simulates the geohydrologic effects of the waste disposal system in a series of discrete time increments through the mine life and after reclamation. The three overall steps in the model are (1) definition of the waste system seepage, (2) computation of the shape of the phreatic surface, and (3) determination of the movement of seepage through the groundwater. At each timestep, or multiple thereof, various information may be output such as seepage concentration or phreatic surface shape. In this manner, the geohydrologic effect of a waste disposal system could be tracked through time. An overview of the model is presented in detail in Golder Associates' Project Report 9 (Ref. 19). The use of this computer model allowed preliminary assessment for screening many more alternatives with more comprehensive results than other methods available.

8.2 Geohydrologic Study Area

The geohydrologic study area was defined as a 22 square mile (56 km^2) area surrounding the orebody. It is bounded on the north by Swamp Creek, on the east by Ground Hemlock Slough and Crane Lake, on the south by Pickerel Lake, and on the west by Rolling Stone and Mole Lakes. The upland area within these boundaries serves as a groundwater recharge area while the surrounding streams and lakes serve as discharge boundaries. Figure 8.1 shows the study area boundaries, the location of the Crandon formation (orebody), and proposed waste disposal facility site areas 40 and 41. The boundaries of the study area are the limits of the groundwater model and function as either discharge (constant head) or no-flow boundaries, as indicated on Figure 8.1.

Considering the scale of the study area, the geology may be approximated as a relatively thin layer of glacial soils overlying bedrock. Figures 8.2 and 8.3 are plan and section drawings across the study area and system 41-114. Section A-A in Figure 8.3 shows the soil zone beneath the tailings ponds in relation to the boundaries of the study area. With the exception of a weathered zone in the Crandon formation, the bedrock is considered to be functionally impermeable. For purposes of groundwater modeling, the glacial overburden was idealized as interlayered strata of till and coarse grained stratified drift. A major coarse



NORTH

SCALE IN KILOMETERS

0 1000 2000 4000 6000

SCALE IN FEET

LEGEND

CONSTANT HEAD BOUNDARY

NO FLOW BOUNDARY

FIGURE 81

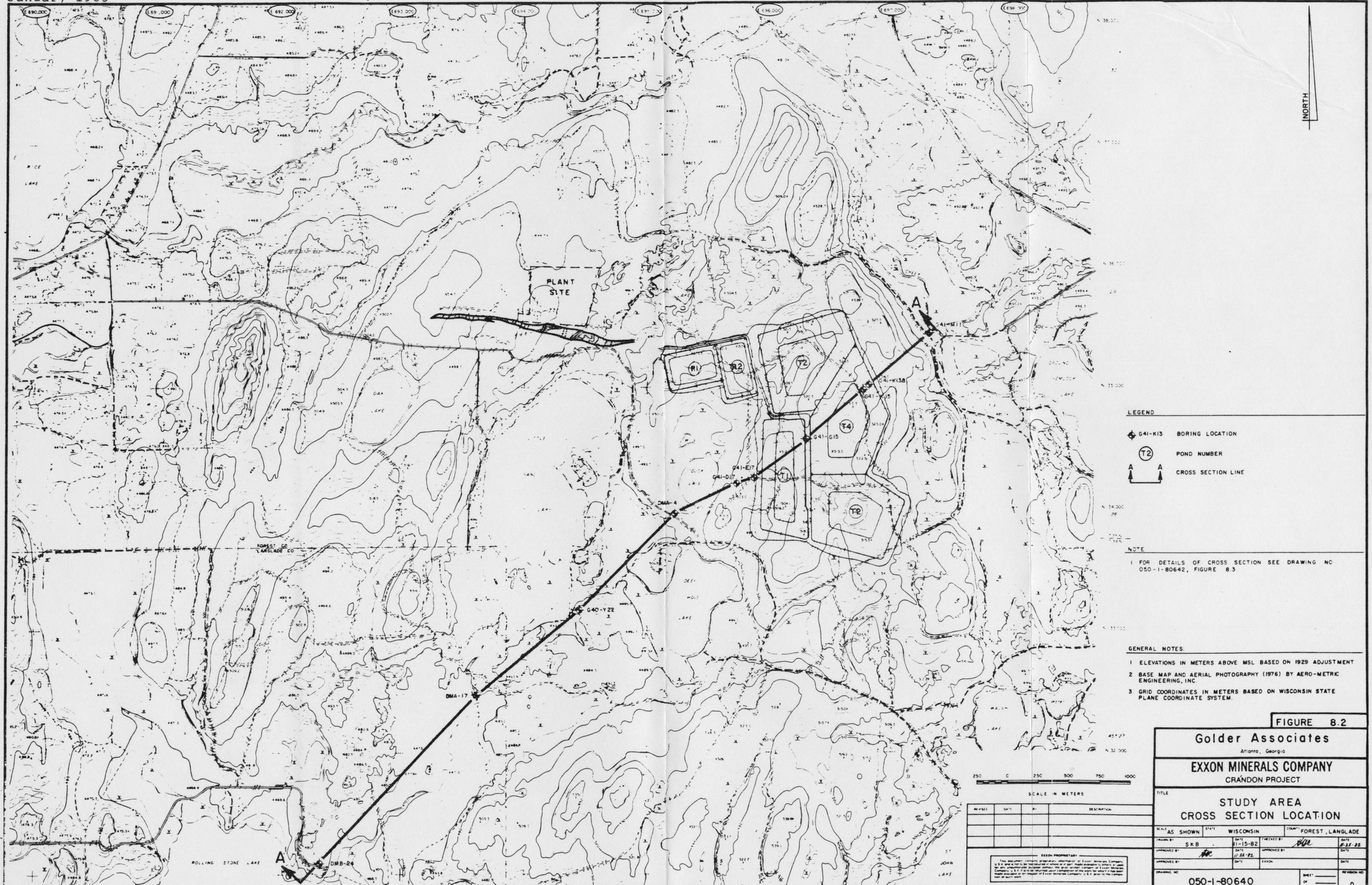
Golder Associates
Atlanta, Georgia

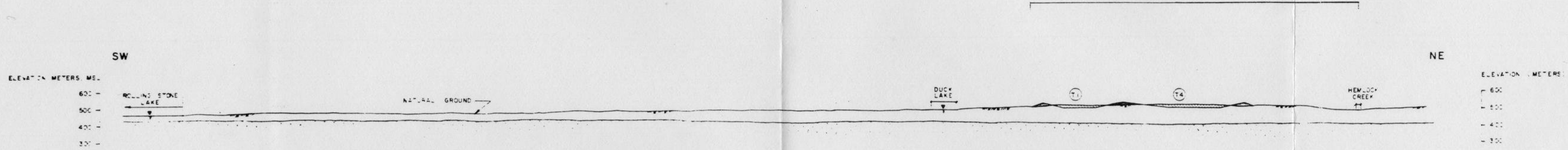
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: STUDY AREA BOUNDARIES

SCALE	STATE	COUNTY
AS SHOWN	WISCONSIN	FOREST
DRAWN BY: SKB	11-12-82	11-12-82
APPROVED BY	11-12-82	

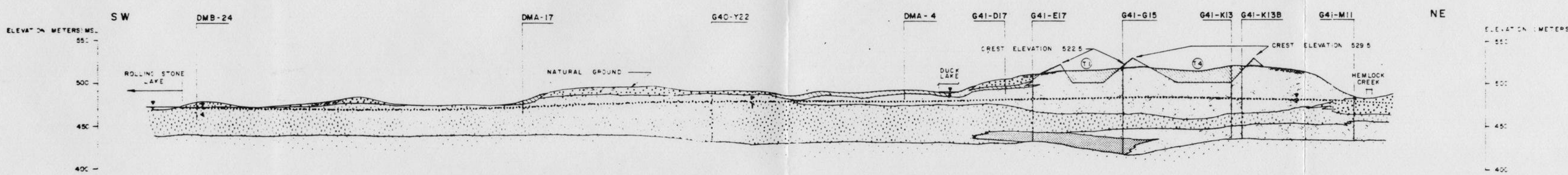
DRAWING NO. 050-1-80938


NORTH
PLANT SITE
A
A
G41-K13
G41-E17
G41-D17
DMA-4
G40-Y22
DMA-17
DMB-24
R1
R2
T2
T4
T1
T2
ROLLING STONE LAKE
FOREST CO
LANGLADE CO
LEGEND
G41-K13 BORING LOCATION
T2 POND NUMBER
A A CROSS SECTION LINE
NOTE
1 FOR DETAILS OF CROSS SECTION SEE DRAWING NO 050-1-80642, FIGURE 8.3.
GENERAL NOTES:
1 ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2 BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
250 0 250 500 750 1000
SCALE IN METERS
FIGURE 8.2
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
STUDY AREA
CROSS SECTION LOCATION
AS SHOWN
WISCONSIN
FOREST, LANGLADE
SKB
11-15-82
050-1-80640



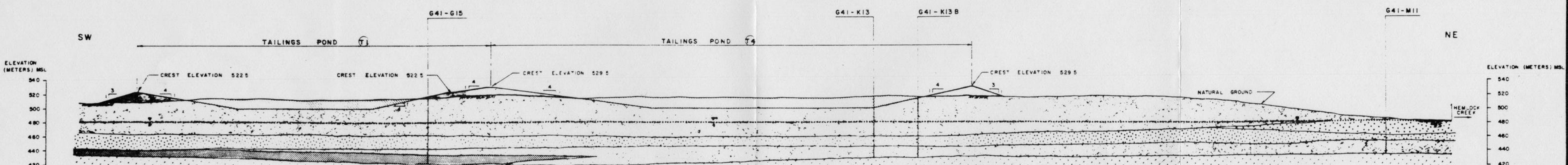
SECTION A-A

SCALE 1:2500 HORIZONTAL
1:12500 VERTICAL



SECTION A-A

SCALE 1:12500 HORIZONTAL
1:2500 VERTICAL



DETAIL A

SCALE 1:2500 HORIZONTAL
1:2500 VERTICAL

LEGEND

- EMBANKMENT FILL
- POND EXCAVATION
- GROUNDWATER SURFACE
- LACUSTRINE
- OUTWASH
- TILL
- COARSE DRIFT
- FINE DRIFT
- BEDROCK
- (T1) POND NUMBER

NOTE

FOR CROSS SECTION LOCATION SEE DRAWING NO. 050-1-80640 FIGURE 8.2.

REVISION	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

FIGURE 8.3

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: STUDY AREA AND SITE 41-114B CROSS SECTIONS

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: CAB	DATE: 11-19-82	CHECKED BY: JCB	DATE: 11/22/82
APPROVED BY:	DATE: 11-22-82	APPROVED BY:	DATE:
APPROVED BY:	DATE:	EXXON	DATE:
DRAWING NO. 050-1-80642		SHEET OF	REVISION NO.

grained stratified drift unit is generally continuous over the study area and is overlain in the upland areas by a well graded till. The coarse grained drift is two to three orders of magnitude more permeable than the till and is considered to be the primary transmissive unit in the area. An idealized hydrogeologic section of the study area is shown in Figure 8.4. The primary path of tailings pond seepage movement is downward through the till and laterally through the drift to the surrounding groundwater fed lakes and streams. The groundwater assessment included herein considers only the lateral movement through the drift.

8.3 Hydrogeologic Parameters

8.3.1 Progressive Refinement

The process of alternative site and design evaluation took place in parallel with data collection efforts. During the site selection and design alternative screening process, more detailed definition of the hydrogeology of the study site became available. Therefore, the model input data was updated during the modeling effort to reflect this additional data. The two sets of input data were termed the "initial" and "final" parameter sets although they apply to the preliminary screening. These parameter sets were used in two phases of preliminary geohydrologic assessment screening analyses. The initial phase took place during June 1981 and the final phase took place during October 1981.

8.3.2 Initial Parameter Set

The purpose of the initial phase of the waste disposal system screening analyses was to assess the long term effectiveness of various seepage control strategies. Tailings pond seepage histories ranging from an unlined system

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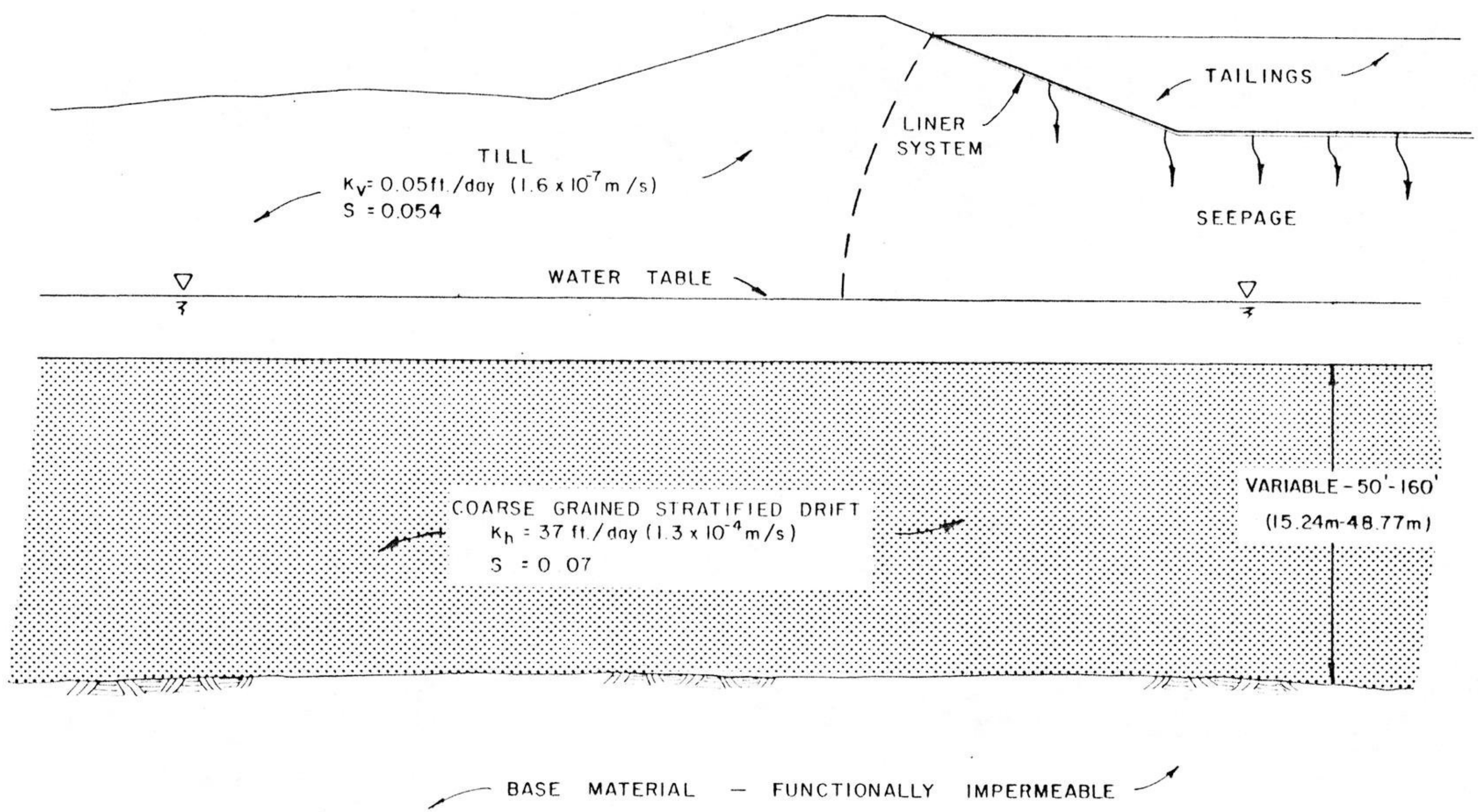


NOTE:

K_h = HORIZONTAL PERMEABILITY

K_v = VERTICAL PERMEABILITY

S = STORATIVITY

Golder Associates

JOB NO. 786085

DRAWN CAB

CHECKED JEB

SCALE NO SCALE

DATE 8-31-81

DWG NO. D50-1-81112

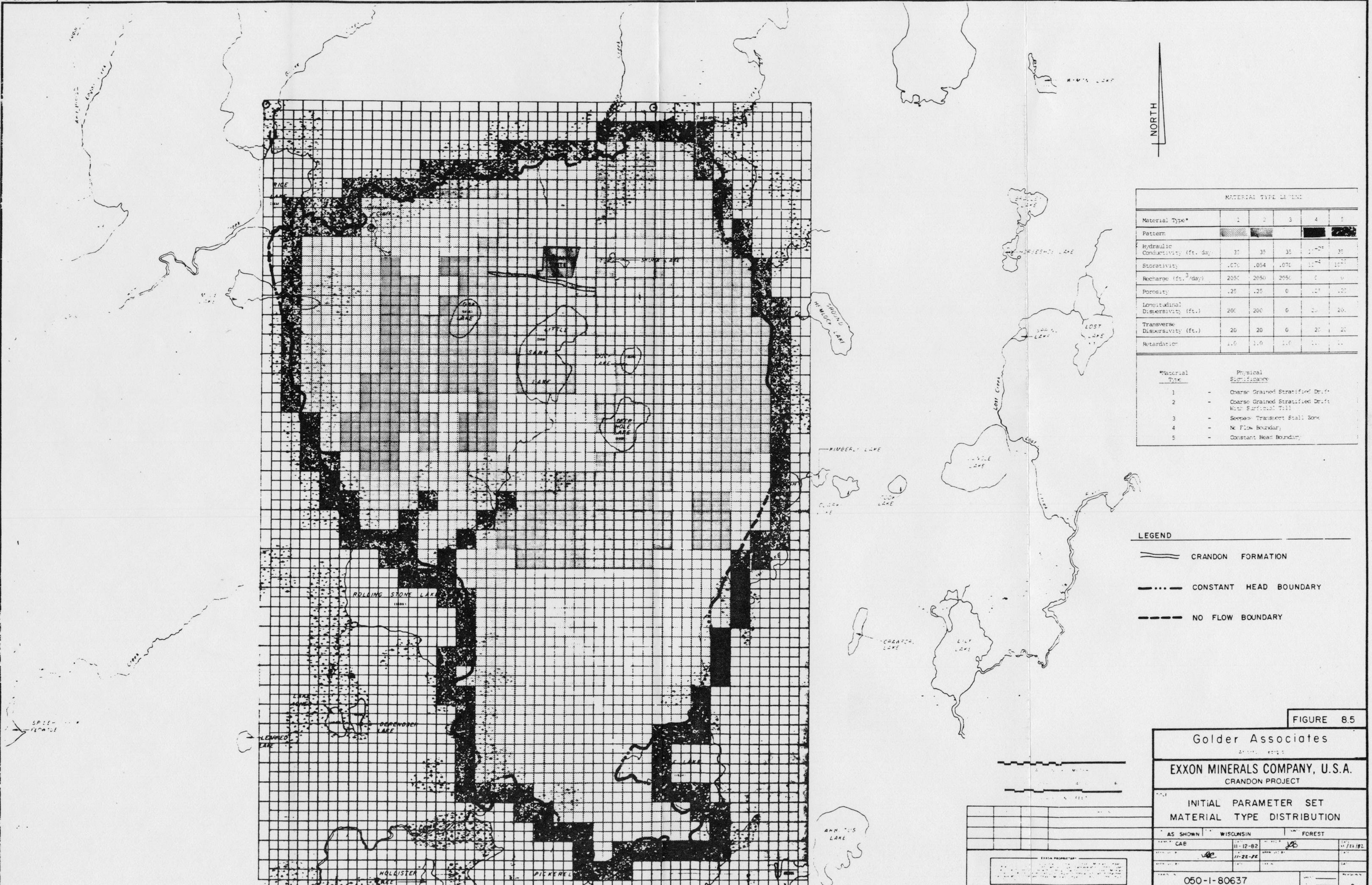
EXXON MINERALS COMPANY

HYDROGEOLOGIC MODEL
IDEALIZED CROSS SECTION

FIGURE 8.4

to a lined system with an underdrain were modeled for an approximate 30 year mine life and 30 years thereafter. Proposed waste disposal system 41-103 was used for these studies.

The groundwater model parameters were specified for each node point in the finite difference grid by assigning a "material type" for each node. Each material was characterized by its hydraulic conductivity, storativity, natural net recharge, porosity, longitudinal and transverse dispersivity, and retardation. Figure 8.5 shows the study area with the material type and parameter values by cell. Material types 1 and 2 represent the primary aquifer materials. Material type 1 with a storativity value of 0.07 was applied where the groundwater zone is completely within the coarse grained stratified drift. Material type 2 with a storativity value of 0.054 was applied where the upper portion of the groundwater zone is within the till above the coarse grained stratified drift. This value reflects the lower drainable porosity of the till which controls the rate of volume release as the top of groundwater fluctuates within the till. Material type 3, 4 and 5 are special material types which provided various groundwater model boundary conditions. Material type 3 had a porosity value of zero which indicated the seepage transport boundaries of the study area. Material type 4 was assigned a hydraulic conductivity of 10^{-25} feet per day ($0.3x10^{-25}$ m/d) to simulate a "no flow" boundary node. Material type 5 was assigned a storativity of 10^{25} to simulate a "constant head" boundary node. The value of 2,050 cubic feet per day (58.2 m^3/d) per groundwater cell (23 acres) for natural recharge was used throughout the study area and represents a value of 9 inches (229 mm) per year.



MATERIAL TYPE LEGEND

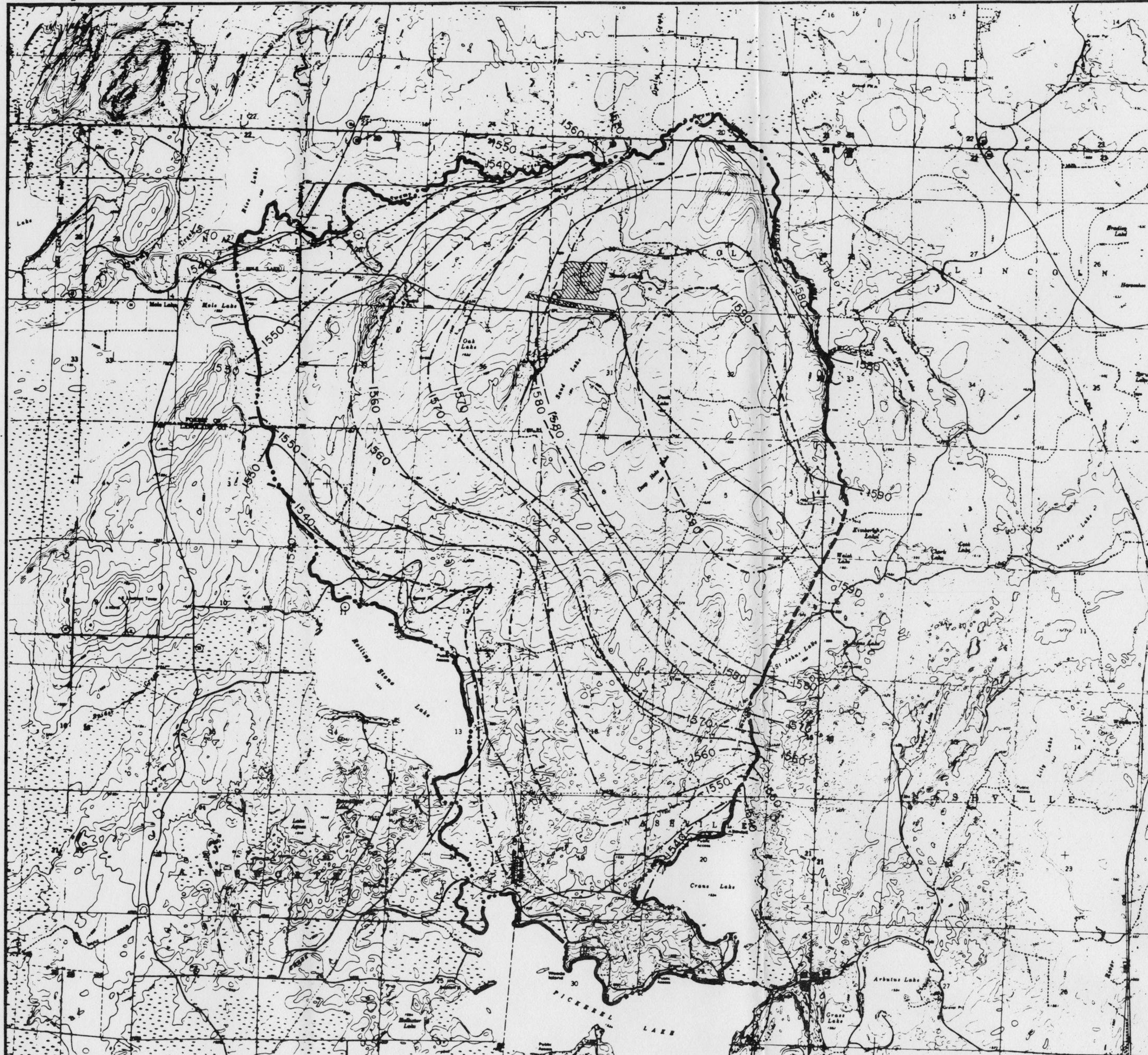
Material Type*	1	2	3	4	5
Pattern					
Hydraulic Conductivity (ft./day)	35	35	35	[illegible]	35
Storativity	.070	.054	.070	[illegible]	[illegible]
Recharge (ft.^{3}/day)	2050	2050	2050	[illegible]	[illegible]
Porosity	.25	.25	0	[illegible]	[illegible]
Longitudinal Dispersivity (ft.)	200	200	0	[illegible]	[illegible]
Transverse Dispersivity (ft.)	20	20	0	[illegible]	[illegible]
Retardation	1.0	1.0	1.0	[illegible]	[illegible]

*Material Type		Physical Significance
1	-	Coarse Grained Stratified Drift
2	-	Coarse Grained Stratified Drift With Surficial Till
3	-	Seepage Transport Stall Zone
4	-	No Flow Boundary
5	-	Constant Head Boundary

FIGURE 8.5

The finite difference grid and seepage transport grids were coincident for the initial study phase at 1000 feet by 1000 feet (305 by 305 m). The coarse grained stratified drift thickness was set at a constant value of 70 feet (21 m) across the site and transmissivity variation was achieved by varying the hydraulic conductivity. Calibration was achieved by varying the overall net annual groundwater recharge for the groundwater system and by varying hydraulic conductivity at specific cells to match localized variations in head distribution. Simulated groundwater head contours across the site were compared against contours drawn from field data taken in September 1980 (Ref. 18). Figure 8.6 shows the observed and simulated groundwater head contours from the initial parameter set.

A sensitivity analysis was performed to determine the overall impact of dispersivity on model results. Longitudinal dispersivity was varied from 0.1 feet (30 mm) to 600 feet (183 m) with corresponding transverse dispersivities of 0.01 feet (30 mm) to 60 feet (18 m). Based on this sensitivity study and review of the literature (Refs. 1 and 8), values of 200 feet (61 m) and 20 feet (6.1 m) were chosen for the longitudinal and transverse dispersivities, respectively. Figures 8.7, 8.8 and 8.9 show the spread of seepage 30 years beyond reclamation (60 years total) for the three above cases. It can be seen from these figures that dispersivity primarily governs the spread of the contours of low concentrations. However, the 10 percent seepage contour is relatively close across the range of dispersivities used, indicating the relative insensitivity of this parameter for the study case. Therefore, use of 200 feet and 20 feet for longitudinal and transverse dispersivities were considered reasonable for the screening effort presented herein.



NORTH

LEGEND

- CONSTANT HEAD BOUNDARY
- NO FLOW BOUNDARY
- SIMULATED GROUNDWATER HEAD CONTOURS
- OBSERVED GROUNDWATER HEAD CONTOURS (MEASURED)
- OBSERVED GROUNDWATER HEAD CONTOURS (INFERRED)

5 0
SCALE IN KILOMETERS

0 1000 2000 4000 6000
SCALE IN FEET

REVISED	DATE	BY	DESCRIPTION

FIGURE 8.6

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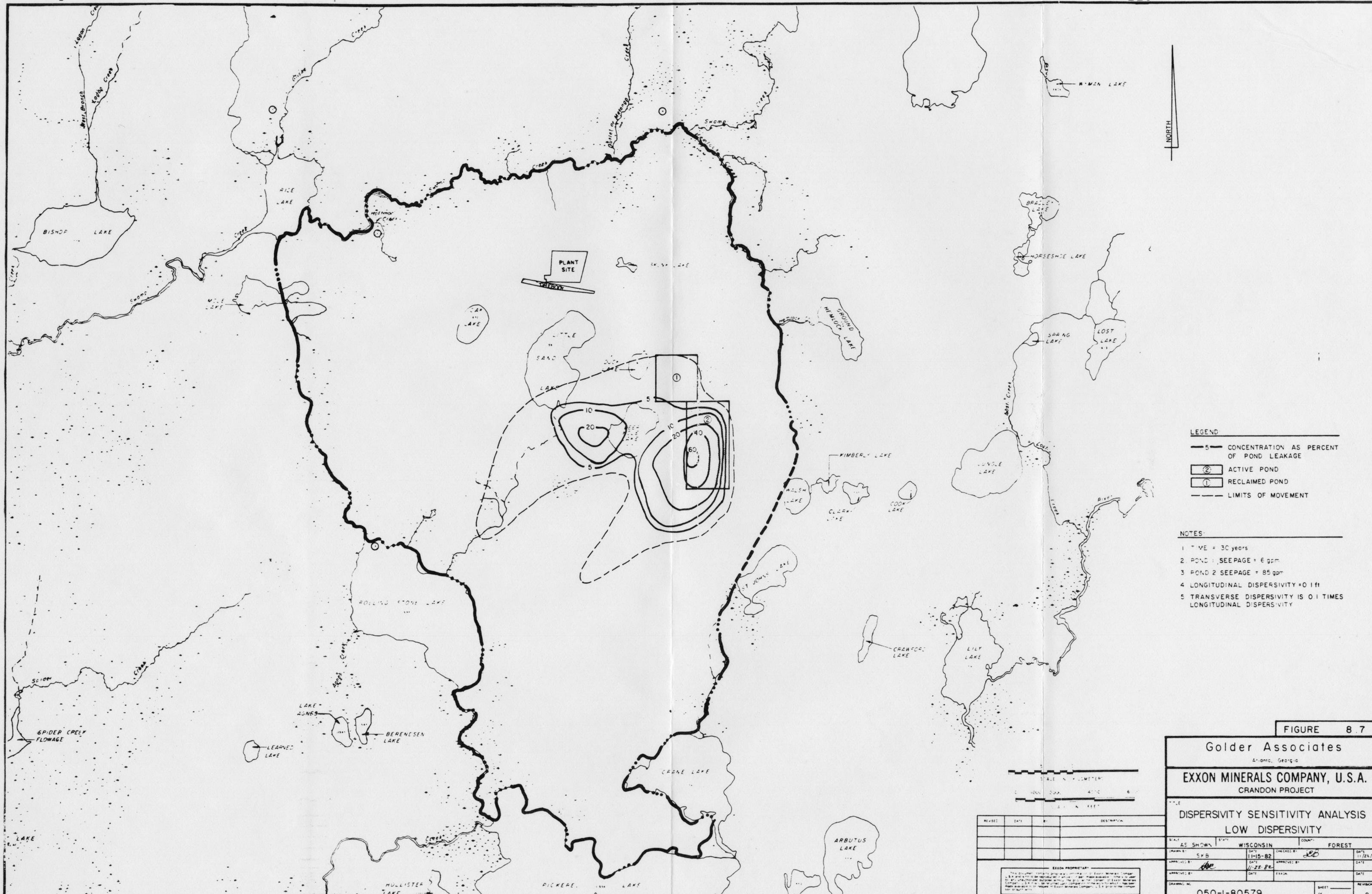
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
INITIAL GROUNDWATER MODEL CALIBRATION

SCALE AS SHOWN	STATE WISCONSIN		COUNTY FOREST	
DRAWN BY SKB	DATE 9-1-81	CHECKED BY JEB		DATE 9/4/81
APPROVED BY	DATE	APPROVED BY		DATE
APPROVED BY	DATE			DATE
DRAWING NO. 050 - 1-80635		SHEET 1 OF 1		REVISION


NORTH
BISHOP LAKE
RICE LAKE
MOLE LAKE
PLANT SITE
LITTLE SAND LAKE
DUCK LAKE
SKUNK LAKE
OAK LAKE
GROUND HEMLOCK LAKE
KIMBERLY LAKE
WELSH LAKE
CLARK LAKE
COOK LAKE
JUNGLE LAKE
SPRING LAKE
LOST LAKE
HORSESHOE LAKE
BRADLEY LAKE
ST. JOHNS LAKE
CRAWFORD LAKE
LILY LAKE
ROLLING STONE LAKE
LAKE AGNES
BERENDSEN LAKE
LEARNED LAKE
SPIDER CREEK FLOWAGE
CRANE LAKE
ARBUTUS LAKE
HOLLISTER LAKE
PICKEREL LAKE
Swamp Creek
5
10
20
40
60
LEGEND
5 CONCENTRATION AS PERCENT OF POND LEAKAGE
② ACTIVE POND
① RECLAIMED POND
LIMITS OF MOVEMENT
NOTES:
1 TIME = 30 years
2. POND 1 SEEPAGE = 6 gpm
3 POND 2 SEEPAGE = 85 gpm
4 LONGITUDINAL DISPERSIVITY = 0.1 ft
5 TRANSVERSE DISPERSIVITY IS 0.1 TIMES LONGITUDINAL DISPERSIVITY
SCALE IN KILOMETERS
SCALE IN FEET
FIGURE 8.7
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
DISPERSIVITY SENSITIVITY ANALYSIS
LOW DISPERSIVITY
AS SHOWN
WISCONSIN
FOREST
SKB
11-15-82
11/22/82
11-22-82
EXXON PROPRIETARY
050-1-80579
0

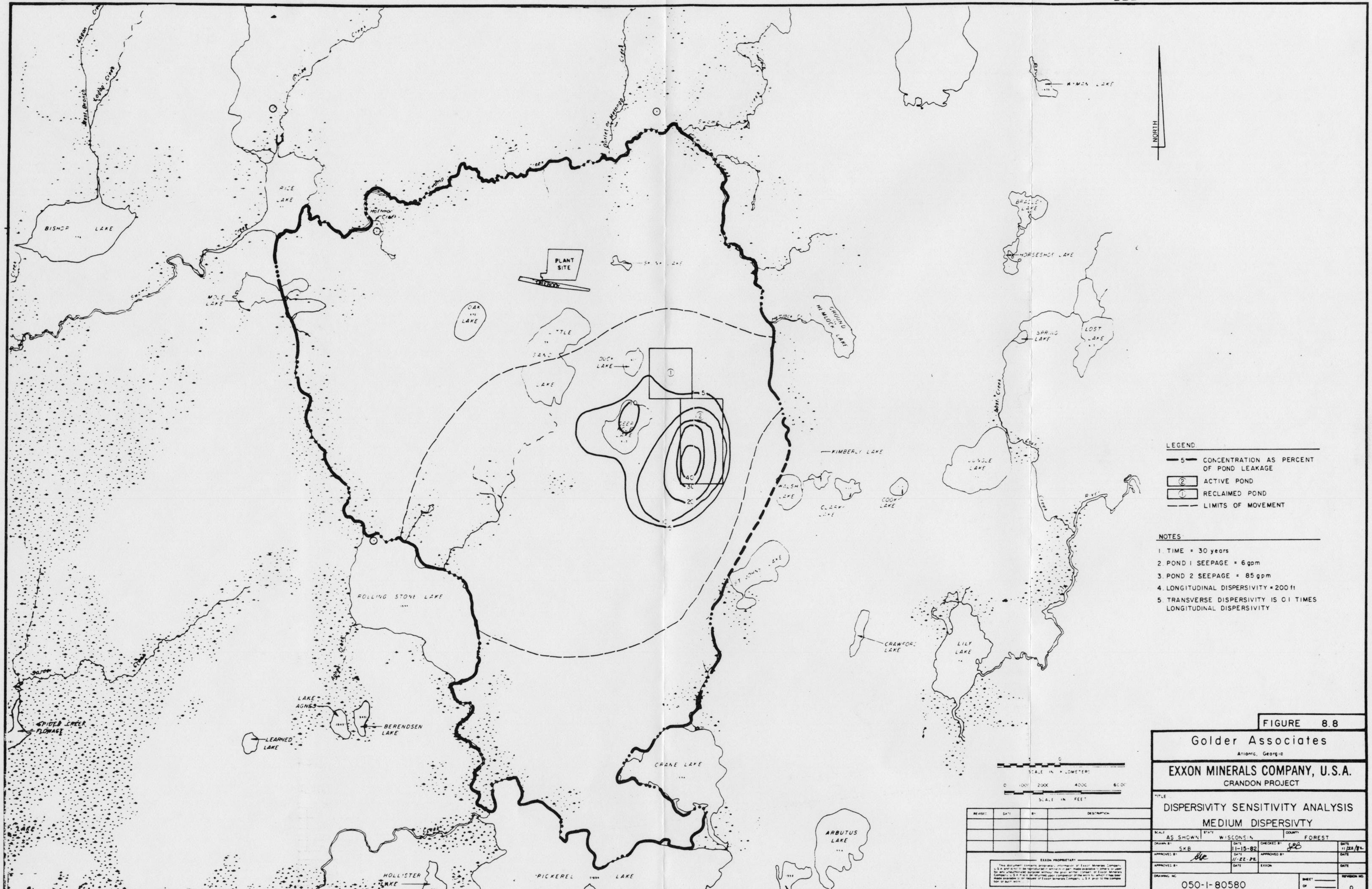

NORTH
PLANT SITE
BISHOP LAKE
RICE LAKE
OAK LAKE
DUCK LAKE
ROLLING STONE LAKE
LAKE AGNES
BERENDSEN LAKE
LEARNED LAKE
SPIDER CREEK FLOWAGE
HOLLISTER LAKE
PICKEREL LAKE
CRANE LAKE
ARBUTUS LAKE
KIMBERLY LAKE
COOK LAKE
CRAWFORD LAKE
LILY LAKE
SPRING LAKE
LOST LAKE
HORSESHOE LAKE
LEGEND
5 CONCENTRATION AS PERCENT OF POND LEAKAGE
2 ACTIVE POND
1 RECLAIMED POND
LIMITS OF MOVEMENT
NOTES
1. TIME = 30 years
2. POND 1 SEEPAGE = 6 gpm
3. POND 2 SEEPAGE = 85 gpm
4. LONGITUDINAL DISPERSIVITY = 200 ft
5. TRANSVERSE DISPERSIVITY IS 0.1 TIMES LONGITUDINAL DISPERSIVITY
SCALE IN KILOMETERS
SCALE IN FEET
FIGURE 8.8
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
DISPERSIVITY SENSITIVITY ANALYSIS
MEDIUM DISPERSIVTY
AS SHOWN
WISCONSIN
FOREST
SKB
11-15-82
11-22-82
050-1-80580

FIGURE 8.8


NORTH
BISHOP LAKE
RICE LAKE
PLANT SITE
KIMBERLY LAKE
ROLLING STONE LAKE
LAKE AGNES
BERENDSEN LAKE
LEARNED LAKE
SPIDER CREEK FLOWAGE
HOLLISTER LAKE
CRANE LAKE
ARBUTUS LAKE
LILY LAKE
CRAWFORD LAKE
SPRING LAKE
LOST LAKE
HORSESHOE LAKE
WYMAN LAKE
ROUND HEMLOCK LAKE
COOK LAKE
CLARK LAKE
5
10
20
30
SCALE IN FEET
LEGEND:
CONCENTRATION AS PERCENT OF POND LEAKAGE
ACTIVE POND
RECLAIMED POND
LIMITS OF MOVEMENT
NOTES:
1. TIME = 30 years
2. POND 1 SEEPAGE = 6 gpm
3. POND 2 SEEPAGE = 85 gpm
4. LONGITUDINAL DISPERSIVITY = 600 ft
5. TRANSVERSE DISPERSIVITY IS 0.1 TIMES LONGITUDINAL DISPERSIVITY
FIGURE 8.9
Golder Associates
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
DISPERSIVITY SENSITIVITY ANALYSIS
HIGH DISPERSIVITY
AS SHOWN
WISCONSIN
FOREST
SKB
11-15-82
11-22-82
050-1-80581
0

8.3.3 Final Parameter Set

The final phase of the screening analysis focused on different slurry pond systems within Site 40 and 41 areas. These tailings pond systems were "generic" in that they were the same depth and area, regardless of site topography. Of particular interest in this evaluation were the relative amounts of waste system seepage directed toward Swamp Creek and Rolling Stone Lake for the various site systems.

A more accurate calibration of the groundwater gradients beneath the Site 41 area than was used in the initial parameter set was considered necessary to assess the relative amounts of seepage being transported to Hemlock Creek and Rolling Stone Lake. The final parameter set included a global hydraulic conductivity from the pumping test and a variable saturated coarse grained stratified drift thickness determined from the geologic and geotechnical data. Figure 8.10 shows the coarse grained stratified drift thickness contours over the study area used to determine a thickness value at each finite difference grid node.

The model was then recalibrated to refine the fit between simulated and observed groundwater heads. Final adjustements were achieved by modifying the net annual aquifer recharge and a value of 12.5 inches per year (318 mm/y) over the study area resulted in the best calibration. Figure 8.11 shows the material type assignment for the finite difference matrix and the parameter values specified for each in the final parameter set. As can be seen in Figure 8.12, the final calibration was a significant improvement over the initial calibration with respect to the plan location of the groundwater divide from northwest to southeast across the groundwater mound beneath the Site 41 area.

LEGEND

- —··— CONSTANT HEAD BOUNDARY
- — — NO FLOW BOUNDARY
- —140— ISOPACH CONTOURS (FEET)
- G41-L19 (80) GOLDER ASSOCIATES BORING (THICKNESS IN FEET)
- DMB-27 (108) DAMES & MOORE BORING (THICKNESS IN FEET)

SCALE IN KILOMETERS: 1, 0, 5

SCALE IN FEET: 0, 1000, 2000, 4000, 6000

REVISED	DATE	BY	DESCRIPTION
1	11-25-81	CAB	80' CONTOUR AT G41-L19 REVISED

EXXON PROPRIETARY

FIGURE 8.10

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON-PROJECT

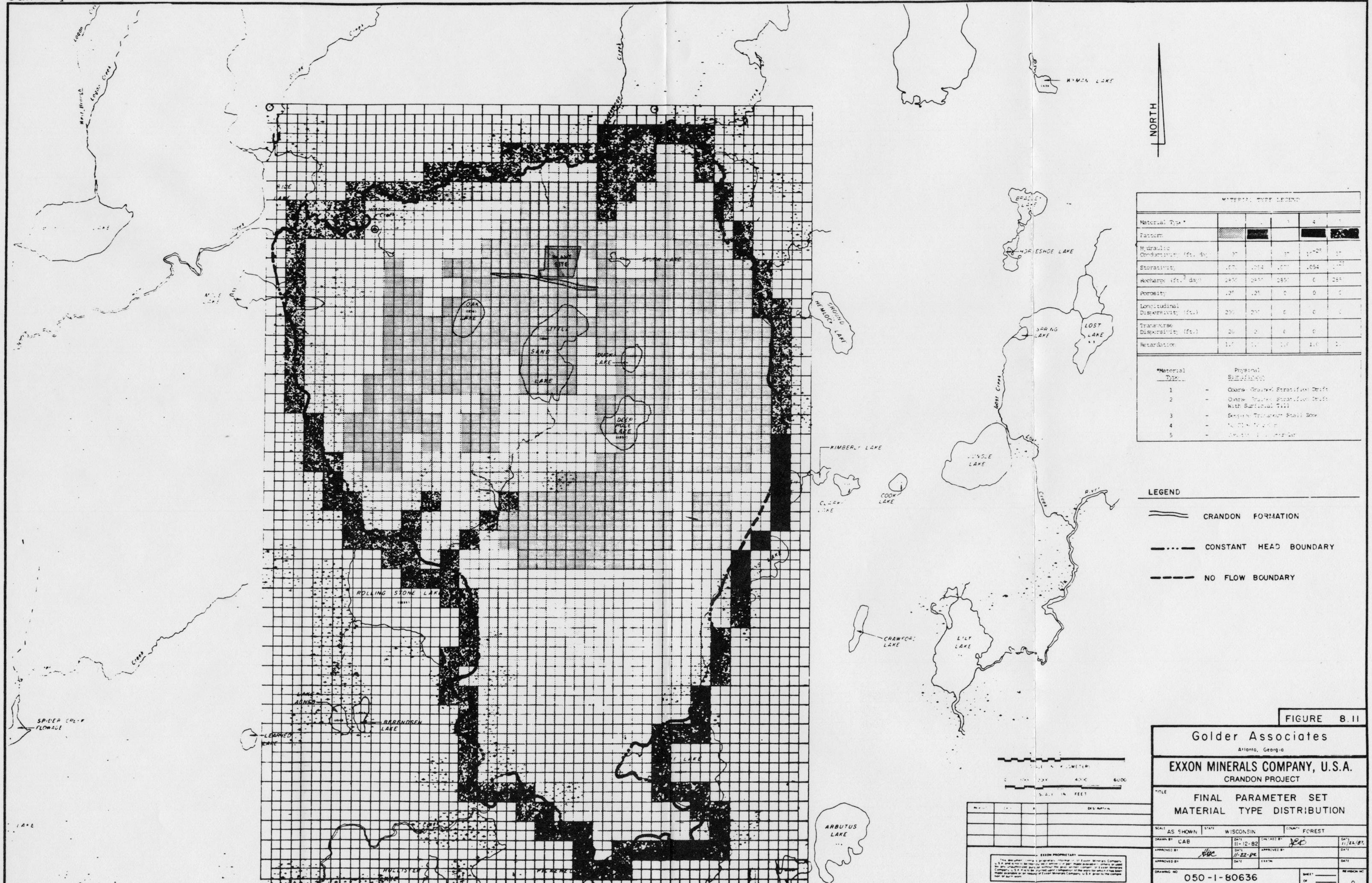
TITLE: COARSE GRAINED STRATIFIED DRIFT ISOPACH CONTOURS

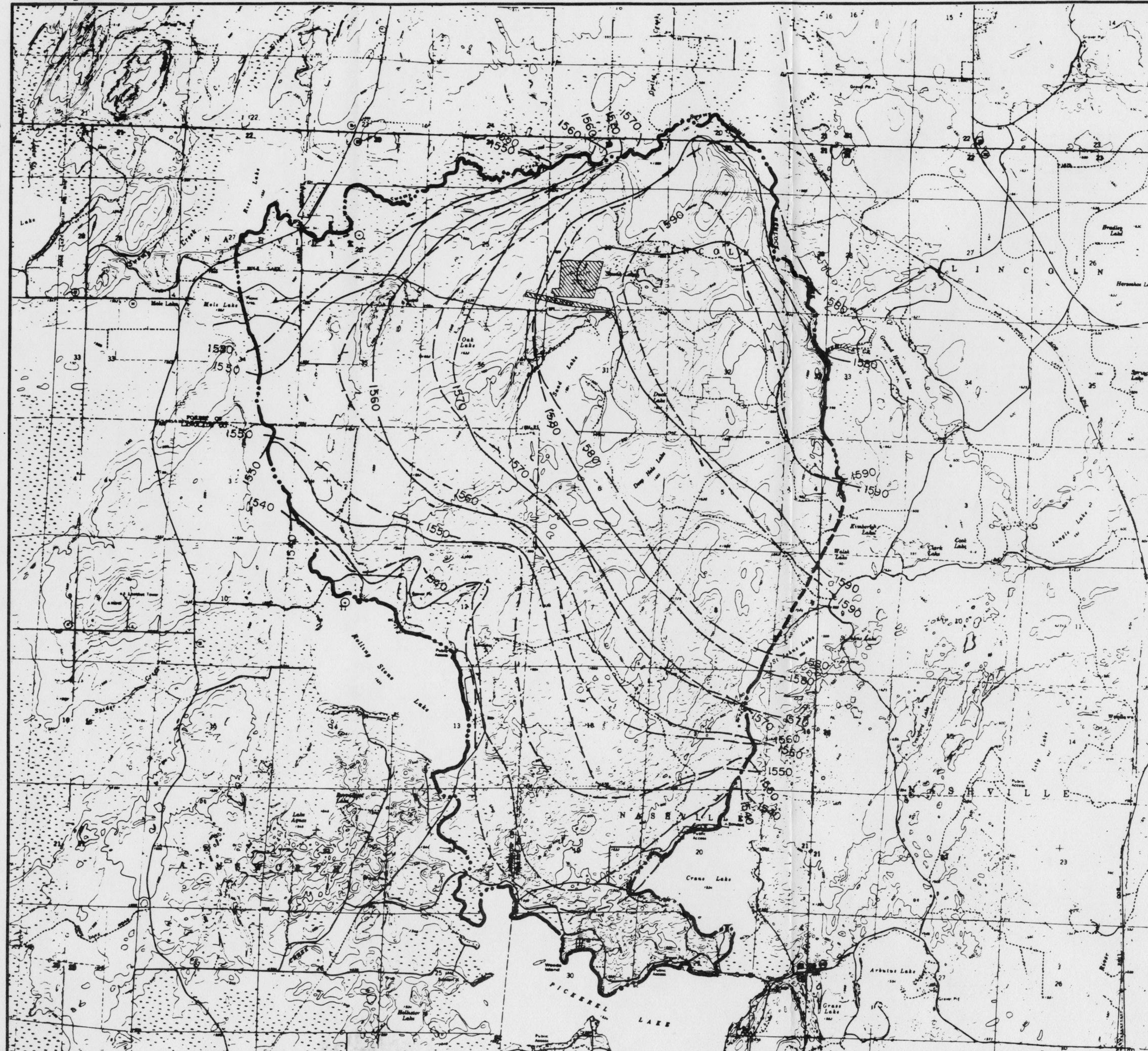
SCALE: AS SHOWN | STATE: WISCONSIN | COUNTY: FOREST

DRAWN BY: CAB | DATE: 10-13-81 | CHECKED BY: JEB | 10-13-81

APPROVED BY: JEB | DATE: 2-5-81

DRAWING NO. 050-1-80517


NORTH
MATERIAL TYPE LEGEND
Material Type*
Pattern
Hydraulic Conductivity
Storativity
Recharge
Porosity
Longitudinal Dispersivity (ft.)
Transverse Dispersivity (ft.)
Retardation
*Material Type
Physical
1 - Coarse Grained Stratified Drift
2
With Surficial Till
3
4
5
LEGEND
CRANDON FORMATION
CONSTANT HEAD BOUNDARY
NO FLOW BOUNDARY
HORSESHOE LAKE
SPRING LAKE
LOST LAKE
KIMBERLY LAKE
JUNGLE LAKE
COOK LAKE
CRAWFORD LAKE
LILY LAKE
ARBUTUS LAKE
ROLLING STONE LAKE
BERENDSEN LAKE
SPIDER CREEK FLOWAGE
DUCK LAKE
DEEP HOLE LAKE
LITTLE SAND LAKE
OAK LAKE
SCALE IN FEET
FIGURE 8.11
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
FINAL PARAMETER SET
MATERIAL TYPE DISTRIBUTION
AS SHOWN
WISCONSIN
FOREST
CAB
11-12-82
11-22-82
050-1-80636
0



LEGEND

CONSTANT HEAD BOUNDARY

NO FLOW BOUNDARY

SIMULATED GROUNDWATER HEAD CONTOURS

GROUNDWATER HEAD CONTOURS FROM FIELD DATA

GROUNDWATER HEAD CONTOURS INFERRED FROM FIELD DATA

REVISED	DATE	BY	DESCRIPTION
1	10-12-81	CAB	RECALIBRATED GROUNDWATER HEAD CONTOURS 10-8-81

EXXON PROPRIETARY

FIGURE 8.12

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

FINAL GROUNDWATER MODEL CALIBRATION

SCALE AS SHOWN	WISCONSIN	OREST
DRAWN BY SKB	11-15-82	CHECKED 11-15-82
APPROVED BY	11-15-82	
DRAWING NO. 050-1-80504		SHEET 1 OF 1

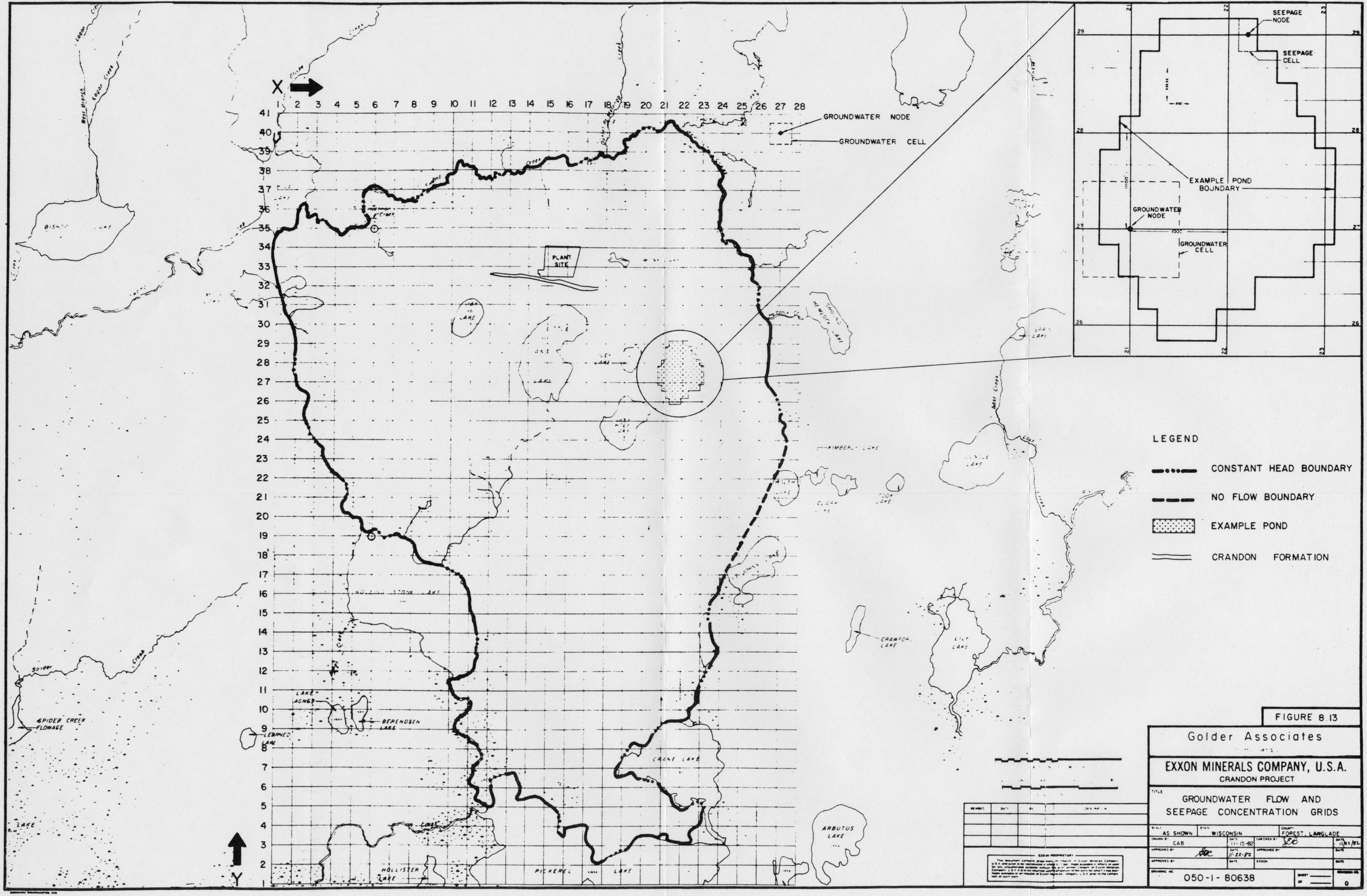
In addition to the refinement of the model parameter set, the final screening study employed a modified version of the groundwater model itself. The resolution in tailings pond placement and seepage concentration obtainable at the 1,000 foot by 1,000 foot (305 m by 305 m) matrix was considered too coarse for the final phase of the preliminary screening study. Therefore, a second matrix which divided the 1,000 foot by 1,000 foot (305 m by 305 m) groundwater element into fifteen 200 foot by 333 foot (61 m by 101 m) seepage elements was employed for seepage computations. Figure 8.13 illustrates the groundwater flow grid and seepage sub-grid.

8.4 Tailings Pond Seepage Estimates

8.4.1 Seepage Estimate Methodology

Potential seepage from a proposed mine waste disposal site may affect both groundwater flow and quality. It is therefore necessary to characterize the time variation of seepage from the tailings ponds, referred to hereafter as the "seepage history". For the tailings pond systems being considered for the Crandon Project, the primary factor governing the seepage rate during operation is the seepage control measures used. A detailed description of seepage rate estimate methodology is presented in Golder Associates' Project Report 3.1 (Ref. 12).

A second factor which could potentially influence the seepage rate is the hydraulic head in the till material beneath the ponds. If the head in the foundation material at the pond bottom is positive, the seepage rate becomes a function of not only the seepage control system but also of the hydraulics of the underlying materials, i.e. the pond and the foundation material act as a single hydraulic unit. The seepage rate estimation methodology for these


X
Y
GROUNDWATER NODE
GROUNDWATER CELL
PLANT SITE
SEEPAGE NODE
SEEPAGE CELL
EXAMPLE POND BOUNDARY
GROUNDWATER NODE
GROUNDWATER CELL
LEGEND
CONSTANT HEAD BOUNDARY
NO FLOW BOUNDARY
EXAMPLE POND
CRANDON FORMATION
BISHOP LAKE
KIMBERLY LAKE
CRAWFORD LAKE
LILY LAKE
LAKE AGNES
BERENDSEN LAKE
SPIDER CREEK FLOWAGE
CRANE LAKE
ARBUTUS LAKE
HOLLISTER LAKE
PICKEREL LAKE
FIGURE 8.13
Golder Associates
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
GROUNDWATER FLOW AND SEEPAGE CONCENTRATION GRIDS
AS SHOWN
WISCONSIN
FOREST, LANGLADE
CAB
11-15-82
11-22-82
050-1-80638
0

two cases is different and the first step was therefore to determine which case applied to the proposed tailings ponds.

The two processes which are likely to give rise to a positive head beneath the liner are (1) a saturated advancing wetting front through the underlying till and (2) build-up of a recharge mound in the till which rises to the pond bottom. It was determined (Ref. 12) that for pond seepage rates less than 1,800 gallons per minute (0.11 m^3/s) per 100 acre (40 ha) pond the wetting front is unlikely to progress in a saturated state. Also, for seepage rates less than 700 gallons per minute (0.04 m^3/s) per 100 acre (40 ha) pond, it is unlikely that the groundwater table will mound to the bottom of the pond. These tailings pond seepage rates are considerably higher than the anticipated rates from any of the proposed waste disposal systems. Therefore, the seepage may be estimated based only on seepage control strategies without consideration of the hydraulics of the foundation material, as long as the above stated flows are not exceeded.

8.4.2 Seepage Histories

As described in Section 8.3, the geohydrologic screening study was performed in two phases. The first phase primarily investigated the effectiveness of various seepage control measures while the second phase addressed the detailed pond layouts within the Site 40 and 41 areas. The first phase considered seepage from proposed system alternative 41-103 with no liner, with a bentonite/till liner of 0.5, 1.0, 2.0, and 5.0 feet (0.15, 0.30, 0.61, and 1.5 m) thicknesses, and with a 1.0 foot (0.30 m) thick bentonite till liner covered by an underdrain system. The second phase considered relative effects of several proposed Site 40 and 41 area systems with the 1.0 foot (0.30 m) liner and underdrain seepage control system.

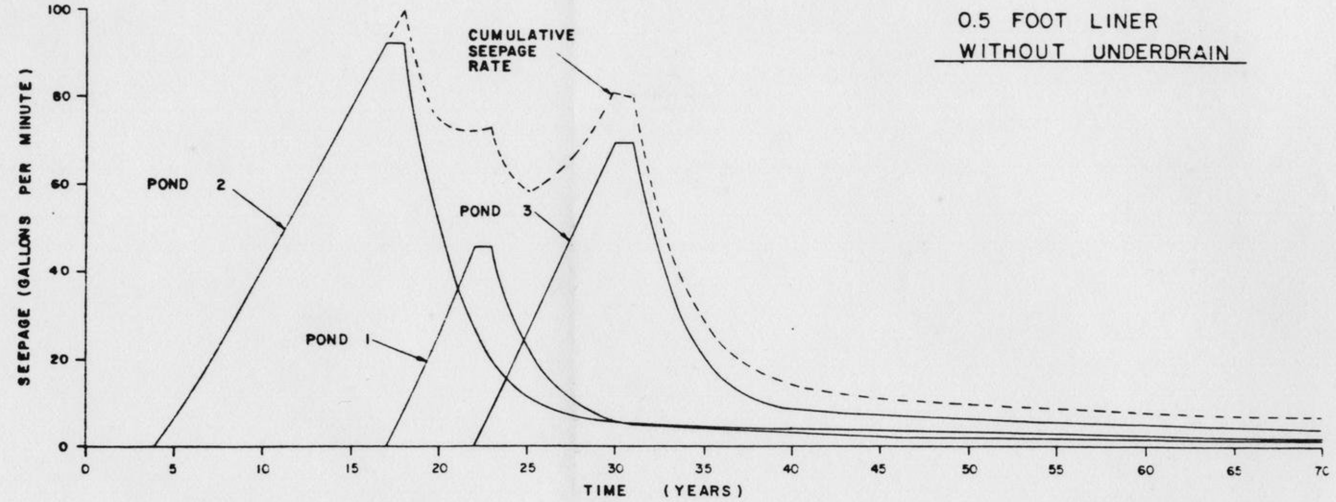
For use in the first phase of the screening analysis, the seepage history was computed for each of the seepage control measures proposed, including the unlined case. These seepage histories were prepared specifically for tailings pond system 41-103 based on the methods presented in Golder Associates' Project Report 3.1 (Ref. 12), but employing the following preliminary parameter values.

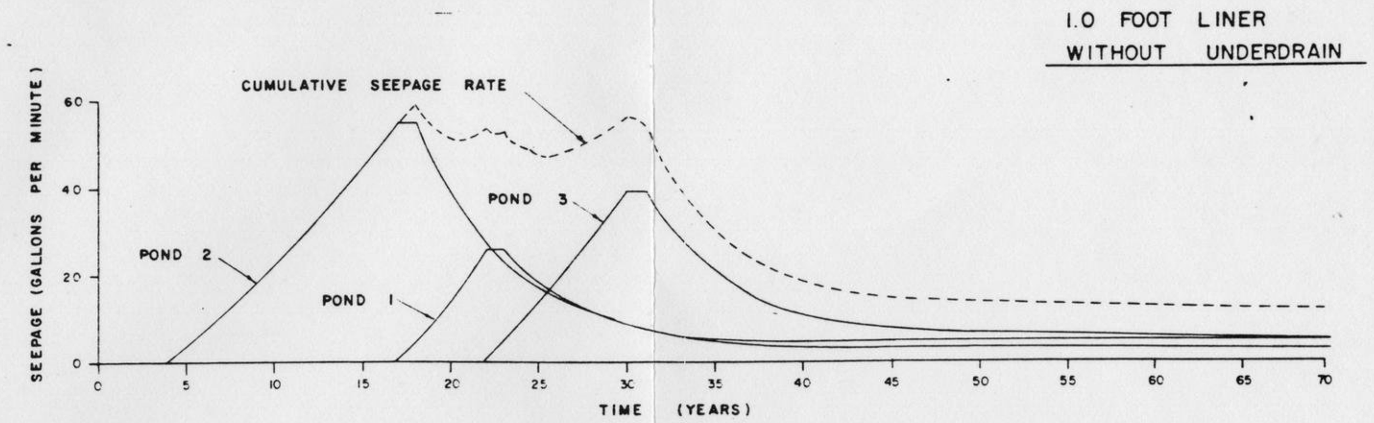
Hydraulic conductivity of liner:	1×10^{-10} m/s (3.3×10^{-10} ft./sec.)
Hydraulic conductivity of tailings:	5×10^{-8} m/s (1.6×10^{-7} ft./sec.)
Drainable porosity of tailings:	0.05
Steady-state infiltration (after pond reclamation)	1.0 inches per year (25 mm/y)

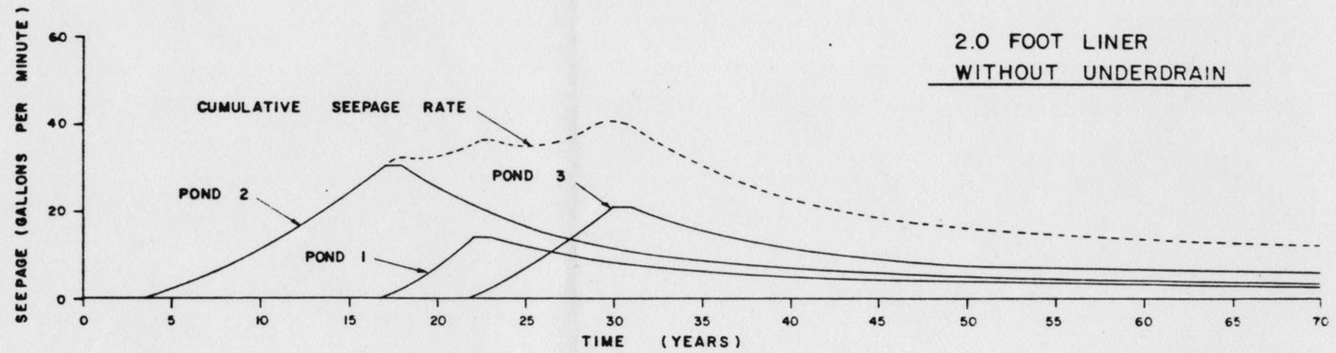
Some of these values differ from those presented in the final Golder Associates' Project Reports 3.1 and 5 (Ref. 12 and Ref. 15). The laboratory testing data (Ref. 15) and the parametric seepage rate study were not available during this assessment effort. The two primary differences are the hydraulic conductivity of the bentonite/till liner material, which was found to be 5×10^{-10} m/s (1.6×10^{-9} ft./sec.) rather than the 1×10^{-10} m/s (3.6×10^{-10} ft./sec.) assumed and the drainable porosity of the tailings, which was estimated to be 0.30 rather than the assumed value of 0.05. The effect of these changes in parameter values are that the flow rates from the ponds would be higher than that used in the preliminary assessment study (because of higher liner hydraulic conductivity) and that the desaturation of the tailings would take longer (because of the higher tailings drainable porosity). However, the preliminary geohydrologic assessment was performed to determine relative impacts of various seepage control measures and detailed pond layouts. In this regard, the results of these studies allowed design decisions to be made and are considered valid for their intended purpose.

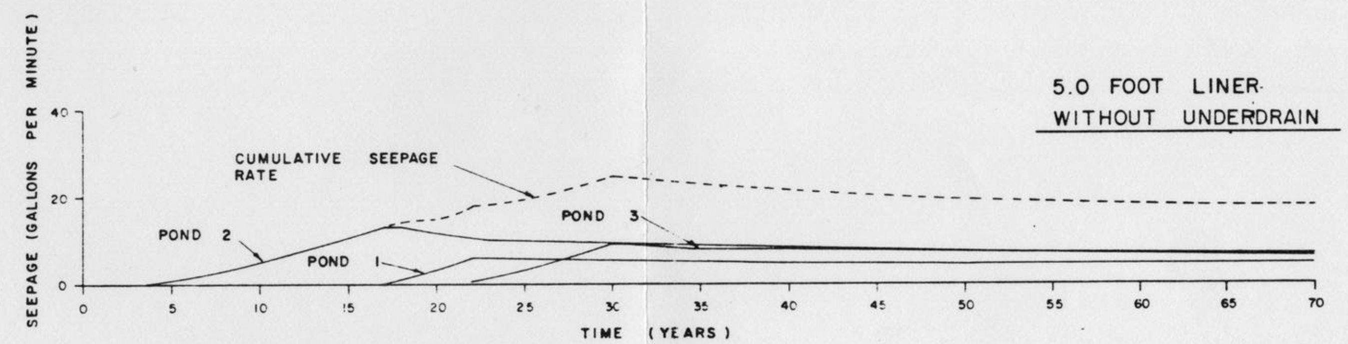
The seepage histories for each of the six seepage control measures studied are shown in Figure 8.14. As can be seen in these figures, the computed cumulative peak seepage rate ranges from about 450 gallons per minute (0.03 m^3/s) for the unlined case down to 18 gallons per minute (0.001 m^3/s) for the liner with underdrain case. Based on the rates computed for these seepage control measures and the resultant effect (to be discussed in the next subsection), the decision was made to propose a bentonite/till liner overlain by an underdrain as the seepage control system. For the final phase of the study a 1.0 foot (0.31 m) thick bentonite/till liner with an underdrain system was assumed.

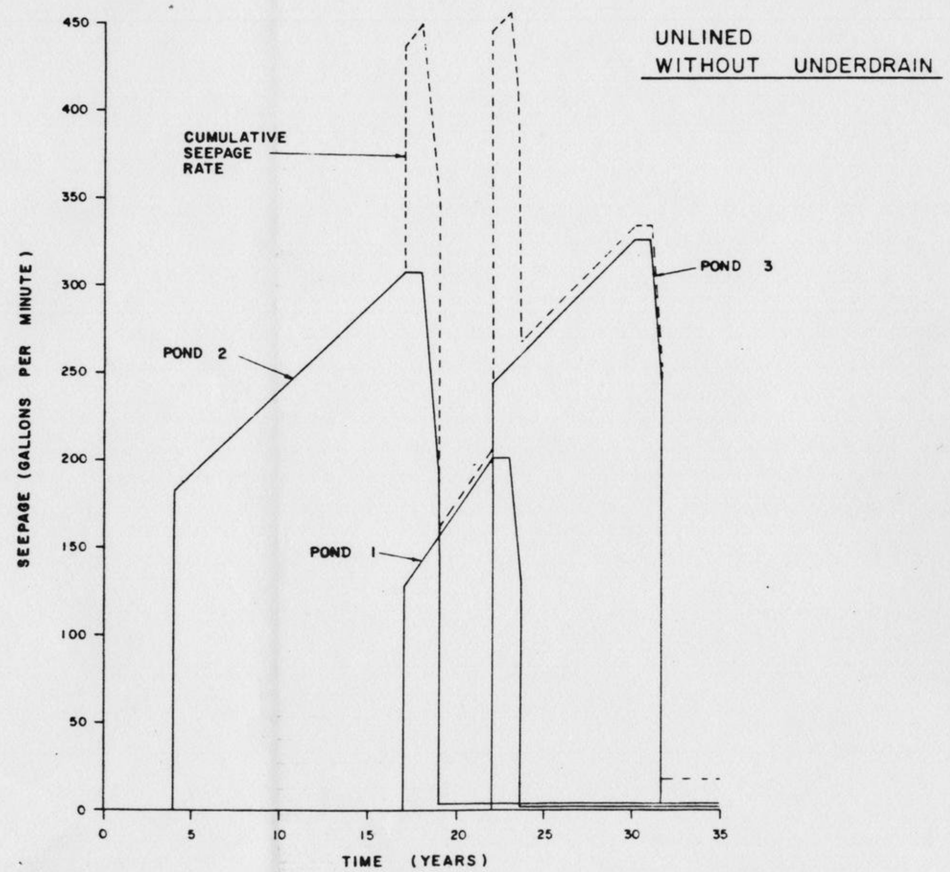
Having selected a seepage control system, the final phase of the preliminary geohydrologic assessment was to study the site alternatives within the proposed Site 40 and 41 areas. Since no detailed tailings pond layouts had been prepared for some of the alternatives to be considered, and to allow maximum flexibility in alternative selection, a generic system consisting of a set of 3 ponds was used. The seepage rate from this generic tailings pond system was simplified to a constant rate for each of the ponds during their operation and a linear increase over a one year period to a steady-state seepage of about 1.0 inch per year (25 mm/y) after reclamation. This seepage history is shown as Figure 8.15. In order to maintain consistency of the peak seepage rates for the underdrain cases between the

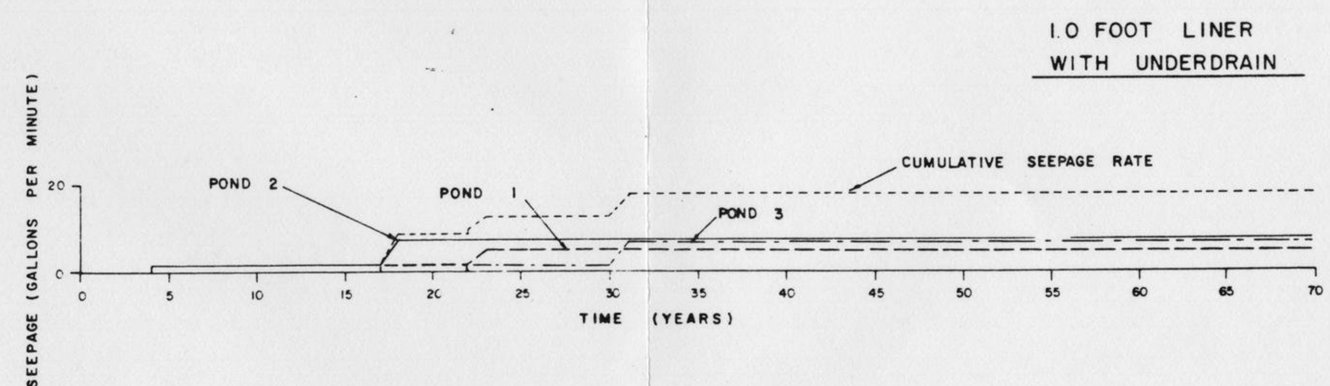












NOTES:

1. ALL SEEPAGE HISTORIES ARE FOR SYSTEM 41-103.
2. ALL TAILING POND LINERS ARE OF TILL/BENTONITE MIX.
3. RECLAIM POND SEEPAGE NOT SHOWN.
4. ALL TIMES ARE RELATIVE TO PLANT START-UP.
5. SEEPAGE HISTORY FOR 1.0 FT. LINER WITH UNDERDRAIN ASSUMES PUMPING CEASES AT POND CLOSURE.

FIGURE 8.14

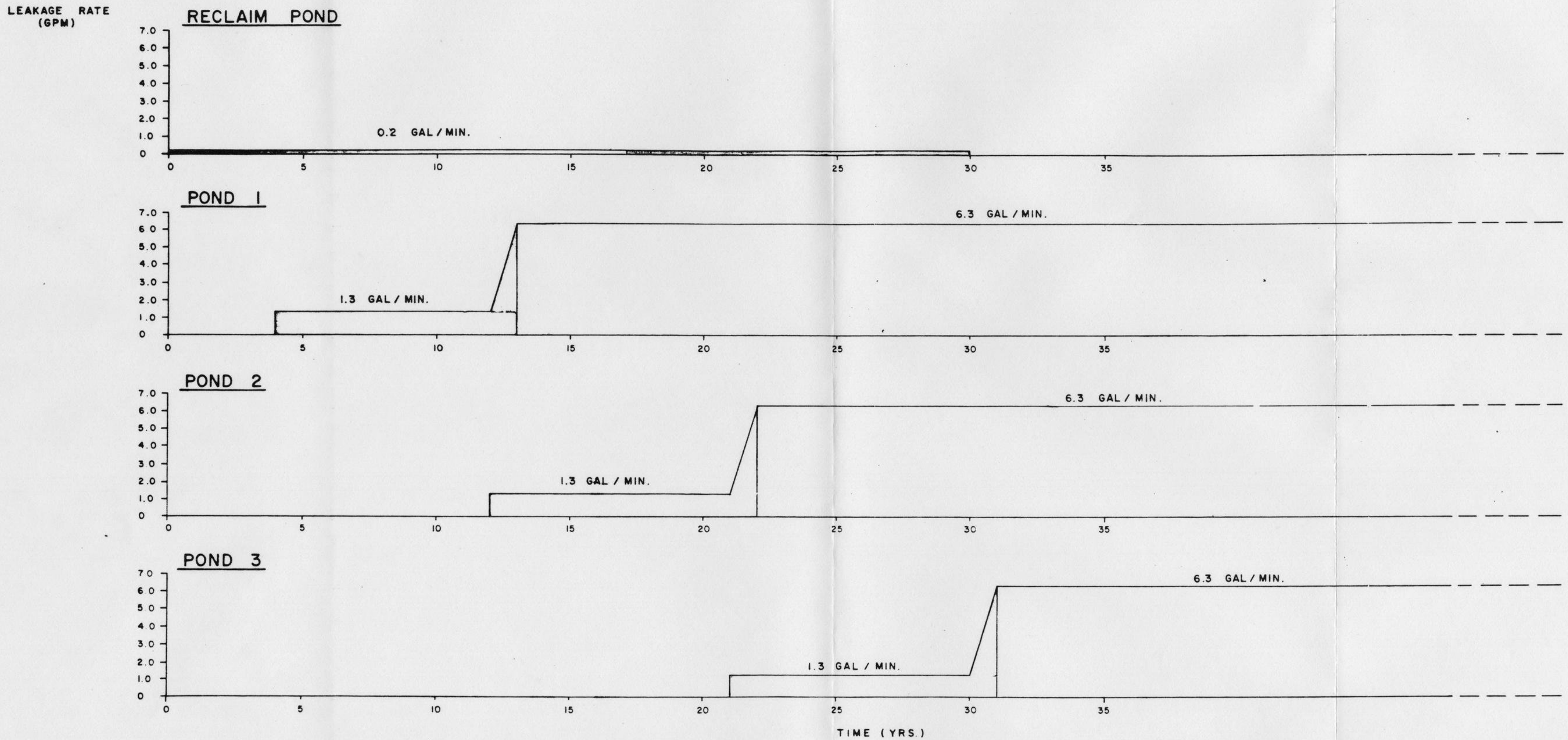
Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

SEEPAGE HISTORY FOR INITIAL STUDY PHASE

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST	
DRAWN BY CAB	DATE 11-16-82	CHECKED BY [signature]	DATE 11/22/82
APPROVED BY [signature]	DATE 11-22-82	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO. 050-1-80641		SHEET ___ OF ___	REVISION NO. 0

REVISED	DATE	BY	DESCRIPTION



NOTE:

1. THESE SEEPAGE HISTORIES REFLECT A 1.0 FT. TILL/BENTONITE LINER WITH AN UNDERDRAIN.

2. UNDERDRAIN PUMPING IS ASSUMED TO CEASE AT POND CLOSURE.

FIGURE 8.15

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT

SEEPAGE HISTORIES FOR FINAL STUDY PHASE

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: CAB	DATE: 11-15-82	CHECKED BY: JEB	DATE: 11-15-82
APPROVED BY:	DATE: 11-15-82	APPROVED BY:	DATE:
DRAWING NO. 050-1-80522		SHEET ___ OF ___	REVISION NO. 0

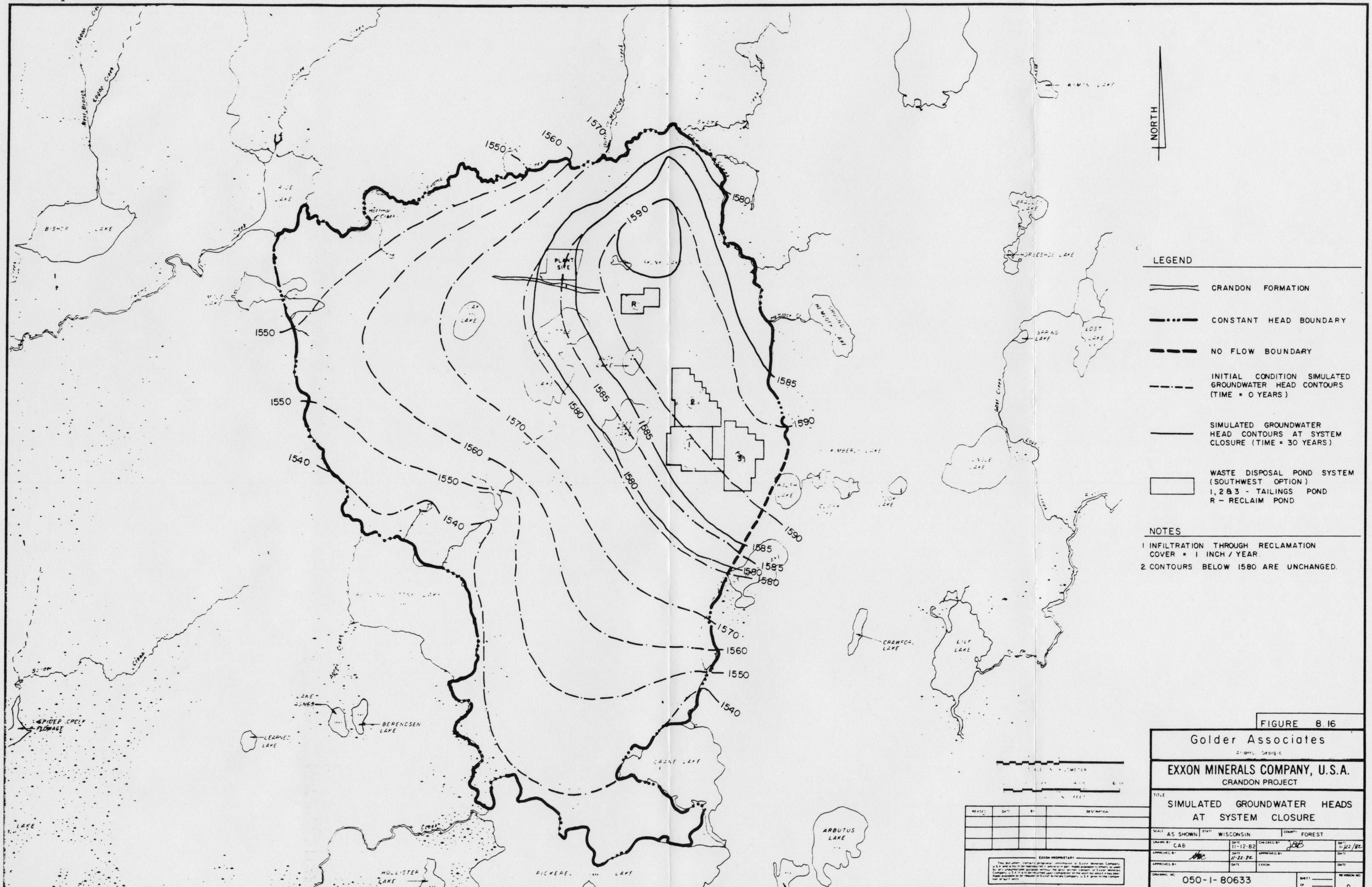
initial and final phases of the study, the depth of water in the underdrain was taken to be 0.12 feet (37 mm) and the steady-state infiltration through the tailings was taken as 0.75 inches per year (19 mm/y). These adjustments were made to account for the variation in the total plan areas of the waste disposal systems.

8.5 Results of Modeling Effort

8.5.1 Physical Geohydrologic Effects

The construction of approximately 400 acres (162 ha) of lined and underdrained waste disposal ponds on the study site would significantly reduce the natural recharge beneath the facility which generally ranges from 6 to 12 inches per year (152 to 305 mm/yr.). For the assumed liner/underdrain case, the seepage histories on Figure 8.15 show the tailings pond leakage during operation to be 1.3 gallons per minute per pond (0.2 in./yr. = 5 mm/y). After reclamation the seepage rate increases to 6.3 gallons per minute per pond (1.0 in./yr. = 25 mm/y). These low seepage rates compared to the natural recharge will have greater effect on groundwater gradients in the Site 41 area than the Site 40 area since the Site 41 area is the high point of a groundwater recharge zone.

To consider this effect, the model simulates the response of the groundwater gradients to the reduced net recharge beneath the ponds. Figure 8.16 illustrates the simulated changes to the groundwater gradients after 30 years of operation of the southwestern generic waste disposal system. Note that the groundwater high beneath the Site 41 area has reduced significantly in areal extent and moved to the northwest. However, the groundwater potentiometric contours below 1580 feet (482 m) elevation are not significantly altered. Figure 8.17 shows the simulated


NORTH
LEGEND
CRANDON FORMATION
CONSTANT HEAD BOUNDARY
NO FLOW BOUNDARY
INITIAL CONDITION SIMULATED GROUNDWATER HEAD CONTOURS (TIME = 0 YEARS)
SIMULATED GROUNDWATER HEAD CONTOURS AT SYSTEM CLOSURE (TIME = 30 YEARS)
WASTE DISPOSAL POND SYSTEM (SOUTHWEST OPTION)
1, 2 & 3 - TAILINGS POND
R - RECLAIM POND
NOTES
1. INFILTRATION THROUGH RECLAMATION COVER = 1 INCH / YEAR.
2. CONTOURS BELOW 1580 ARE UNCHANGED.
PLANT SITE
R
1
2
3
1540
1550
1560
1570
1580
1585
1590
BISHOP LAKE
RICE LAKE
CRANE LAKE
ARBUTUS LAKE
HOLLISTER LAKE
PICKEREL LAKE
BERENDSEN LAKE
LAKE JONES
SPIDER CREEK FLOWAGE
HORSESHOE LAKE
SPRING LAKE
LOST LAKE
LILY LAKE
CRAWFORD LAKE
FIGURE 8.16
Golder Associates
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
SIMULATED GROUNDWATER HEADS AT SYSTEM CLOSURE
AS SHOWN
WISCONSIN
FOREST
CAB
11-12-82
050-1-80633
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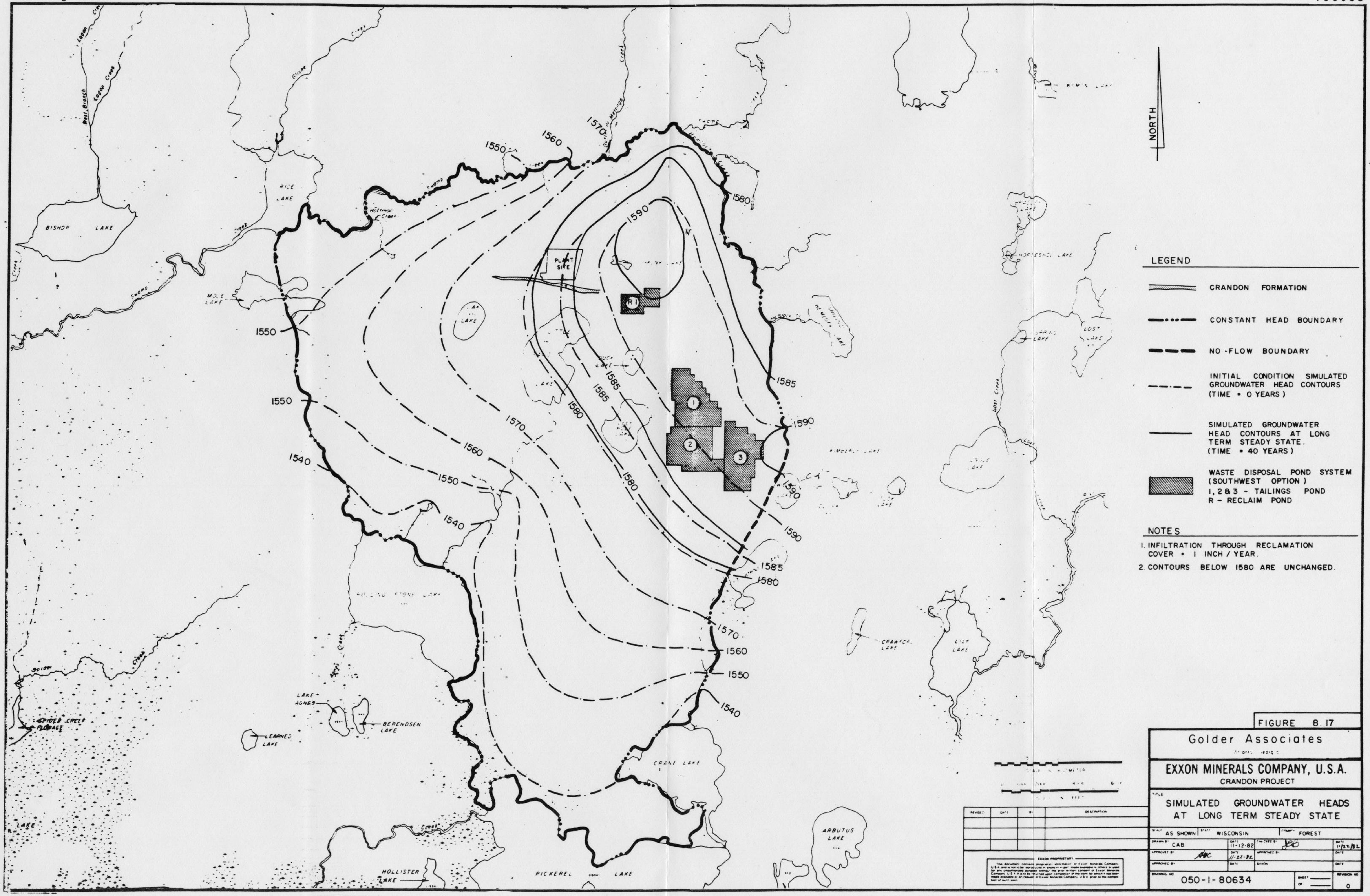
DESIGN PRODUCTS CO


NORTH
LEGEND
CRANDON FORMATION
CONSTANT HEAD BOUNDARY
NO-FLOW BOUNDARY
INITIAL CONDITION SIMULATED GROUNDWATER HEAD CONTOURS (TIME = 0 YEARS)
SIMULATED GROUNDWATER HEAD CONTOURS AT LONG TERM STEADY STATE. (TIME = 40 YEARS)
WASTE DISPOSAL POND SYSTEM (SOUTHWEST OPTION)
1, 2 & 3 - TAILINGS POND
R - RECLAIM POND
NOTES
1. INFILTRATION THROUGH RECLAMATION COVER = 1 INCH / YEAR.
2. CONTOURS BELOW 1580 ARE UNCHANGED.
BISHOP LAKE
RICE LAKE
MOLE LAKE
PLANT SITE
HORSESHOE LAKE
LOST LAKE
LILY LAKE
CRANE LAKE
ARBUTUS LAKE
HOLLISTER LAKE
PICKEREL LAKE
BERENDSEN LAKE
LAKE AGNES
SPIDER CREEK FLOWAGE
1550
1560
1570
1580
1585
1590
1540
R1
1
2
3
FIGURE 8.17
Golder Associates
EXXON MINERALS COMPANY, U.S.A.
CRANDON PROJECT
SIMULATED GROUNDWATER HEADS AT LONG TERM STEADY STATE
AS SHOWN
WISCONSIN
FOREST
CAB
11-12-82
11-22-82
050-1-80634
0

groundwater potentiometric contours 10 years after reclamation of the southwestern generic mine waste disposal system with an assumed infiltration value of 1.0 inch per year (25 mm/yr.) through the reclamation cap. Note that the groundwater mound beneath the Site 41 area has not fully recovered to its original configuration. This is because the reclamation cap limits the infiltration to a level much lower than the present rate.

8.5.2 Seepage Transport Analysis

The primary function of the preliminary hydrologic assessment was to determine the relative directions, rate, and quantity of movement of pond seepage in the saturated coarse grained stratified drift between various proposed waste disposal systems. It should be emphasized that the seepage transport results presented herein are based on several simplifying assumptions, as listed below.

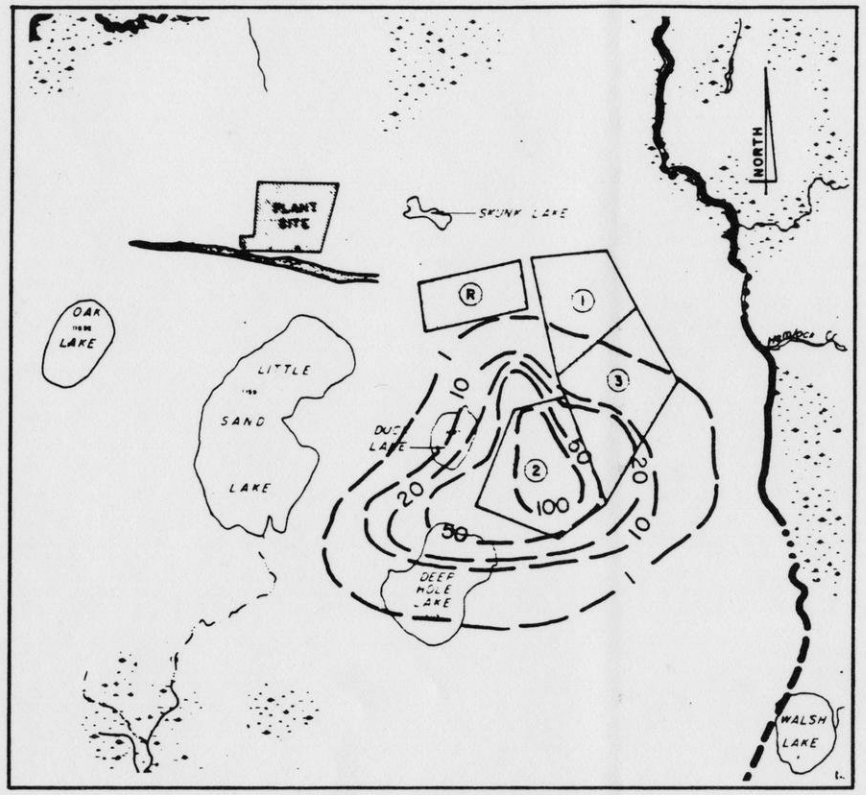
1. Transit time between pond bottom and saturated coarse grained stratified drift was ignored.
2. Unsaturated and saturated zone retardation was ignored.
3. Unsaturated and saturated zone chemical attenuation was ignored.
4. Considered pond seepage to be 100 percent unspecified "solute".
5. The seepage concentration contours represent the concentration of seepage within the saturated coarse grained stratified drift assuming complete mixing (vertical integration) of the seepage in the drift. Based on Bear (Ref. 2) this assumption is valid beyond 10 to 15 times the saturated coarse grained stratified drift thickness away from the seepage source.

Therefore, the times and concentrations presented herein are not conservative but are of value for relative comparison of alternatives.

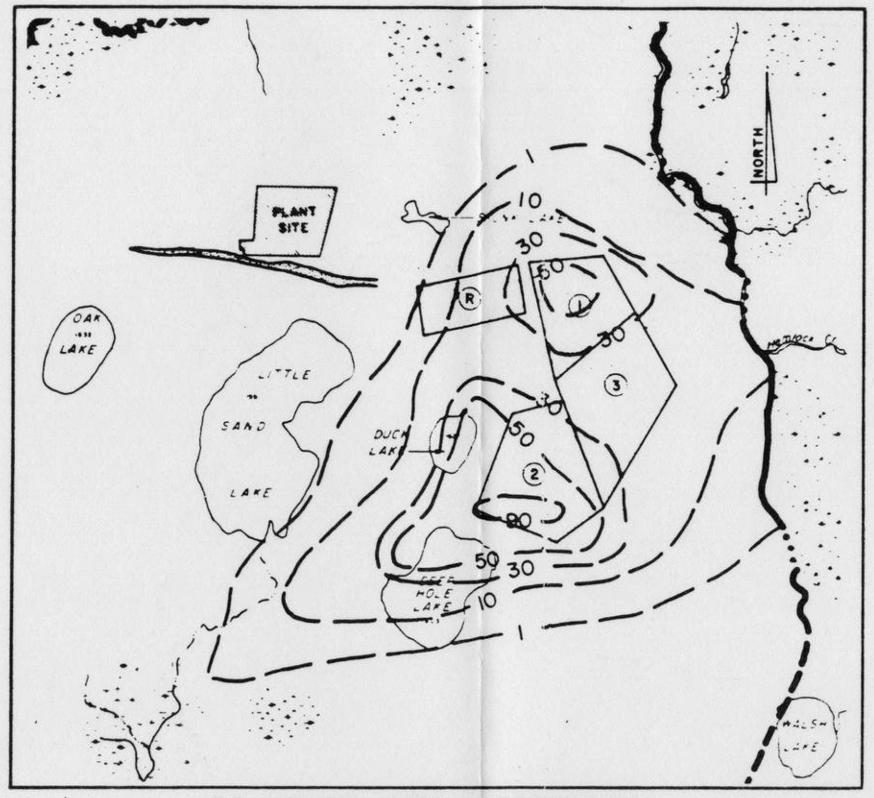
Based upon the seepage rate, groundwater gradients beneath a proposed pond and nature of the coarse grained stratified drift, the incremental movement of pond seepage each year was computed. The percent of seepage in the coarse grained stratified drift was determined for each "seepage cell" and contours of equal percentages were drawn. A series of these simulated seepage concentration contours for up to a 200 year period were compared for each proposed system to assess the relative hydrologic effects of each.

The first phase of the analysis investigated the relative effect of various seepage control measures using proposed system 41-103. Figure 8.18 shows the simulated progression of seepage from an unlined system at 15 years, 30 years, 60 years and 120 years after the system begins operation. The seepage concentration contours indicate the percent of the groundwater in the coarse grained stratified drift which originated from the ponds. Note that at year 15 with tailings pond number 2 in service, 100 percent of the groundwater in the aquifer originated from the overlying pond. This is due to the flat groundwater gradients which result from the very low pond seepage and the limited groundwater movement produced. The seepage plume moves to the southwest toward Rolling Stone Lake and to the northeast toward Hemlock Creek since the proposed waste management facility straddles the groundwater mound. At year 120, the plume is near its steady-state position.

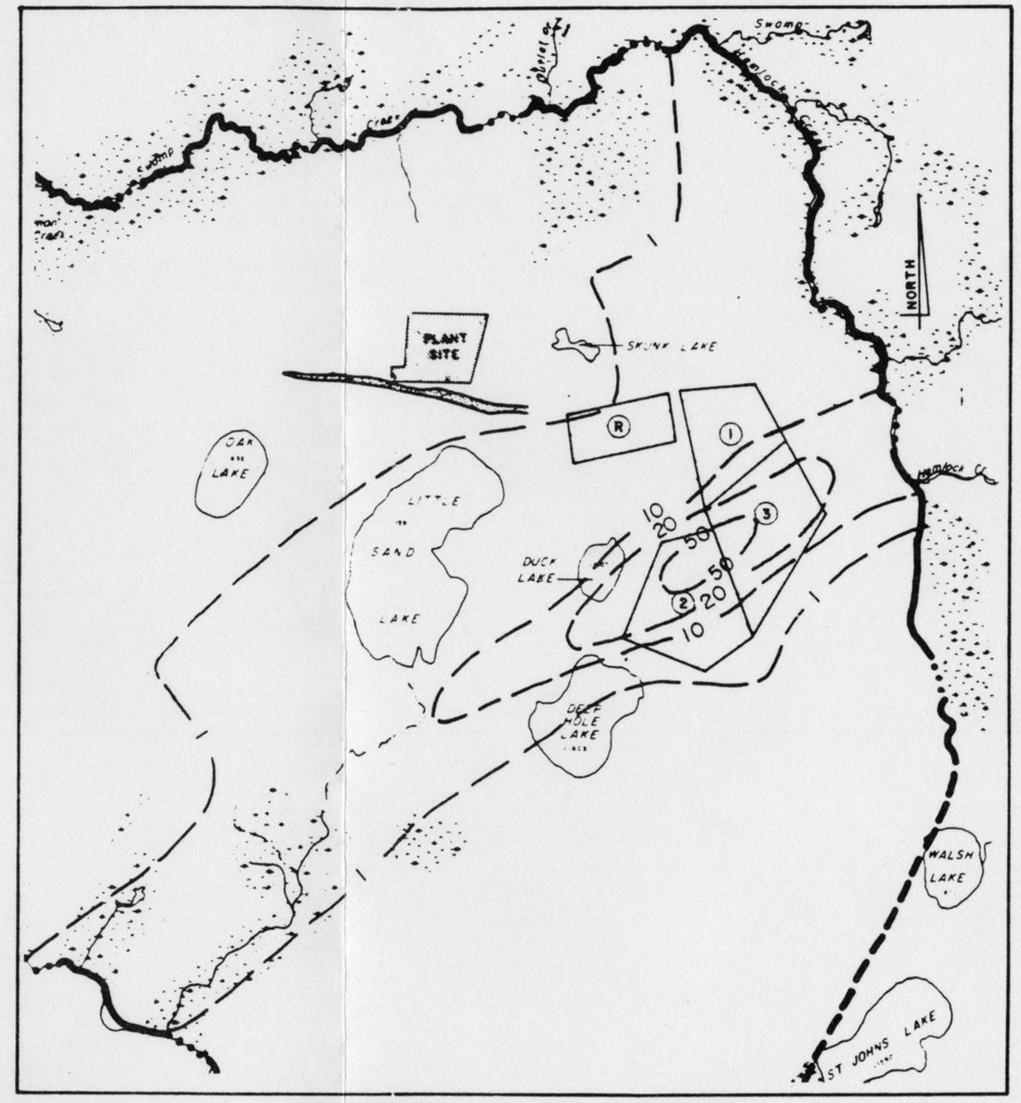
Seepage concentration plumes were simulated for a range of seepage control measures at the proposed 41-103 system ranging from unlined to an underdrain system. Figure 8.19 shows a comparison of the simulated seepage concentration plumes at 30 years (the assumed end of the service life of the facility) for the seepage control measures



15 YEARS INTO OPERATION



30 YEARS INTO OPERATION
(AT CLOSURE)



90 YEARS AFTER CLOSURE

NOTES:

1. GROUNDWATER MODEL PARAMETERS FOR THESE ANALYSES PRESENTED ON DRAWING NO. 050-1-80637, FIGURE 8.5.
2. SEEPAGE HISTORY SHOWN ON DRAWING NO. 050-1-80641, FIGURE 8.14.
3. RECLAIM POND ASSUMED LINED WITH SYNTHETIC LINER OVER 6" THICK TILL / BENTONITE MIX FOR ALL CASES.
4. TIMES PRESENTED ASSUME THAT POND SEEPAGE ENTERS SATURATED COARSE GRAINED STRATIFIED DRIFT AT TIME ZERO.

LEGEND

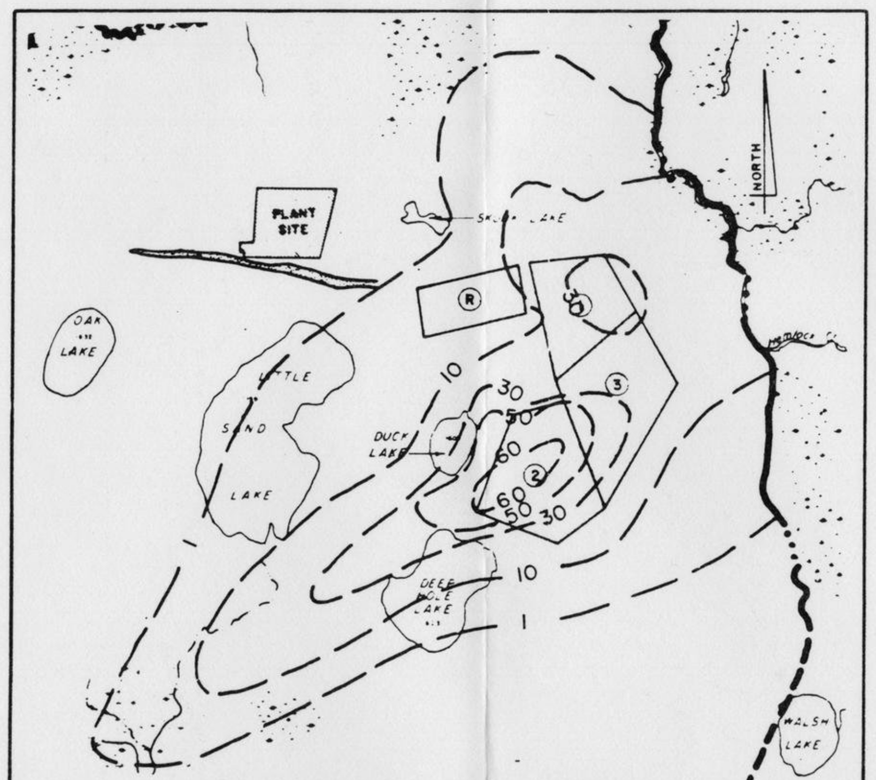
— — 10 — — POND SEEPAGE CONCENTRATION CONTOURS (PERCENT)

(1) WASTE SYSTEM POND: R - RECLAIM POND
1,2,3 - TAILINGS POND

CRANDON FORMATION

GROUNDWATER NO FLOW BOUNDARY

GROUNDWATER CONSTANT HEAD BOUNDARY



30 YEARS AFTER CLOSURE

0 1000 2000 4000 6000
SCALE IN FEET

REVISED	DATE	BY	DESCRIPTION

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FIGURE 8.18

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Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE SEEPAGE CONCENTRATION CONTOURS UNLINED TAILINGS POND COMPARISON SITE 41-103

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST
DRAWN BY CAB — DATE 11-1-82	CHECKED BY JEB	DATE 11/22/82
APPROVED BY [signature] — DATE 11-22-82	APPROVED BY	DATE
APPROVED BY — DATE	EXXON	DATE
DRAWING NO. 050-1-80625	SHEET ___ OF ___	REVISION NO. 0

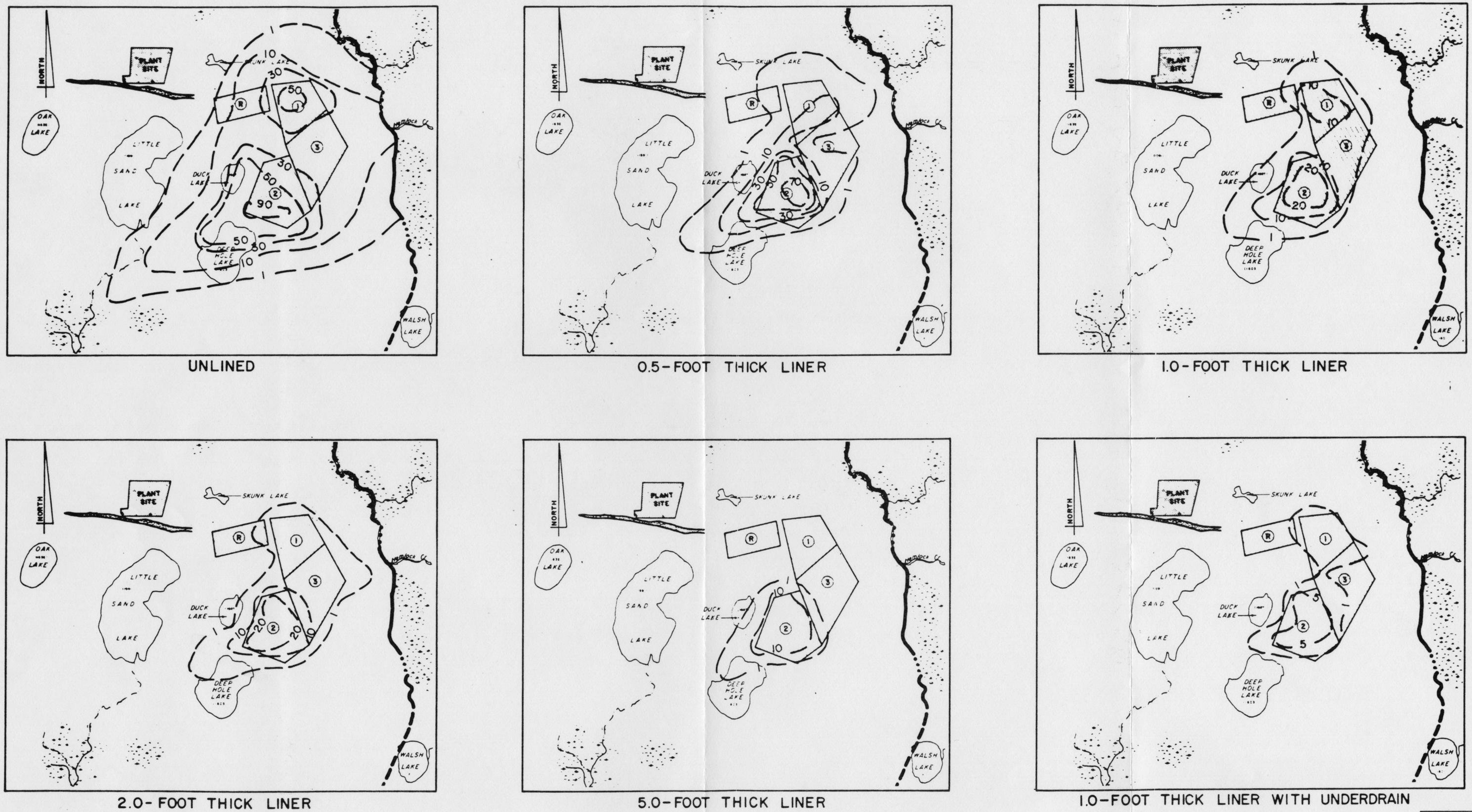

FIGURE 8.19

NOTES

1. ALL ANALYSES ARE AT SYSTEM CLOSURE, 30 YEARS INTO OPERATION.
2. TIMES PRESENTED ASSUME THAT POND SEEPAGE ENTERS SATURATED COARSE GRAINED STRATIFIED DRIFT AT TIME ZERO.
3. GROUNDWATER MODEL PARAMETERS FOR THESE ANALYSES PRESENTED ON DRAWING NO. 050-1-80637, FIGURE 8.5.
4. SEEPAGE HISTORY SHOWN ON DRAWING NO. 050-1-80641, FIGURE 8.14.
5. TAILINGS POND LINERS ARE TILL / BENTONITE MIX AT THE THICKNESS SHOWN.
6. RECLAIM POND ASSUMED LINED WITH SYNTHETIC LINER OVER A 6" THICK TILL / BENTONITE MIX FOR ALL CASES.

LEGEND

- — 10 — POND SEEPAGE CONCENTRATION CONTOURS (PERCENT)
- (1) WASTE SYSTEM POND: R - RECLAIM POND; 1, 2 & 3 - TAILINGS POND
- CRANDON FORMATION
- — — — GROUNDWATER NO FLOW BOUNDARY
- — · · · — GROUNDWATER CONSTANT HEAD BOUNDARY

0 1000 2000 4000 6000
SCALE IN FEET

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

SEEPAGE CONCENTRATION CONTOURS
TAILINGS POND LINER COMPARISON
SITE 41-103

SCALE AS SHOWN	STATE WISCONSIN	COUNTY FOREST
DRAWN BY CAB	DATE 11-1-82	CHECKED BY	DATE 11/22/82
APPROVED BY	DATE 11-22-82	APPROVED BY	DATE
DRAWING NO. 050-1-80626	SHEET OF	REVISION NO. 0

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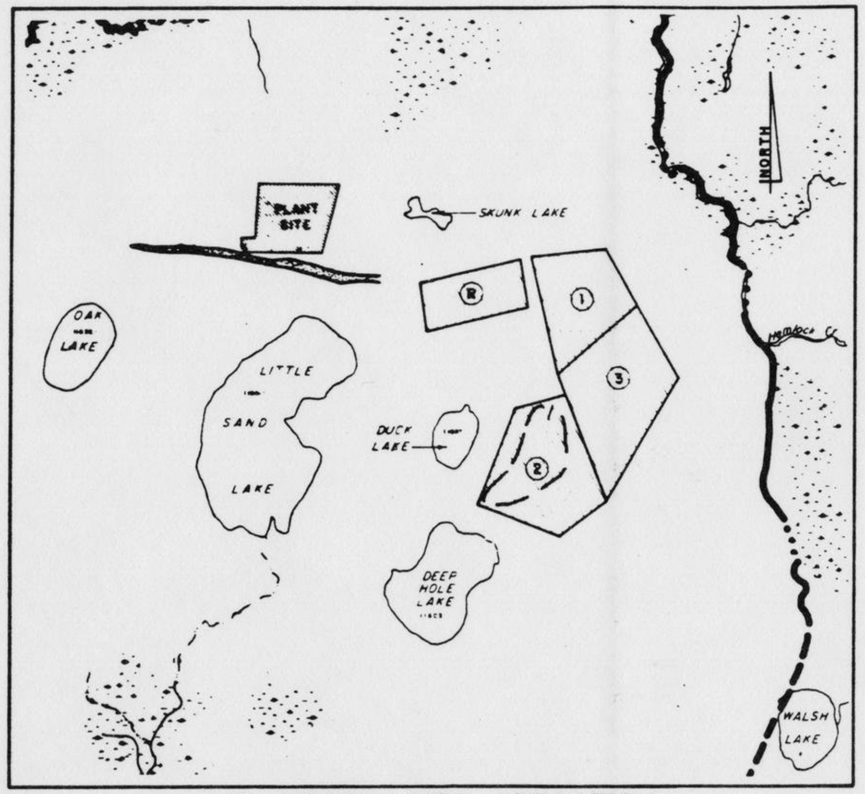
studied. Both the peak concentrations and the extent of the 1 percent contour are decreased with increasingly effective seepage control measures. Based upon this comparison, an underdrain system with a liner was adopted as the proposed seepage control system.

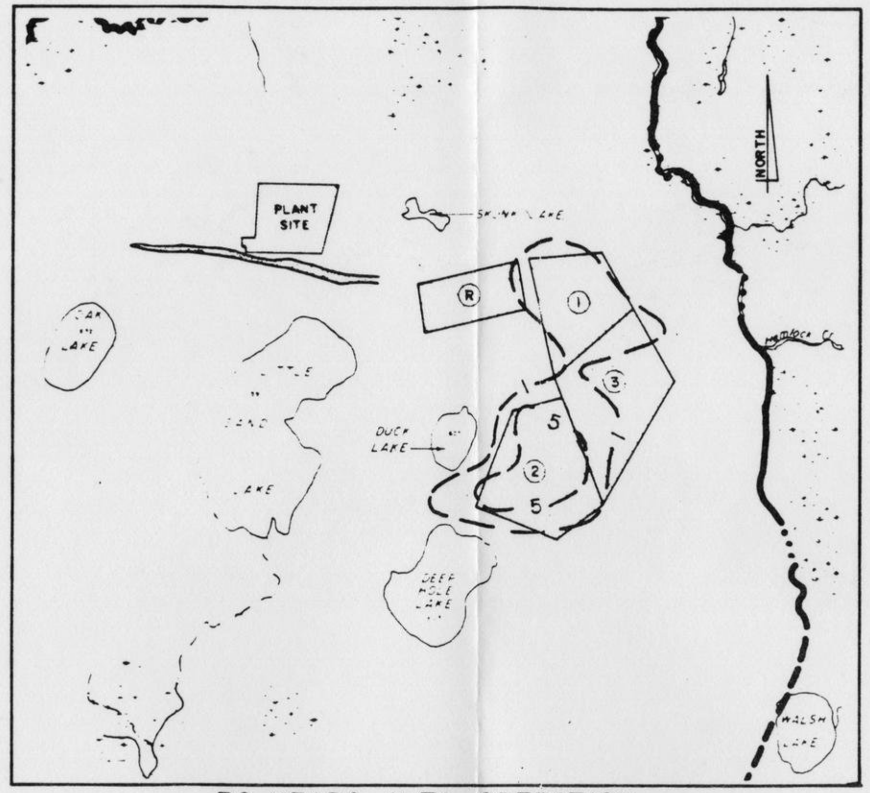
Figure 8.20 shows a sequence of simulated seepage concentration plumes at 15, 30, 60 and 120 years for the 41-103 site with a liner and underdrain system. The underdrain seepage history included in Figure 8.20 shows the increase in pond seepage after reclamation, yielding increased seepage concentrations from year 30 to year 60. However, this increased seepage rate allows the previously depressed groundwater mound beneath the Site 41 area to partially recover. This increases the lateral gradients, which increases seepage movement, and results in a steady-state condition by year 120 with a peak seepage concentration in the aquifer of 5 percent.

The second phase of the preliminary hydrologic assessment investigated 3 alternative sites within the Site 41 area and one within the Site 40 area. The seepage histories employed in this phase were based on an underdrain system over a 1.0 foot (0.31 m) thick liner. The purpose of the second phase of the study was to determine the relative effect of placement of the ponds within the Site 40 and 41 areas. Therefore, the analyses used a generic 3 pond system with equal plan area at each location and equal seepage histories. Each pond is about 130 acres (52.6 ha) with a total tailings area of about 390 acres (157.8 ha).

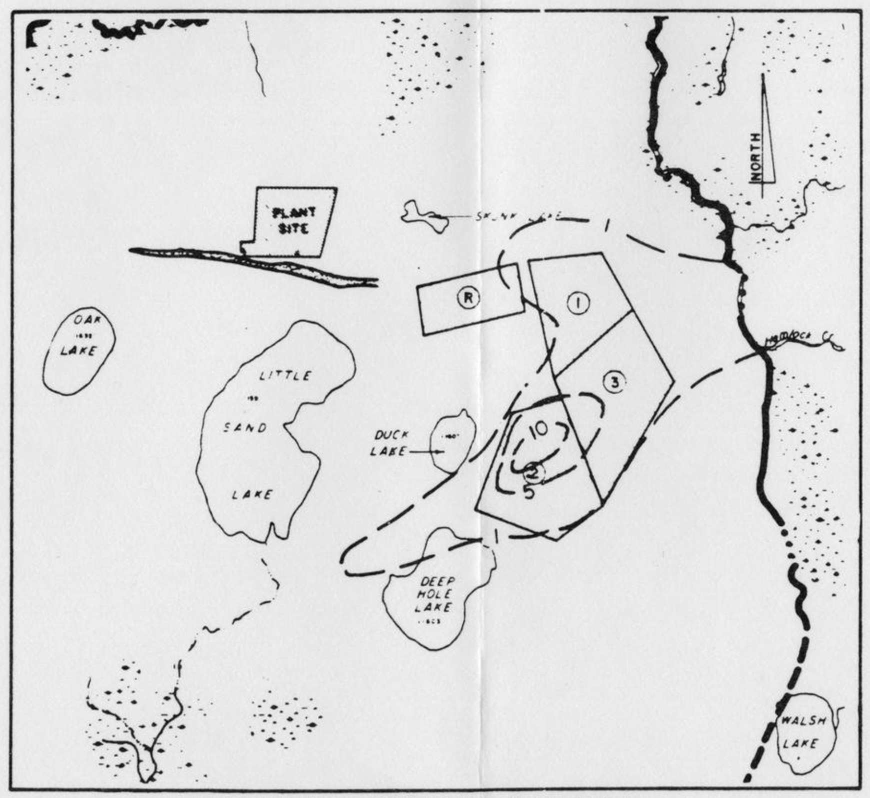
The three Site 41 area alternatives studied included a center option which straddles the groundwater mound, a western option which encroaches on the 1000 foot (305 m) offset from Duck Lake, and a southwest option which covers



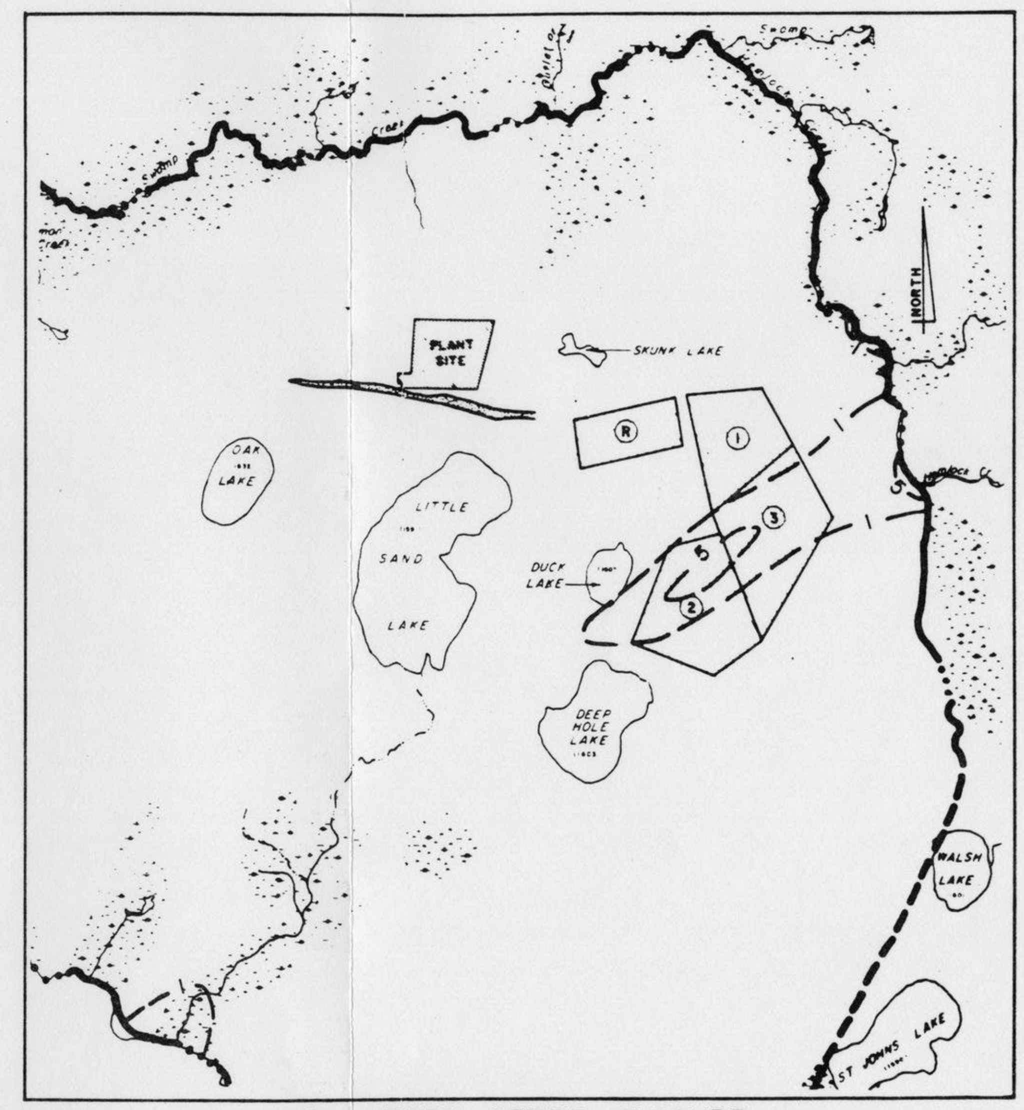
15 YEARS INTO OPERATION



30 YEARS INTO OPERATION
(AT CLOSURE)



30 YEARS AFTER CLOSURE



90 YEARS AFTER CLOSURE

NOTES

1. TIMES PRESENTED ASSUME THAT POND SEEPAGE ENTERS SATURATED COARSE GRAINED STRATIFIED DRIFT AT TIME ZERO.
2. TAILINGS POND LINER BENEATH UNDERDRAIN IS 1.0 FT. THICK TILL / BENTONITE MIX
3. SEEPAGE HISTORY SHOWN ON DRAWING NO. 050-1-80641 , FIGURE 8.14.
4. GROUNDWATER MODEL PARAMETERS FOR THESE ANALYSES PRESENTED ON DRAWING NO 050-1-80637, FIGURE 8.5.
5. RECLAIM POND ASSUMED LINED WITH SYNTHETIC LINER OVER A 6" THICK TILL / BENTONITE MIX FOR ALL CASES.

LEGEND

— —10— — POND SEEPAGE CONCENTRATION CONTOURS (PERCENT)

(1) WASTE SYSTEM POND : R - RECLAIM POND
1, 2 & 3 - TAILINGS POND

CRANDON FORMATION

GROUNDWATER NO FLOW BOUNDARY

GROUNDWATER CONSTANT HEAD BOUNDARY

0 1000 2000 4000 6000
SCALE IN FEET

FIGURE 8.20

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SEEPAGE CONCENTRATION CONTOURS WITH UNDERDRAIN AND LINER SITE 41-103

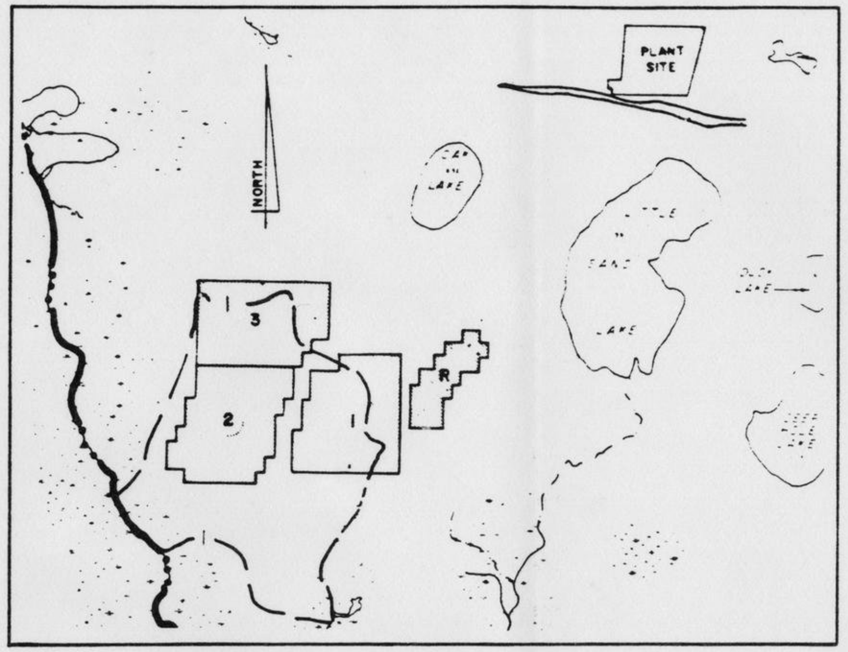
SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: CAB	DATE: 11-1-82	CHECKED BY:	DATE: 11/23/82
APPROVED BY:	DATE: 11-22-82	APPROVED BY:	DATE:
APPROVED BY:	DATE:	EXXON	DATE:
DRAWING NO: 050-1-80627	SHEET OF		REVISION NO: 0

REVISION	DATE	BY	DESCRIPTION

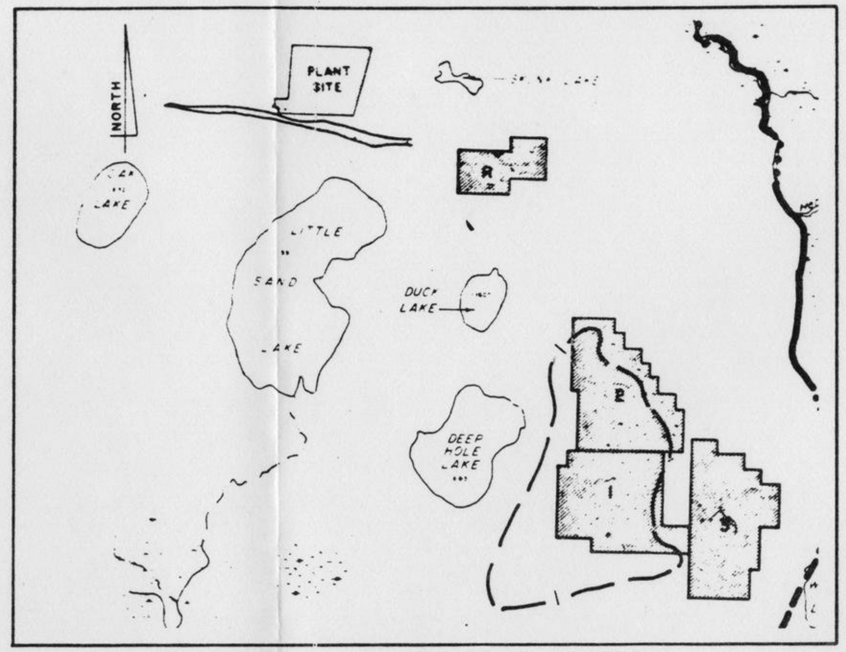
the large wetland to the east of Deep Hole Lake and minimizes seepage movement toward Hemlock Creek. The Site 40 area option studied is to the southwest of Oak Lake. Figure 8.21 shows the 4 sites studied and the simulated seepage concentration contours at year 31, one year after assumed reclamation. The groundwater gradients beneath the Site 40 option slope uniformly to the southwest, causing the seepage plume to move toward Rolling Stone Lake, about 2000 feet (610 m) away. This short travel distance yields relatively little time compared to the other options for attenuation and dispersion of the seepage in the aquifer. The 41 Western and 41 Center sites are similar in that they straddle the groundwater mound beneath the Site 41 area. Both options show simulated peak concentrations of 10 percent and show seepage plume movement toward Hemlock Creek. The Site 41 Southwest option is positioned on the southwest side of the Site 41 area groundwater mound and therefore shows no movement of seepage toward Hemlock Creek.

To assess the long term hydrologic effects, seepage movement was simulated until a steady-state condition was reached. Figure 8.22 shows the resulting seepage plumes. The Site 40 area option reached steady-state conditions by about 100 years after operation began due to its close proximity to Rolling Stone Lake and its tributary. The peak seepage concentration at this site is lower than the other options studied, but the seepage flows directly toward Rolling Stone Lake with relatively less time for attenuation or other mitigating influences than the other options.

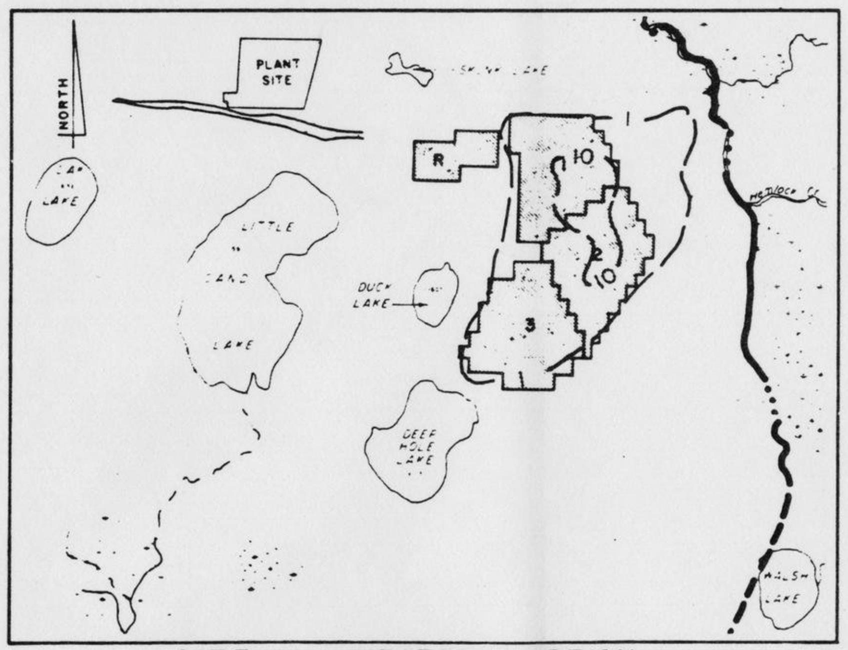
The Site 41 area options all require about twice the time to reach steady-state conditions and the seepage plumes are presented at about year 200. The Site 41 Center and Site 41 Western options both show steady-state seepage



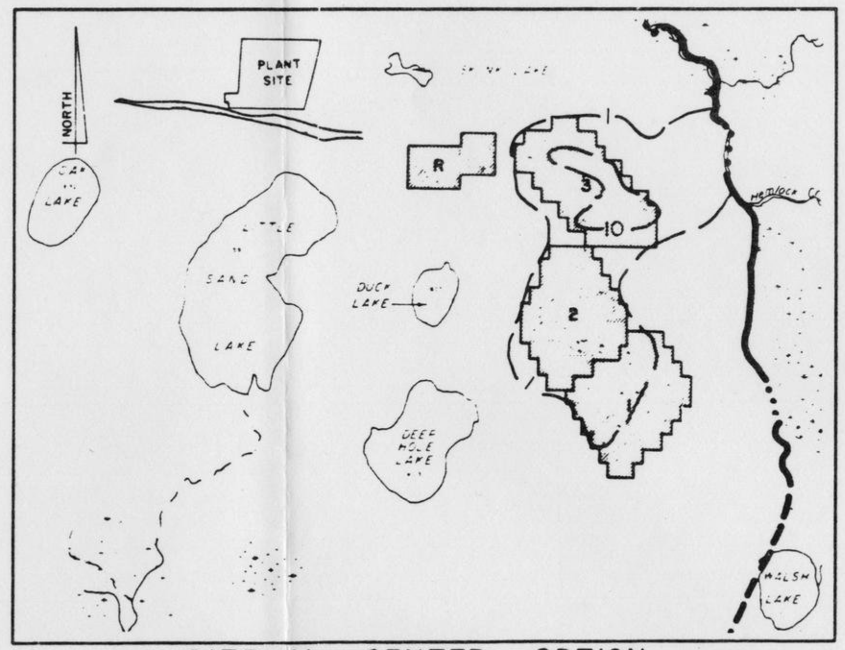
SITE 40



SITE 41 - SOUTHWEST OPTION



SITE 41 - WESTERN OPTION



SITE 41 - CENTER OPTION

NOTES

1. TIMES PRESENTED ASSUME THAT POND SEEPAGE ENTERS SATURATED COARSE GRAINED STRATIFIED DRIFT AT TIME ZERO.
2. ALL ANALYSES PRESENTED ARE AT 1 YEAR AFTER SYSTEM CLOSURE.
3. RECLAIMATION COVER INFILTRATION IS 1 INCH / YEAR
4. RECLAIM POND ASSUMED LINED WITH SYNTHETIC LINER OVER A 6" THICK TILL / BENTONITE MIX FOR ALL CASES.
5. TAILINGS POND LINER BENEATH UNDERDRAIN IS 1.0' THICK TILL/ BENTONITE MIX.
6. GROUNDWATER MODEL PARAMETERS FOR THESE ANALYSES PRESENTED ON DRAWING NO. 050-1-80636, FIGURE 8.11.
7. SEEPAGE HISTORY SHOWN ON DRAWING NO. 050-1-80522, FIGURE 8.15.

LEGEND

—— 10 ——	POND SEEPAGE CONCENTRATION CONTOURS (PERCENT)
[1]	WASTE SYSTEM POND: R - RECLAIM POND 1, 2 & 3 - TAILINGS POND
═══	CRANDON FORMATION
— — — —	GROUNDWATER NO FLOW BOUNDARY
— · · · —	GROUNDWATER CONSTANT HEAD BOUNDARY

0 1000 2000 4000 6000
SCALE IN FEET

REVISED	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

FIGURE 8.21

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

SEEPAGE CONCENTRATION CONTOURS
SITING COMPARISONS
SITES 40 AND 41

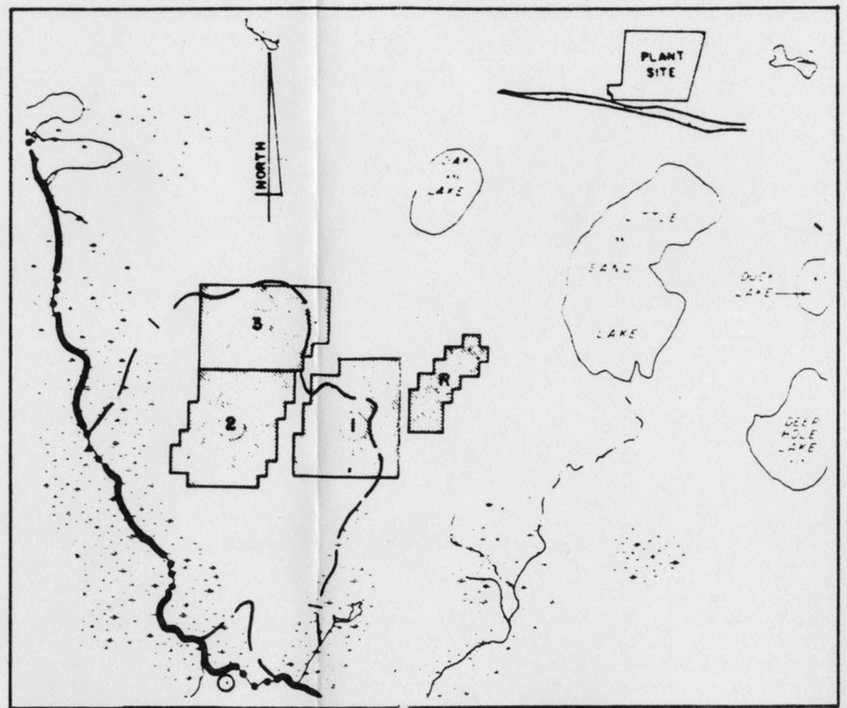
AS SHOWN	WISCONSIN	FOREST
DRAWN BY: CAB	DATE: 11-1-82	DATE: 11/22/82
DRAWING NO. 050-1-80628	SHEET ___ OF ___	REVISION NO. 0

NOTES

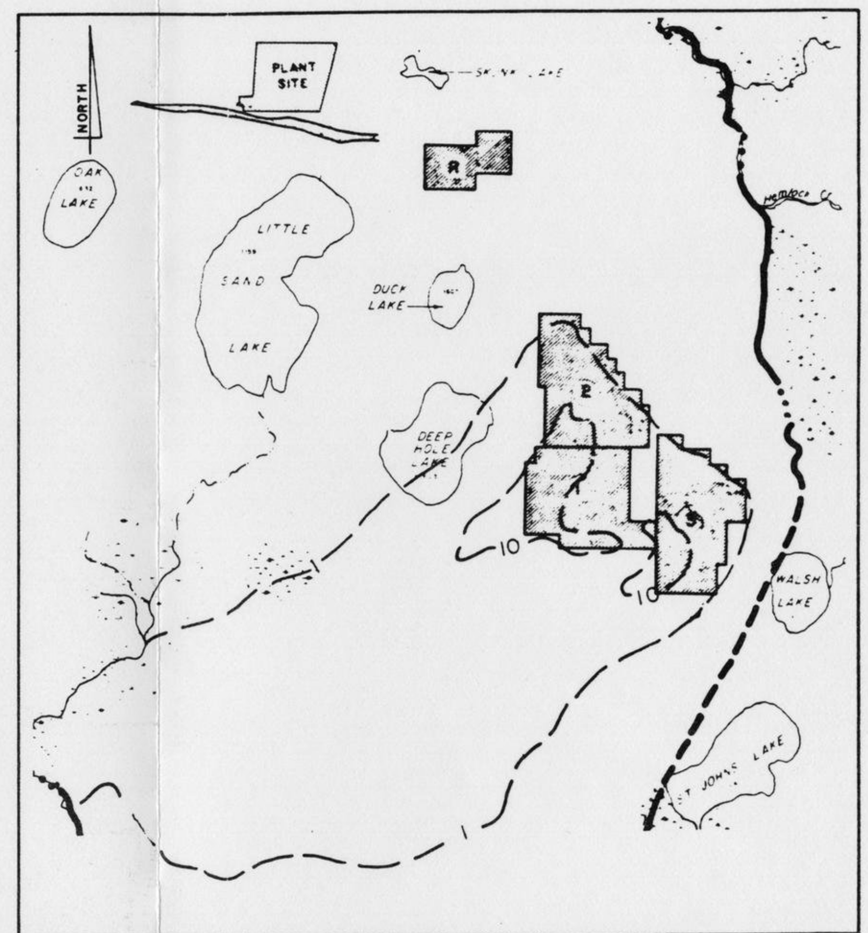
1. TIMES PRESENTED ASSUME THAT POND SEEPAGE ENTERS SATURATED COARSE GRAINED STRATIFIED DRIFT AT TIME ZERO
2. RECLAIM POND ASSUMED LINED WITH SYNTHETIC LINER OVER A 6" THICK TILL / BENTONITE MIX FOR ALL CASES
3. TAILINGS POND LINER BENEATH UNDERDRAIN IS 1.0' THICK TILL / BENTONITE MIX.
4. RECLAIMATION COVER INFILTRATION IS 1.0 INCH / YEAR.
5. GROUNDWATER MODEL PARAMETERS FOR THESE ANALYSES PRESENTED ON DRAWING NO 050-1-80636, FIGURE 8.11.
6. SEEPAGE HISTORY SHOWN ON DRAWING NO 050-1-80522, FIGURE 8.15.

LEGEND

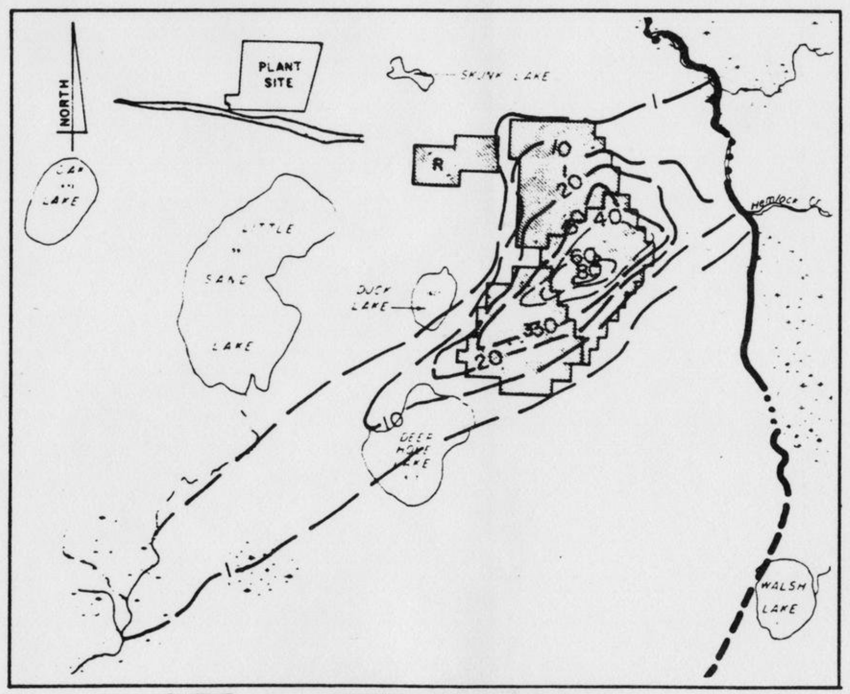
— — 10 — —	POND SEEPAGE CONCENTRATION CONTOURS (PERCENT)
[1]	WASTE SYSTEM POND: R - RECLAIM POND; 1, 2 & 3 - TAILINGS POND
═══	CRANDON FORMATION
— — — —	GROUNDWATER NO FLOW BOUNDARY
—··· —	GROUNDWATER CONSTANT HEAD BOUNDARY



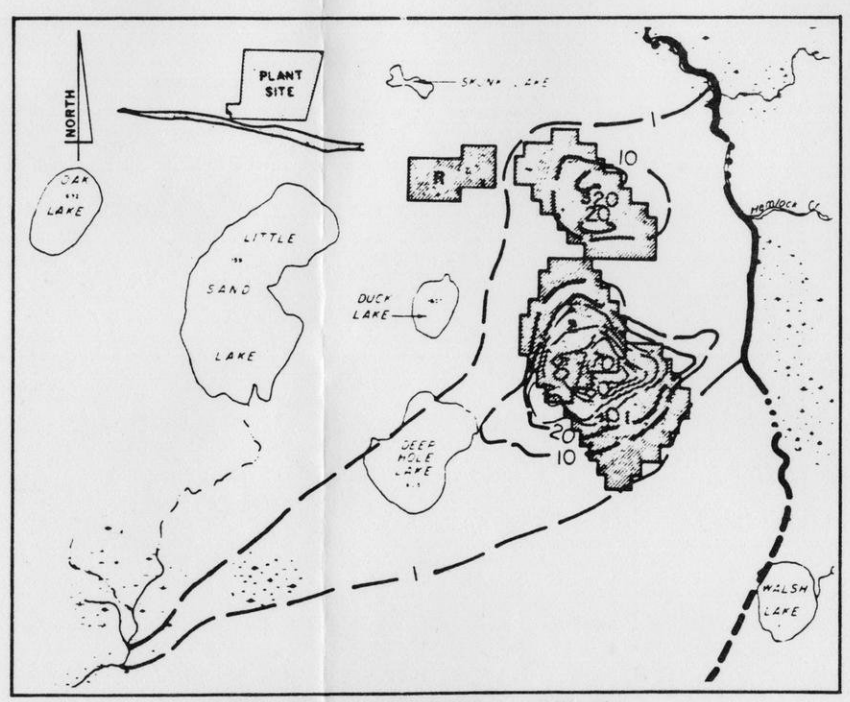
SITE 40
70 YEARS AFTER CLOSURE



SITE 41 - SOUTHWEST OPTION
170 YEARS AFTER CLOSURE



SITE 41 - WESTERN OPTION
170 YEARS AFTER CLOSURE



SITE 41 - CENTER OPTION
170 YEARS AFTER CLOSURE

0 1000 2000 4000 6000
SCALE IN FEET

FIGURE 8.22

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

SEEPAGE CONCENTRATION CONTOURS
STEADY STATE COMPARISON
SITES 40 AND 41

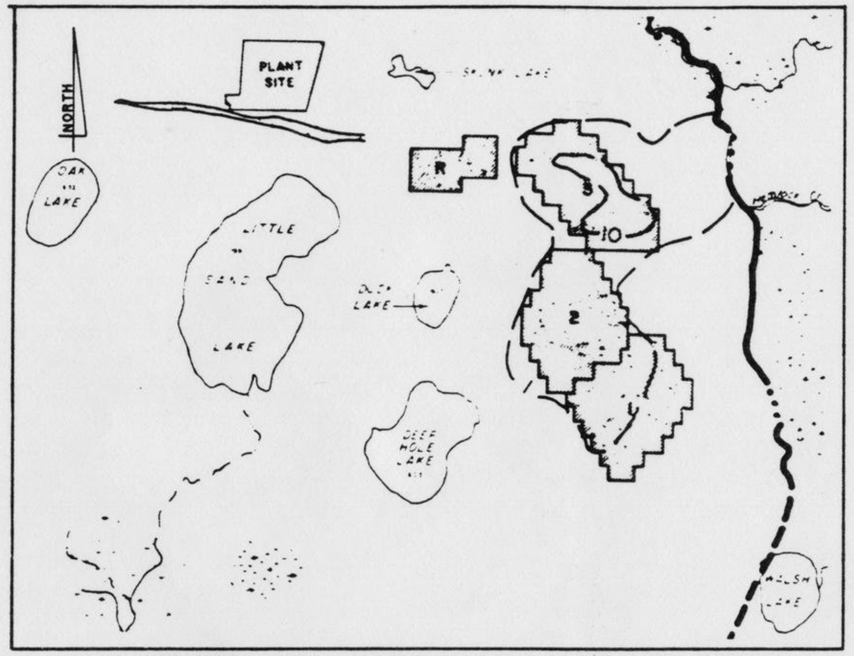
SCALE AS SHOWN | STATE WISCONSIN | COUNTY FOREST
DRAWN CAB | DATE 11-1-82
DATE 11-22-82
DRAWING NO. 050-1-80629 | REVISION 0

EXXON PROPRIETARY

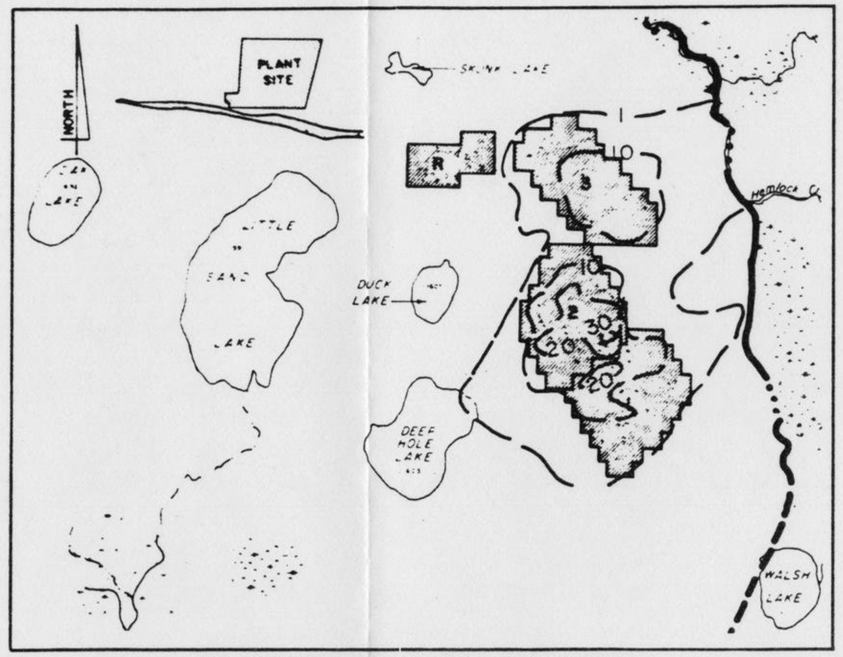
plumes which move toward Rolling Stone Lake and Hemlock Creek. Also, peak seepage concentrations of 70 and 80 percent are reached beneath the ponds. These high concentrations are due to the flattening of the groundwater gradients beneath the ponds from decreased infiltration. The resulting low gradients slow the lateral movement of seepage and yield a zone of limited movement that tends to hold the seepage beneath the facility.

The Site 41 Southwestern option, located southwest of the Site 41 area groundwater divide, shows the simulated seepage plume moving only toward Rolling Stone Lake. Since the ponds do not straddle the Site 41 area groundwater mound, the gradient modification from reduced infiltration does not produce the limited movement zone seen in the other two Site 41 area options. The peak seepage concentration reached is about 10 percent. the distance to Rolling Stone Lake is about 12,000 feet (3660 m), providing relatively long opportunity for geochemical attenuation.

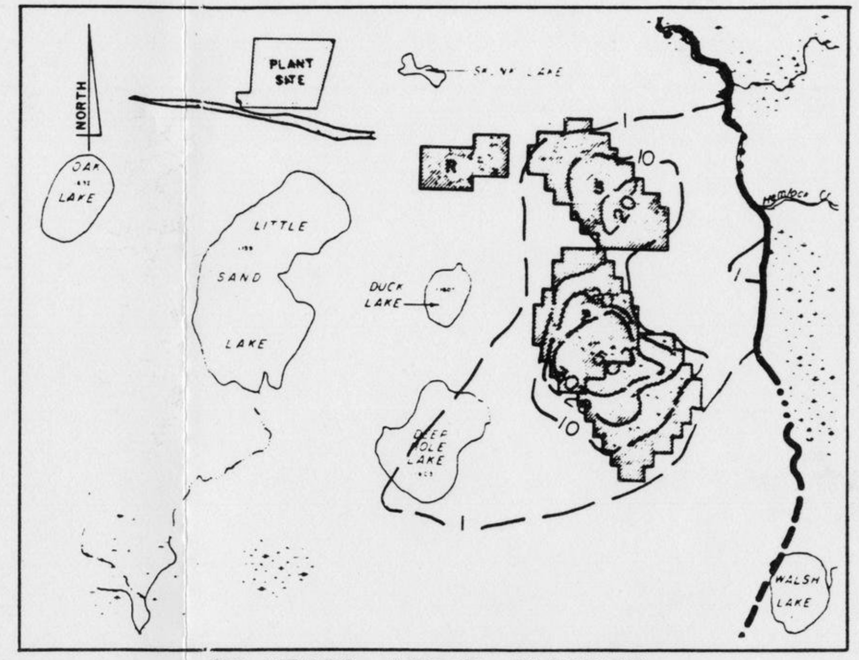
The steady-state seepage plume configuration is highly dependent upon the infiltration through the reclamation cover. The seepage plumes shown in Figure 8.22 are from an infiltration rate of about 1 inch per year (25.4 mm/yr.). To determine the sensitivity of this parameter a similar analysis was performed on the 41 Center option with approximately 3 inches per year (76.2 mm/yr.) infiltration. Figure 8.23 shows a comparison of seepage plumes at about 30, 60, and 100 years for each of the two infiltration rates. Note that both the extent of seepage movement and peak concentrations reached are greater for the 3 inch per year (76.2 mm/yr.) infiltration rate.



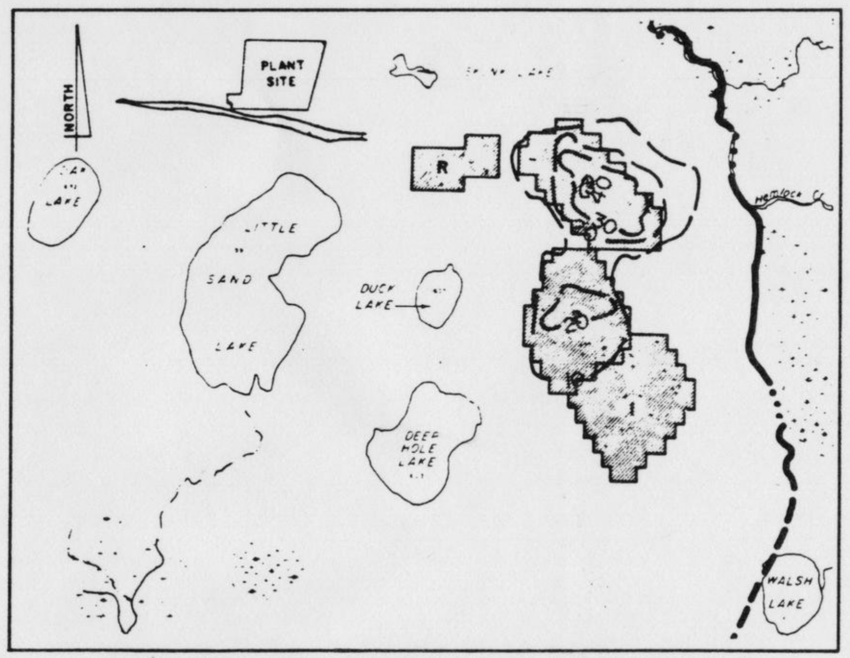
30 YEARS INTO OPERATION (AT CLOSURE)
COVER INFILTRATION = 1 INCH/YEAR



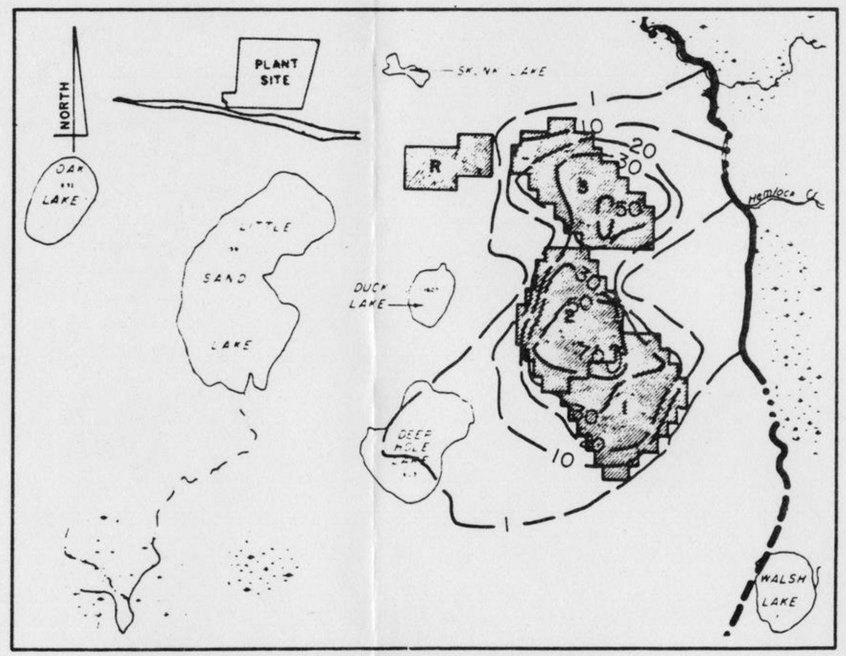
30 YEARS AFTER CLOSURE
COVER INFILTRATION = 1 INCH/YEAR



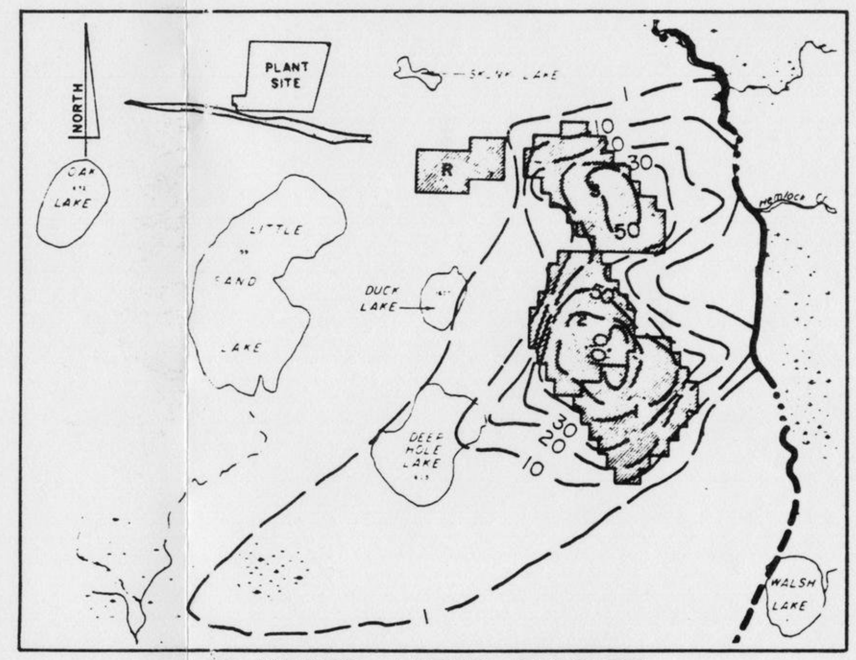
70 YEARS AFTER CLOSURE
COVER INFILTRATION = 1 INCH/YEAR



30 YEARS INTO OPERATION (AT CLOSURE)
COVER INFILTRATION = 3 INCHES/YEAR



30 YEARS AFTER CLOSURE
COVER INFILTRATION = 3 INCHES/YEAR



70 YEARS AFTER CLOSURE
COVER INFILTRATION = 3 INCHES/YEAR

LEGEND

- — — 10 — — POND SEEPAGE CONCENTRATION CONTOURS (PERCENT)
- [1] WASTE SYSTEM POND: R - RECLAIM POND; 1, 2 & 3 - TAILINGS POND
- CRANDON FORMATION
- GROUNDWATER NO FLOW BOUNDARY
- GROUNDWATER CONSTANT HEAD BOUNDARY

NOTES

1. TIMES PRESENTED ASSUME THAT POND SEEPAGE ENTERS SATURATED COARSE GRAINED STRATIFIED DRIFT AT TIME ZERO.
2. RECLAIM POND ASSUMED LINED WITH SYNTHETIC LINER OVER A 6" THICK TILL / BENTONITE MIX FOR ALL CASES.
3. TAILINGS POND LINER BENEATH UNDERDRAIN IS 1.0' THICK TILL / BENTONITE MIX
4. GROUNDWATER MODEL PARAMETERS FOR THESE ANALYSES PRESENTED ON DRAWING NO. 050-1-80636, FIGURE 8.11.
5. SEEPAGE HISTORY SHOWN ON DRAWING NO. 050-1-80522, FIGURE 8.15.

0 1000 2000 4000 6000
SCALE IN FEET

REVISED	DATE	BY	DESCRIPTION

FIGURE 8.23

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SEEPAGE CONCENTRATION CONTOURS RECLAMATION COVER COMPARISON SITE 41 - CENTER OPTION

SCALE: AS SHOWN | STATE: WISCONSIN | COUNTY: FOREST
DRAWN BY: CAB | DATE: 11-?-82 | CHECKED BY: JEB | DATE: 11/22/82
APPROVED BY: [signature] | DATE: 11 22 82
DRAWING NO. 050-1-80630 | REVISION NO. 0

8.6 Conclusions

The seepage concentration contours which resulted from this alternative screening study allowed the hydrologic impact of various waste management system alternatives to be incorporated in the overall alternatives review process. The concentration values presented herein should not be taken as a detailed assessment of hydrologic effects, since several simplifying assumptions were made. Also, no allowance has been made for the time for seepage movement vertically from the pond bottom to the coarse grained stratified drift. However, the relative effects of the alternatives studied are evident from the results of the study. Five major conclusions resulted from this preliminary assessment.

1. An underdrain and bentonite/till liner will provide the lowest seepage rate of the systems considered and is proposed as the seepage control system.

2. Mine waste disposal facilities can be designed in the Site 41 area to provide lesser overall environmental effect on the groundwater and surface water system than the Site 40 area because of the longer average flow path and increased opportunity for chemical attenuation.

3. Of the Site 41 area systems studied, System 41 Southwest provides the least groundwater effects on the Hemlock Creek/Swamp Creek surface water system.

4. The Site 41 area Center and Western options result in a zone of limited movement beneath the waste system that tends to retard movement of seepage.

5. The final steady-state seepage (cover infiltration) has a major influence on the steady-state plume configuration.

The decision to employ an underdrain and liner system was based upon the low amount of seepage expected from the system and limited extent of the preliminary seepage plume. The operating underdrain system reduces the pressure head of pond water acting against the liner beneath the drain. Reducing the head reduces the driving force of the seepage on the liner and hence reduces the amount of seepage through the liner. Subsequent studies presented in Golder Associates' Project Report 3.2 (Ref. 13) have shown that the varying thickness of the liner from 5 feet (1.5 m) to 6 inches (152 mm) has very little effect on the seepage rate through the liner because it is controlled by head build-up in the underdrain. Therefore, a 6 inch (152 mm) thick liner has been recommended for the final mine waste disposal system.

The preference of the Site 41 area over the Site 40 area is based upon the long flow path between the Site 41 area to Rolling Stone Lake and its tributaries and the increased opportunity for geochemical attenuation/retardation and dispersive effects. The 41 Southwest option at the Site 41 area is preferred from the standpoint of avoidance of significant seepage into Hemlock and Swamp Creeks. The significant direction of plume advance from system 41 Southwest is toward Rolling Stone Lake, approximately 3 miles (1.8 km) from the facility. In addition to its length, this flow path has relative low groundwater gradients. Therefore, the long travel time of the simulated system 41 Southwest seepage plume allows maximum opportunity for geochemical attenuation and retardation as the seepage crosses the 1200 foot (366 m) compliance boundary and as it flows toward Rolling Stone Lake. However, these studies do not account for the coarse grained stratified drift being near the ground surface over a large portion of the Site 41 Southwest option which would decrease vertical flow time of seepage and reduce the potential for chemical attentuation. The Center and Western alternatives in the Site 41 area provide a zone of limited movement beneath the waste system area. Although high seepage concentrations develop beneath the systems, the concentrations moving away from the area are low and occur over long time periods which permit more opportunity for dilution.

9.0 RECOMMENDED SLURRY SYSTEM

9.1 Selected Site

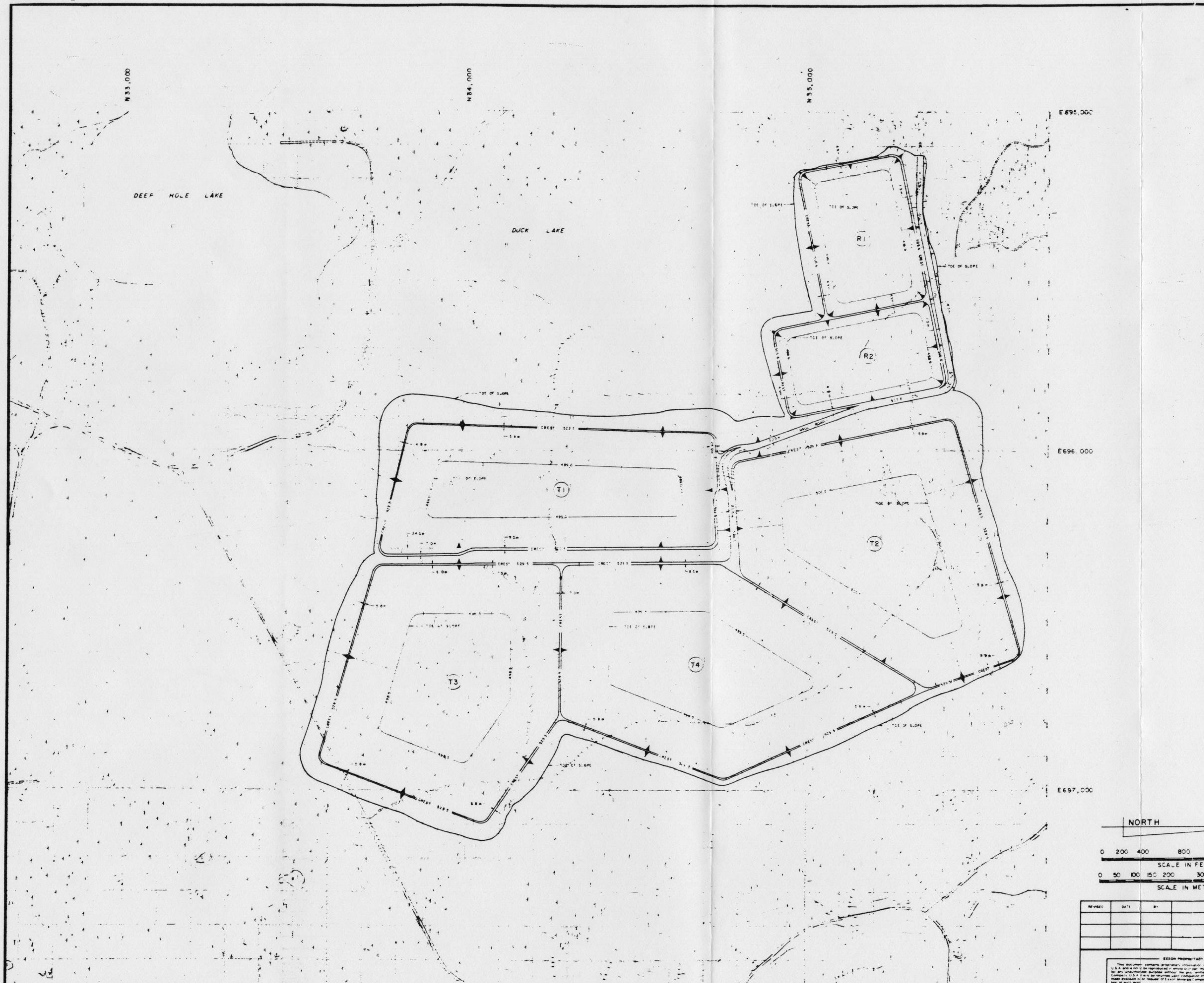
From the various alternative site systems compared in Section 7 of this report and from the screening analyses of preliminary potential groundwater effects discussed in Section 8 of this report, it is Exxon's and Golder Associates' collective opinion that System 41-114 is the most viable mine waste disposal system. System 41-114 covers and/or effects more wetland acreage than other systems, but adheres to the criteria of proposed NR 182 in being more than 1,000 feet (305 m) from the lakes. System 41-114 is a four pond system and thus has stage construction and stage reclamation advantages over system 41-109, the only other system maintaining the 1,000 foot (305 m) lake offset. The study of the Site 41 center and west options showed that System 41-114 is essentially equal in potential groundwater effects to systems 41-103, 106, and 109. These potential effects are directed toward Rolling Stone Lake and to a lesser degree toward Hemlock Creek which drains into Swamp Creek. System 41-121 is the only system which does not potentially effect the Hemlock Creek/Swamp Creek system. However, system 41-121 covers the large wetland east of Deep Hole Lake which is a major surface feature in the Deep Hole Lake drainage area and there is very little glacial till beneath this system in the vicinity of the large wetland east of Deep Hole Lake.

Having been selected as the most advantageous mine waste disposal site system, further preliminary engineering design has been done with system 41-114. In order to facilitate ease of discussion and comparison of the more detailed design features, the recommended system has been designated 41-114B. The 41-114 designation is applicable to the system and commensurate level of detail as presented in Section 7 of this report.

9.2 System 41-114B Layout

The final system 41-114B layout is presented on Figure 9.1. The tailings ponds and reclaim ponds are shown at a larger scale on Figures 9.2 and 9.3 respectively. These drawings reflect the waste disposal system plan which has been developed to provide for permanent storage of the mine/mill waste products based on an estimated 77 million DMT orebody. The system has been designed so that waste rock is included in the embankments or used as rock slope protection. Cover material for reclamation will be obtained from material excavated within the tailings pond areas. Benches have been added to the interior slope of tailings pond embankments to facilitate construction and to permit vertical staged construction of the liner, underdrain, and rock slope protection. Two reclaim ponds are included in the system with different normal water levels and a mixing box between them so that chemicals can be added as the water flows from one pond to the other. Seepage control liners will be included in the reclaim ponds and tailings ponds with an underdrain system installed above the tailings pond liners. Typical cross sections of the system 41-114B layout are shown on Figures 9.4 through 9.7.

The system 41-114B layout differs in plan location from the 41-114 system in the position of the reclaim ponds and the outline of tailings pond T4. The reclaim pond locations have been adjusted to keep the embankments outside of the wetland northeast of Duck Lake. This modification was in response to the most recent definition of wetland boundaries. Tailings pond T4 is larger in plan



WASTE DISPOSAL SYSTEM AND RECLAIM POND DATA

Tailings and Reclaim Pond Area (ha) (1)	233.6	Abandonment Cover Seal Thickness (m)	0.15
Tailings Pond Abandonment Area (ha) (2)	202.2	Minimum Abandonment Cover Thickness (m)	1.7
Wetlands Covered (ha) (3)	22.7	Underdrain Drain Layer Thickness (m)	0.46
Pond Excavation ($x10^6 m^3$)	13.579	Minimum Underdrain Filter Layer Thickness (Note 1) (m)	0.46
Till and Waste Rock Embankment Fill ($x10^6 m^3$)	6.566	Minimum Rock Slope Protection Thickness (Note 2) (m)	1.0
Waste Rock Embankment Fill ($x10^6 m^3$)	1.04	Reclaim Pond Synthetic Liner Thickness (mm)	0.91
Minimum Crest Width (Note 3) (m)	4.9	Reclaim Pond Till/Bentonite Liner Thickness (m)	0.15
Processed Till For Mine Back Makeup ($x10^6 m^3$)	1.605	Sand Cushion Above Synthetic Liner Thickness (m)	0.46
Tailings Slope (%)	0.5	Sand Cushion Below Synthetic Liner Thickness (m)	0.30
Minimum Abandonment Cover Slope (%)	2.0	Protective Cushion Above Synthetic Liner Thickness (m)	0.46
Till/Bentonite Tailings Pond Liner Thickness (m)	0.15	Transition Below Reclaim Pond Rock Slope Protection Thickness (m)	0.30

WASTE DISPOSAL SYSTEM AND RECLAIM POND DATA NOTES

POND DATA \ POND NUMBER	R1	R2	T1 (See Note 11)	T2	T3	T4	Σ
Period of Use (yrs) (4)	0-30	0-30	4-9	10-16	17-23	24-30	—
Area Inside Crest (ha)	12.70	11.65	33.08	43.86	40.29	39.98	18[illegible].56
Bottom Area (ha)	8.14	8.13	11.11	15.32	12.92	14.10	69.72
Lined Slope Area (ha)	4.74	3.81	20.39	32.64	26.09	27.22	114.89
Maximum Interior Depth (m)	8.7	7.0	23.5	29.0	31.0	30.0	—
Maximum Exterior Fill Height (m)	13.1	13.0	29.0	32.5	21.7	13.6	—
Crest Elevation (m) (5)	505.6	505.6	522.5	529.5	529.5	529.5	—
Lowest Bottom Elevation (m)	496.9	498.6	499.0	500.5	498.5	499.5	—
Struck Storage Volume ($x10^6 m^3$) (6)	0.59	0.59	5.00	7.56	7.24	7.67	27.47
Tailings Storage Volume ($x10^6 m^3$)	—	—	4.34	6.57	6.29	6.67	23.87
Till Excavation ($x10^6 m^3$)	0.369	0.308	2.346	3.755	2.867	3.934	13.579
Till Embankment ($x10^6 m^3$)	0.245	0.156	1.869	1.324	1.759	0.173	5.526
Synthetic Liner Area (ha)	13.64	12.47	—	—	—	—	26.[illegible]
Till/Bentonite Liner Volume ($x10^6 m^3$) (10)	0.020	0.018	0.073	0.077	0.063	0.069	0.320
Underdrain Drain Material Volume ($x10^6 m^3$)	—	—	0.221	0.226	0.179	0.202	0.828
Underdrain Filter Material Volume ($x10^6 m^3$) (7)	—	—	0.214	0.35[illegible]	0.273	0.293	1.13[illegible]
Rock Slope Protection Volume ($x10^6 m^3$) (8)	0.021	0.012	0.270	0.243	0.170	0.181	0.897
Abandonment Cover Volume ($x10^6 m^3$) (9)	—	—	0.885	1.514	1.260	1.903	5.562
Till/Bentonite Abandonment Cover Seal ($x10^6 m^3$) (10)	—	—	0.051	0.066	0.060	0.110	0.287
Sand Cushion Above Synthetic Liner ($x10^6 m^3$)	0.014	0.008	—	—	—	—	0.022
Sand Cushion Below Synthetic Liner ($x10^6 m^3$)	0.039	0.035	—	—	—	—	0.074
Protective Cushion Above Synthetic Liner ($x10^6 m^3$)	0.048	0.047	—	—	—	—	0.095
Transition Below Reclaim Pond Rock Slope Protection ($x10^6 m^3$)	0.008	0.004	—	—	—	—	0.012
Underdrain Collector Pipe Length (m)	—	—	1760	1610	1380	1545	6295
Sump Discharge Pipe Length (m)	—	—	345	410	435	425	1615

WASTE DISPOSAL SYSTEM DATA AND RECLAIM POND DATA NOTES

1. Measured to outside toe of slope
2. Includes tailings ponds only.
3. Represents wetland areas within limits of construction
4. Start of construction for Crandon Project at beginning of year one.
5. Crest width varies from 4.9 meters to 9.0 meters depending on number of pipelines along crest
6. Measured below a level surface below freeboard height. Freeboard for R1 is 2.59 meters. Freeboard for all other ponds is 0.91 meters. Σ for tailings ponds only
7. Underdrain filter 1.0 meter thick beneath rock slope protection on tailings ponds T2, T3, and T4
8. Rock slope protection 2.0 meters thick on tailings pond T1
9. Includes working mat and material for grading below top seal and 1.0 meter till cover over top seal
10. Volume is 13% higher than till required to provide allowance for bentonite
11. Excavation, fill, and underdrain material volume for grading below waste rock embankment and storage area included with tailings pond T1 volume

GENERAL NOTES

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. SITE AREA MAPPING AT 1.0 METER CONTOUR INTERVAL. ADDITIONAL AREA TO THE NORTH AND WEST WAS ADDED AT THE AVAILABLE 2.0 METER CONTOUR INTERVAL TO PROVIDE ADDITIONAL COVERAGE
4. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM

FIGURE 9.1

Golder Associates
Atlanta, Georgia

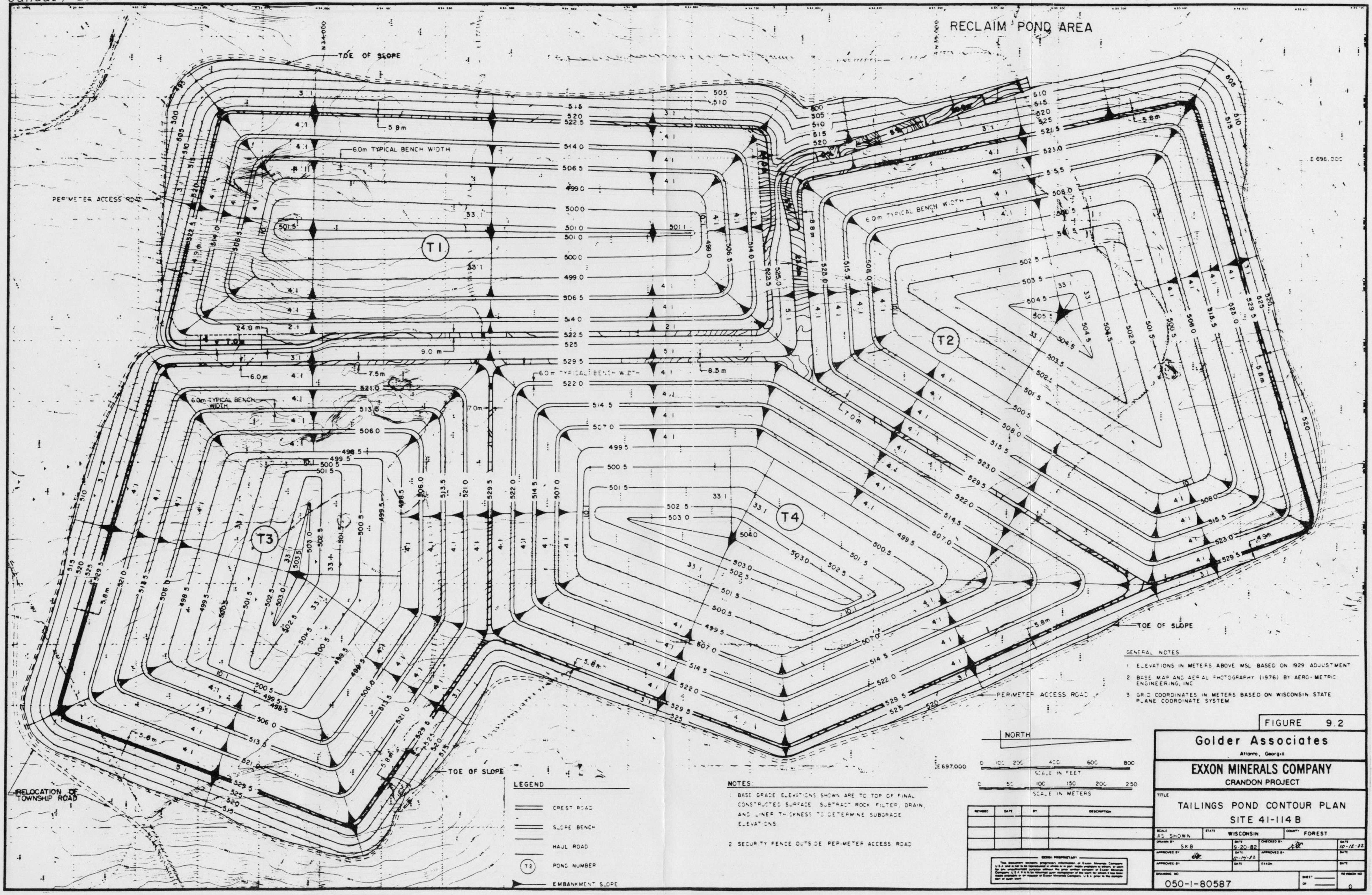
EXXON MINERALS COMPANY
CRANDON PROJECT

WASTE DISPOSAL SYSTEM
SITE 41-114B

SCALE: AS SHOWN | STATE: WISCONSIN | COUNTY: FOREST

DRAWN BY: SKB | DATE: 9-22-82 | DATE: 12-10-82

050-1-80631


RECLAIM POND AREA
TOE OF SLOPE
PERIMETER ACCESS ROAD
6.0m TYPICAL BENCH WIDTH
T1
T2
T3
T4
RELOCATION OF TOWNSHIP ROAD
LEGEND
CREST ROAD
SLOPE BENCH
HAUL ROAD
T2 POND NUMBER
EMBANKMENT SLOPE
NOTES:
1 BASE GRADE ELEVATIONS SHOWN ARE TO TOP OF FINAL CONSTRUCTED SURFACE. SUBTRACT ROCK FILTER, DRAIN, AND LINER THICKNESS TO DETERMINE SUBGRADE ELEVATIONS.
2 SECURITY FENCE OUTSIDE PERIMETER ACCESS ROAD
NORTH
SCALE IN FEET
SCALE IN METERS
GENERAL NOTES
1 ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2 BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC
3 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM
FIGURE 9.2
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
TAILINGS POND CONTOUR PLAN
SITE 41-114 B
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY SKB
9-20-82
050-1-80587

WASTE DISPOSAL SYSTEM AND RECLAIM POND DATA			
Tailings and Reclaim Pond Area (ha) (1)	233.6	Abandonment Cover Seal Thickness (m)	0.5
Tailings Pond Abandonment Area (ha) (2)	202.2	Minimum Abandonment Cover Thickness (m)	1.7
Wetlands Covered (ha) (3)	22.7	Underdrain Drain Layer Thickness (m)	0.46
Pond Excavation (x10⁶ m³)	13.579	Minimum Underdrain Filter Layer Thickness (Note 1) (m)	0.46
Till and Waste Rock Embankment Fill (x10⁶ m³)	6.566	Minimum Rock Slope Protection Thickness (Note 2) (m)	1.0
Waste Rock Embankment Fill (x10⁶ m³)	1.04	Reclaim Pond Synthetic Liner Thickness (mm)	0.9
Minimum Crest Width (Note 3) (m)	4.9	Reclaim Pond Till/Bentonite Liner Thickness (m)	0.5
Processed Till For Mine Back Makeup (x10⁶ m³)	1.605	Sand Cushion Above Synthetic Liner Thickness (m)	0.46
Tailings Slope (%)	0.5	Sand Cushion Below Synthetic Liner Thickness (m)	0.30
Minimum Abandonment Cover Slope (%)	2.0	Protective Cushion Above Synthetic Liner Thickness (m)	0.46
Till/Bentonite Tailings Pond Liner Thickness (m)	0.15	Transition Below Reclaim Pond Rock Slope Protection Thickness (m)	0.30

WASTE DISPOSAL SYSTEM AND RECLAIM POND DATA NOTES

POND DATA \ POND NUMBER	R1	R2	T1 (See Note 11)	T2	T3	T4	Σ
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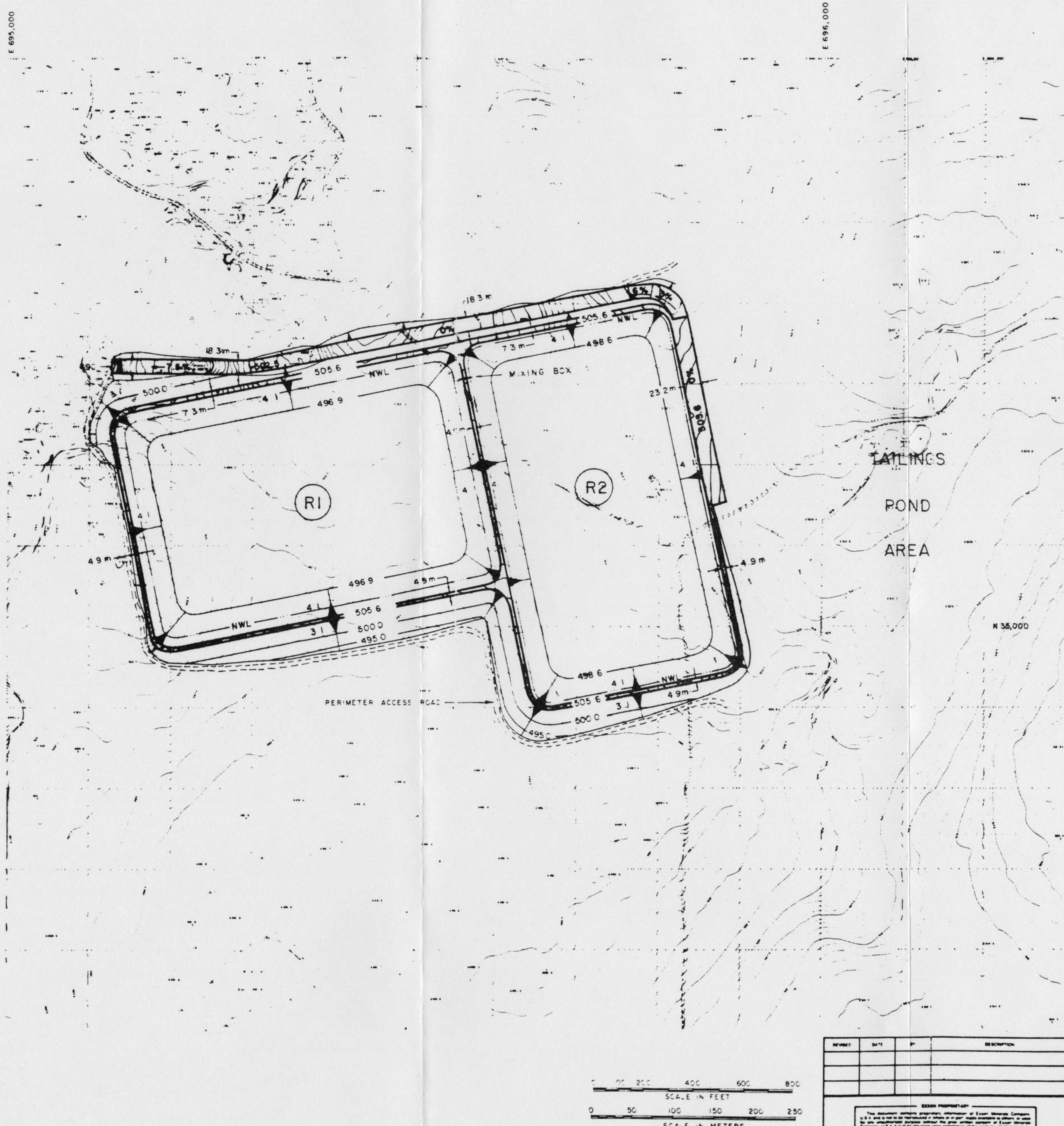
Area inside Crest (ha)	12.70	11.65	33.08	43.86	40.29	39.98	181.56
Bottom Area (ha)	8.14	8.13	11.11	15.32	12.92	14.10	69.72
Lined Slope Area (ha)	4.74	3.81	20.39	32.64	26.09	27.22	114.89
Maximum Interior Depth (m)	8.7	7.0	23.5	29.0	31.0	30.0	—
Maximum Exterior Fill Height (m)	13.1	13.0	29.0	32.5	21.7	13.6	—
Crest Elevation (m) (5)	505.6	505.6	522.5	529.5	529.5	529.5	—
Lowest Bottom Elevation (m)	496.9	498.6	499.0	500.5	498.5	499.5	—
Struck Storage Volume (x10⁶ m³) (6)	0.59	0.59	5.00	7.56	7.24	7.67	27.47
Tailings Storage Volume (x10⁶ m³)	—	—	4.34	6.57	6.29	6.67	23.87
Till Excavation (x10⁶ m³)	0.369	0.308	2.346	3.755	2.867	3.934	13.579
Till Embankment (x10⁶ m³)	0.245	0.156	1.869	1.324	1.759	[illegible]	5.526
Synthetic Liner Area (ha)	13.64	12.47	—	—	—	—	26
Till/Bentonite Liner Volume (x10⁶ m³) (10)	0.020	0.018	0.073	0.077	0.063	0.069	0.320
Underdrain Drain Material Volume (x10⁶ m³)	—	—	0.22	0.226	0.179	0.202	0.828
Underdrain Filter Material Volume (x10⁶ m³) (7)	—	—	0.214	0.351	0.273	0.293	[illegible]
Rock Slope Protection Volume (x10⁶ m³) (8)	0.021	0.012	0.270	0.243	0.170	0.181	0.897
Abandonment Cover Volume (x10⁶ m³) (9)	—	—	0.885	1.514	1.260	1.903	5.562
Till/Bentonite Abandonment Cover Seal (x10⁶ m³) (10)	—	—	0.05	0.066	0.060	0.110	0.287
Sand Cushion Above Synthetic Liner (x10⁶ m³)	0.014	0.008	—	—	—	—	0.022
Sand Cushion Below Synthetic Liner (x10⁶ m³)	0.039	0.035	—	—	—	—	0.074
Protective Cushion Above Synthetic Liner (x10⁶ m³)	0.048	0.047	—	—	—	—	0.095
Transition Below Reclaim Pond Rock Slope Protection (x10⁶ m³)	0.008	0.004	—	—	—	—	0.012
Underdrain Collector Pipe Length (m)	—	—	1760	1610	1380	1545	6295
Sump Discharge Pipe Length (m)	—	—	345	410	435	425	1615

WASTE DISPOSAL SYSTEM DATA AND RECLAIM POND DATA NOTES

1. Measured to outside toe of slope
2. Includes tailings ponds only
3. Represents wetland areas within limits of construction
4. Start of construction for Crandon Project at beginning of year one
5. Crest width varies from 4.9 meters to 9.0 meters depending on number of pipelines along crest
6. Measured below a level surface below freeboard height. Freeboard for R1 is 2.59 meters. Freeboard for all other ponds is 0.91 meters. Σ for tailings ponds only
7. Underdrain filter 1.0 meter thick beneath rock slope protection on tailings ponds T2, T3, and T4
8. Rock slope protection 2.0 meters thick on tailings pond T1
9. Includes working mat and material for grading below top seal and 1.0 meter till cover over top seal
10. Volume is 13% higher than till required to provide allowance for bentonite
11. Excavation, fill, and underdrain material volume for grading below waste rock embankment and storage area included with tailings pond T1 volume



LEGEND

- CREST ROAD
- HAUL ROAD
- (R2) POND NUMBER
- —NWL NORMAL OPERATING WATER LEVEL

NOTES

1. BASE GRADE ELEVATIONS SHOWN ARE TO TOP OF FINAL CONSTRUCTED SURFACE. SUBTRACT ROCK, FILTER, DRAIN, AND LINER THICKNESS TO DETERMINE SUBGRADE ELEVATIONS.
2. SECURITY FENCE OUTSIDE PERIMETER ACCESS ROAD

GENERAL NOTES

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM

FIGURE 9.3

Golder Associates
Atlanta, Georgia

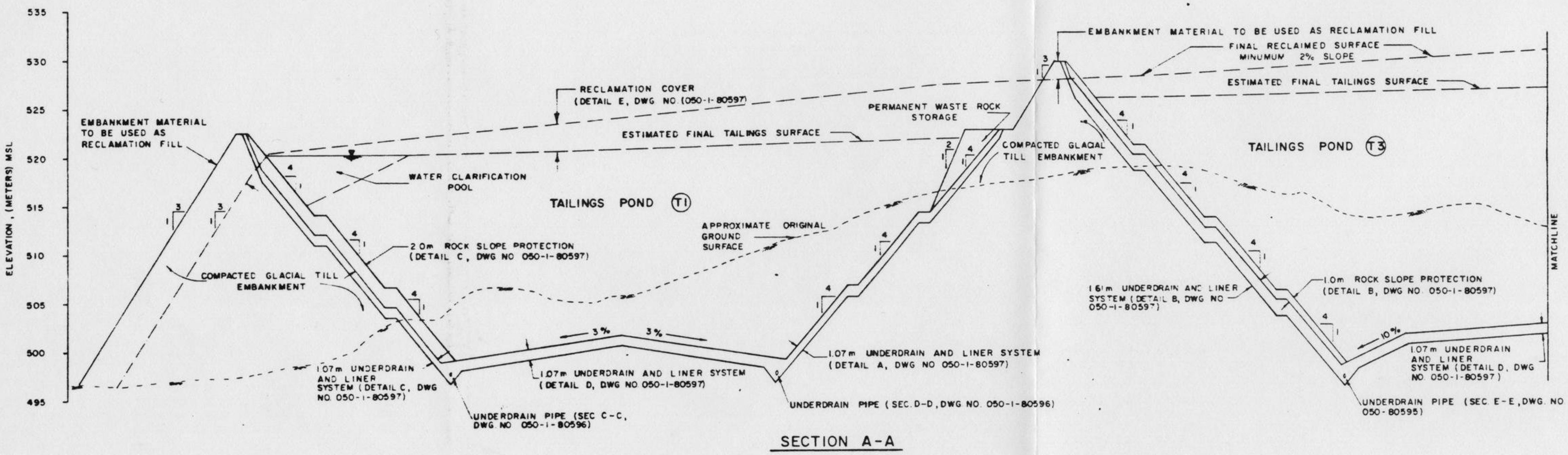
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: RECLAIM PONDS CONTOUR PLAN - SITE 41-114 B

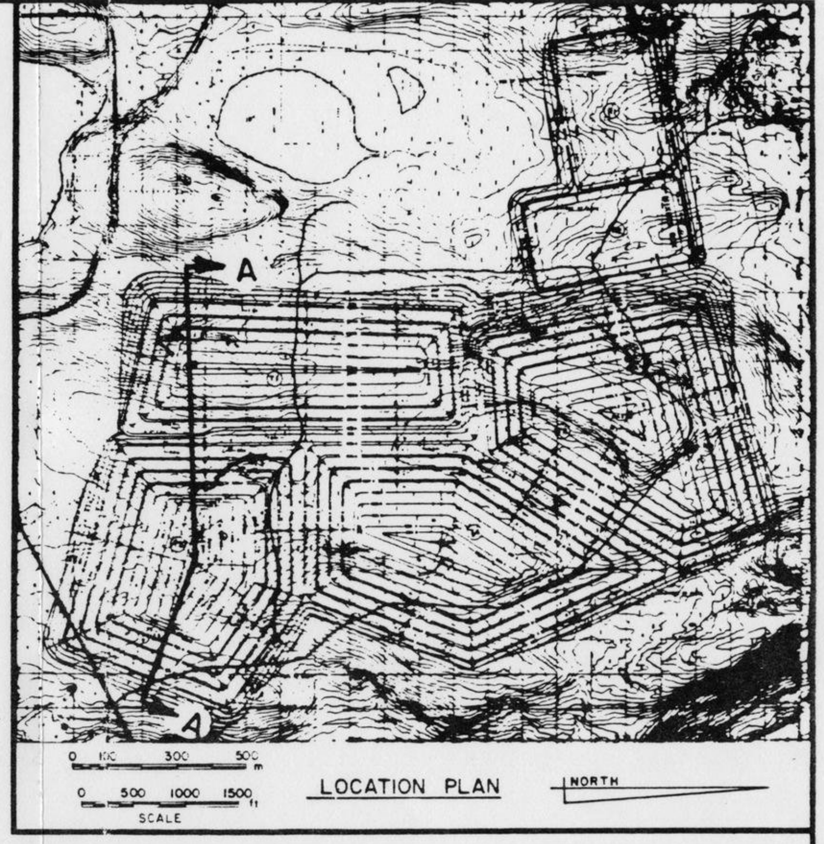
REVISED	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

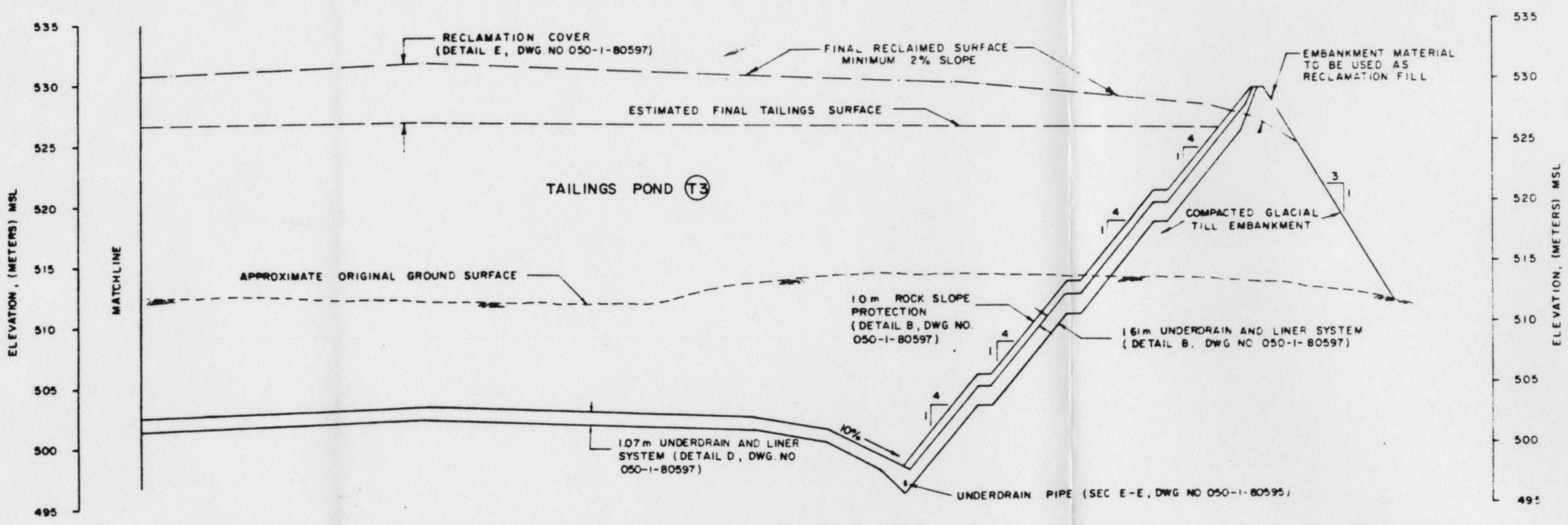
SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: SKB	DATE: 9-20-82	CHECKED BY: RMS	DATE: 11/22/82
APPROVED BY: [signature]	DATE: 11-22-82	APPROVED BY:	DATE:
APPROVED BY:	DATE:	EXXON	DATE:
DRAWING NO: 050-1-80586	SHEET ___ OF ___		REVISION NO: 0



SECTION A-A



LOCATION PLAN



SECTION A-A (con't)

NOTES AND PRELIMINARY SPECIFICATIONS

1. Glacial till embankment material shall be finer than 152 mm (6 in.) and compacted to 95% maximum dry density, within ±3% of optimum moisture content, as determined by ASTM D-698.
2. Liner material shall be glacial till finer than 19.1 mm (0.75 in.) modified with bentonite. Liner shall be compacted to 95% maximum dry density, at or above optimum moisture content, as determined by ASTM D-698.
3. Drain material shall be finer than 51 mm (2 in.) and coarser than 0.42 mm (No. 40 U.S. Standard sieve).
4. Filter material shall be glacial till finer than 152 mm (6 in.) and shall not be compacted.
5. Rock slope protection shall consist of mine waste rock.

HORIZONTAL SCALE IN FEET: 0 100 200 300 400

HORIZONTAL SCALE IN METERS: 0 25 50 75 100 125

VERTICAL EXAGGERATION 5x

REVISED	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

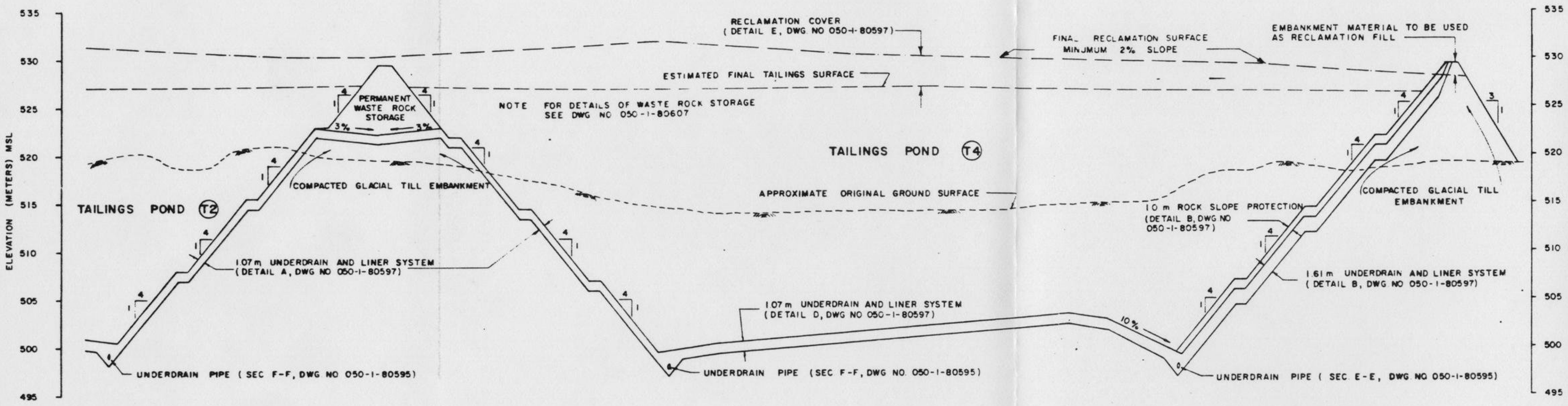
FIGURE 9.4

Golder Associates
Atlanta, Georgia

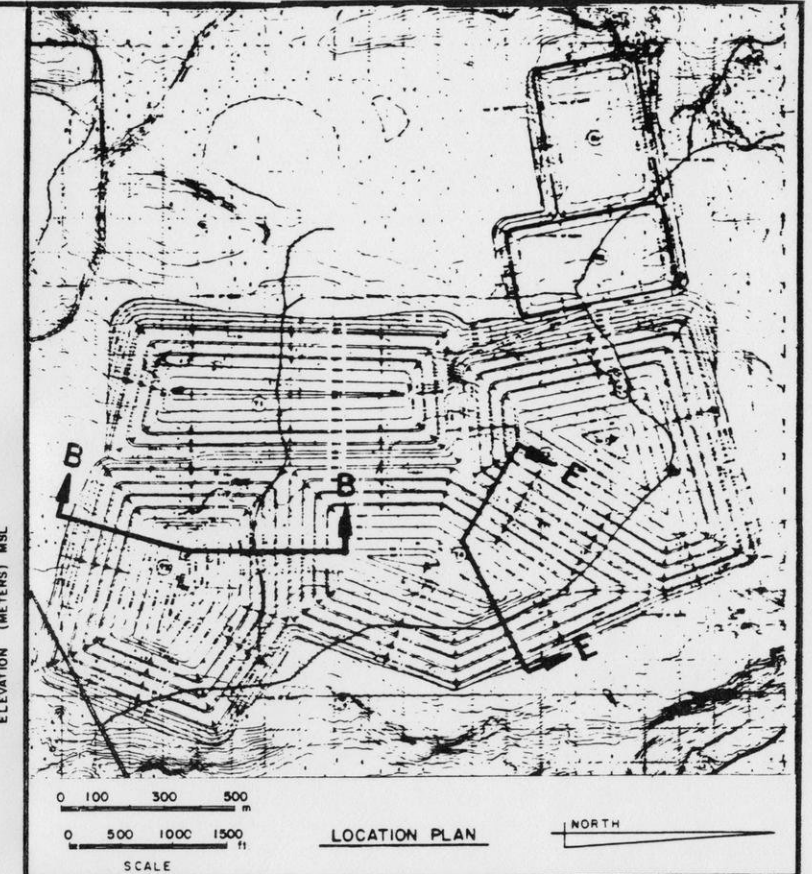
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SECTION A - A
SITE 41-114B

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: CAB, GHC	DATE: 9-20-82	CHECKED BY: RMS	DATE
APPROVED BY	DATE: 10-14-82	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO: 050-1-80593		SHEET	REVISION NO: 0

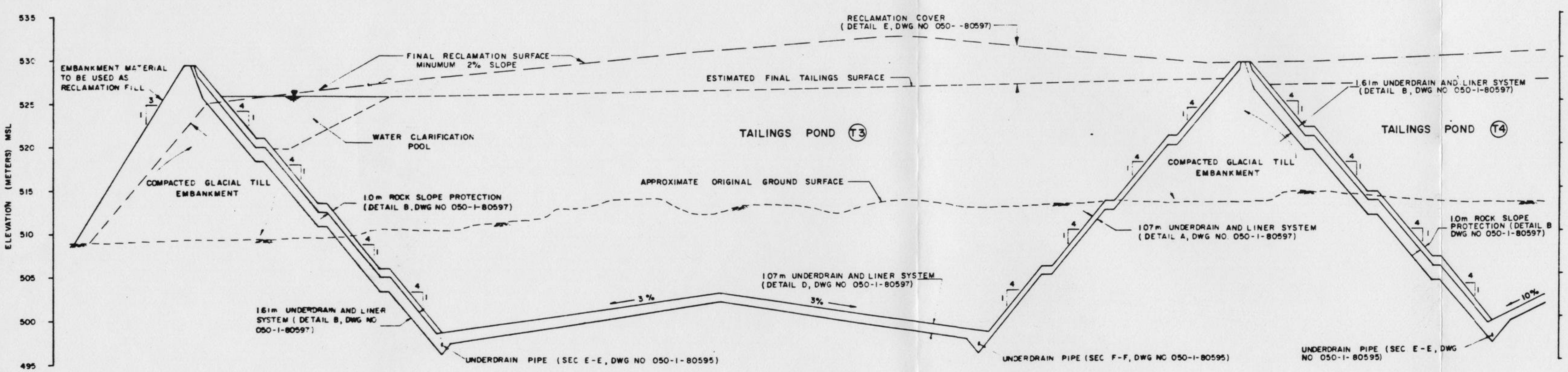


SECTION E-E

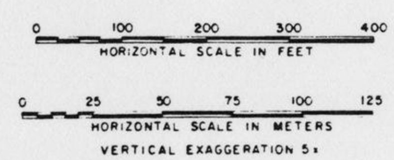


NOTES AND PRELIMINARY SPECIFICATIONS

1. Glacial till embankment material shall be finer than 152 mm (6 in.) and compacted to 95% maximum dry density, within ±3% of optimum moisture content, as determined by ASTM D-698.
2. Liner material shall be glacial till finer than 19.1 mm (0.75 in.) modified with bentonite. Liner shall be compacted to 95% maximum dry density, at or above optimum moisture content, as determined by ASTM D-698.
3. Drain material shall be finer than 51 mm (2 in.) and coarser than 0.42 mm (No. 40 U.S. Standard sieve).
4. Filter material shall be glacial till finer than 152 mm (6 in.) and shall not be compacted.
5. Rock slope protection shall consist of mine waste rock.



SECTION B-B



REVISED	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

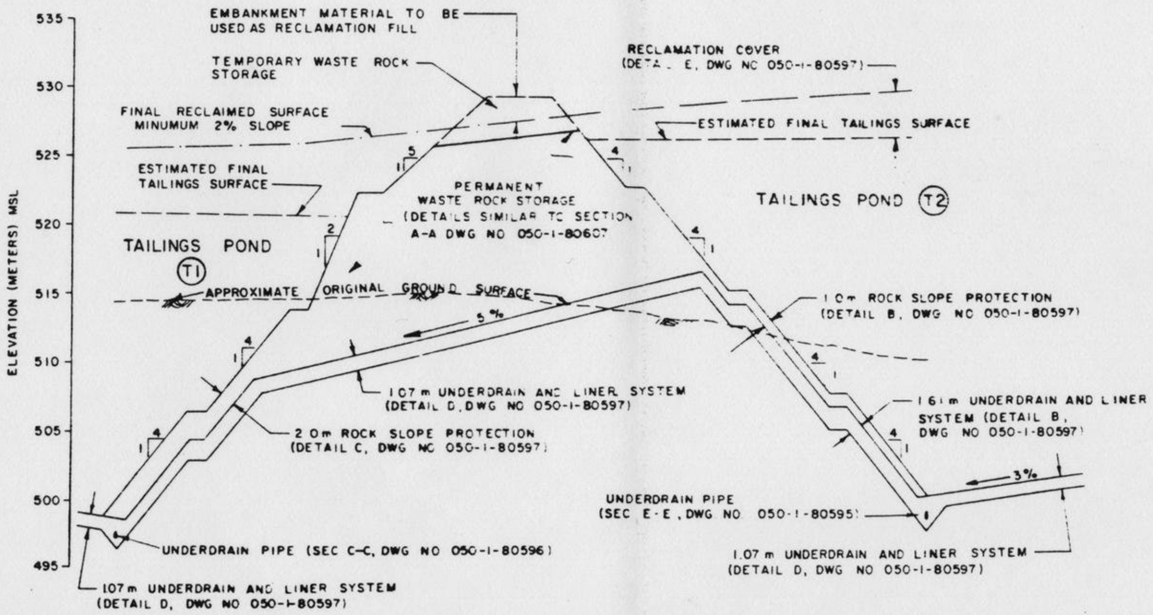
FIGURE 9.5

Golder Associates
Atlanta, Georgia

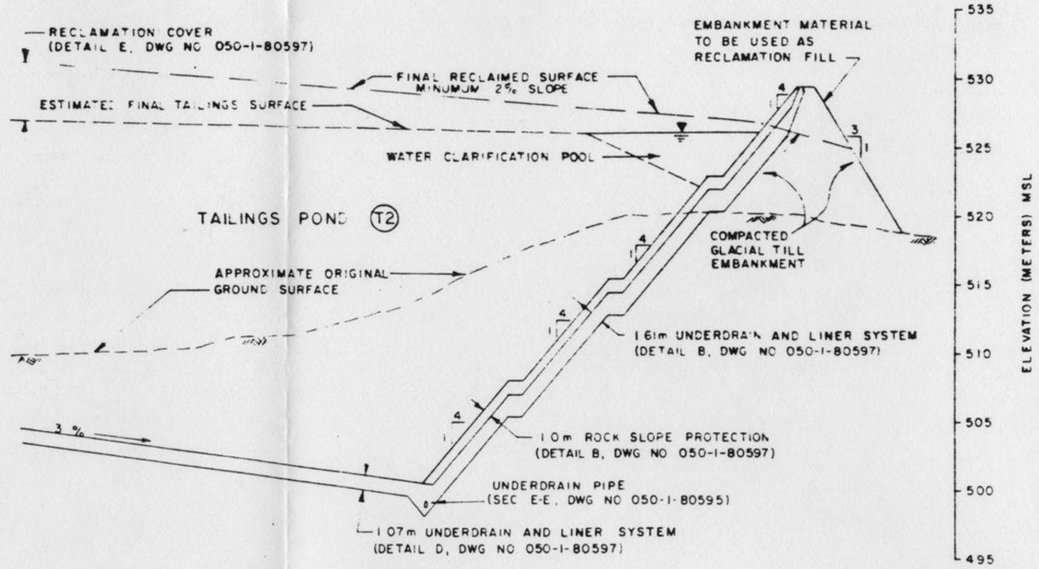
EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SECTION B-B AND E-E
SITE 41-114 B

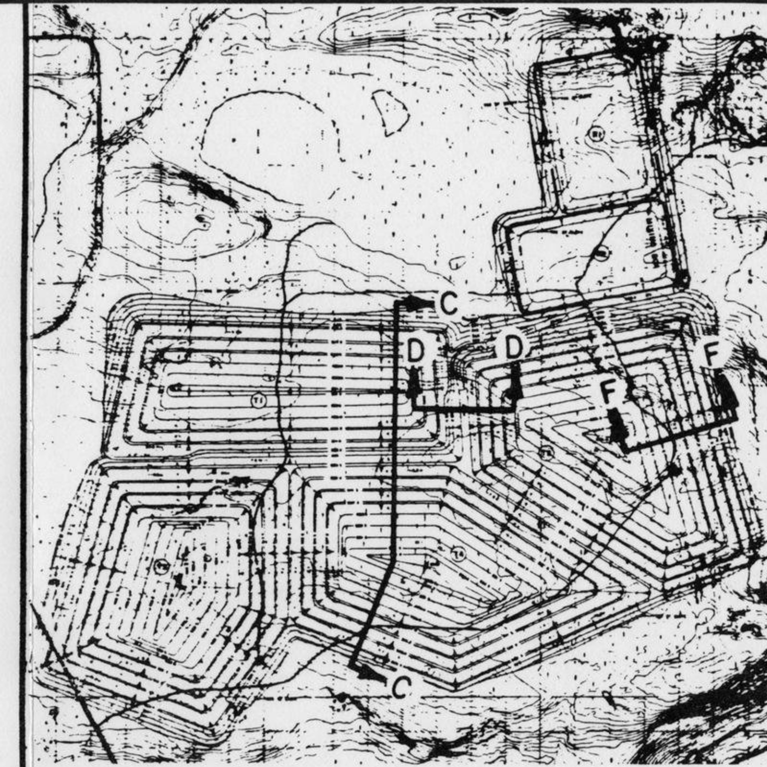
SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: CAB	DATE: 9-20-82	CHECKED BY: RMS	DATE: 7.22.82
APPROVED BY:	DATE: 10-14-82	APPROVED BY:	DATE:
APPROVED BY:	DATE:	EXXON	DATE:
DRAWING NO: 050-1-80602		SHEET OF	REVISION NO: 0



SECTION D-D

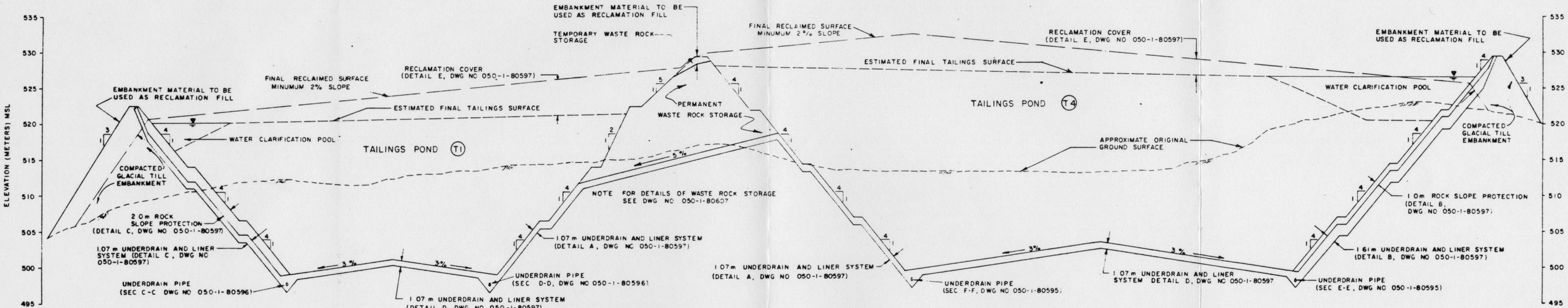


SECTION F-F



LOCATION PLAN

SCALE 0 100 300 500 m; 0 500 1000 1500 ft — NORTH



SECTION C-C

NOTE & PRELIMINARY SPECIFICATIONS

1. Glacial till embankment material shall be finer than 152 mm (6 in) compacted to 95 maximum dry density, within ± 3 of optimum moisture content, as determined by ASTM-D-698.
2. Liner material shall be glacial till finer than 19.1 mm (0.75 in) modified with bentonite. Liner shall be compacted to 95 maximum dry density, at or above optimum moisture content, as determined by ASTM D-698
3. Drain material shall be finer than 51 mm (2 in) and coarser than 0.42 mm (No. 40 U.S. Standard Sieve)
4. Filter material shall be glacial till finer than 152 mm (6 in) and shall not be compacted
5. Rock slope protection shall consist of mine waste rock

0 100 200 300 400 HORIZONTAL SCALE IN FEET

0 25 50 75 100 125 HORIZONTAL SCALE IN METERS

VERTICAL EXAGGERATION 5x

REVISION	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

FIGURE 9.6

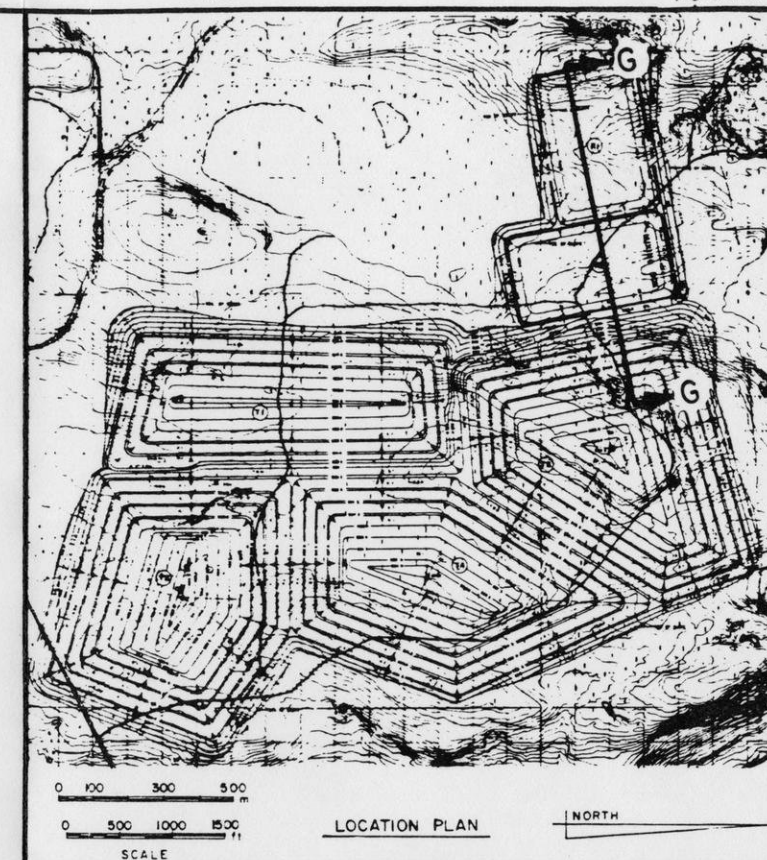
Golder Associates
Atlanta, Georgia

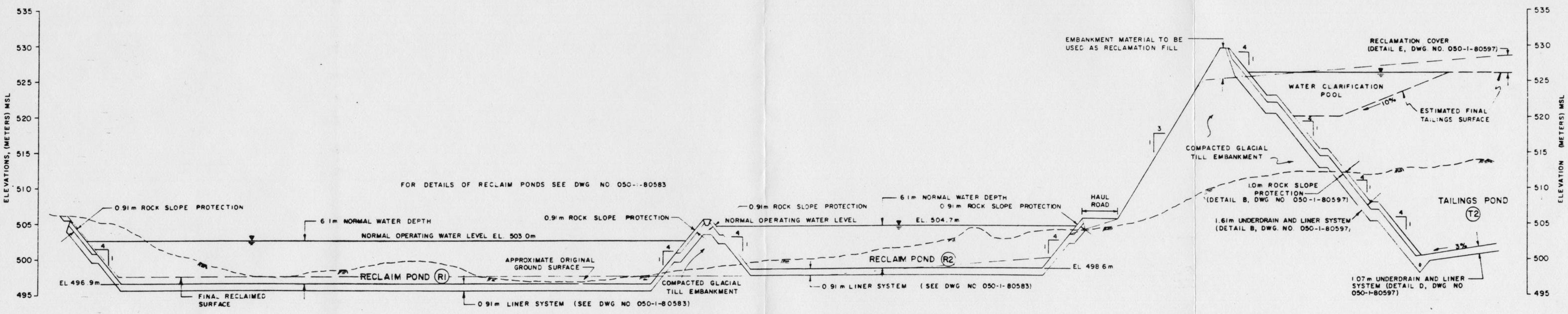
EXXON MINERALS COMPANY
CRANDON PROJECT

SECTIONS C-C, D-D, AND F-F - SITE 41-114 B

SCALE	STATE	COUNTY	
AS SHOWN	WISCONSIN	FOREST	
DRAWN BY SKB	DATE 9-20-82	CHECKED BY RMS	DATE 9/26/82
APPROVED BY	DATE 10-14-82	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE

DRAWING NO 050-1-80606 — REVISION NO 0





SECTION G-G

HORIZONTAL SCALE IN FEET: 0 100 200 300 400

HORIZONTAL SCALE IN METERS: 0 25 50 75 100 125

VERTICAL EXAGGERATION 5x

NOTES & PRELIMINARY SPECIFICATION

1. Glacial till embankment material shall be finer than 152 mm (6 in) compacted to 95 maximum dry density, within ± 3 of optimum moisture content, as determined by ASTM-D698
2. Liner material shall be glacial till finer than 19.1 mm [illegible], modified with bentonite. Liner shall be compacted to 95 maximum dry density, at or above optimum moisture content, as determined by ASTM D-698
3. [illegible] material shall be finer than [illegible] and coarser than 0.42 mm (No. 40 U.S. Standard Sieve
4. Filter material shall be glacial till finer than 152 mm [illegible] and shall not be compacted
5. Rock slope protection shall consist of mine waste rock.

REVISION	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

FIGURE 9.7

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: SECTION G-G
SITE 41-114B

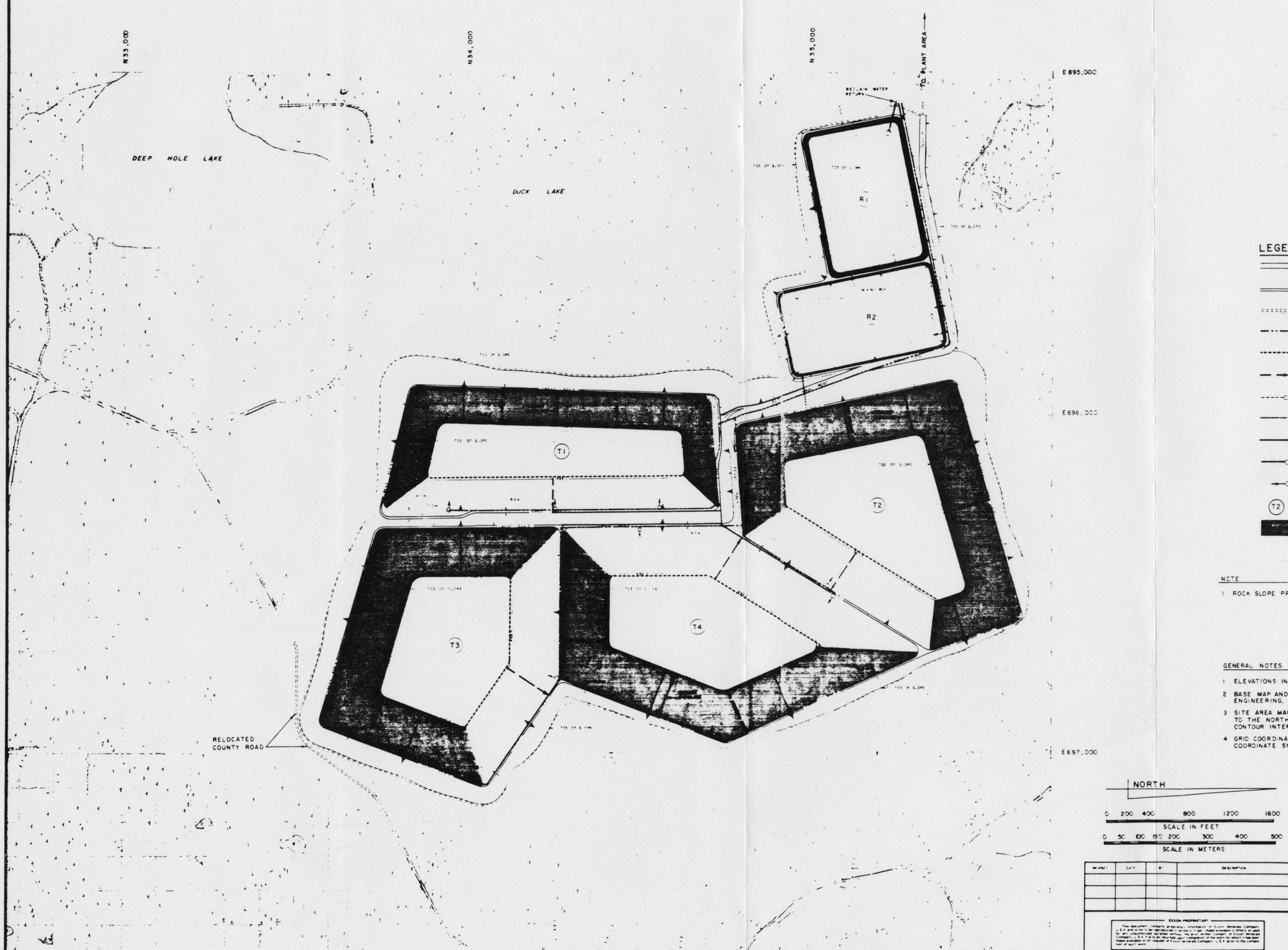
SCALE	STATE	COUNTY	
AS SHOWN	WISCONSIN	FOREST	
DRAWN BY: LJW	DATE: 9-20-82	CHECKED BY: RMS	DATE: 9/26/82
APPROVED BY:	DATE: 10-14-82	APPROVED BY:	DATE
APPROVED BY:	DATE	EXXON	DATE
DRAWING NO. 050-1-80605		SHEET OF	REVISION NO. 0

area than was shown for the 41-114 system. In preparing the 41-114B system layouts, the 1:2500 scale basemap (Figure 9.2) was employed; this is about twice the one inch to 400 foot (1:4800) English scale basemap used in preparing all previous layouts. This larger scale was selected in order to accommodate the increase in detail for the final preliminary engineering design of the tailings ponds. As the system 41-114B layout was being prepared at this larger scale, it was found that the fourth tailings pond had to be increased in size about ten percent to accommodate the estimated volume of tailings.

It was also noted when using the larger scale maps for the 41-114B system that the northeastern embankment of tailings pond T4 as shown on the 41-114 system layout encroached on the wetland just to the northeast of this same embankment. Thus, this increased level of accuracy has pointed out that 54 acres (21.9 ha) of wetland would have been covered by the 41-114 system instead of the 49 acres (19.8 ha) noted in Section 7. The revision of the location of the northeastern embankment of tailings pond T4 does not raise the wetland acreage covered above 54 acres (21.9 ha).

9.3 Tailings Pond Seepage Control Measures

Seepage control measures for operating tailings ponds will consist of a 6 inch (150 mm) thick till/bentonite liner overlain by a two layer underdrain system. The underdrain system will consist of an 18 inch (450 mm) thick sand drain layer covered by a minimum 18 inch (450 mm) thick filter layer of glacial till. Waste rock will be used as slope protection over the glacial till filter layer along those sides of the tailings ponds where free water is expected to pond; the sides opposite the tailings input. The plan location of the waste rock slope protection is shown on Figure 9.8. The waste rock will be 6.6 feet (2 m)



LEGEND

- HAUL ROAD
- CREST / ACCESS ROAD
- PERIMETER ACCESS ROAD (SECURITY FENCE OUTSIDE ACCESS ROAD)
- TAILINGS PIPELINE
- UNDERDRAIN COLLECTION PIPELINE
- UNDERDRAIN DISCHARGE PIPELINE
- DECANT PIPELINE FROM FLOATING PUMP
- DECANT AND UNDERDRAIN WATER PIPELINE
- THICKENER OVERFLOW
- RECLAIM WATER RETURN FROM FIXED PUMP
- TAILINGS INPUT POINT
- (T2) POND NUMBER
- ROCK SLOPE PROTECTION

NOTE

1 ROCK SLOPE PROTECTION DETAILS SHOWN ON DRAWING NUMBER 050-1-80597

GENERAL NOTES

1 ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2 BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3 SITE AREA MAPPING AT 1.0 METER CONTOUR INTERVAL. ADDITIONAL AREA TO THE NORTH AND WEST WAS ADDED AT THE AVAILABLE 2.0 METER CONTOUR INTERVAL TO PROVIDE ADDITIONAL COVERAGE
4 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM

FIGURE 9.8

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE
ROCK SLOPE PROTECTION PLAN
SITE 41-114B

SCALE	STATE	COUNTY
AS SHOWN	WISCONSIN	FOREST

DRAWN BY	DATE	CHECKED BY	DATE
SKB	10-20-82	[signature]	11-22-82
APPROVED BY [signature]	DATE 11-22-82	APPROVED BY	DATE

DRAWING NO. 050-1-80623

thick in tailings pond T1 and 3.3 feet (1 m) thick in tailings ponds T2, T3, and T4. This thickness varies because of availability of the waste rock. In tailings pond T1 the underdrain filter layer along the free water side slopes will be 18 inches (450 mm) thick but in tailings ponds T2, T3, and T4 it will be increased to 3.3 feet (1 m) thick because of the thinner layer of waste rock slope protection. A detailed discussion of the use of underdrains to control seepage is presented in Golder Associates' Project Report 3.2 (Ref. 13).

The till/bentonite liner will be made by mixing processed glacial till with bentonite. The till will be screened at the 3/4 inch (19.1 mm) sieve size, or crushed to produce a till with a maximum aggregate size of 3/4 inches (19.1 mm). Present estimates suggest the bentonite will be mixed with the processed till at a proportion of 8 percent by weight. Additional testing of the till/bentonite mix during final design may indicate a lesser percentage of bentonite to be adequate. Current analyses are based on developing this liner with a permeability of 5×10^{-10} m/s (1.6×10^{-9} ft./sec.). Preliminary laboratory testing on the till/bentonite liner material is presented in Golder Associates' Project Report 5 (Ref. 15).

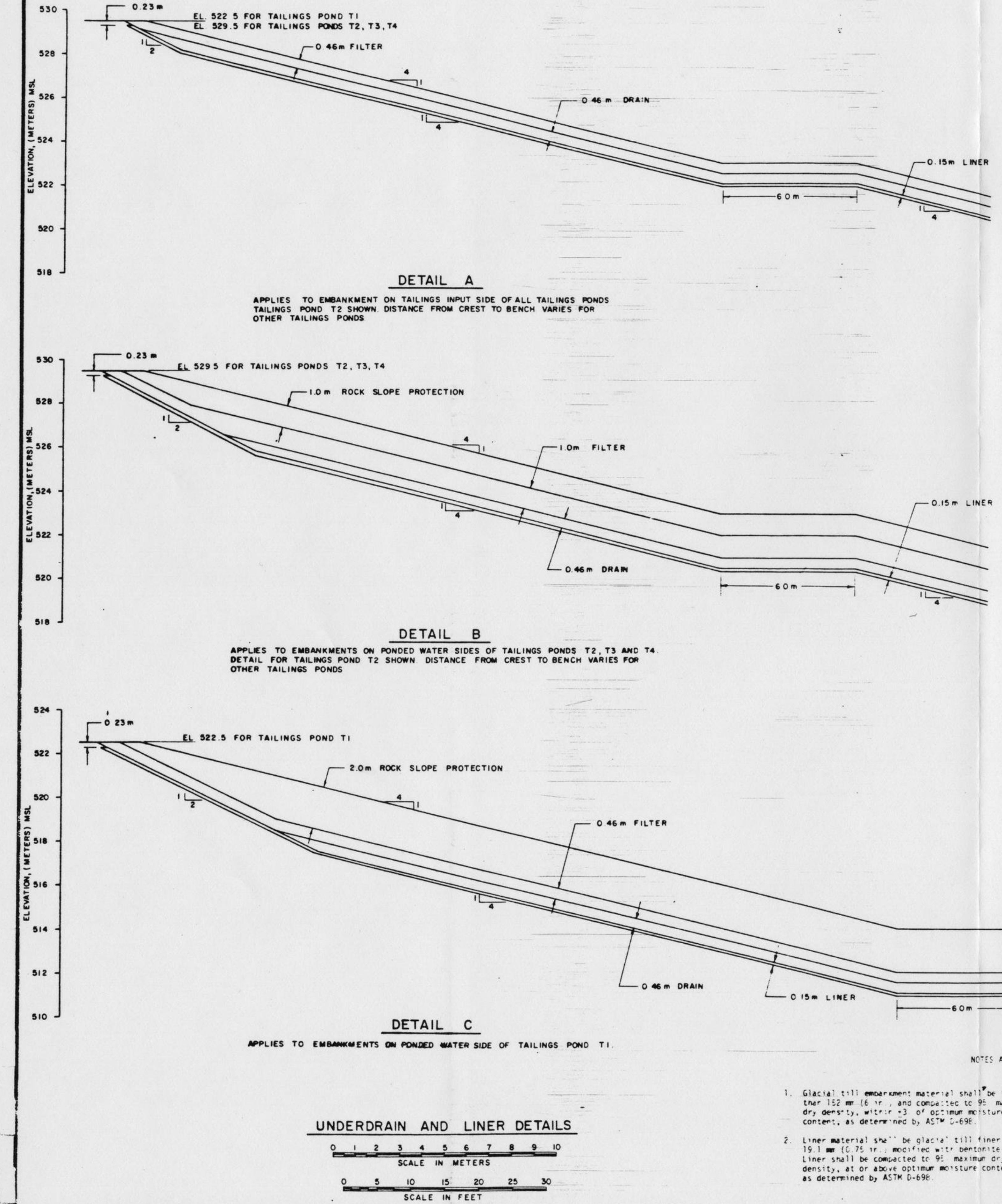
The tailings pond bottoms will be sloped toward the embankments (shown on Figures 9.2 and 9.4 to 9.7) to direct seepage in the underdrain to the inside toe of slope of the embankments. A collection pipe will be placed around the perimeter of the inside toe of the embankments. Three discharge pipes per tailings pond will be placed down the inside embankment slopes to intersect with the bottom perimeter pipe. Pumps will be placed in these discharge pipes to lift the collected seepage to the surface where it will be piped to the reclaim ponds.

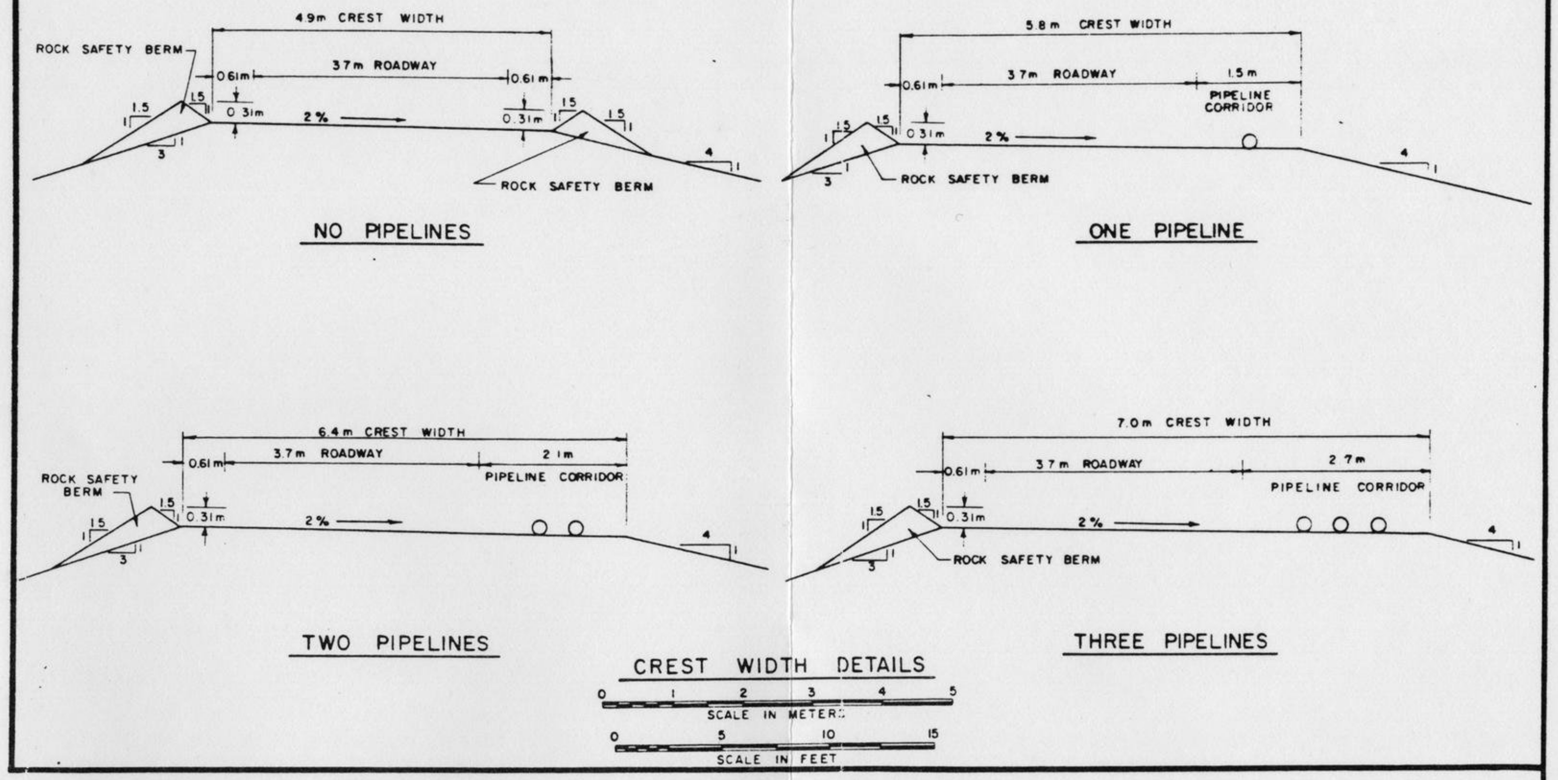
Details of the liner, underdrain system, and underdrain collection and discharge pipes are presented on Figures 9.9 and 9.10, and 9.11.

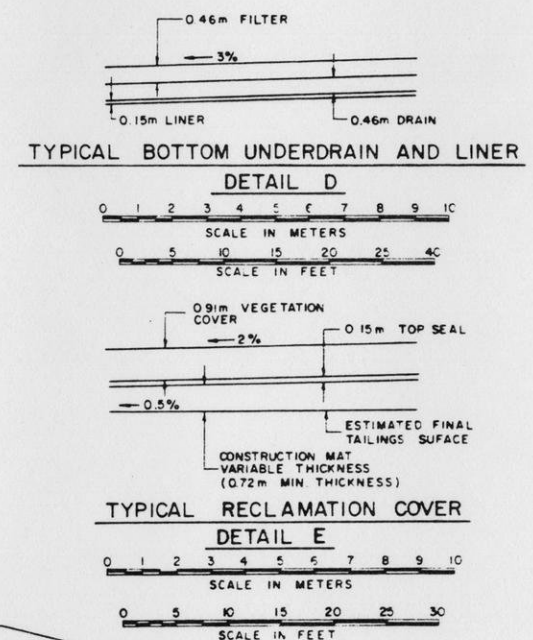
Based on the analytical procedures and analyses presented by Golder Associates' Project Reports 3.1 and 11 (Ref. 12 and 21). the estimated seepage history projected for the 41-114B system is presented on Figure 9.12. As shown on this figure, the maximum seepage rate from the system is estimated to be 92.4 gallons per minute ($5.8x10^{-3}$ m^3/s). The maximum rate for each individual pond is less than 30 gallons per minute ($19x10^{-4}$ m^3/s).

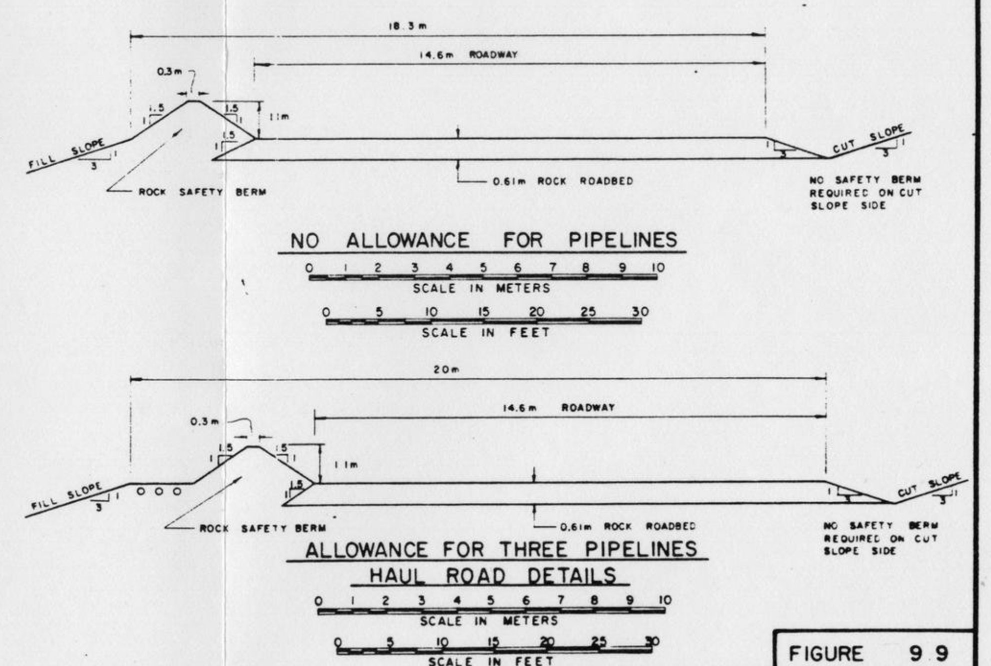
9.4 Reclaim Pond Details

The two reclaim ponds, R1 and R2, will provide for retention of two months of process water at normal operating levels which is a maximum water depth of approximately 20 feet (6.1 m). Reclaim pond R2 includes a 3 foot (0.91 m) freeboard above this level and reclaim pond R1 includes an 8.5 foot (2.6 m) freeboard above this level. Both ponds will accept storage of the 24 hour-100 year design storm of 5.1 inches (130 mm) of precipitation, within the freeboard height, as required by proposed legislation NR 182. Reclaim pond R1 has been designed with an 8.5 foot (2.6 m) freeboard height to store two weeks of water from the mine in the event of a shut-down of the excess water treatment system. This is 50.4 million gallons ($1.91x10^5$ m^3) of water, at a rate of 2,500 gallons per minute (9.46 m^3/s) for 14 days, which is equal to about 5.2 feet (1.6 m) of storage height above the normal operating water level in pond R1. The minimum 3 foot (0.91 m) freeboard height with rock slope protection is sufficient to prevent overtopping by the maximum wave produced by the









NOTES AND PRELIMINARY SPECIFICATIONS

1. Glacial till embankment material shall be finer than 152 mm (6 in.), and compacted to 95 maximum dry density, within ±3 of optimum moisture content, as determined by ASTM D-698.
2. Liner material shall be glacial till finer than 19.1 mm (0.75 in.) modified with bentonite. Liner shall be compacted to 95 maximum dry density, at or above optimum moisture content, as determined by ASTM D-698.
3. Drain material shall be finer than 51 mm (2 in.) and coarser than 0.42 mm (No. 40 U.S. Standard sieve).
4. Filter material shall be glacial till finer than 152 mm (6 in.) and shall not be compacted.
5. Rock slope protection shall consist of mine waste rock.

FIGURE 9.9

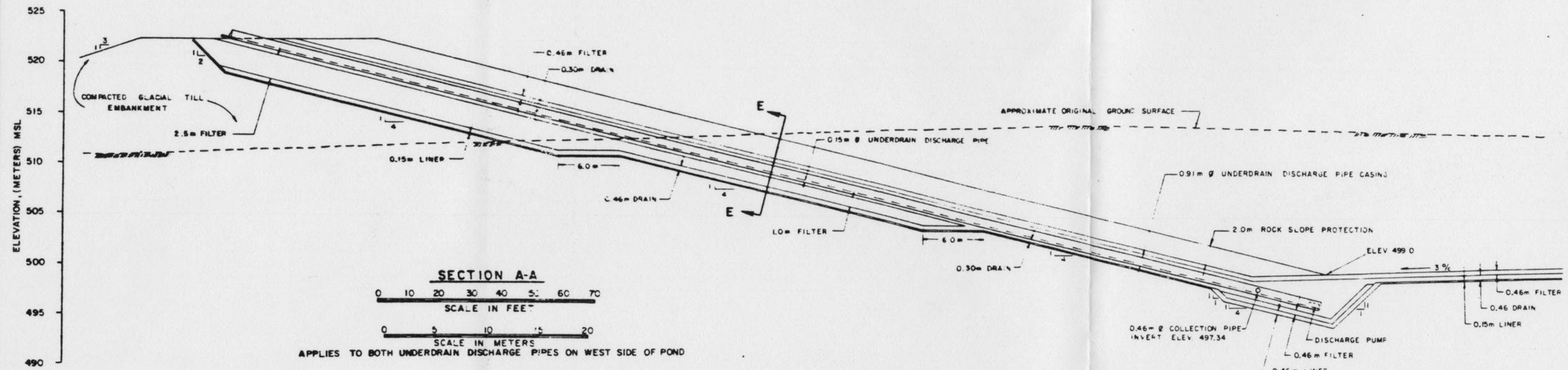
Golder Associates
Atlanta, Georgia

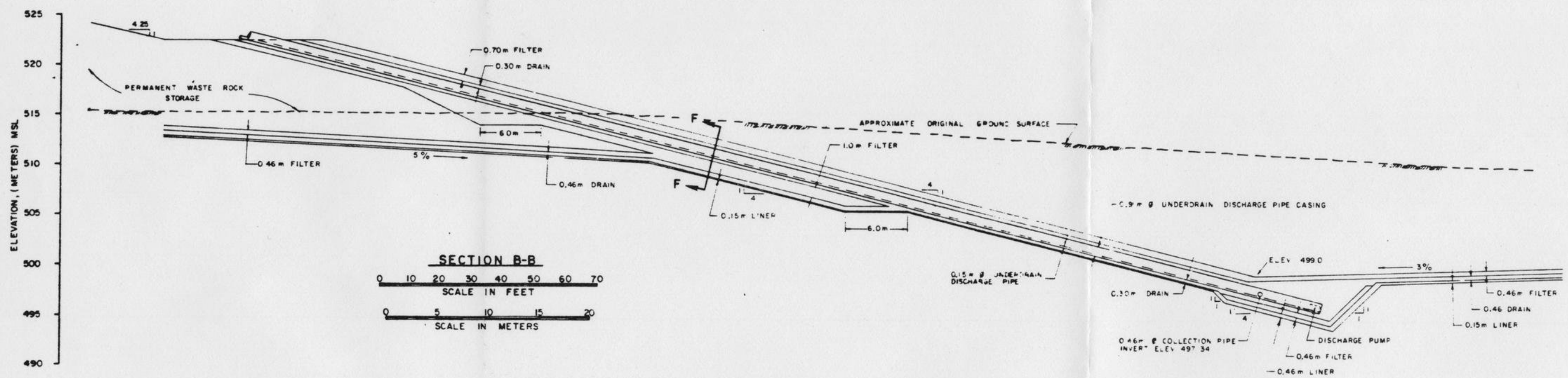
EXXON MINERALS COMPANY
CRANDON PROJECT

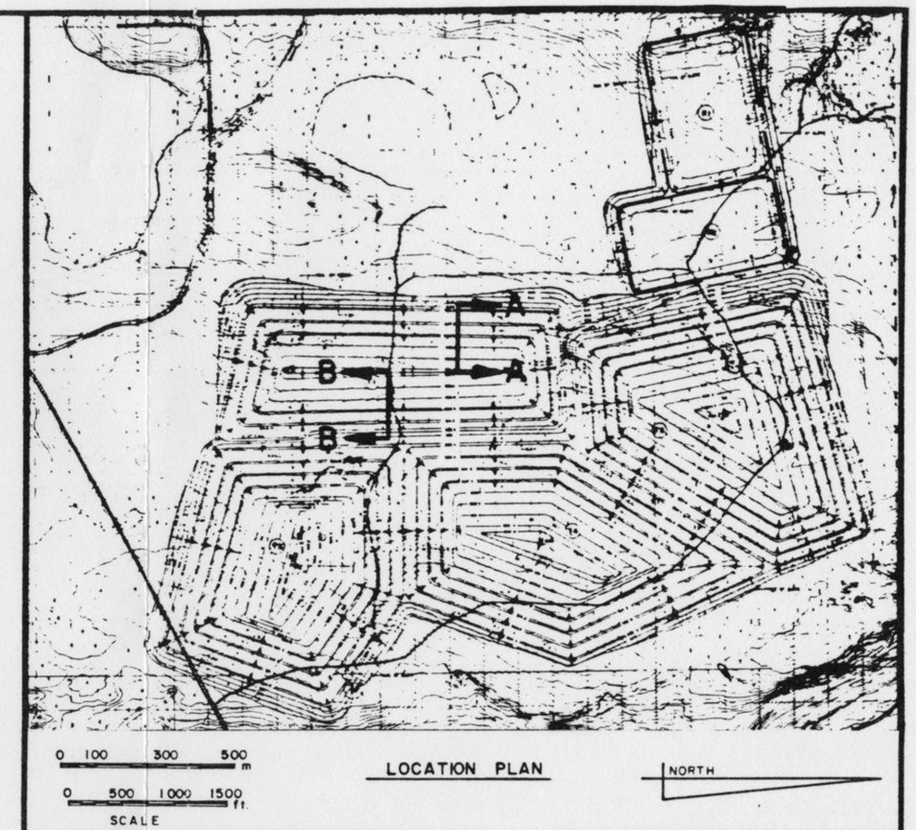
UNDERDRAIN, LINER, RECLAMATION COVER, HAUL ROAD AND CREST WIDTH DETAILS

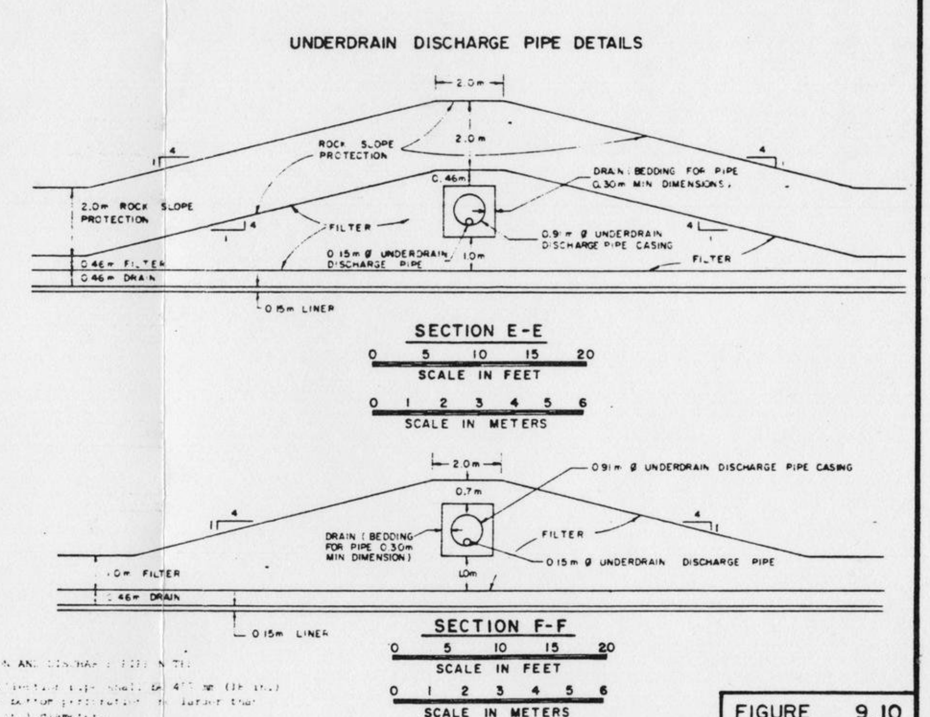
SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: CAB	DATE: 9-20-82	CHECKED BY: RMS	DATE: 9/22/82
APPROVED BY	DATE: 10-11-82	APPROVED BY	DATE
APPROVED BY	DATE	EXXON	DATE
DRAWING NO. 050-1-80597		SHEET OF	REVISION NO. 0

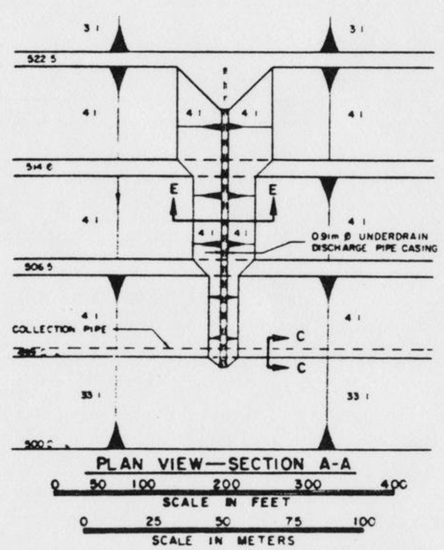
REVISED | DATE | BY | DESCRIPTION

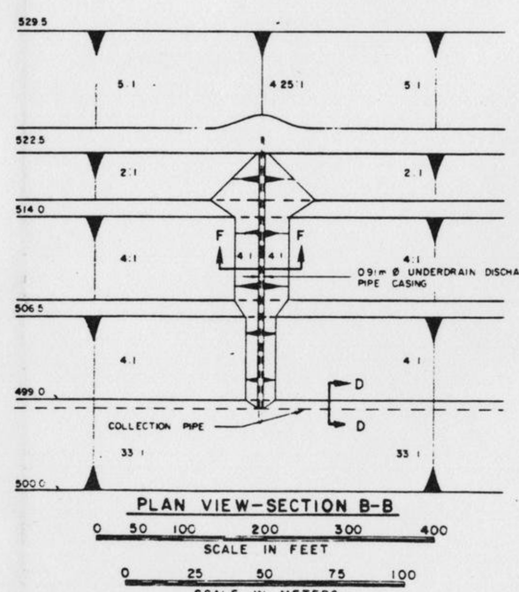


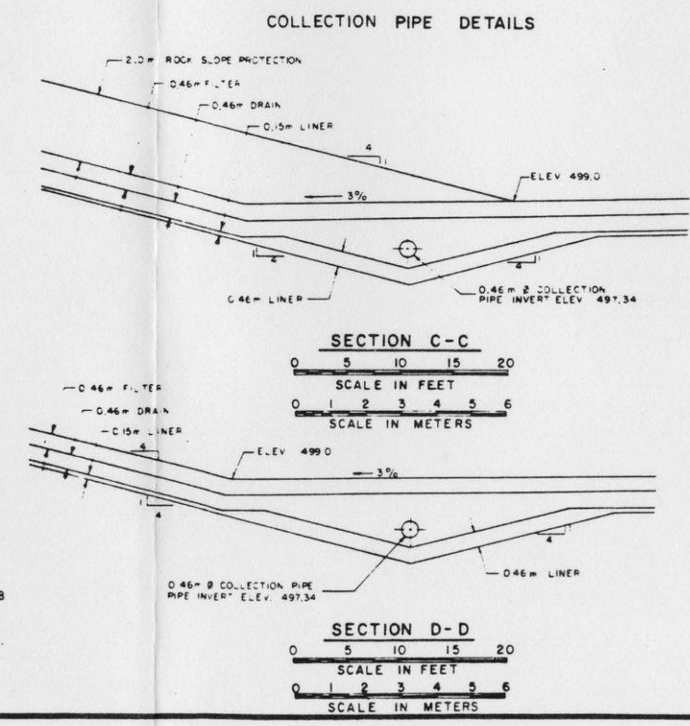












NOTES & PRELIMINARY SPECIFICATIONS

1. Glacial till embankment material shall be finer than 152 mm (6 in.) and compacted to 95% maximum dry density, within ±3% of optimum moisture content, as determined by ASTM D-698.
2. Liner material shall be glacial till finer than 19.1 mm (0.75 in.) modified with bentonite. Liner shall be compacted to 95% maximum dry density, at or above optimum moisture content, as determined by ASTM D-698.
3. Drain material shall be finer than 51 mm (2 in.) and coarser than 0.42 mm (No. 40 U.S. Standard sieve).
4. Filter material shall be glacial till finer than 152 mm (6 in.) and shall not be compacted.
5. Rock slope protection shall consist of mine waste rock.

NOTE:
SEE DRAWING NUMBER 050-1-80598 FOR LOCATION OF UNDERDRAIN DISCHARGE AND COLLECTION PIPES.

[illegible]

REVISED	DATE	BY	DESCRIPTION

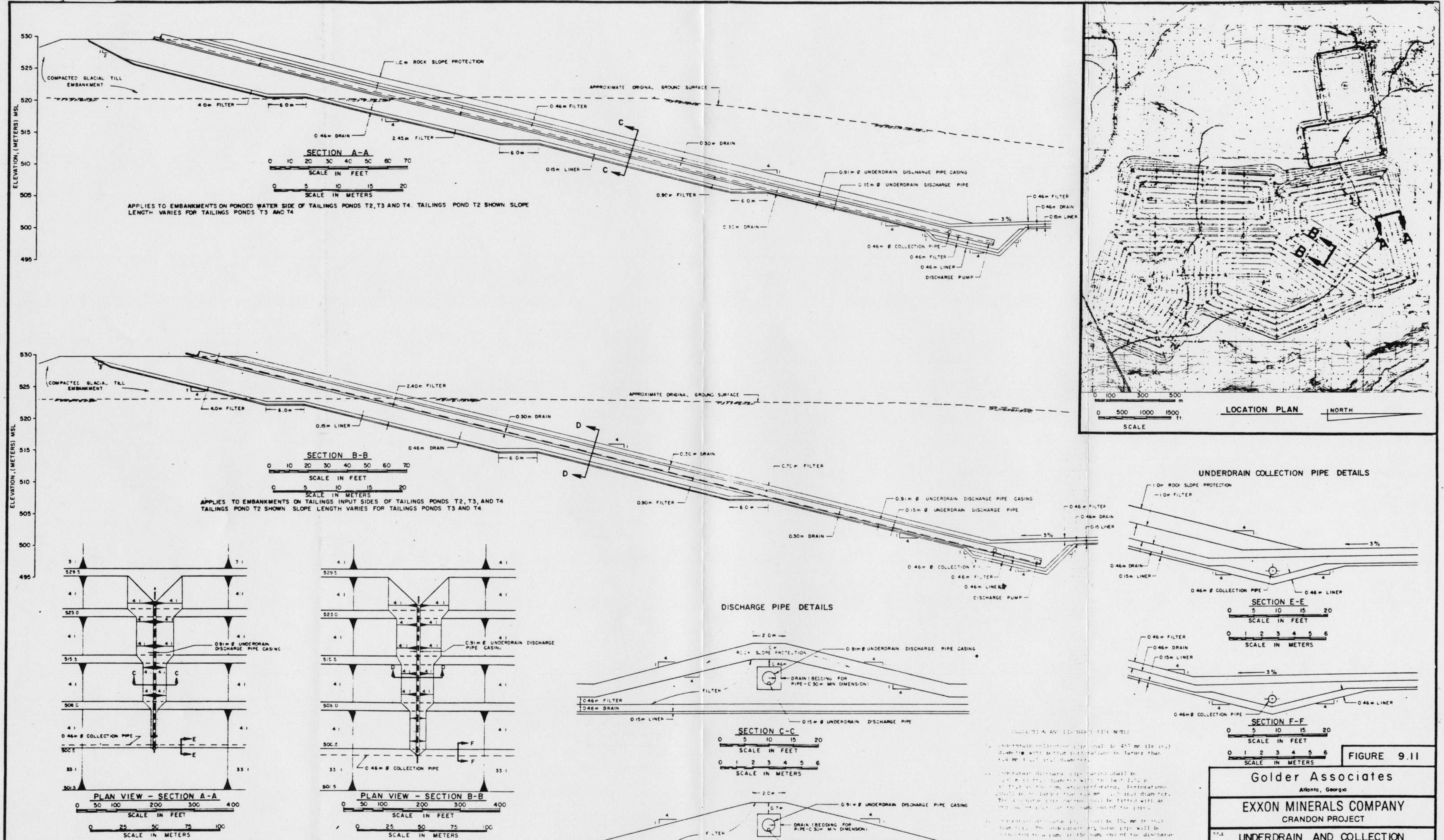
FIGURE 9.10

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: UNDERDRAIN AND COLLECTION PIPE DETAILS TAILINGS POND T1

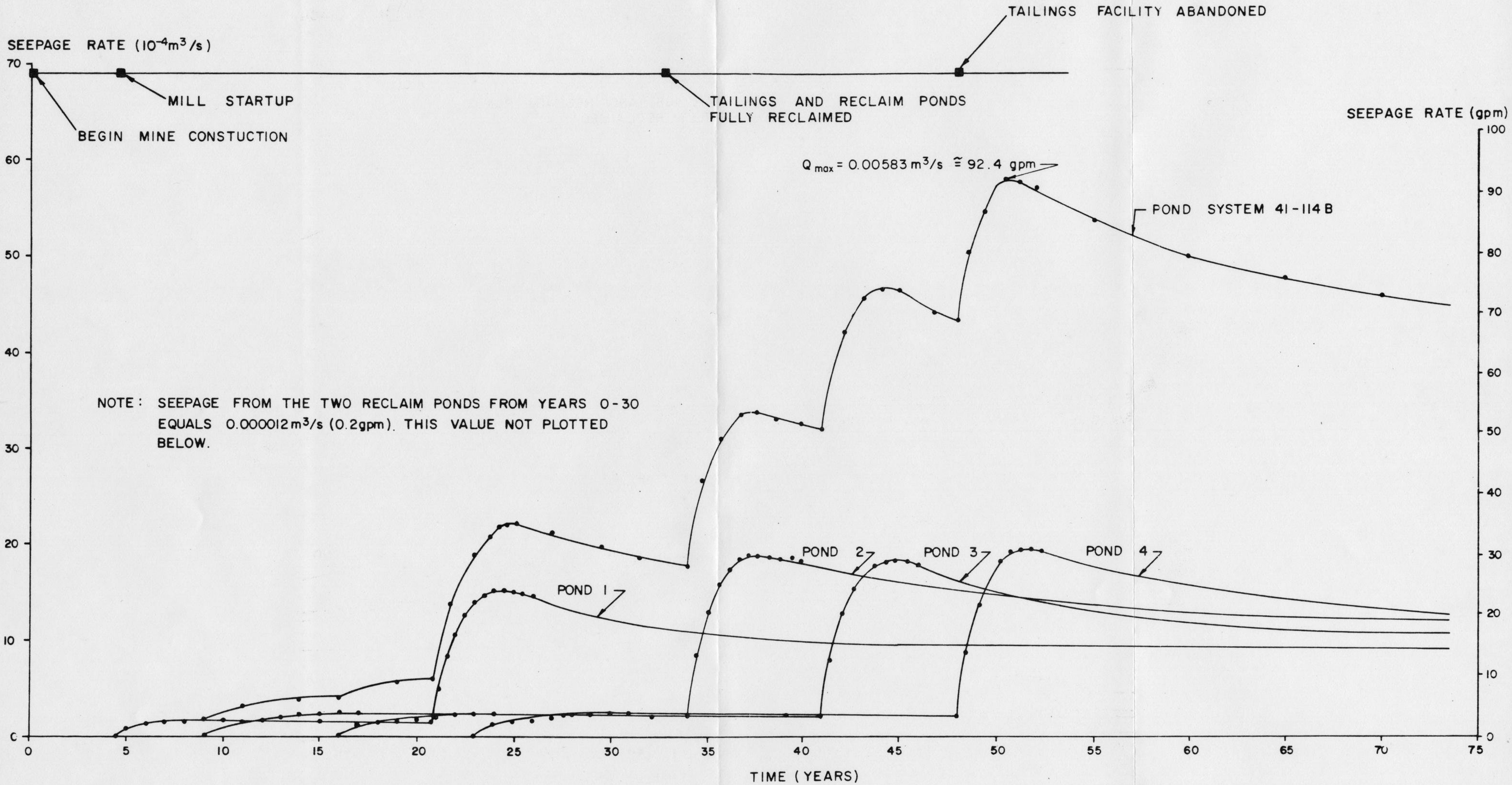
SCALE: AS SHOWN | STATE: WISCONSIN | COUNTY: FOREST
DRAWN BY: CAB | DATE: 9-20-82 | CHECKED BY: RMS
DRAWING NO: 050-1-80596 | REVISION NO: 0



NOTES & PRELIMINARY SPECIFICATIONS

1. Glacial till embankment material shall be finer than 152 mm (6 in.) and compacted to 95% maximum dry density, within ±3% of optimum moisture content as determined by ASTM D-698.
2. Liner material shall be glacial till finer than 19.1 mm (0.75 in.) modified with bentonite. Liner shall be compacted to 95% maximum dry density, at or above optimum moisture content, as determined by ASTM D-698.
3. Drain material shall be finer than 51 mm (2 in.) and coarser than 0.42 mm (No. 40 U.S. Standard sieve)
4. Filter material shall be glacial till finer than 152 mm (6 in.) and shall not be compacted.
5. Rock slope protection shall consist of mine waste rock.

NOTE:
SEE DRAWING NUMBER 050-1-80598 FOR LOCATION OF UNDERDRAIN DISCHARGE AND COLLECTION PIPES.



SEEPAGE HISTORY BASED ON THE FOLLOWING UNDERDRAIN PUMPING SCHEDULE

TAILINGS POND NUMBER	1	2	3	4
UNDERDRAIN PUMPING START (YEARS)	4.5	9.0	16.0	33.0
UNDERDRAIN PUMPING END (YEARS)	20.8	34.0	41.0	48.0

JOB NO. 786085	SCALE AS SHOWN	SEEPAGE RATE HISTORIES SITE 41-114B
DRAWN CAB	DATE 8-16-82	
CHECKED [signature]	DWG NO ______	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 9.12

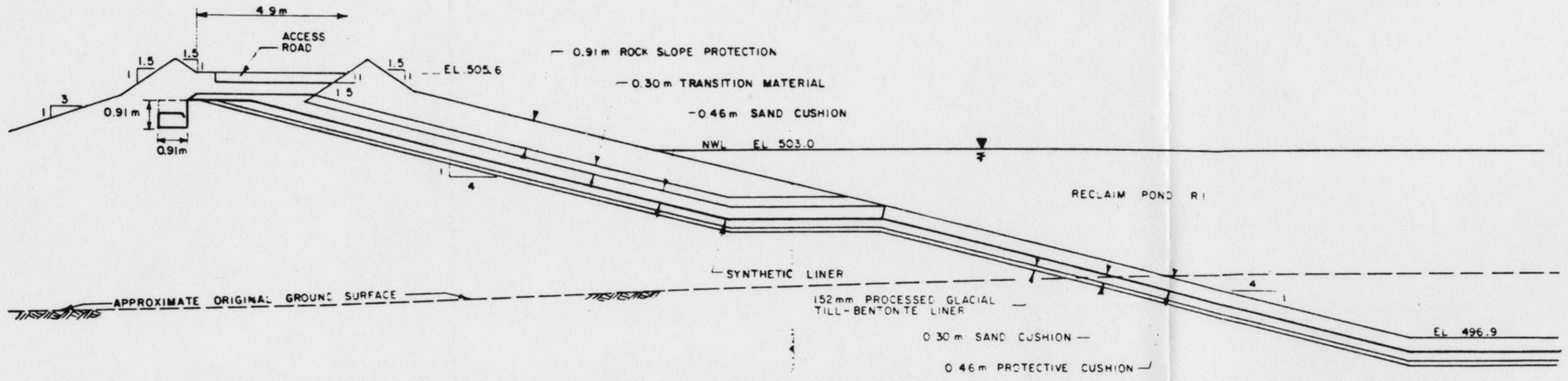
one hour-100 year wind of 90 miles per hour (145 km/h). Details of the analyses of these design features are presented in Golder Associates' Project Report 11 (Ref. 21).

Since the two reclaim ponds will be used for water retention only, there will always be a minimum of about 20 feet (6.1 m) of water in the ponds acting against the liner. To reduce seepage to a low rate, a till/bentonite liner would have to be several feet thick. Thus, the two reclaim ponds have been designed with a synthetic liner underlain by a 6 inch (150 mm) thick till/bentonite liner. Two possible alternative synthetic liner materials have been selected as being suitable for this project and the design details show both alternatives. Details for the reclaim pond liners and rock slope protection are shown on Figure 9.13.

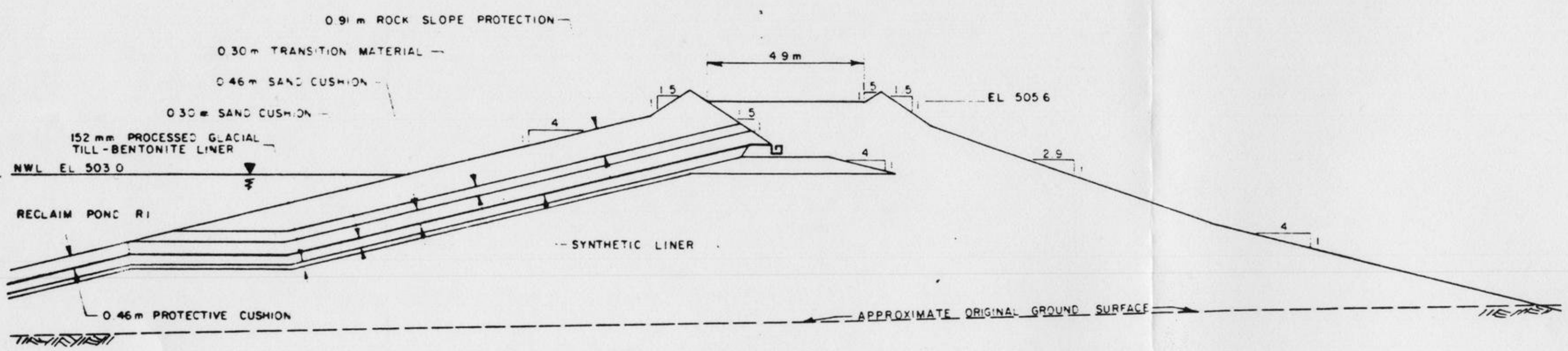
Normal water levels in the two reclaim ponds have been set 3 feet (0.91 m) apart with the level in pond R2 higher than in pond R1. A mixing box with a simple overflow weir entrance will be located between the two ponds. Water will flow from pond R2 to pond R1 during normal operating periods. The mixing box will allow the addition of chemicals to the water, such as the addition of lime for pH adjustment, with mixing taking place in the mixing box. Details of the location of the mixing box are shown on Figure 9.14. Other details such as baffle design within the box, have been left for final design.

9.5 Waste Rock Utilization

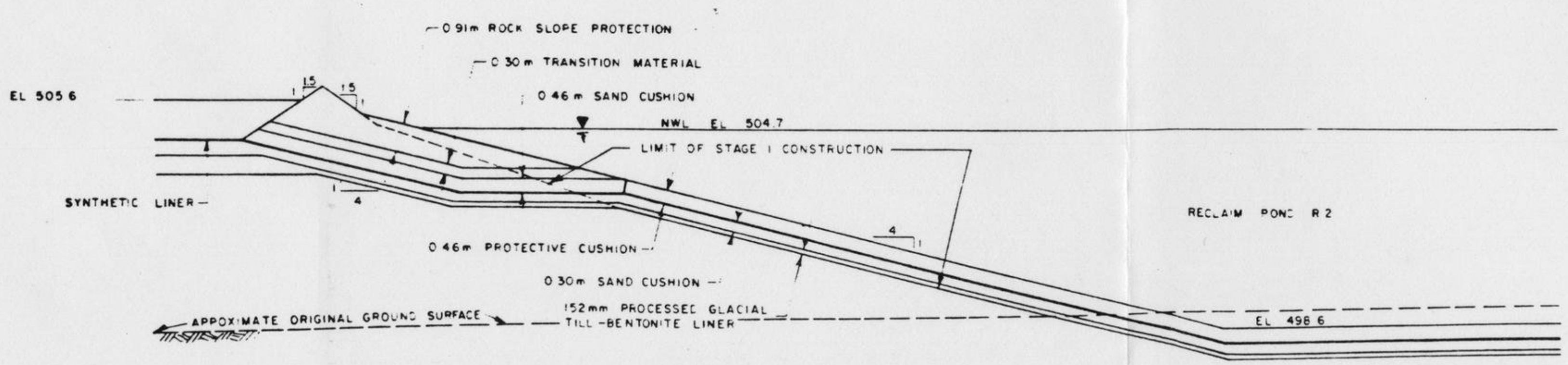
Waste rock is produced throughout the life of the mine, but at non-uniform rates. The rate of waste rock production is presented on Figure 9.15. Once the mill is in operation, all rock from the mine will be crushed to sizes below 6 inches (152 mm) before being hoisted to the



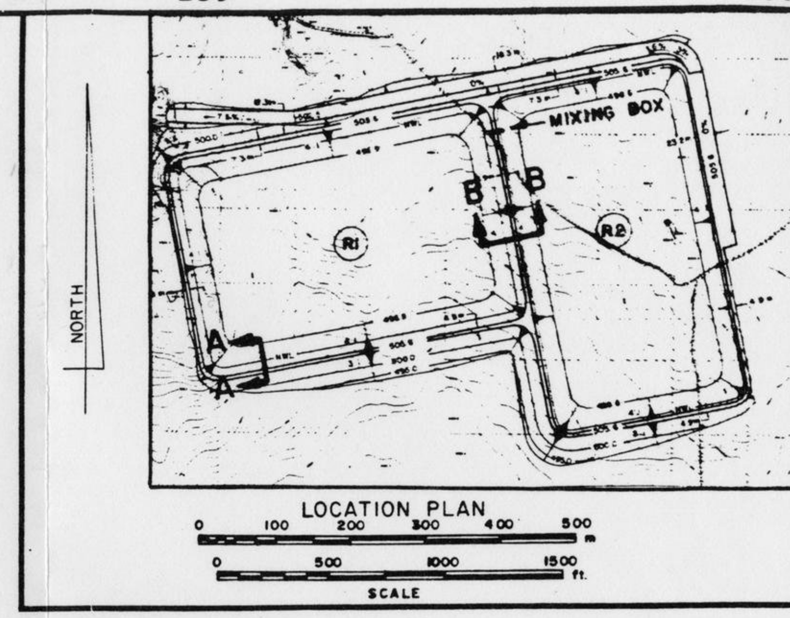
SECTION A-A
(SEE NOTE 2)



SECTION B-B STAGE 1
RECLAIM POND R1 CONSTRUCTED FIRST



SECTION B-B STAGE 2
RECLAIM POND R2 CONSTRUCTED SECOND



LOCATION PLAN

Notes:

1. NWL - Normal operating water level.
2. Section for Reclaim Pond R2 will be similar except the freeboard will be 0.91m (3.0 ft.).
3. Liner to be made with processed glacial till finer than 19.1mm (3/4 in. U.S. Standard sieve) modified with bentonite. Liner to be compacted to 95% maximum dry density determined by ASTM D-698.
4. Rock slope protection to consist of pre-production waste rock.
5. Transition material beneath rock slope protection shall be glacial soil coarser than 4.76mm (#4 U.S. Standard sieve) with D_{85} = 31.7mm (1.25 in.)
6. Synthetic liner shall be nominally 0.91mm (36 mil) thick and consist of either of the following:
   a.) Hypalon (Chlorosulfonated polyethelene).
   b.) HDPE (High density polyethelene).
7. The sand cushion above the synthetic liner (beneath the rock slope protection) shall not be compacted and shall conform to the following:
   a) For the Hypalon liner this sand cushion shall be concrete sand conforming to ASTM C-33 or processed glacial soil finer than 4.76mm (#4 U.S. Standard sieve) with a minimum of 20% finer than 0.074mm (#200 U.S. Standard sieve).
   b.) For the HDPE liner this sand cushion shall be glacial soil finer than 4.76mm (#4 U.S. Standard sieve) with a minimum of 20% finer than 0.074mm (#200 U.S. Standard sieve).
8. The protective cushion above the Hypalon or HDPE synthetic liner (at locations other than under the rock slope protection) shall be glacial soil finer than 4.76mm (#4 U.S. Standard sieve) and shall not be compacted.
9. The sand cushion below the synthetic liner shall conform to the following:
   a.) For the Hypalon liner the cushion shall be the same gradation as that required for the cushion above the liner except that it may not contain carbonaceous material. It shall be compacted to 95% maximum dry density determined by ASTM D-698.
   b. For the HDPE liner the cushion shall be finer than 4.76mm (#4 U.S. Standard seive) with a minimum of 5 finer than 0.074mm (#200 U.S. Standard sieve). This cushion shall not contain carbonaceous material. It shall not be compacted.
10. Specifications related to the sand cushions above and below the synthetic liner and the protective cushion above the synthetic liner are subject to modification to comply with requirements of the synthetic liner manufacturer.

0 5 10 15 20 25 30 35
SCALE IN FEET

0 1 2 3 4 5 6 7 8 9 10
SCALE IN METERS

REVISED	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

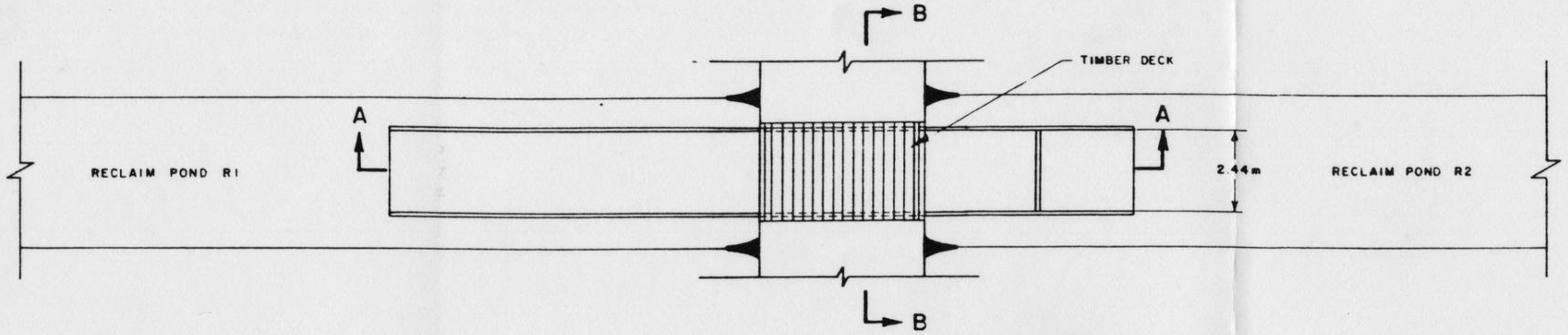
FIGURE 9.13

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

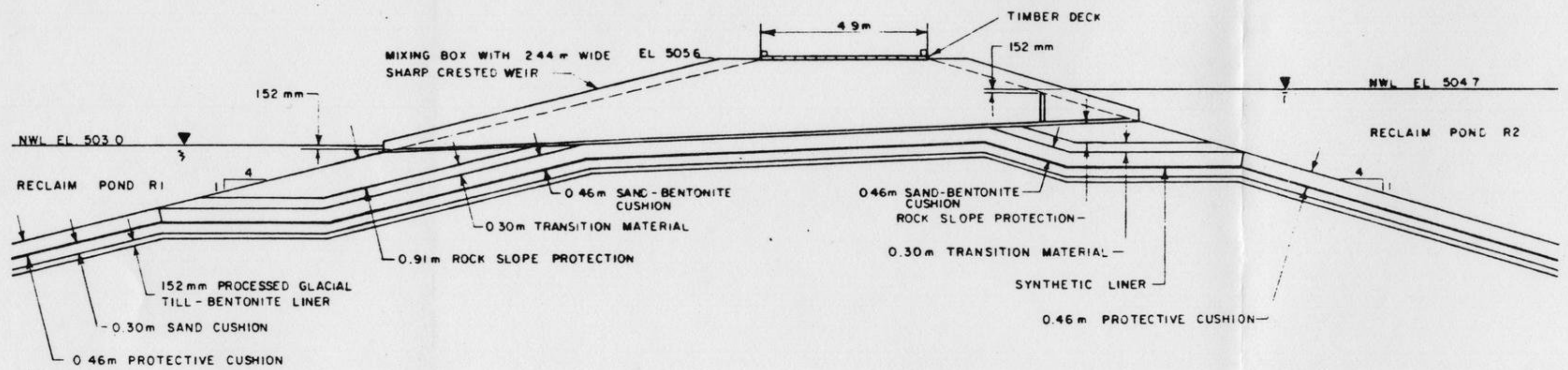
RECLAIM POND DETAILS

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: SKB	DATE: 9-20-82	CHECKED BY: [signature]	DATE: 10-13-82
APPROVED BY: [signature]	DATE: 10-14-82	APPROVED BY:	DATE:
APPROVED BY:	DATE:	EXXON:	DATE:
DRAWING NO.: 050-1-80583		SHEET OF	REVISION NO.: 0

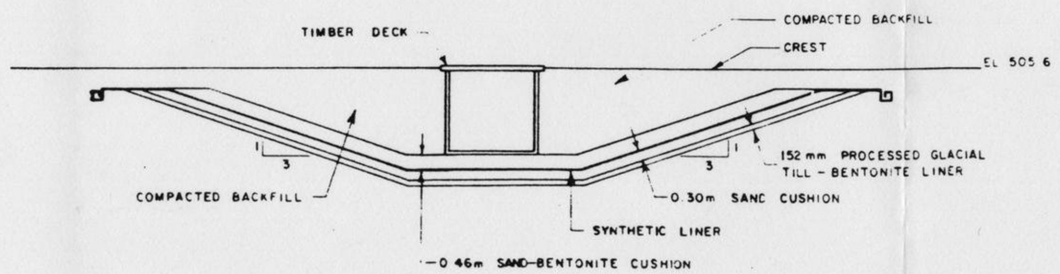


PLAN VIEW

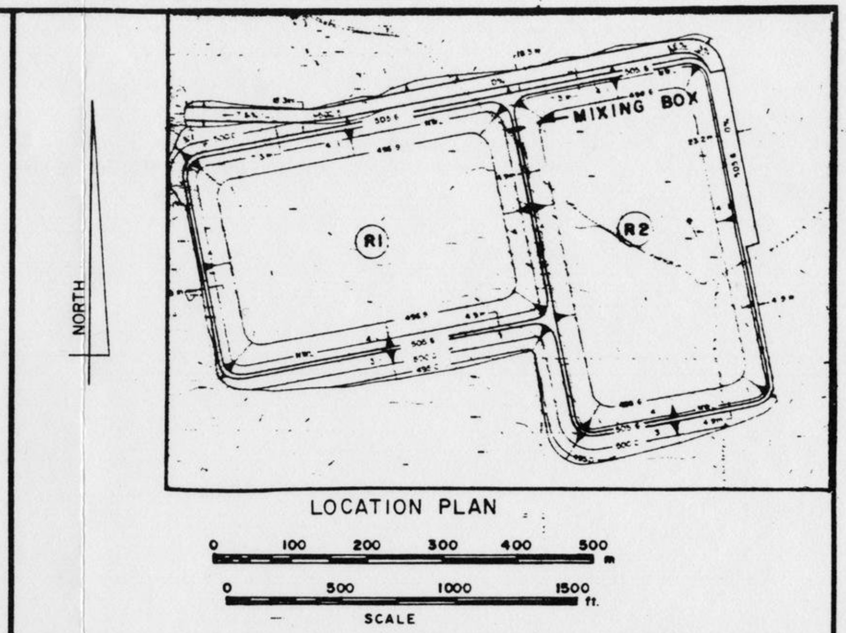
MIXING BOX BETWEEN THE TWO RECLAIM PONDS



SECTION A-A



SECTION B-B



LOCATION PLAN

Notes:

1. NWL - Normal operating water level
2. Details of Mixing Box

   Type: Sharp Crested, Rectangular Weir
   Width: 2.44m (8.0 ft.)
   Depth of Flow: 152mm (6 in.)
   Depth of Tail Water: 152mm (6 in.)
   Box Height: Variable

   The weir box should be designed for structural and mixing requirements.

3. For description of the following materials see notes on Drawing Number 050-1-80583, Reclaim Pond Details:

   Synthetic Liner
   Glacial till/bentonite liner
   Protective cushion above synthetic liner
   Transition material below rock slope protection
   Rock slope protection

4. The sand-bentonite cushion replaces the sand cushion above the synthetic liner around the mixing box. The sand-bentonite cushion above either type of synthetic liner in the mixing box area shall consist of processed glacial till finer than 4.76mm (#4 U.S. Standard sieve) mixed with 8 bentonite by weight. The sand-bentonite cushion shall be compacted to at least 95 maximum dry density as determined by ASTM D-698.
5. The sand cushion below the synthetic liner in the mixing box area shall conform to the gradation provided on Drawing Number 050-1-80583. The sand cushion below either type of synthetic liner in the mixing box area shall be compacted to at least 95% maximum dry density as determined by ASTM D-698.
6. The compacted backfill around the mixing box shall consist of glacial till finer than 4.76mm (#4 U.S. Standard sieve) and shall be compacted to at least 95% maximum dry density as determined by ASTM D-698.
7. Synthetic liner and processed glacial till-bentonite liner under the mixing box shall be connected to these respective liners installed on the embankment slopes.
8. Specifications related to the cushions below and above synthetic liners are subject to modifications to comply with the requirements of the synthetic liner manufacturer.

0 5 10 15 20 25 30 35
SCALE IN FEET

0 1 2 3 4 5 6 7 8 9 10
SCALE IN METERS

REVISE	DATE	BY	DESCRIPTION

EXXON PROPRIETARY

FIGURE 9.14

Golder Associates
Atlanta Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

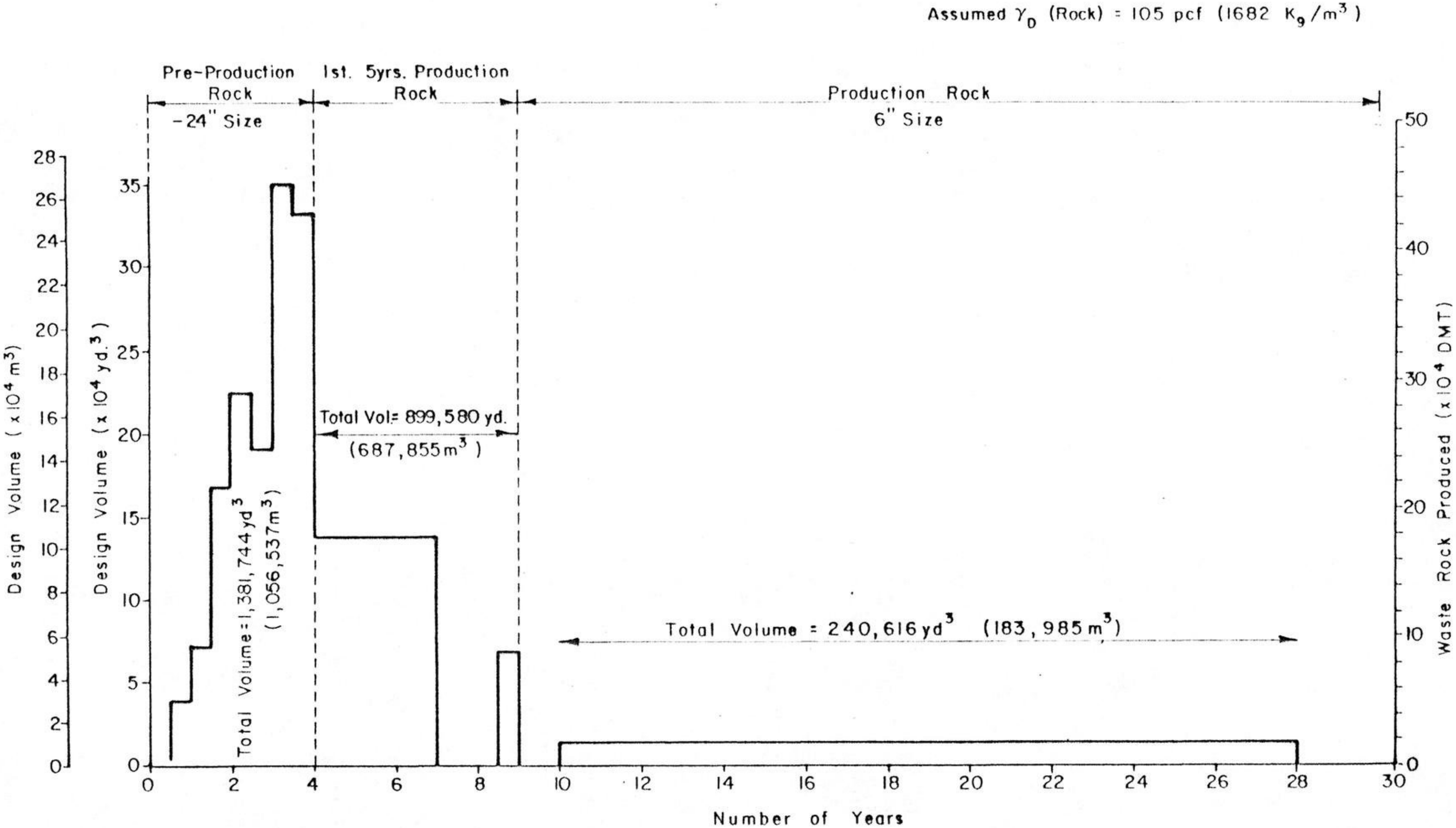
RECLAIM POND
MIXING BOX DETAILS

SCALE	STATE	COUNTY
AS SHOWN	WISCONSIN	FOREST

DRAWN BY	DATE
SKB	9-20-82
DATE	10-14-82

DRAWING NO. 050-1-80582 REVISION NO. 0

GAF DRAFTING MEDIA



Golder Associates

JOB NO. 786085

DRAWN SKB

CHECKED

SCALE AS SHOWN

DATE 10-22-82

DWG NO —

WASTE ROCK PRODUCTION SCHEDULE

EXXON MINERALS COMPANY

FIGURE 9.15

surface. Prior to this time, all pre-production rock is estimated by Exxon to be less than 24 inches (608 mm) in size. Most of the waste rock being hoisted to the surface will be pre-production waste rock.

Waste rock can be most effectively used as a construction material if it can be used as it is produced rather than being stockpiled and re-handled. For this project, because of the schedule of waste rock production, most of the waste rock will have to be used prior to the time when the mill is in operation. Therefore, most of the waste rock will be used to construct pond embankments prior to the time when these embankments are needed for completing the tailings ponds.

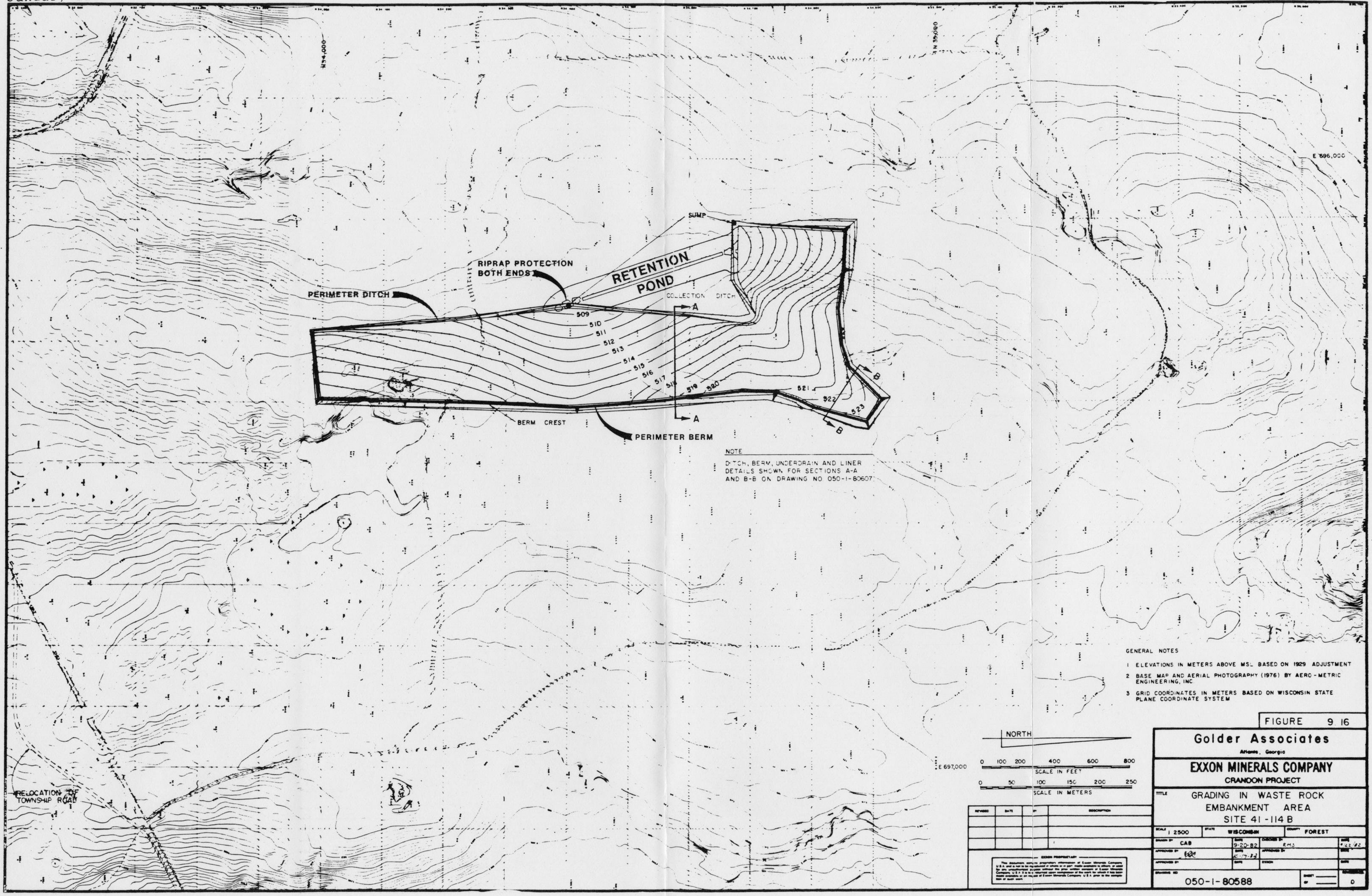
Because some of the waste rock will contain sulfide minerals (all non-sulfide waste rock and overburden from shaft sinking and early mine development is assumed to be used in construction of the plant and/or roads) it has a potential to produce an acidic leachate. Thus, the waste rock is treated as a waste product and is kept within the waste disposal area above the liners and liner/underdrain seepage control measures of the various ponds. Because of this, the waste rock used in embankment construction has been confined to common embankments (those between ponds) and will have the natural ground beneath these areas graded toward the earliest constructed pond. These areas will have the tailings pond liner and underdrain systems constructed beneath them to direct seepage into the earliest constructed tailings pond. Prior to a pond being operated, and on the side where the later pond will be constructed, lined berms with collection ditches will be constructed to collect precipitation runoff and precipitation infiltration from the underdrain. This water will be pumped to the reclaim pond or to an operating tailings pond. Figure 9.16 shows the regrading to be done in the area where waste rock will be used for embankment construction. Figure 9.17 shows detailed cross sections through the waste rock embankment.

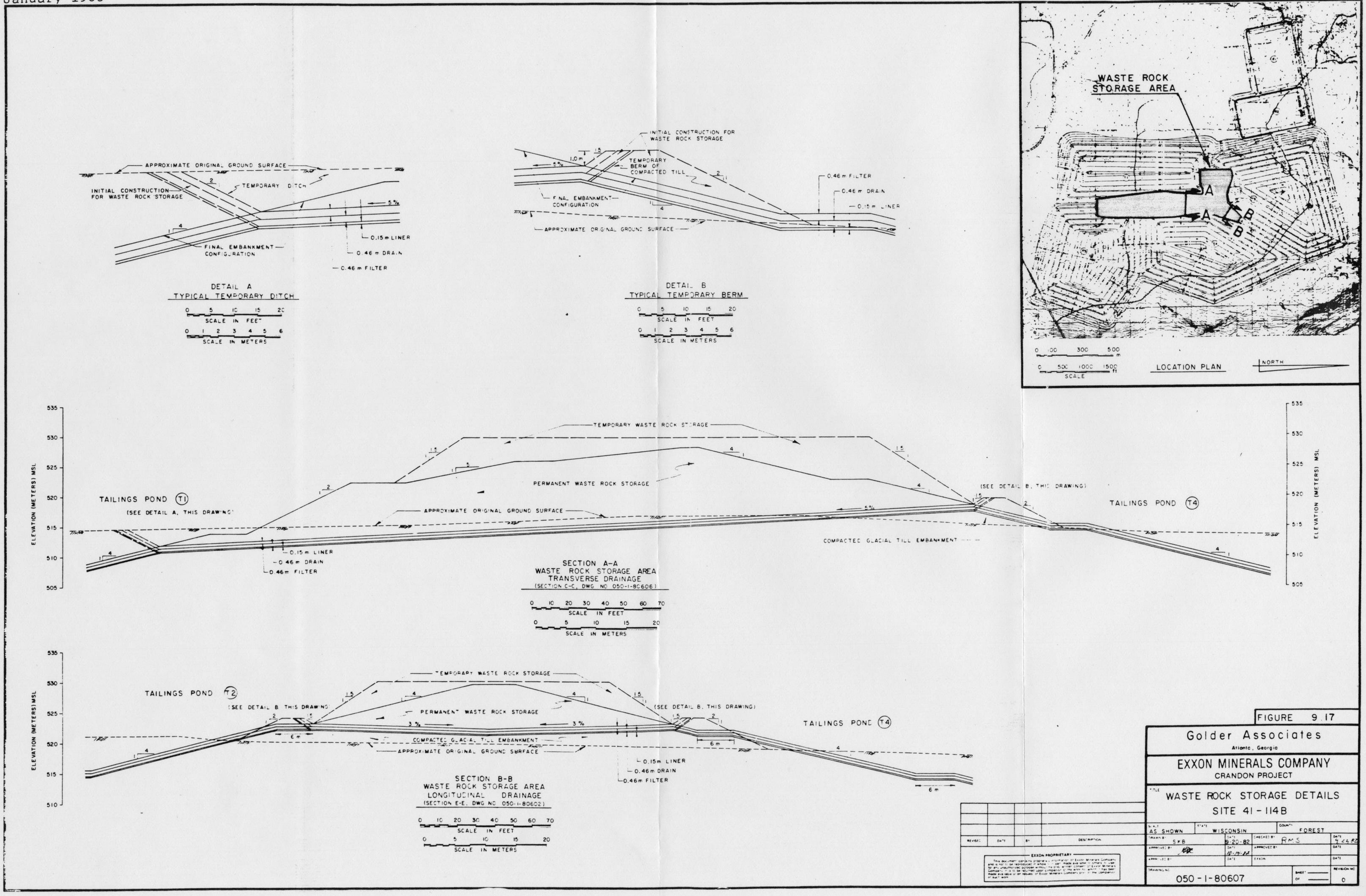
The waste rock embankment area will also be used for temporary storage of waste rock which will be needed at later times for construction of slope protection. This will be done by constructing the side slopes as steep as 1.5 horizontal to 1.0 vertical and raising the rock level slightly above the final pond crest elevations. These slopes are steeper than other interior embankment slopes since the liner and underdrain is beneath the waste rock rather than being placed on the waste rock. As waste rock is needed as a construction mateial, it can be taken from this area without affecting normal pond operations. This area may also be utilized for temporary storage of pre-production ore.

When the tailings ponds are reclaimed, waste rock will be used as part of the material for grading the surface over the tailings and/or in forming a construction mat over the tailings. The waste rock will be kept below the final reclamation cover and seal.

9.6 Tailings Distribution

The tailings will be pumped at 50 percent solids concentration, by weight, from the mill to the tailings ponds. The tailings will be input at one side (or sides) of the ponds. Clarified water will be pumped from the surface of the pond and water from the pond underdrain will be pumped to the reclaim ponds. A floating barge mounted pump is presently anticipated for pumping the ponded surface water. A fixed pump will take water from the reclaim pond


RETENTION POND
SUMP
RIPRAP PROTECTION BOTH ENDS
PERIMETER DITCH
COLLECTION DITCH
PERIMETER BERM
BERM CREST
A
B
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
NOTE
DITCH, BERM, UNDERDRAIN AND LINER DETAILS SHOWN FOR SECTIONS A-A AND B-B ON DRAWING NO. 050-1-80607.
N 34,000
N 35,000
E 696,000
E 697,000
RELOCATION OF TOWNSHIP ROAD
GENERAL NOTES
1 ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2 BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM
NORTH
0 100 200 400 600 800
SCALE IN FEET
0 50 100 150 200 250
SCALE IN METERS
FIGURE 9.16
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
GRADING IN WASTE ROCK EMBANKMENT AREA SITE 41-114 B
1 2500
WISCONSIN
FOREST
CAB
9-20-82
050-1-80588
0

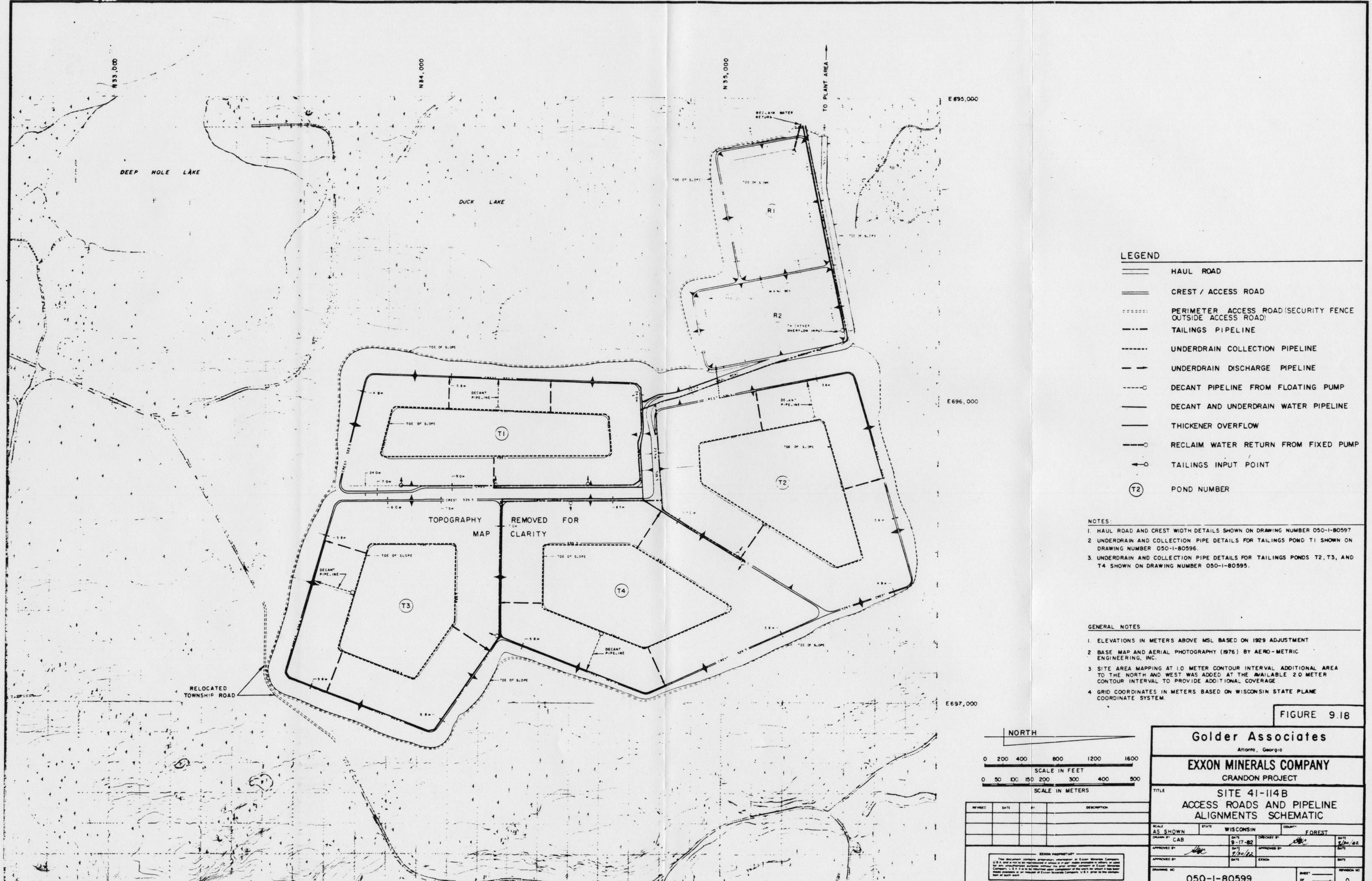

APPROXIMATE ORIGINAL GROUND SURFACE
INITIAL CONSTRUCTION FOR WASTE ROCK STORAGE
TEMPORARY DITCH
5%
FINAL EMBANKMENT CONFIGURATION
0.15m LINER
0.46m DRAIN
0.46m FILTER
DETAIL A
TYPICAL TEMPORARY DITCH
SCALE IN FEET
SCALE IN METERS
INITIAL CONSTRUCTION FOR WASTE ROCK STORAGE
1.0m
TEMPORARY BERM OF COMPACTED TILL
0.46m FILTER
0.46m DRAIN
0.15m LINER
FINAL EMBANKMENT CONFIGURATION
APPROXIMATE ORIGINAL GROUND SURFACE
DETAIL B
TYPICAL TEMPORARY BERM
SCALE IN FEET
SCALE IN METERS
WASTE ROCK STORAGE AREA
LOCATION PLAN
SCALE
NORTH
TEMPORARY WASTE ROCK STORAGE
PERMANENT WASTE ROCK STORAGE
TAILINGS POND T1
(SEE DETAIL A, THIS DRAWING)
APPROXIMATE ORIGINAL GROUND SURFACE
(SEE DETAIL B, THIS DRAWING)
TAILINGS POND T4
COMPACTED GLACIAL TILL EMBANKMENT
ELEVATION (METERS) MSL
0.15m LINER
0.46m DRAIN
0.46m FILTER
SECTION A-A
WASTE ROCK STORAGE AREA
TRANSVERSE DRAINAGE
(SECTION C-C, DWG NO 050-1-80606)
SCALE IN FEET
SCALE IN METERS
TEMPORARY WASTE ROCK STORAGE
TAILINGS POND T2
(SEE DETAIL B, THIS DRAWING)
PERMANENT WASTE ROCK STORAGE
(SEE DETAIL B, THIS DRAWING)
TAILINGS POND T4
COMPACTED GLACIAL TILL EMBANKMENT
APPROXIMATE ORIGINAL GROUND SURFACE
0.15m LINER
0.46m DRAIN
0.46m FILTER
SECTION B-B
WASTE ROCK STORAGE AREA
LONGITUDINAL DRAINAGE
(SECTION E-E, DWG NO 050-1-80602)
SCALE IN FEET
SCALE IN METERS
FIGURE 9.17
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
WASTE ROCK STORAGE DETAILS
SITE 41-114B
AS SHOWN
WISCONSIN
FOREST
050-1-80607
EXXON PROPRIETARY

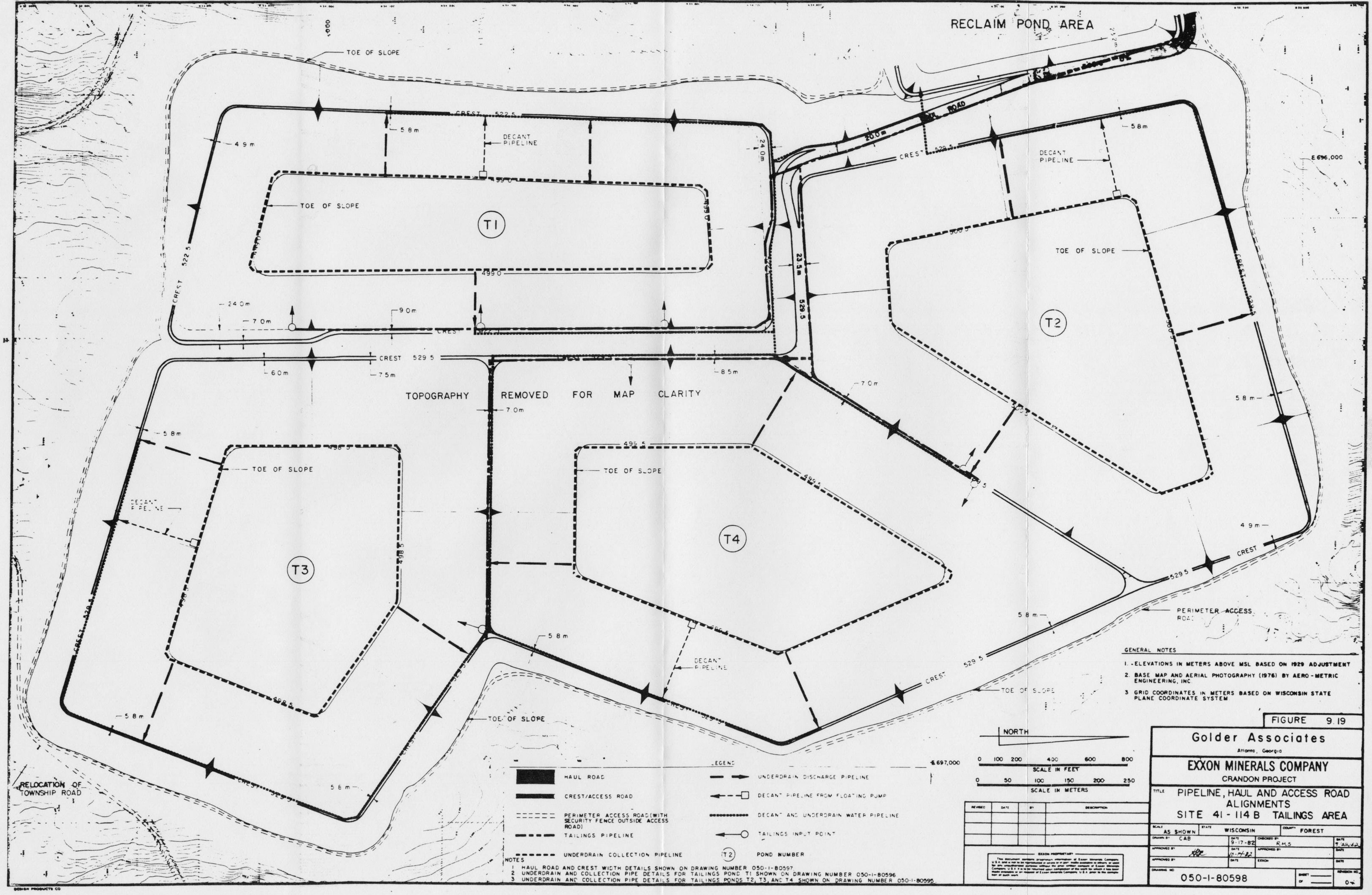
to the mine/mill complex for re-use. The pipeline alignments for the entire system are shown on Figure 9.18 and the alignments around the tailings ponds are shown on Figure 9.19. Although all alignments are shown, they will be constructed only as needed depending on which ponds are in operation. A schematic diagram of the pipelines and their approximate sizes is shown on Figure 9.20.

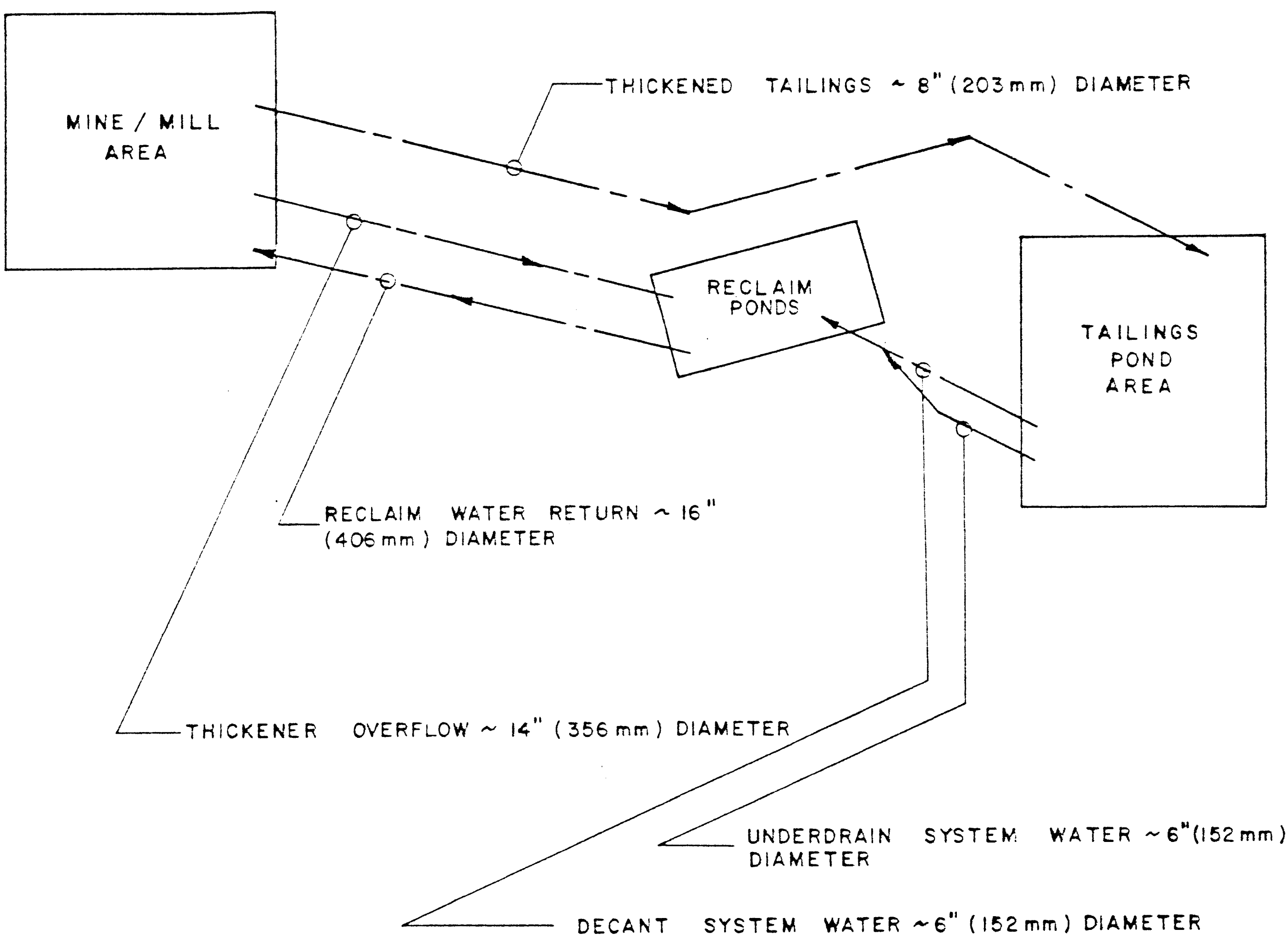
The tailings and return water pipelines follow the embankment crests and will be placed along the inside edge of the crests. The crest widths vary depending on the number of pipelines to be carried. The pond crests also serve as access roads. The relationship between the number of pipelines and the crest width was previously shown on Figure 9.9.

The anticipated tailings input points are noted on Figure 9.21. With tailings input at these locations, the estimated surface of the tailings when the ponds are filled is shown on Figure 9.21. This surface is based on an estimated 0.5 percent slope to the tailings beach, and an estimated ponded water surface of about 20 percent of the tailings pond area with water about 20 feet (6.1 m) deep. Estimates of the volume of material needed for reclamation have been based on the tailings surfaces shown on Figure 9.21 and the anticipated final reclaimed surface.

Tailings surfaces other than those shown on Figure 9.21 can be developed with different fixed locations of the tailings input points and/or by moving the input points around the crest and over previously deposited tailings. A more detailed discussion of these options is presented in Golder Associates' Project Report 10 (Ref. 20). Although maximizing the storage efficiency of the tailings within a


N33,000
N34,000
N35,000
TO PLANT AREA
E695,000
E696,000
E697,000
DEEP HOLE LAKE
DUCK LAKE
RECLAIM WATER RETURN
TOE OF SLOPE
R1
R2
T1
T2
T3
T4
DECANT PIPELINE
TOPOGRAPHY REMOVED FOR MAP CLARITY
RELOCATED TOWNSHIP ROAD
LEGEND
HAUL ROAD
CREST / ACCESS ROAD
PERIMETER ACCESS ROAD (SECURITY FENCE OUTSIDE ACCESS ROAD)
TAILINGS PIPELINE
UNDERDRAIN COLLECTION PIPELINE
UNDERDRAIN DISCHARGE PIPELINE
DECANT PIPELINE FROM FLOATING PUMP
DECANT AND UNDERDRAIN WATER PIPELINE
THICKENER OVERFLOW
RECLAIM WATER RETURN FROM FIXED PUMP
TAILINGS INPUT POINT
POND NUMBER
NOTES:
1. HAUL ROAD AND CREST WIDTH DETAILS SHOWN ON DRAWING NUMBER 050-1-80597
2 UNDERDRAIN AND COLLECTION PIPE DETAILS FOR TAILINGS POND T1 SHOWN ON DRAWING NUMBER 050-1-80596.
3. UNDERDRAIN AND COLLECTION PIPE DETAILS FOR TAILINGS PONDS T2, T3, AND T4 SHOWN ON DRAWING NUMBER 050-1-80595.
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2 BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3 SITE AREA MAPPING AT 1.0 METER CONTOUR INTERVAL ADDITIONAL AREA TO THE NORTH AND WEST WAS ADDED AT THE AVAILABLE 2.0 METER CONTOUR INTERVAL TO PROVIDE ADDITIONAL COVERAGE.
4 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
NORTH
0 200 400 800 1200 1600
SCALE IN FEET
0 50 100 150 200 300 400 500
SCALE IN METERS
FIGURE 9.18
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
SITE 41-114B
ACCESS ROADS AND PIPELINE ALIGNMENTS SCHEMATIC
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CAB
DATE 9-17-82
CHECKED BY
DATE 9/30/82
APPROVED BY
DATE 9/30/82
DRAWING NO 050-1-80599
REVISION NO 0


RECLAIM POND AREA
TOE OF SLOPE
CREST 522.5
DECANT PIPELINE
T1
T2
T3
T4
CREST 529.5
TOPOGRAPHY REMOVED FOR MAP CLARITY
PERIMETER ACCESS ROAD
RELOCATION OF TOWNSHIP ROAD
E 696,000
E 697,000
LEGEND
HAUL ROAD
CREST/ACCESS ROAD
PERIMETER ACCESS ROAD (WITH SECURITY FENCE OUTSIDE ACCESS ROAD)
TAILINGS PIPELINE
UNDERDRAIN COLLECTION PIPELINE
UNDERDRAIN DISCHARGE PIPELINE
DECANT PIPELINE FROM FLOATING PUMP
DECANT AND UNDERDRAIN WATER PIPELINE
TAILINGS INPUT POINT
POND NUMBER
NOTES
1 HAUL ROAD AND CREST WIDTH DETAILS SHOWN ON DRAWING NUMBER 050-1-80597.
2 UNDERDRAIN AND COLLECTION PIPE DETAILS FOR TAILINGS POND T1 SHOWN ON DRAWING NUMBER 050-1-80596
3 UNDERDRAIN AND COLLECTION PIPE DETAILS FOR TAILINGS PONDS T2, T3, AND T4 SHOWN ON DRAWING NUMBER 050-1-80595.
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC
3 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM
NORTH
0 100 200 400 600 800
SCALE IN FEET
0 50 100 150 200 250
SCALE IN METERS
FIGURE 9.19
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE PIPELINE, HAUL AND ACCESS ROAD ALIGNMENTS SITE 41-114 B TAILINGS AREA
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CAB
DATE 9-17-82
CHECKED BY RMS
DATE 9/22/82
DATE 10-14-82
DRAWING NO 050-1-80598
REVISION NO. 0



JOB NO. 786085	SCALE NONE	PIPELINE SIZES AND ALIGNMENT SCHEMATIC
DRAWN CAB	DATE 8-16-82	
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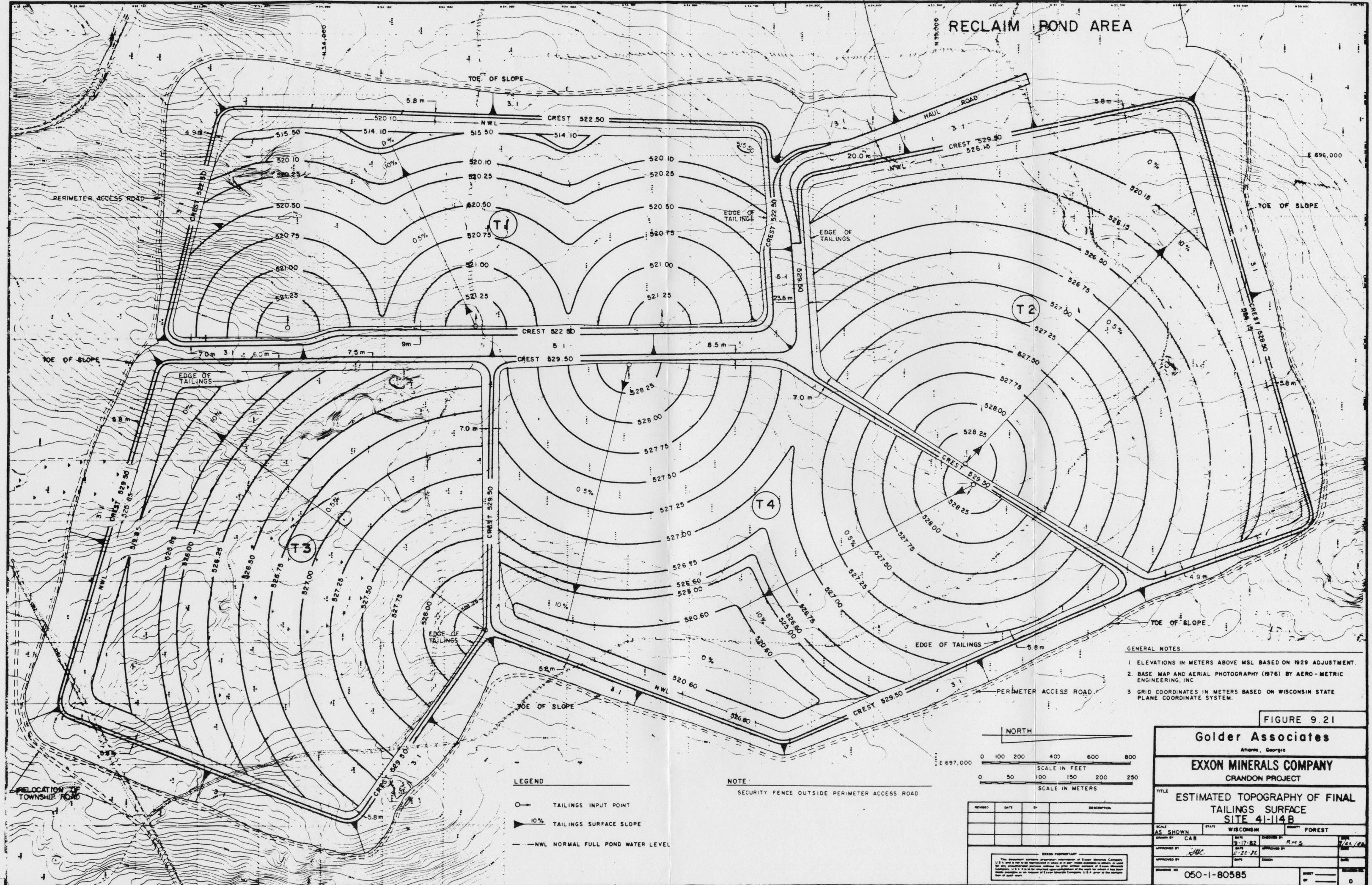
Golder Associates		EXXON MINERALS COMPANY — FIGURE 9.20


RECLAIM POND AREA
TOE OF SLOPE
CREST 522.50
NWL
HAUL ROAD
CREST 529.50
PERIMETER ACCESS ROAD
EDGE OF TAILINGS
T1
T2
T3
T4
CREST 529.50
RELOCATION OF TOWNSHIP ROAD
LEGEND
TAILINGS INPUT POINT
10% TAILINGS SURFACE SLOPE
NWL NORMAL FULL POND WATER LEVEL
NOTE
SECURITY FENCE OUTSIDE PERIMETER ACCESS ROAD
NORTH
SCALE IN FEET
SCALE IN METERS
GENERAL NOTES:
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
FIGURE 9.21
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
ESTIMATED TOPOGRAPHY OF FINAL TAILINGS SURFACE SITE 41-114B
AS SHOWN
WISCONSIN
FOREST
CAB
9-17-82
RHS
050-1-80585

pond optimizes the storage volume to pond embankment volume ratio, it may increase the volume of earthwork needed for reclamation. From the various options studied (Ref. 20) the one shown herein is relatively simple and easily obtainable. However, during operation of the first pond various input techniques could be tried to see if a slightly different surface can be obtained which would maximize storage efficiency without greatly increasing the required cover volume. It may also be possible to re-grade the tailings to reduce the required volume of reclamation cover. Variations in tailings deposition configuration and working with previously deposited tailings are best left to the time when the ponds are in operation. These details cannot be accurately planned at this point in the preliminary engineering design process.

9.7 Access and Haul Roads

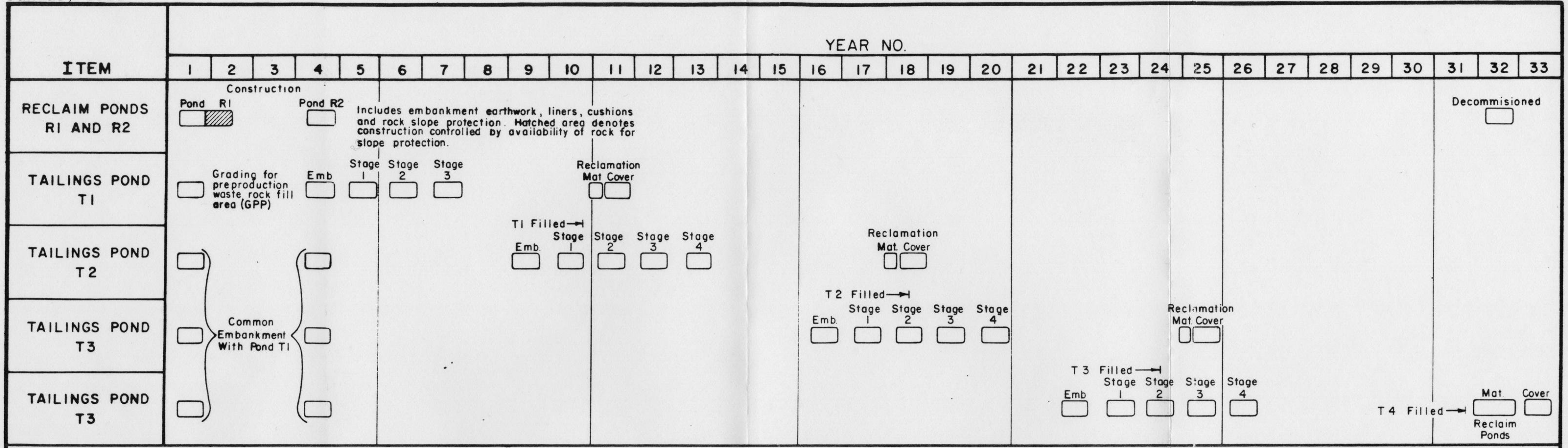
Access roads are needed along the pond crests and toe of exterior embankment slopes for inspection and periodic maintenance of the waste disposal system facilities. Haul roads are those which will also be used by rock trucks hauling waste rock to the waste disposal area for embankment construction or storage for later use as rock slope protection. All access and haul roads will be surfaced with rock or granular material to provide an all weather surface. The access and haul road alignments were highlighted on Figures 9.18 and 9.19.

The pond crests are designed to accommodate a minimum 16 foot (4.9 m) wide access road with safety berms or guard rails which permits one way traffic. In some areas the crests are wider because the tailings and/or water recycle pipelines also run along the crests. The perimeter access road (at the exterior toe of slope) is designed to be 20 feet (6.1 m) wide for two way traffic. The rock haul roads are 50 feet (15 m) in width with safety berms and permit two way traffic. Additional width is provided for pipelines in some areas. Typical cross sections of these various access and haul roads were previously shown on Figure 9.9.

9.8 Earthwork and Staged Construction

The reclaim pond embankments will be constructed of glacial till excavated from within the area covered by the reclaim ponds. Embankments for the four tailings ponds will be constructed of glacial till from within the tailings pond area and from waste rock. Glacial till from within the system area will also be used as reclamation cover, processed for liner material, processed for underdrain drain material, processed for sand cushion material for the reclaim pond liner, and processed for use as mine backfill. The volume of glacial till to be excavated is approximately 17.8 million cubic yards ($13.6x10^6$ m^3). Of this volume, approximately 7.2 million cubic yards ($5.5x10^6$ m^3) will be used for embankment construction, 5.5 million cubic yards ($4.2x10^6$ m^3) as processed materials, and 5.0 million cubic yards ($3.8x10^6$ m^3) as reclamation cover. A more detailed listing of the earthwork volumes on a pond-by-pond basis were included on Figures 9.1 and 9.3.

System 41-114B is designed to provide for staged construction on an individual pond basis and to provide for limited vertical staged construction of the liner, underdrain and rock slope protection within an individual tailings pond. A bar chart schedule for construction of the system is presented on Figure 9.22. The timing of construction is set to match the time at which the various ponds will be needed for water storage and/or tailings storage. Some of the embankments will be constructed ear-



Notes:

1. Tailings pond construction is scheduled to begin (except for waste rock embankment which coincides with waste rock production schedule) as late as possible to have the ponds in service as per tailings production. Tailings ponds assumed to be vertically staged as follows:

Embankment:	Includes all excavation. Includes soil fill to finished subgrade.
Stage 1:	Includes liner, underdrain, and rock slope protection (as applicable) over pond bottom and up to the level of the lowest bench.
Stage 2,3,4:	Includes liner, underdrain, and rock slope protection (as applicable) to next highest bench or crest as appropriate.

2. Completion of reclaim pond R1 dependent on generation of pre-production waste rock. Reclaim pond R1 includes processed material and off site borrow material for sand cushion below the synthetic liner.

JOB NO. 786085	SCALE NOT TO SCALE	CONSTRUCTION BAR CHART SCHEDULE
DRAWN SKB	DATE 10 21 82	
CHECKED [signature]	DWG NO. ——	
Golder Associates		EXXON MINERALS COMPANY — FIGURE 9.22

lier than required by the tailings production schedule because they are made of waste rock and their construction timing is established by the production schedule of waste rock from the mine. A more detailed description of the waste rock utilization was presented in Section 9.5.

Construction of the mine waste disposal system will begin by providing an area for storage of pre-production waste rock, constructing reclaim pond R1, and beginning to place the preproduction waste rock in its storage area which will utlimately become part of the common embankment between tailings ponds T1, T2, T3, and T4. This construction will be done while mine access shafts and underground development is beginning. No tailings will be produced during this period.

The next major stage will be construction of the second reclaim pond, R2, and the first tailings pond, T1. This work will be completed prior to production of tailings. The reclaim ponds will be filled to provide start-up water for the mill. Tailings pond T1 will have to be completed up to the level of the lowest interior construction berm in order to accept tailings. In later years, the underdrain, liner, and rock slope protection can be placed to higher level berms on the interior slopes of the embankments as needed. This vertical staging could be of benefit in leveling out over time the production rates of processed material for the underdrain and liner.

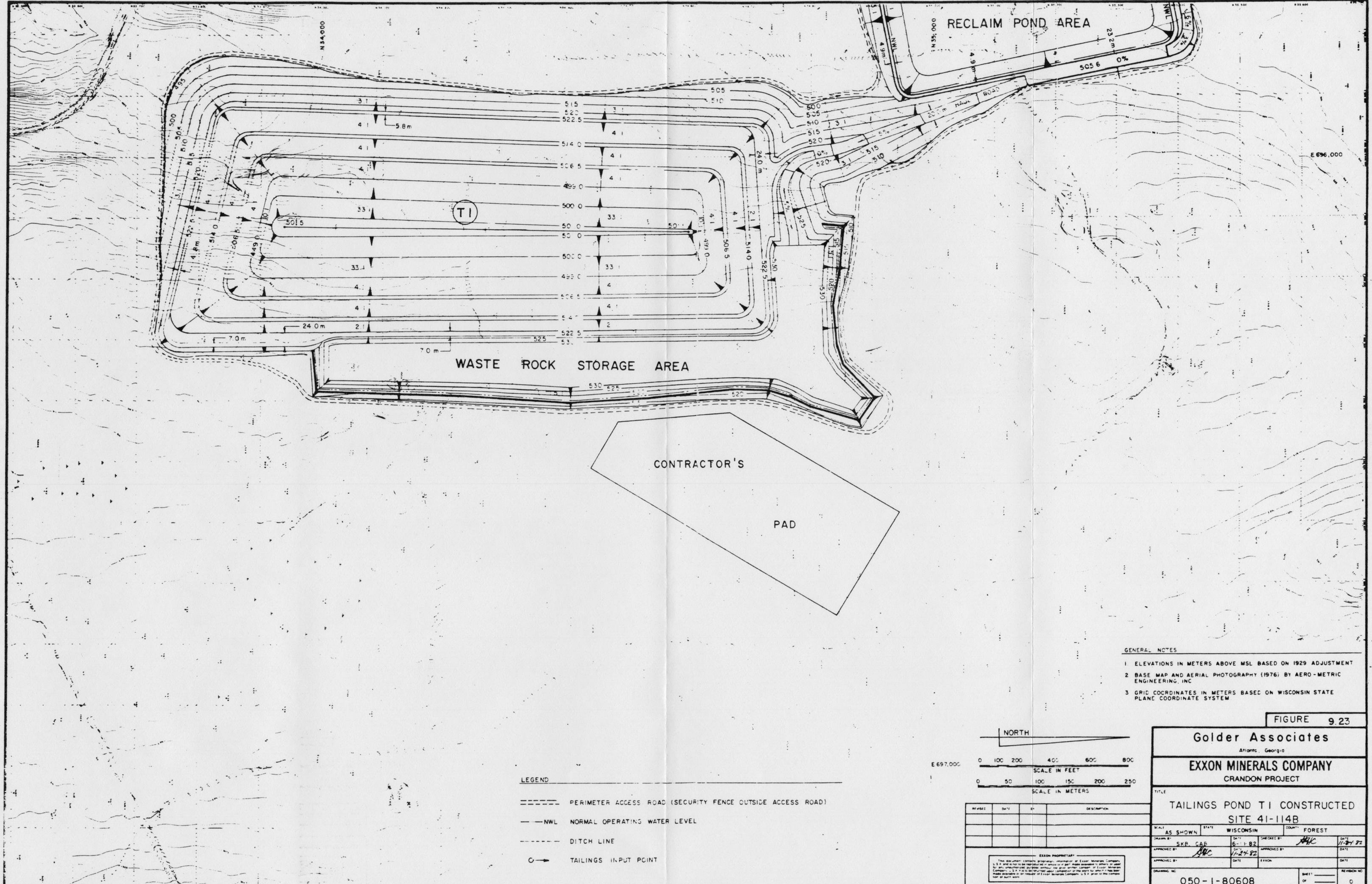
The next three major stages of development are construction of tailings ponds T2, T3, and T4, respectively. Construction schedules will be set so that each tailings pond is completed up to the lowest berm prior to filling of the preceeding tailings pond. Each tailings pond may have the underdrain, liner, and rock slope protection vertically staged as described for tailings pond T1.

The various major construction stages described in the preceeding paragraphs are illustrated on Figures 9.23 through 9.26. In addition to staged construction, the waste disposal facility is designed to permit staged reclamation. The beginning reclamation stages, with reclamation cover on tailings ponds T1 and T2, are shown on Figures 9.25 and 9.26. The remainder of the reclamation stages are shown on the figures presented and discussed in Section 9.9, which follows.

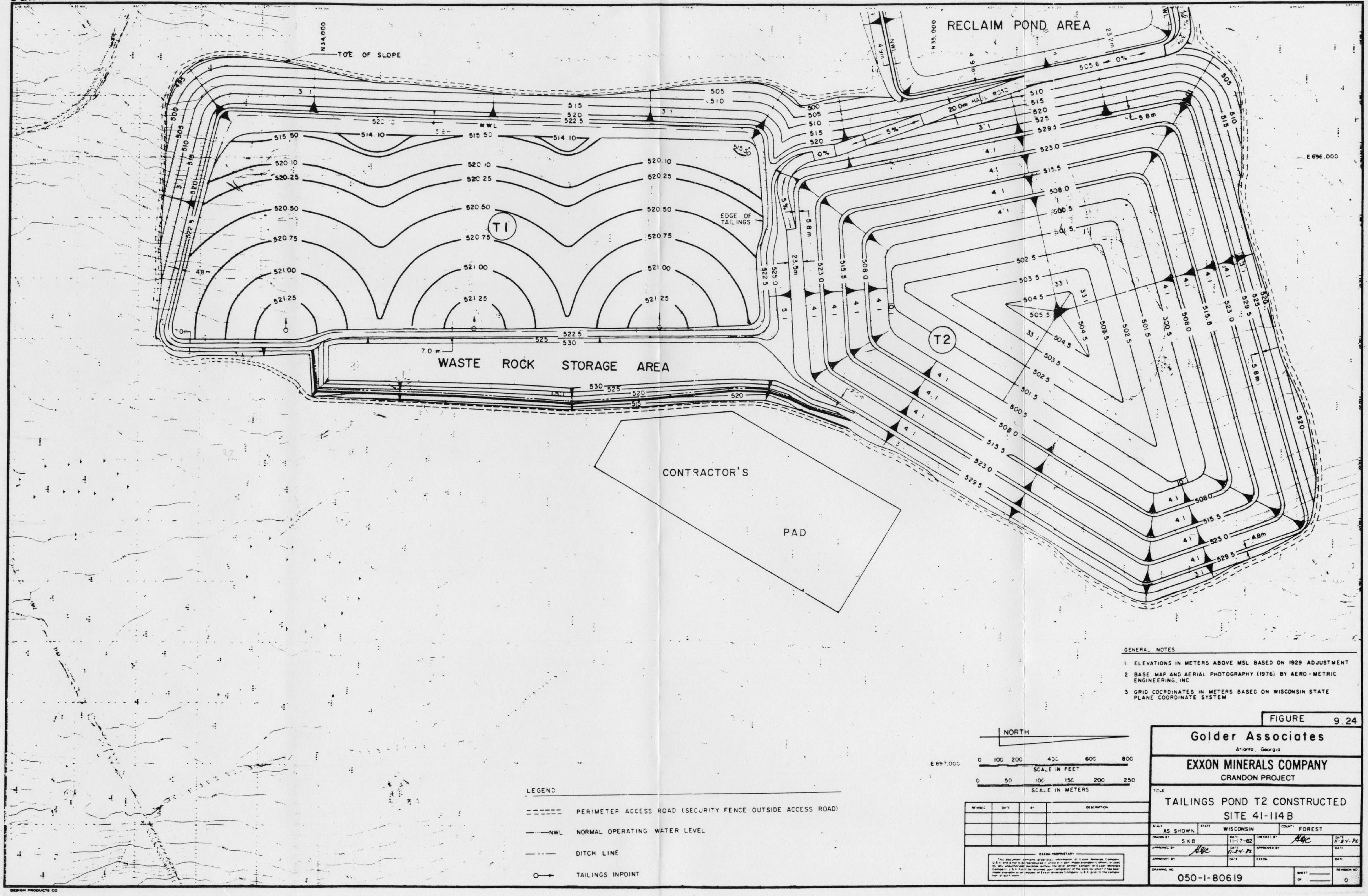
9.9 Reclamation

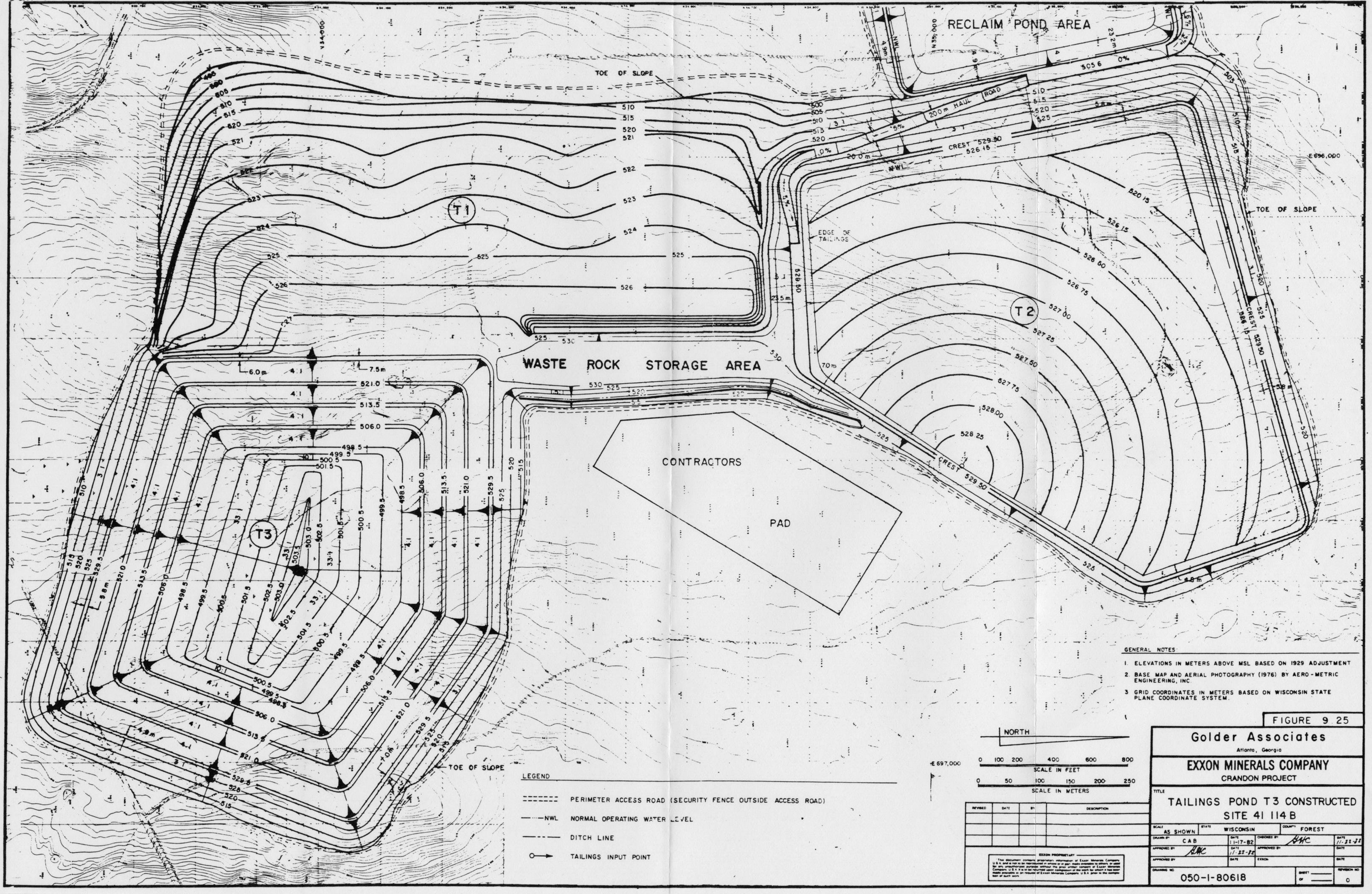
The tailings disposal reclamation system is designed with a 6 inch (150 mm) till/bentonite admixture seal covered by 3 feet (0.91 m) of glacial till. Glacial till and waste rock, some of which will come from previously constructed embankments, will be used to grade the pond surface to a minimum 2 percent slope. The thickness of the material used for grading will vary, but is anticipated to be at least 2 feet (0.61 m) thick in order to provide a working mat above the tailings. A typical detail for the cover system was previously shown on Figure 9.9.

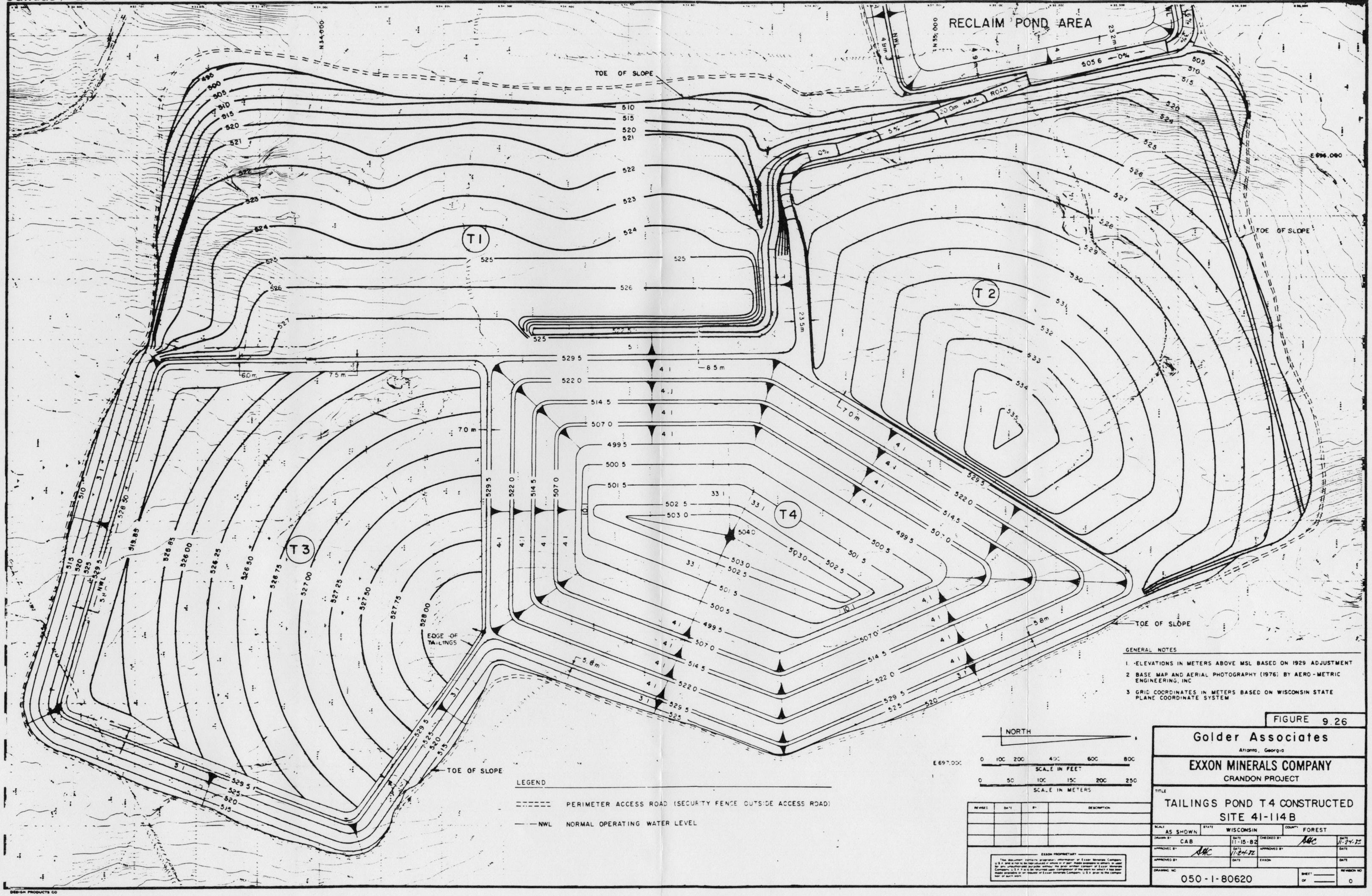
It is estimated that the till/bentonite seal layer will restrict infiltration seepage into the tailings to a maximum of about 3.4 inches per year (89 mm/y), which is equivalent to about 18 gallons per minute (1.1×10^{-3} m^3/s) for a nominal 100 acre (40 ha) pond. This figure assumes that the till above the seal layer is continually saturated for 41 weeks of the year (frozen for 11 weeks) so that the seal has a constant 3 foot (0.61 m) head of water above it. The actual infiltration seepage rate will be less than



RECLAIM POND AREA
WASTE ROCK STORAGE AREA
T1
CONTRACTOR'S
PAD
HAUL ROAD
GENERAL NOTES
1 ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2 BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC
3 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM
LEGEND
PERIMETER ACCESS ROAD (SECURITY FENCE OUTSIDE ACCESS ROAD)
NWL NORMAL OPERATING WATER LEVEL
DITCH LINE
TAILINGS INPUT POINT
NORTH
SCALE IN FEET
SCALE IN METERS
FIGURE 9.23
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TAILINGS POND T1 CONSTRUCTED
SITE 41-114B
AS SHOWN
WISCONSIN
FOREST
050-1-80608


RECLAIM POND AREA
TOE OF SLOPE
N34,000
N35,000
E696,000
E697,000
EDGE OF TAILINGS
T1
T2
WASTE ROCK STORAGE AREA
CONTRACTOR'S PAD
20.0m HAUL ROAD
NWL
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM
NORTH
0 100 200 400 600 800
SCALE IN FEET
0 50 100 150 200 250
SCALE IN METERS
LEGEND
PERIMETER ACCESS ROAD (SECURITY FENCE OUTSIDE ACCESS ROAD)
NWL NORMAL OPERATING WATER LEVEL
DITCH LINE
TAILINGS INPOINT
FIGURE 9.24
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TAILINGS POND T2 CONSTRUCTED
SITE 41-114B
AS SHOWN
WISCONSIN
FOREST
SKB
11-17-82
050-1-80619
0


RECLAIM POND AREA
TOE OF SLOPE
200 m HAUL ROAD
CREST 529.50
EDGE OF TAILINGS
T1
T2
T3
WASTE ROCK STORAGE AREA
CONTRACTORS
PAD
GENERAL NOTES:
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.
LEGEND
PERIMETER ACCESS ROAD (SECURITY FENCE OUTSIDE ACCESS ROAD)
NWL NORMAL OPERATING WATER LEVEL
DITCH LINE
TAILINGS INPUT POINT
NORTH
SCALE IN FEET
SCALE IN METERS
FIGURE 9.25
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TAILINGS POND T3 CONSTRUCTED
SITE 41 114 B
AS SHOWN
WISCONSIN
FOREST
CAB
11-17-82
050-1-80618

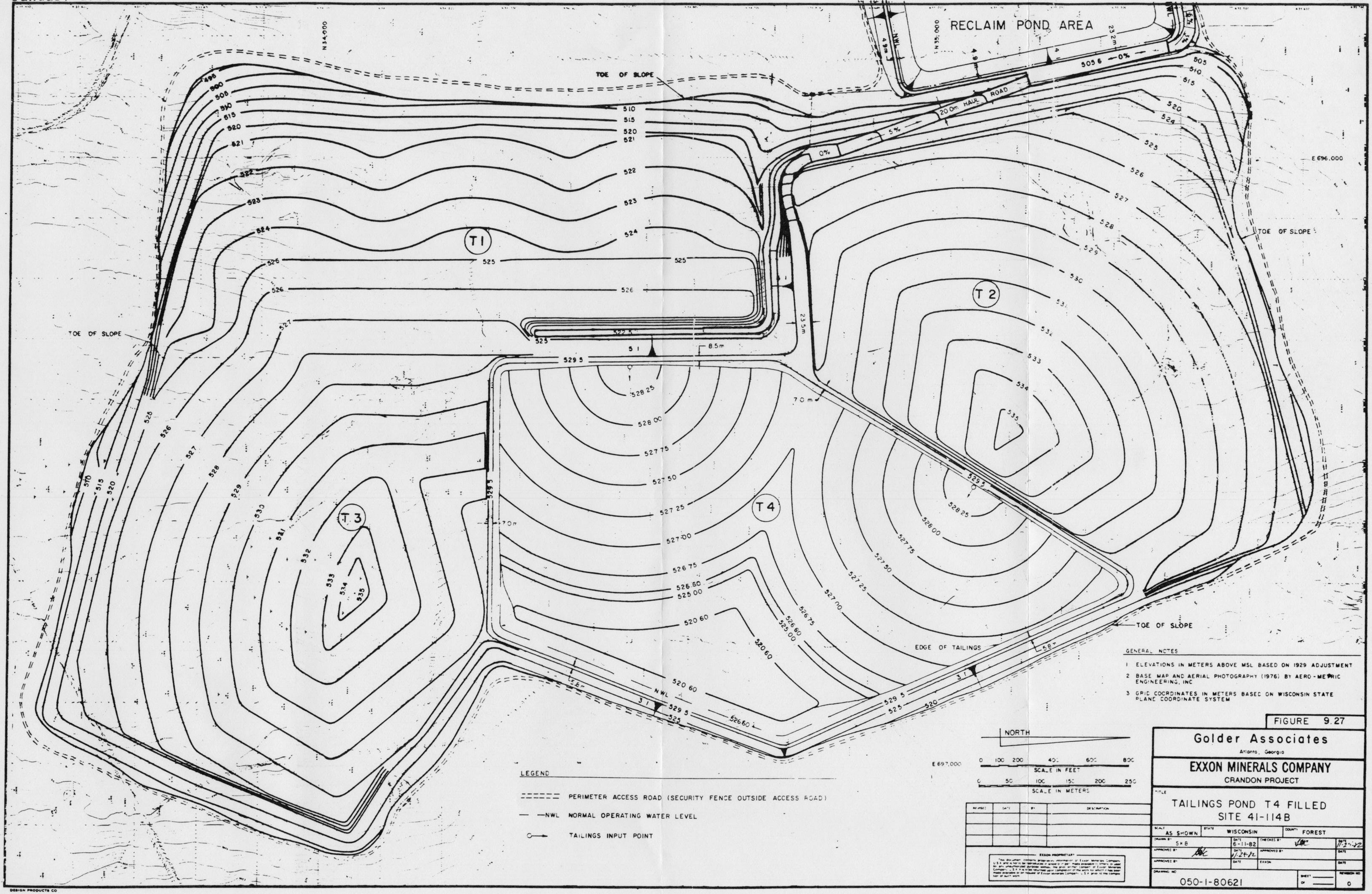

RECLAIM POND AREA
TOE OF SLOPE
T1
T2
T3
T4
20.0m HAUL ROAD
EDGE OF TAILINGS
GENERAL NOTES
1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2 BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC
3 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM
LEGEND
PERIMETER ACCESS ROAD (SECURITY FENCE OUTSIDE ACCESS ROAD)
NWL NORMAL OPERATING WATER LEVEL
NORTH
SCALE IN FEET
SCALE IN METERS
FIGURE 9.26
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TITLE
TAILINGS POND T4 CONSTRUCTED
SITE 41-114B
SCALE AS SHOWN
STATE WISCONSIN
COUNTY FOREST
DRAWN BY CAB
DATE 11-15-82
DRAWING NO 050-1-80620
REVISION NO 0
EXXON PROPRIETARY
DESIGN PRODUCTS CO

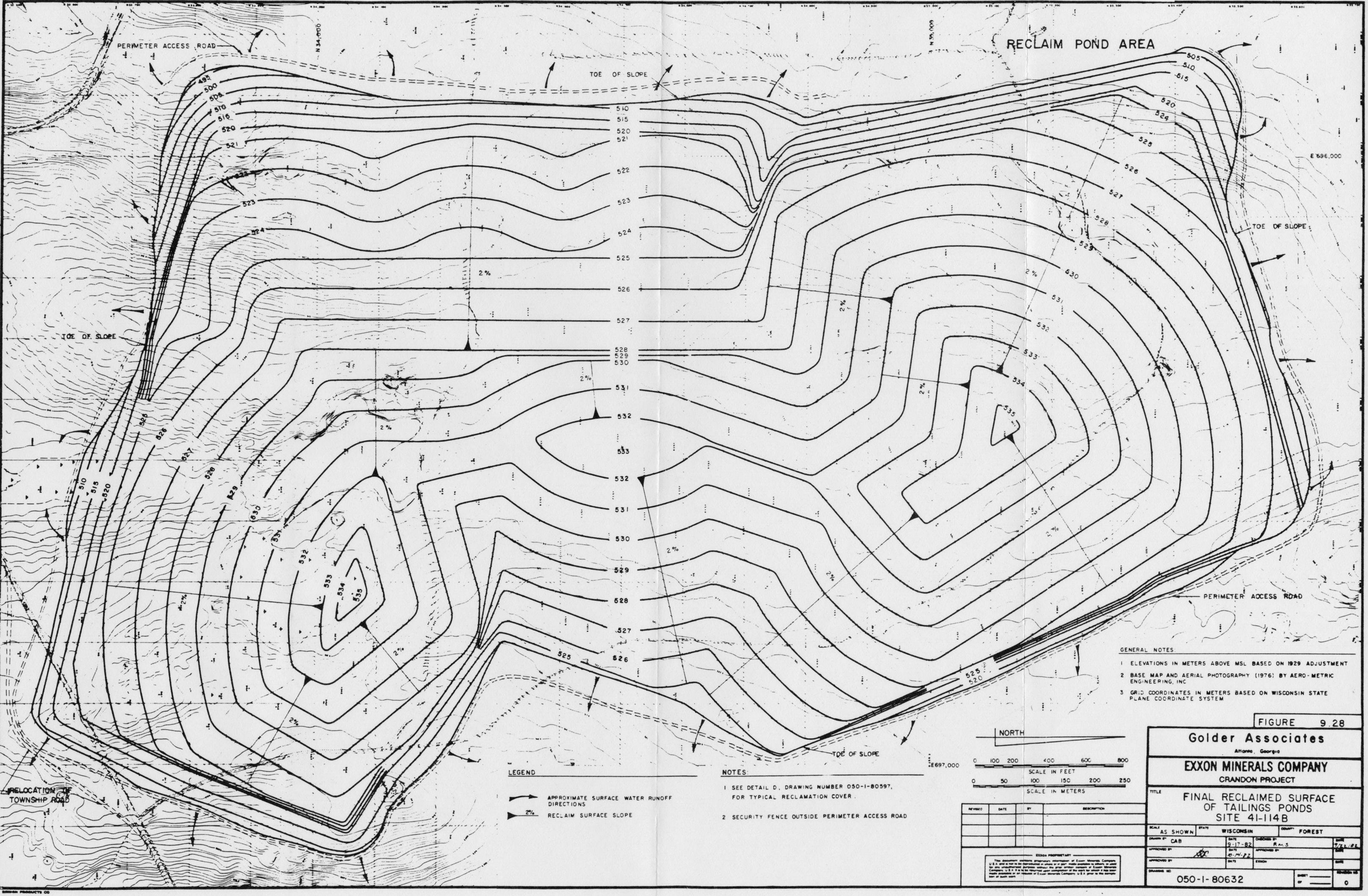
this value when accounting for evapotranspiration. Details of the procedures used for estimating this seepage rate, based strictly on hydraulic considerations, are presented in Golder Associates' Project Report 10 (Ref. 20).

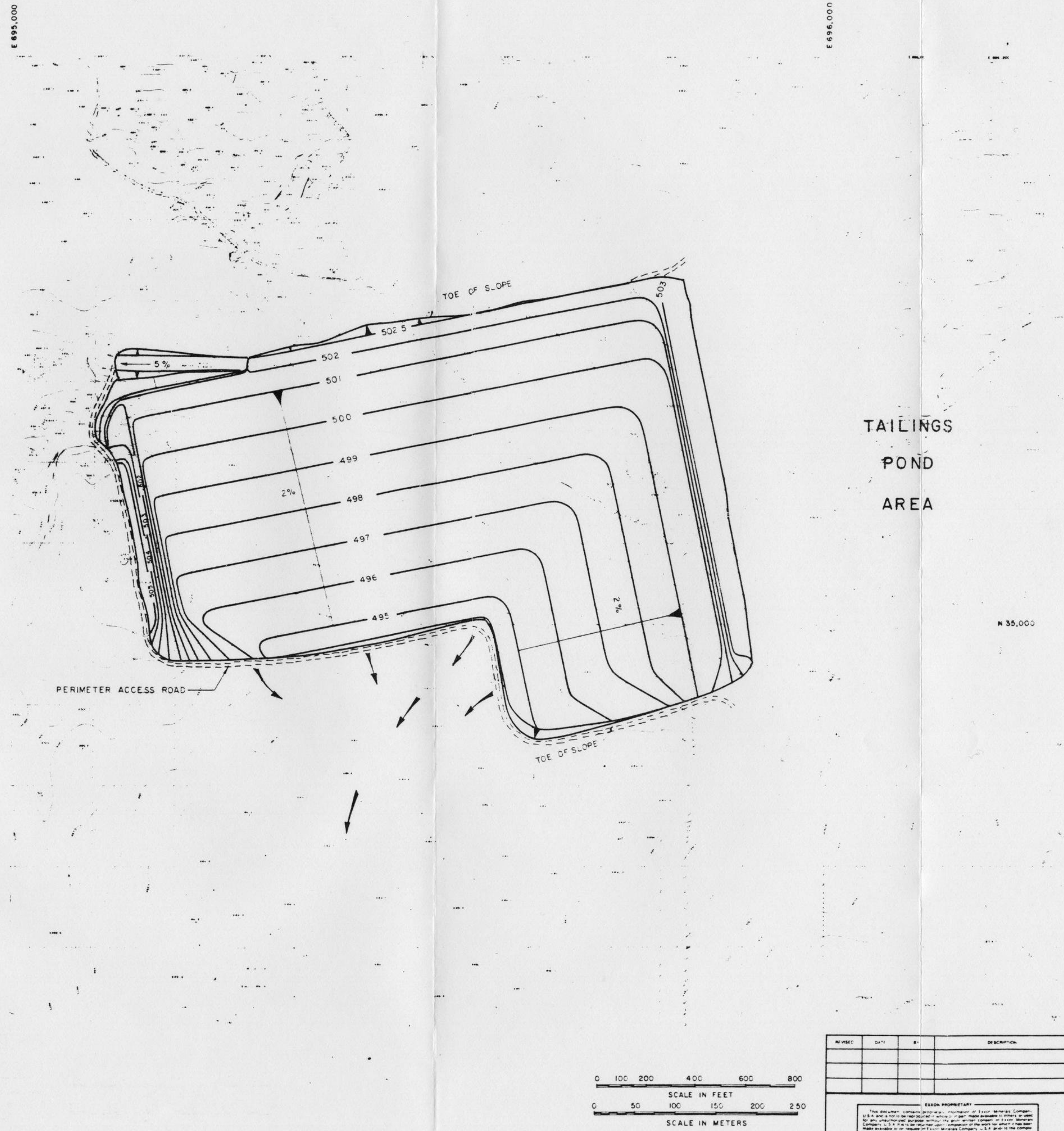
The mine waste disposal system is designed so that reclamation can be done in stages. After each tailings pond is filled and taken out of service, the ponded water will be pumped to the reclaim ponds or, in the case of the last tailings pond, to the treatment facility for discharge. The working mat above the tailings can be constructed in the winter months when the tailings surface is frozen to insure adequate trafficability for construction equipment. The remainder of the grading, seal construction, and final cover will follow. Figures 9.25 and 9.26, which were shown in Section 9.8, indicate intermediate steps in the staged reclamation process for tailings ponds T1 and T2. The stage for tailings pond T3 is shown on Figure 9.27. After the mill is no longer producing tailings, the water in the reclaim ponds and in the last tailings pond will be treated for discharge. The liner materials from the reclaim ponds and rock slope protection materials will be placed in the last tailings pond prior to its final cover being placed. The reclaim pond area will be re-graded with the glacial till embankment soils. The final reclaimed surface of the tailings ponds is shown on Figure 9.28. The final reclaimed surface of the reclaim ponds is shown on Figure 9.29.

9.10 Groundwater Monitoring

Proposed locations for installation of groundwater observation wells for purposes of groundwater quality monitoring are shown on Figure 9.30. These locations have been selected based on the anticipated direction of potential seepage flow within the groundwater system as predicted by


RECLAIM POND AREA
TOE OF SLOPE
20.0m HAUL ROAD
T1
T2
T3
T4
EDGE OF TAILINGS
NWL
GENERAL NOTES
1 ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2 BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC
3 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM
LEGEND
PERIMETER ACCESS ROAD (SECURITY FENCE OUTSIDE ACCESS ROAD)
NWL NORMAL OPERATING WATER LEVEL
TAILINGS INPUT POINT
NORTH
SCALE IN FEET
SCALE IN METERS
FIGURE 9.27
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
TAILINGS POND T4 FILLED
SITE 41-114B
AS SHOWN
WISCONSIN
FOREST
6-11-82
050-1-80621


RECLAIM POND AREA
PERIMETER ACCESS ROAD
TOE OF SLOPE
TOE OF SLOPE
TOE OF SLOPE
TOE OF SLOPE
PERIMETER ACCESS ROAD
RELOCATION OF TOWNSHIP ROAD
E 696,000
E697,000
N 34,000
N 35,000
2%
LEGEND
APPROXIMATE SURFACE WATER RUNOFF DIRECTIONS
2% RECLAIM SURFACE SLOPE
NOTES:
1 SEE DETAIL D, DRAWING NUMBER 050-1-80597, FOR TYPICAL RECLAMATION COVER.
2 SECURITY FENCE OUTSIDE PERIMETER ACCESS ROAD
GENERAL NOTES:
1 ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2 BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC
3 GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM
NORTH
0 100 200 400 600 800
SCALE IN FEET
0 50 100 150 200 250
SCALE IN METERS
FIGURE 9.28
Golder Associates
Atlanta, Georgia
EXXON MINERALS COMPANY
CRANDON PROJECT
FINAL RECLAIMED SURFACE OF TAILINGS PONDS SITE 41-114B
AS SHOWN
WISCONSIN
FOREST
CAB
9-17-82
10-14-82
050-1-80632
0



LEGEND

- APPROXIMATE SURFACE WATER RUNOFF DIRECTIONS
- 2% RECLAIM SURFACE SLOPE

NOTES

1. FOR RECLAMATION THE SOIL/BENTONITE AND SYNTHETIC LINERS WILL BE REMOVED AND DISPOSED, AREA WILL BE REGRADED, FERTILIZED, AND REVEGETATED.
2. SECURITY FENCE OUTSIDE PERIMETER ACCESS ROAD

GENERAL NOTES:

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT.
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC
3. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.

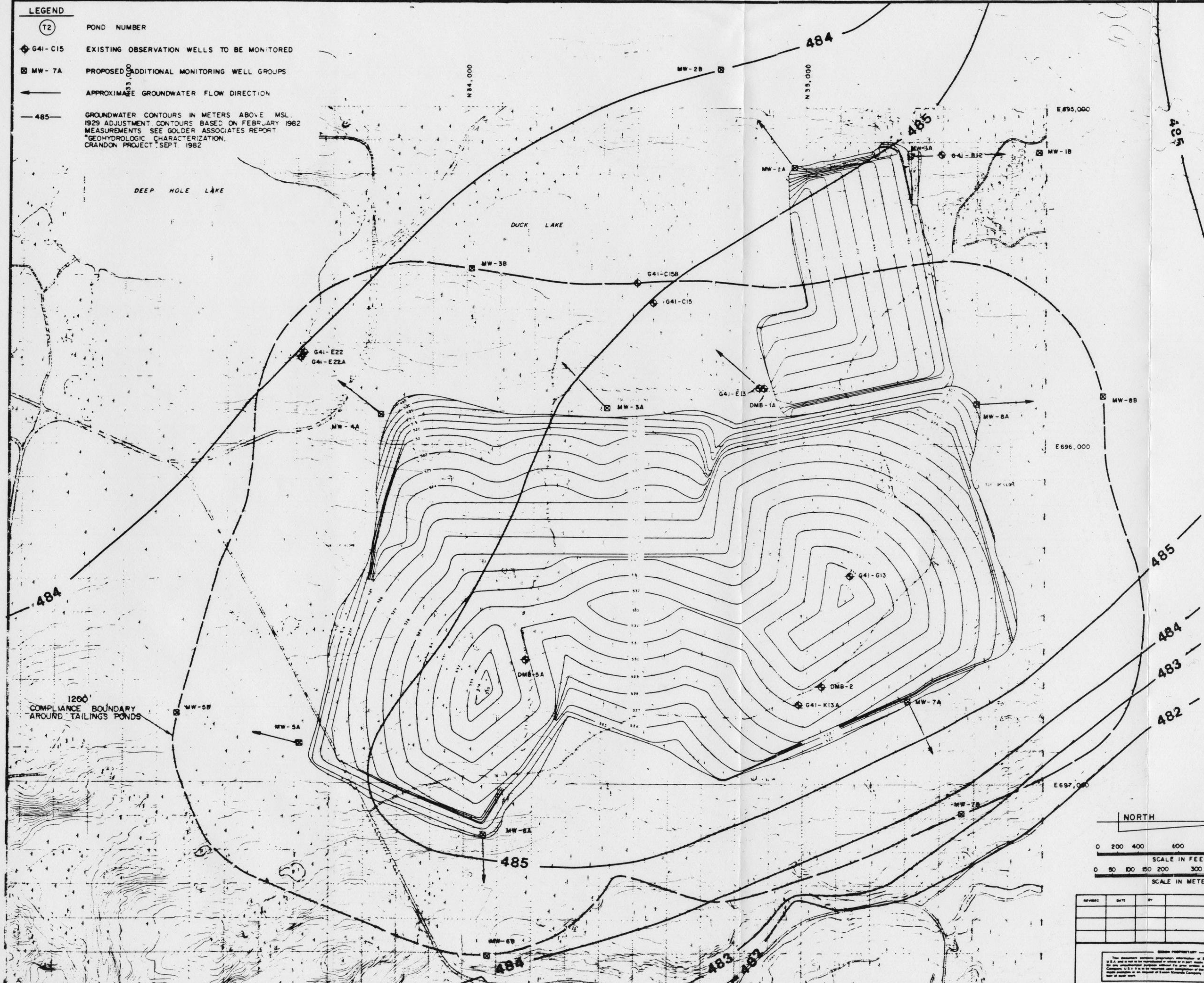
FIGURE 9.29

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: FINAL RECLAIMED SURFACE OF RECLAIM PONDS SITE 41 - 114 B

SCALE: AS SHOWN	STATE: WISCONSIN	COUNTY: FOREST	
DRAWN BY: CAB	DATE: 9-17-82	CHECKED BY: RMS	DATE: 9/22/82
APPROVED BY: [signature]	DATE: 11-22-82	APPROVED BY:	DATE:
APPROVED BY:	DATE:	EXXON:	DATE:
DRAWING NO: 050-1-80590	SHEET: OF:		REVISION NO: 0



GROUNDWATER MONITORING WELL SCHEDULE

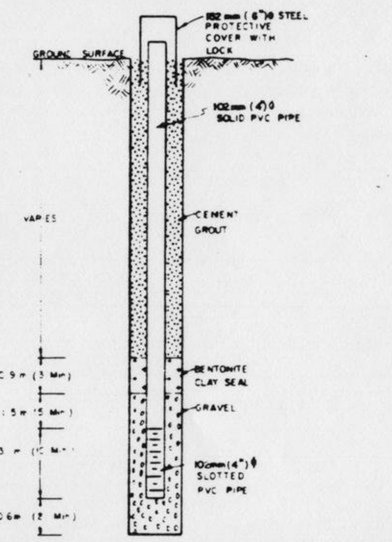
MONITORING WELL NO. (3)	Slotted Section Location (1) Till	Drift	MONITORING WELL NO. (3)	Slotted Section Location (1) Till	Drift
MW-1A-T	X		MW-5A-T	X	
G41-B12		X	MW-5A-D		X
MW-1B-T	X		MW-5B-T	X	
MW-1B-D		X	MW-5B-D		X
MW-2A-T	X		MW-6A-T	X	
MW-2A-D		X	MW-6A-D		X
MW-2B-T	X		MW-6B-T	X	
MW-2B-D		X	MW-6B-D		X
DMB-1A	X		MW-7A-T	X	
G41-E13		X	MW-7A-D		X
G41-C15		X	MW-7B-T	X	
G41-C15B	X		MW-7B-D		X
MW-3A-T	X		MW-8A-T	X	
MW-3A-D		X	MW-8A-D		X
MW-3B-T	X		MW-8B-T	X	
MW-3B-D		X	MW-8B-D		X
MW-4A-T	X		G41-G13 (2)		X
MW-4A-D		X			
G41-E22		X	DMB-2 (2)		X
G41-E22A	X		G41-K13A (2)	X	
			DMB-5A (2)	X	

(1) Till - Slotted section set in glacial till.
Drift - Slotted section set below glacial till in coarse grained stratified drift.

(2) To be grouted closed when tailings pond is constructed.

(3) MW series wells to be installed. G41 and DMB series wells presently in place.

TYPICAL MW SERIES MONITORING WELL DETAIL



NOTE: G41 AND DMB SERIES MONITORING WELLS HAVE 102 mm (4") PROTECTIVE COVER AND 51mm (2") PVC SLOTTED AND SOLID PIPE

GENERAL NOTES

1. ELEVATIONS IN METERS ABOVE MSL BASED ON 1929 ADJUSTMENT
2. BASE MAP AND AERIAL PHOTOGRAPHY (1976) BY AERO-METRIC ENGINEERING, INC.
3. SITE AREA MAPPING AT 1.0 METER CONTOUR INTERVAL. ADDITIONAL AREA TO THE NORTH AND WEST WAS ADDED AT THE AVAILABLE 2.0 METER CONTOUR INTERVAL TO PROVIDE ADDITIONAL COVERAGE.
4. GRID COORDINATES IN METERS BASED ON WISCONSIN STATE PLANE COORDINATE SYSTEM.

NORTH

0 200 400 800 1200 1600
SCALE IN FEET
0 50 100 150 200 300 400 500
SCALE IN METERS

FIGURE 9.30

Golder Associates
Atlanta, Georgia

EXXON MINERALS COMPANY
CRANDON PROJECT

TITLE: GROUNDWATER MONITORING WELL LOCATIONS SCHEDULE AND DETAILS

SCALE: AS SHOWN | STATE: WISCONSIN | COUNTY: WISCONSIN
DRAWN BY: CAB | DATE: 9-22-82 | CHECKED BY: [signature] | DATE: 11-22-82
APPROVED BY: [signature] | DATE: 11-22-82
DRAWING NO: 050-1-81120 | REVISION NO: 0

the site screening studies discussed in Section 8. For each general direction of monitoring, a set of wells is proposed near the outside toe of embankment slope and at the compliance boundary. Additional sets are located at intermediate points within the boundaries of tailings ponds T2, T3, and T4. As each pond is put into service, these intermediate monitoring wells will be grouted shut.

At each monitoring location, a pair of wells is planned. One well will be screened over the thickness of the glacial till strata below groundwater and above the coarse grained stratified drift. The second well will be screened over the thickness of the coarse grained stratified drift. Typical details of the monitoring wells are also shown on Figure 9.30.

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JEB:GHC:dap

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