Y/SUB/WM-213

Y-12

OAK RIDGE
Y-12
PLANT

MARTIN MARIETTA

CONSTRUCTION QUALITY ASSURANCE REPORT

FOR THE

Y -12 CONSTRUCTION/DEMOLITION LANDFILL VII (CDL VII)

OAK RIDGE, TENNESSEE

Peter M. Burton, P.E.

November 1994

Prepared by
Burns and McConnell Waste Consultants, Inc.
Engineers-Geologists-Scientists
Overland Park, Kansas
under
Contract No. DE-AC05-900R21860

for

Oak Ridge Y-12 Plant
Oak Ridge, Tennessee 37831-8169
managed by
Martin Marietta Energy Systems, Inc.
under contract DE-AC05-84OR214000
for the
U. S. DEPARTMENT OF ENERGY

MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY
UCN-13672 (2 10-90)

CONSTRUCTION
QUALITY ASSURANCE
REPORT

FOR THE

Y12-CONSTRUCTION DEMOLITION LANDFILL VII (CDL-VII)

OAK RIDGE, TENNESSEE

Burns & McDonnell Waste Consultants, Inc.

ENGINEERS-GEOLOGISTS-SCIENTISTS · 100% EMPLOYEE-OWNED

CONSTRUCTION
QUALITY ASSURANCE
REPORT

FOR THE

Y12-CONSTRUCTION DEMOLITION LANDFILL VII (CDL-VII)

OAK RIDGE, TENNESSEE

November 1994

Project No. 90-823-1-004-03

PETER M. BURTON
No. 00101214

11/18/94

Prepared by

Burns & McDonnell Waste Consultants, Inc.
Engineers-Geologists-Scientists
Overland Park, Kansas

MASTER

Under Contract No. DE-AC05-900R21860
for the
U.S. Department of Energy

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

PART I - SUMMARY

This Construction Quality Assurance (CQA) Report provides documentation that Bid Option 2 of the Y-12 Plant Construction Demolition Landfill VII (CDL-VII) was constructed in substantial compliance with the Tennessee Department of Environment and Conservation (TDEC) approved design, as indicated and specified in the permit drawings, approved changes, and specifications. CDL-VII is located in Anderson County on the south side of Chestnut Ridge, approximately 0.5 miles south of the Y-12 Plant in Oak Ridge, Tennessee.

This report applies specifically to the limits of excavation for Area No. I portions of the perimeter maintenance road and drainage channel and Sedimentation Pond No. 3. A partial "As-Built" survey was performed and is included.

Gary Maggert

Gary Maggert, P.E.

Pete Burton, P.E.

* * * * *

TABLE OF CONTENTS

* * * * *

PART II - INTRODUCTION

The United States Department of Energy (DOE) has finished construction of Bid Option 2 of the Y-12 Construction Demolition Landfill VII (a class IV disposal facility) at the Y-12 Plant in Oak Ridge, Tennessee. The purpose of this CQA report is to provide documentation that the landfill bottom and limits of excavation, portions of the perimeter drainage system and perimeter maintenance road, and Sedimentation Pond No. 3 were constructed in substantial compliance with the contract drawings, approved changes, specifications, and CQA manual, to support start-up of CDL-VII.

The Tennessee Department of Environment and Conservation (TDEC) issued Permit No. DML 011030045, dated December 13, 1993, to allow construction and operation of the landfill. The permit was issued based on TDEC's review of the permit application, drawings, operations manual, CQA manual, and hydrogeologic study. These documents were prepared by Burns & McDonnell Waste Consultants, Inc. (BMWCI) in accordance with the guidelines given by the Tennessee Solid Waste Processing and Disposal Regulations, Rule Chapter 1200-1-7, adopted March 18, 1990, and last amended September 29, 1993.

BMWCI was retained by the DOE Oak Ridge Operations to provide design services for Bid Option 2 (Area No. I of CDL-VII) and other work. The contract between BMWCI and DOE for design services related to the CDL-VII was modified by DOE on April 14, 1992, to allow BMWCI to also provide CQA services. These CQA services included observing the construction activities related to Bid Option 2 and preparing this report. Law Engineering (Knoxville, Tennessee) provided field testing as required through a contract with MK Ferguson, the project construction manager for DOE.

Construction of Area No. I of CDL-VII is now complete and ready for operation.

* * * * *

PART III - PROJECT DESCRIPTION

A. GENERAL

The landfill site is located between Old Bethel Valley Road and Chestnut Ridge near the east end of the Y-12 Plant in Oak Ridge, Tennessee. The total project has the following four contractual components:

1. BASE BID

The base bid consists of the construction of an access road from New Bethel Valley Road to the site, a landfill facilities building, and utilities (water, sewer, electrical, and communications).

2. BID OPTION 1

Bid Option 1 consists of the construction of Area No. I of ILF-V; the complete leachate collection system for Area No. I and leachate sewers for future Area Nos. II, III, IV, and V; leachate holding tanks, transfer pumps, and a secondary containment basin for the leachate holding tanks; the perimeter gas venting system for Area No. I; the perimeter maintenance road and perimeter drainage channels defining the limits of waste for current and future areas; and the necessary infrastructure required for associated erosion, sediment, and drainage control.

3. BID OPTION 2

Bid Option 2 consists of the excavation of Area I of the Construction/Demolition Landfill VII (CDL-VII); portions of the perimeter maintenance road and perimeter drainage channels; and the necessary infrastructure required for associated erosion, sediment, and drainage control.

4. ALTERNATIVE BID OPTION

The Alternative Bid Option consists of the construction of a second access road to the site. This access road will provide direct access to the site from the Y-12 plant across Chestnut

Ridge, without having to travel on public thoroughfares. Design of this component was completed and authorized for construction after CDL-VII was constructed.

This report only addresses Bid Option 2. An overall site plan is included in Appendix A of this report.

Area No. I is approximately 260 feet wide by 770 feet long. The floor slopes from east to west and south to north, with the overall trend being toward the northwest to Sedimentation Pond No. 3. The side slopes are laidback at a slope of approximately three horizontal to one vertical (3H:1V). The west slope will be excavated for the future Area No. II. Additional excavation will occur to the south for future Area No. IV.

An all weather access road has been constructed, entering Area No. I in the southeast corner and extending along the south edge.

Sedimentation Pond No. 3 was constructed for the specific purposes of detaining storm runoff to control peak discharge rates and providing detention time to permit solids transported in the runoff to settle. In-situ soils were suitable such that no compacted soil liner was required in the bottom of the Sedimentation Pond No. 3 in order to minimize leakage.

The contract drawings show a coordinate grid system, contours, and elevations for horizontal and vertical control. The contour lines indicated are the top of the subgrade of the excavated area itself and the top of the finished surface elsewhere. In general, the contour interval is 5 feet, with more detailed contours provided in specific detailed plans.

B. SOIL LINER

No soil liner is required. The landfill bottom and side slopes consist primarily of in-situ soils. Material properties, compaction characteristics, and hydraulic conductivity (permeability) of the proposed borrow soil were evaluated during the geologic investigation for the landfill as part of the design services provided under an agreement between Dr. David E. Daniel and Martin Marietta Energy Systems, Inc. (MMES). The following two reports were prepared by Dr. Daniel:

- "Results of Hydraulic Conductivity Tests and Recommended Water Content-Dry Density Criteria for Potential Borrow Soils," prepared for Martin Marietta Energy Systems, Inc. by David E. Daniel, October 12, 1992.

- "Final Report, Permeability of Compacted Soils from the East and West Borrow Areas," prepared for Martin Marietta Energy Systems, Inc. by David E. Daniel, March 27, 1989.

These reports are included in Appendix D of this report.

C. PERIMETER MAINTENANCE ROAD AND DRAINAGE CHANNEL

The perimeter maintenance road ultimately will extend completely around the fully developed landfill (Areas I through VI). Currently only the northern side and the northern part of the east side have been completed. Riprapped drainage channels are constructed adjacent to the maintenance road and at other critical locations to provide for drainage.

* * * * *

PART IV - CONSTRUCTION QUALITY ASSURANCE PROGRAM

A. GENERAL

A CQA program was prepared and described in the permit application submitted to the TDEC. Most of the critical CQA effort is associated with future closure and the construction of the compacted soil cap with low hydraulic conductivity. The CQA manual provides details for determining an appropriate material for the construction of a compacted soil cap. It also provides methods and procedures to be used in monitoring the installation of the future compacted soil cap. A copy of the CQA manual for this project is included in Appendix G of this report.

B. SOIL LINER

As previously state, no soil liner is required. However, the CQA manual did call for boulders and large rocks found in the bottom of the landfill excavation to be removed and the remaining holes or voids to be backfilled with compacted soil.

The subgrade was observed during construction operations. A few areas were identified as being defective.

Defective subgrade materials were excavated, removed, and replaced with competent material.

The replaced material was constructed in compacted lifts or layers which were a maximum of 6 inches thick. Loose lift thicknesses were limited to 9 inches. The underlying compacted layer was scarified prior to the placement of the overlying loose lift. The compaction was accomplished using self-propelled sheepsfoot and smooth drum rollers (CAT CP563 and CAT CS563).

The moisture content was adjusted, if required, as permitted by the construction specifications. Excess moisture was removed by scarifying the surface and allowing the soil to dry. Moisture was added, if required, by scarifying the in-place compacted material and applying water using a water truck equipped with a spreader bar or spray nozzle. At no time was it necessary to increase the moisture content by more than 3 percent. Consequently, a separate moisture conditioning area was not required.

C. SEDIMENTATION POND NO. 3 AND DRAINAGE SYSTEM

The principal spillway, consisting of a 36-inch diameter corrugated metal pipe (CMP) riser with 72-inch diameter CMP trash rack was installed in accordance with the plans and specifications. The 36-inch discharge pipe from the riser connected to an existing storm sewer installed under the Base Bid Option.

A 60-inch diameter CMP culvert was installed under the perimeter maintenance road to handle the discharge from the emergency spillway. The westward relocation of the emergency spillway to the upstream end of the 60-inch pipe, combined with other grading modifications, significantly increased the volume of Sedimentation Pond No. 3. As a result, the emergency spillway should be used less frequently and the detention time and settling efficiency of the siltation pond should be increased. This modification to the design was reviewed and approved by TDEC prior to implementation.

Other minor modifications were also made to the riprapped drainage channels to accommodate changes resulting primarily from the need to provide an additional soil stock pile area on the east end of the site.

D. PERMANENT SURVEY MONUMENTS

Three new permanent survey monuments have been installed in the immediate area. They are located as follows:

- north of CDL-VII and the perimeter maintenance road (Monument No. 1994-Y-120)

- north of the leachate holding tanks (Monument No. 1994-Y-121)
- at the northwest corner of ILF-V on the south side of the perimeter drainage channel (Monument No. 1994-Y-122)

All three are brass markers embedded in concrete and protected by guard posts. The concrete extends a minimum of 3 feet into the ground to protect the monument from frost heave.

Only the monument number is stamped on the brass markers. Coordinates and elevations are not stamped on them due to recent and planned refinement of the data and grid systems. See BMWCI letter in Appendix F for additional information.

E. AS-BUILT SURVEY

"As-Built" surveys addressing horizontal and vertical control of key components of the developed landfill included the following items:

- Elevations of Landfill Area No. I at periphery of the bottom
- Elevations of the top of the excavated area
- Elevations of the sedimentation pond and principal and emergency spillways
- Locations and elevations of the storm drainage infrastructure
- Locations and elevations of three permanent monuments

"As-Built" survey drawings are included in Appendix F.

F. CONSTRUCTION QUALITY ASSURANCE RESPONSIBILITIES

Construction quality assurance was provided by periodic observation and monitoring by a BMWCI CQA monitor.

Due to construction delays it became impractical for BMWCI to maintain a full-time person to provide continuous CQA service after March 31, 1994. The CQA monitor or his representatives made numerous site visits after March 31, 1994 to check and observe construction procedures and methods. In addition, regular contact with MMES was maintained and progress reports furnished to the DOE on a periodic basis.

G. PROJECT SCHEDULE

The contract for the construction of the Base Bid and Bid Option 1 was awarded to the AVISCO Construction Company, and the notice to proceed was given on May 19, 1993. The notice to proceed on Bid Option 2 was given on January 24, 1994.

A pre-construction meeting for the construction of the Base Bid and Bid Option 1 was held on May 4, 1993, at the Y-12 Plant. The minutes of this meeting are included in Appendix C of this report. No pre-construction meeting for Bid Option 2 was held.

A meeting with representatives from TDEC, DOE, MMES, and BMWCI was held on May 11, 1993, at the TDEC offices in Knoxville to discuss the process of documenting field changes that may develop during construction. The minutes of this meeting are included in Appendix C.

The bulk of the work on CDL-VII consisted of mass excavation with the remainder being related to storm drainage. The effort was substantially complete in May, 1994. A good stand of vegetation now covers the site to minimize erosion.

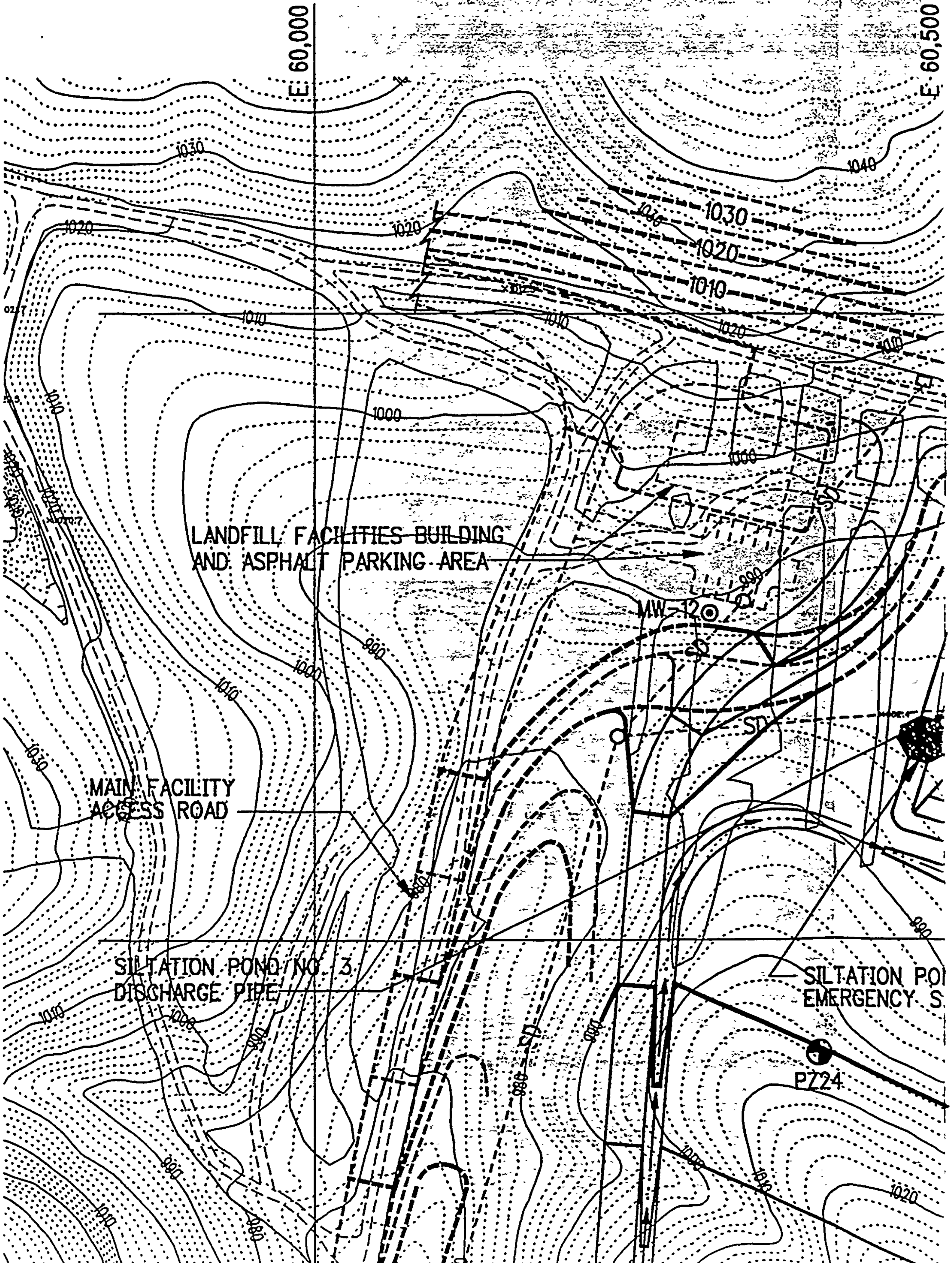
H. GENERAL PROCEDURES

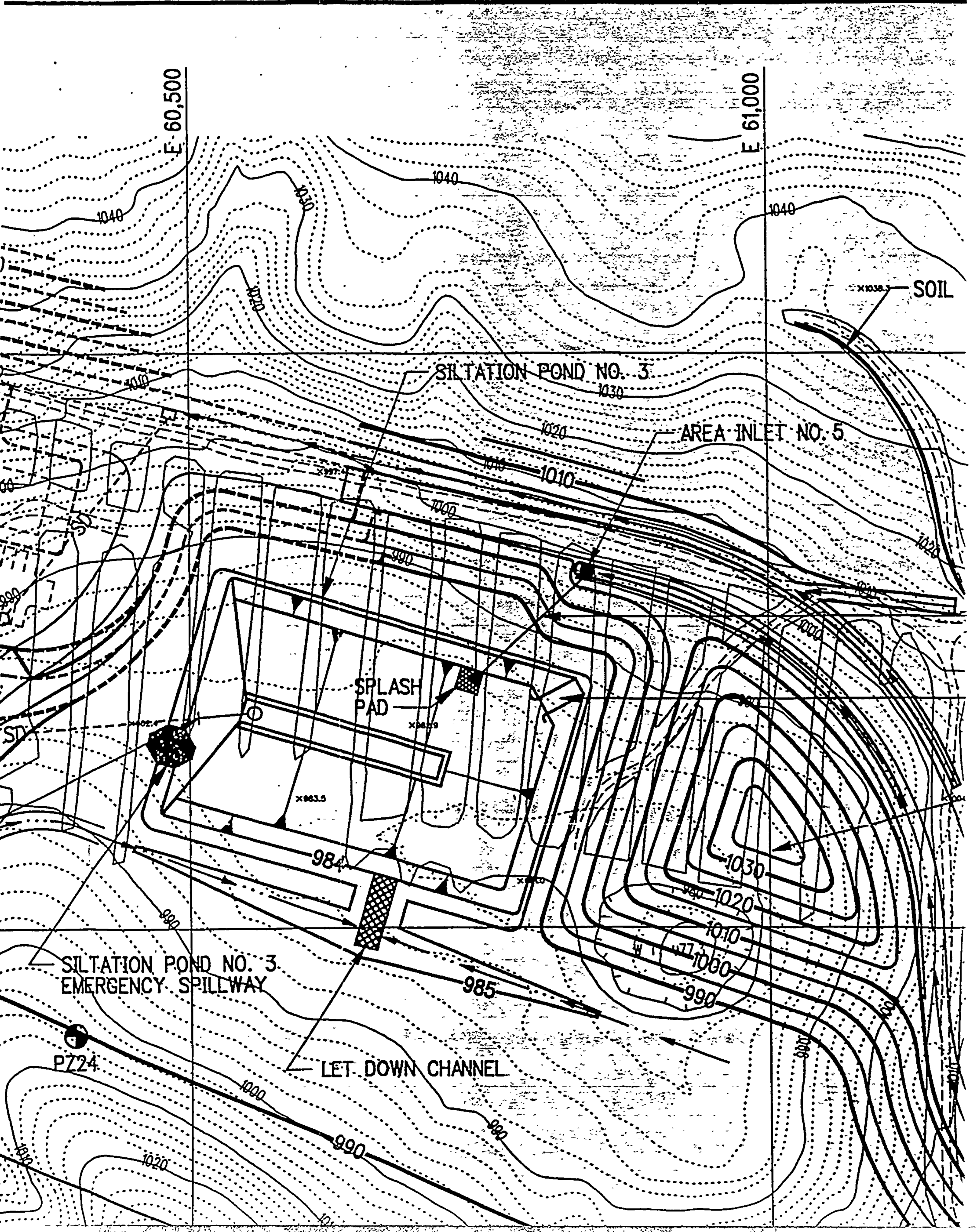
The CQA monitor or his representative made periodic trips to the project site to observe ongoing progress and construction methods and procedures, and maintained close contact with MMES. Large rocks, when encountered, were removed and the voids that remained were filled with compacted soil. Soft areas in the landfill bottom were over excavated to remove unsuitable material. The over excavations were then backfilled with compacted soil. Significant areas of removal are shown in Appendix F.

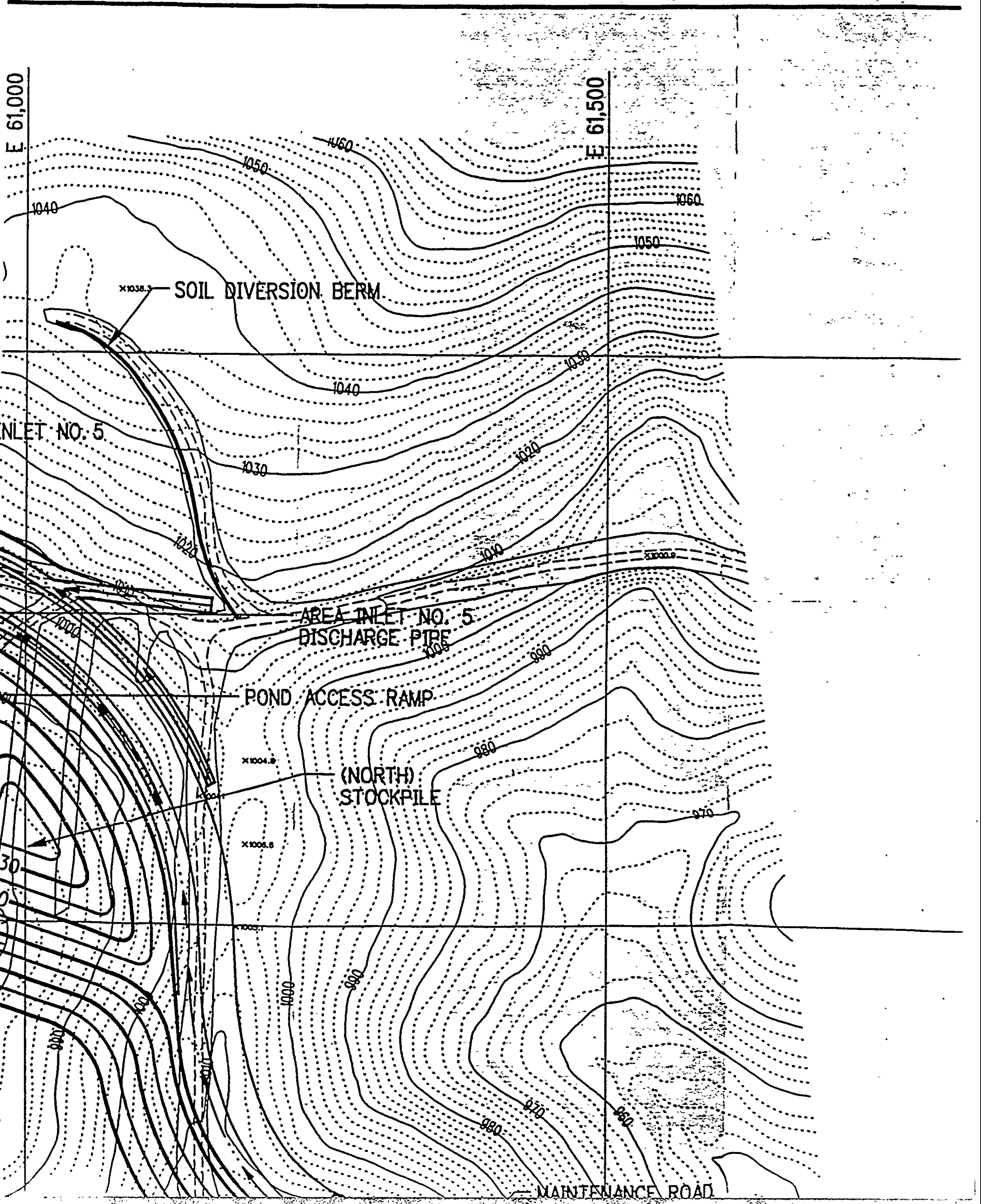
* * * * *

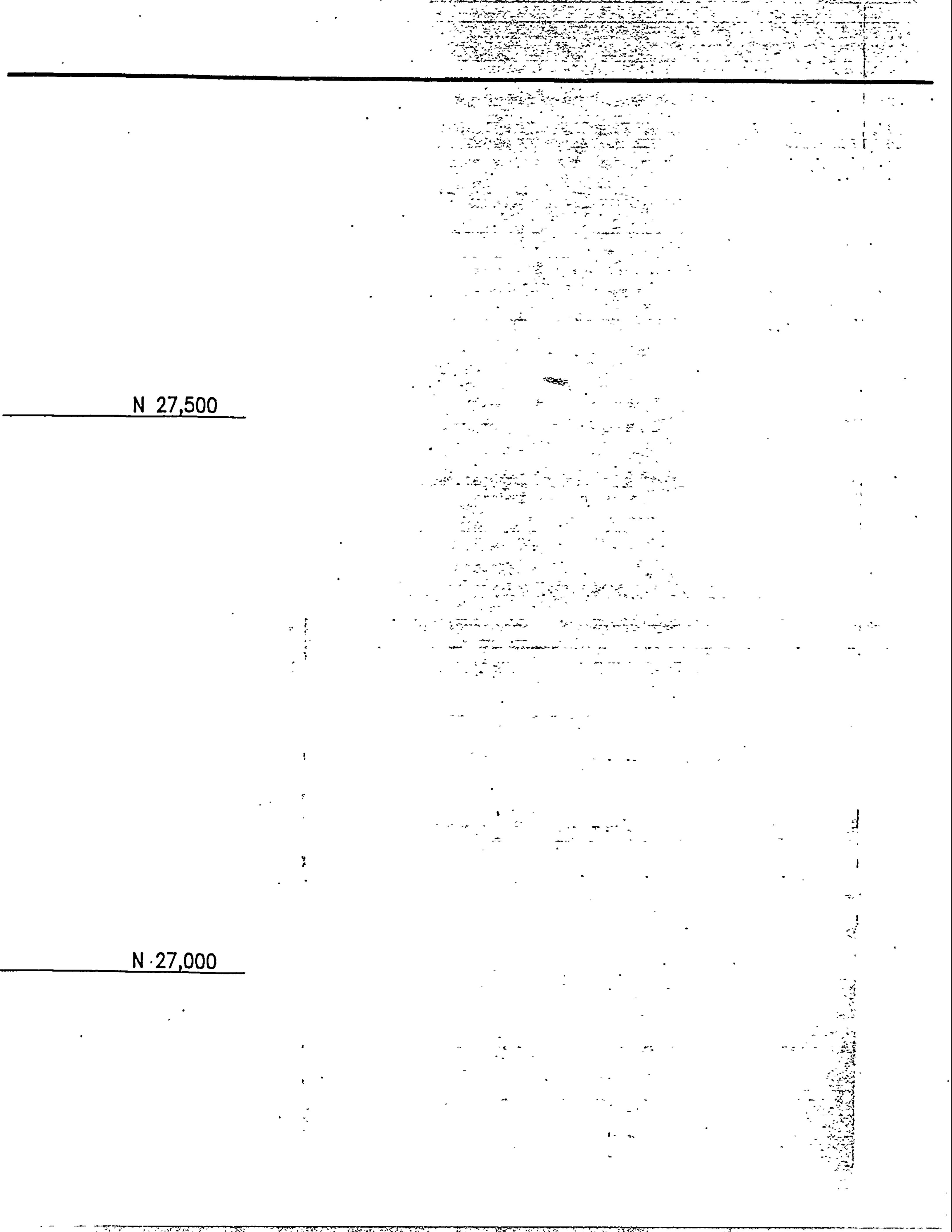
APPENDIX A

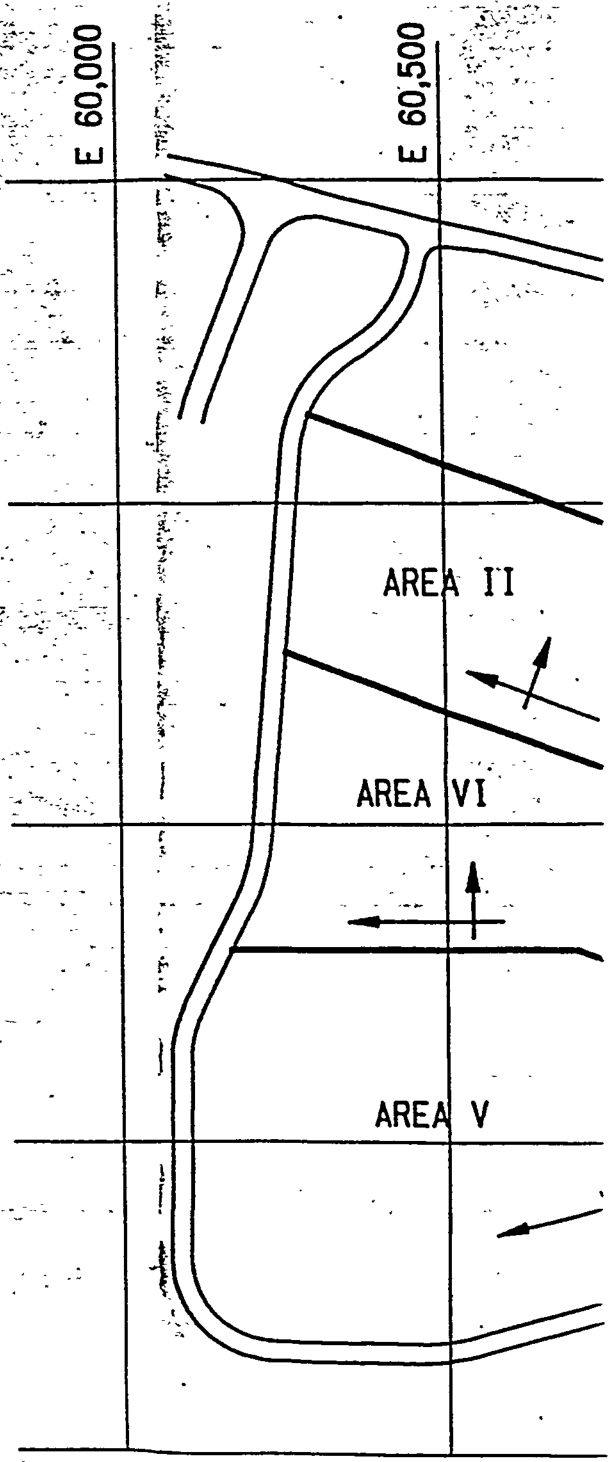
GENERAL SITE PLAN


E 60,000
E 60,500
1030
1040
1030
1020
1020
1020
1010
1010
1010
1020
1010
1000
1000
1010
1020
LANDFILL FACILITIES BUILDING
AND ASPHALT PARKING AREA
990
MW-12
SD
SD
SD
990
1000
1010
1030
MAIN FACILITY
ACCESS ROAD
980
SILTATION POND NO. 3
DISCHARGE PIPE
SILTATION PO
EMERGENCY S
990
1010
1000
990
SD
980
990
PZ24
1000
1010
1020
990
1010
980


E 60,500
E 61,000
1040
1040
1040
1030
1020
1010
SOIL
SILTATION POND NO. 3
1030
1020
AREA INLET NO. 5
1010
1010
1000
990
1020
1010
1000
SD
SD
990
SPLASH PAD
×983.5
984
1030
1020
1010
1000
990
985
990
990
SILTATION POND NO. 3
EMERGENCY SPILLWAY
PZ24
LET DOWN CHANNEL
1000
990
990
1020
1010

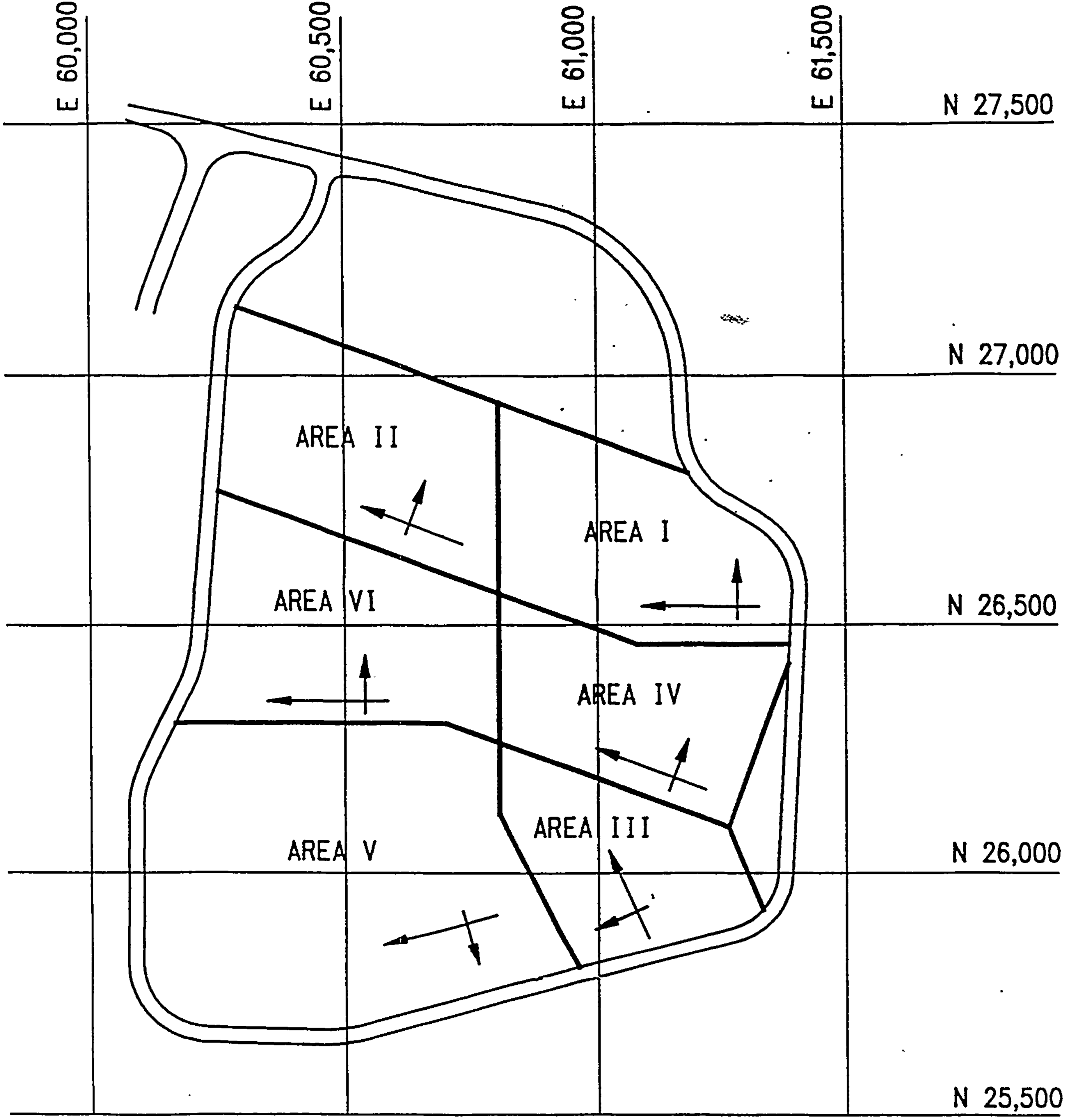

E 61,000
E 61,500
1040
1050
1060
1060
1050
SOIL DIVERSION BERM
×1036.3
1040
1030
NLET NO. 5
1030
1020
1020
1010
×1000.9
1010
1000
AREA INLET NO. 5
DISCHARGE PIPE
1000
990
POND ACCESS RAMP
×1004.9
(NORTH)
STOCKPILE
980
×1006.6
970
30
1000
990
1000
990
1010
970
980
960
MAINTENANCE ROAD


N 27,500
N 27,000



DEVEL
(F

LIFT PF

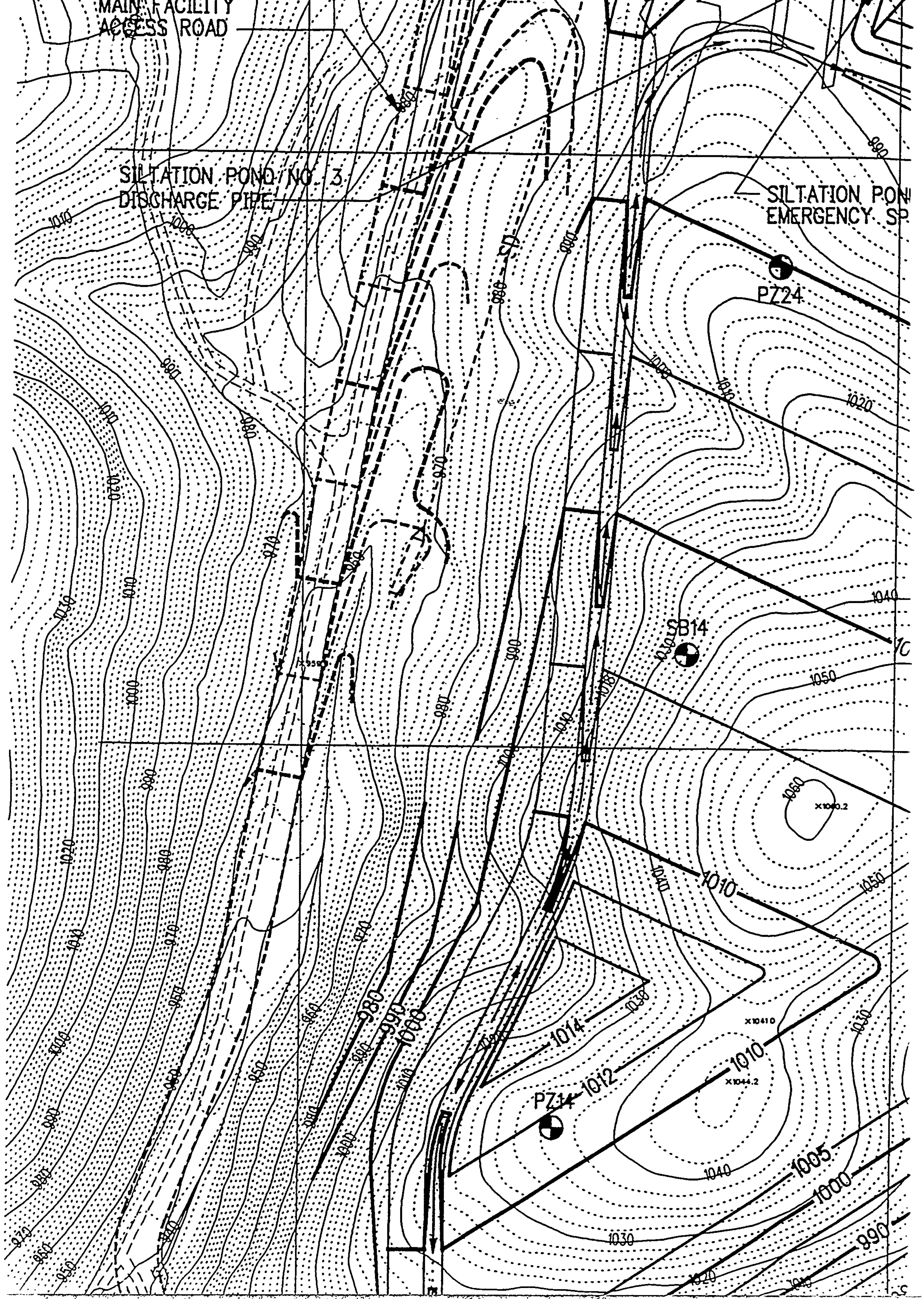


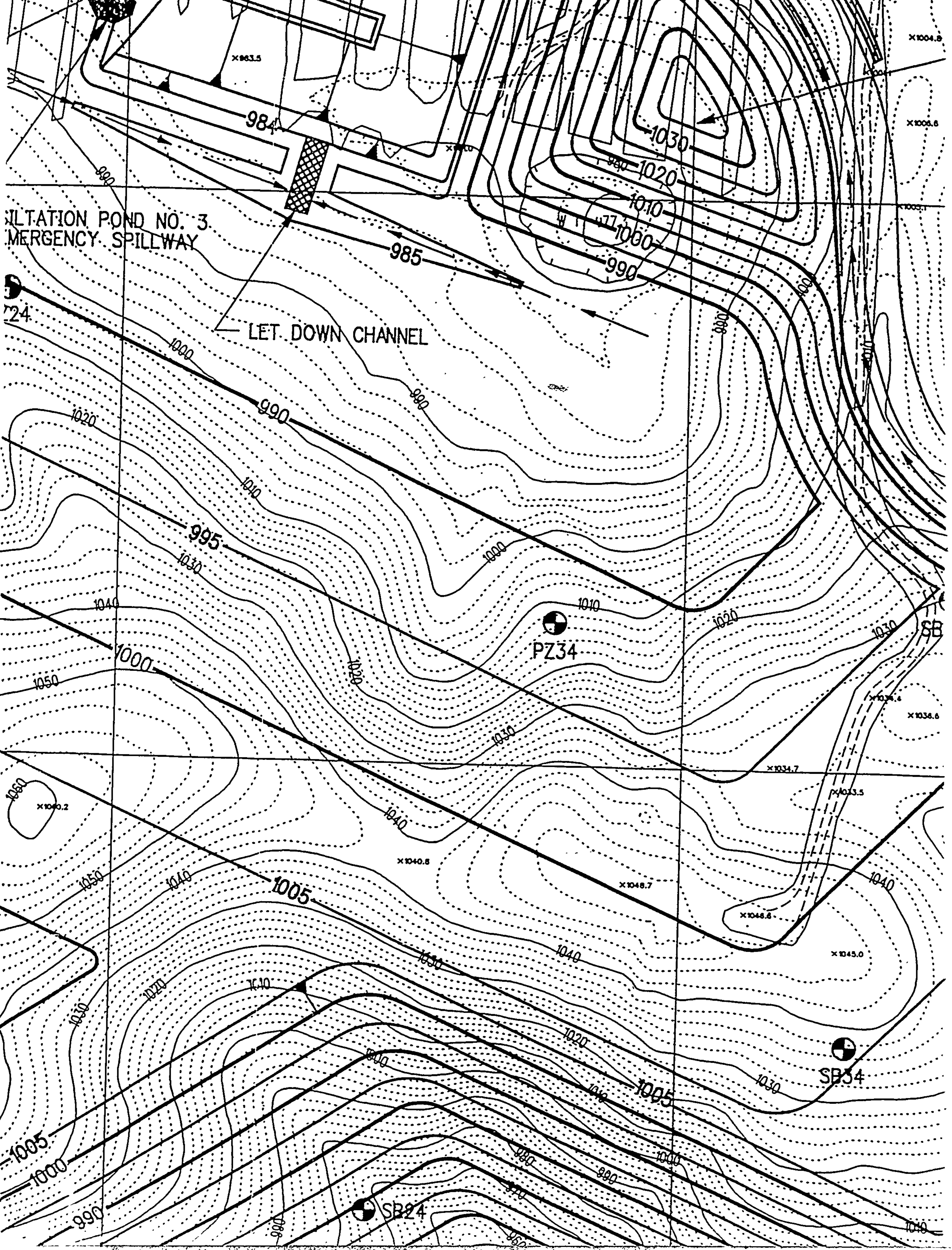
DEVELOPMENT SEQUENCE

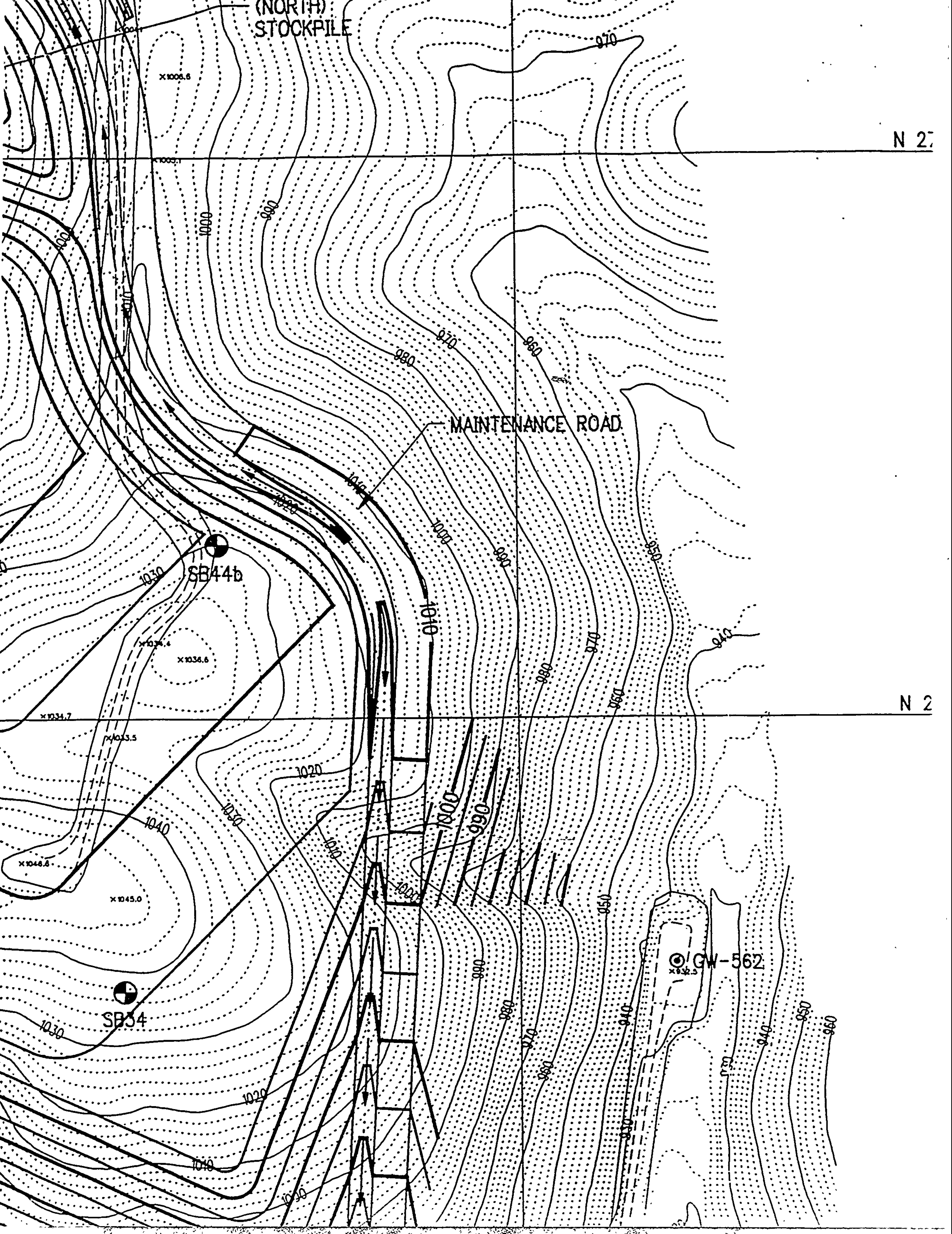
(FOR REFERENCE ONLY)
NOT TO SCALE

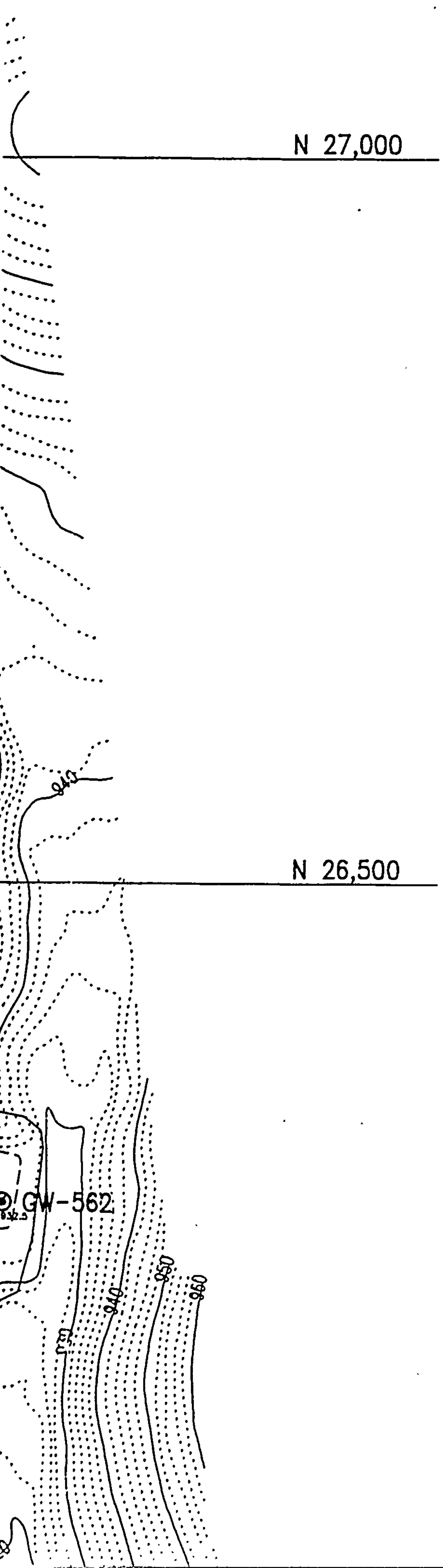
→ ROW PROGRESSION

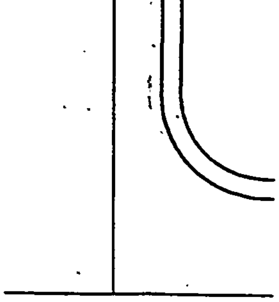
↓ LIFT PROGRESSION

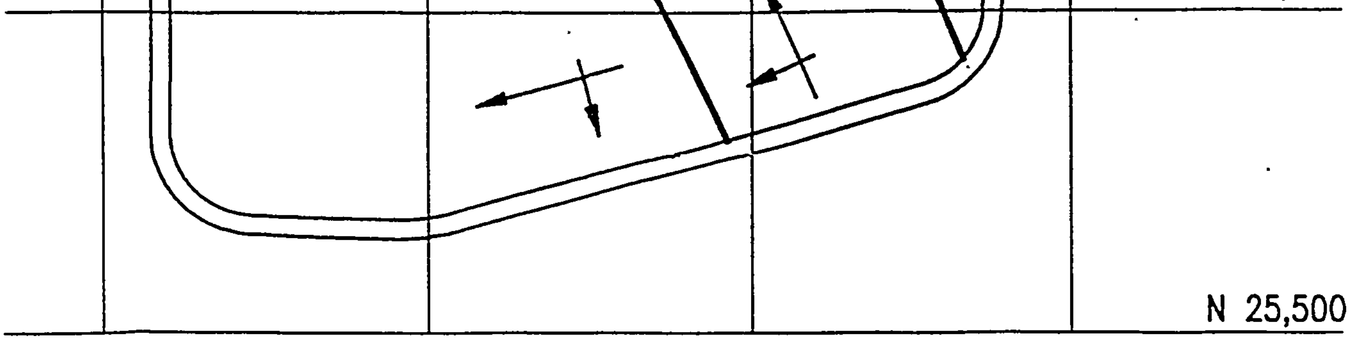

MAIN FACILITY
ACCESS ROAD
SILTATION POND NO. 3
DISCHARGE PIPE
SILTATION PON
EMERGENCY SP
PZ24
SB14
PZ14
1010
1008
990
980
970
960
950
1000
1020
1030
1040
1050
1060
X1040.2
1012
1014
X1041.0
X1044.2
1005
1010
1000
990
SD


ILTATION POND NO. 3
MERGENCY SPILLWAY
LET DOWN CHANNEL
Z24
PZ34
SB34
SB24
SB
984
985
990
995
1000
1005
1010
1020
1030
1040
1050
1060
×983.5
×1004.8
×1006.6
×1003.1
×1040.2
×1040.6
×1036.4
×1036.6
×1034.7
×1033.5
×1046.7
×1046.6
×1045.0


(NORTH)
STOCKPILE
MAINTENANCE ROAD
SB44b
SB34
GW-562
N 2
N 2
×1006.6
×1005.1
×1034.4
×1036.6
×1034.7
×1033.5
×1046.8
×1045.0
970
990
1000
1000
1010
1010
1020
1030
1040
1030
1020
1010
1000
990
980
970
960
950
940
930


N 27,000
940
N 26,500
GW-562
930
940
950
950





DEVELOPMENT SEQUENCE

(FOR REFERENCE ONLY)
NOT TO SCALE

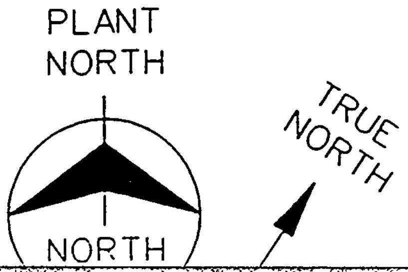
ROW PROGRESSION

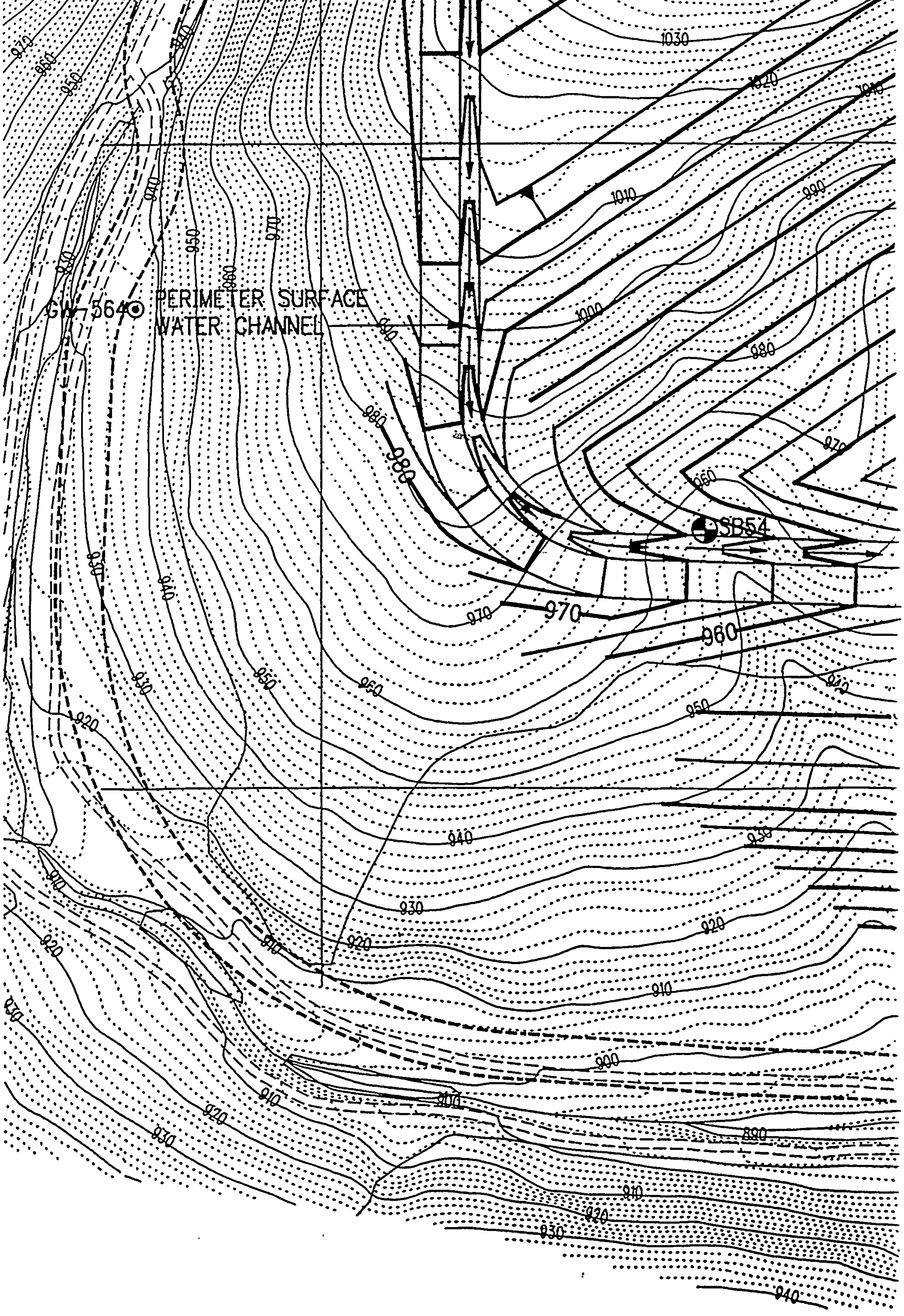
LIFT PROGRESSION

NOTE:

1. THIS DRAWING REPRESENTS THE DEVELOPMENT OF THE ENTIRE LANDFILL OVER THE LIFE OF THE FACILITY, AND IS TO BE USED FOR REFERENCE ONLY.
2. SILTATION PONDS NO. 1 AND NO. 2 ARE NOT INCLUDED WITH THIS BID OPTION.
3. AREA INLETS NO. 1 THROUGH NO. 4 ARE NOT INCLUDED WITH THIS BID OPTION.

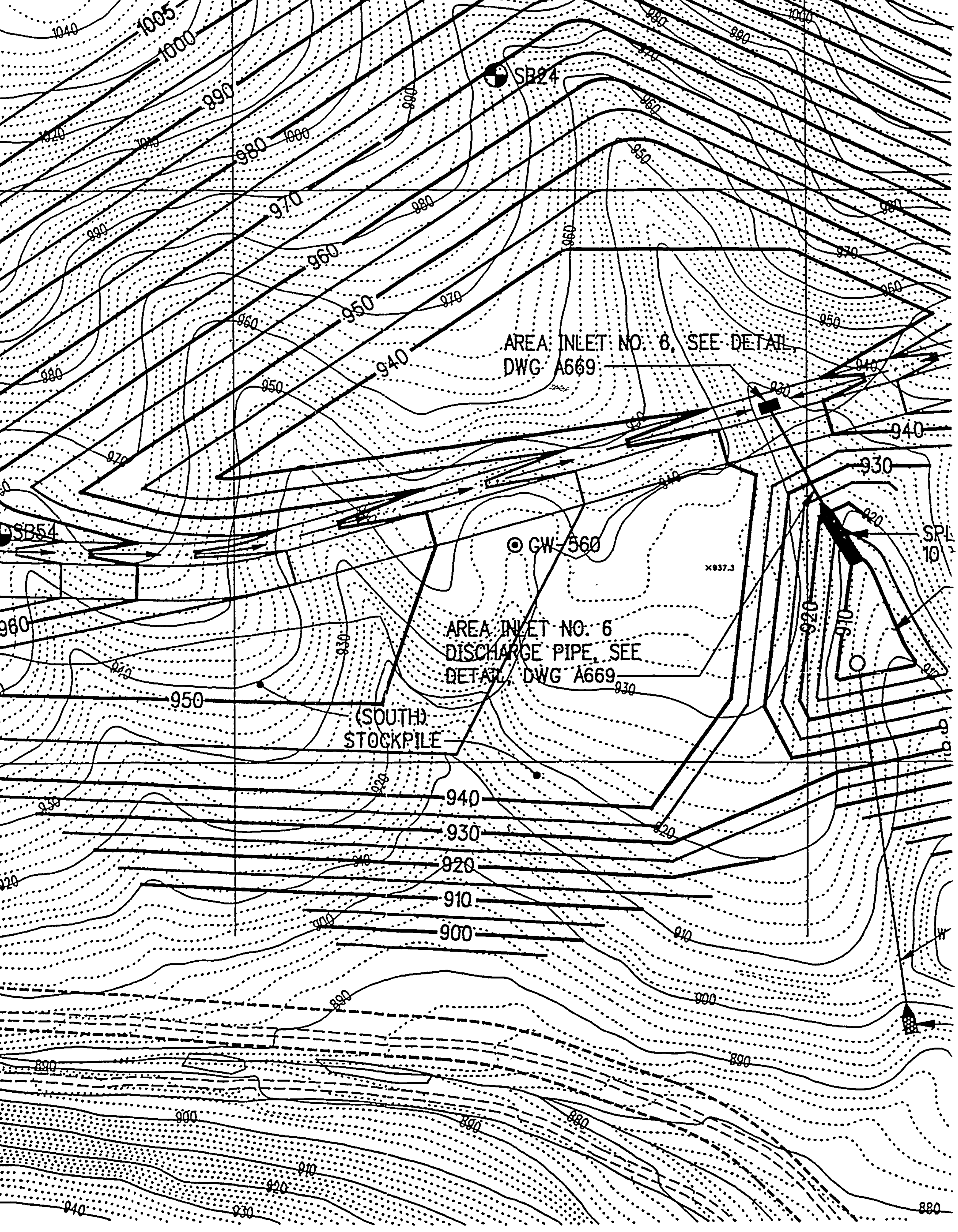
FOR REFERENCE SYMBOLS, ABBREVIATIONS, DRAWING LIST AND LEGENDS, SEE INDEX SHEET, DWG. C2E900000A646 (PERMIT) OR C2E900000A792 (CONSTRUCTION).

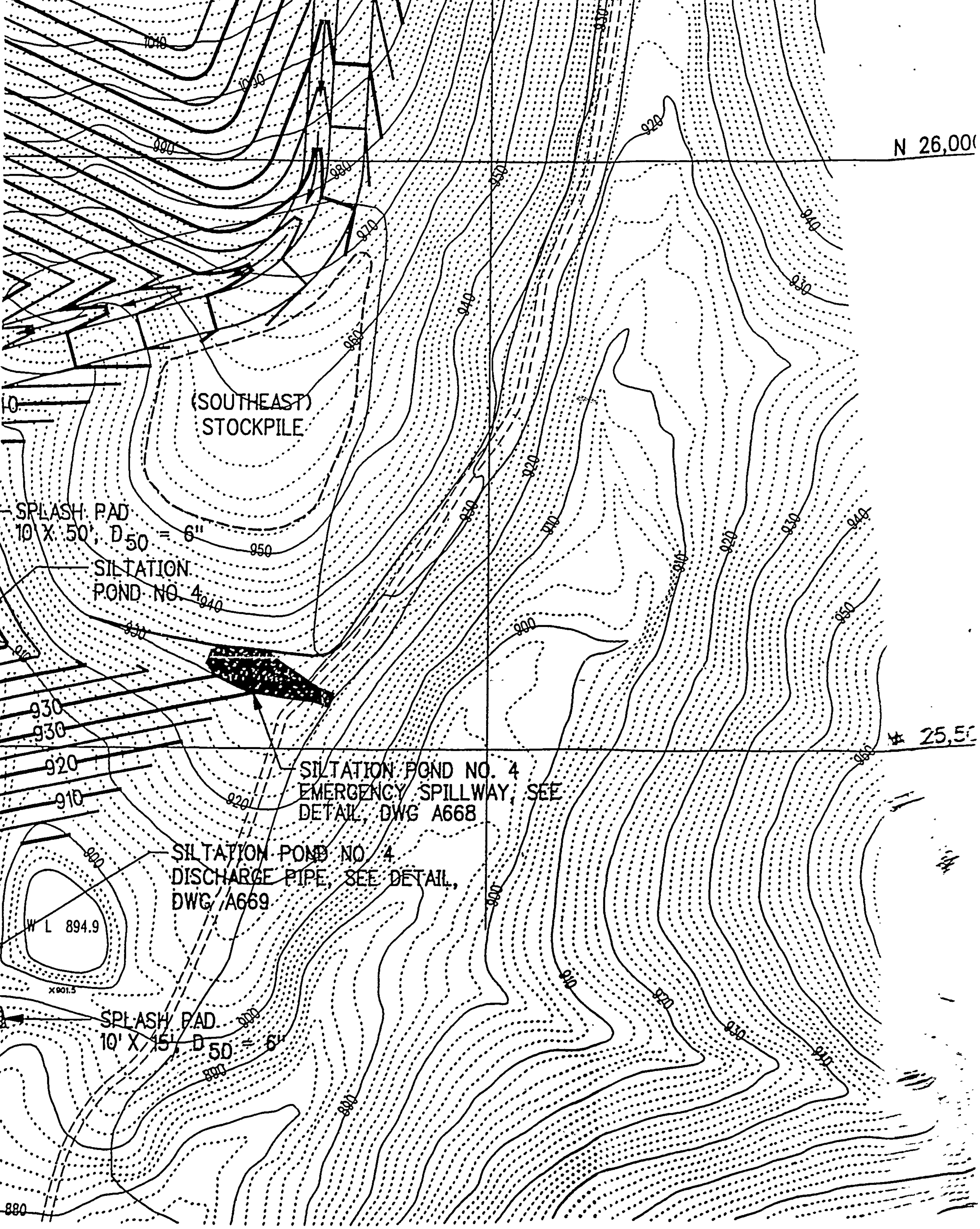


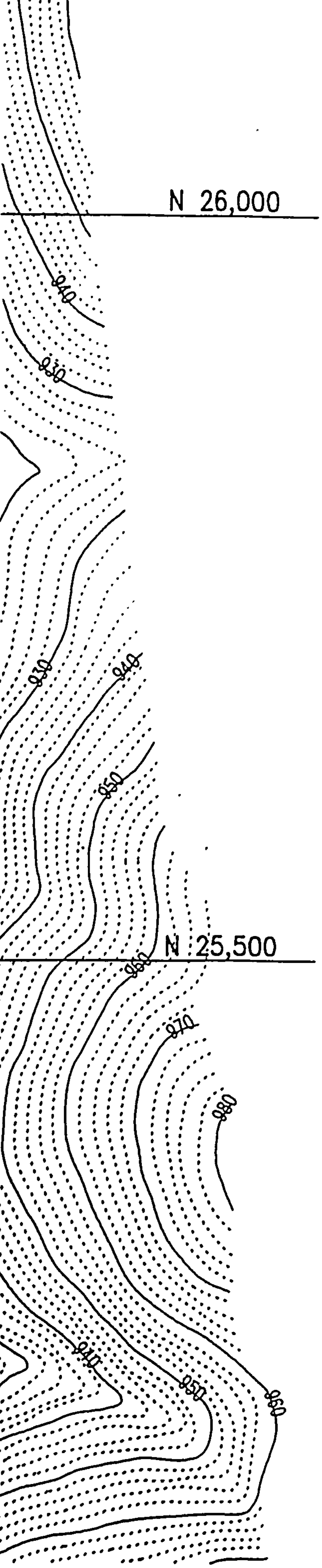


19:23/DEJ (PERMIT SET)

3-49.51-63
=NONE
.50


AREA INLET NO. 6, SEE DETAIL, DWG A669
AREA INLET NO. 6 DISCHARGE PIPE, SEE DETAIL, DWG A669
(SOUTH) STOCKPILE
SB24
SB54
GW-560
×937.3
1005
1000
990
980
970
960
950
940
930
920
910
900
890
880
1040
1020
1010


N 26,00
N 25,5
(SOUTHEAST) STOCKPILE
SPLASH PAD 10' X 50', D_{50} = 6"
SILTATION POND NO. 4
SILTATION POND NO. 4 EMERGENCY SPILLWAY, SEE DETAIL, DWG A668
SILTATION POND NO. 4 DISCHARGE PIPE, SEE DETAIL, DWG A669
W L 894.9
x901.5
SPLASH PAD 10' X 15', D_{50} = 6"
1010
1000
990
980
970
960
950
940
930
920
910
900
890
880


N 26,000
940
930
930
940
950
N 25,500
960
970
980
940
950
960

0	ISSUED
REV. NO.	

DE

DOE CONTRACT NO.

Y-
STE

TO
/

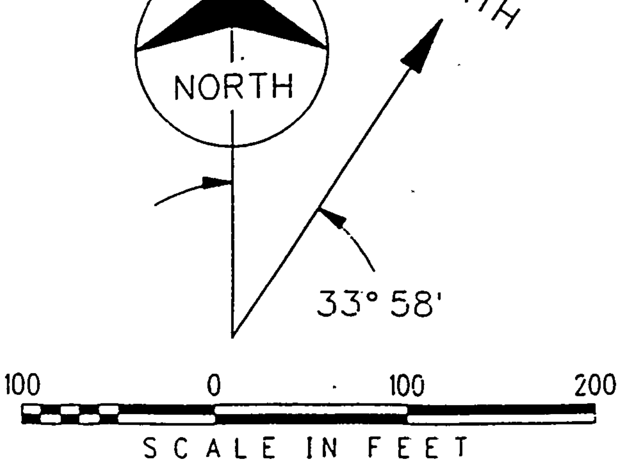
S I T E

DRAWN BY
D. JAEGER

PLANT
Y-12

BL

SUBMITTED FOR APPF



0	ISSUED FOR PERMITTING/CFC	JRT		NR
REV. NO.	ISSUE OR REVISION PURPOSE-DESCRIPTION	A-E	OPERATOR	DOE
		INITIALS AND DATE		

UNITED STATES
DEPARTMENT OF ENERGY

THIS DRAWING PREPARED BY

Burns & McDonnell

ENGINEERS - ARCHITECTS - CONSULTANTS

Kansas City, Missouri

DOE CONTRACT NO. DE-AC05-900R21860

A-E NO. 90-821-1

PROJECT NAME

Y-12 CONSTRUCTION/DEMOLITION LANDFILL VII,
STEAM PLANT ASH DISPOSAL (SPAD), WBS 1.1.2.1
BID OPTION 2

DRAWING TITLE

TOTAL SITE DEVELOPMENT AND EXCAVATION PLAN

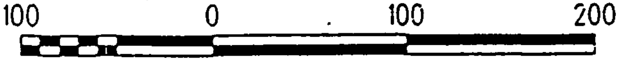
OPERATING CONTRACTOR CODE

SITE DEV EXCAV PLAN CDLVII

DRAWN BY D. JAEGER	DATE 7-23-91	DESIGNED, CHECKED BY A. STARNS	DATE 7-23-91	CHECKED BY J. THORNBURY	DATE 7-23-9

PLANT Y-12	BLDG. AREA	FLOOR A	SCALE 1"=100'	1 3	48 C	49 P	50 T	TYPE P	CLASS U

SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED	DRAWING APPROVED



SCALE IN FEET

REV. NO.	ISSUE OR REVISION PURPOSE-DESCRIPTION	A-E	OPERATOR	DOE
0	ISSUED FOR PERMITTING/CFC	JRT		NR
		INITIALS AND DATE		

UNITED STATES DEPARTMENT OF ENERGY

THIS DRAWING PREPARED BY

Burns & McDonnell

ENGINEERS - ARCHITECTS - CONSULTANTS

Kansas City, Missouri

DOE CONTRACT NO. DE-AC05-900R21860

A-E NO. 90-821-1

PROJECT NAME

Y-12 CONSTRUCTION/DEMOLITION LANDFILL VII,
STEAM PLANT ASH DISPOSAL (SPAD), WBS 1.1.2.1
BID OPTION 2

DRAWING TITLE

TOTAL SITE DEVELOPMENT AND EXCAVATION PLAN

OPERATING CONTRACTOR CODE

SITE DEV EXCAV PLAN CDLVII

DRAWN BY	DATE	DESIGNED, CHECKED BY	DATE	CHECKED BY	DATE
D. JAEGER	7-23-91	A. STARNS	7-23-91	J. THORNBURY	7-23-9

PLANT	BLDG.	FLOOR	SCALE	1	48	49	50	TYPE	CLASS
Y-12	AREA	A	1"=100'	3	C	P	T	P	U

SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED	DRAWING APPROVED
		NR
A-E DATE	OPERATING CONTRACTOR DATE	DOE DATE

PROJECT	WORK ORDER NO.	DRAWING NUMBER	REV. NO.
CDL-VII	S08680	C2E900000A660	0

APPENDIX B

OPERATING PERMITS

STATE OF TENNESSEE
DEPARTMENT OF ENVIRONMENT AND CONSERVATION

5th Floor, L & C Tower
401 Church Street
Nashville, TN 37243-1535

DML 01-0045

December 13, 1993

Mr. L. L. Radcliffe
P.O. Box 2009
Oak Ridge, TN 37831

Permit #: DML-01-103-0045

Dear Mr. Radcliffe:

The Tennessee Department of Environment and Conservation has decided to issue the enclosed permit to the U.S. Department of Energy for the operation of Class IV Construction/Demolition Landfill.

I appreciate your interest in complying with state statutes and look forward to working with you again.

Sincerely,

Tom Tiesler

Tom Tiesler, Director
Division of Solid Waste Management

JTT/DBM/F1083333/SWM2 SW-175

Enclosure

cc: Knoxville Field Office

State of Tennessee
Department of Environment and Conservation
Division of Solid Waste Management

Solid Waste Management Progr
5th Floor, L & C Tower
401 Church Street
Nashville, Tennessee 37243-1

REGISTRATION AUTHORIZING SOLID WASTE DISPOSAL ACTIVITIES IN TENNESSEE

Registration Number: DML 01103 0045

Date Issued: December 13, 1993

Issued to: U.S. Department of Energy, for a facility located within the U.S. DOE Oak Ridge Reservation in Anderson County, off New Bethel Valley Road approximately 1.5 miles west of the intersection with State Route 62.

Activities Authorized: construction, operation, closure, and post-closure monitoring and maintenance of a "Class IV" construction/demolition landfill for the disposal of construction/demolition waste, and industrial waste of similar composition to construction/demolition waste, generated from the manufacturing plants and research facilities within the Oak Ridge Reservation and DOE prime contractors in the Oak Ridge area.

By my signature, this registration is issued in compliance with the provisions of the Tennessee Disposal Act (Tennessee Code Annotated, Section 68-211-101, et seq.), and applicable regulations developed pursuant to this law and in effect; and in accordance with the conditions and other terms set forth in this registration document and the attached Registration Conditions.

Tom Tiesler

Tom Tiesler, Director
Division of Solid Waste Management

JTT:RSB:pg 20149207930901

DML 011030045

Registration Number ____________

PERMIT TERMS AND CONDITIONS

1. RECERTIFICATION BY PERMITTEE FOR FACILITIES WHOSE INITIAL OPERATION IS DELAYED - If the facility does not initiate construction and/or operation within one year of the date of this permit, the permittee must recertify the application in accordance with Rules 1200-1-7-.02(2)(e).

2. Duty to Comply - The permittee must comply with all conditions of this permit, unless otherwise authorized by the Department. Any permit noncompliance, except as otherwise authorized by the Department, constitutes a violation of the Act and is grounds for enforcement action, or for permit termination, revocation and reissuance, or modification.

3. Need to Halt or Reduce Activity Not a Defense - It shall not be a defense for a permittee in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this permit.

4. Duty to Mitigate - In the event of noncompliance with the permit, the permittee shall take all reasonable steps to minimize releases to the environment, and shall carry out such measures as are reasonable to prevent adverse impacts on human health or the environment.

5. Proper Operation and Maintenance - The permittee shall at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by the permittee to achieve compliance with the conditions of this permit. Proper operation and maintenance includes effective performance, adequate funding, adequate operator staffing and training, and adequate laboratory and process controls, including appropriate quality assurance procedures. This provision requires the operation of back-up or auxiliary facilities or similar systems only when necessary to achieve compliance with the conditions of the permit.

6. Permit Actions - This permit may be modified, revoked and reissued, or terminated for cause. The filing or a request by the permittee for a permit modification, revocation and reissuance, or termination, or a notification of planned changes or anticipated noncompliance, does not stay any existing permit condition.

7. Property Rights - This permit does not convey any property rights of any sort, or any exclusive privilege.

Duty to Provide Information - The permittee shall furnish to the Commissioner, within a reasonable time, any relevant information which the Commissioner may request to determine whether cause exists for modifying, revoking and reissuing, or terminating this permit, or to determine compliance with this permit. The permittee shall also furnish to the Commissioner, upon request, copies required to be kept by this permit.

Inspection and Entry - The permittee shall allow the Commissioner, or an authorized representative, to:

(i) Enter at any reasonable time the permittee's premises where a regulated facility or activity is located or conducted, or where records must be kept under the conditions of this permit;

(ii) Have access to and copy, at reasonable times, any records that must be kept under the conditions of this permit;

(iii) Inspect at any reasonable time any facilities, equipment (including monitoring and control equipment), practices or operations regulated or required under this permit (NOTE: If requested by the permittee at the time of sampling, the Commissioner shall split with the permittee any samples taken.);

(iv) Sample or monitor at reasonable times, for the purposes of assuring permit compliance or as otherwise authorized by the Act, any substances or parameters at any location/ and

(v) Make photographs for the purpose of documenting items of compliance or noncompliance at waste management units, or where appropriate to protect legitimate proprietary interests, require the permittee to make such photos for the Commissioner.

Monitoring and Records

(i) Samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity.

(ii) The permittee shall retain records of all required monitoring information. The permittee shall maintain records for all ground-water monitoring wells and associated ground-water surface elevations, for the active life of the facility, and for the post-closure care period as well. This period may be extended by request of the Commissioner at any time.

20. Special Waste - Except as specifically provided for in the Facility-Specific Conditions of this permit, the permittee may not accept for disposal any special waste unless approved to do so in writing by this Department.

21. Automobile Batteries

This facility is specifically prohibited from accepting automobile batteries for disposal.

Registration Number DML 011030045

VARIANCES AND WAIVERS

1. The following variances or waivers from standards or requirements in Rule 1200-1-7, Solid Waste Processing and Disposal Amendments, are hereby granted in accordance with Rule 1200-1-7-.01(5):

No variances from normal regulatory requirements have been requested or deemed necessary for this site.

DML 011030045
Registration Number

FACILITY-SPECIFIC PERMIT CONDITIONS

1. The following conditions of this permit are established pursuant to Rule 1200-1-74-.02(4)(b):

   a. No radioactive wastes may be disposed of in this site. Incoming loads shall be screened with radiation detectors and source controls shall be implemented to assure that this condition is met.

   b. Construction/demolition wastes and associated soils may not be contaminated with mercury, PCB's, or petroleum products above regulated levels. Asbestos or beryllium-containing materials may not be disposed of in this site. Construction waste may not include paint or adhesive containers or any kind of drums.

   c. Garbage or other putrescible materials may not be disposed of in this site.

   d. Perched groundwater zones within the landfill excavations or less than five (5) feet below base grade must be drained out, and any landfill base soils which must be removed must be recompacted in accordance with the Construction Quality Assurance Plan, before any solid waste may be disposed of in the affected areas.

   e. Surface drainage from fill areas must be directed away from the sinkhole located to the northeast of the landfill site.

RSB:pg 26149207930901 SW9

APPENDIX C

MEETING MINUTES

US DEPARTMENT OF ENERGY
Y-12 SPAD
Project No. 90-823-1-001

Project Conference Report

Date: May 4, 1993

Time: 9:00 a.m.

Place: MK Ferguson-Oak Ridge

Meeting: Title III Disposal Facilities Kick-Off Meeting

Attendees:

Name	Company	Telephone
Mary Ann Reeves	USDOE	615-576-1831
Jeff Thornbury	Burns & McDonnell	816-822-3480
Pete Burton	Burns & McDonnell	816-822-3487
Dan Ailey	MMES	615-574-5885
Chuck Hutzler	MMES	615-574-1379
Teresa Pierce	MMES	615-574-7562
Ron Collins	MMES	615-574-3257
Jerry Hampton	AVISCO	615-241-3577
Jim Blevins	AVISCO	615-241-3577
Mitch Carpenter	AVISCO	615-679-8726
Petty Ferguson	AVISCO	615-241-3577
Stephen Allen	Blain Const.	615-524-8454
Tim Heath	MK Ferguson	

- Introduction of meeting attendees made and agenda distributed by Mary Ann Reeves. (copy attached)

- Mary Ann Reeves discussed the roles and responsibilities of all parties. (copy attached)

- Time Heath discussed the safety and health issues related to project. He gave Burns & McDonnell a copy of the Construction Work Release (CWR) that all persons are required to sign before coming onto the site. All persons must sign-in at AVISCO office prior to going on-site. Pete Burton will be issued a pass by AVISCO which will give him unlimited access without signing in. All personnel on-site required to wear hard hats and safety glasses.

- Tim Heath addressed hoisting and rigging plan and said that for now this would not be required. May need to address at a later date.

- Ron Collins discusses the Shop Drawing review cycle and expressed some concerns about turn-around times, discrepancies, and review assignments. Ron stated that all Vendor data submittals will be given to Burns & McDonnell (three copies). Burns & McDonnell needs to return two copies to Ron Collins. Drawing submittals are only two copies with one copy returned to Ron.

- AVISCO has a concern about a group of submittals being returned in which only one or two items may be rejected but because it is contained in a submittal package, the entire package is rejected. To resolve this problem, Burns & McDonnell will do the following:

    1) List on Vendor Data Form (green) which submittals are given A, B, C, or D actions so contractor is not delayed on approvals.

    2) Use Burns & McDonnell shop drawing stamp on all submittals including drawings. This will be in addition to what is currently provided.

- The procedure for rush items if for AVISCO to notify Tim Heath and Ron Collins so that they can "walk" the submittal through to get a quick turn-around time.

- Jeff Thornbury stated the importance of Burns & McDonnell being given a copy of the Final approved submittals for record and inclusion into the final QA/QC document to be provided to the State of Tennessee. Burns & McDonnell deliverable to the State of Tennessee will consist of as-built drawings plus the QA/QC report.

- Chuck Hutzler indicated TDHE requirements for notification of any minor or major changes pertaining to the landfills construction. A meeting is scheduled for next Tuesday, May 11, at TDHE office in Knoxville to discuss this requirement. Burns & McDonnell will be responsible in field of identifying minor and major changes which will be required to notify TDHE. Explained that only changes to the design which could conflict with the approved state permit needs to be identified. This will be verified at TDHE meeting

- Burns & McDonnell will only be involved in preparation of cost estimates for CID work if Tim Heath does not feel comfortable with performing the estimate. Usually anything over an estimated $10,000 will come through Burns & McDonnell. Tim will notify Burns & McDonnell if an estimate is needed.

- Burns & McDonnell will not have an on-site office trailer but instead will work out of the Burns & McDonnell Oak Ridge office. Pete Burton will have an on-site vehicle. Pete needs to have adequate means of communication such as pager, etc.

- AVISCO indicated that clearing operations should be completed within a week or so. They estimate being able to start work on the Landfill V by mid to end of May. AVISCO indicated that they are on a very tight construction schedule that will probably take completion of Landfill V into December.

- Burns & McDonnell was given a copy of AVISCO project schedule for the Base Bid work and a partial list of submittals. A schedule for Option 1 will be prepared and incorporated into overall schedule. Jeff Thornbury noted that it might be good to have a separate schedule for completion of Option 1 in case TDHE requested this information. This will be discussed later if needed.

- Meeting adjourned at approximately 11:45 a.m.

- Jeff Thornbury, Pete Burton, and Dan Ailey went on a site visit with Jerry Hampton at approximately 12:30 p.m.

JT/tm306

Department of Energy
Oak Ridge Field Office
P.O. Box 2001
Oak Ridge, Tennessee 37831— 8620

October 12, 1993

Mr. Jack P. Crabtree, Regional Director
Division of Solid Waste Management
Tennessee Department of Environment
and Conservation
2700 Middlebrook Pike, Suite 220
Knoxville, Tennessee 37921

Dear Mr. Crabtree:

CONSTRUCTION OF INDUSTRIAL LANDFILL V AND CONSTRUCTION/DEMOLITION LANDFILL VI - FIELD CHANGES

A meeting was held earlier this year with the Tennessee Department of Environmental and Conservation (TDEC) to obtain a clarified understanding of TDEC expectations regarding field changes during the construction of the recently permitted landfills, Industrial Landfill V and Construction/Demolition Landfill VI. The enclosure summarizes the key issues that were discussed during that meeting, and is transmitted to you to document that agreement. It is requested that we be promptly notified of any questions or concerns, so they can be addressed.

Please address any questions or comments to Ralph Skinner (Program Manager) at 576-7403.

Sincerely,

Larry L. Radcliffe, Director for
Waste Management and Technology
Development Division

Enclosure

cc w/enclosure:
M. A. Reeves, CE-524
J. L. Sager, EW-922
D. G. Ailey, 9739, MS 8209
D. J. Bostock, 9704-2, MS 8010
C. E. Frye, K-1037, MS 7357
J. E. Heiskell, 9983-71, MS 8180
C. W. Hutzler, 9204-1, MS 8053
W. G. McMillan, 9704-2, MS 8009
M. L. Willoughby, 9204-1, MS 8053

Enclosure 1

CONSTRUCTION OF INDUSTRIAL LANDFILL V AND CONSTRUCTION/DEMOLITION LANDFILL VI

On May 11, 1993, a meeting was held with the Tennessee Department of Environment and Conservation (TDEC) to discuss the process for handling field changes that may develop during the construction of the two newly permitted landfills, Industrial Landfill V (IFL V) and Construction/Demolition Landfill VI (CDL VI). The following personnel were in attendance at the meeting held at the TDEC Knoxville office.

Jeff Thornbury	Burns & McDonnell
Pete Burton	Burns & McDonnell
Rick Brown	TDEC, Division of Solid Waste Management
Larry Cook	TDEC, Division of Solid Waste Management
Jack Crabtree	TDEC, Division of Solid Waste Management
Chuck Hutzler	Martin Marietta Energy Systems, Inc., (MMES), Solid Waste Engineering
Mickey Willoughby	MMES, Solid Waste Engineering
Don Bohrman	MMES, Environment Management
Boyd Hallman	MMES, Construction Engineering
George Hogg, P.E.	MMES, Construction Engineering

A registered engineer is required to inspect the construction of both landfills. MMES will provide the registered engineer for CDL VI. The Department of Energy has hired Burns and McDonnell, Inc., to provide the registered engineering services for the construction of ILF V.

The registered engineer will perform oversight of inspections and tests required by the permit drawings and specifications to ensure the design requirements are met. The acceptance of each inspection and test will be documented. As applicable, all field changes will be approved by the project team and documented by the registered engineer. After a change has been internally approved, it will be reported to the TDEC for their approval.

The regulations governing the landfill permits segregate field changes into "major" and "minor" categories. Major changes require extensive reviews and significant processing time, and every reasonable effort will be made to avoid any major changes. Every effort will be made to construct the landfills in accordance with the landfill permit documents and to minimize any "minor" changes. This method for handling changes only applies to changes in the TDEC-permitted portions of the projects.

The TDEC is flexible in the method of reporting changes. Field changes characterized as "minor" will be reported by MMES through the Department of Energy Oak Ridge Operations Office (DOE-ORO), to the TDEC (either by phone or in person). Following this advance notification, formal submission will be made to the TDEC for approval. TDEC indicated they are willing to provide advance review of minor changes to avoid impact on the landfill construction schedules.

Upon final acceptance of the completed projects, the registered engineers will provide quality control documents, copies of inspections, tests, changes, red-lined or as-built drawings, and a certified letter of assurance and acceptance for transmittal through appropriate channels to the TDEC.

TDEC indicated that they need to inspect the landfill construction when the excavation is approaching base grade. Also, TDEC needs to inspect the construction of the compacted clay liner and leachate collection system for ILF V. Two to three working days advance notice should be provided to TDEC for performing the inspections.

Facility-Specific Permit Condition No. 1 of the permit for CDL VI requires that a "professional hydrogeologist" perform inspections during the landfill construction. TDEC agreed that a "professional geologist with groundwater experience" will satisfy this requirement.

Although not discussed specifically at this meeting, DOE intends to utilize this approach for Construction/Demolition Landfill VII.

APPENDIX D

SOIL LINER OBSERVATION/MATERIAL EVALUATION TEST REPORTS

FINAL REPORT

PERMEABILITY OF COMPACTED SOILS FROM THE EAST AND WEST BORROW AREAS

Y-12 Plant

Oak Ridge, Tennessee

Prepared for:

Martin Marietta Energy Systems, Inc.
P.O. Box 2009
Oak Ridge, Tennessee 37831

Prepared by:

David E. Daniel
Civil Engineer
3702 Cima Serena
Austin, Texas 78759

March 27, 1989

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (continued)

PERMEABILITY OF COMPACTED SOILS FROM THE EAST AND WEST BORROW AREAS

Purpose

This report summarizes the results of laboratory compaction and permeability tests on soils from the east and west borrow areas. The tests were conducted to determine whether clay soils proposed for capping waste disposal units at the Oak Ridge Y-12 Plant can be compacted to achieve a coefficient of permeability less than or equal to 1×10^{-7} cm/s as required in the closure plan for these facilities. A second purpose of the study is to define criteria that will ensure proper compaction of the soils to achieve a permeability $\leq 1 \times 10^{-7}$ cm/s.

Soil Material

The soils proposed for capping waste disposal units at the Y-12 plant come from excavation areas referred to as the "east borrow area" and "west borrow area." Within each borrow area, soils are broadly grouped into three types: Type A, Type B, and Type C. Type C soils are light tan, highly plastic, silty materials that are characterized by low dry unit weights upon compaction. Type B soils are bright red, sandy soils characterized by low optimum water content and relatively large dry unit weights after compaction. Type A soils are a reddish-tan mixture of Type B and Type C materials. The typical ranges of compaction characteristics used for distinguishing one type of soil from another are listed below:

	Standard Proctor Compaction Data	
Soil Type	Optimum Water Content	Maximum Dry Unit Weight
A	21 - 30%	≥ 85 pcf
B	15 - 21%	≥ 94 pcf
C	21 - 30+%	≤ 85 pcf

Samples of Type A, Type B, and Type C soil were shipped to the University of Texas for testing. Atterberg limits tests were performed following procedures outlined in ASTM standard D-4318. Results of Atterberg limits tests are summarized in Table 1.

Table 1. Summary of Atterberg Limits Tests

Borrow Area	Soil	Test Group	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)
West	A	1	53 - 56	27 - 34	19 - 29
	A	2	53	34	19
East	A	1	55	28	27
West	B	1	34	16	18
East	B	1	34	14	20
	B	2	46	30	16

The reason why a range of results is shown for Type A Soil, Group 1, from the west borrow area is that more than one set of Atterberg limits test was performed on this material. One set of tests was conducted on the other materials.

For convenience, the Type A soils from the west borrow area and the Type B soils from the east borrow area were each divided into two groups for purposes of discussion in this report. Most of the Type A soils from the west borrow area soils were placed in Group 1. Some permeability tests were performed to determine how reproducible the tests results were; the soils used for the replication study are categorized as "Group 2" materials.

Most of the tests on Type B soils from the east borrow area were performed on Group 2 soils. A few tests were conducted on the Group 1 soils at the beginning of the study to identify, on a preliminary basis, whether the Type B soils could be compacted to achieve a permeability $\leq 1 \times 10^{-7}$ cm/s.

Only one small shipment of Type C soil was received. It was expected that the Type C soils could not be compacted to produce a permeability $\leq 1 \times 10^{-7}$ cm/s, which indeed was the case. Atterberg limits were not measured for the Type C soil.

The specific gravity of solids of the soils was assumed to be 2.75. The assumed specific gravity of solids was used in calculating degrees of saturation of compacted test specimens and in plotting zero air voids curves. The assumption that the specific gravity of soils was 2.75 was not of critical importance, and this is why a single, assumed value was used for all the soil types.

Laboratory Test Procedures

Soil Processing

The soils were excavated from the appropriate borrow area, placed in 5-gal buckets, sealed, and shipped to the University of Texas laboratories for testing. The soils from various buckets were blended together and then passed through a 1/2-inch sieve. Any clay material, e.g., a soil clod, retained on the 1/2-inch sieve was broken down by hand to pass through the sieve; stones too large to pass through the sieve were removed. Only a few stones were encountered. Some laboratories air dry the soil, pulverize it, and then sieve the soil through a No. 4 sieve (which has openings of 4.76 mm, or about 0.2 in.) to prepare the material for compaction. In this study, it was desired to make the soil processing resemble field processing as closely as possible; therefore the soil was not crushed and passed through the No. 4 sieve.

The soil was divided into batches, and the water content of each batch was adjusted to the desired value by adding, where necessary, distilled water. The soil was stored in plastic bags after moisture adjustment.

Compaction

In the field, compaction is accomplished by spreading the soil in thin layers (lifts) and compacting it with heavy equipment. In the laboratory, soil is typically compacted with standard-sized weights dropped from standard heights. It is almost impossible to match the energy of compaction in the laboratory with the energy delivered by field construction equipment because the energy of a drop weight cannot be directly related to the passage of a piece of equipment over soil. Therefore, it is best to use a range of compactive energies in the laboratory to span the range of possible compactive energy in the field.

The soil was compacted in the laboratory using three procedures:

1. Standard Proctor. The soil was compacted into 4-inch-diameter molds as described in ASTM standard D-698, Method A. The only deviations from the ASTM standard were: (1) each lift was scarified prior to placing a new lift (to ensure good bonding between lifts), and (2) the soil was not sieved through a No. 4 sieve prior to compaction.

2. Modified Proctor. Soil was compacted into 4-inch-diameter molds as described in ASTM standard D-1557, Method A. The only deviations are as described above for standard Proctor.

3. Reduced Proctor. This method was a modification of the standard Proctor method. The modification involved use of only 15 blows per lift of the compaction hammer rather than the usual 25 blows per lift. The maximum dry unit weight produced by this method of compaction

is typically about 95% of the maximum produced by standard Proctor compaction.

The reduced Proctor procedure involves minimal compactive energy; field compaction with a reasonable number of passes of modest-sized equipment will certainly deliver more compactive energy than this procedure. The standard Proctor procedure involves a modest compactive energy that compares well with normal compaction with modest-sized equipment. Modified Proctor compaction corresponds to compaction with very heavy equipment and represents a reasonable upper limit of compactive energy.

Soils were mixed at different water contents, remolded (compacted) using one of the three methods described above, and then tested for permeability.

Permeability Tests

Approach. There is no standard method of permeability testing for low-permeability soils. Subcommittee D18.04 on Hydrologic Properties of Soil and Rock of the American Society for Testing and Materials (ASTM) is responsible for developing and maintaining permeability-testing standards for soils. The author of this report is the chairman of this ASTM Subcommittee. The Subcommittee is currently developing two standards for measuring the permeability of low-permeability soils in the laboratory. One standard involves flexible-wall permeameters with backpressure saturation. The second standard involves rigid-wall permeameters with no backpressure for testing laboratory-compacted soils that are permeated directly in the mold into which the soil was compacted.

A discussion of the relative merits of both types of test is given in an article by Daniel, Anderson, and Boynton, "Fixed-Wall Versus Flexible-Wall Permeameters," ASTM Special Technical Publication 874, 1985, pp. 107-126. Daniel et al. note that "... the type of permeameter used has little effect for compacted clay permeated with water." Daniel et al. go on to note that rigid-wall, compaction-mold permeameters are "... ideally suited for testing laboratory-compacted specimens of clay that will be subjected to low overburden stress in the field ..." and that flexible-wall permeameters are "... ideal for soils that will be subjected to substantial overburden pressure, for example, ... compacted clay that will be overlain by significant thicknesses of soil or solid waste." The application of a confining stress in the flexible-wall permeameter tends to close any cracks or other hydraulic defects that are present in the soil and, in this way, to lower the permeability of the soil. One should not apply a confining stress larger than expected in the field because the measured permeability will be too low. As Daniel et al. note, it is almost impossible to measure the permeability of a low-permeability soil in a flexible-wall permeameter without applying a significant confining stress at the outflow end of the test specimen. For this reason, Daniel et al. do not recommend using the flexible-wall permeameter for testing soils located near the ground surface.

For this study, the soil of interest is proposed for capping land disposal units. A very small overburden pressure will act on the low-permeability layer in the cap. Also, the depth of water ponded above the low-permeability soil will not exceed approximately 1 ft, and the existence of any hydraulic head on the low-permeability layer will only be intermittent. The rigid-wall, compaction-mold permeameter used without backpressure appears to be more applicable to these circumstances than the flexible-wall permeameter with backpressure. For this reason, the rigid-wall permeameter was used without backpressure for most of the tests described in this report. The only potential problem with the use of a rigid-wall permeability test without backpressure is that gas bubbles might be trapped in the laboratory test specimen and lower the permeability of the soil (the permeability of a soil decreases as the amount of gas in the soil increases). However, with proper precautions, excessive gas need not be trapped in the laboratory test specimens. To prevent buildup of gas, the following procedures were used:

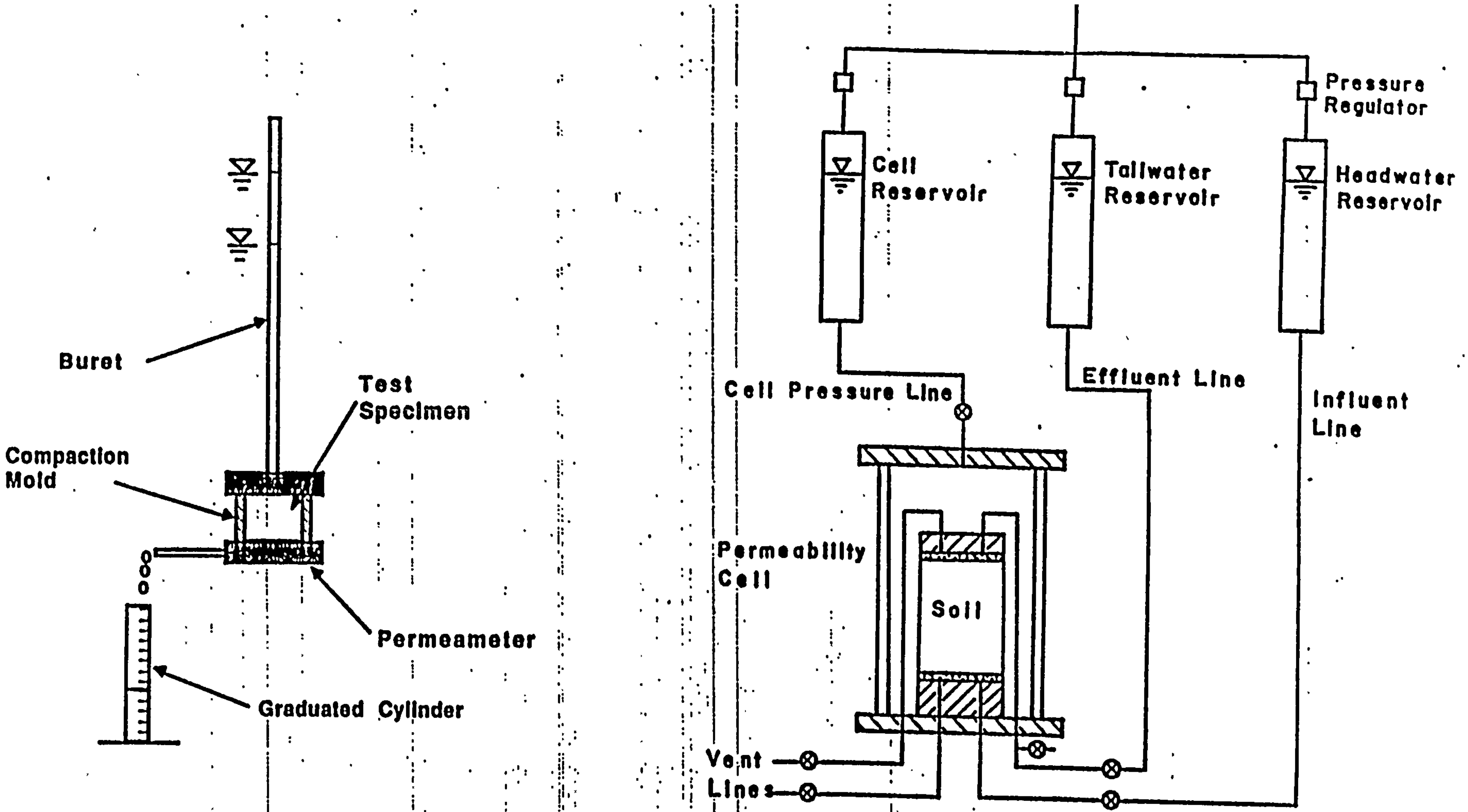
1. A head of water of 5 ft was applied to the top of the soils -- this head, which is much greater than will exist on the cover, helped to compress gas and to minimize the volume occupied by gas;
2. Degassed water was used -- the permeant water contained virtually no dissolved air and therefore helped to strip gas from the soil rather than add gas to the soil;
3. Tests were continued until outflow rates equalled inflow rates and the permeability was steady -- this ensured that enough flow took place to reach long-term, steady conditions.

The continuation of permeation with degassed water until outflow rates equalled inflow rates required testing times of several weeks (up to 2 months) for test specimens having permeabilities $\leq 1 \times 10^{-7}$ cm/s.

Several comparative tests were performed using flexible-wall permeameters with and without backpressure. The results are discussed later but show that the type of cell was unimportant that permeabilities measured with and without backpressure were essentially identical.

Specific Procedures. The laboratory test set-up is sketched in Figure 1. Most permeability tests were performed using rigid-wall cells (Figure 1A), but a few comparative tests using flexible-wall tests (Figure 1B) were also performed.

In the rigid-wall cells, the soil was permeated in the same 4-inch-inside-diameter Proctor mold into which the soil had been compacted. No vertical confinement was applied to the top of the soil, and the soil was free to swell. Falling-head tests with a constant tailwater pressure were performed. Rates of inflow and outflow were measured to ensure continuity of flow. The soils were permeated by ponding about 5 ft of water above the test specimens, which produced a hydraulic gradient of about 13. The permeant liquid was 0.005 N $CaSO_4$, which was used because it is the recommended liquid in draft ASTM



A. Fixed-Wall Cell

B. Flexible-Wall Cell

Figure 1. Schematic Drawings of Permeability Testing Systems

standards and does not tend to produce a decrease in permeability. The permeant liquid was degassed under vacuum to ensure that there was no buildup of air bubbles in the test specimens.

For tests in flexible-wall cells, an effective confining pressure of 3 psi was used at the inflow end, and an effective confining stress of 1 psi was applied at the outflow end. This extremely low effective confining stress was thought to be the lowest stress that could be applied and still maintain contact between the confining membrane and soil. The head loss across the soil was 2 psi of pressure, or a head of about 4.5 ft of water. Most flexible-wall tests were performed with a backpressure of 40 psi, but a few were performed without backpressure. Measurements generally showed B coefficients > 0.95 for the backpressured test specimens, which confirms that soils were fully saturated by the backpressure.

The tests were continued until rates of inflow and outflow were equal and the permeability was steady with time. The tests lasted from a few days to as long as 2 months for the least slowly permeable soils. The final permeability was calculated by averaging the last three permeability measurements obtained after the permeability was steady. The calculated values were rounded off to one significant figure.

Results of Tests

The results of tests performed without backpressure are summarized in Table 2. Compaction curves are shown in Figures 2 - 5. Compaction data for standard Proctor compaction are summarized in Table 3.

The compaction characteristics of the Type B soils from the east borrow area, Group 2, indicated that the soil was borderline A-B material. The optimum water content from standard Proctor compaction was 23 %, which was higher than was considered typical for Type B soils, but the maximum dry unit weight from standard Proctor compaction was 102 pcf, which is significantly higher than values usually seen for Type A soils and was more typical of Type B soils. The soil was colored bright red, was sandy, and had the appearance of a Type B soil. For these reasons, the material was categorized as Type B soil.

Type A Soils

East Borrow Area. The permeability data for Type A soils obtained from the east borrow area are plotted in Figure 6. Note that permeabilities less than 1 x 10^{-7} cm/s were achieved with all three compaction energies, but over different ranges of molding water content.

The compaction data are replotted in Figure 7 with solid symbols used to represent samples having permeabilities $\leq 1 \times 10^{-7}$ cm/s and open symbols representing samples having permeabilities $> 1 \times 10^{-7}$ cm/s. A zone of acceptable water content-density points is defined in this figure. The

Table 2. Results of Permeability Tests on Compacted Soil Tested without Backpressure

Sample Designation	Borrow Area	Soil Type	Group	Type of Compaction	Molding Water Content (%)	Dry Unit Weight (pcf)	Permeability (cm/s)
WA21.0-2	West	A	1	Reduced Proctor	21.1	86.5	2×10^{-3}
WA24.0-2	West	A	1	Reduced Proctor	23.7	90.8	2×10^{-3}
WA26.0-2	West	A	1	Reduced Proctor	26.1	93.0	2×10^{-7}
WA28.0-2	West	A	1	Reduced Proctor	28.3	91.4	5×10^{-8}
WA30.0-2	West	A	1	Reduced Proctor	31.3	87.1	1×10^{-7}
WA32.0-3	West	A	1	Reduced Proctor	32.0	87.7	7×10^{-8}
WA19.5-2	West	A	1	Standard Proctor	19.7	94.2	8×10^{-5}
WA22.0-2	West	A	1	Standard Proctor	21.3	93.8	6×10^{-5}
WA27.5-3	West	A	1	Standard Proctor	25.4	95.0	1×10^{-7}
WA27.5-4	West	A	1	Standard Proctor	25.5	96.2	3×10^{-8}
WA27.5-5	West	A	1	Standard Proctor	26.0	95.2	2×10^{-8}
WA27.5-6	West	A	1	Standard Proctor	29.6	90.6	1×10^{-7}
WA27.5-7	West	A	1	Standard Proctor	28.5	90.0	5×10^{-8}
WA27.5-8	West	A	1	Standard Proctor	26.5	95.1	1×10^{-7}
WA27.5-9	West	A	1	Standard Proctor	27.4	93.6	2×10^{-7}
WA27.5-10	West	A	1	Standard Proctor	27.1	93.8	2×10^{-8}
WA30.5-2	West	A	1	Standard Proctor	28.5	89.8	7×10^{-8}
WA30.5-3	West	A	1	Standard Proctor	29.3	90.7	8×10^{-8}
WA30.5-5	West	A	1	Standard Proctor	29.4	90.0	2×10^{-7}
WA32.0-1	West	A	1	Standard Proctor	32.0	84.8	3×10^{-7}
WA32.0-2	West	A	1	Standard Proctor	32.0	85.1	2×10^{-7}
WA18.0-1	West	A	1	Modified Proctor	17.8	104.9	6×10^{-8}

Table 2. Results of Permeability Tests on Compacted Soil Tested without Backpressure (continued)

Sample Designation	Borrow Area	Soil Type	Group	Type of Compaction	Molding Water Content (%)	Dry Unit Weight (pcf)	Permeability (cm/s)
WA21.0-1	West	A	1	Modified Proctor	21.6	106.6	6×10^{-9}
WA24.0-1	West	A	1	Modified Proctor	24.0	101.1	2×10^{-8}
WA26.0-1	West	A	1	Modified Proctor	25.9	97.3	2×10^{-8}
WA28.0-1	West	A	1	Modified Proctor	27.3	93.9	4×10^{-8}
WA30.0-1	West	A	1	Modified Proctor	29.9	89.3	1×10^{-7}
WA24.0-3R	West	A	2	Standard Proctor	24.2	90.5	1×10^{-6}
WA24.0-4R	West	A	2	Standard Proctor	24.2	88.6	6×10^{-6}
WA-24.0-5R	West	A	2	Standard Proctor	24.2	89.1	4×10^{-6}
WA-26.0-3R	West	A	2	Standard Proctor	25.7	90.4	1×10^{-6}
WA-26.0-4R	West	A	2	Standard Proctor	25.7	90.4	1×10^{-6}
WA-26.0-5R	West	A	2	Standard Proctor	25.7	90.1	9×10^{-7}
WA-28.0-3R	West	A	2	Standard Proctor	28.1	92.0	4×10^{-8}
WA-28.0-4R	West	A	2	Standard Proctor	28.1	92.0	3×10^{-8}
WA-28.0-5R	West	A	2	Standard Proctor	28.1	92.3	4×10^{-8}
WA-30.0-3R	West	A	2	Standard Proctor	30.2	90.7	3×10^{-8}
WA-30.0-4R	West	A	2	Standard Proctor	30.2	89.9	5×10^{-8}
WA-30.0-5R	West	A	2	Standard Proctor	30.2	90.1	5×10^{-8}
WA-32.0-4R	West	A	2	Standard Proctor	32.1	86.1	9×10^{-8}
WA-32.0-5R	West	A	2	Standard Proctor	32.1	86.1	1×10^{-7}
WA-32.0-6R	West	A	2	Standard Proctor	32.1	87.0	5×10^{-8}
EA-26.0-2	East	A	1	Reduced Proctor	26.3	83.7	1×10^{-4}
EA-28.0-2	East	A	1	Reduced Proctor	28.5	86.5	4×10^{-5}

Table 2. Results of Permeability Tests on Compacted Soil Tested without Backpressure (continued)

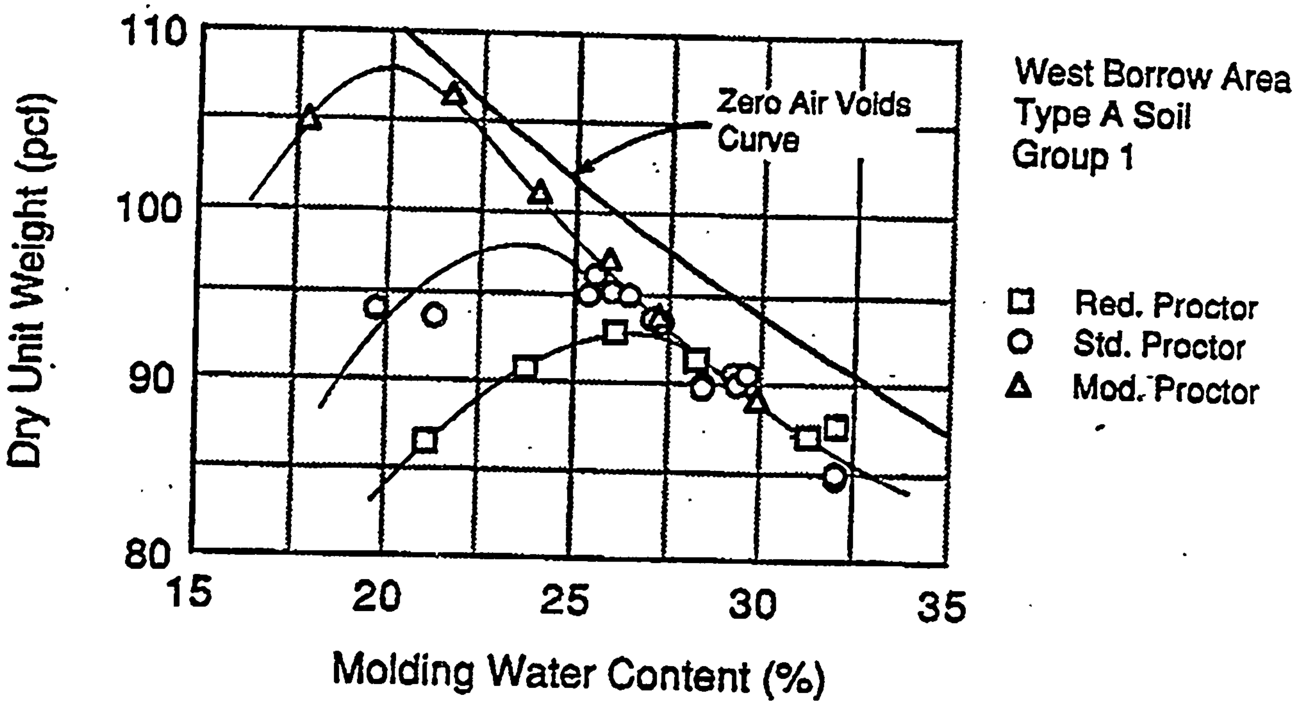
Sample Designation	Borrow Area	Soil Type	Group	Type of Compaction	Molding Water Content (%)	Dry Unit Weight (pcf)	Permeability (cm/s)
EA-30.0-2	East	A	1	Reduced Proctor	30.6	89.4	6×10^{-8}
EA-32.0-2	East	A	1	Reduced Proctor	32.6	87.0	6×10^{-8}
EA-34.0-2	East	A	1	Reduced Proctor	34.4	84.6	1×10^{-7}
EA-36.0-2	East	A	1	Reduced Proctor	36.6	81.5	3×10^{-6}
EA-24.0-1	East	A	1	Standard Proctor	24.2	87.3	8×10^{-6}
EA-26.0-1	East	A	1	Standard Proctor	25.7	88.4	8×10^{-6}
EA-28.0-1	East	A	1	Standard Proctor	27.5	90.2	5×10^{-7}
EA-30.0-1	East	A	1	Standard Proctor	29.5	91.9	4×10^{-8}
EA-32.0-1	East	A	1	Standard Proctor	31.5	89.5	5×10^{-8}
EA-34.0-1	East	A	1	Standard Proctor	34.4	84.5	2×10^{-7}
EA-21.0-6	East	A	1	Modified Proctor	21.1	99.6	4×10^{-8}
EA-24.0-3	East	A	1	Modified Proctor	24.2	100.5	1×10^{-8}
EA-26.0-3	East	A	1	Modified Proctor	26.7	97.9	1×10^{-8}
EA-28.0-3	East	A	1	Modified Proctor	28.4	95.0	2×10^{-8}
EA-30.0-3	East	A	1	Molified Proctor	30.6	91.9	3×10^{-8}
EA-32.0-3	East	A	1	Modified Proctor	32.4	86.8	5×10^{-8}
WB-13.0-3	West	B	1	Reduced Proctor	13.0	97.0	6×10^{-5}
WB-17.0-3	West	B	1	Reduced Proctor	16.9	104.0	6×10^{-6}
WB-20.0-2	West	B	1	Reduced Proctor	19.8	106.4	2×10^{-7}
WB-22.0-2	West	B	1	Reduced Proctor	21.8	103.4	3×10^{-7}
WB-25.0-2	West	B	1	Reduced Proctor	24.1	97.8	1×10^{-6}
WB-13.0-1	West	B	1	Standard Proctor	13.0	103.4	8×10^{-6}

Table 2. Results of Permeability Tests on Compacted Soil Tested without Backpressure (continued)

Sample Designation	Borrow Area	Soil Type	Group	Type of Compaction	Molding Water Content (%)	Dry Unit Weight (pcf)	Permeability (cm/s)
WB-17.0-1	West	B	1	Standard Proctor	17.0	109.4	1×10^{-7}
WB-21.0-1	West	B	1	Standard Proctor	21.0	104.9	2×10^{-7}
WB-25.0-1	West	B	1	Standard Proctor	24.7	99.6	2×10^{-6}
WB-27.0-1	West	B	1	Standard Proctor	25.6	93.6	2×10^{-8}
WB-8.0-1	West	B	1	Modified Proctor	8.0	111.9	9×10^{-7}
WB-10.0-1	West	B	1	Modified Proctor	10.1	116.4	3×10^{-7}
WB-13.0-2	West	B	1	Modified Proctor	13.0	120.1	3×10^{-8}
WB-17.0-2	West	B	1	Modified Proctor	16.6	113.0	4×10^{-8}
WB-20.0-1	West	B	1	Modified Proctor	20.0	106.1	1×10^{-7}
WB-22.0-1	West	B	1	Modified Proctor	21.9	102.0	3×10^{-7}
EA-18.5-2	East	B	1	Standard Proctor	19.3	106.8	1×10^{-7}
EA-18.5-3	East	B	1	Standard Proctor	18.9	107.3	9×10^{-8}
EA-18.5-4	East	B	1	Standard Proctor	18.7	107.9	6×10^{-8}
EA-18.5-5	East	B	1	Standard Proctor	18.3	108.0	7×10^{-8}
EA-21.0-2	East	B	1	Standard Proctor	22.1	98.5	2×10^{-7}
EA-21.0-3	East	B	1	Standard Proctor	22.1	100.5	2×10^{-7}
EA-21.0-4	East	B	1	Standard Proctor	22.1	99.8	3×10^{-7}
EA-21.0-5	East	B	1	Standard Proctor	22.1	99.8	3×10^{-7}
EB-22.0-3	East	B	2	Reduced Proctor	22.1	91.5	9×10^{-5}
EB-25.0-3	East	B	2	Reduced Proctor	24.9	96.5	4×10^{-4}
EB-27.0-3	East	B	2	Reduced Proctor	27.3	94.3	5×10^{-7}
EB-31.0-1	East	B	2	Reduced Proctor	30.2	89.9	2×10^{-6}

Table 2. Results of Permeability Tests on Compacted Soil Tested without Backpressure (continued)

Sample Designation	Borrow Area	Soil Type	Group	Type of Compaction	Molding Water Content (%)	Dry Unit Weight (pcf)	Permeability (cm/s)
EB-17.0-1	East	B	2	Standard Proctor	17.1	89.9	2×10^{-4}
EB-22.0-1	East	B	2	Standard Proctor	21.5	99.0	9×10^{-7}
EB-25.0-1	East	B	2	Standard Proctor	24.9	99.4	8×10^{-8}
EB-27.0-1	East	B	2	Standard Proctor	27.3	95.3	2×10^{-7}
EB-30.0-1	East	B	2	Standard Proctor	30.4	90.1	1×10^{-6}
EB-32.0-1	East	B	2	Standard Proctor	32.5	85.8	2×10^{-6}
EB-17.0-2	East	B	2	Modified Proctor	17.7	108.3	2×10^{-8}
EB-20.0-1	East	B	2	Modified Proctor	21.1	107.1	4×10^{-9}
EB-22.0-2	East	B	2	Modified Proctor	23.0	103.7	2×10^{-8}
EB-25.0-2	East	B	2	Modified Proctor	25.0	99.1	1×10^{-7}
EB-27.0-2	East	B	2	Modified Proctor	27.1	95.5	1×10^{-7}
EB-30.0-2	East	B	2	Modified Proctor	30.1	88.3	1×10^{-6}
EC30.0-1	East	C	1	Standard Proctor	30.7	78.4	1×10^{-5}
EC-36.0-1	East	C	1	Standard Proctor	36.6	79.6	7×10^{-6}
EC-39.0-1	East	C	1	Standard Proctor	39.3	77.7	4×10^{-6}
EC-41-1	East	C	1	Standard Proctor	41.0	75.2	8×10^{-6}



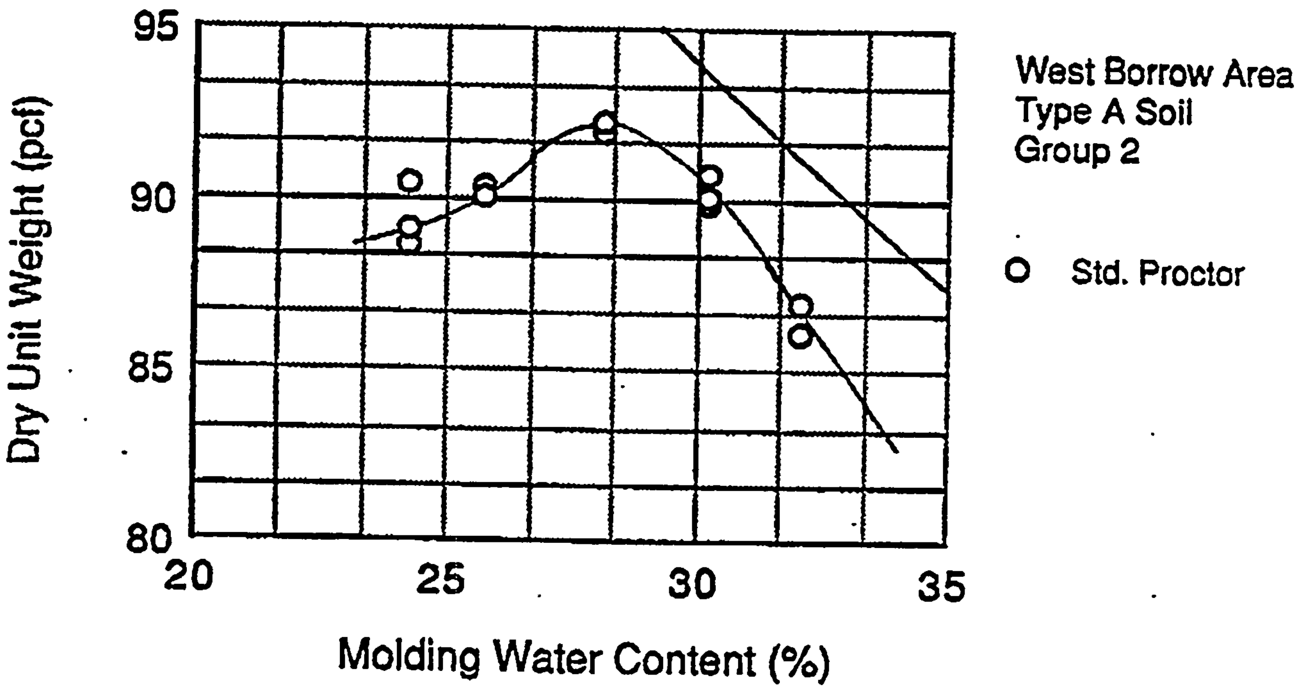


Figure 2 Compaction Curves for Type A Soils from the West Borrow Area

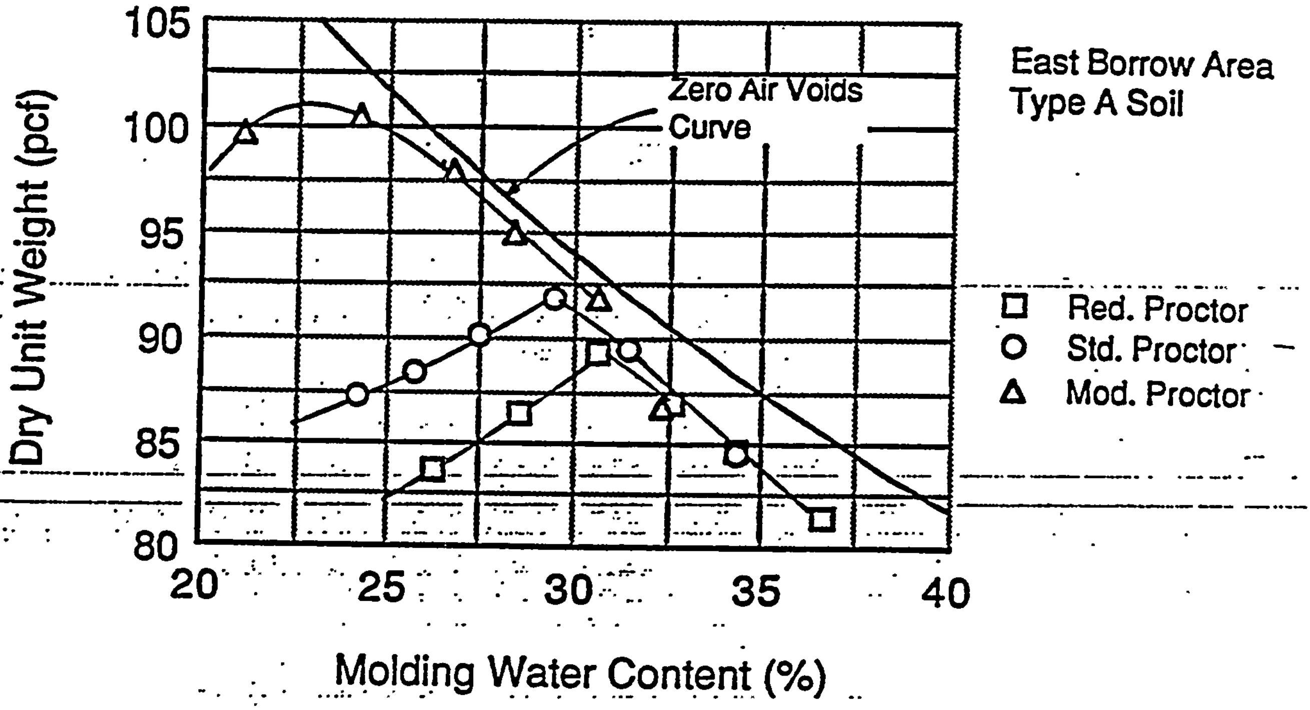


Figure 3 Compaction Curves for Type A Soil from the East Borrow Area

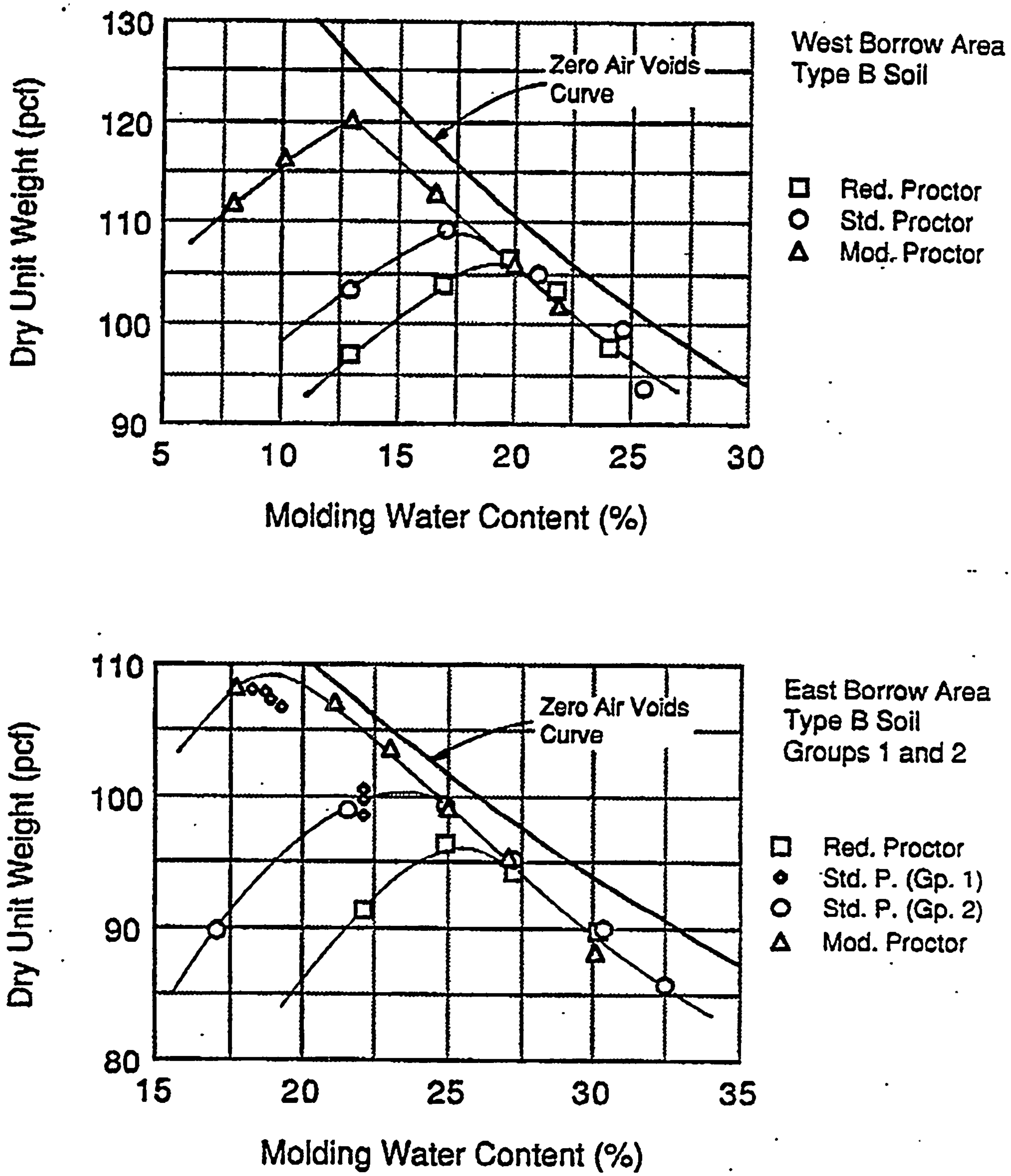


Figure 4 Compaction Curves for Type B Soils from the East and West Borrow Areas

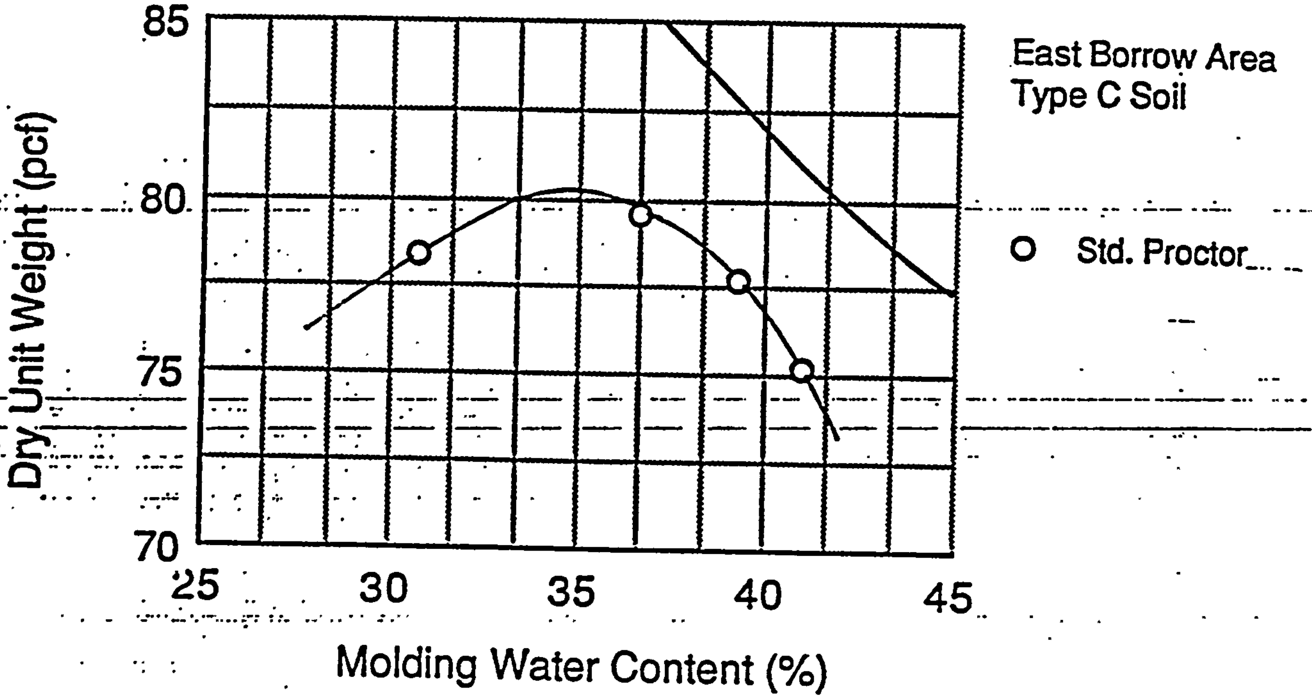


Figure 5 Compaction Curve for Type C Soil from the East Borrow Area

Table 3. Summary of Compaction Data

Borrow Area	Soil Type	Group	Liquid Limit(%)	Plasticity Index (%)	Std. Proctor Compaction Optimum w* (%)	Std. Proctor Compaction Maximum γ_d** (pcf)
West	A	1	53-56	19-29	23	98
		2	53	19	28	92
East	A		55	27	29	92
West	B	1	34	18	17	109
East	B	1	34	20	15	111
		2	46	16	23	101
East	C	1	-	-	35	81

---

*water content

**dry unit weight

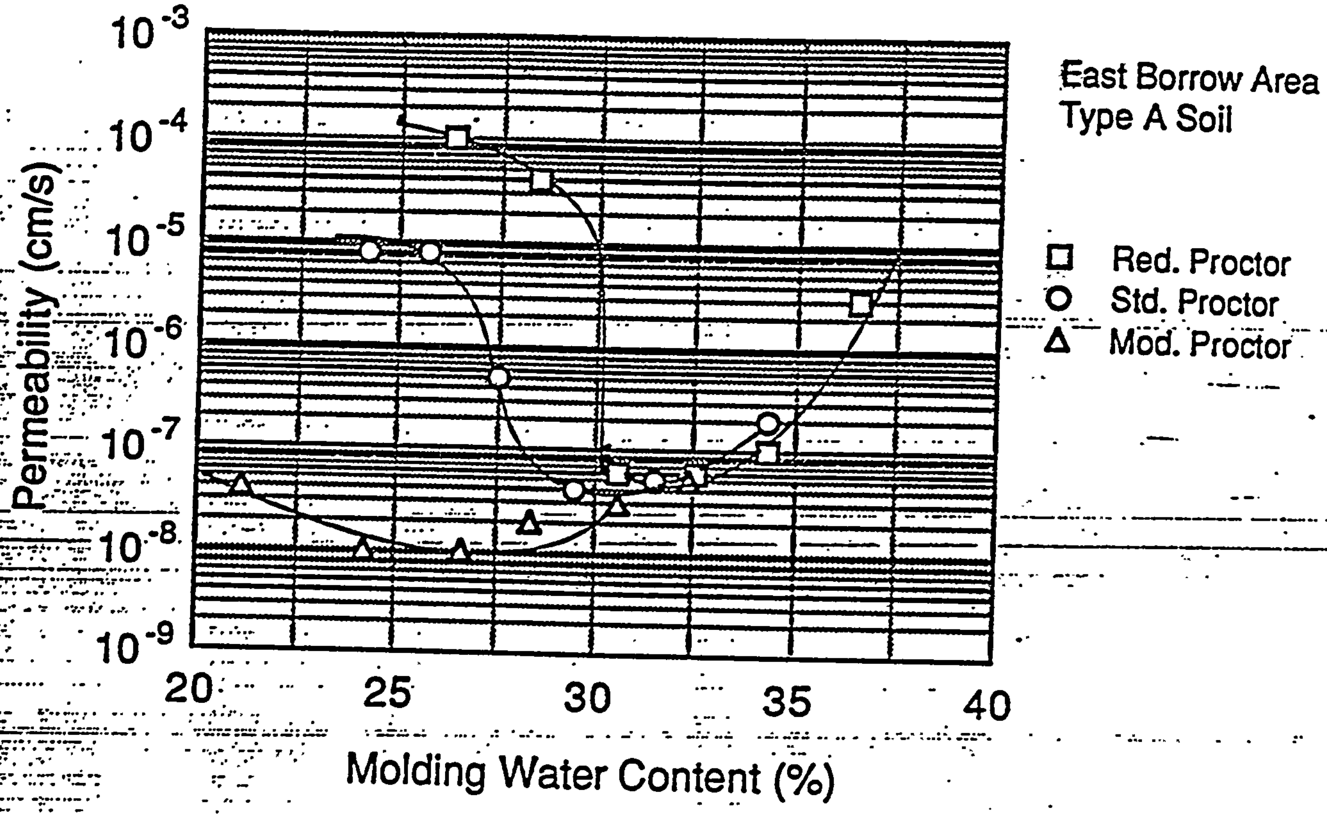


Figure 6 Permeability Versus Molding Water Content for Type A Soil from the East Borrow Area

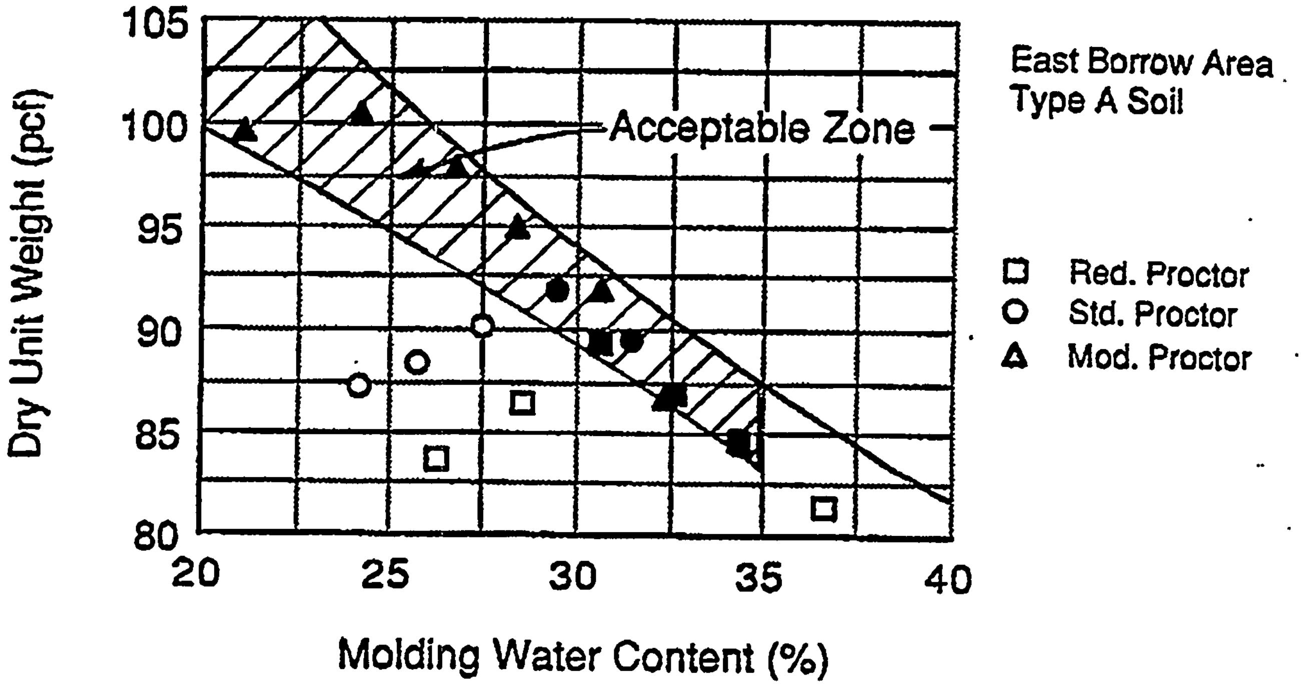


Figure 7 Compaction Data for Type A Soil from the East Borrow Area. Solid Symbols Denote Samples with Permeabilities ≤ 1 x 10^{-7} cm/s and Open Symbols Denote Samples with Permeabilities > 1 x 10^{-7} cm/s

acceptable zone applies to all compaction energies, including the very low one termed "reduced Proctor." The "Acceptable Zone" denotes the water content-density combinations that would be recommended for the soils tested.

The permeability data for Type A soils from the east borrow area are plotted as a function of initial (as-compacted) degree of saturation in Figure 8. The degree of saturation is defined as the volume of water divided by the volume of voids in a soil. As soil is compacted, the volume of void space is reduced, but the volume of water remains virtually constant (unless desiccation is permitted). Thus, as soil is compacted, the degree of saturation decreases. On some projects, degree of saturation has proven to be a useful construction quality control measure to determine whether the soil has been adequately compacted. The data in Figure 8 show that permeability is a function of degree of saturation for Type A soils from the east borrow area; the permeability is consistently $\leq 1 \times 10^{-7}$ cm/s when the degree of saturation is $\geq 92\%$.

West Borrow Area. The permeability data for Type A soil from the west borrow area are plotted in Figure 9. Again, permeabilities less than 1×10^{-7} cm/s were achieved with all three compaction energies, but over different ranges of molding water content.

The compaction data are replotted in Figure 10 with solid symbols used to represent samples having permeabilities $\leq 1 \times 10^{-7}$ cm/s and open symbols representing samples having permeabilities $> 1 \times 10^{-7}$ cm/s. A zone of acceptable water content-density points is again shown. The two "Acceptable Zones" for Type A soils from the east and west borrow areas are very similar. In essence, one Acceptable Zone is defined for the Type A soils.

The permeabilities are plotted as a function of degree of saturation in Figure 11. As with the Type A soil from the east borrow area, the West A soils had permeabilities less than or equal to 1×10^{-7} cm/s when the degree of saturation after compaction was greater than or equal to 92%.

All Type A Soils from Both Borrow Areas. The compaction data for all Type A soils from both borrow areas are plotted in Figure 12 with solid symbols used to represent samples having permeabilities $\leq 1 \times 10^{-7}$ cm/s and open symbols used to represent samples with permeabilities $> 1 \times 10^{-7}$ cm/s. A single "Acceptable Zone" is defined for all Type A soils.

Type B Soils

West Borrow Area. The permeability data for Type B soils obtained from the west borrow area are plotted in Figure 13. Note that only a few permeabilities less than 1×10^{-7} cm/s were achieved and that a large compactive effort (modified Proctor) was needed to achieve consistently a permeability $\leq 1 \times 10^{-7}$ cm/s.

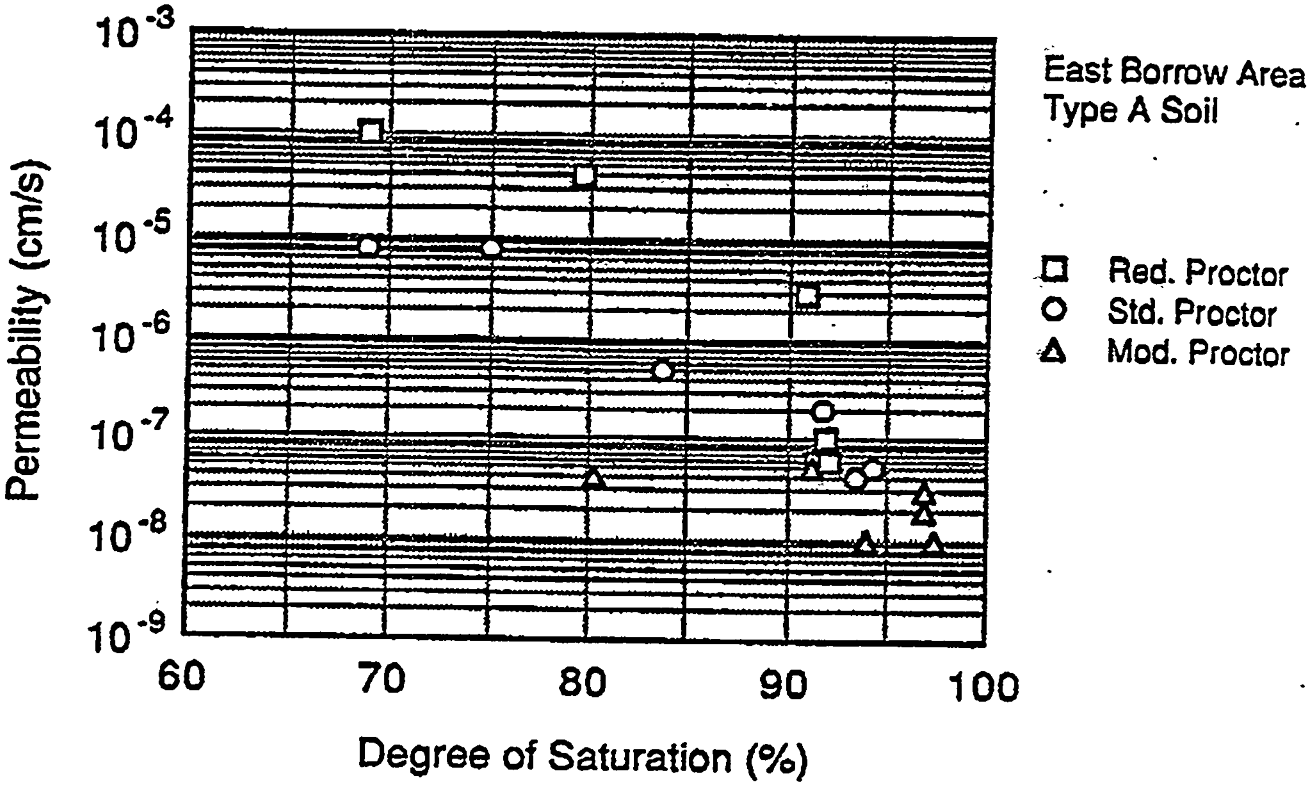


Figure 8 Permeability Versus As-Compacted Degree of Saturation for Type A Soil from the East Borrow Area

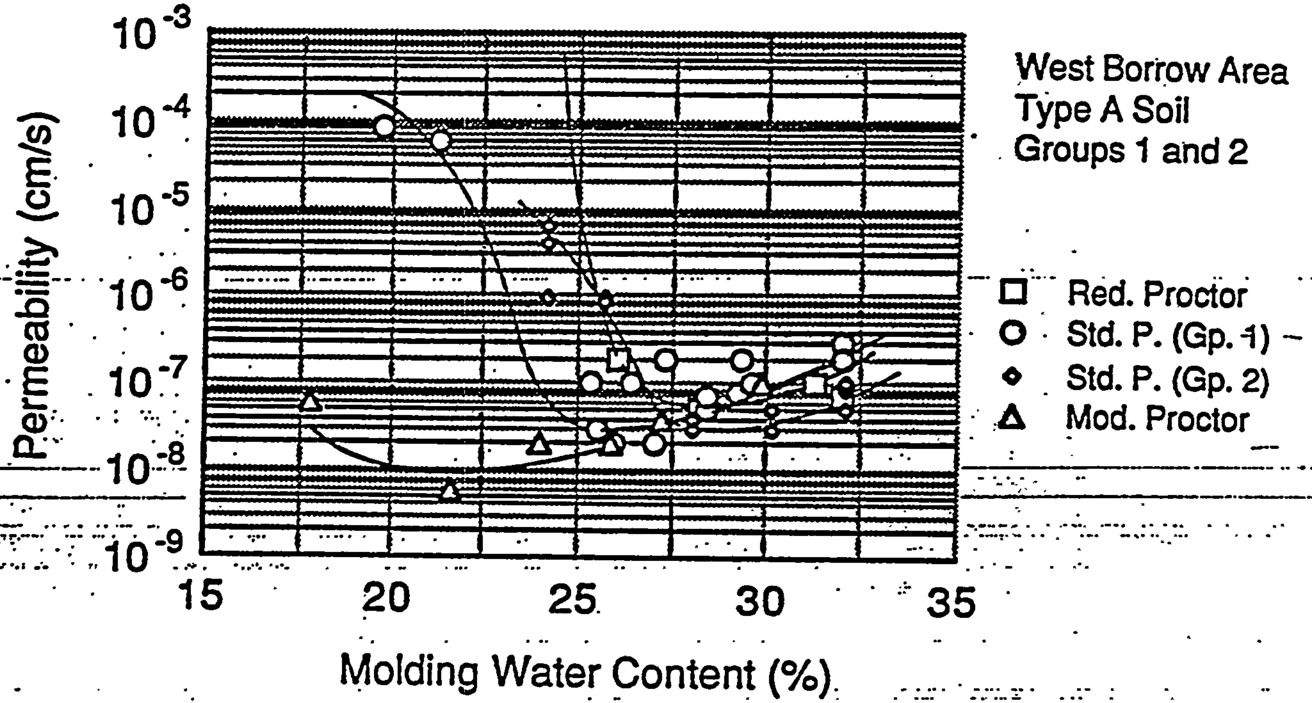


Figure 9 Permeability Versus Molding Water Content for Type A Soils from the West Borrow Area

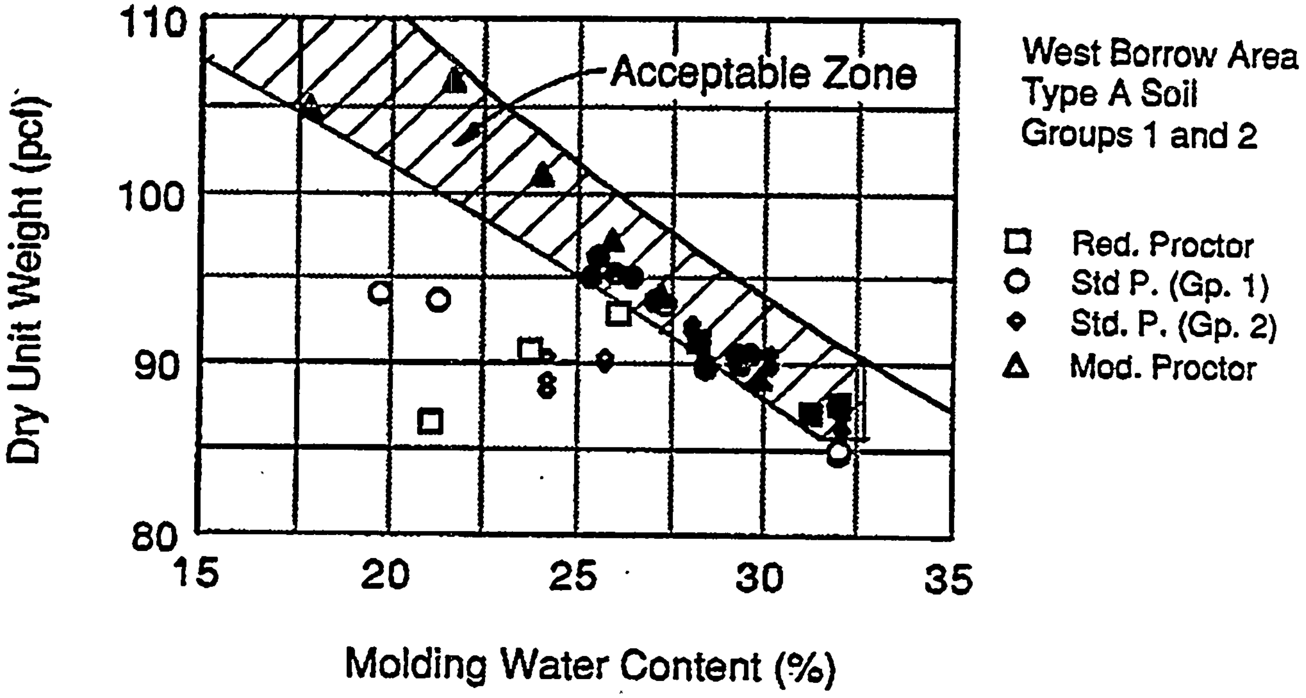


Figure 10 Compaction Data for Type A Soil from the West Borrow Area. Solid Symbols Denote Samples with Permeabilities ≤ 1 x 10^{-7} cm/s and Open Symbols Denote Samples with Permeabilities > 1 x 10^{-7} cm/s

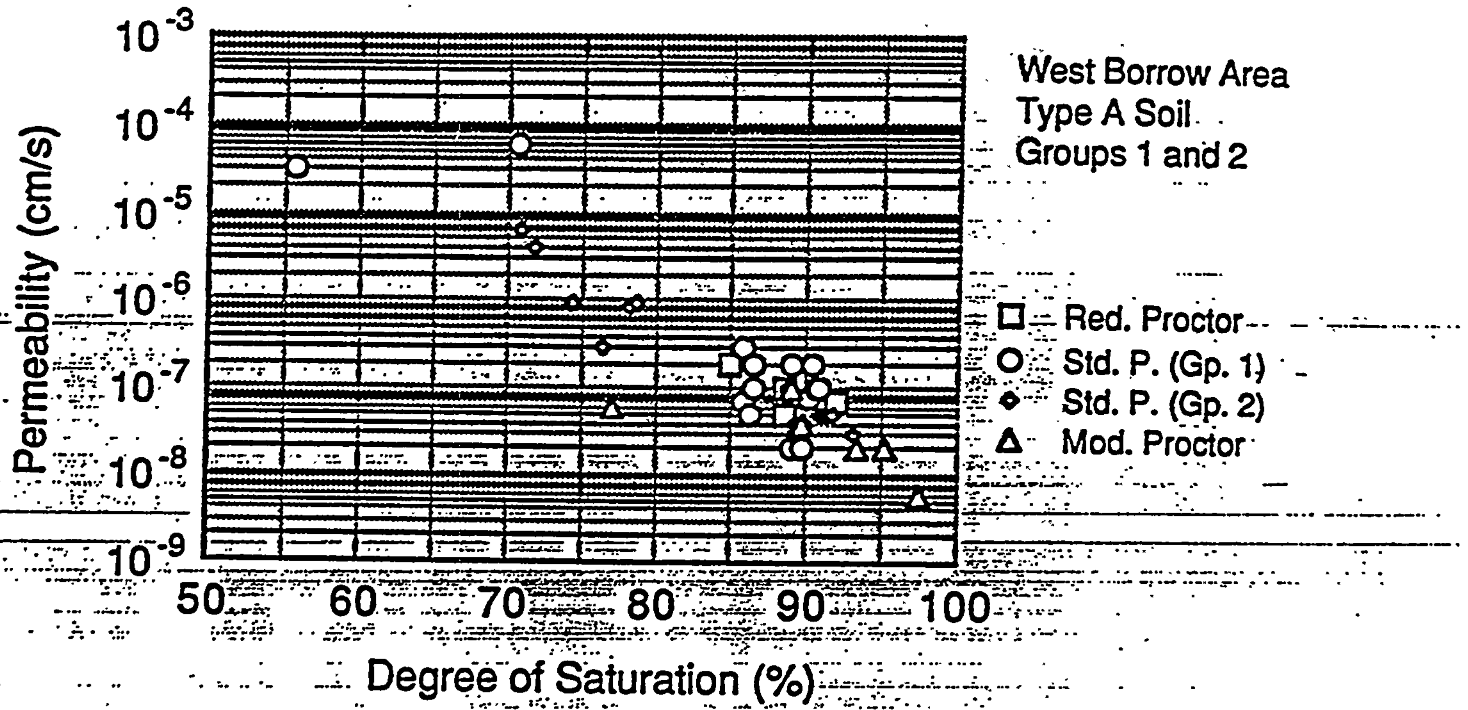


Figure 11 Permeability Versus As-Compacted Degree of Saturation for Type A Soil from the West Borrow Area

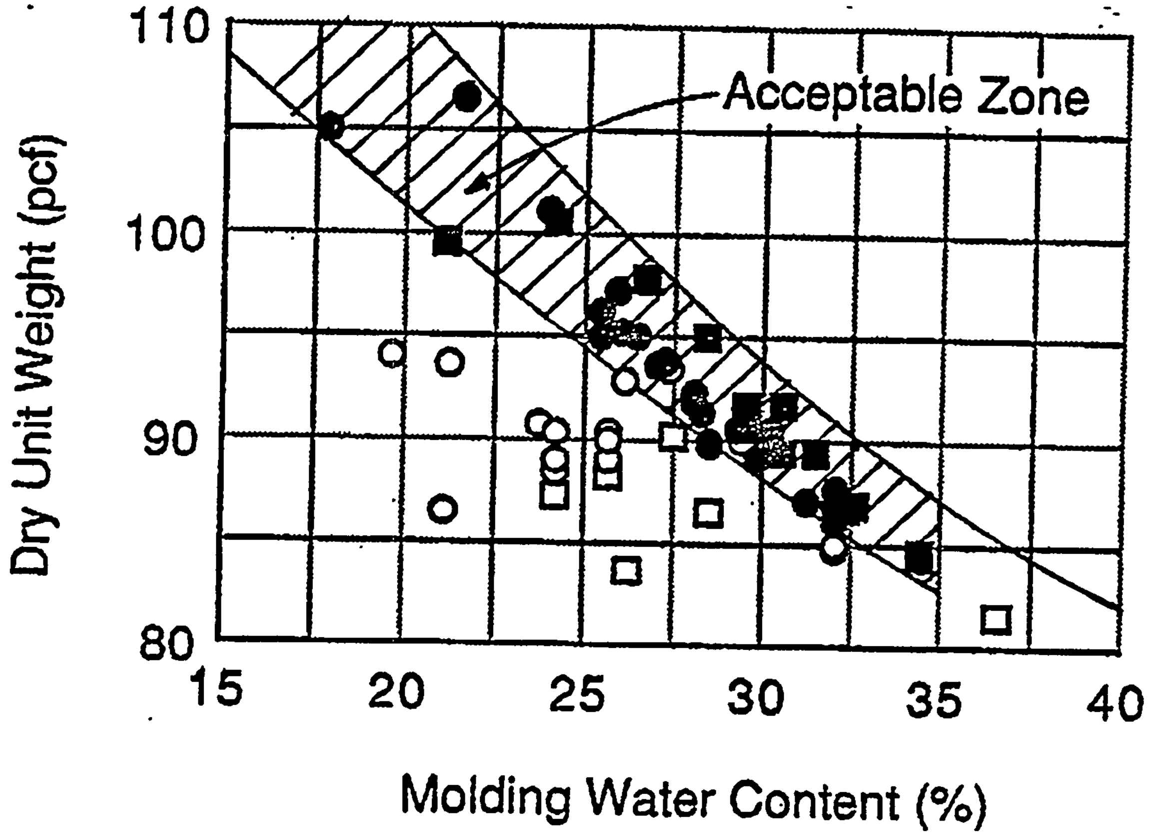


Figure 12 Compaction Data for Type A Soil from East and West Borrow Areas. Solid Symbols Denote Samples with Permeabilities ≤ 1 x 10^{-7} cm/s and Open Symbols Denote Samples with Permeabilities > 1 x 10^{-7} cm/s. Square Symbols Represent Soils from the East Borrow Area, and Circular Symbols Represent Soils from the West Borrow Area.

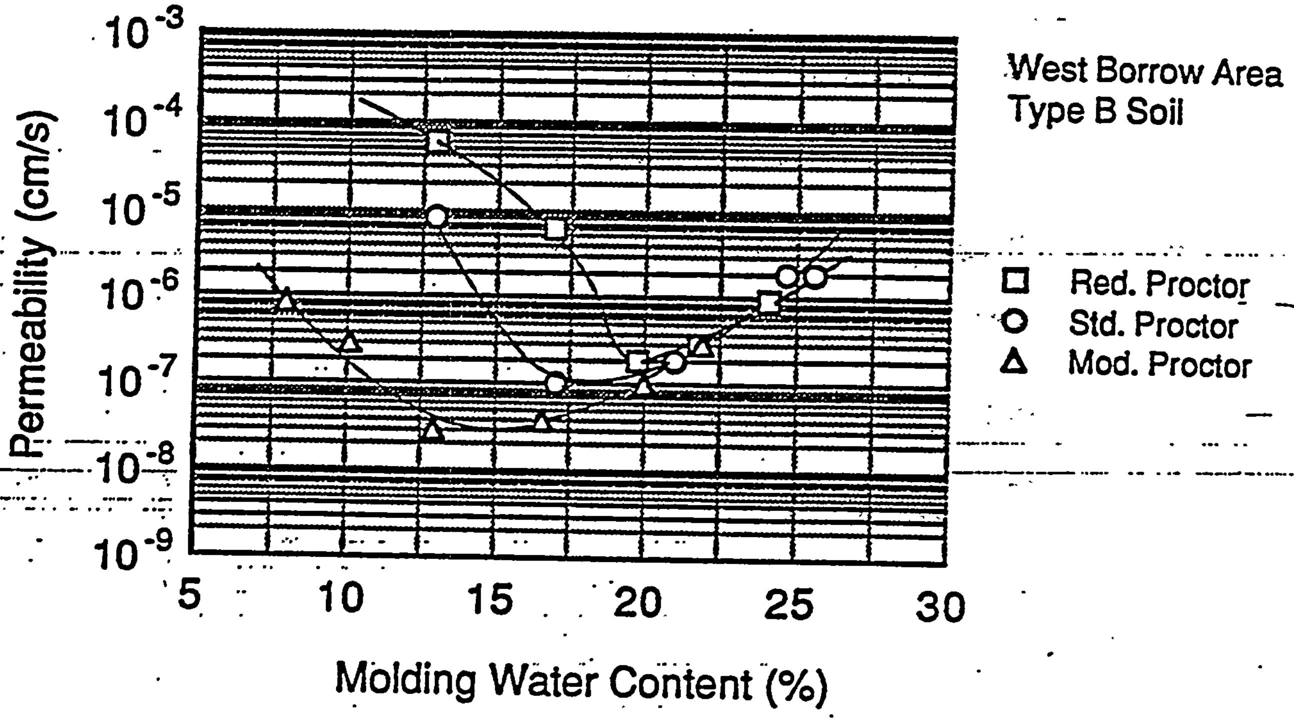


Figure 13 Permeability Versus Molding Water Content for Type B Soil from the West Borrow Area

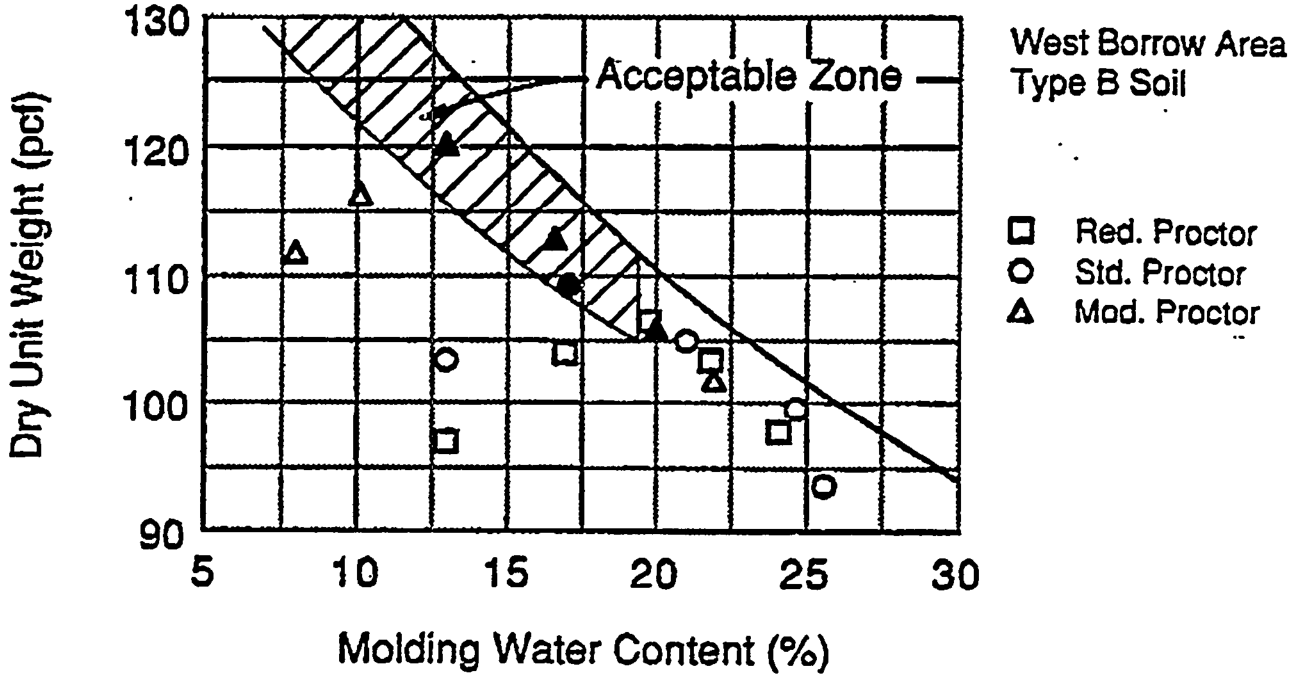


Figure 14 Compaction Data for Type B Soil from the West Borrow Area. Solid Symbols Denote Samples with Permeabilities ≤ 1 x 10^{-7} cm/s and Open Symbols Denote Samples with Permeabilities > 1 x 10^{-7} cm/s

The compaction data are replotted in Figure 14 with solid symbols used to represent samples having permeabilities ≤ 1 x 10^{-7} cm/s and open symbols representing samples having permeabilities > 1 x 10^{-7} cm/s. A zone of acceptable water content-density points is defined in this figure.

The permeability data for Type B soils from the west borrow area are plotted as a function of initial (as-compacted) degree of saturation in Figure 15. The data in Figure 15 show that the permeability of Type B soils from the west borrow area is not as consistently controlled by degree of saturation as was the permeability of the Type A soils. For Type B soils from the west borrow area, acceptable permeabilities were achieved at degrees of saturation as low as 83%, and soils compacted to high degrees of saturation (≥ 92%) did not necessarily have permeabilities ≤ 1 x 10-7 cm/s. The West B soils appear to require compaction to high densities (≥ 105 pcf) rather than remolding to high degrees of saturation.. It is not uncommon for the permeability of sandy soils to be controlled by density, and because the Type B soils are sandier than the Type A soils, the critical importance of density for Type B soils (but not Type A soils) is not surprising.

East Borrow Area.- The permeability data for Type B soil from the east borrow area are plotted in Figure 16. Again, as with the Type B soil from the west borrow area, permeabilities ≤ 1 x 10^{-7} cm/s were consistently achieved only with modified Proctor compaction.

The compaction data are replotted in Figure 17 with solid symbols used to represent samples having permeabilities ≤ 1 x 10^{-7} cm/s and open symbols representing samples having permeabilities > 1 x 10^{-7} cm/s. A zone of acceptable water content-density points is again shown. The East B soils did not seem to require compaction to quite so large a dry unit weight as the West B soils, but the Group 2, East B soil had a relatively high optimum water content (23% from standard Proctor compaction compared to 15% for the West B soil) and was borderline A-B soil.

The permeabilities of the East B soils are plotted as a function of degree of saturation in Figure 18. Degree of saturation alone does not appear to be a good indicator of permeability.

All Type B Soils from both Borrow Areas. The compaction data for all Type B soils from both borrow areas are plotted in Figure 19. A range of acceptable water content - density points is shown. A single acceptable zone is defined. However, the zone is more restrictive for dry unit weights below 105 pcf.

Type C Soils

The permeabilities of the Type C soils are plotted as a function of molding water content in Figure 20. It is clear that this soil could not be

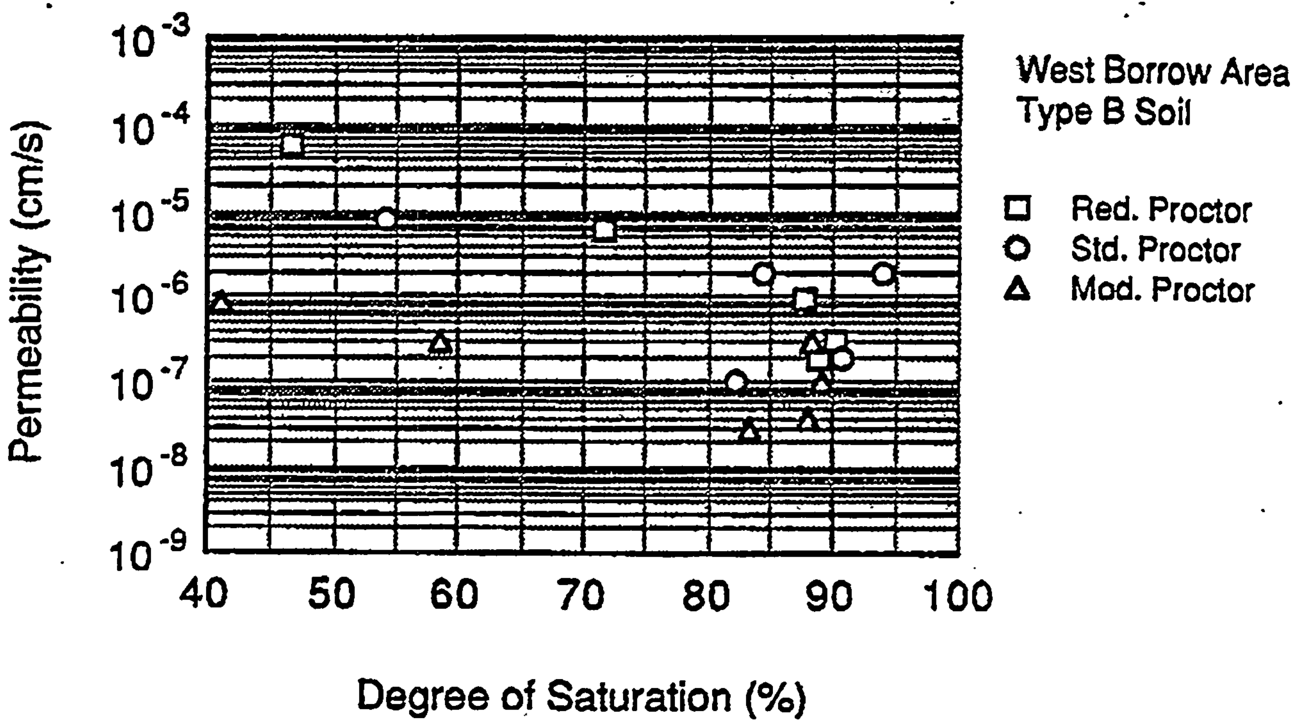


Figure 15 Permeability Versus As-Compacted Degree of Saturation for Type B Soil from the West Borrow Area

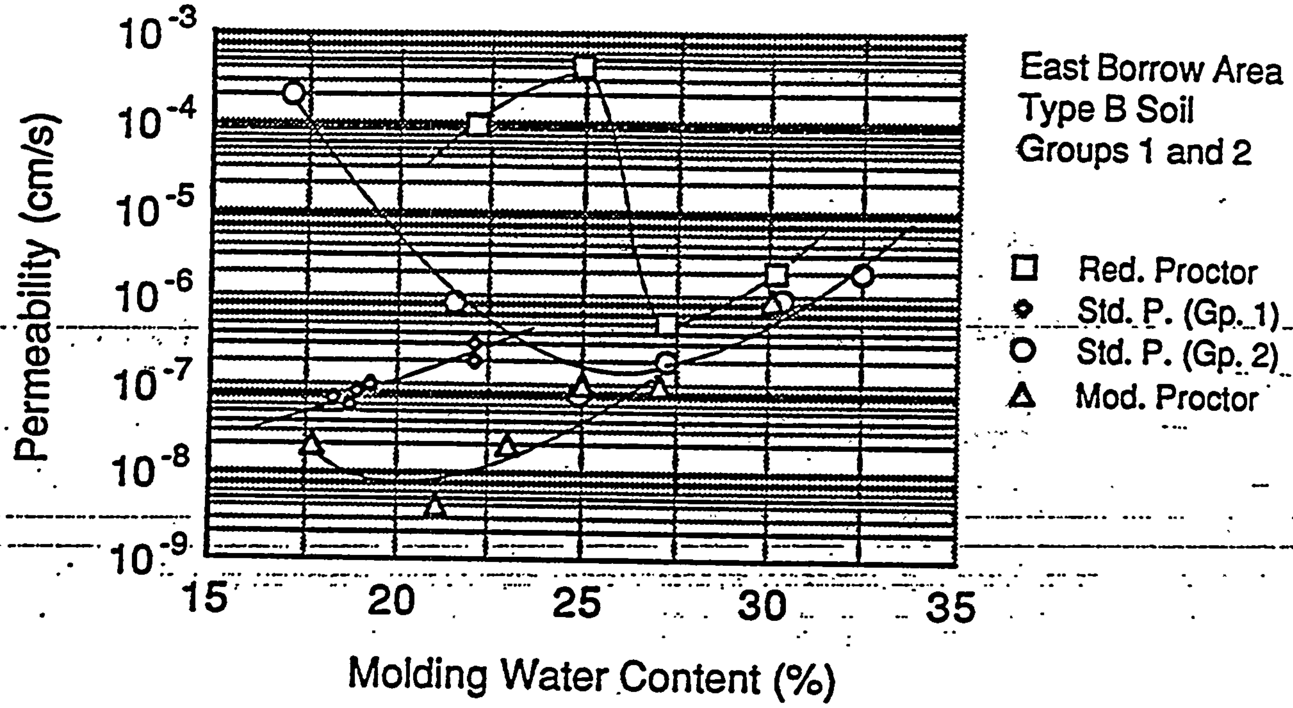


Figure 16 Permeability Versus Molding Water Content for Type B Soil from the East Borrow Area

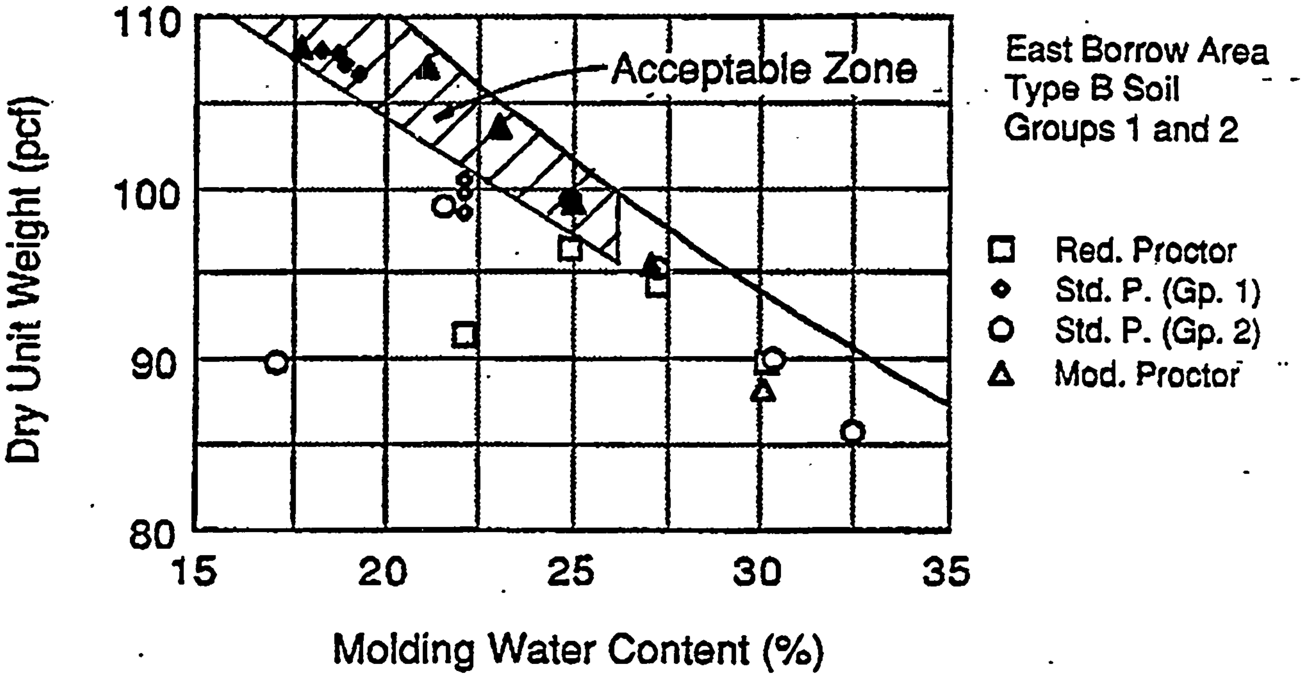


Figure 17 Compaction Data for Type B Soil from the East Borrow Area. Solid Symbols Denote Samples with Permeabilities $\leq 1 \times 10^{-7}$ cm/s and Open Symbols Denote Samples with Permeabilities $> 1 \times 10^{-7}$ cm/s

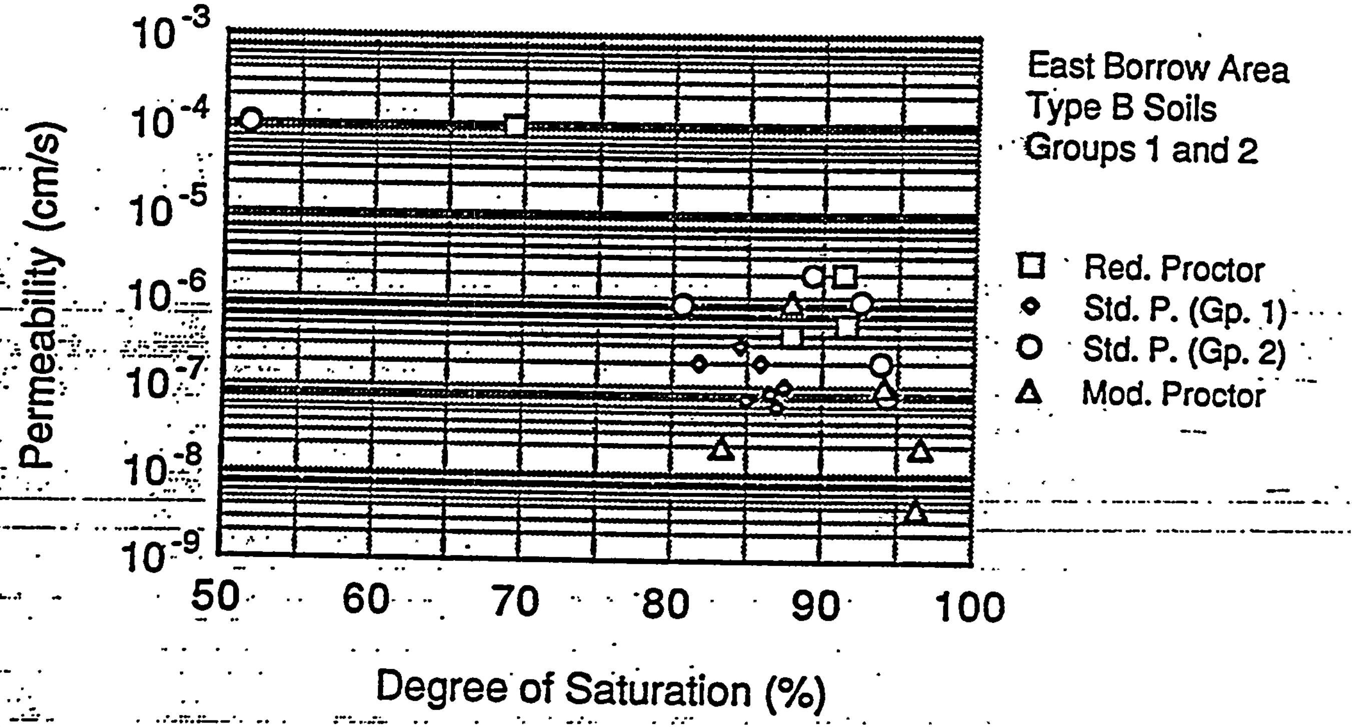


Figure 18 Permeability Versus As-Compacted Degree of Saturation for Type B Soil from the East Borrow Area

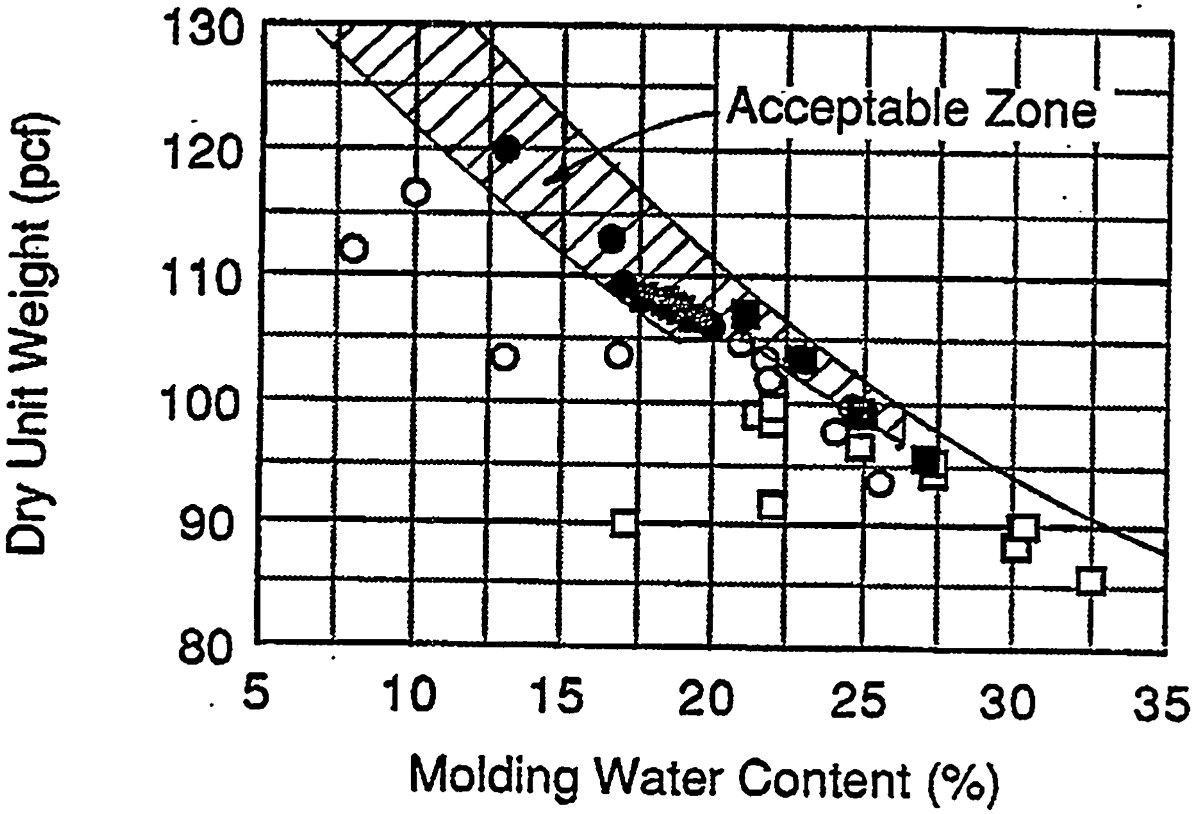


Figure 19 Compaction Data for Type B Soils from the East and West Borrow Areas. Solid Symbols Denote Samples with Permeabilities $\leq 1 \times 10^{-7}$ cm/s and Open Symbols Denote Samples with Permeabilities $> 1 \times 10^{-7}$ cm/s. Square Symbols Represent Soils from the East Borrow Area, and Circular Symbols Represent Soils from the West Borrow Area

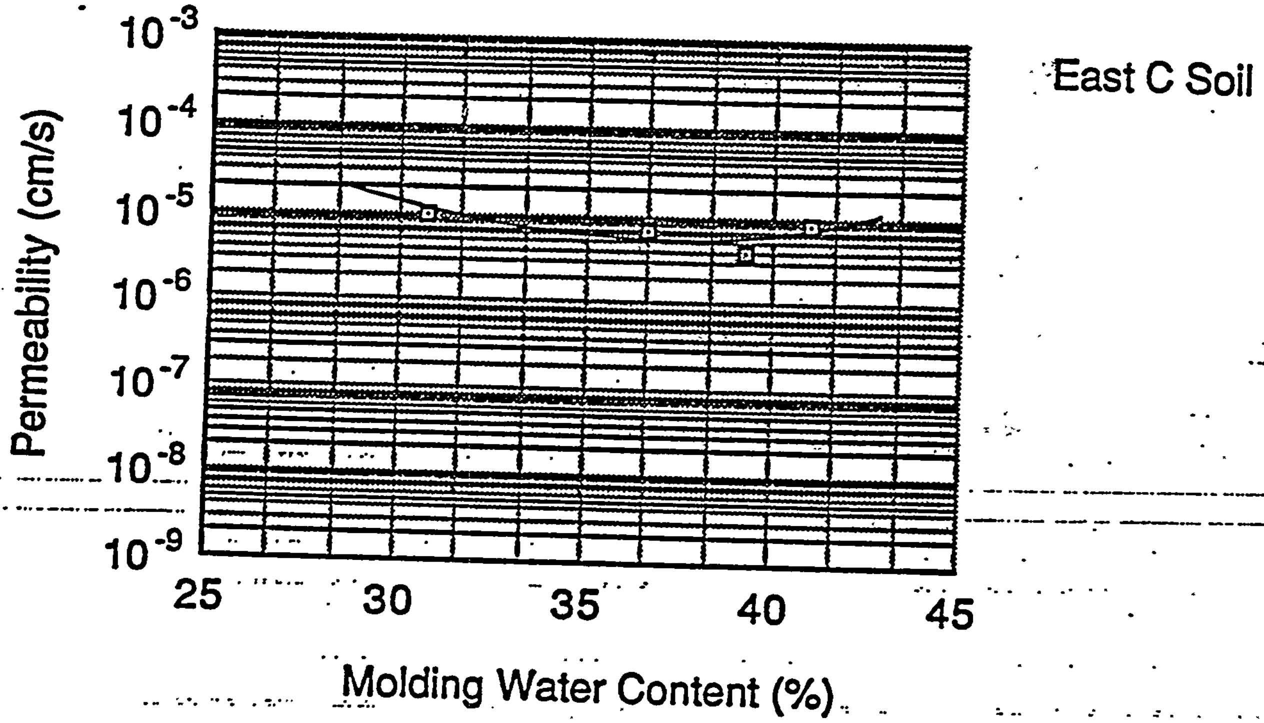


Figure 20 Permeability Versus Molding Water Content for Type C Soil from the East Borrow Area

compacted to a permeability even close to 1 x 10^{-7} cm/s with standard Proctor compaction. For this reason, further tests were not performed.

Replication Tests

During the course of this study, questions were raised about the reproducibility of the test data. Unfortunately, data do not exist in the literature to demonstrate how reproducible compaction/permeability tests are. To study the reproducibility of the tests, an investigation was undertaken.

Three buckets of Type A soil from the west borrow area were mixed together and processed as described earlier; the soils are referred to as "Type A, Group 2" soils from the west borrow area. The soil was divided into 5 batches, each of which was mixed to a different water content. The soils were compacted with standard Proctor procedures and then permeated as described earlier. The results of these tests were included in earlier discussions and were presented in Table 2 but are reviewed in this subsection in light of reproducibility of test results.

Compaction data are plotted in Figure 21, and permeability data are plotted in Figure 22. Detailed statistical analyses of the data are possible but were beyond the scope of this study. The data in Figure 22 illustrate qualitatively the experimental scatter and reproducibility of test data. The data give confidence that tests on soils having a permeability ≤ 1 x 10^{-7} cm/s can be consistently reproduced.

Tests on Soils with Backpressure

A few tests were performed in flexible-wall permeameters with backpressure saturation to study how backpressure saturation affected the results. The soils were set up in flexible-wall permeameters using a system shown schematically in Figure 1B. Tests were conducted on Type A soils from the west borrow area and on Type B soils from the east borrow area.

The test results are summarized in Table 4. In some cases, the soils were tested first without backpressure and were then tested with backpressure; in these cases a direct determination of the effect of backpressure saturation could be made assuming that the soil had not undergone any alteration during the testing process. It is seen from Table 4 that the ratio of permeability (k) with backpressure to k without backpressure is approximately equal to one. It is concluded that backpressure had an insignificant effect. An examination of the other data from tests with backpressure showed no significant deviations from results presented earlier for tests performed without backpressure.

It has been the author's experience that backpressure saturation rarely has much effect on the test results, provided tests without backpressure are performed with degassed water and are continued until inflow and outflow rates are equal (which was the case for this study).

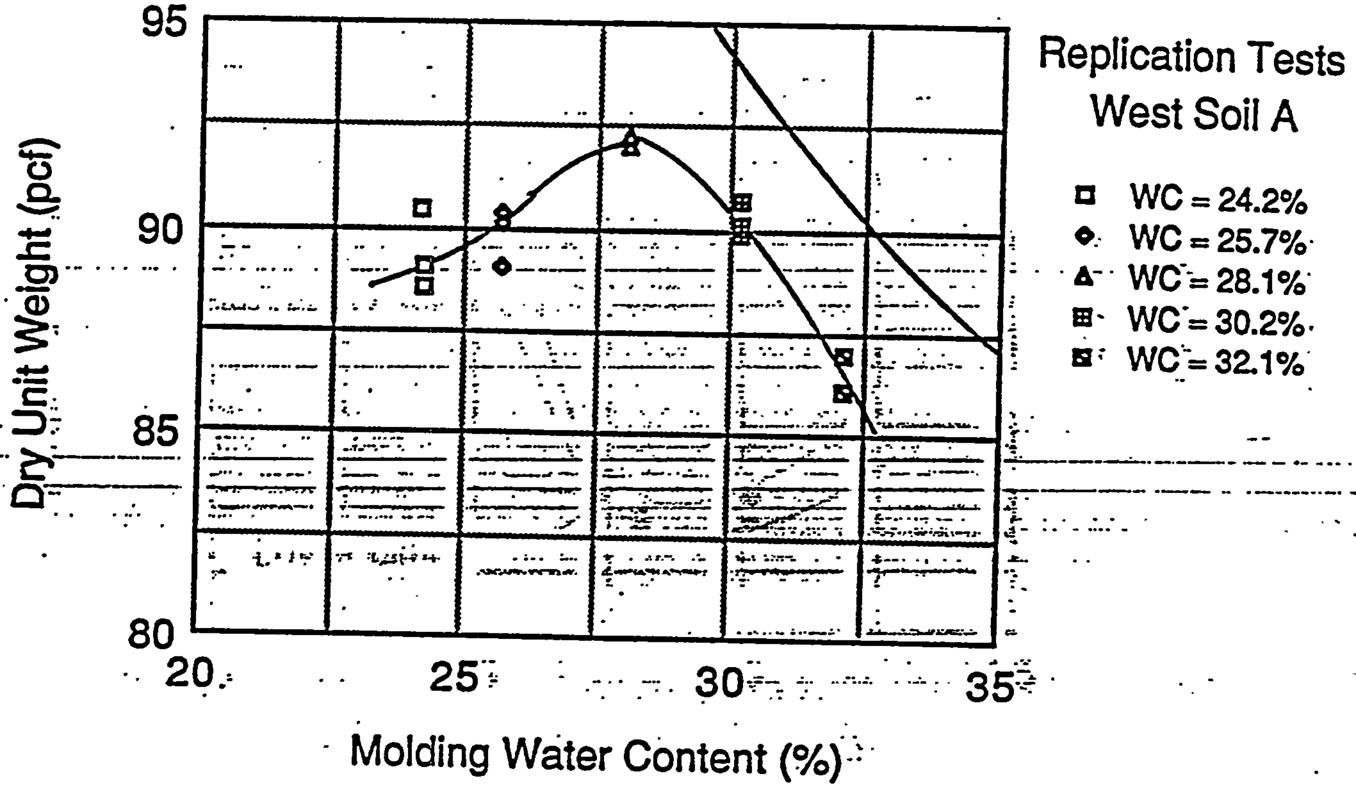


Figure 21 Compaction Curve for Type A, Group 2 Soils from the West Borrow Area Used for Study of Reproducibility of Test Results

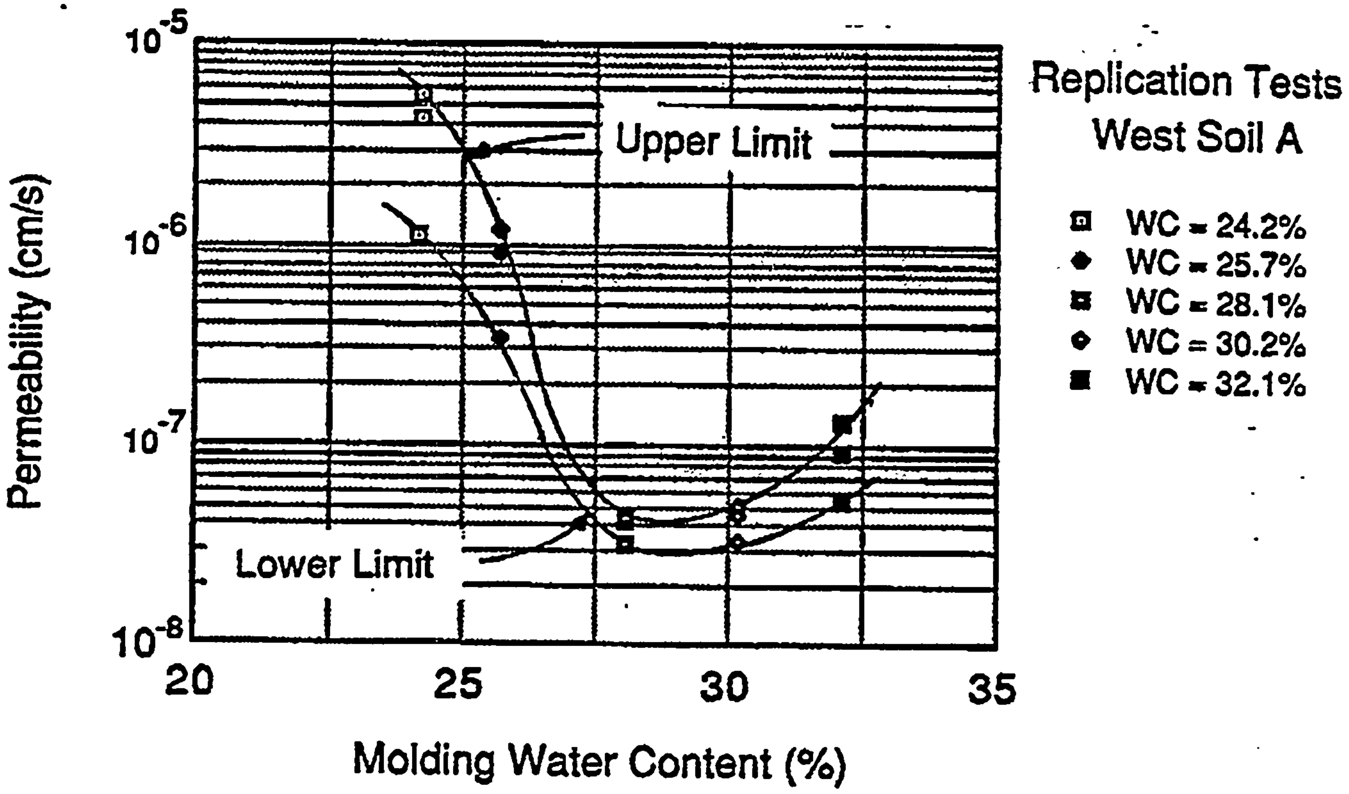


Figure 22 Permeability Versus Molding Water Content For Type A, Group 2 Soils from the West Borrow Area Used for Study of Reproducibility of Test Results.

Table 4. Summary of Results of Permeability Tests with Backpressure

Sample Designation	Borrow Area	Soil Type	Group	Std. Proctor Compaction		Permeability, k (cm/s)		Ratio of k with/without Backpressure
				w(%)	γ_d(pcf)	Backpressure	No Backpressure	
WA19.5-1	West	A	1	19.2	88.7	5×10^{-5}	—	—
WA22.0-1	West	A	1	22.0	90.5	1×10^{-5}	—	—
WA24.5-1	West	A	1	24.6	95.6	1×10^{-6}	—	—
WA27.5-1	West	A	1	27.3	94.1	9×10^{-8}	—	—
WA27.5-2	West	A	1	27.4	93.1	7×10^{-8}	—	—
WA27.5-3	West	A	1	25.4	95.0	1×10^{-7}	1×10^{-7}	1
WA27.5-6	West	A	1	29.6	90.6	1×10^{-7}	1×10^{-7}	1
WA30.5-1	West	A	1	30.5	87.5	2×10^{-7}	—	—
WA30.5-5	West	A	1	29.4	90.0	1×10^{-7}	2×10^{-7}	0.5
EA13.5-1	East	B	1	12.5	109.8	2×10^{-7}	—	—
EA16.0-1	East	B	1	15.9	110.0	1×10^{-7}	—	—
EA16.0-2	East	B	1	15.2	111.1	3×10^{-7}	—	—
EA18.5-1	East	B	1	18.3	102.8	2×10^{-7}	—	—

Table 4. Summary of Results of Permeability Tests with Backpressure (continued)

Sample Designation	Borrow Area	Soil Type	Group	Std. Proctor Compaction		Permeability, k (cm/s)		Ratio of k with/without
				w(%)	γ_d(pcf)	Backpressure	No Backpressure	Backpressure
EA18.5-2	East	B	1	19.3	106.8	2x10^{-7}	1x10^{-7}	2
EA18.5-3	East	B	1	18.9	107.3	2x10^{-7}	9x10^{-8}	2
EA21.0-1	East	B	1	20.9	102.1	3x10^{-7}	—	—
EA21.0-2	East	B	1	22.1	98.5	2x10^{-7}	2x10^{-7}	1
EA21.0-3	East	B	1	22.1	100.5	2x10-7	2x10^{-7}	1
EA24.0-1	East	B	1	23.8	97.7	5x10^{-7}	—	—
EA27.0-1	East	B	1	27.4	93.3	9x10^{-7}	—	—

Note: w = water content

γ_d = dry unit weight

Flexible-Wall Versus Rigid-Wall Permeameters

Among some individuals, the question of whether rigid-wall or flexible-wall permeameters should be used is a subject of debate. In this study, rigid-wall permeameters were chosen because the author did not want to apply excessive confining stress to the soil, and tests at low confining stress are extremely difficult with flexible-wall permeameters.

It was not possible to make a direct determination of the influence of type of permeameter because the same test specimen could not be tested in both types of permeameters. However, similar test specimens were permeated in rigid-wall and flexible-wall permeameters without backpressure, and the results are summarized in Table 5. All specimens for which results are listed in Table 5 were compacted with standard Proctor procedures. The tests scatter because the molding water contents and densities scatter. The ratio of permeability from rigid-wall cells to permeability measured in flexible-wall cells varied from 0.3 to 1.5. This variation was almost certainly the result of variations between the compacted soils. The average of the permeability ratios is close to unity. Given variations between samples, there did not appear to be significant difference in the results between rigid-wall and flexible-wall permeameters.

Comparison of Findings to Earlier Submittal

An earlier submittal from DOE to the Tennessee Department of Health and Environment (TDHE) dated April 15, 1988, indicated that the soils could be compacted to produce a permeability on the order of 10^{-7} cm/s (between 1 and 10 x 10^{-7} cm/s), but did not show that permeabilities $\leq 1 \times 10^{-7}$ cm/s could be achieved. It was mistakenly thought at the time that it was adequate for the soil to have a permeability on the order of 10^{-7} cm/s. Later, when the closure plans were reviewed more carefully, it was confirmed that the permeability had to be less than or equal to 1 x 10^{-7} cm/s.

This study was undertaken to address the question of whether the soils could be compacted to achieve a permeability less than 1 x 10^{-7} cm/s. Because the earlier submittal did not lead to this conclusion, but the study described here did show that permeabilities $\leq 1 \times 10^{-7}$ cm/s could be achieved, some discussion of the differences between the two investigations is warranted.

The following factors were found to be different in the earlier study and the one described here and are thought to have contributed significantly to the differences in findings:

1. Soil Preparation. In the earlier study, the soil was air dried and sieved through a No. 4 sieve (which has openings of about 0.19 inch). All material retained on the sieve was discarded. A careful examination by the author showed that the material removed by the sieve included gravel particles as well as air-dried clods of soil. The clods of soil were rich in clay. This process led to some of the clay being sieved out of the

Table 5 Effect of Type of Permeameter on the Measured Permeability of Soils Compacted with Standard Proctor Procedures

Borrow Area	Soil Type	Sample	Molding Water Content (%)	Permeability, k (cm/s) Fixed-Wall Cell	Permeability, k (cm/s) Flexible-Wall Cell	Ratio of Average k for Fixed/Flexible Wall
East	B	EA18.5-2	19.3		1×10^{-7}	0.7
		EA18.5-3	18.9		9×10^{-8}	
		EA18.5-4	18.7	6×10^{-8}		
		EA18.5-5	18.3	7×10^{-8}		
East	B	EA21.0-2	22.1		2×10^{-7}	1.5
		EA21.0-3	22.1		2×10^{-7}	
		EA21.0-4	22.1	3×10^{-7}		
		EA21.0-5	22.1	3×10^{-7}		
West	A	WA27.5-3	25.4		1×10^{-7}	0.3
		WA27.5-8	26.5		1×10^{-7}	
		WA27.5-10	27.1		2×10^{-8}	
		WA27.5-4	25.5	3×10^{-8}		
		WA27.5-5	26.0	2×10^{-8}		
West	A	WA27.5-6	29.6		1×10^{-7}	0.6
		WA27.5-7	28.5		5×10^{-8}	
		WA30.5-5	29.4		2×10^{-7}	
		WA30.5-2	28.5	7×10^{-8}		
		WA30.5-3	29.3	8×10^{-8}		

soil in the previous investigation. The soil will not be sieved in the field, and clay will not be removed from the soil in the field. It is for this reason that the clay material was not sieved out of the soil in this investigation. The removal of clay from the soil being tested probably contributed significantly to the measurement of higher permeabilities in the earlier study compared to this one.

2. Soil Compaction. In the earlier investigation, soils were compacted into molds using a hand-held tamping rod. There was no control over the compactive energy delivered to the soil. The soil was simply packed into the mold to a predetermined density typically equal to 95% of the maximum density from a standard Proctor compaction test. In many, if not all, of the samples, the compactive energy delivered by the hand-held tamper was much less than the energy from a heavy piece of construction equipment. In this investigation, 3 controlled compactive energies were used to span the range of compactive energy that might be expected in the field. Use of a lower compactive energy in the earlier study probably contributed significantly to the measurement of higher permeabilities compared to this study.

3. Error in Calculation. Falling-head permeability tests with a rising tailwater level were performed in the earlier investigation. The equation used to calculate permeability was equivalent to the following one:

$$k = \frac{a\,L}{A\,t}\ \ln\left(\frac{H_1}{H_2}\right) \qquad 1$$

where k is the permeability of the soil, a is the area of the standpipe in which the water level falls or rises, L is the length of the soil sample, A is the cross-sectional area of the soil sample, t is the elapsed time between readings, H_1 is the head loss across the soil at the start of a permeability determination, and H_2 is the head loss at the end of a determination. This is the correct equation for a falling head test with a constant tailwater pressure, but it is incorrect for the case in which the tailwater level rises. The correct equation for a falling head test with a rising tailwater level is:

$$k = \frac{a\,L}{2\,A\,t}\ \ln\left(\frac{H_1}{H_2}\right) \qquad 2$$

where the parameters are the same as before. Note that if one uses Eq. 1 when Eq. 2 should be used, the calculated permeability will be too large by a factor of 2. All of the permeabilities reported in the earlier submittal are too large by a factor of 2.

Perhaps no one of the three factors listed above is of tremendous significance, but in combination, the differences are thought to have combined to produce significantly different findings between the earlier submittal and the one described in this report. It is believed that the findings reported here are more applicable to the closure project at the Y-12 plant because (1) clay was not sieved out of the soil (since it will not be removed from the soil in the field), (2) compaction energy was controlled to span a range of energies that might reasonably be expected in the field, and (3) the correct equations were used to determine the permeability of the soil.

Conclusions

Type A and B soils from the east and west borrow areas can be compacted to produce a permeability $\leq 1 \times 10^{-7}$ cm/s. To achieve a permeability $\leq 1 \times 10^{-7}$ cm/s, the laboratory tests described herein show that soils should be compacted to water content - density points that lie within the Acceptable Zone shown in Figures 12 and 19.

The results of this study differ somewhat from the earlier TDHE submittal. The differences are attributed to: (1) the sieving of clay from the soil used in the earlier investigation; (2) the use of an uncontrolled and low compactive effort in the earlier study; and (3) an error in calculation of permeability that led to permeabilities that were too large by a factor of 2. The tests performed for this study are thought to be more representative of field conditions and, therefore, more applicable.

In developing the conclusions reported above, an extensive program of laboratory permeability testing was undertaken. Every effort was made to make sure that the testing procedures were not biasing the permeabilities. Tests performed without backpressure using rigid-wall and flexible-wall permeameters showed similar results. Tests performed in flexible-wall cells with and without backpressure showed that the effect of backpressure was insignificant. An investigation of the reproducibility of test data showed that test specimens with a permeability $\leq 1 \times 10^{-7}$ cm/s could be consistently produced and that the findings from the permeability testing program were reproducible.

Recommendations

The following recommendations are made:

1. There appears to be no reason why the Type A and Type B soils from the east and west borrow areas should not be used for capping disposal units at the Y-12 facility, provided (as expected) that the equipment available for use can compact the soils to the required water content - density points.

2. It is recommended that the "Acceptable Zone" plotted in Figures 12 and 19 provide the primary basis for accepting or rejecting the compaction of soil for the low-permeability soil barriers. If a water content - density point for a completed area within a lift lies within the Acceptable Zone, it is recommended that the water content - density test be considered to have "passed." (Note: Due to variations in specific gravity of solids, it is possible for a point to lie above the Acceptable Zone; such a point is acceptable). If the density point lies below the Acceptable Zone, the test should be treated as one that has "failed" and corrective action, e.g., additional compaction, should be taken.

3. Type C soils should not be used to build low-permeability soil barriers. The water content - density points for Type C soil cannot possibly fall within the Acceptable Zone shown in Figures 12 and 19 because the dry density of Type C soil is extremely low. Thus, use of the Acceptable Zone in these two figures as described in Recommendation 2 above automatically ensures that Type C soils will not be used.

4. The soil contains some pieces of chert. Whenever chert fragments larger than about 3 inches across are seen, the fragments should be removed.

5. Good construction practice for low-permeability soil liners and caps involves compaction of the soil in thin lifts with a heavy, footed roller. It is recommended that the lifts of soil have a nominal compacted thickness ≤ 6 inches. The recommended type of roller is a footed roller with feet that have a minimum length of 6 to 9 inches. It is recommended that the roller weigh at least 30,000 pounds static weight and that at least 6 passes of the equipment be made over the soil in each lift.

6. Construction quality control by qualified engineers and technicians is essential to the successful construction of low-permeability liners and covers and is recommended for this project.

7. Each lift of the low-permeability soil barrier should be protected from damage caused by desiccation. It is recommended that a completed lift of soil be rolled with a smooth steel-drum roller to seal off the surface. If necessary, water should be periodically sprayed onto the completed lift to prevent drying. Prior to placing the next lift of soil, the surface of the previously compacted lift should be scarified with a disc to a depth of at least 1 inch to ensure good bonding between lifts.

RESULTS OF HYDRAULIC CONDUCTIVITY TESTS

AND

RECOMMENDED WATER CONTENT-DRY DENSITY CRITERIA FOR POTENTIAL BORROW SOILS

Prepared for

Martin Marietta Energy Systems, Inc.
P.O. Box 2003
Oak Ridge, TN 37831

Purchase Order No. 80K-AQG46V

Prepared by

David E. Daniel
Civil Engineer
3702 Cima Serena Drive
Austin, TX 78759

October 12, 1992

TABLE OF CONTENTS

RESULTS OF HYDRAULIC CONDUCTIVITY TESTS
AND
RECOMMENDED WATER CONTENT-DRY DENSITY CRITERIA FOR POTENTIAL BORROW SOILS

Purpose

This report summarizes the results of laboratory hydraulic conductivity tests performed on laboratory-compacted soil samples that were obtained from test pits excavated at several potential borrow areas at Oak Ridge National Laboratory (ORNL) and the Y-12 plant in Oak Ridge, Tennessee. The objective of the testing was to evaluate water content-density criteria necessary to ensure that compacted soils will have a hydraulic conductivity $\leq 1 \times 10^{-7}$ cm/s.

The testing program was developed to confirm that the compaction criteria for the soils tested are similar to the criteria developed in an earlier study described in the report, "Permeability of Compacted Soils from the East and West Borrow Sites, Y-12 Plant, Oak Ridge, Tennessee," prepared by the author of this report and dated March 6, 1989. In the 1989 study, more than 100 hydraulic conductivity tests were performed on three types of soils from two borrow areas. The soils tested in the 1989 study were compacted with 3 compactive energies over a wide range in molding water content. In addition, the 1989 study included an assessment of the effect of various laboratory testing variables upon hydraulic conductivity as well as an evaluation of the repeatability of test results.

The soils tested in the current study were obtained from sites that are geologically identical to the borrow areas tested in the 1989 study. Thus, the compaction criteria are expected to be nearly identical for the soils tested for this study and those tested for the 1989 study.

The specific objectives of this study were to:

1. Prepare compacted test specimens for hydraulic conductivity testing using a representative range in compactive energy and an appropriate molding water content for the particular compactive energy.
2. Perform hydraulic conductivity tests on the compacted soil specimens.
3. Compare the results of the compaction/hydraulic conductivity tests with those from the 1989 study to determine if the criteria developed in the 1989 study are valid for the soils tested in this investigation.
4. Based upon the results of the tests and analysis, provide recommendations concerning appropriate compaction criteria.

Soils Investigated

The soil samples that were tested in this study were obtained from shallow test pits excavated into soils from the following potential sites for borrow soils:

1. HPRR Borrow Site at ORNL.
2. Landfill V, Y-12 Plant.
3. Landfill VI, Y-12 Plant.
4. Landfill VII, Y-12 Plant.

Shallow test pits were excavated with a backhoe at selected locations. Locations of test pits, and information about the soils from the test pits, are presented in two reports:

1. "Backhoe Investigation of Proposed HPRR Borrow Site at ORNL, Oak Ridge Tennessee," by Ogden Environmental and Energy Services, August 12, 1992.
2. Backhoe Investigation of Proposed Industrial Landfill V, Construction-Demolition Landfill VII at Y-12 Plant, Oak Ridge, Tennessee," by Ogden Environmental and Energy Services, August 12, 1992.

The test pits were logged, and bulk samples were taken at several depths within each test pit. The samples were analyzed to determine the water content, grain-size distribution, and Atterberg limits. In addition, compaction tests were performed on 24 bulk samples to define the compaction characteristics of the soils and to aid in selecting representative bulk samples for hydraulic conductivity testing. The author reviewed the trench locations, descriptions of soil samples, and test results. Based upon this review, 11 bulk soil samples were selected for hydraulic conductivity testing. The samples were selected to provide coverage of the full range of materials encountered at the site.

Data provided by Ogden for the 11 samples are summarized in Tables 1 (compaction and plasticity data) and Table 2 (grain-size and classification data). The range and average values (in parentheses) of various parameters may be summarized as follows:

• Percent Fines[1]:	35 - 99 (66)
• Percent Gravel[2]:	0 - 36 (17)
• Liquid Limit (%):	36 - 70 (55)
• Plasticity Index (%):	19 - 40 (30)
• Optimum Water Content (%)[3]:	18 - 33 (25)
• Max. Dry Unit Weight (pcf)[3]:	87 - 109 (96)

The results reported above are contrasted with similar test parameters from the 1989 study, where comparative data are available, as follows:

Test Parameter	Typical Value from 1989 Study for Type A Soil	Typical Value from This Investigation
Liquid Limit (%)	55	55
Plasticity Index (%)	24	30
Optimum Water Content (%)[3]	27	25
Max. Dry Unit Weight (pcf)[3]	94	96

---

[1] Defined as Percent by Dry Weight Passing the No. 200 Sieve (Opening Size = 0.075 mm).

[2] Defined as Percent by Dry Weight Retained on the No. 4 Sieve (Opening Size = 4.76 mm).

[3] Standard Compaction, ASTM D698.

Table 1. Data on Compaction Characteristics and Atterberg Limits for Eleven Soil Samples Tested.

Borrow Area	Test Pit	Sample Number	Depth (ft)	Standard Proctor Optimum Water Content (%)	Standard Proctor Maximum Dry Unit Weight (pcf)	Modified Proctor Optimum Water Content (%)	Standard Proctor Maximum Dry Unit Weight (pcf)	Liquid Limit (%)	Plasticity Index (%)
HPRR	A	2/2	8-10	30	90	25	99	63	32
HPRR	B	2/2	9-11	33	87	27	96	70	34
HPRR	C	2/2	7-9	18	106	16	115	45	19
HPRR	E	3/3	10-12	26	97	19	106	58	28
HPRR	H	1/2	2-4	25	98	18	110	57	32
Landfill V	A	2/2	9-11	16	109	13	119	36	20
Landfill V	B	2/2	7-9	25	93	19	106	52	29
Landfill VI	A	1/2	4-6	27	94	21	104	48	28
Landfill VI	C	2	8-10	24	90	19	106	64	40
Landfill VII	C	1	5-7	24	98	20	108	56	30
Landfill VII	D	1	3-5	24	99	18	110	54	35

Table 2. Data on Percent Gravel, Percent Fines, and Unified Soil Classification Symbol for Eleven Soils Tested.

Borrow Area	Test Pit	Sample Number	Depth (ft)	Percent Gravel	Percent Fines	Soil Classification Symbol
HPRR	A	2/2	8-10	7	63	CH
HPRR	B	2/2	9-11	0	99	MH
HPRR	C	2/2	7-9	13	76	CL
HPRR	E	3/3	10-12	36	46	GC
HPRR	H	1/2	2-4	21	67	CH
Landfill V	A	2/2	9-11	17	67	CL
Landfill V	B	2/2	7-9	18	63	CH
Landfill VI	A	1/2	4-6	5	75	CL
Landfill VI	C	2	8-10	26	64	CH
Landfill VII	C	1	5-7	34	35	GC
Landfill VII	D	1	3-5	6	73	CH

It can be seen from the comparative data presented at the bottom of page 3 that the soils tested in this investigation are practically identical to the Type A soils from the 1989 study. This finding was anticipated because the materials are all from the same geologic environment.

Test Procedures

Soils were collected from the field, placed in 5-gal buckets, sealed, and shipped to the University of Texas laboratories for testing. Any materials larger than 1/2 inch were removed by hand. The soil was processed without drying the material back, except when drying was necessary to produce the desired molding water content if that water content was less than the natural water content of the material as shipped.

Compaction curves for the 11 samples were provided by Ogden Environmental and Energy Sources. Two compaction curves were provided for each sample: (1) standard Proctor compactive energy, ASTM D698, and (2) modified Proctor compactive energy, ASTM D1557. From the curves, an estimate was made of the optimum water content for reduced compaction, which is compaction that is identical to standard Proctor compaction except that only 15 blows per lift are provided from the ram rather than the usual 25 blows.

The sample preparation procedure was as follows:

1. The desired, or "target," water content was identified for each sample for reduced, standard, and modified compaction, based on the compaction curves provided by Ogden. The target water content was about 3 percentage points wet of optimum.
2. Soil samples were mixed to the 3 target water contents for each of the 11 samples. The materials were sealed, stored for at least 48 hours, and tested to confirm that the water content was correct.
3. Compacted test specimens were prepared for each compactive energy and soil sample (3 compactive energies and 11 soil samples for a total of 33 test specimens). Appendix A contains plots of the compaction curves provided by Ogden and the actual water content-dry unit weight values of the test specimens

prepared for this study. In most cases, the water content-dry unit weight values that were obtained for the hydraulic conductivity test specimens were very close to the compaction curves defined by Ogden. Natural variation in soils is expected to lead to some variation in test results. In a few cases, the dry unit weight was not as close to the target value as desired, or the hydraulic conductivity seemed anomalous. In these cases, a replicate test specimen was prepared.

4. Test specimens were permeated in the same compaction mold in which the materials were compacted. Permeation was with tap water without application of any external confining stress. Permeation continued for each test specimen until hydraulic conductivity was steady. The head applied to the test specimens remained constant throughout the tests.

The test procedures employed for this investigation are identical to those used for the 1989 study. The testing procedures (fixed-wall cell with no vertical confining stress and no backpressure) are thought to be appropriate for final cover systems that will be subjected to low overburden stress.

Results

The results of hydraulic conductivity tests are summarized in Tables 3 (HPRR site), 4 (Landfill V), 5 (Landfill VI), and 6 (Landfill VII). Thirty seven hydraulic conductivity tests were performed, including replicate tests for questionable specimens. Of the 37 tests that were performed, 32 produced hydraulic conductivities $\leq 1 \times 10^{-7}$ cm/s. Hydraulic conductivity was $> 1 \times 10^{-7}$ cm/s in 5 tests. However, for 4 of the 5 tests that yielded hydraulic conductivities $> 1 \times 10^{-7}$ cm/s, new test specimens were prepared and the specimens were permeated in replicate tests -- all 4 replicate tests gave hydraulic conductivities $\leq 1 \times 10^{-7}$ cm/s in the retest. Occasional deviations from a hydraulic conductivity target are to be expected, particularly when low compactive energies (e.g., reduced compaction energy) are used.

Table 3. Summary of Results of Hydraulic Conductivity Tests on Soils from HPRR Site at ORNL.

Borrow Area	Test Pit	Sample Number	Depth (ft)	Compaction Method	Molding Water Content (%)	Dry Unit Weight (pcf)	Hydraulic Conductivity (cm/s)	Remarks
HPRR	A	2/2	8-10	Reduced	34	86	4×10^{-8}	
HPRR	A	2/2	8-10	Standard	33	88	4×10^{-8}	
HPRR	A	2/2	8-10	Modified	28	96	8×10^{-9}	
HPRR	B	2/2	9-11	Reduced	38	81	2×10^{-8}	
HPRR	B	2/2	9-11	Standard	35	84	3×10^{-8}	
HPRR	B	2/2	9-11	Modified	29	94	2×10^{-8}	
HPRR	C	2/2	7-9	Reduced	23	96	1×10^{-7}	
HPRR	C	2/2	7-9	Standard	20	102	5×10^{-7}	See Replicate on Next Line
HPRR	C	2/2	7-9	Standard	21	102	4×10^{-8}	Replicate Test
HPRR	C	2/2	7-9	Modified	19	108	1×10^{-8}	
HPRR	E	3/3	10-12	Reduced	31	90	3×10^{-7}	See Replicate on Next Line
HPRR	E	3/3	10-12	Reduced	31	91	1×10^{-7}	Replicate Test
HPRR	E	3/3	10-12	Standard	29	93	3×10^{-8}	
HPRR	E	3/3	10-12	Modified	21	104	1×10^{-8}	
HPRR	H	1/2	2-4	Reduced	29	91	7×10^{-8}	
HPRR	H	1/2	2-4	Standard	28	94	4×10^{-8}	
HPRR	H	1/2	2-4	Modified	20	103	2×10^{-8}	

Table 4. Summary of Results of Hydraulic Conductivity Tests on Soils from Landfill V at Y-12 Plant.

Borrow Area	Test Pit	Sample Number	Depth (ft)	Compaction Method	Molding Water Content (%)	Dry Unit Weight (pcf)	Hydraulic Conductivity (cm/s)	Remarks
Landfill V	A	2/2	8-10	Reduced	20	103	6×10^{-8}	
Landfill V	A	2/2	8-10	Standard	19	106	9×10^{-8}	
Landfill V	A	2/2	8-10	Modified	16	114	8×10^{-9}	
Landfill V	B	2/2	9-11	Reduced	29	91	3×10^{-8}	
Landfill V	B	2/2	9-11	Standard	27	94	2×10^{-8}	
Landfill V	B	2/2	9-11	Modified	20	103	1×10^{-8}	

Table 5. Summary of Results of Hydraulic Conductivity Tests on Soils from Landfill VI at Y-12 Plant.

Borrow Area	Test Pit	Sample Number	Depth (ft)	Compaction Method	Molding Water Content (%)	Dry Unit Weight (pcf)	Hydraulic Conductivity (cm/s)	Remarks
Landfill VI	A	1/2	4-6	Reduced	31	90	2×10^{-7}	See Replicate on Next Line
Landfill VI	A	1/2	4-6	Reduced	31	88	5×10^{-8}	Replicate Test
Landfill VI	A	1/2	4-6	Standard	29	92	1×10^{-7}	
Landfill VI	A	1/2	4-6	Modified	23	102	2×10^{-8}	
Landfill VI	C	2/2	8-10	Reduced	28	88	3×10^{-7}	
Landfill VI	C	2/2	8-10	Standard	26	89	6×10^{-8}	
Landfill VI	C	2/2	8-10	Modified	21	104	9×10^{-9}	

Table 6. Summary of Results of Hydraulic Conductivity Tests on Soils from Landfill VII at Y-12 Plant.

Borrow Area	Test Pit	Sample Number	Depth (ft)	Compaction Method	Molding Water Content (%)	Dry Unit Weight (pcf)	Hydraulic Conductivity (cm/s)	Remarks
Landfill VII	C	1/2	5-7	Reduced	29	92	1×10^{-7}	
Landfill VII	C	1/2	5-7	Standard	27	94	2×10^{-7}	See Replicate on Next Line
Landfill VII	C	1/2	5-7	Standard	26	95	3×10^{-8}	Replicate Test
Landfill VII	C	1/2	5-7	Modified	22	104	1×10^{-8}	
Landfill VII	D	1/2	3-5	Reduced	28	92	2×10^{-8}	
Landfill VII	D	1/2	3-5	Standard	27	94	5×10^{-8}	
Landfill VII	D	1/2	3-5	Modified	20	108	6×10^{-8}	

Overall, the hydraulic conductivity tests were successful in demonstrating that the soils can be compacted to produce a hydraulic conductivity $\leq 1 \times 10^{-7}$ cm/s.

Water Content-Dry Unit Weight Criterion

Water content-dry unit weight points are plotted in Figure 1. Open symbols are used for samples with hydraulic conductivities $> 1 \times 10^{-7}$ cm/s and solid symbols are used for samples with hydraulic conductivities $\leq 1 \times 10^{-7}$ cm/s. The Acceptable Zone defined from the 1989 study is also shown in Fig. 1. The data obtained from this study are consistent with the Acceptable Zone from the 1989 study. The data demonstrate that the same Acceptable Zone from the 1989 study is applicable to the soils tested in this investigation.

The Acceptable Zone shown in Fig. 1 is based upon hydraulic conductivity. Other considerations besides hydraulic conductivity are often important. For example, the soil should not be compacted at such a high water content that the shear strength is unacceptably low.

Conclusions and Recommendations

Based on the data presented in this report, the compaction criteria developed in a 1989 study of "Type A" soils are applicable to the potential borrow soils tested in this study. It is recommended that the same Acceptable Zone applied to Type A soils in 1989 be assumed to apply to the soils from the HPRR, Landfill V, Landfill VI, and Landfill VII sites. However, caution should be excercised during construction to ensure that soils are not so wet that the materials are too soft, even though low hydraulic conductivity is achieved.

There is no indication that soil from any one of the potential borrow sites is superior or inferior to soil from the other borrow sites, in terms of ability to produce a low-permeability compacted soil liner. Thus, selection of borrow sites should be based upon other criteria.

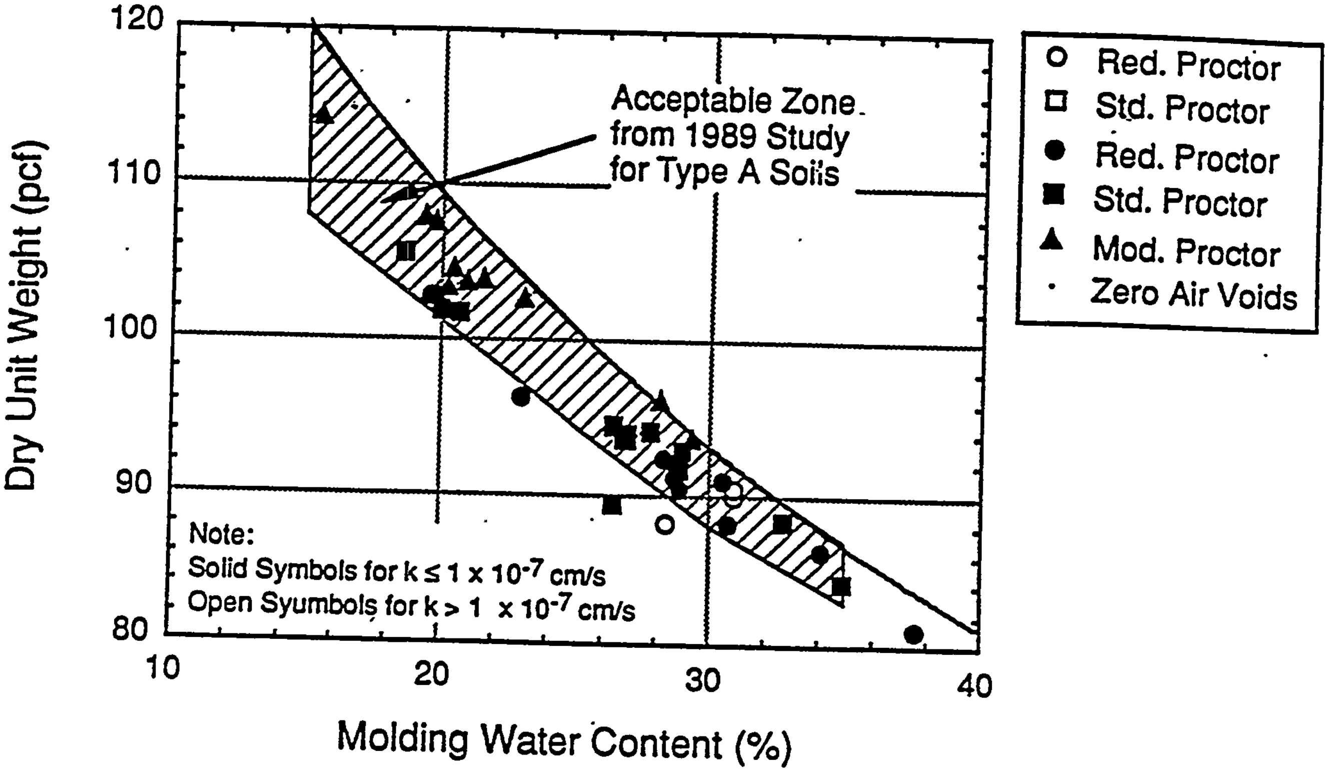
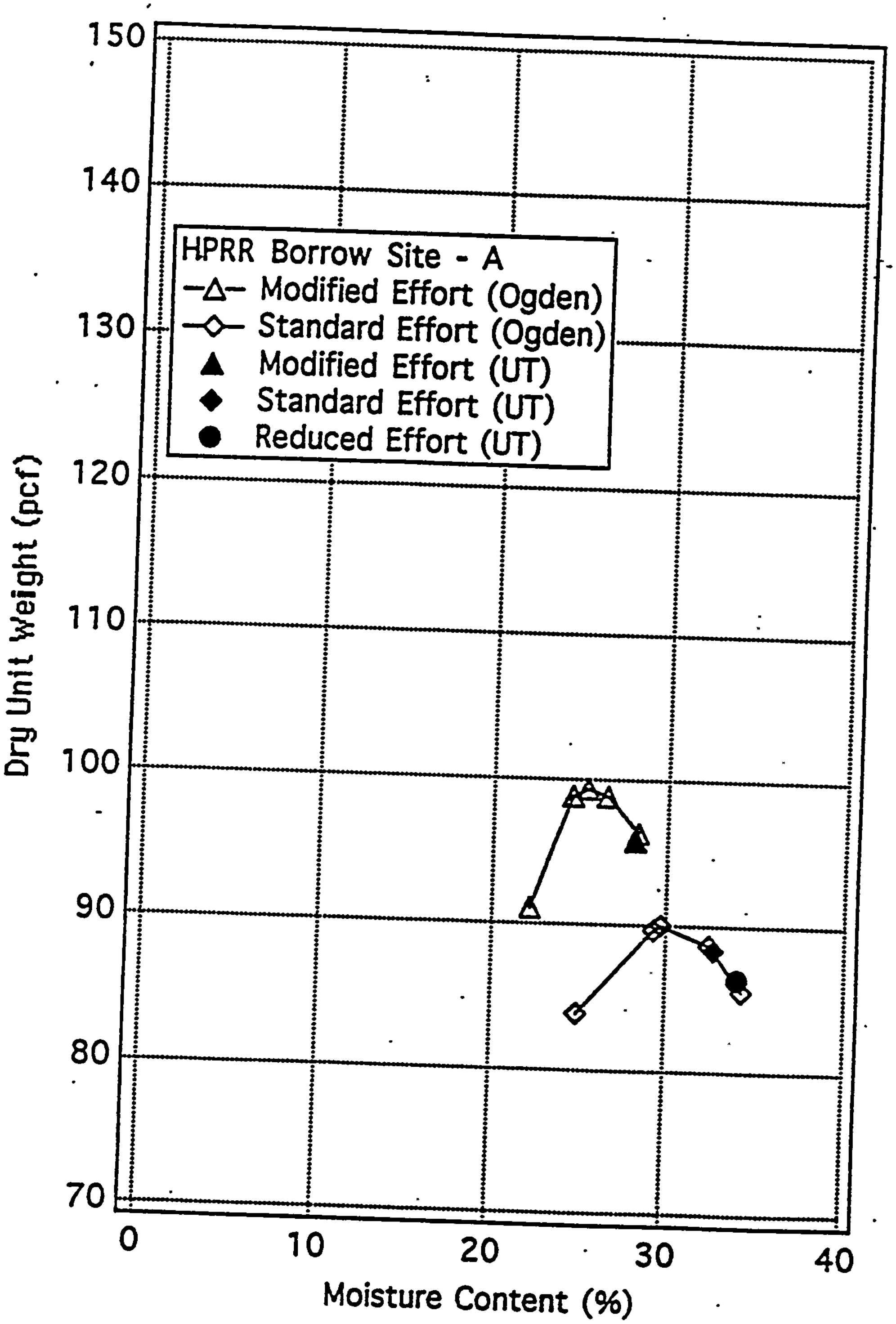
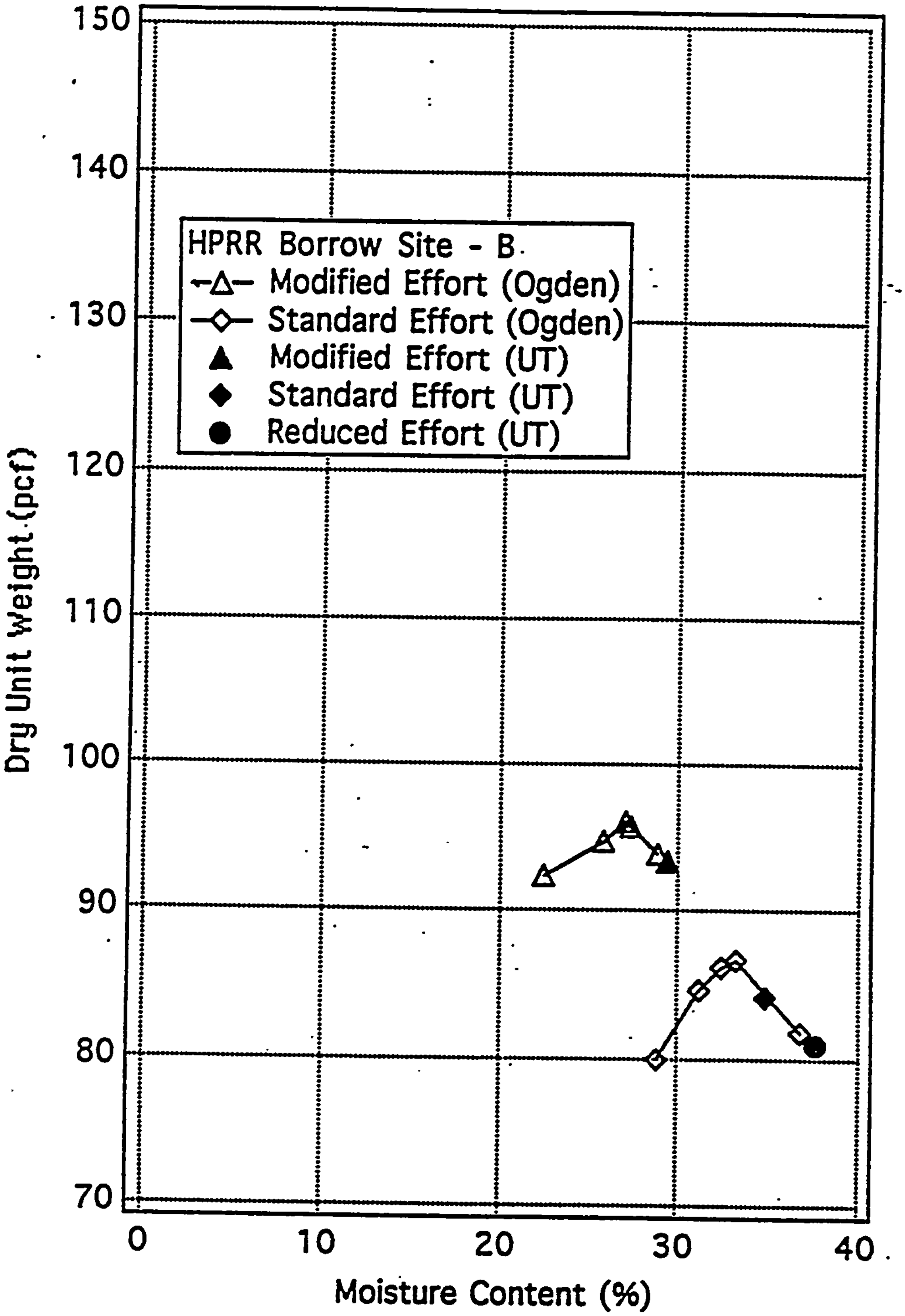


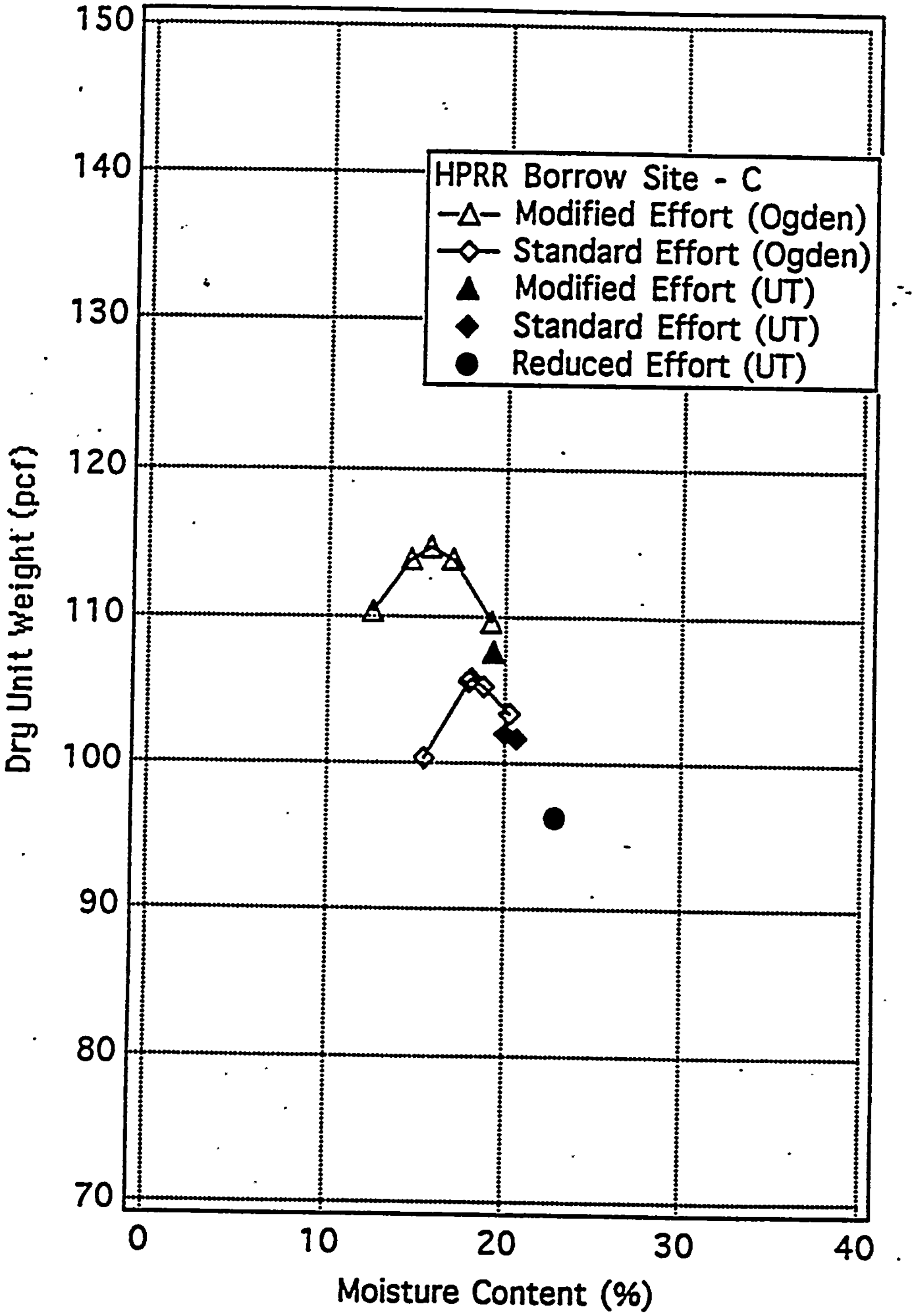
Figure 1. Water Content - Dry Unit Weights that Produced Ranges of Hydraulic Conductivity.

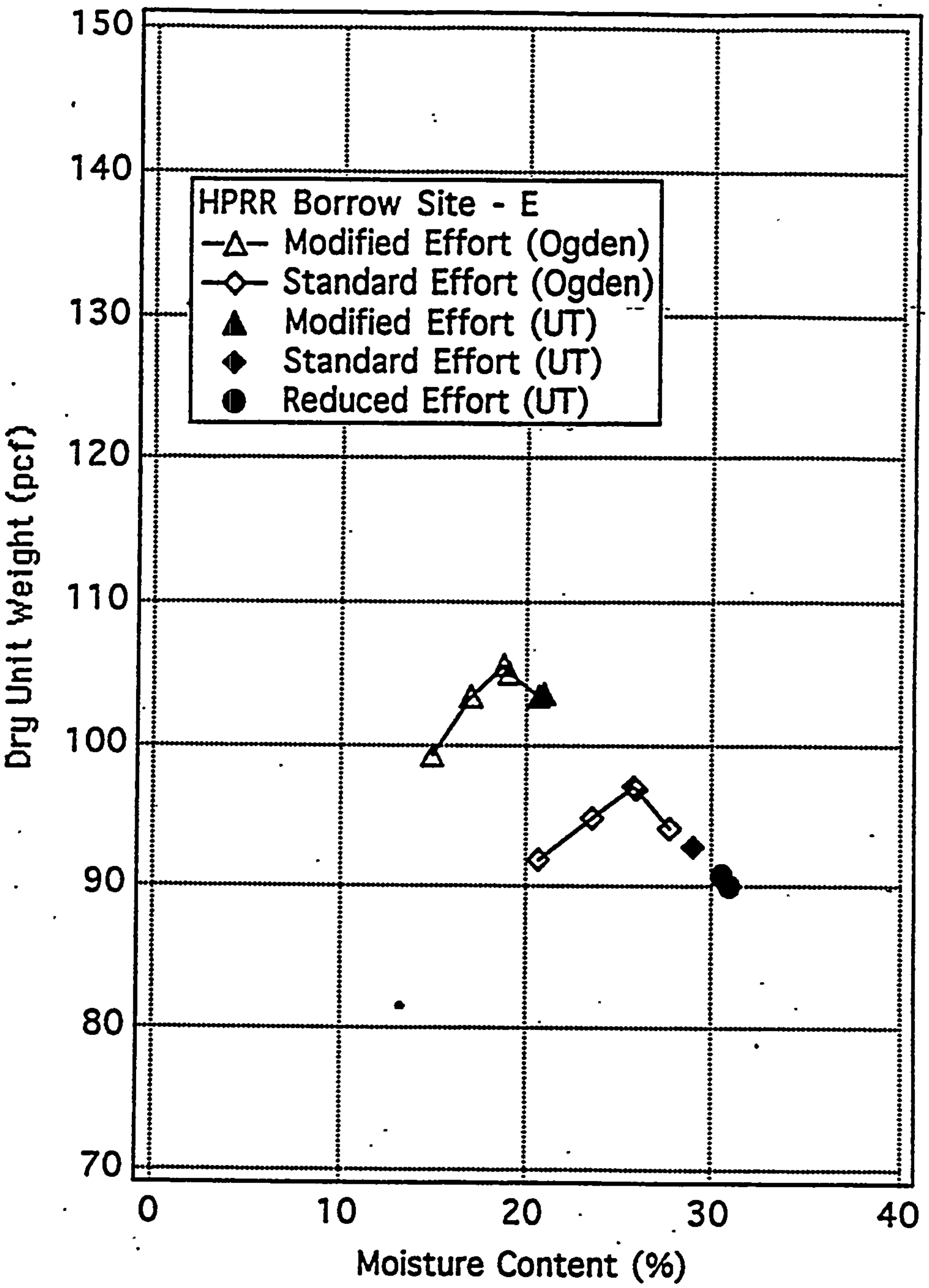
APPENDIX

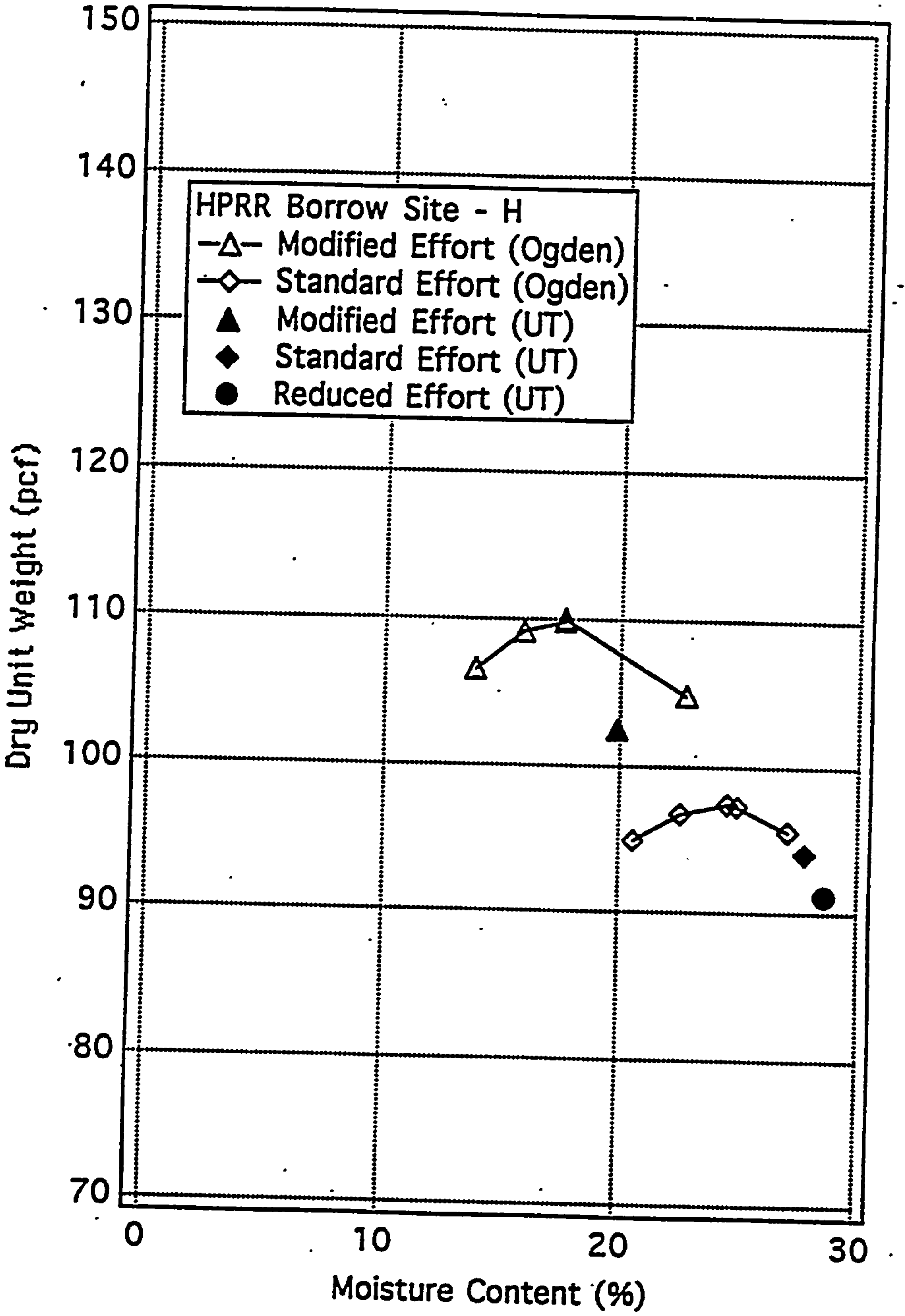
COMPACTION CURVES FROM OGDEN ENVIRONMENTAL AND ENERGY SERVICES AND COMPACTION TEST RESULTS FROM THIS STUDY

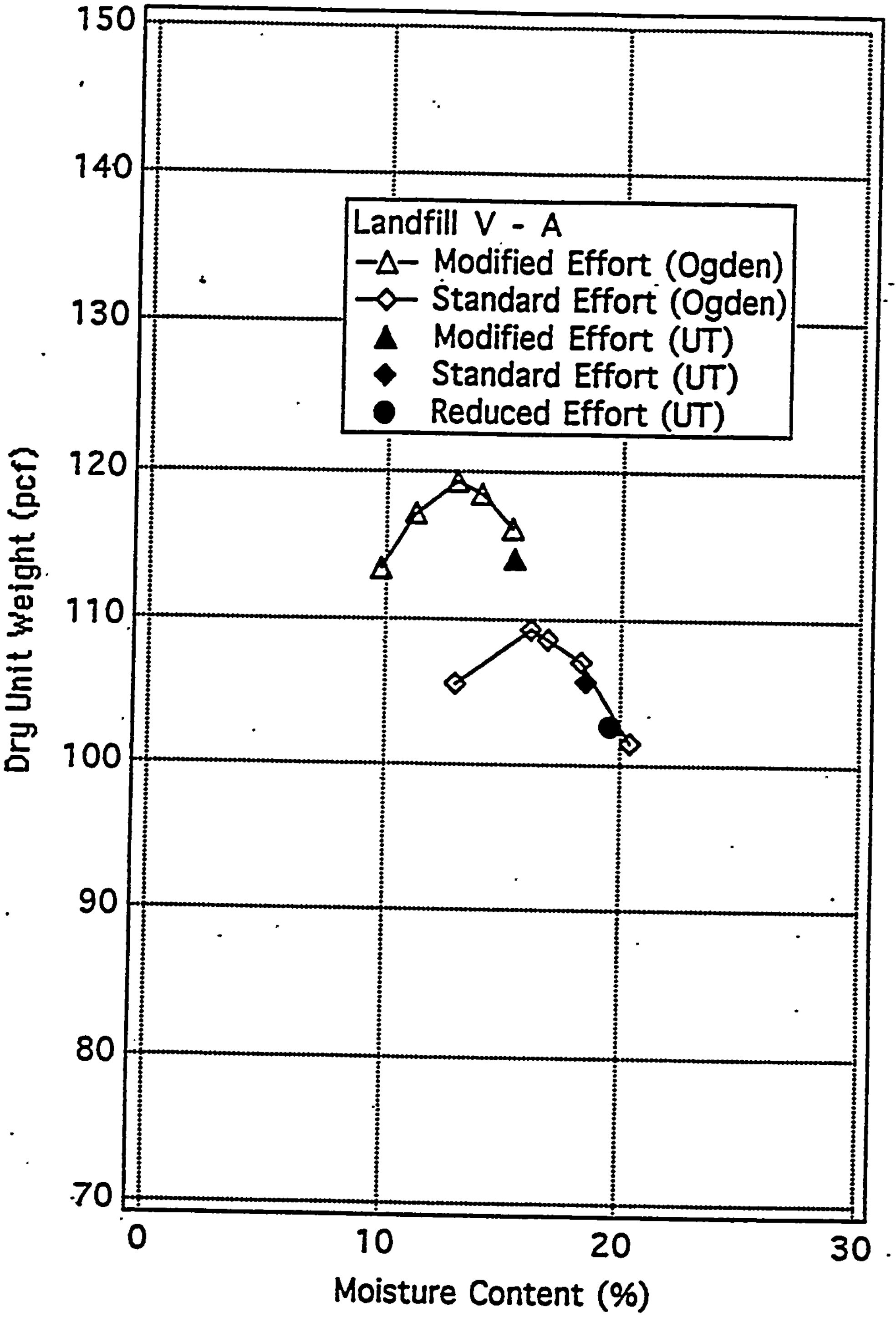

HPRR Borrow Site - A
Modified Effort (Ogden)
Standard Effort (Ogden)
Modified Effort (UT)
Standard Effort (UT)
Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
40
Moisture Content (%)

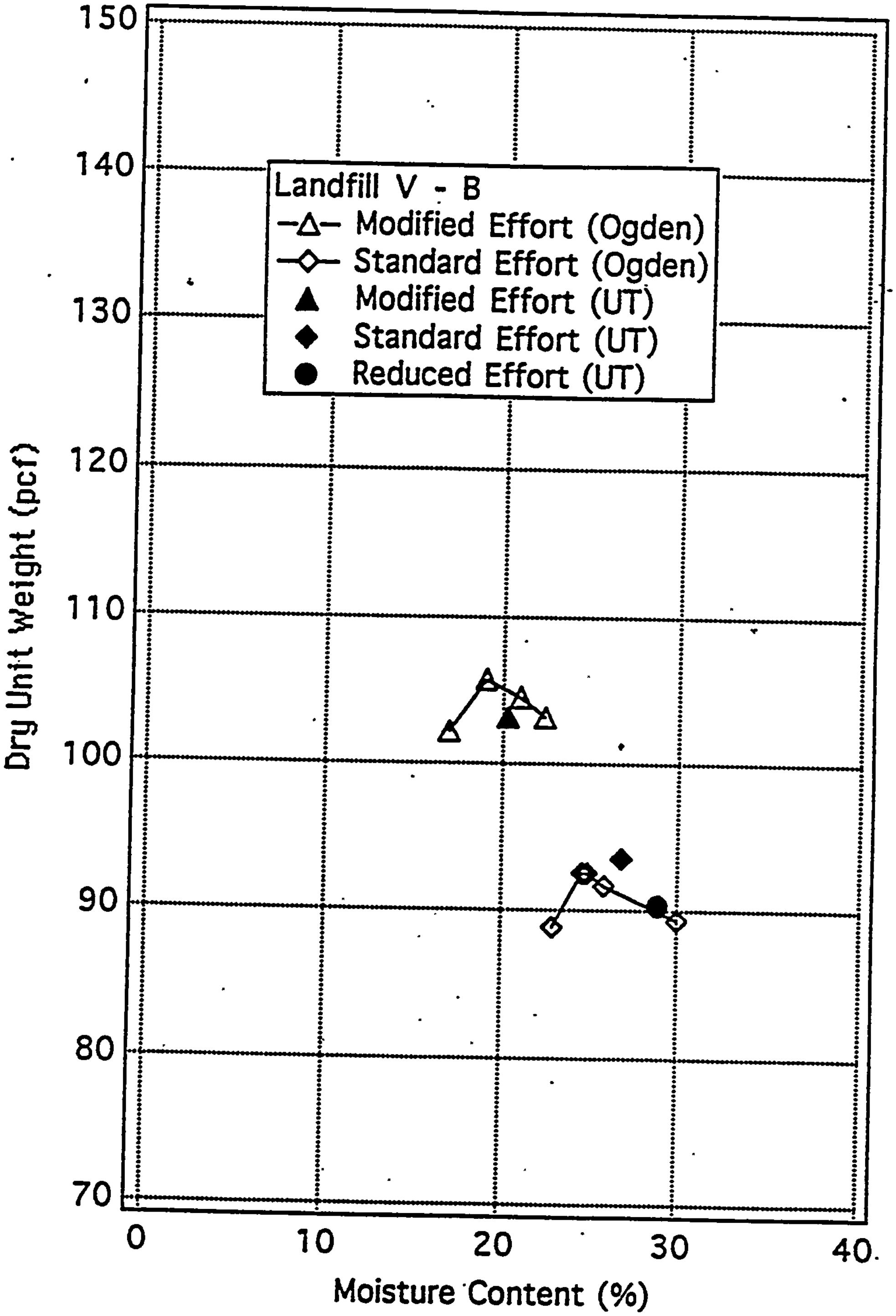

HPRR Borrow Site - B
Modified Effort (Ogden)
Standard Effort (Ogden)
Modified Effort (UT)
Standard Effort (UT)
Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
40
Moisture Content (%)

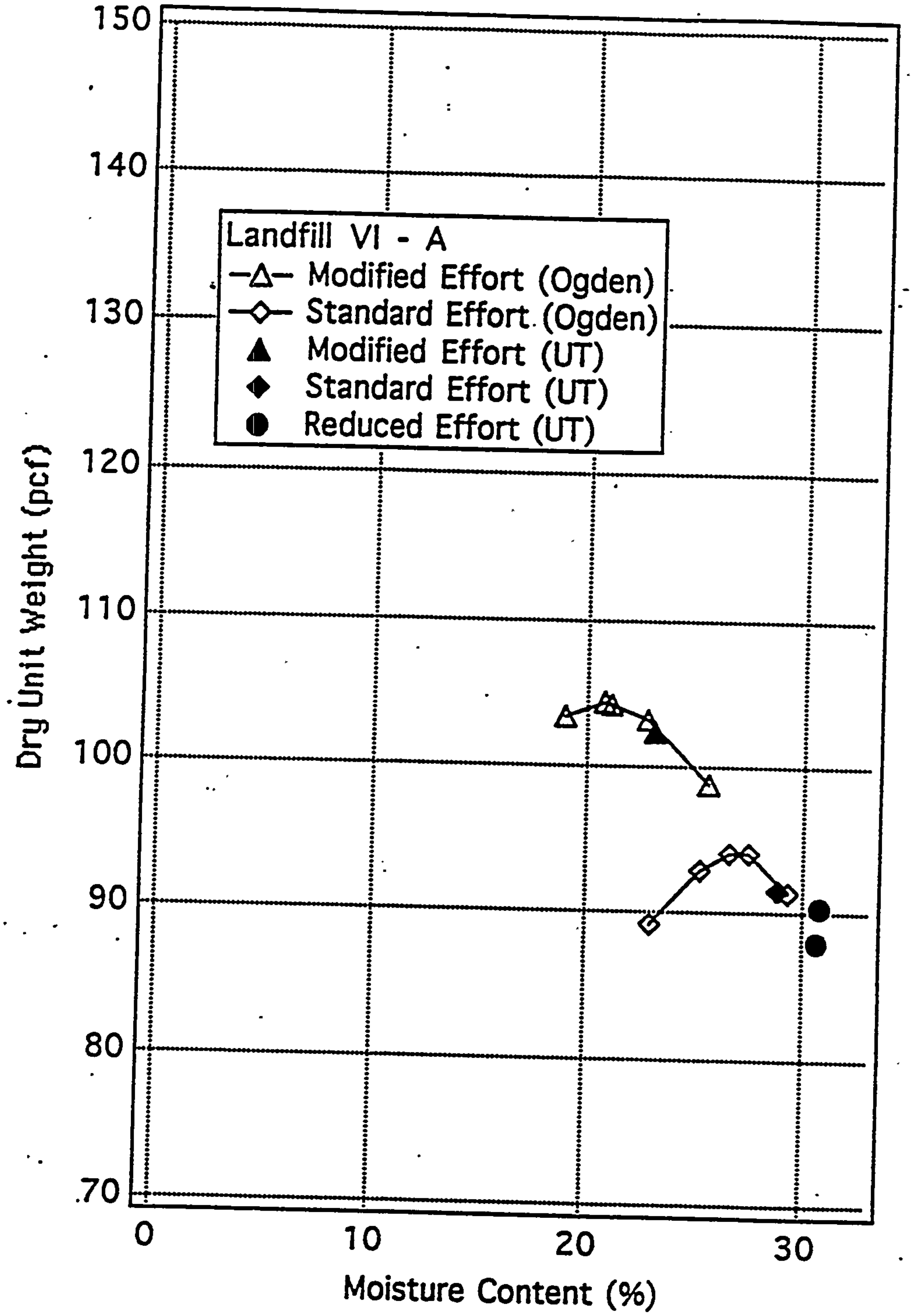

HPRR Borrow Site - C
Modified Effort (Ogden)
Standard Effort (Ogden)
Modified Effort (UT)
Standard Effort (UT)
Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
Moisture Content (%)
0
10
20
30
40

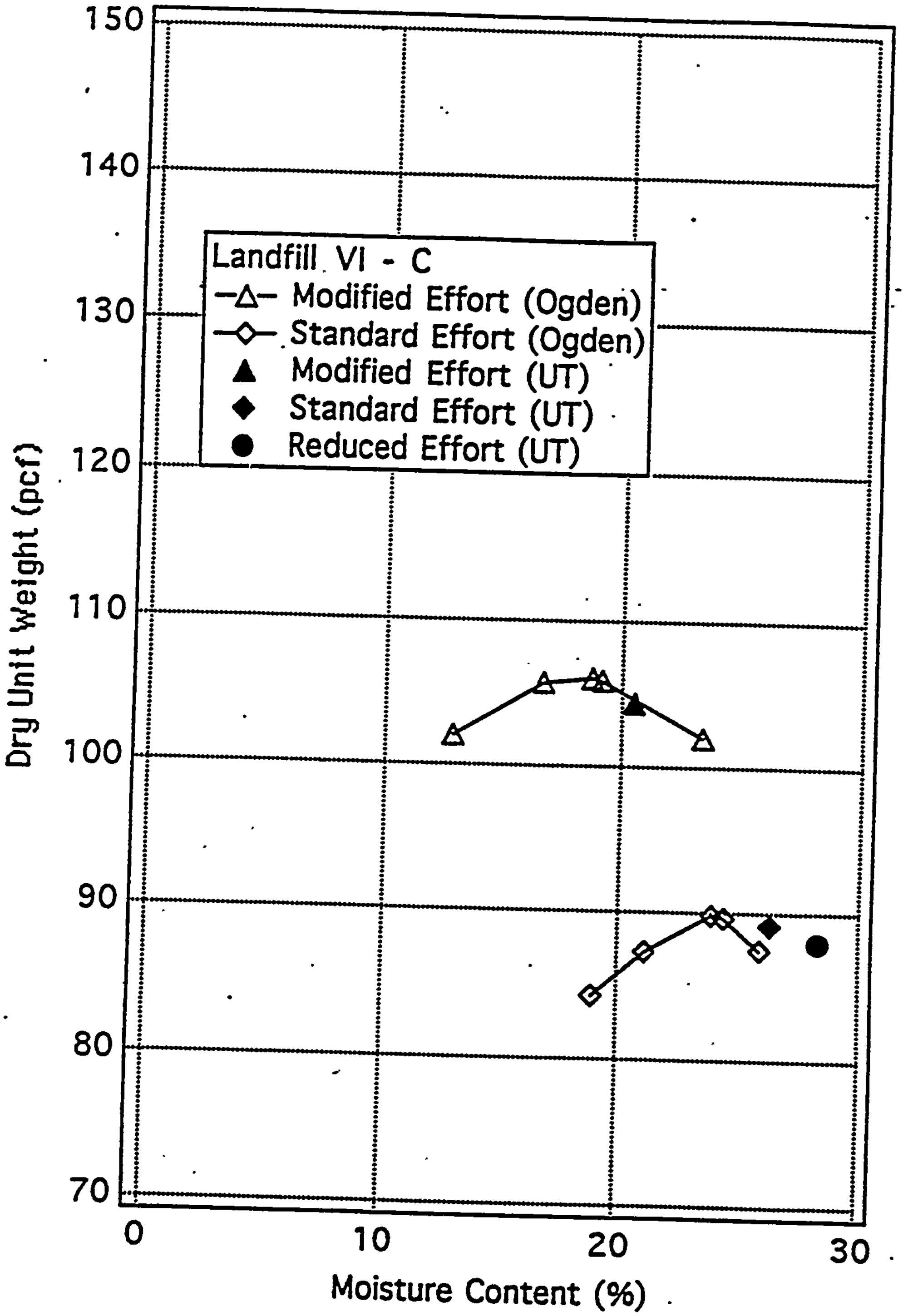

HPRR Borrow Site - E
—△— Modified Effort (Ogden)
—◇— Standard Effort (Ogden)
▲ Modified Effort (UT)
◆ Standard Effort (UT)
● Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
40
Moisture Content (%)

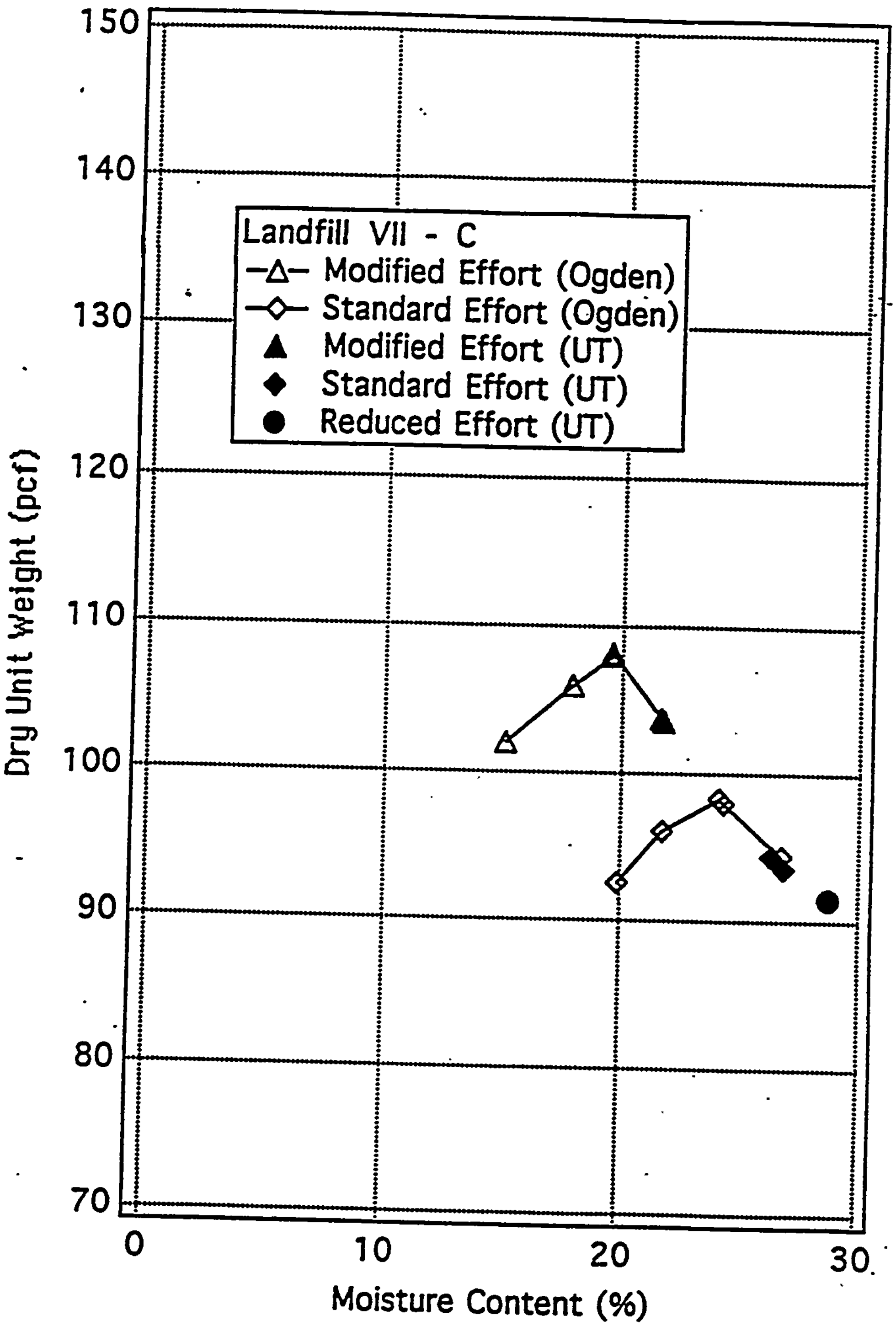

HPRR Borrow Site - H
Modified Effort (Ogden)
Standard Effort (Ogden)
Modified Effort (UT)
Standard Effort (UT)
Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
Moisture Content (%)

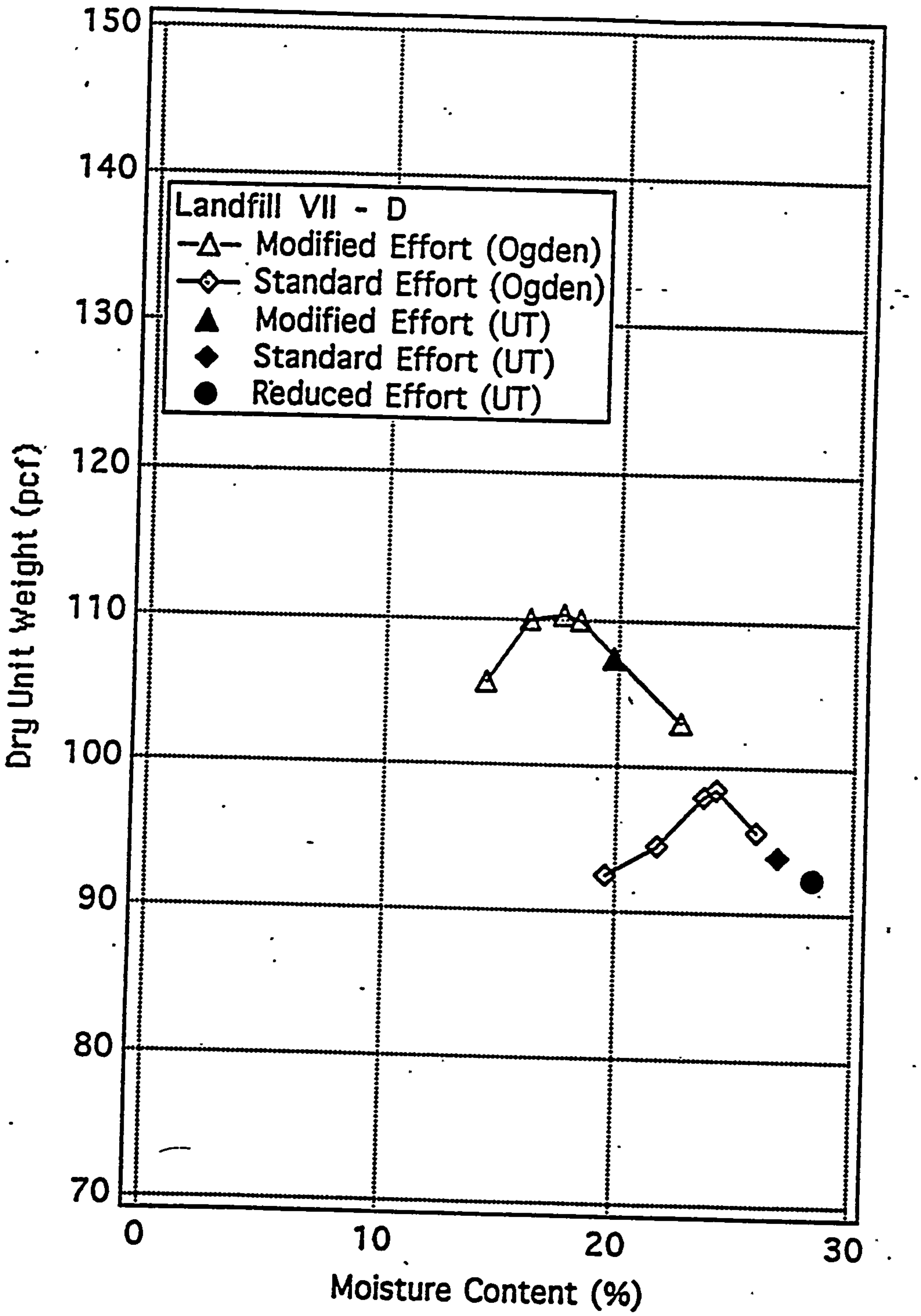

Landfill V - A
—△— Modified Effort (Ogden)
—◇— Standard Effort (Ogden)
▲ Modified Effort (UT)
◆ Standard Effort (UT)
● Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
Moisture Content (%)


Landfill V - B
Modified Effort (Ogden)
Standard Effort (Ogden)
Modified Effort (UT)
Standard Effort (UT)
Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
40
Moisture Content (%)


Landfill VI - A
—△— Modified Effort (Ogden)
—◇— Standard Effort (Ogden)
▲ Modified Effort (UT)
◆ Standard Effort (UT)
● Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
Moisture Content (%)

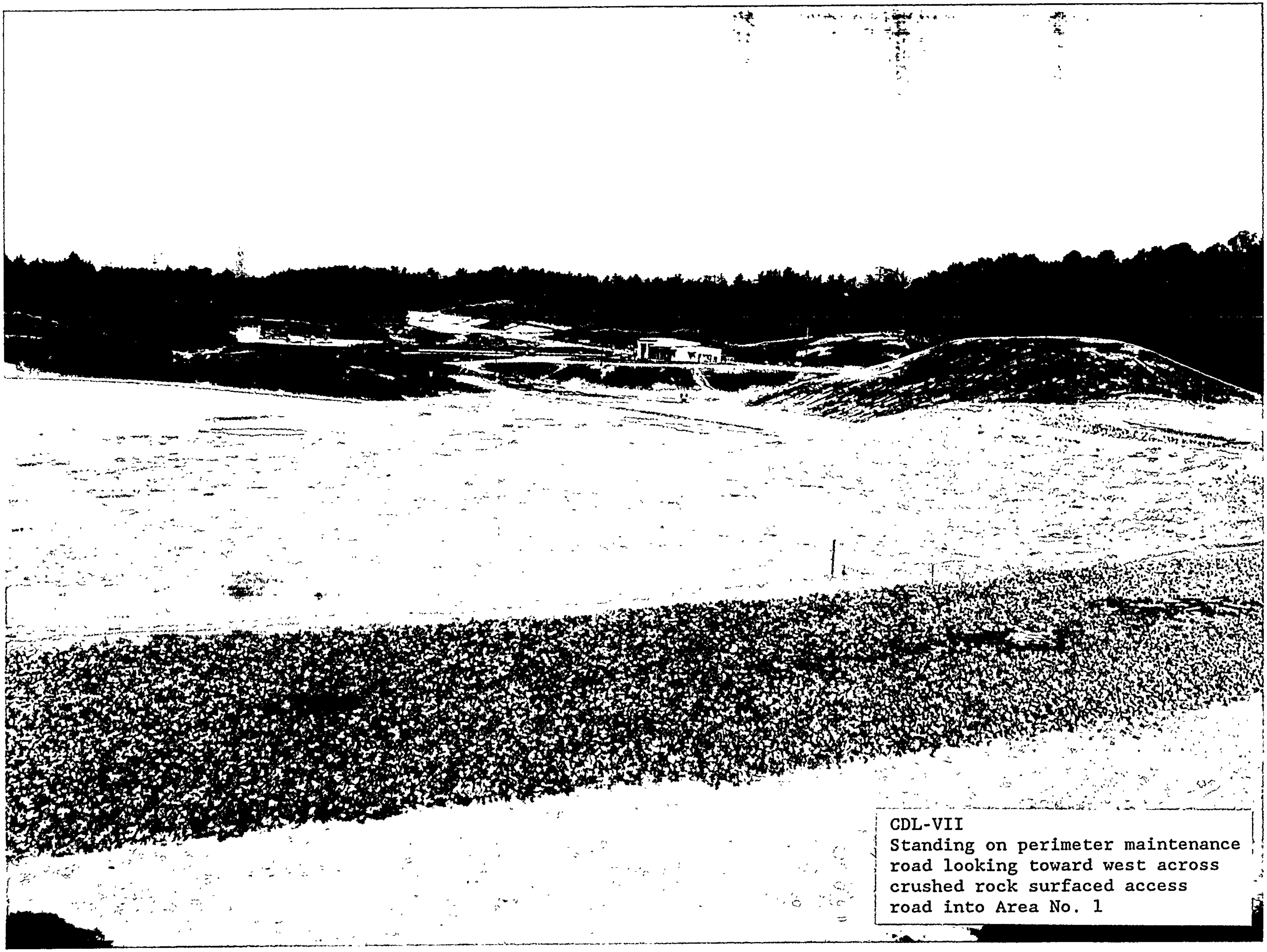

Landfill VI - C
Modified Effort (Ogden)
Standard Effort (Ogden)
Modified Effort (UT)
Standard Effort (UT)
Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
Moisture Content (%)


Landfill VII - C
Modified Effort (Ogden)
Standard Effort (Ogden)
Modified Effort (UT)
Standard Effort (UT)
Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
Moisture Content (%)

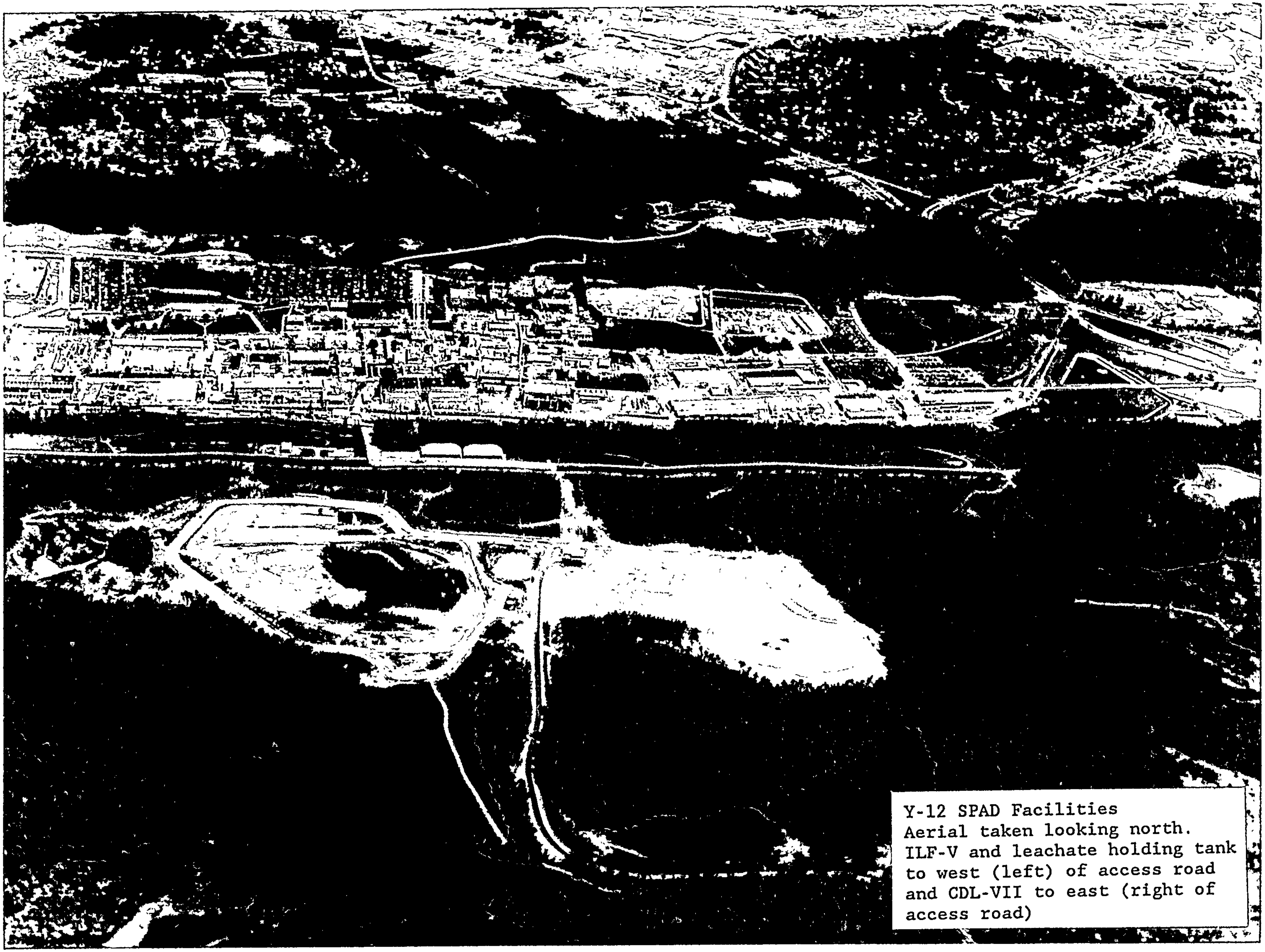

Landfill VII - D
Modified Effort (Ogden)
Standard Effort (Ogden)
Modified Effort (UT)
Standard Effort (UT)
Reduced Effort (UT)
Dry Unit Weight (pcf)
150
140
130
120
110
100
90
80
70
0
10
20
30
Moisture Content (%)

APPENDIX E

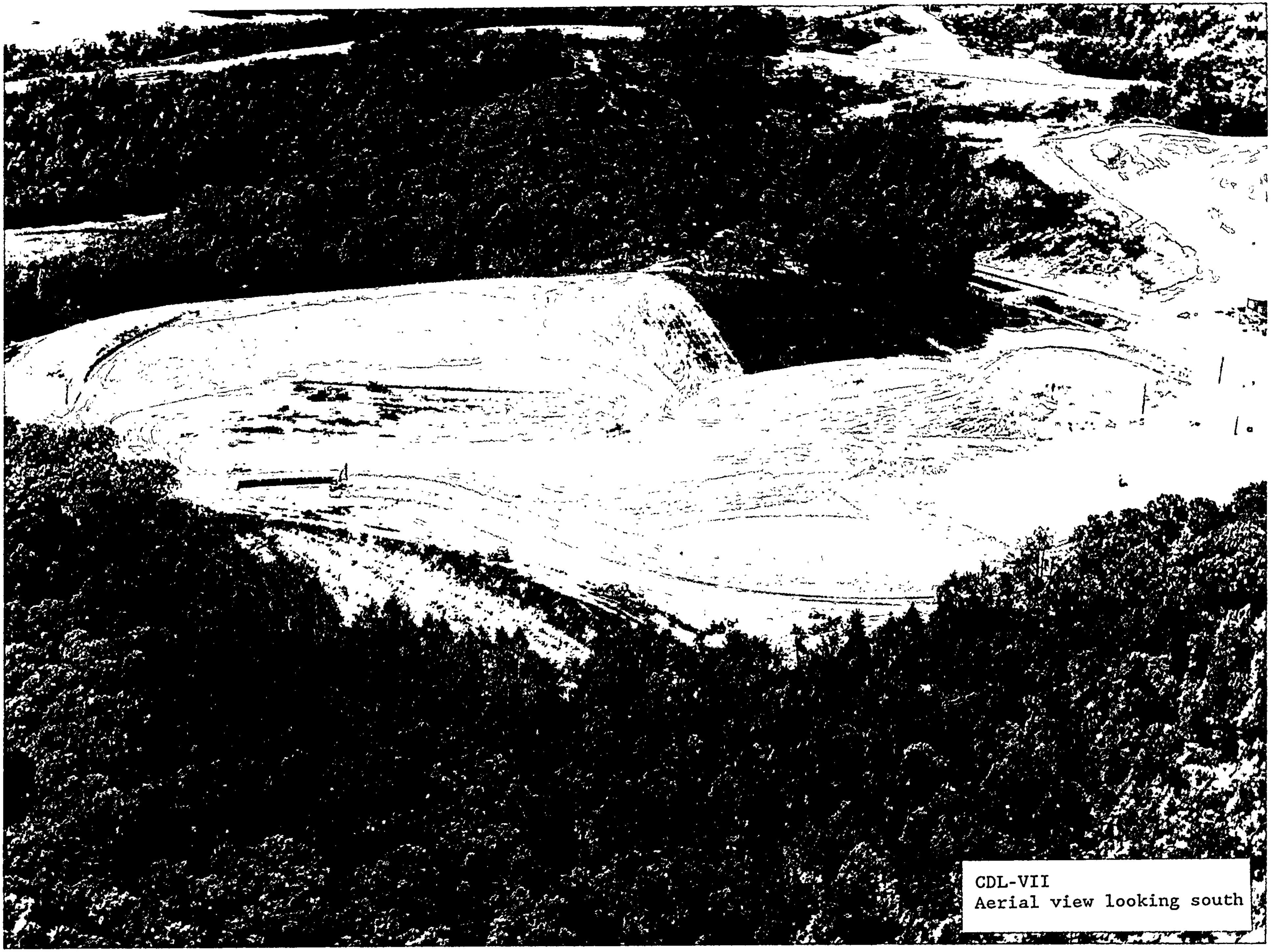
PHOTOGRAPHS



CDL-VII
Standing on perimeter maintenance road looking toward west across crushed rock surfaced access road into Area No. 1



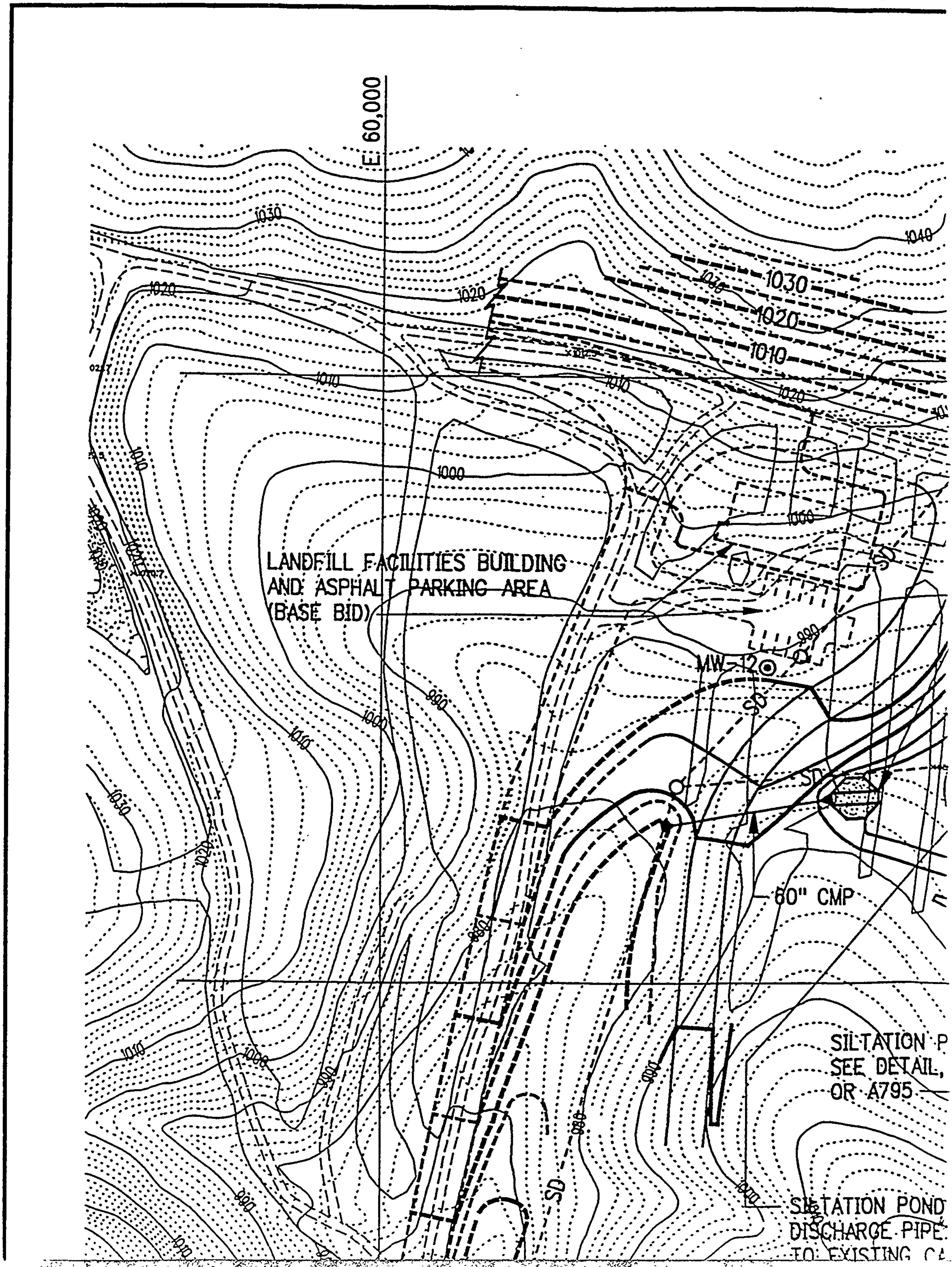
Y-12 SPAD Facilities
Aerial taken looking north.
ILF-V and leachate holding tank to west (left) of access road and CDL-VII to east (right of access road)

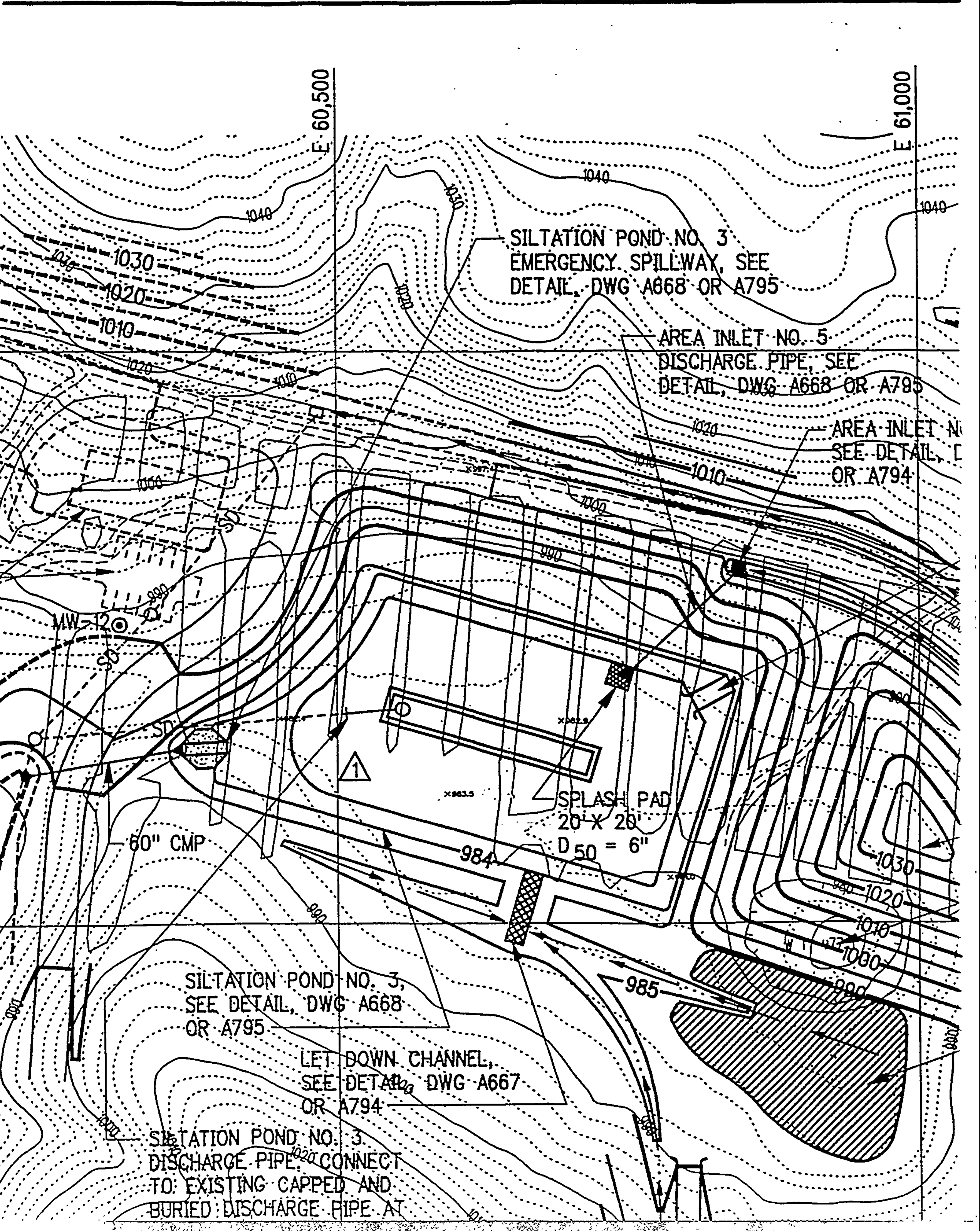


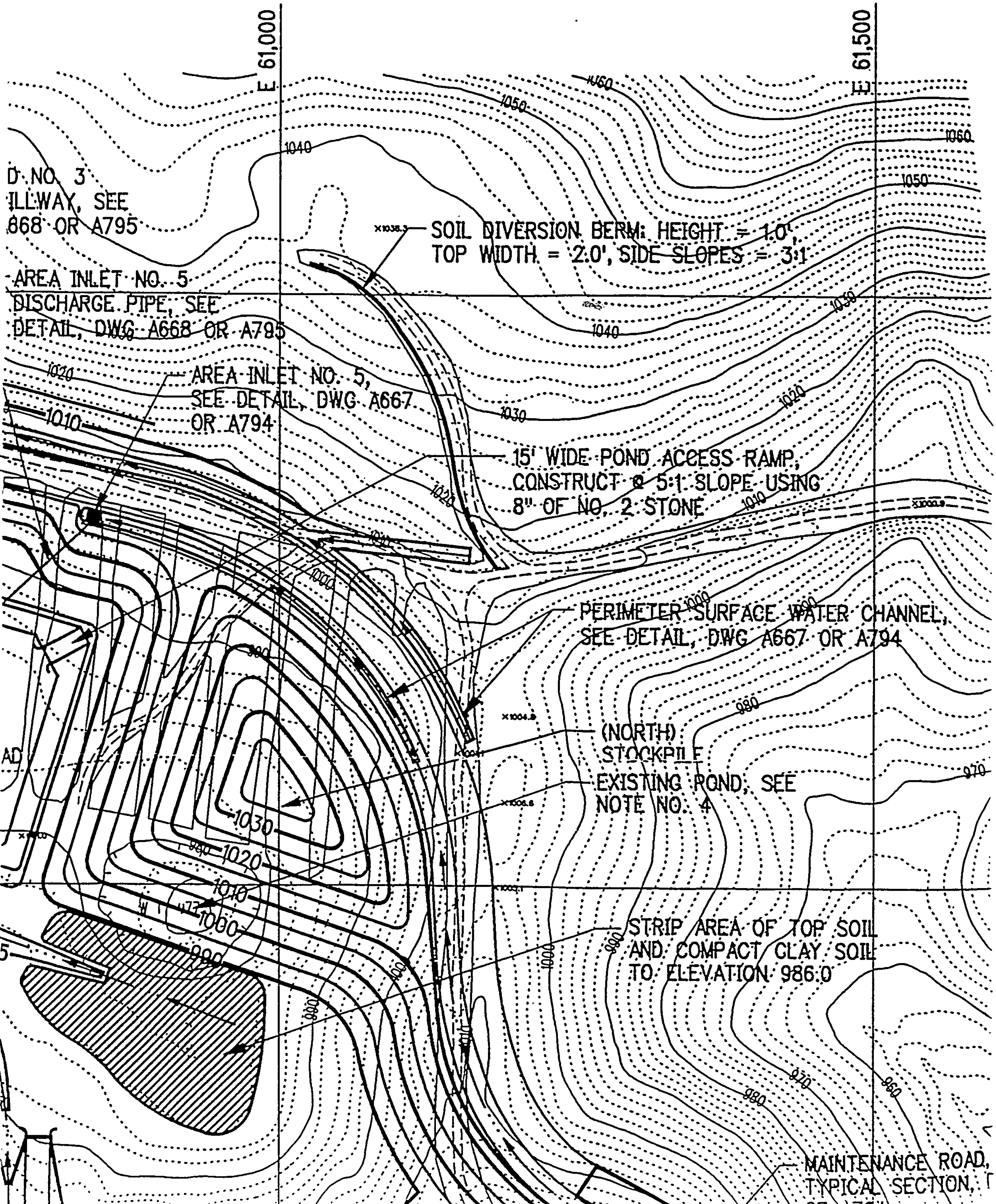
CDL-VII
Aerial view looking south

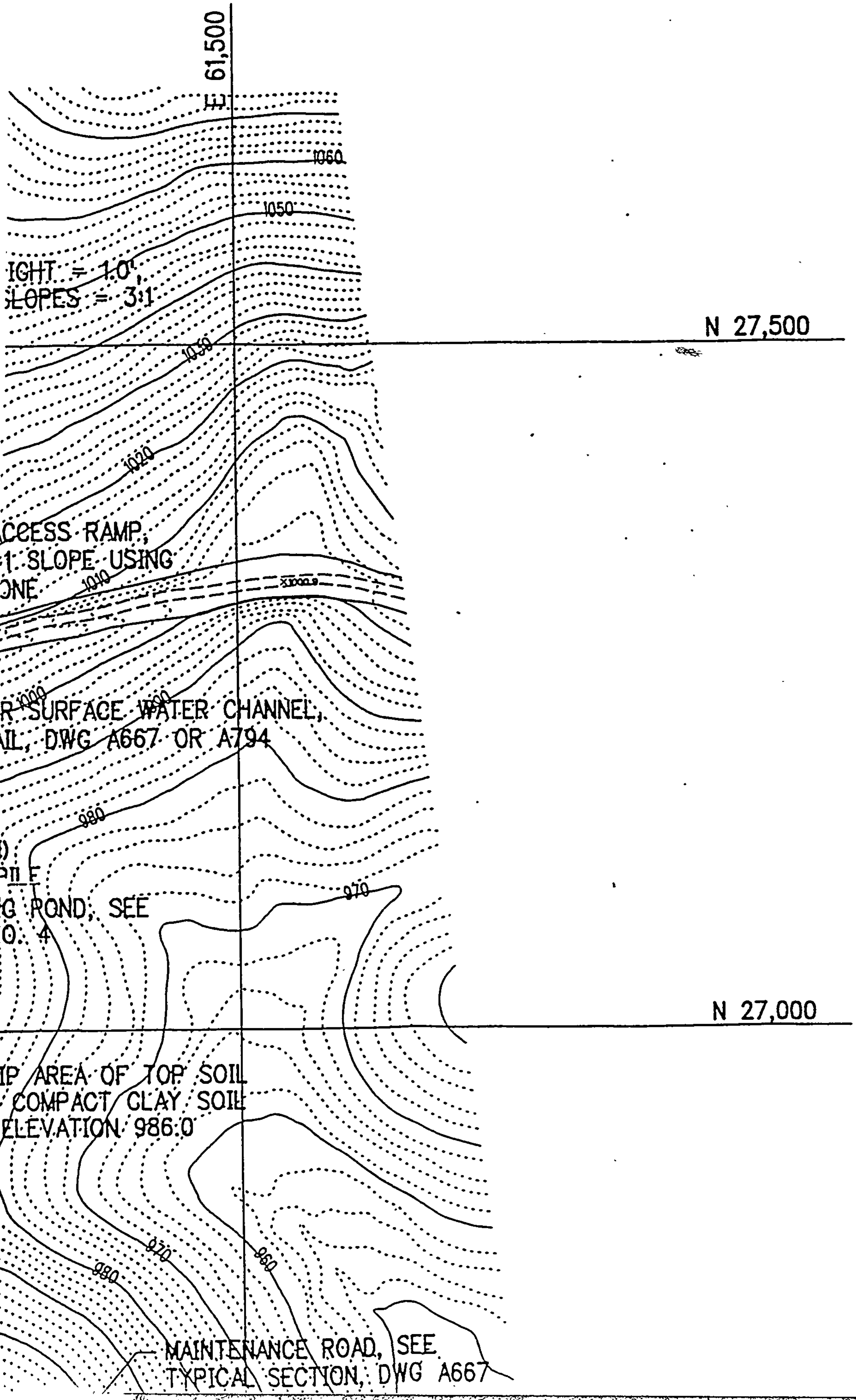
APPENDIX F

AS-BUILT DRAWINGS AND SURVEYS


E. 60,000
1030
1040
1020
1030
1020
1010
1010
1010
1020
1000
1000
LANDFILL FACILITIES BUILDING
AND ASPHALT PARKING AREA
(BASE BID)
990
MW-12
SD
SD
SD
SD
990
1000
1010
1030
1020
60" CMP
1010
1000
990
990
980
980
990
1000
SILTATION P
SEE DETAIL,
OR A795
SILTATION POND
DISCHARGE PIPE
TO EXISTING CA

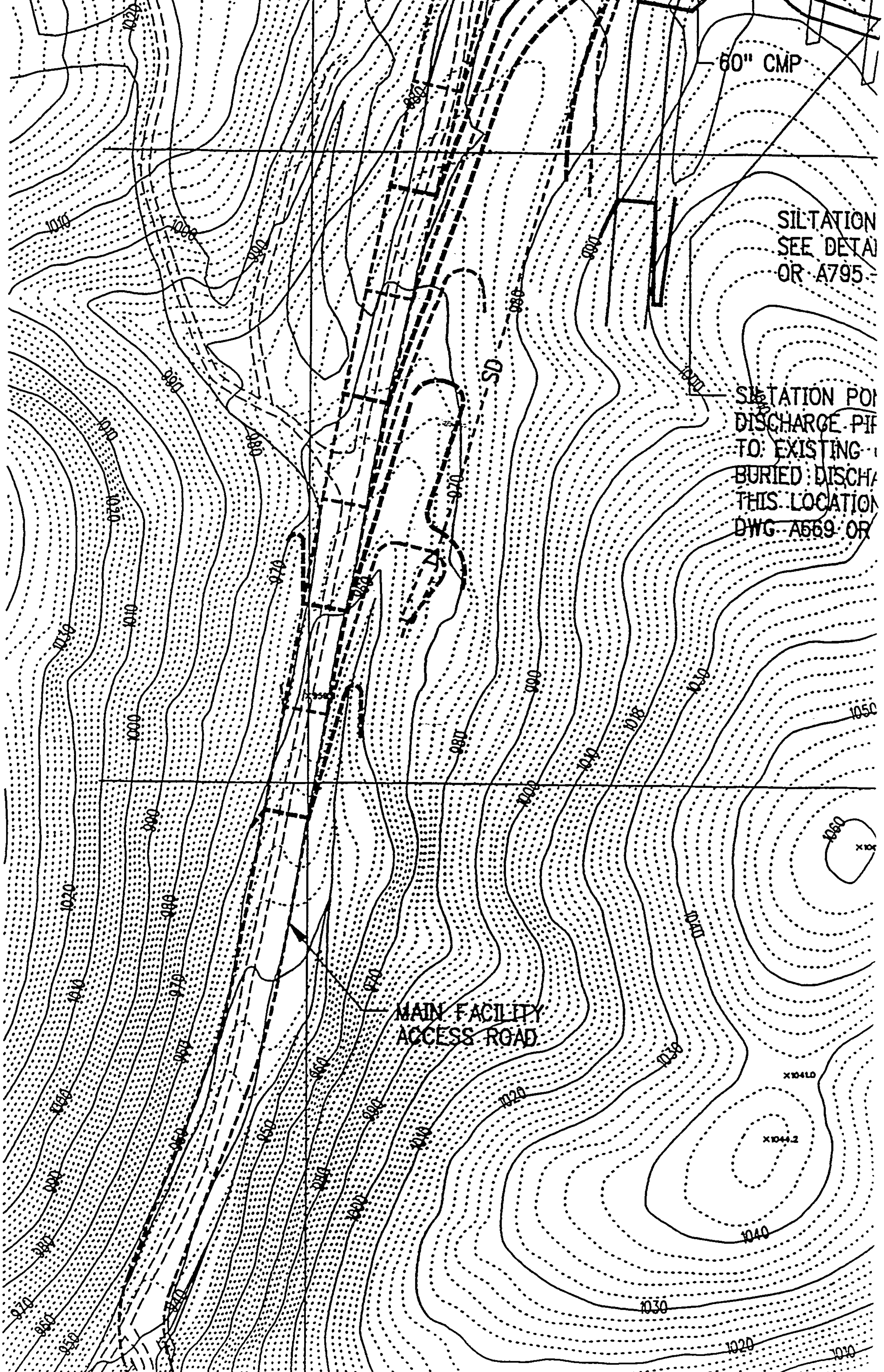

E 60,500
E 61,000
1040
1040
1040
1030
1030
1020
1020
1010
1020
1010
1000
990
1020
1010
1000
1010
990
990
1030
1020
1010
1000
990
980
984
985
60" CMP
MW-12
SD
SD
SD
SD
1
SILTATION POND NO. 3
EMERGENCY SPILLWAY, SEE
DETAIL, DWG A668 OR A795
AREA INLET NO. 5
DISCHARGE PIPE, SEE
DETAIL, DWG A668 OR A795
AREA INLET N
SEE DETAIL, D
OR A794
SPLASH PAD
20' X 20'
D_{50} = 6"
SILTATION POND NO. 3,
SEE DETAIL, DWG A668
OR A795
LET DOWN CHANNEL,
SEE DETAIL, DWG A667
OR A794
SILTATION POND NO. 3
DISCHARGE PIPE. CONNECT
TO EXISTING CAPPED AND
BURIED DISCHARGE PIPE AT

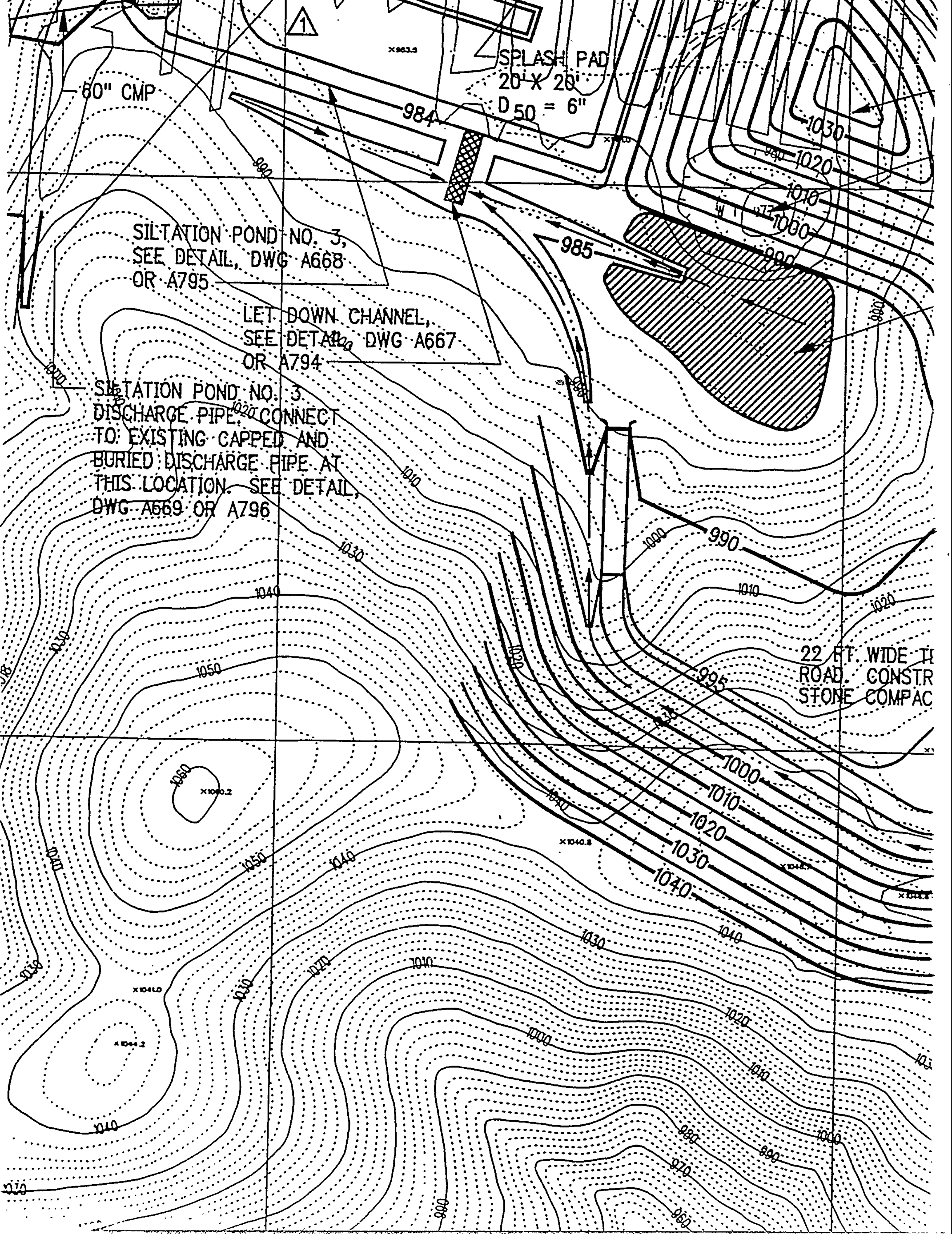

E 61,000
E 61,500
D NO. 3
ILLWAY, SEE
868 OR A795
SOIL DIVERSION BERM: HEIGHT = 1.0',
TOP WIDTH = 2.0', SIDE SLOPES = 3:1
AREA INLET NO. 5
DISCHARGE PIPE, SEE
DETAIL, DWG A668 OR A795
AREA INLET NO. 5,
SEE DETAIL, DWG A667
OR A794
15' WIDE POND ACCESS RAMP,
CONSTRUCT @ 5:1 SLOPE USING
8" OF NO. 2 STONE
PERIMETER SURFACE WATER CHANNEL,
SEE DETAIL, DWG A667 OR A794
(NORTH)
STOCKPILE
EXISTING POND, SEE
NOTE NO. 4
STRIP AREA OF TOP SOIL
AND COMPACT CLAY SOIL
TO ELEVATION 986.0
MAINTENANCE ROAD,
TYPICAL SECTION,
AD
1060
1050
1040
1030
1020
1010
1000
990
980
970
960


E 61,500
1060
1050
IGHT = 1.0',
SLOPES = 3:1
N 27,500
1030
1020
CCESS RAMP,
1 SLOPE USING
ONE
1010
X1000.9
1000
990
R SURFACE WATER CHANNEL,
IL, DWG A667 OR A794
980
)
PILE
G POND, SEE
O. 4
970
N 27,000
IP AREA OF TOP SOIL
COMPACT CLAY SOIL
ELEVATION 986.0
970
980
960
MAINTENANCE ROAD, SEE
TYPICAL SECTION, DWG A667

NOTES:

1. EXISTING TOPOGRAPHY PROVIDED BY SURDEX CORPORATION, INC., ST. LOUIS, MO., DATE OF PHOTOGRAPHY: 12-6-90.
2. ALL PROPOSED CONTOURS ARE FINISH SURFACE ELEVATIONS.
3. LOCATION COORDINATES AND CONSTRUCTION STAKING INFORMATION PERTAINING TO ROADS, DRAINAGE CHANNELS, PIPING, PONDS AND STRUCTURES ARE PROVIDED ON DRAWING A659, CONSTRUCTION LAYOUT PLAN.
4. FILL MATERIAL UTILIZED TO FILL EXISTING PONDS SHALL BE COMPACTED AND TESTED TO MEET REQUIREMENTS OF COMPACTED CLAY SOIL LINER AS DESCRIBED IN CONSTRUCTION SPECIFICATIONS AND CONSTRUCTION QUALITY ASSURANCE PLAN.
5. AS EXCESS SOIL IS STOCKPILED, IT SHALL BE PLACED IN 8 TO 12 INCH LOOSE LIFTS AND UNIFORMLY COMPACTED WITH HEAVY EQUIPMENT (MINIMUM 30,000 LBS STATIC WEIGHT) WITH PNEUMATIC TIRES OR A SHEEPSFOOT ROLLER. A MINIMUM OF 6 PASSES WITH THE EQUIPMENT SHALL BE PERFORMED PER LIFT. VISUAL INSPECTION OF EACH LIFT WILL BE PERFORMED BY THE COMPANY REPRESENTATIVE TO VERIFY SUFFICIENT COMPACTION HAS BEEN ACHIEVED TO PROMOTE STOCKPILE STABILITY AND PREVENT EROSION. A SILT FENCE SHALL BE PROVIDED AT THE BASE OF EMBANKMENTS TO CONTROL EROSION. UPON COMPLETION OF SOIL STOCKPILE AREAS, ROUGHEN TOP 12" OF SOIL AND PLANT VEGETATIVE COVER.
6. ADEQUATE MEASURES SHALL BE TAKEN DURING ALL PHASES OF CONSTRUCTION TO CONTROL SILTATION RUNOFF. SILT FENCES SHALL ALSO BE INSTALLED AROUND SOIL STOCKPILE AREAS IF REQUIRED. FOR CONSTRUCTION OF SILT FENCES, SEE DETAIL, DRAWING A667 OR A794.
7. SILTATION PONDS NO. 1 AND NO. 2 ARE NOT INCLUDED OR SHOWN ON THIS BID OPTION. AREA INLETS NO. 1 THROUGH NO. 4 ARE NOT INCLUDED ON THIS BID OPTION.
8. LIMITS FOR CLEARING AND GRUBBING FOR THIS PROJECT WILL BE STAKED BY COMPANY REPRESENTATIVE PRIOR TO START OF CONSTRUCTION. LIMIT BOUNDARY WILL


60" CMP
SILTATION
SEE DETA
OR A795
SILTATION PO
DISCHARGE PI
TO EXISTING
BURIED DISCH
THIS LOCATION
DWG A669 OR
MAIN FACILITY
ACCESS ROAD
SD
1020
1010
1000
990
980
970
960
950
1030
1040
1050
1060
1018
x1041.0
x1044.2



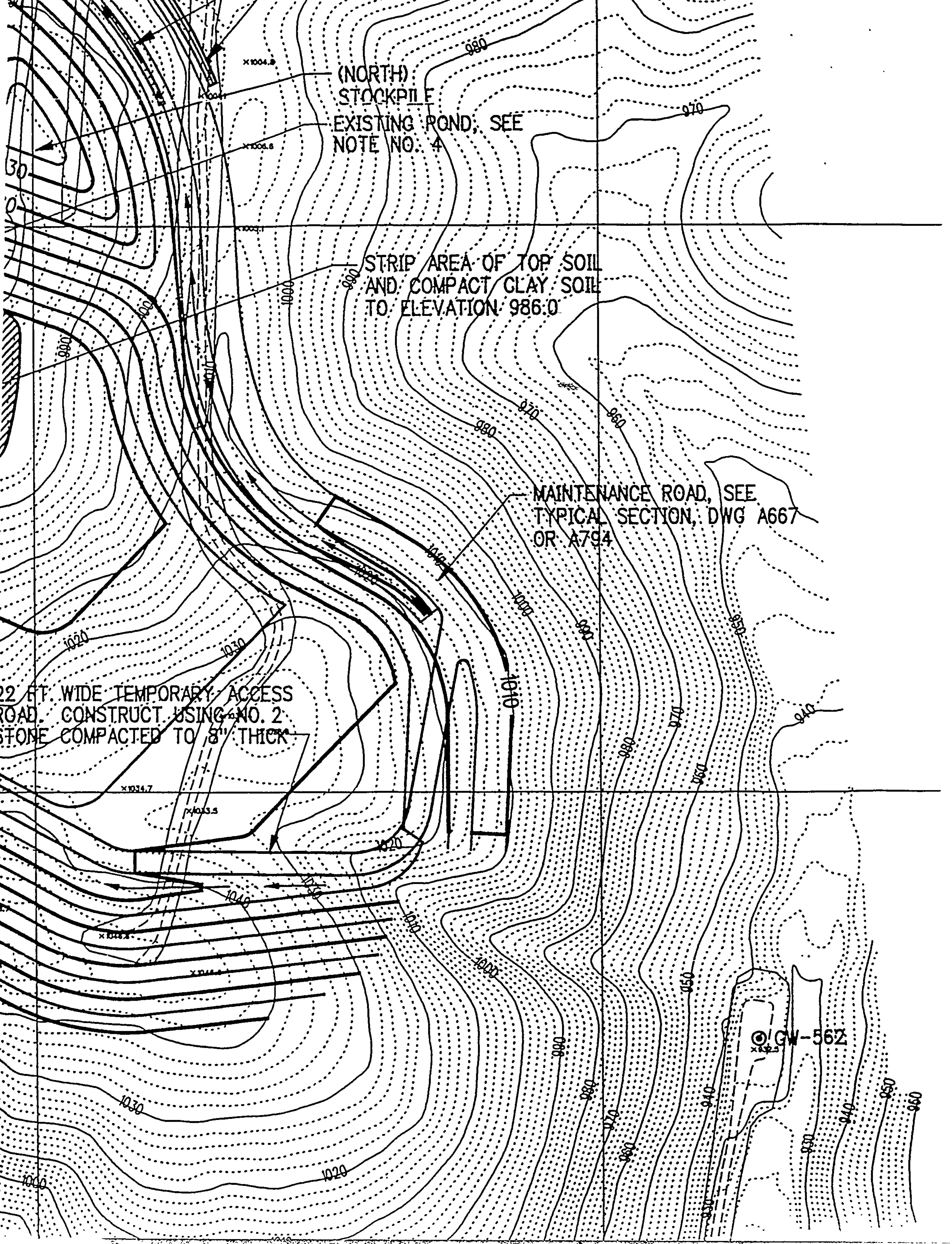
SPLASH PAD 20' X 20' D_{50} = 6"

SILTATION POND NO. 3, SEE DETAIL, DWG A668 OR A795

LET DOWN CHANNEL, SEE DETAIL, DWG A667 OR A794

SILTATION POND NO. 3 DISCHARGE PIPE. CONNECT TO EXISTING CAPPED AND BURIED DISCHARGE PIPE AT THIS LOCATION. SEE DETAIL, DWG A669 OR A796

22 FT. WIDE T
ROAD. CONSTR
STONE COMPAC



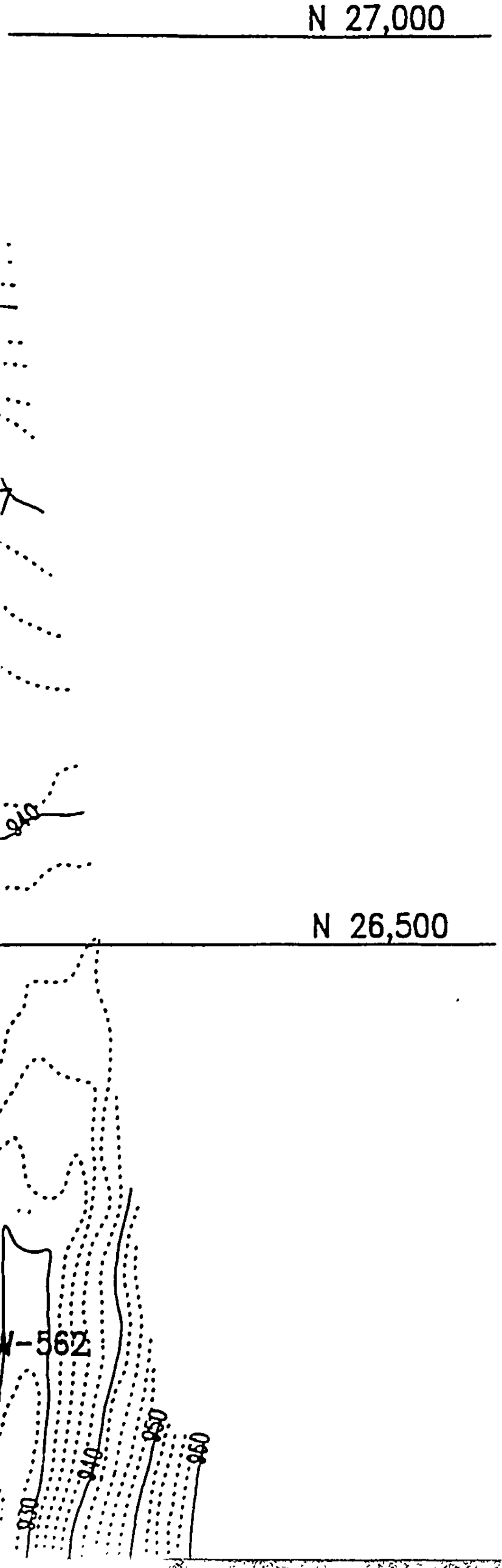
(NORTH) STOCKPILE

EXISTING POND, SEE NOTE NO. 4

STRIP AREA OF TOP SOIL AND COMPACT CLAY SOIL TO ELEVATION 986.0

MAINTENANCE ROAD, SEE TYPICAL SECTION, DWG A667 OR A794

22 FT. WIDE TEMPORARY ACCESS ROAD. CONSTRUCT USING NO. 2 STONE COMPACTED TO 8" THICK

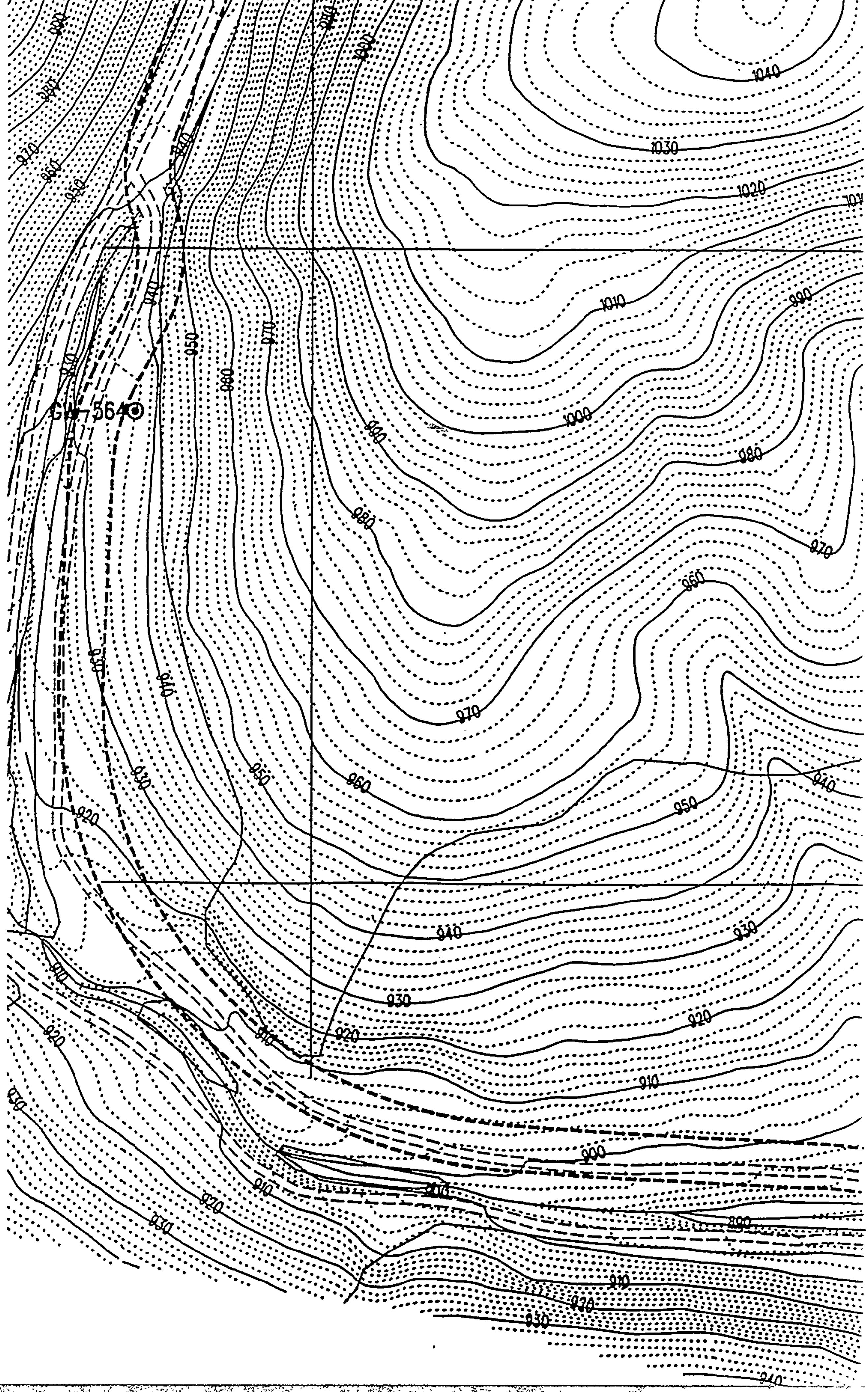

N 27,000
910
N 26,500
W-562
950
940
960
930

COMPACTED WITH HEAVY EQU
30,000 LBS STATIC WEIGHT) WITH PNEUMATIC TIRES OR A SHEEPSFOOT ROLLER. A MINIMUM OF 6 PASSES WITH THE EQUIPMENT SHALL BE PERFORMED PER LIFT. VISUAL INSPECTION OF EACH LIFT WILL BE PERFORMED BY THE COMPANY REPRESENTATIVE TO VERIFY SUFFICIENT COMPACTION HAS BEEN ACHIEVED TO PROMOTE STOCKPILE STABILITY AND PREVENT EROSION. A SILT FENCE SHALL BE PROVIDED AT THE BASE OF EMBANKMENTS TO CONTROL EROSION. UPON COMPLETION OF SOIL STOCKPILE AREAS, ROUGHEN TOP 12" OF SOIL AND PLANT VEGETATIVE COVER.

6. ADEQUATE MEASURES SHALL BE TAKEN DURING ALL PHASES OF CONSTRUCTION TO CONTROL SILTATION RUNOFF. SILT FENCES SHALL ALSO BE INSTALLED AROUND SOIL STOCKPILE AREAS IF REQUIRED. FOR CONSTRUCTION OF SILT FENCES, SEE DETAIL, DRAWING A667 OR A794.
7. SILTATION PONDS NO. 1 AND NO. 2 ARE NOT INCLUDED OR SHOWN ON THIS BID OPTION. AREA INLETS NO. 1 THROUGH NO. 4 ARE NOT INCLUDED ON THIS BID OPTION.
8. LIMITS FOR CLEARING AND GRUBBING FOR THIS PROJECT WILL BE STAKED BY COMPANY REPRESENTATIVE PRIOR TO START OF CONSTRUCTION. LIMIT BOUNDARY WILL ENCOMPASS ALL AREAS OF CONSTRUCTION.
9. DASHED LINES INDICATE WORK UNDER BASE BID AND ARE SHOWN FOR INFORMATION ONLY.

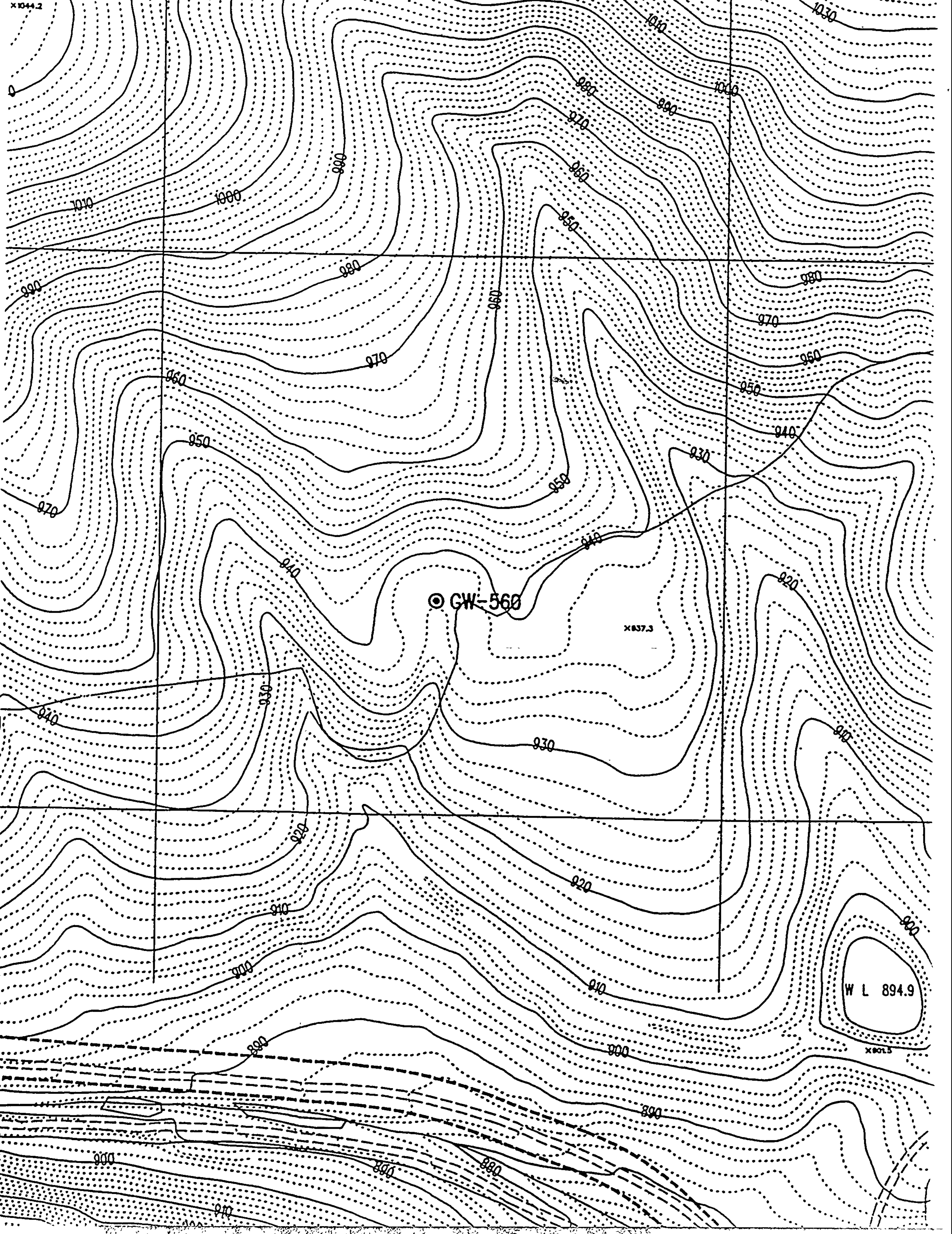
FOR REFERENCE SYMBOLS, ABBREVIATIONS, DRAWING LIST AND LEGENDS, SEE INDEX SHEET, DWG. C2E900000A646 (PERMIT) OR C2E900000A792 (CONSTRUCTION).

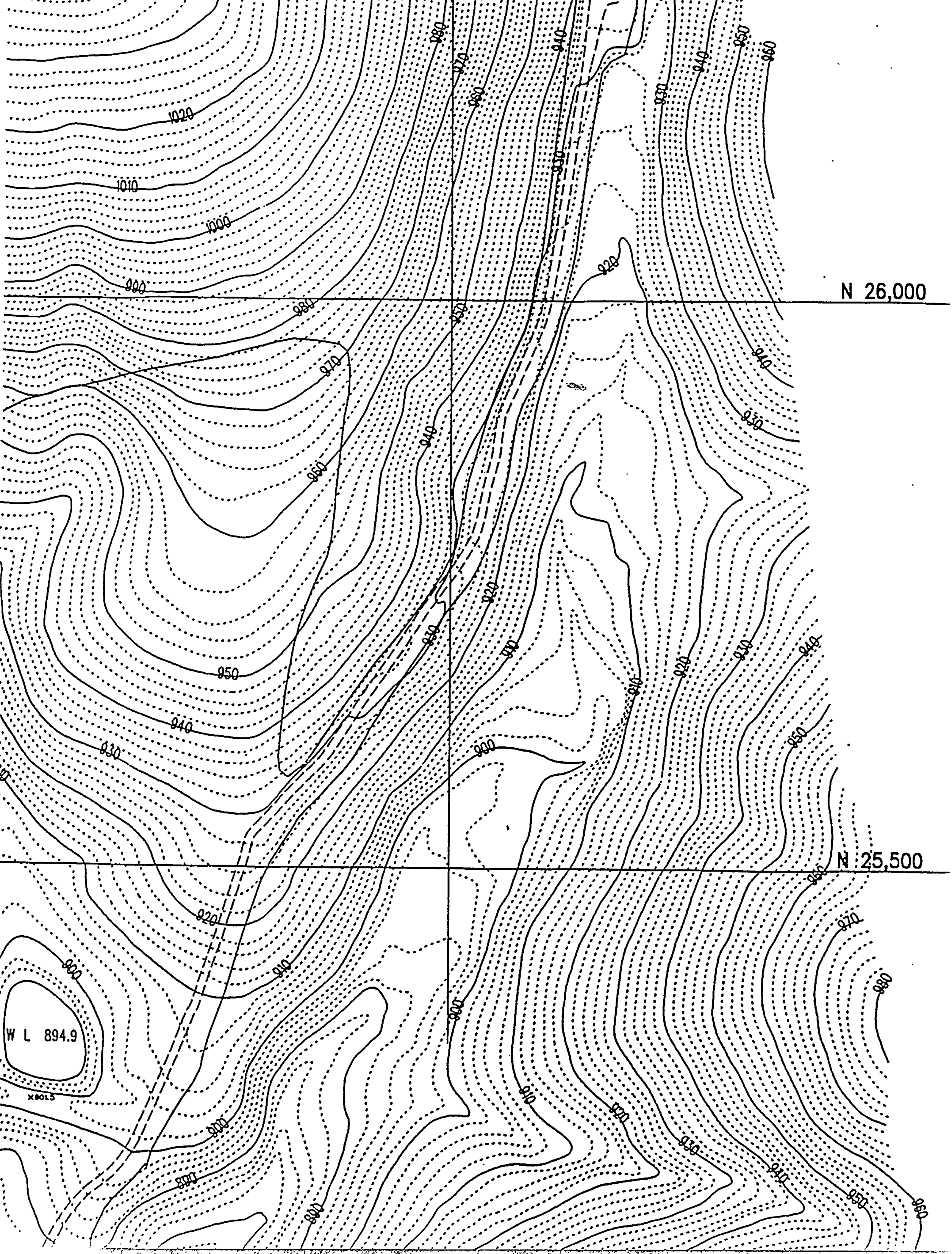
PLANT
NORTH



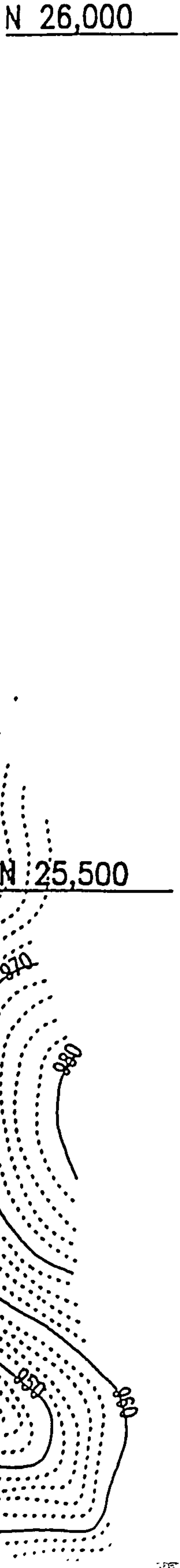
OAD.ETEROAD.DGN.OF=1.3-63

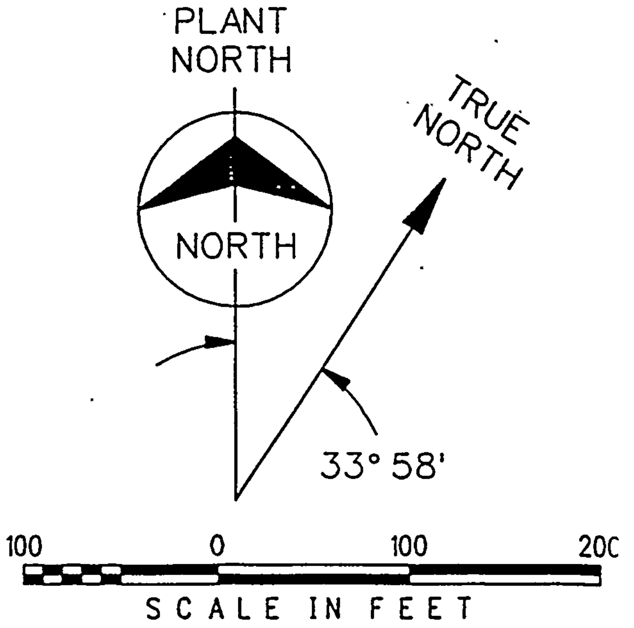
RUIT SET)


×1044.2
1030
1010
1000
980
990
970
960
950
990
1010
1000
980
990
960
970
960
950
970
950
940
930
950
940
980
970
960
950
940
GW-560
×837.3
930
940
920
930
910
920
920
910
900
910
W L 894.9
×901.5
900
890
890
900
890
880
910



N 26,000
N 25,500
W L 894.9
X901.5
1020
1010
1000
990
980
970
960
950
940
930
920
910
900
890


N 26,000
N 25,500
970
980
950
960



1	RECORD DRAWING
0	ISSUED FOR PERMITTING/CFC
REV. NO.	ISSUE OR REVISION PURPOSE-DESCRIPTION

UNITED STATES
DEPARTMENT OF EN

THIS DRAWING PREPARED BY

Burns & McDonne

ENGINEERS - ARCHITECTS - CONSULTA

DOE CONTRACT NO. DE-AC05-900R21860 Kansas City, Missouri A-E NO. 9

PROJECT NAME

Y-12 CONSTRUCTION/DEMOLITION LA
STEAM PLANT ASH DISPOSAL (SPAD),
BID OPTION 2

DRAWING TITLE

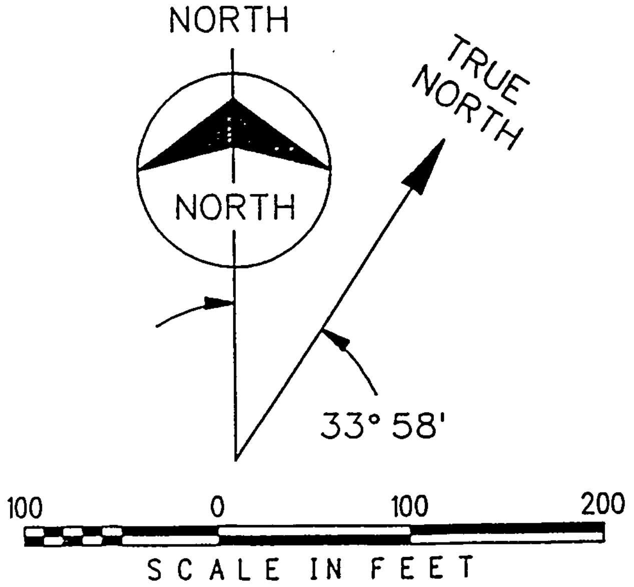
INITIAL CONSTRUCTI

OPERATING CONTRACTOR CODE

I N I T C O N S T P L A N C D

PETER M. BURTON
REGISTERED ENGINEER
No. 00101214
STATE OF TENNESSEE

11/14/94



REV. NO.	ISSUE OR REVISION PURPOSE-DESCRIPTION	A-E	OPERATOR	DOE
△1	RECORD DRAWING			NR
0	ISSUED FOR PERMITTING/CFC	JRT	..	NR
		INITIALS AND DATE		

UNITED STATES DEPARTMENT OF ENERGY

THIS DRAWING PREPARED BY

Burns & McDonnell

ENGINEERS - ARCHITECTS - CONSULTANTS

Kansas City, Missouri

DOE CONTRACT NO. DE-AC05-900R21860

A-E NO. 90-821-1

PROJECT NAME

Y-12 CONSTRUCTION/DEMOLITION LANDFILL VII,
STEAM PLANT ASH DISPOSAL (SPAD), WBS 1.1.2.1
BID OPTION 2

DRAWING TITLE

INITIAL CONSTRUCTION PLAN

OPERATING CONTRACTOR CODE

I N I T C O N S T P L A N C D L V I I

11/14/94

DRAWN BY	DATE	DESIGNED, CHECKED BY	DATE	CHECKED BY	DATE
[illegible]	7-23-9	A. STARNS	7-23-9	J. THORNBURY	7-23-9

REV. NO.	ISSUE OR REVISION PURPOSE-DESCRIPTION	INITIALS AND DATE		
		A-E	OPERATOR	DOE
△1	RECORD DRAWING			NR
0	ISSUED FOR PERMITTING/CFC	JRT	..	NR

UNITED STATES DEPARTMENT OF ENERGY

THIS DRAWING PREPARED BY

Burns & McDonnell

ENGINEERS - ARCHITECTS - CONSULTANTS

DOE CONTRACT NO. DE-AC05-900R21860 Kansas City, Missouri A-E NO. 90-821-1

PROJECT NAME

Y-12 CONSTRUCTION/DEMOLITION LANDFILL VII,
STEAM PLANT ASH DISPOSAL (SPAD), WBS 1.1.2.1
BID OPTION 2

DRAWING TITLE

INITIAL CONSTRUCTION PLAN

OPERATING CONTRACTOR CODE

INIT CONST PLAN CDL VII

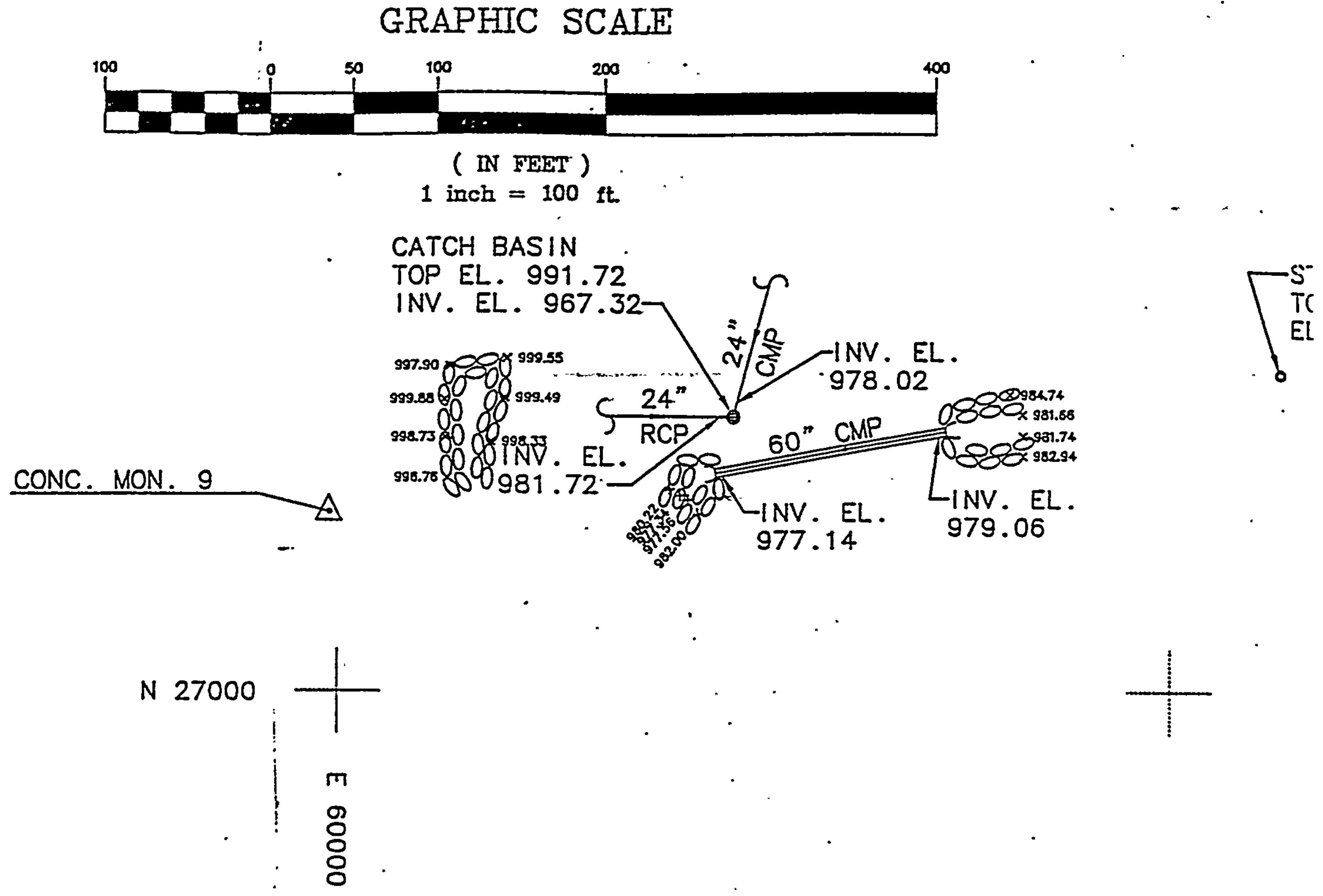
11/14/94

DRAWN BY	DATE	DESIGNED, CHECKED BY	DATE	CHECKED BY	DATE
D. JAEGER	7-23-9	A. STARNS	7-23-9	J. THORNBURY	7-23-9

PLANT	BLDG.	FLOOR	SCALE	1	48	49	50	TYPE	CLASS
Y-12	AREA	A	1"=100'	3	C	P	T	P	U

SUBMITTED FOR APPROVAL	APPROVAL RECOMMENDED	DRAWING APPROVED
		NR
A-E DATE	OPERATING CONTRACTOR DATE	DOE DATE

PROJECT	WORK ORDER NO.	DRAWING NUMBER	REV. NO.
CDL-VII	S08680	C2E900000A661	1



I HEREBY CERTIFY THAT THE INFORMATION HEREON IS AN AS-BUILT SURVEY OF A PORTION OF THE DETENTION AND DRAINAGE STRUCTURES AT THE Y-12 CDL VII SITE AS SURVEYED ON AUGUST 4 & 5, 1994, AND IS CORRECT TO THE BEST OF MY KNOWLEDGE AND BELIEF.

REGISTERED SURVEYOR: Kevin A. King Aug. 26, 1994
NO. 1433

UNITED STATES
DEPARTMENT OF ENERGY

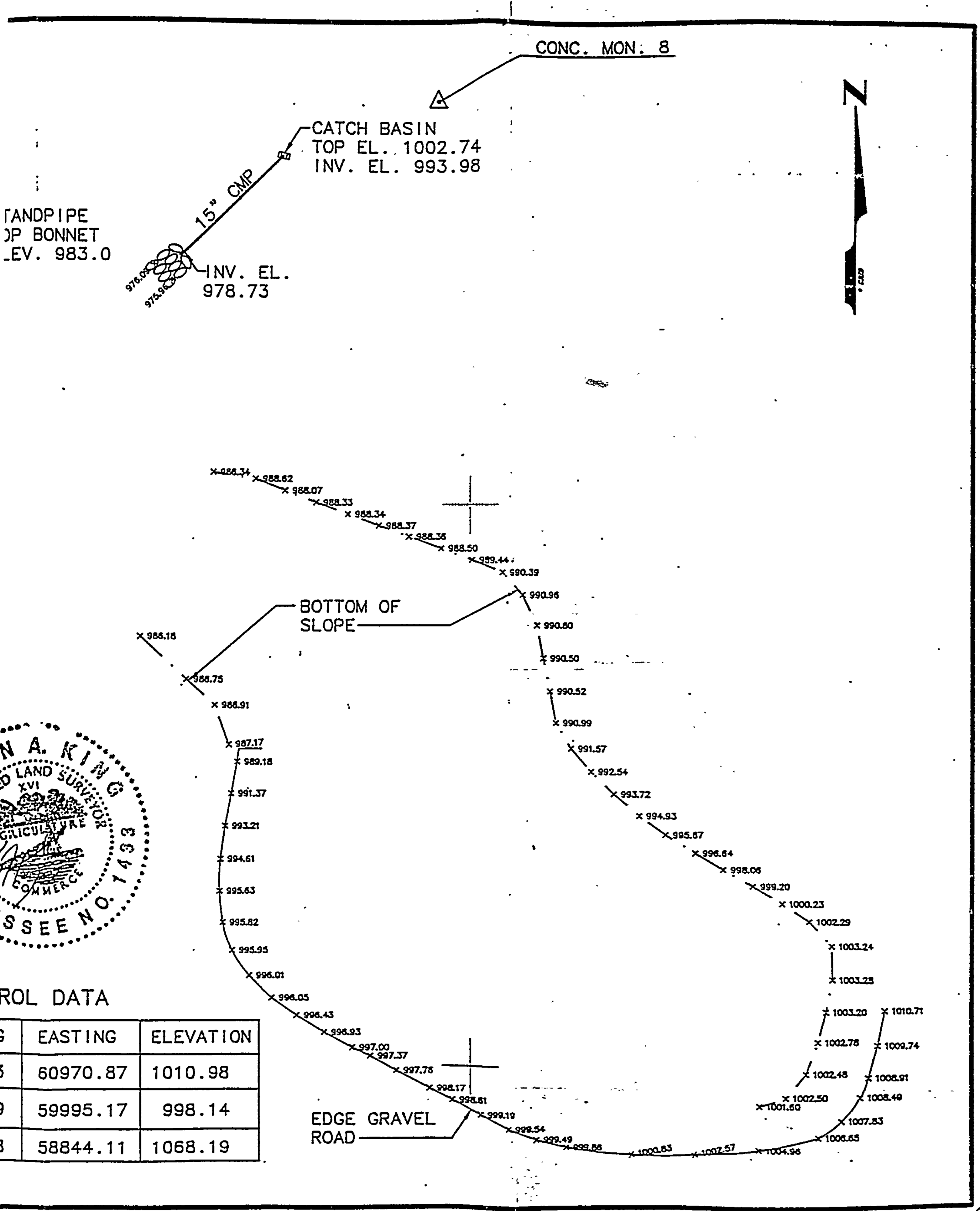
BURNS & McDONNELL — KANSAS CITY, MISSOURI
ETE CONSULTING ENGINEERING, INC — OAK RIDGE, TENNESSEE
DOE CONTRACT NO. DE-AC05-910R21999 A-E COMM 2385A

PROJECT NAME
CDL VII SITE

DRAWING TITLE
PARTIAL AS-BUILT SURVEY OF THE DETENTION AND DRAINAGE STRUCTURES

CONTR

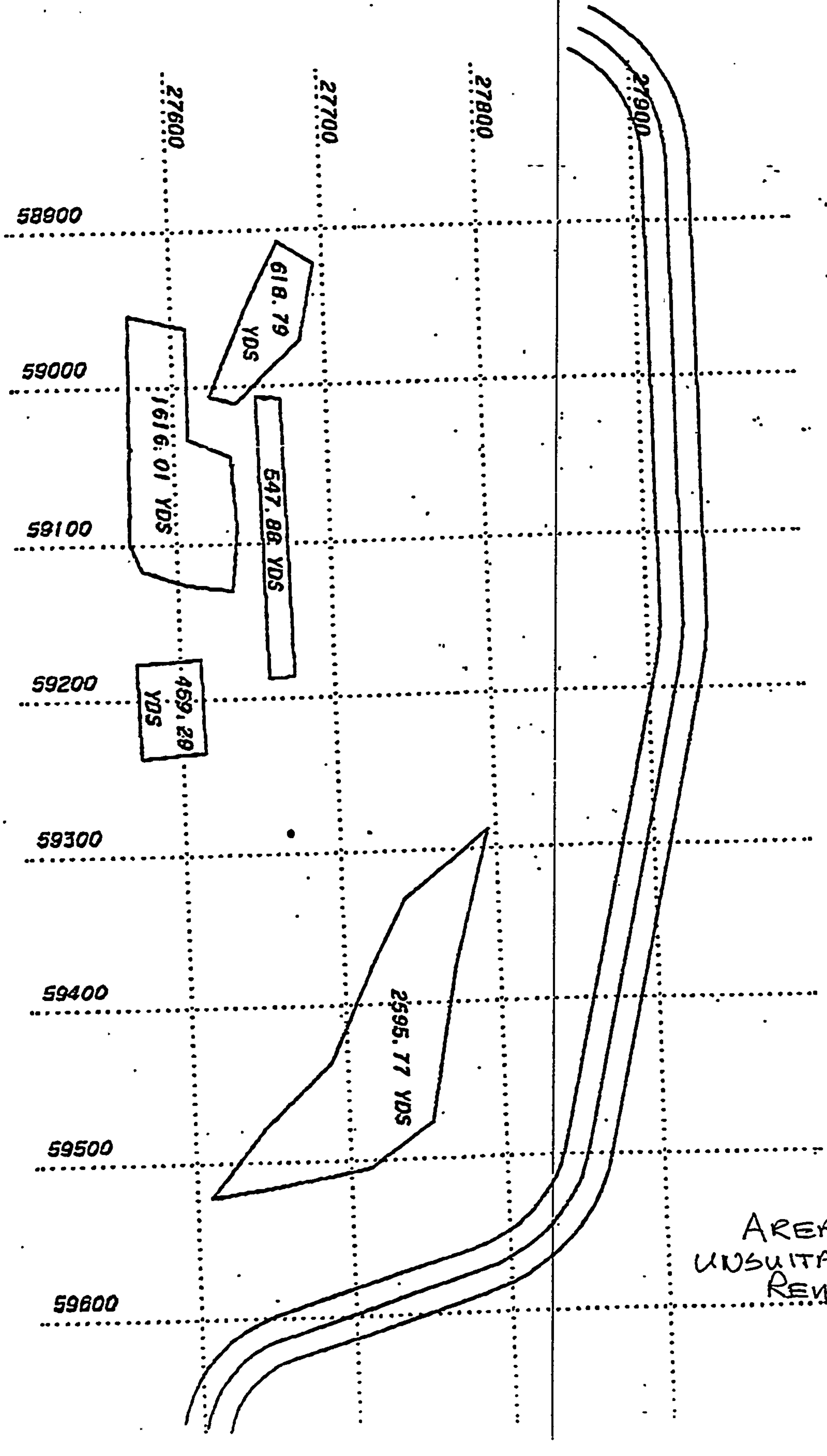
POINT	NORTHING
CM8	27353.53
CM9	27106.99
CM10	27877.88



ROL DATA

G	EASTING	ELEVATION
3	60970.87	1010.98
9	59995.17	998.14
8	58844.11	1068.19

①



AREAS OF
UNSUITABLE SUBGR
REMOVAL

Burns & McDonnell
Waste Consultants, Inc.
ENGINEERS-GEOLOGISTS-SCIENTISTS - 100% EMPLOYEE-OWNED

August 29, 1994

Mr. Jerry Hampton
AVISOC Inc.
8018 Kingston Pike
Knoxville, TN 37919

SPAD Landfill - Survey Monuments
USY12TB
90-823-1-004-02

Dear Jerry:

The coordinate and elevations of the 3 survey monuments constructed on the project have been reviewed and approved. The monument numbers, their coordinates, and elevations are as follows:

Monument No.	Northing	Easting	Elevation
1994-Y-120	27,353.5273	60,970.8743	1010.98
1994-Y-121	27,106.9946	59,995,1745	998.14
1994-Y-122	27,877.8766	58,844.1082	1068.19

Only the monument number will be stamped onto the brass marker. Northings, Eastings, and elevations will not be stamped on the markers due to recent and planned refinements of the data and grid systems. The current coordinates are based on the Y-12 plant grid system.

Additional information to be stamped on the three monuments include the "primary" center designation, "U.S. Dept. of Energy" and "Survey Marker" if they are not already shown on the brass marker.

All persons should check with the Civil Engineering Department for verification prior to using these coordinates. Specific persons to ask for are Bill Manrod at (615) 576-8742 or Keith Craft at (615) 576-5806.

A copy of the permanent survey monument information is attached for your information. The brass markers installed do not exactly comply with the details of this sheet, but have been previously approved and are acceptable. Contact Keith Craft at (615) 576-5806 if you have any questions.

Sincerely,

Gary Maggert

Gary Maggert, P.E.

GM/sjh.555

cc: Dan Ailey, P.E.
Chuck Huteler, P.E.
Keith Craft, R.L.S.

10881 Lowell, Overland Park, Kansas 66210
Phone (816)333-8787 Fax (816)822-3463
ESTABLISHED 1898

GENERAL DESIGN AND COMPUTATION SHEET

JOB PERMANENT SURVEY MONUMENT

Rev. 7-12-94

DATE 12-16-93

SHEET of

ESD NO.

COMPUTED ROD/KEC

CHECKED BY

CENTER DESIGNATION

△ GPS

△ PRIMARY

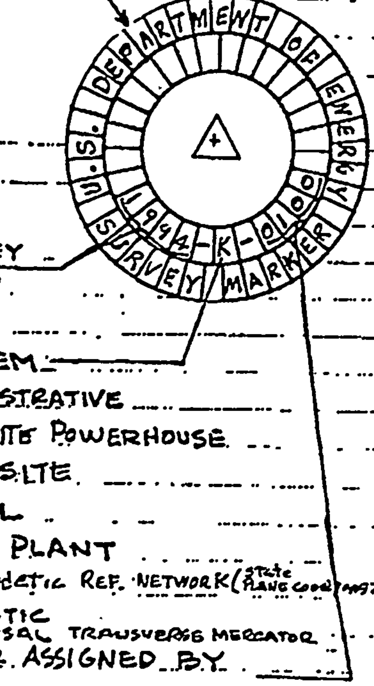
△ SECONDARY

⊙ NGS/USGS/TVA

• OTHERS

○ VERTICAL ONLY

BRASS MARKER ~~DISK~~



YEAR SURVEY PERFORMED

GRID SYSTEM

A - ADMINISTRATIVE
PH - K-25 SITE POWERHOUSE
K - K-25 SITE
X - ORNL
Y - Y-12 PLANT
T - TN. GEODETIC REF. NETWORK (STATE PLANE COORDINATES)
G - GEODETIC
UTM - UNIVERSAL TRANSVERSE MERCATOR

NUMBER ASSIGNED BY ENERGY SYSTEMS, INC.

OTES:

1. MARKER SHALL BE FORGED UNLEADED BRASS, 2" DIAMETER DOME TOP, AND 2" LONG STEM.

2. CONCRETE MONUMENT SHALL BE A MINIMUM OF 8" IN DIAMETER, AND 36" BELOW GRADE. TOP TO BE DOMED TO MATCH DOME TOP OF MARKER WITH CENTER OF MONUMENT 1" ABOVE GRADE AND EDGE AT GRADE.

3. CONCRETE SHALL BE 3000 P.S.I. MINIMUM ~~AT 28 D~~ COMPRESSIVE STRENGTH AT 28 DAYS.

4. FOR GPS MONUMENTS, USE DESIGN APPROVED BY CIVIL ENGINEERING, ENERGY SYSTEMS.

APPENDIX G

CQA MANUAL

Y/WM-094

CONSTRUCTION QUALITY ASSURANCE PLAN
FOR THE
Y-12 CONSTRUCTION/DEMOLITION LANDFILL VII

March 1992

Project No. 90-821-1

Prepared by

Burns & McDonnell
Engineers--Architects--Consultants
Kansas City, Missouri

Under Contract No. DE-AC05-90OR21860
W.B.S. 1.1.2.1
for the
U.S. Department of Energy

Y-12 CONSTRUCTION/DEMOLITION LANDFILL VII
CONSTRUCTION QUALITY ASSURANCE PLAN
TABLE OF CONTENTS

Y-12 CONSTRUCTION/DEMOLITION LANDFILL VII
CONSTRUCTION QUALITY ASSURANCE PLAN

I. INTRODUCTION

The application of Construction Quality Assurance (CQA) procedures is critical to the successful construction and performance of compacted soil caps and covers and other soil placement for the Y-12 Construction/Demolition Landfill VII (CDL-VII). This CQA Plan is designed to verify that (1) the materials used in construction are adequate; (2) the methods of construction are acceptable; and (3) the cap is adequately protected during and after installation. This plan addresses the qualifications and duties of the Quality Assurance (QA) Officer; provides minimum standards for materials selection; and presents recommendations for soil placement, quality control testing, and required documentation.

Portions of this CQA Plan were patterned after the recommendation presented by Dr. David E. Daniel, University of Texas, in a paper entitled, "Summary Review of Construction Quality Control for Compacted Soil Liners and Covers."

II. QUALITY ASSURANCE OFFICER

Construction of the compacted clay cap of the Class IV landfill will be closely monitored by the QA Officer, appointed by the Company Representative. The QA Officer will be a professional engineer licensed to practice by the State of Tennessee, will be knowledgeable in the field of soil mechanics, and will have a good working knowledge of the use of construction equipment and procedures in the placement and compaction of soils.

The QA Officer or authorized representative has the following duties:

1. Provide written, certified documentation attesting to conformance to the design specifications and the CQA Plan with respect to construction of caps within the CDL-VII.

2. Be present during the construction of the compacted caps and embankments, and other soil placement in order to determine the optimum mixture of materials, moisture content, and density to be used in the construction of the facilities as specified in the construction documents.

3. Use such soil analyses as deemed necessary to determine the optimum construction methods and procedures to be used in constructing the cap.

4. Be present at appropriate intervals during landfill bottom excavation. When landfill bottom excavation is complete, the QA

Officer shall assure proper soil placement in cavities resulting from large boulder removal.

III. MATERIALS SELECTION

One of the most important considerations in materials selection is the achievement of low hydraulic conductivity in compacted soil caps. The soils available on-site appear to be of excellent quality in this regard. From the geotechnical investigations performed at this site, it appears that these soils contain a relatively high percentage of fines (silt and clay) and correspondingly low percentages of larger particles.

The soils at the site consist primarily of thick residual silts and clays overlain by a thin mantle of topsoil. The soils have a high chert content (up to approximately five percent of the total soil volume) occurring in erratic zones or lenses. The soils, as classified by the Unified Soil Classification System (USCS), are high and low plasticity clays (CH and CL), plastic silts (ML), and some clayey and silty sand (SC and SM).

Experience and laboratory testing for the soil types available indicate that, in general, the soils can be compacted to achieve a hydraulic conductivity (k) less than or equal to 1×10^{-7} centimeters per second if:

1. The amount of fines (defined as dry-weight percentage passing the No. 200 sieve) is greater than or equal to 30 percent.

2. The plasticity index (PI) of the soil is greater than or equal to 10.

Stones or rocks present in the soil material can increase the hydraulic conductivity if too many are present, or if they are too large. For this project, the amount of gravel (defined as dry-weight percentage retained on the No. 4 sieve) shall not be more than 20 percent. Dry or hard clods of material are difficult to compact and shall be pulverized prior to adding water.

Some additional laboratory analyses will be required to determine the optimum soil properties of soils available on-site and the degree of compaction, water content, etc., that will be required to achieve the permeability specified. In order to best determine the properties of the actual soils set aside for construction of caps, samples will be taken from the stockpiles soils or excavation site and sent to a laboratory for sieve analysis and hydraulic conductivity tests to determine the moisture content, density, and compaction effort required to obtain the required hydraulic conductivity. It is estimated that one sample will be tested for every 1,000 to 1,500 cubic yards of soil used in the construction. These samples would be taken from different locations within the stockpile to ensure that a representative sample had been obtained. These analyses will be used to determine the optimum moisture, density, and compaction effort required to reach the specified hydraulic conductivity for the actual soils to be used in constructing each section of the cap.

IV. SOIL PLACEMENT

Moisture content, subgrade preparation, soil compaction, and protection of the placed soil are the most important factors in constructing low hydraulic conductivity soil caps and in filling cavities that were created by removal of large boulders in the landfill bottom.

Moisture Content

Low hydraulic conductivity cannot be obtained if the soil is too dry at the time it is compacted. Conversely, if the soil is too moist, it will be difficult to compact and will be susceptible to desiccation cracking. The soils must be within the proper acceptable ranges of moisture content as provided in the construction drawings.

Small adjustments in moisture content may be made just prior to compaction. However, large adjustments (more than three percent in moisture content) shall not be made prior to compaction, because the soil must be given time to moisten or dry uniformly. To make large adjustments in moisture content, the soil shall be worked in a separate moisture conditioning area. It is important to mix the soil during wetting or drying and to allow time for the soil to equilibrate. After moisture adjustment, the soil shall be hauled for placement and compaction.

Subgrade Preparation

If large boulders are encountered during the landfill bottom excavation, they will be removed and the resulting cavity will be filled to the landfill bottom elevation with soil placed and compacted in the manner discussed below.

Soil Compaction

The soil shall be placed in lifts of proper thickness. Otherwise, the lower portion of the lift will not be well compacted, and lifts will not be effectively bonded. Loose lifts no more than 230 millimeters (9 inches) in thickness and compacted lifts no more than approximately 150 millimeters (6 inches) in thickness are required.

Compaction equipment to be used consists of heavy, footed rollers with feet that fully penetrate a loose lift of soil. The roller must be heavy to ensure that adequate compactive energy is delivered to the soil. Fully-penetrating feet knead the soil over the full depth of the lift and help to bond lifts. The roller shall have a static weight of at least 30,000 pounds (14,000 kilograms). However, a balance must be struck between the weight of the roller and the moisture content of the soil (the drier the soil, the heavier the roller).

It is important that compaction equipment pass over a given area a sufficient number of times. Dry density alone is not always a good indicator of compactive energy, especially for soils compacted wetter than optimum. The minimum number of passes with footed rollers shall be 6 passes per lift. A pass is defined as one pass of the compactor over an area, not one pass of an axle. Some compactors have footed drums on the front and rear and compact the soil twice with one pass, although feet should not impact the same spot with the front and rear drums. Other compactors have just one drum and compact the soil just once per pass. More passes are likely needed with a roller that has a single drum.

Protection of Placed Soil

Placed soil shall be protected from desiccation cracking and frost damage. A smooth-drum roller shall be used to compact the surface of a completed lift. This forms a hard "skin," which helps to minimize desiccation.

The smooth skin also helps to shed on-site surface water. When the soil is placed on a previously compacted lift, the surface should be scarified to a nominal depth of 25 millimeters (1 inch) prior to placing soil for the next lift. In this manner, lifts are blended together and seepage is eliminated along lift interfaces, which is critical to cap uniformity. In addition to smooth-rolling the surface, the soil may require that moisture be added periodically and/or covered temporarily with plastic sheeting. This will be determined by the QA Officer.

V. QUALITY CONTROL TESTING

Placement of Soil

The loose lift thickness can be checked visually at the working face of placement. If uniform lift thickness is questionable, holes can be excavated at appropriate locations in the lift, and the loose lift thickness can be measured.

If the Seller chooses to control fill levels with grade stakes, care must be taken to remove the grade stakes and to repair holes left by the grade stakes. The QA Officer should see that grade stakes are not buried in the compacted soil. The holes left by grade stakes should be packed with soil material or bentonite that is tamped into the hole in layers with a rod.

Compaction of Soil

The QA Officer will provide construction oversight to assure proper compaction of soil as indicated on the drawings and in the previous section of this document.

Protection of a Completed Lift

This type of inspection is best done by visual observation to determine if adequate measures have been taken to protect each lift of soil from desiccation and freezing.

VI. REPORTING

The QA Officer or authorized representative shall prepare a site visit report for each visit to the site. As a minimum, the report will include the following items:

- Name of inspector
- Date of visit
- Date of each quality assurance test
- Location of each quality assurance test
- Results of test, if field determined
- Any discrepancies or deviations from the construction plans or specifications
- Summary of any discussion with the Seller
- Description of any materials stored on-site
- General comments and observations

APPENDIX H

TDEC CORRESPONDENCE

Department of Energy

Oak Ridge Operations
P.O. Box 2001
Oak Ridge, Tennessee 37831—8620

May 23, 1994

Mr. Jack P. Crabtree, Regional Director
Division of Solid Waste Management
Tennessee Department of Environment
  and Conservation
2700 Middlebrook Pike, Suite 220
Knoxville, Tennessee 37921

Dear Mr. Crabtree:

CONSTRUCTION/DEMOLITION LANDFILL VII - PERMIT NUMBER DNL-01-103-0045 - MINOR REVISIONS TO DESIGN

The following design revision requests for the subject landfill are hereby submitted to the Tennessee Department of Environment and Conservation (TDEC) for formal concurrence and approval.

These minor revisions were discussed on the dates indicated with Mr. Rick Brown of TDEC Knoxville Field Office. In both instances, Mr. Brown provided tentative approval of the requested change.

- Drawing C2E900000A660 details the grading plan and construction of Siltation Pond Number 3. The grading around the emergency spillway for this structure must be modified to accommodate the addition of Chestnut Ridge Access Road (CRAR) construction. The modification includes the relocation of the spillway, the addition of a sixty-inch corrugated metal pipe culvert and modification to the side slopes of the siltation pond. This revision was discussed by telephone with Mr. Brown on March 24, 1994. Parties in this teleconference included Mr. Brown; Gary Maggert of Burns and McDonnell Waste Consultants, Inc.; and Dan Ailey and Chuck Hutzler of Martin Marietta Energy Systems, Inc., (Reference Construction Interface Document CID Number 135).

- Drawing C2E900000A661 details the grading and excavation plan for Area I of the Construction/Demolition Landfill VII disposal area. During excavation, a pocket of soft and yielding and/or organic material was encountered at the base grade elevation. It was proposed that this unsuitable material be excavated to five feet below base grade and the opening backfilled with compacted clay. This method of repair was used for similar situations encountered during the construction of nearby Industrial Landfill V. This was discussed with Mr. Brown on April 19, 1994. (Reference [CID] Number 133.)

These design revisions will be appropriately annotated on the facility as-built drawings.

If you require additional information, please contact Ralph Skinner at 576-7403.

Sincerely,

Larry L. Radcliffe, Director
Waste Management and Technology
Development Division

cc:
G. R. Hudson, CE-52
W. G. McMillian, DP-82
C. E. Frye, K-1037, MS 7357

Department of Energy

Oak Ridge Operations
P.O. Box 2001
Oak Ridge, Tennessee 37831— 8620

June 9, 1994

Mr. Jack P. Crabtree, Regional Director
Division of Solid Waste Management
Tennessee Department of Environment
and Conservation
2700 Middlebrook Pike, Suite 220
Knoxville, Tennessee 37921

Dear Mr. Crabtree:

INDUSTRIAL LANDFILL V, CONSTRUCTION/DEMOLITION LANDFILL VII, AND CONSTRUCTION/DEMOLITION LANDFILL VI - PERMIT NUMBER IDL-01-103-0083, DML 01-103-0045, AND DML 01-103-0036 RESPECTIVELY - MINOR REVISIONS TO DESIGN

The following design revision requests for the subject landfills are hereby submitted to the Tennessee Department of Environmental and Conservation (TDEC) for formal concurrence and approval.

These revisions for Industrial Landfill V (ILF V) and Construction/Demolition Landfill VII (CDL VII) were discussed on May 2, 1994, with Mr. Rick Brown of TDEC Knoxville Field Office. In both instances, Mr. Brown provided tentative approval of the requested change.

- Drawing C2E900000A636 for ILF V and Drawing C2E900000A667 for CDL VII require that the standpipe for sedimentation ponds be wrapped with a filter fabric. This fabric is to have a pore size of 70 to 100 sieve. This small pore size will not allow the sedimentation ponds to drain due to clogging of the pores. The filter fabric is to be changed to a fabric having a pore size of 20 to 30 sieve. This should promote proper drainage of the sedimentation ponds. (Reference Construction Interface Document Number 139).

The design revision for ILF V and CDL VII will be appropriately annotated on the respective facility as-built drawings. These changes were also discussed with Barbara Rector of the Tennessee Oversight Agreement, Oak Ridge Office by Dan Ailey, Project Manager, on May 2, 1994. Ms. Rector concurred with the change.

In addition, a similar revision is needed for CDL VI.

- The red-lined Drawing C2E800676C006, provided as part of the Professional Engineering Certification Package, showed the standpipe for the sedimentation pond wrapped with Trevira 1120 filter fabric or an approved substitute. Trevira 1120 has a small pore size equivalent to a 70 sieve. This small pore size will not allow the sedimentation pond to drain rapidly enough, due to clogging of the pores. The filter fabric is to be changed to a minimum pore size equivalent to a sieve size 20 or greater. This adjustment will allow the proper drainage to maintain a dry pond and retain the necessary soil fines.

If you require additional information, please contact Ralph Skinner (Program Manager) at 576-7403.

Sincerely,

Larry L. Radcliffe, Director
Waste Management and Technology
Development Division

cc:
M. A. Reeves, CE-524
W. G. McMillian, DP-82
C. E. Frye, K-1037, MS 7357

DISTRIBUTION:

C. E. Frye, 1037, MS 7357
C. W. Hutzler, - RC, 9204-1, MS 8053
A. K. Lee/DOE-OSTI, 9731, MS 8157 (2)
E. M. Murrill, 9204-1, MS 8053
L. L. Radcliffe, FOB, MS 8620 (3)
M. A. Reeves, DOE-ORO, FOB, MS 8710
M. L. Willoughby, 9204-1, MS 8053
YES DCC9Reference PRN Y1992-0251), 9739, MS 8117
Y-12 Central Files, 9711-5, MS 8169