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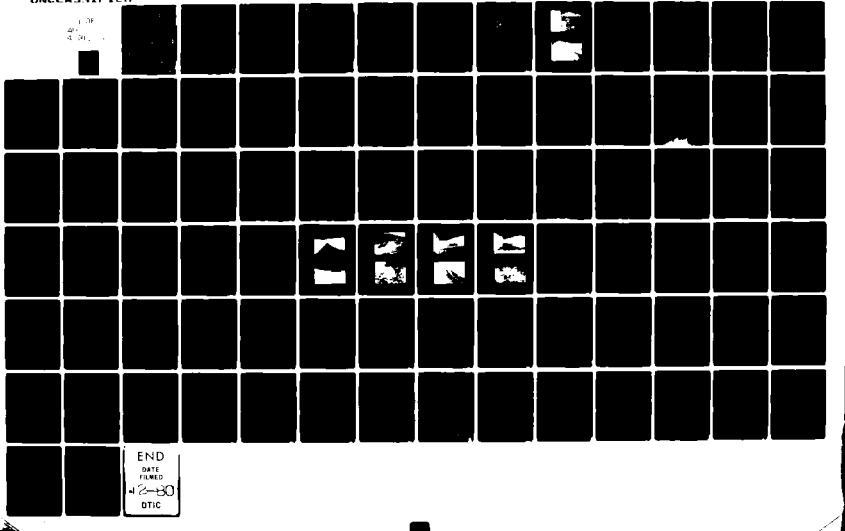

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CHESAPEAKE BAY BASIN
WILBUR CREEK, CALVERT COUNTY

MARYLAND

LEVEL II

COLUMBIA LNG

NDI ID NO MD-116

COLUMBIA LNG CORPORATION

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

Prepared For
DEPARTMENT OF THE ARMY
Baltimore District, Corps of Engineers
Baltimore, Maryland 21203

DACW 31-80-C-0050

By
RUMMEL, KLEPPER & KAHL
Consulting Engineers
Baltimore, Maryland 21202

JULY 1980

411913

(10) Edward J. Zeigler (1)

CHESAPEAKE BAY,
WILBUR CREEK, CALVERT COUNTY,
MARYLAND,

(6) National Dam Inspection Report.

COLUMBIA LNG
(NDI-ID Number MD-116),

COLUMBIA LNG CORPORATION

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1035 N. Calvert Street
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PREFACE

This report is prepared under guidance contained in the Recommended Guidelines for Safety Inspection of Dams, for Phase I Investigations. Copies of these guidelines may be obtained from the Department of the Army, Office of Chief of Engineers, Washington, D.C. 20314.

The purpose of a Phase I investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon visual observations and review of available data. Detailed investigations and analyses involving topographic mapping, subsurface investigations, material testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the inspection is intended to identify any need for such studies which should be performed by the owner.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of the dam depends on numerous and constantly changing internal and external factors which are evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through frequent inspections can unsafe conditions be detected and only through continued care and maintenance can these conditions be prevented or corrected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the spillway design flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. The spillway design flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

The assessment of the conditions and recommendations was made by the consulting engineer in accordance with generally and currently accepted engineering principles and practices.

CHESAPEAKE BAY

WILBUR CREEK, CALVERT COUNTY

MARYLAND

COLUMBIA LNG

NDI ID NO. MD-116

COLUMBIA LNG CORPORATION

PHASE I INSPECTION REPORT

NATIONAL DAM INSPECTION PROGRAM

July 1980

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PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

BRIEF ASSESSMENT OF GENERAL CONDITION
AND RECOMMENDED ACTION

Name of Dam:	Columbia LNG NDI ID NO. MD-116
Size:	
Main Dam:	Intermediate (830 acre-feet, 74 feet high)
Secondary Dam:	Small (27 acre feet, 34 feet high)
Hazard Classification:	
Main Dam:	High
Secondary Dam:	Significant
Owner:	Columbia LNG Corporation 20 Montchanin Road Wilmington, Delaware 19807
State Located:	Maryland
County Located:	Calvert
Stream:	Wilbur Creek
Date of Inspections:	July 2, 1980 and August 5, 1980

Based on the visual inspection, available records, past operational performance, and in accordance with the guideline criteria established for these studies, Columbia LNG is judged to be in fair condition.

The facility inspected at Columbia LNG is a complex consisting of a main dam and a secondary dam. The dams were completed in 1974 to retain spoil generated during the dredging of a trench for a tunnel to be constructed to an offshore docking facility in the Chesapeake Bay. The tunnel provides access to the docking facility and contains two pipelines used to convey liquified natural gas from the docking facility to storage tanks onshore. Dredged spoil was directed into the main impoundment where it was retained while larger sediments settled out of suspension. Partially clarified water was directed through a drop inlet spillway into the secondary impoundment right of the right abutment of the main dam. In the secondary impoundment, additional retention time was provided for fine sediments to settle out of suspension. Sufficiently clarified water was directed from the secondary impoundment back to the Chesapeake Bay through a drop inlet spillway and pipeline through the embankment.

Dredging for the tunnel was completed in 1974, and currently the only inflow into the main impoundment is surface runoff from the drainage area and precipitation directly on the lake. Inflow into the secondary impoundment is overflow from the main impoundment, precipitation directly on the lake, and a minor amount of surface runoff.

The water level behind the main dam varies, but during normal flow the pool level is controlled by the principal spillway weir notch crest at elevation +76.2. The principal spillway is located just upstream of the right abutment of the dam. The water level in the secondary impoundment is normally maintained at +49.2, weir notch crest elevation of the drop inlet spillway which is located near the center of the upstream embankment.

A minor amount of erosion was noted along the waterline of the upstream slope of the main embankment. No slope protection is provided on the upstream slope of either the main or secondary dams. An erosion gully was noted along the left abutment of the main dam, approximately half way up the slope. Two seepage areas were noted near the toe of the main dam. One area is located left of the collection box and did not have a measureable flow. The second area is approximately 120' right of the collection box and had an estimated flow of 2 gpm. Two seepage areas were noted downstream of the toe of the secondary dam and left of the downstream channel. The seepage nearest the toe flowed at an estimated rate of 10 gpm and could represent leakage from the buried collection box located in the general vicinity. The other seepage area starts approximately 100 feet downstream of the outlet conduit and extends approximately 100 feet along the downstream channel. All seepages noted were relatively clear and did not appear to be transporting fines.

According to the hydrologic and hydraulic analyses, both the main and secondary dams will pass 100 percent of the Probable Maximum Flood without overtopping, and therefore the spillway of each dam is considered adequate.

The following remedial measures are recommended to be accomplished by the Owner:

1. Repair the erosion noted just above the water line along the upstream slope of the main dam.

2. Retain a Professional Engineer experienced in dam design and construction to investigate the sources of the seepage areas noted near the downstream toe of the main embankment and the seepage areas located downstream of the toe of the secondary dam. The seepages should be monitored and, if necessary, should be controlled in accordance with the recommendations of the Professional Engineer.

3. Develop a formal warning system to alert any personnel downstream of the dam in the event of emergencies.

Columbia LNG
NDI ID NO. MD-116

Submitted by:

RUMMEL, KLEPPER & KAHL

Edward J. Zeigler

Edward J. Zeigler, P.E.
Associate

Date: August 28, 1980

Approved by:

James W. Peck

JAMES W. PECK
Colonel, Corps of Engineers
District Engineer

Date: 18 Sep 80

Upstream Face of Main Embankment

Downstream Face of Main Embankment

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

COLUMBIA LNG
NDI ID NO. MD-116

SECTION 1
PROJECT INFORMATION

1.1 General.

a. Authority. The Dam Inspection Act, Public Law 92-367, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a program of inspection of dams throughout the United States.

b. Purpose. The purpose of the dam inspection program is to determine if the dam constitutes a hazard to human life or property.

1.2 Description of Project.

a. Dams and Appurtenances. The main and secondary dams of the Columbia LNG spoil embankments are earth fill dams constructed with compacted random fill. Each dam has a chimney drain and a slurry trench cutoff wall. The main dam is 74± feet high at its maximum section and is approximately 670 feet long. The main dam was constructed across Wilbur Creek. The secondary dam is 34 feet high at its maximum section and is approximately 230 feet long.

Inflow into the main impoundment is either from surface runoff from the drainage area or from precipitation falling directly on the lake. A distinct channel for Wilbur Creek upstream of the main dam could not be identified. Inflow into the secondary impoundment is overflow from the main impoundment, precipitation falling directly on the lake, and a minor amount of surface runoff.

The flood discharge facility for the main dam consists of the principal spillway which is a drop inlet. The drop inlet conveys overflow to the secondary impoundment through a 42 inch asbestos bonded corrugated steel pipe. The principal spillway is located just upstream of the right abutment of the main dam. The flood discharge facility for the secondary dam also consists of a drop inlet spillway. The drop inlet of the secondary dam conveys water through the dam embankment in a 48 inch asbestos bonded corrugated metal pipe. The overflow is discharged into a channel containing riprap which serves as energy dissapators. Water flows from this channel into a fresh water marsh.

The normal pool elevations of both impoundments correspond to the crest elevations of the respective drop inlets.

b. Location. The spoil embankment complex is located approximately 0.5 mile inland from the Chesapeake Bay and approximately 1.2 miles northwest of the Cove Point Lighthouse in Calvert County, Maryland. The Columbia LNG facility is shown on the U.S.G.S. Quadrangle, Cove Point Maryland, at latitude N 38° 23' 24", and longitude W 67° 24' 6". A location map is included as Plate E-1.

c. Size Classification. Main dam - Intermediate (830 acre-feet, 74 feet high); Secondary dam - Small (27 acre-feet, 34 feet high).

d. Hazard Classification. High Hazard. There is a guardhouse, tunnel portal, and ventilation building for the 6400± foot long tunnel, and liquified natural gas pipelines downstream of the main dam which could sustain damage in a flood resulting from a dam failure. Failure of the secondary dam also has a potential to damage the LNG pipelines, but a significant hazard classification is warrented.

e. Ownership. Columbia LNG Corporation, 20 Montchanin Road, Wilmington, Delaware 19807

f. Purpose of Dams. To contain spoil generated during dredging of a trench for a liquified natural gas tunnel constructed to an offshore docking facility.

g. Design and Construction History. Construction of the dams was completed in 1974. The dams and appurtenant structures were designed by Woodward - Moorhouse & Associates, Inc. of New York. The dams were constructed by C.J. Langenfelder & Son, Inc. of Baltimore, Maryland. According to the typical section of both embankments shown on the contract drawings, both dams are constructed of compacted random fill. Each dam has a chimney drain and slurry trench cutoff wall.

In 1976, revisions were made to the drop inlet boxes of both the main dam and secondary dam spillways. These revisions were designed by Woodward-Moorhouse & Associates, Inc. of New York, and constructed by C. J. Langenfelder & Son, Inc. of Baltimore, Maryland.

h. Normal Operating Procedure. As they presently exist, the lakes retained by both dams are normally maintained at or just below the crest elevation of the drop inlet spillway.

1.3 Pertinent Data.

a. Drainage Area.

Main Dam	0.19 square miles
Secondary Dam	0.02 square miles

b. Discharge at Dam Site.

Main Dam	170 cfs outflow at elevation 87.5
Secondary Dam	178 cfs outflow at elevation 54.8

c. Elevation (Feet Above m.s.l.).

(1) Main Dam

Top of Dam	87.5 (design) 87.5(low point on crest)
Normal Pool	76.2(Spillway notch crest)
Upstream Invert Outlet Works	72.5
Downstream Invert Outlet Works	51.0
Downstream Toe	14±
Maximum Tailwater	Will normally be below the outlet invert

(2) Secondary Dam

Top of Dam	55.0 (design) 54.8(low point on crest)
Normal Pool	49.2(Spillway notch crest)
Upstream Invert Outlet Works	40.4
Downstream Invert Outlet Works	20
Downstream Toe	21±
Maximum Tailwater	Will be below the outlet invert

d. Reservoir Length.

Normal Pool Level - Main Dam	680'
Normal Pool Level - Secondary Dam	250'

e. Storage (Acre-Feet).

(1) Main Dam

Normal Pool Level	514
Top of Dam	830

(2) Secondary Dam

Normal Pool Level	15
Top of Dam	27

f. Reservoir Surface (Acres).

(1) Main Dam

Normal Pool	23.3
Top of Pool	30.2

(2) Secondary Dam

Normal Pool	1.6
Top of Dam	2.3

g. Dam.

(1) Main Dam

Type	Earthfill
Length	670+'
Height	74+' maximum
Top Width	30'
Volume of Fill	280,000+ cu. yds.
Side Slopes	Upstream 1V:2.5H Downstream 1V:3H
Zoning	None
Impervious Core	None
Cutoff	Slurry trench cutoff wall chimney drain in embankment
Grout Curtain	None

(2) Secondary Dam

Type	Earthfill
Length	230+'
Height	34+' maximum
Top Width	30'
Volume of Fill	39,500+ cu. yds.
Side Slopes	Upstream 1V:2.5H Downstream Top of slope, 1V:3H Bottom of slope, 1V:7H
Zoning	None
Impervious Core	None
Cutoff	Slurry trench cutoff wall chimney drain in embankment
Grout Curtain	None

h. Outlet Works.

(1) Main Dam

Type	Free flow conduit
Pipe Size and Material	42 inch asbestos bonded corrugated steel pipe
Entrance Invert	72.5
Exit Invert	51.0
Type of Energy Dissipator	Stone riprap

(2) Secondary Dam

Type	Free flow conduit
Pipe Size and Material	48 inch asbestos bonded corrugated steel pipe
Entrance Invert	40.4
Exit Invert	20.0
Type of Energy Dissipator	Stone Riprap

i. Principal Spillway.

(1) Main Dam

Type	Drop Inlet
Crest of Elevation of Spillway Notch	76.2
Length of Spillway Notch	6 feet
Crest Elevation of Spillway	76.7
Length of Spillway	24 feet (including notch)

(2) Secondary Dam

Type	Drop Inlet
Crest of Elevation of Spillway Notch	49.2
Length of Spillway Notch	10 feet
Crest Elevation of Spillway	49.7
Length of Spillway	25 feet (including notch)

SECTION 2
DESIGN DATA

2.1 Design

a. Data Available. The available information was provided by the State of Maryland, Water Resources Administration. The information includes contract drawings dated May 15, 1973, and the design report entitled, Erosion and Sediment Control Measures at LNG Receiving Terminal Site, Cove Point, Maryland, revised May 30, 1973. As-built drawings of revisions made to the main and secondary spillways dated 1976 were available at the Columbia LNG plant.

(1) Hydrology and Hydraulics. Hydrologic and hydraulic calculations for the dams are included in the design report.

(2) Embankment. Design calculations and results of the subsurface investigations are summarized in the design report.

(3) Appurtenant Structures. The structural details of the appurtenant structures are shown on the contract drawings dated 1973. The revisions made to the drop inlet boxes of both the main and secondary dams are shown on the 1976 as-built drawings available at the Columbia LNG plant.

b. Design Features.

(1) Embankment. The main dam was constructed across Wilbur Creek and the secondary dam was constructed across a small valley right of the main dam. An extensive subsurface investigation was conducted under the supervision of Woodward-Moorhouse & Associates, Inc., to evaluate the foundation conditions of the dam and to locate borrow sources.

The typical sections for both dams shown on the contract drawings indicate that the dams are constructed of compacted random fill. Constructed along the center of each dam is a chimney drain, and constructed along the upstream side of each chimney drain is a slurry trench cutoff wall. Drainage from the chimney drains is collected in abutment filters in the embankment and directed into a collection box located just beyond the toe of the embankment of each dam. The collection box for the main dam was accessible, but the collection box for the secondary dam was buried. Drainage is directed from the toe collection boxes to a third collection box through 8 inch diameter steel pipes. From this collection box, the drainage is discharged into the

fresh water marsh. A 3' foot deep main spillway filter was constructed adjacent to the right abutment of the main dam to intercept any water that may seep around the right abutment of the dam. Typical sections of the dams are shown on copies of the contract drawings included in Appendix E.

Piezometers were installed on the crest and on the downstream slope of both dams to monitor the water level in the embankment both during and after the dredging operation. Seventeen piezometers were installed in the main dam and three piezometers were installed in the secondary dam. Personnel at the Columbia LNG facility continually check and record the water levels in the piezometers.

(2) Appurtenant Structures. The appurtenant structures of each dam consist of a principal spillway which includes a drop inlet and the outlet works. The drop inlet of the main dam conveys overflow into the secondary impoundment through a 42 inch corrugated steel pipe. The drop inlet of the secondary dam conveys overflow through the embankment in a 48 inch corrugated steel pipe. The contract drawings indicate that the 48 inch pipe has three anti-seepage collars.

c. Design Data.

(1) Hydrology and Hydraulics. Design data are included in the design report.

(2) Embankment. Design data are included in the design report and on the contract drawings.

2.2 Construction. Construction of the dams was completed in 1974. Revisions were made to the drop inlet boxes of both dam spillways in 1976. As-built drawings are available at the Columbia LNG plant.

2.3 Operation. The only records maintained by the owner are water levels regularly recorded in the piezometers on both the main and secondary dams.

2.4 Other Investigatons. An engineer from the Wilmington office of the Columbia LNG Corporation conducts an inspection of both dams and appurtenant structures annually.

2.5 Evaluation.

a. Availability. The design report and the contract drawings are available, and the as-built drawings of revisions made to the main and secondary dam spillways was available at the Columbia LNG Plant.

b. Adequacy. The available data is considered sufficient to evaluate the design and construction of the dams.

SECTION 3
VISUAL INSPECTION

3.1 Findings.

a. General. The on site inspection of each Columbia LNG spoil embankent consisted of:

(1) Visual inspection of the embankment, abutments, and embankment toe.

(2) Visual examination of the appurtenant structures.

(3) Evaluation of the downstream area hazard potential.

The specific observations are shown on Plate A-1.

b. Embankment. The general inspection of each embankment consisted of searching for indications of structural distress, such as cracks, subsidence, bulging, wet areas, seeps and boils, and observing general maintenance conditions, vegetative cover, erosion, and other surficial features.

(1) Main Dam. Minor erosion was noted on the upstream slope along the waterline. There is no slope protection on the upstream slope. An erosion gully was noted along the left abutment approximately half way up the slope. A small seepage of immeasurable flow area was noted near the downstream toe left of the collection box. The source of the seepage is not evident. Another seepage area was noted near the toe of the dam approximately 120 feet right of the collection box. The estimated flow rate of the seepage was 2 gpm.

The crest of the dam was surveyed and the variance in elevation was 18 inches between the high and low points. Also, the low point on the crest corresponds to the design crest elevation of the main dam, +87.5. Freeboard at the time of inspection was approximately 13.5 feet. The dam crest profile is included on Plate A-2.

(2) Secondary Dam. Two seepage areas were noted downstream of the toe and left of the drainage channel. The seepage area nearest the toe has an estimated flow rate of 10 gpm, is located near a buried collection box, and could be associated with leakage from the box. The second seep is located approximatley 100' downstream of toe and extends along the drainage channel for 100'. The water flowing from both seepage areas was clear.

The crest of the dam was surveyed and the variance in elevation was 12 inches between the high and low points. Also, the low point on the crest is 2.5 inches below the design crest elevation of the secondary dam which is +55. Freeboard at the time of inspection was approximately 8 feet. The dam crest profile is included on Plate A-3.

c. Appurtenant Strucutures. The appurtenant structures were found to be in satisfactory condition. The collection box located at the toe of the secondary dam should be uncovered and checked for possible leakage.

d. Reservoir Area. In general, the reservoirs of both dams are surrounded by heavily grassed or wooded areas.

e. Downstream Channel. The structures downstream from the main dam include a guardhouse, the tunnel portal and ventilation building for the underwater tunnel to the docking facility, and two above ground liquified natural gas pipelines. If the main dam failed, the resulting flood could damage these facilities. The downstream channel of the secondary dam empties into a fresh water marsh. If the secondary dam failed, the resulting flood could damage the facilities noted directly downstream of the main dam. However, based on our visual observations, damages sustained from a failure of the secondary dam would be significantly less than damages sustained by a failure of the main dam. Consequently, a high hazard classification is warranted for the main dam and a significant hazard classification is warranted for the secondary dam.

3.2 Evaluation. The visual examination and observations of the Columbia LNG spoil embankments indicate that both dams are in fair condition and the appurtenant structures are in good condition. It is recommended that the minor erosion on the upstream slope of the main dam be repaired. A Professional Engineer experienced in dam design and construction should be retained to investigate the sources of the seepage noted along or beyond the toes of the main dam and the secondary dam and to recommend measures for controlling the seepages if they are related to the dams.

SECTION 4
OPERATIONAL FEATURES

4.1 Procedure. There are no formal operating procedures for either dam. The pool level of each reservoir is normally maintained at or just below the weir crest elevation of the drop inlet spillways.

4.2 Maintenance of the Dams. Maintenance of the dams is considered to be fair. The downstream slopes of both dams and the upstream slope of the secondary dam are mowed regularly. Each dam is subjected to a thorough in house inspection annually.

4.3 Maintenance of Operating Facilities. The maintenance of the operating facilities is considered to be satisfactory.

4.4 Warning System No formal warning system exists for alerting personnel downstream of the dams in the case of any emergency.

4.5 Evaluation. The overall maintenance condition of the dams and the appurtenant structures is considered to be satisfactory.

SECTION 5
HYDRAULICS AND HYDROLOGY

5.1 Evaluation of Features.

a. Design Data. The revised May 30, 1973 report, Erosion and Sediment Control Measures at LNG Receiving Terminal Site, Cove Point Maryland, indicates that the design of the main impoundment spillway was based upon an inflow design flood of 212 cubic feet per second (cfs) resulting from a 100-year, 6-hour storm of 6.5 inches over the impoundment drainage area of 0.19 square miles. The report indicates that the secondary impoundment, which receives most of its inflow from the spillway outletting from the main impoundment, has a spillway capacity sized for an inflow design flow of 230 cfs. The drainage area tributary directly to the secondary impoundment is 0.02 square miles and the combined secondary impoundment drainage area including that of the main impoundment totals 0.21 square miles.

b. Experience Data. No records of maximum pool levels are available.

c. Visual Observations. Several observations made during the visual inspection of the Columbia LNG impoundments are particularly relevant to the hydraulic and hydrological evaluations.

(1) Embankments. The survey of the existing dam crest profiles performed during the visual inspection indicates that the main impoundment crest lies at or slightly above its design elevation with the low point equalling its design crest elevation of 87.5 feet above mean sea level. While the crest level of the secondary impoundment is generally higher than its design elevation of 55 feet above m.s.l., the field survey indicates the crest low point to be 0.2 below the dam crest design elevation. Crest profiles established from these inspections were employed in subsequent hydraulic analyses.

(2) Appurtenant Structures. The drop inlet spillways observed during the visual inspection for the main and secondary impoundments have not been constructed in conformance with the spillways shown on the May, 1973 contract drawings for the dam itself. It was learned during the visual inspection that the overflow weir structures were constructed in 1976, or two years following completion of the dam embankments. Rating curves which reflect these as-built conditions have been derived for the drop-inlet spillways and outlet works and are employed in subsequent hydraulic analyses.

At the time of the visual inspection it was observed that pool levels behind both the main and secondary embankments were several feet below the level of the impoundment spillways. It was observed that spillway and outlet works for both of these impoundments were free of debris and were dry.

(3) Downstream Conditions. While there are no dwellings downstream from the Columbia LNG spoils impoundment complex, the portal structure for the tunnel which connects the liquified natural gas plant with the offshore docking and unloading facilities lies directly in the path of the main dam at a distance of only 500 feet from its downstream toe, and therefore is susceptible to serious damage in the event of a failure of the main dam embankment. The potential for loss of human lives exists at this location since security personnel regularly patrol the tunnel entrance. In addition the liquified natural gas transmission mains which exit from the tunnel portal and travel overland to the LNG storage facilities would also be vulnerable to serious damage should a failure of the main impoundment occur. Failure of the secondary dam may result in some damage to the above mentioned facilities causing an interruption of their use but, because these facilities are not in direct line with the secondary embankment, the potential for serious damage of these facilities is significantly less than the damage potential resulting from failure of the primary impoundment. In keeping with the potential hazard classification criteria established by the Office of the Chief of Engineers (OCE), these downstream conditions suggest that a "high" classification be assigned to the main dam of the Columbia LNG impoundment complex and a "significant" classification be assigned to the secondary dam.

d. Overtopping potential. According to the criteria promulgated by the Office of the Chief of Engineers, the recommended Spillway Design Flood (SDF) for a dam classified as "intermediate" with a "high" hazard potential, such as the main dam, is 100 percent of the Probable Maximum Flood (PMF) and the recommended SDF for a dam classified as "small" with a "significant" hazard potential, such as the secondary dam, ranges between a 100-year flood and 50 percent of the PMF. The Probable Maximum Precipitation (PMP) index as adjusted for the LNG impoundment complex drainage area is 20.0 inches in 24 hours.

(1) Main Impoundment. Employing criteria established by the Corps of Engineers, Baltimore District, 100 percent and 50 percent PMF inflow hydrographs developed using the HEC-1 computer program have peaks of 316 cfs and 158 cfs,

respectively for the main impoundment. It is important to note that the peak flow for 50 percent of the PMF derived is significantly less than the 212 cfs design inflow previously determined in the design report for a 100-year storm. This disparity is understandable since it is recognized that the Snyder method of synthetic unit hydrograph determination employed in the HEC-1 model may produce hydrograph peaks somewhat less than those derived using other methods when applied to relatively small drainage areas where the time of concentration is relatively short. However, in accordance with guidance provided by the Corps of Engineers, Baltimore District, no adjustment have been made to the PMF's determined for the Columbia LNG impoundment complex to account for this disparity.

PMF inflow hydrographs were routed through the Columbia LNG main impoundment for percentages ranging from 20 percent of the PMF to 100 percent PMF with each routing starting at the normal pool elevation of 76.2 feet above m.s.l. For the 50% PMF routing, the impoundment water level reached an elevation of 78.0 feet above mean sea level or 9.5 feet below the low point in the dam crest. For the 100% PMF routing, the reservoir water level reached an elevation of 80.8 feet above mean sea level remaining below the low point in the dam crest at an elevation of 87.5 feet above mean sea level. See Appendix D for a tabulation of the flood routing results.

(2) Secondary Impoundment. Outflow hydrographs from the main impoundment, developed from the above mentioned flood routings, were combined with inflow hydrographs developed for the drainage area tributary only to the secondary impoundment to derive combined inflow hydrographs for the secondary impoundment. The resultant combined inflow hydrographs have peaks of 137 cfs for a 100 percent PMF and 68 cfs for a 50 percent PMF.

PMF inflow hydrographs were routed through the Columbia LNG secondary impoundment for percentages ranging from 20 to 100 percent of the PMF with each routing starting at the normal pool elevation of 49.2 feet above m.s.l. For the 50 percent PMF routing, the impoundment water level reached an elevation of 50.3 feet above m.s.l. or 4.5 feet below the low point in the dam crest. For the 100 percent PMF routing the impoundment water level reached an elevation of 51.8 feet above m.s.l. remaining 3 feet below the low point in the secondary dam crest at an elevation of 54.8 feet above mean sea level. Results for intermediate routings are found in Appendix D.

e. Spillway Adequacy.

(1) Main Impoundment. The main impoundment of the Columbia LNG impoundment complex will pass 100 percent of the PMF without overtopping, and therefore its spillway is rated adequate.

(2) Secondary Impoundment. The secondary impoundment of the LNG impoundment complex will pass 100 percent of the PMF without overtopping. Since this flood is greater than the Spillway Design Flood required for the secondary dam, the spillway capacity for this impoundment is rated adequate.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability.

a. Visual Observations.

(1) Embankment.

(a) Main Dam. Of the deficiences of the main dam noted in SECTION 3, the more severe are the two seepage areas noted near the toe on either side of the collection box. At this time, these deficiencies are not considered serious relative to the stability of the dam.

(b) Secondary Dam. The only deficiencies were the two seepage areas noted downstream of the toe. The seepages are considered extensive enough to possibly affect the stability of the dam if they are related to the dam.

We recommend that the sources of the seepages at the main and secondary dams be investigated by a professional engineer experienced in the design and construction of dams, and that measures be taken to control the seepage if they are related to the dam.

(2) Appurtenant Structures. The structural conditions of the appurtenant structures of both dams are considered to be satisfactory.

b. Design and Construction Data.

(1) Embankment. Based on the available design calculations and the contract drawings, there are no conditions which adversely affect the stability of either dam.

(2) Appurtenant Structures. The contract drawings for the dams dated 1973 were obtained from the State of Maryland Water Resources Administration and the as-built drawings of revisions made to the main and secondary dam spillways dated 1976 are available at the Columbia LNG Plant.

c. Operating Records. The structural stability of the dams is not considered to be affected adversely by the operational features of the dams.

d. Seismic Stability. The dams are located in Seismic Zone 1. Based on our visual observations, the static stability of both dams appears to be adequate. Consequently, neither structure should present hazards from earthquakes.

SECTION 7
ASSESSMENT AND RECOMMENDATIONS/REMEDIAL MEASURES

7.1 Dam Assessment.

a. Assessment. The Columbia LNG main reservoir is an intermediate, high hazard impoundment and the secondary reservoir is a small, significant hazard impoundment. Failure of the main dam embankment could cause serious damage to the liquid natural gas tunnel, portal facilities and pipelines located immediately downstream. Failure of the secondary dam embankment could also damage these facilities, but to a lesser degree. The visual observations indicate that both the main dam and the secondary dam are in fair condition. However, the sources of the seepage areas noted near or downstream of both dams should be investigated by a Professional Engineer experienced in the design and construction of dams. The investigating engineer should recommend measures of controlling the seepages if they are related to either dam, and the Owner should implement the recommended measures.

Hydrologic and hydraulic analyses indicate that both the main and secondary impoundments will pass 100 percent of the PMF without overtopping, and therefore the spillway capacity for each of these dams is rated adequate.

b. Adequacy of Information. Available information, in conjunction with the visual observations, is considered to be sufficient to make the recommendations that are given below.

c. Urgency. Although there is no urgency in instituting the remedial measures recommended below, the measures should be accomplished in a timely manner.

d. Necessity for Additional Data. We recommend that the Owner retain a qualified Professional Engineer to conduct an investigation to determine the source of the seepage noted at or below the toes of the main and secondary dams and to recommend a means of controlling the seeps if they are related to the dams.

7.2 Recommendations/Remedial Measures.

It is recommended that the following remedial measures be implemented by the Owner:

a. Repair the erosion noted just above the water line along the [illegible] slope of the main dam.

b. Retain a Professional Engineer experienced in dam design and construction to investigate the sources of the seepage areas noted near the downstream toe of the main embankment and the seepage areas located downstream of the toe of the secondary dam. The seepages should be monitored and, if necessary, should be controlled in accordance with the recommendations of the Professional Engineer.

c. Develop a formal warning system to alert any personnel downstream of the dam in the event of emergencies.

APPENDIX A

VISUAL INSPECTION CHECKLIST

PHASE I

APPENDIX A
VISUAL INSPECTION CHECKLIST
PHASE I

Name of Dam: Columbia LNG County (or City): Calvert State: Maryland

NDI ID. No.: MD- 116 Type of Dam: Earth fill Hazard Category: Main Dam: HIGH 2nd Dam: SIGNIFICANT

Date(s) Inspection: 7/2/80 & 8/5/80 Weather: Clear Temperature: 90°F

Pool Elevation at Time of Inspection: Main: 74±' 2nd: 47±' M.S.L. Tailwater at Time of Insp. Main: 47±' 2nd: None M.S.L.

Inspection Personnel:

Douglas Nauman
Jim Wise

Review Inspection Personnel:

Edward J. Zeigler
Frank H. Donaldson
Douglas Nauman

Douglas Nauman Recorder

VISUAL INSPECTION
PHASE I
EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SURFACE CRACKS	None	
USUSUAL MOVEMENT OR CRACKING AT OR BEYOND THE TOE	None	
SLOUGHING OR EROSION OF EMBANKMENT AND ABUTMENT SLOPES	Minor erosion gully noted along left abutment on downstream slope of main dam.	
VERTICAL AND HORIZONTAL ALIGNMENT OF THE CREST	Horiz. alignment of both dams is satisfactory; vertical alignment of main dam varies 18"; vertical alignment of 2nd dam varies 12"	Low point on crest of main dam is equal to design crest elev.; Low point on 2nd dam is 2.5" below design crest elev.
RIPRAP FAILURES	No riprap protection on upstream slope of either main or 2nd dams. Minor erosion noted along upstream bank of main dam	Repair erosion along upstream bank of main dam.

VISUAL INSPECTION
PHASE I
EMBANKMENT

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
JUNCTION OF EMBANKMENT AND ABUTMENT, SPILLWAY AND DAM	Minor erosion noted along left abutment of downstream slope of main dam	
ANY NOTICEABLE SEEPAGE *	Main Dam: Two seepage areas near toe - one with immeasurable flow right of collection box, the other with 2± gpm flow right of box	Sources of seepages not evident; recommend retaining prof. engineer to investigate sources and recommend measures to control seepage.
STAFF GAGE AND RECORDER	None	
DRAINS	Main Dam: Chimney filter drain and plugged 30" temporary drain. 2nd Dam: Chimney filter drain and spillway outlet works	Spillway outlet works of Main dam located right of right abutment.
* NOTICEABLE SEEPAGE (CONTINUED)	Secondary Dam: Two seepage zones noted beyond toe and left of drain. channel. Est. flow of seepage nearest toe is 10 gpm.	Same recommendation as for "Main Dam" above

VISUAL INSPECTION
PHASE I
OUTLET WORKS

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CRACKING AND SPALLING OF CONCRETE SURFACES IN OUTLET CONDUIT	None	
INTAKE STRUCTURE	Main Dam: Drop Inlet Secondary Dam: Drop Inlet	
OUTLET STRUCTURE	Main Dam: 42-inch asbestos bonded corrugated steel pipe Secondary Dam: 48-inch asbestos bonded corrugated steel pipe	
OUTLET CHANNEL	Main Dam: Overflow discharges directly into 2nd ary impoundment Secondary Dam: short channel discharges into fresh water marsh.	
EMERGENCY GATE	None for either dam	

VISUAL INSPECTION
PHASE I
UNGATED SPILLWAY - PRINCIPAL SPILLWAY

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE WEIR	Main Dam: Concrete box around drop inlet has 6' weir notch Secondary Dam: Concrete box around drop inlet has 10' weir notch	
APPROACH CHANNEL	None	
DISCHARGE CHANNEL	Main Dam: overflow discharged directly into secondary impoundment Secondary Dam: Short (<300') channel discharges into marsh	Riprap energy dissipators placed directly downstream of outlet pipes from both dams.
BRIDGE AND PIERS	None	

VISUAL INSPECTION
PHASE I
GATED SPILLWAY

VISUAL EXAMINATION	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONCRETE SILL	None	
APPROACH CHANNEL	None	
DISCHARGE CHANNEL	None	
BRIDGE PIERS	None	
GATES AND OPERATION EQUIPMENT	None	

VISUAL INSPECTION
PHASE I
INSTRUMENTATION

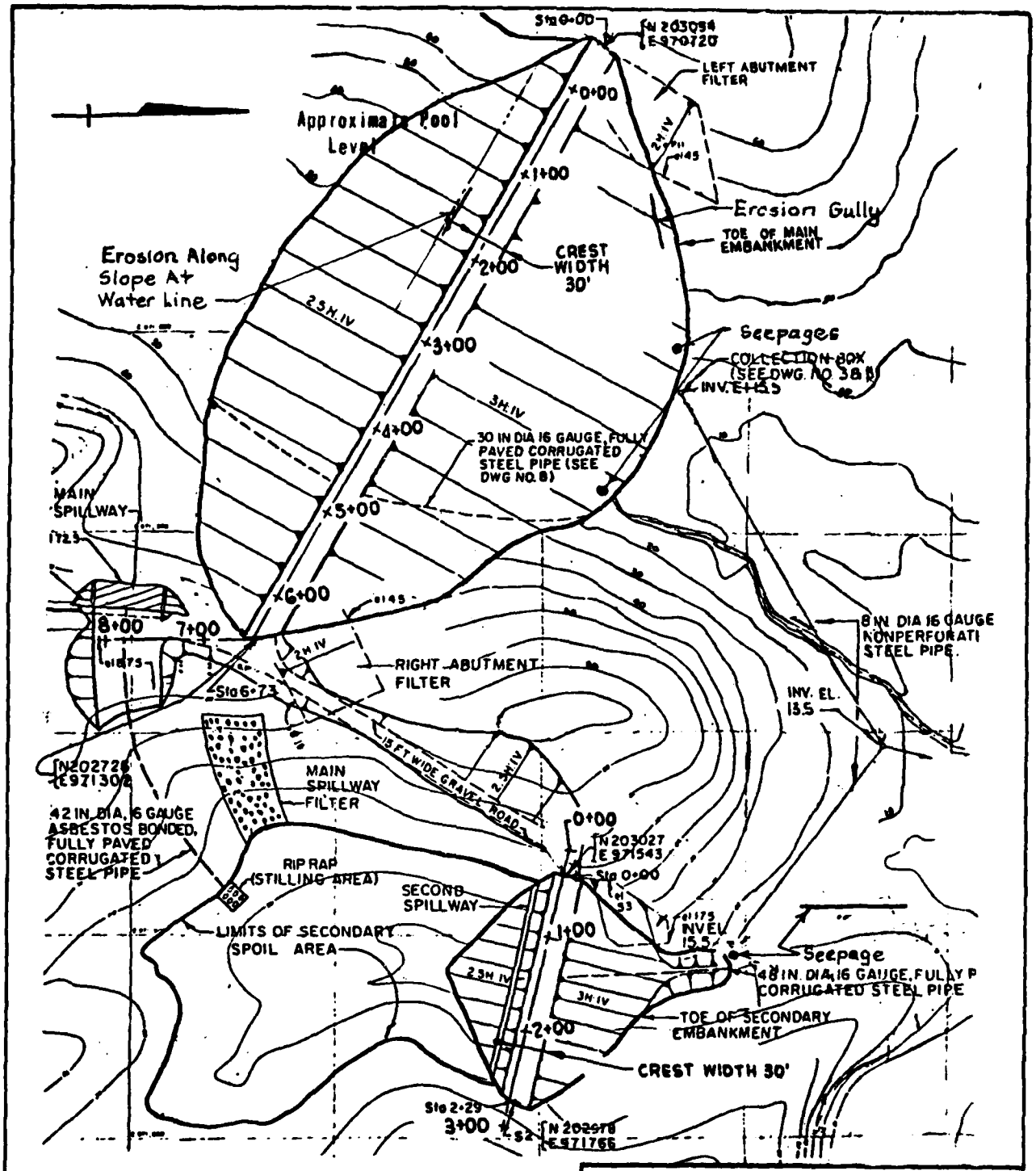
VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
MONUMENTATION/SURVEYS	None	
OBSERVATION WELLS	Three located beyond toe of main Dam, One located beyond top of Secondary Dam	
WEIRS	None	
PIEZOMETERS	Main Dam: 17 located along crest and on downstream slope Secondary Dam: 3 located on downstream slope	The Owner regularly measures and records water levels in the piezometers.
OTHER	Settlement plates were installed in both embankments, 6 in main dam and 2 in secondary dam	Settlement plates have not been monitored since completion of dredging

VISUAL INSPECTION
PHASE I
RESERVOIR

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
SLOPES	Niether dam has upstream slope protection. Reservoir slopes are either wooded or grass covered	Minor erosion noted along water line of main dam
SEDIMENTATION	None noted	
UPSTREAM RESERVOIRS	Main impoundment is upstream of Secondary Dam. No other upstream reservoirs noted.	

VISUAL INSPECTION
PHASE I
DOWNSTREAM CHANNEL

VISUAL EXAMINATION OF	OBSERVATIONS	REMARKS OR RECOMMENDATIONS
CONDITION (OBSTRUCTIONS, DEBRIS, ETC.)	Downstream channel of Secondary Dam discharges into a fresh water marsh.	
SLOPES	Downstream channel of Secondary Dam is shallow with near vertical slopes which are partially protected by riprap	
APPROXIMATE NUMBER OF HOMES AND POPULATION	Plant facilities downstream of dams include guard house, tunnel portal, and ventilation building for tunnel	Two above-ground liquified natural gas pipelines are also downstream



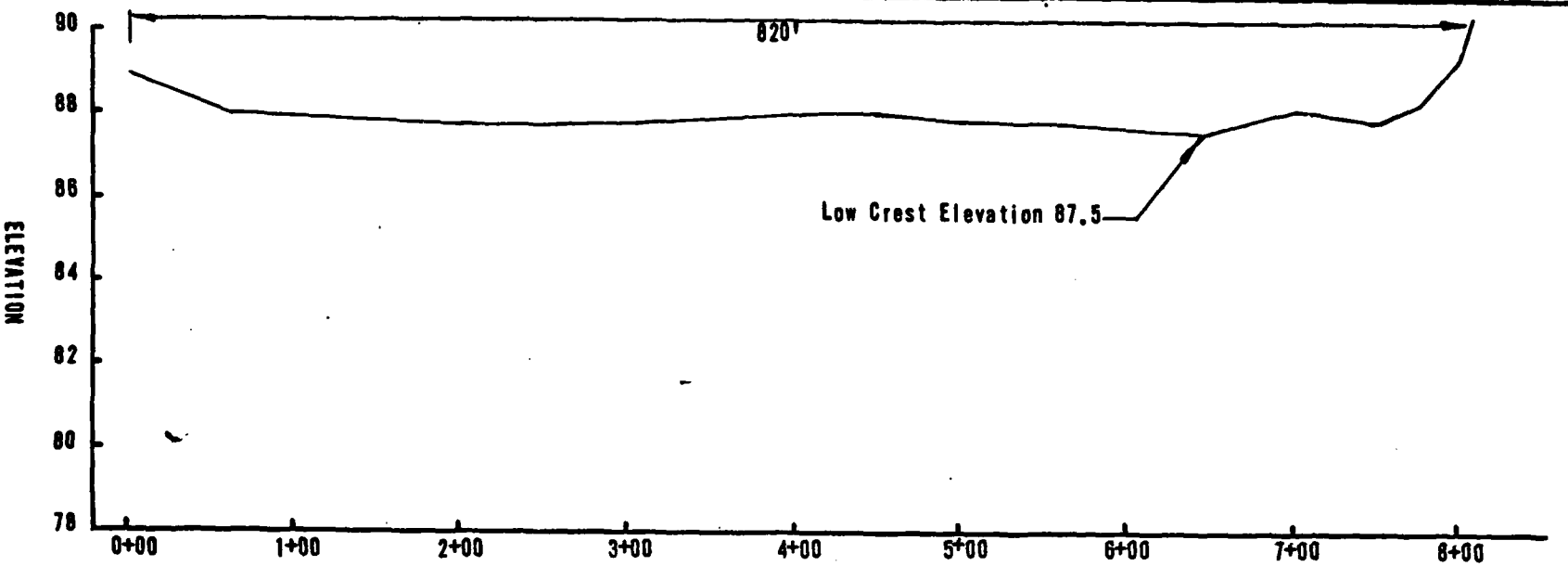
PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

COLUMBIA LNG

COLUMBIA LNG CORPORATION

RESULTS OF VISUAL INSPECTION

JULY 1980 PLATE A-1



DAM CREST SURVEY

(LOOKING DOWNSTREAM)

NOTE:

DAM CREST SURVEY STATIONS ARE SHOWN ON PLATE A-1.

DATUM ELEVATION IS INTERPOLATED FROM CONTRACT DRAWINGS

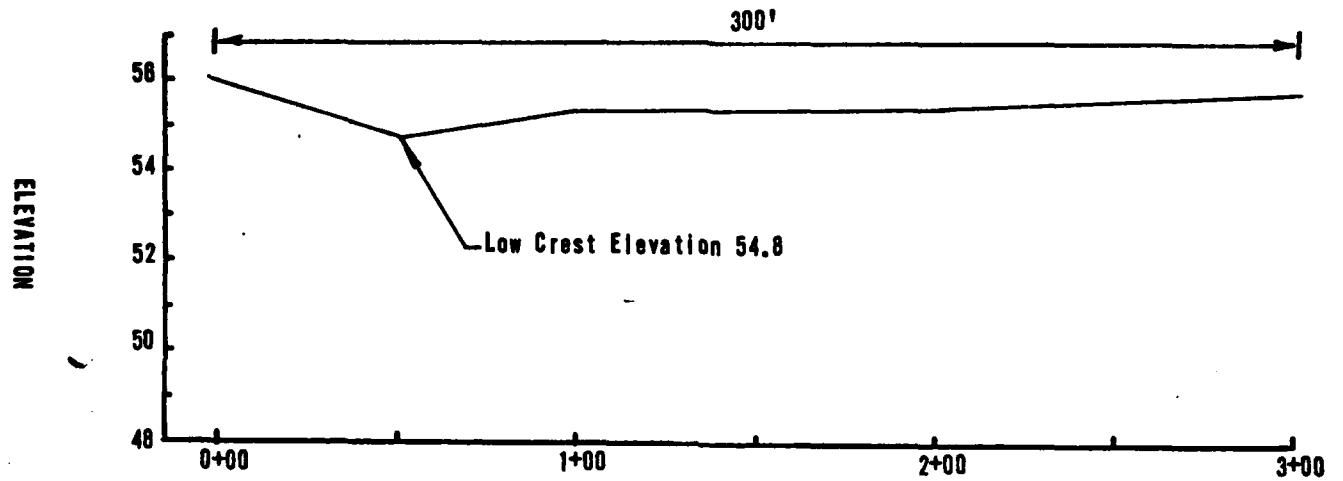
PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

COLUMBIA LNG-
MAIN DAM
COLUMBIA LNG CORPORATION

DAM CREST SURVEY

JULY 1980

PLATE A-2



DAM CREST SURVEY

(LOOKING DOWNSTREAM)

NOTE:

DAM CREST SURVEY STATIONS ARE SHOWN ON PLATE A-1.

DATUM ELEVATION IS INTERPOLATED FROM CONTRACT DRAWINGS

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

COLUMBIA LNG
SECONDARY DAM

COLUMBIA LNG CORPORATION

DAM CREST SURVEY

JULY 1980

PLATE A-3

APPENDIX B

ENGINEERING DATA CHECKLIST

PHASE I

APPENDIX B

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

NAME OF DAM Columbia LNG

ID# NDI ID NO. MD-116

ITEM	REMARKS
AS-BUILT DRAWINGS	Contract drawings entitled, "Columbia LNG Spoil Embankments, Cove Point, Maryland" by Woodward Moorhouse & Assoc., Inc. dated May 15, 1973. As-Builts of revisions to spillways dated 1976 available at LNG plant.
REGIONAL VICINITY MAP	Refer to Location Map, Plate E-1 in Appendix
CONSTRUCTION HISTORY	Construction records for dam construction kept at Columbia LNG plant.
TYPICAL SECTIONS OF DAM	Included in Constract Drawings and on Plate E-2 in Appendix
OUTLETS - PLAN - DETAILS - CONSTRAINTS - DISCHARGE RATINGS	Refer to Appendix D for outlet ratings. Plan and Details of Drop inlets for both main and secondary dams included on As-Built drawings dated 1976 available at Columbia LNG plant

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

ITEM	REMARKS
RAINFALL/RESERVOIR RECORDS	None
DESIGN REPORTS	Refer to report, " Erosion and Sediment Control Measures at LNG Receiving Terminal Site, Cove Point, Md., revised May 30, 1973.
GEOLOGY REPORTS	Refer to Design Report dated May 30, 1973
DESIGN COMPUTATIONS HYDROLOGY & HYDRAULICS DAM STABILITY SEEPAGE STUDIES	Refer to Design Report dated May 30, 1973
MATERIALS INVESTIGATIONS BORING RECORDS LABORATORY FIELD	Refer to Design Report dated May 30, 1973

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

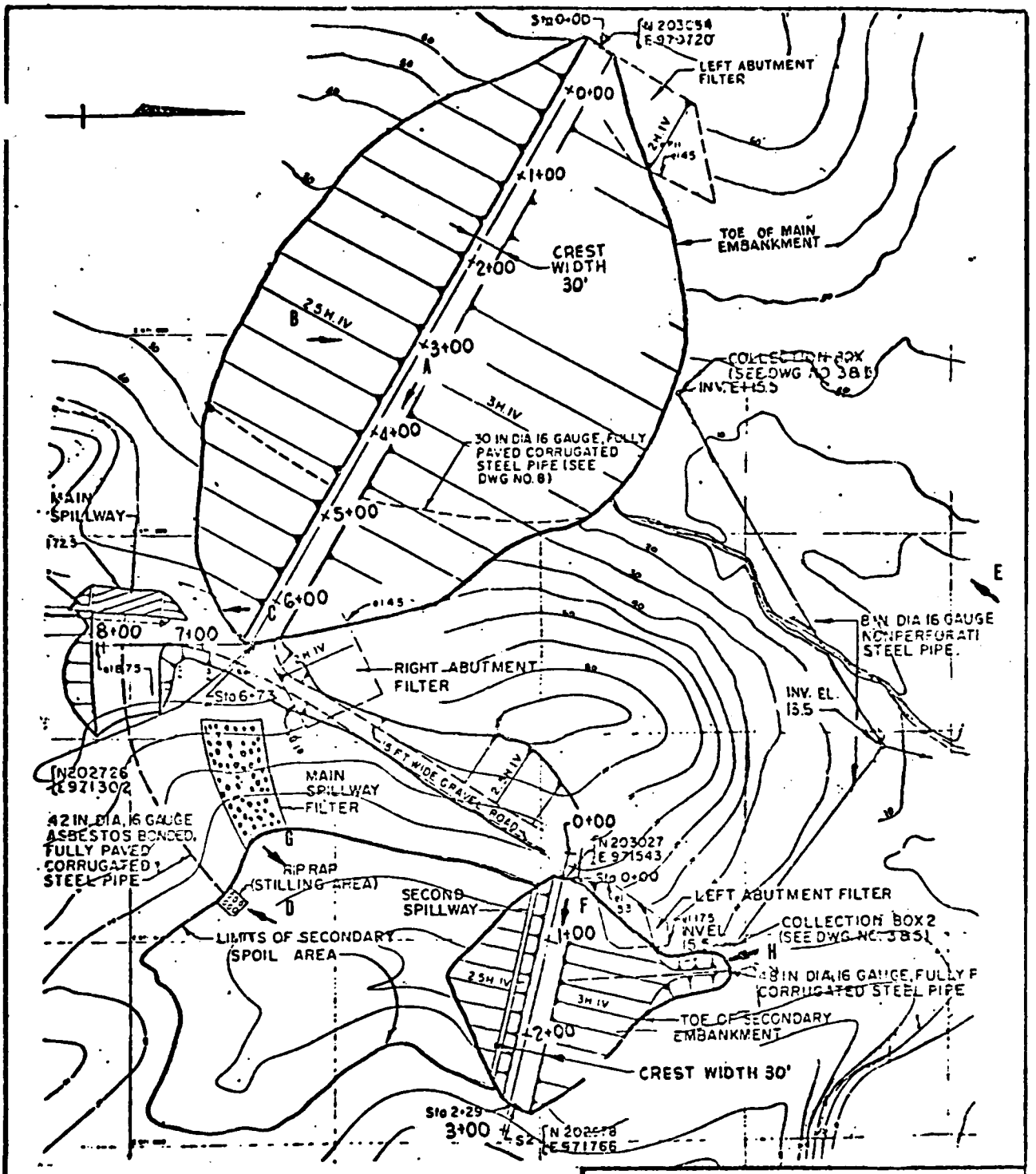
ITEM	REMARKS
POST CONSTRUCTION SURVEYS OF DAM	Engineering staff of Columbia LNG Corporation conducts annual inspection of both dams and appurtenant structures.
BORROW SOURCES	Borrow obtained from on-site source
MONITORING SYSTEMS	Refer to Contract Drawings for locations of piezometers, observation wells, and settlement plates. Of the three, only the piezometers are still being monitored.
MODIFICATIONS	Owner sealed off 30-inch drain through main embankment prior to dredging. Modifications were made to drop inlet boxes of both main and secondary dam spillways in 1976.
HIGH POOL RECORDS	None

CHECKLIST
ENGINEERING DATA
DESIGN, CONSTRUCTION, OPERATION
PHASE I

ITEM	REMARKS
POST CONSTRUCTION ENGINEERING STUDIES AND REPORTS	Engineering staff of Columbia LNG Corporation conducts annual inspection of both dams and appurtenant structures.
PRIOR ACCIDENTS OR FAILURE OF DAM DESCRIPTION REPORTS	None
MAINTENANCE OPERATION RECORDS	None
SPILLWAY PLAN SECTIONS DETAILS	Outlet structure drain pipe details for both spillways shown on Contract Drawings Modifications to drop inlet boxes shown on As-Built Drawings dated 1976 available at Columbia LNG plant.
OPERATING EQUIPMENT PLANS AND DETAILS	None

APPENDIX C

PHOTOGRAPHS



SCALE

0 100' 200' 300'

Camera Location And Direction

A Photograph Identification Letter

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

COLUMBIA LNG

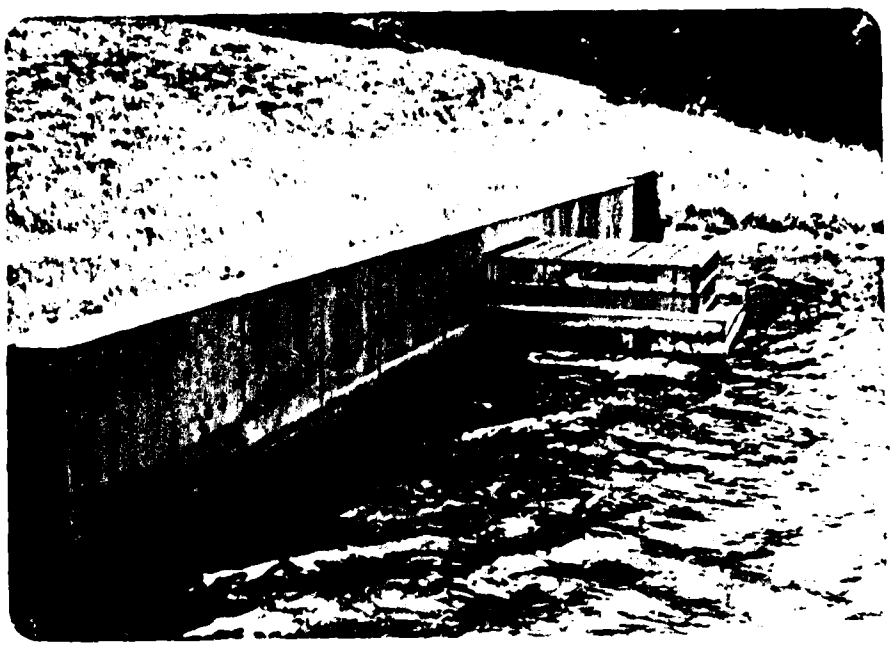
COLUMBIA LNG CORPORATION

GUIDE TO LOCATION OF PHOTOGRAPHS

JULY 1980 PLATE C-1

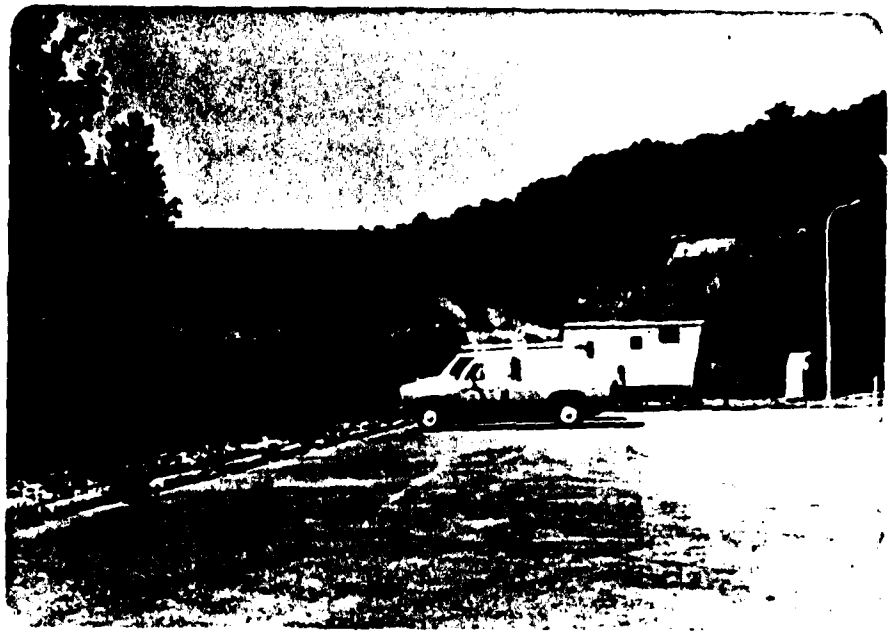
A. Crest of main embankment

B. Piezometers on crest of main embankment



C. Main Spillway (drop inlet)

D. Outlet pipe from main spillway



E. Guardhouse downstream of main embankment

F. Crest of secondary embankment

G. Upstream slope of secondary embankment and drop inlet

H. Outlet pipe from secondary embankment

APPENDIX D

HYDROLOGY AND HYDRAULICS

BASE DATA FOR DETERMINATION OF PROBABLE MAXIMUM FLOOD, UNIT HYDROGRAPH AND *INFLOW HYDROGRAPHS*

Name of Dam: Columbia LNG Main Dam, NDI-ID MD-116

Unit Hydrograph Parameters

Watershed Drainage Area	0.194 sq. miles
Main Channel Length, L	0.66 miles
Main Channel to Centroid Length, Lca	0.30 miles
Lag Time $tp = Ct (L \times Lca)^{0.3}$	2.5 hours
Basin Zone Location from Unit Hydrograph Coefficient Map	37
Basin Coefficients	
Cp^1	0.35
Ct^1	4.07

Inflow Hydrograph Parameters[1]

Base Flow at Start of Storm	1.5 c.f.s./sq. mile
Initial Rainfall Loss	1 inch
Uniform Rainfall Loss	0.05 inches/hour
Ratio of Peak Discharge Used to Compute Base Flow which Deviates from Hydrograph Falling Limb	0.05
Ratio of Recession Flow occuring 10 Tabulation Intervals Later	2.0

Rainfall Data[2]

Probable Maximum Precipitation Index for 24 hours and 200 square miles	25 inches (Zone 6)
Percentage Adjustments of PMP for Drainage Area	
6 hour storm	112%
12 hour storm	123%
24 hour storm	132%

---

[1] Basin Coefficients and Hydrograph Data established by Corps of Engineers Baltimore District.

[2] Hydrometeorological Report 33, Corps of Engineers, 1956

BASE DATA FOR DETERMINATION OF PROBABLE MAXIMUM FLOOD, UNIT HYDROGRAPH AND INFLOW HYDROGRAPHS

Name of Dam: Columbia LNG Secondary Dam, NDI-ID MD-116

Unit Hydrograph Parameters

Watershed Drainage Area	0.0184 sq. miles
Main Channel Length, L	0.12 miles
Main Channel to Centroid Length, Lca	0.07 miles
Lag Time $tp = Ct\ (L \times Lca)^{0.3}$	0.946 hours
Basin Zone Location from Unit Hydrograph Coefficient Map	37
Basin Coefficients	
Cp_1	0.35
Ct_1	4.07

Inflow Hydrograph Parameters[1]

Base Flow at Start of Storm	1.5 c.f.s./sq. mile
Initial Rainfall Loss	1 inch
Uniform Rainfall Loss	0.05 inches/hour
Ratio of Peak Discharge Used to Compute Base Flow which Deviates from Hydrograph Falling Limb	0.05
Ratio of Recession Flow occuring 10 Tabulation Intervals Later	2.0

Rainfall Data[2]

Probable Maximum Precipitation Index for 24 hours and 200 square miles	25 inches
Percentage Adjustments of PMP for Drainage Area	
6 hour storm	112%
12 hour storm	123%
24 hour storm	132%

---

[1] Basin Coefficients and Hydrograph Data established by Corps of Engineers Baltimore District.

[2] Hydrometeorological Report 33, Corps of Engineers, 1956

Tabulation of Reservoir Area and Storage Vs. Elevation[1]

Name of Dam: Columbia LNG Main Dam, NDI-ID MD-116

Pool Elevation feet above m.s.l.	Surface[1] Area acres	Reservoir[2] Storage acre-feet
25 (Reservoir Bottom)	0	0
30	1.4	3.5
50	9.5	112
70	18.5	392
87.5 (Top of Dam)	30.2	830
90	31.8	896

Name of Dam: Columbia LNG Secondary Dam, NDI-ID MD-116

Pool Elevation feet above m.s.l.	Surface[1] Area acres	Reservoir[2] Storage acre-feet
28 (Reservoir Bottom)	0	0
30	0.07	0.07
40	0.7	4.0
50	1.7	16.1
54.8 (Top of Dam)	2.3	27.3
60	3.0	39.4
70	4.7	77.9

---

[1] Area Plainimetered from 80-scale photogrammetric mapping shown May 15, 1973 contract drawings by Woodward-Moorhouse & Associates, Inc.

[2] Computed by Rummel, Klepper & Kahl. Refer to "Reservoir Storage Computations" on Page D-4.

RESERVOIR STORAGE COMPUTATIONS

Name of Dam: Columbia LNG , NDI-ID MD-116

MAIN DAM

ELEV. FEET	PLAINMETERED AREA SQUARE INCHES	AREA ACRES	AVG. AREA ACRES	INCREMENTAL VOLUME ACRE-FEET	ACCUMULATED VOLUME ACRE-FEET
25	0	0			0
			0.69	3.45	
30	9.3	1.37			3.5
			5.43	108.6	
50	64.6	9.49			112
			14.02	280.4	
70	126.0	18.54			392
			25.19	503.8	
90	216.6	31.84			896

SECONDARY DAM

ELEV. FEET	PLAINMETERED AREA SQUARE INCHES	AREA ACRES	AVG. AREA ACRES	INCREMENTAL VOLUME ACRE-FEET	ACCUMULATED VOLUME ACRE-FEET
28	0	0			0
			0.0335	0.067	
30	0.45	0.067			0.07
			0.389	3.89	
40	4.80	0.71			4.0
			1.21	12.1	
50	11.55	1.70			16.1
			2.33	23.3	
60	20.15	2.96			39.4
			3.85	38.5	
70	32.24	4.74			77.9

[1] Area plainmetered from 80-scale photogrammetric mapping shown on May 15, 1973 contract drawings by Woodward-Moorehouse and Associates, Inc.

SPILLWAY/OUTLET RATING CURVE TABULATION[1]

Name of Dam: Columbia LNG Main Dam, NDI-ID MD-116

Pool Elevation feet above m.s.l.	6-Foot Weir Notch Capacity c.f.s.	24-Foot Weir Capacity c.f.s.	Outlet Capacity c.f.s.
76.2	0		
76.7	13.8	0	
77.0	17.7	16	76.8
78.0		125	89.7
79.0		290	101
80.0		491	111
84.0		1600	145
88.0		3070	172
90.0		3917	184

Calculation Basics

6-Foot Weir Notch Capacity (Modified sharp crested weir with vertical upstream face)

$Q = CLH^{1.5}$

$Q = 3.25 \times 6 \times H^{1.5}$

$Q = 25.2\ H^{1.5}$, whre H = Pool Elevation = 76.2

24-Foot Weir Capacity (Modified sharp crested weir with vertical upstream face)

$Q = CLH^{1.5}$

$Q = 3.35 \times 24 \times H^{1.5}$

$Q = 80.4\ H^{1.5}$, where H = Pool Elevation = 76.7

Outlet Capacity of 42-inch Pipe (Orifice Control)

$Q = Ca\sqrt{2gH}$

$Q = 0.6 \times 9.62\sqrt{64.4}\ H^{0.5}$

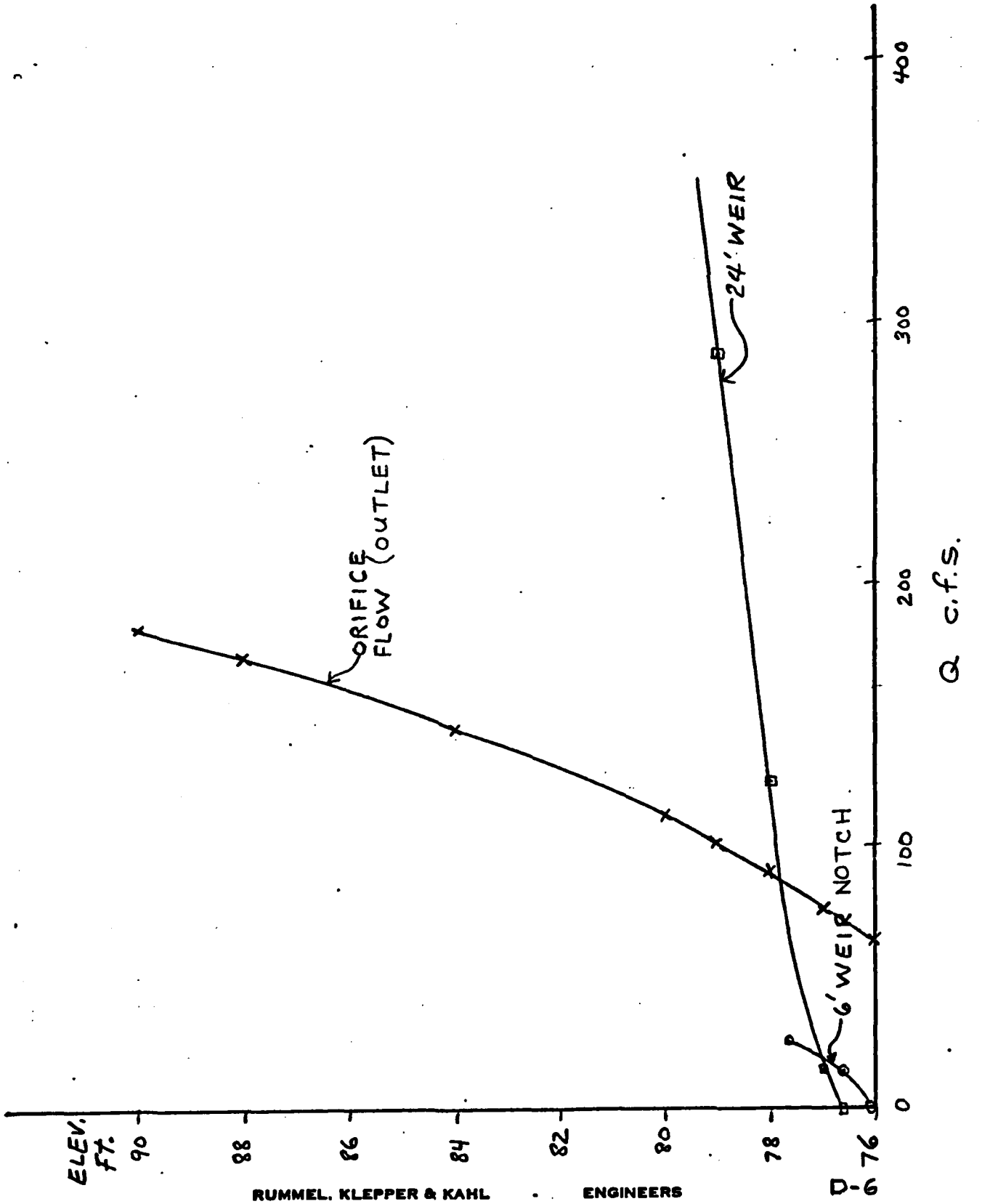
$Q = 46.3\ H^{.5}$, where H = Pool Elevation = 74.3

---

1 Computed by Rummel, Klepper & Kahl

BY GES DATE 7/31/80 SUBJECT Columbia - NC SHEET NO. 9 OF
CHKD. BY DATE JOB NO. 580-21-11.D

Outlet Rating Curve for Main Dam.



RUMMEL, KLEPPER & KAHL · ENGINEERS

D-6

SPILLWAY/OUTLET RATING CURVE TABULATION[1]

Name of Dam: Columbia LNG Secondary Dam, NDI-ID MD-116

Pool Elevation feet above m.s.l.	10-Foot Weir Notch Capacity c.f.s.	25-Foot Weir Capacity c.f.s.	Outlet Capacity c.f.s.
49.2	0		
49.7	12.9	0	
50.0	26.1	50	120.8
51.0		104	135.1
52.0		139	150.0
53.0		165	160.0
54.0		189	171.0
55.0		210	181.2
56.0		229	191.0

Calculation Basics

10-Foot Weir Notch Capacity (Modified sharp crested weir with inclined upstream face)

$Q = CLH^{1.5}$

$Q = 3.65 \times 10 \text{ ft} \times H^{1.5}$

$Q = 36.5\ H^{1.5}$, where H = Pool Elevation minus 49.2

25-Foot Weir Capacity (Modified sharp crested weir with inclined upstream face)

$Q = CLH^{1.5}$

$Q = 3.65 \times 25 \text{ ft} \times H^{1.5}$

$Q = 91.25\ H^{1.5}$, where H = Pool Elevation minus 49.7

Outlet Capacity of 48-inch Pipe (Orifice Control)

$Q = Ca\sqrt{2gH}$

$Q = 0.6 \times 12.56\text{ft} \times \sqrt{64.4\ H^{.5}}$

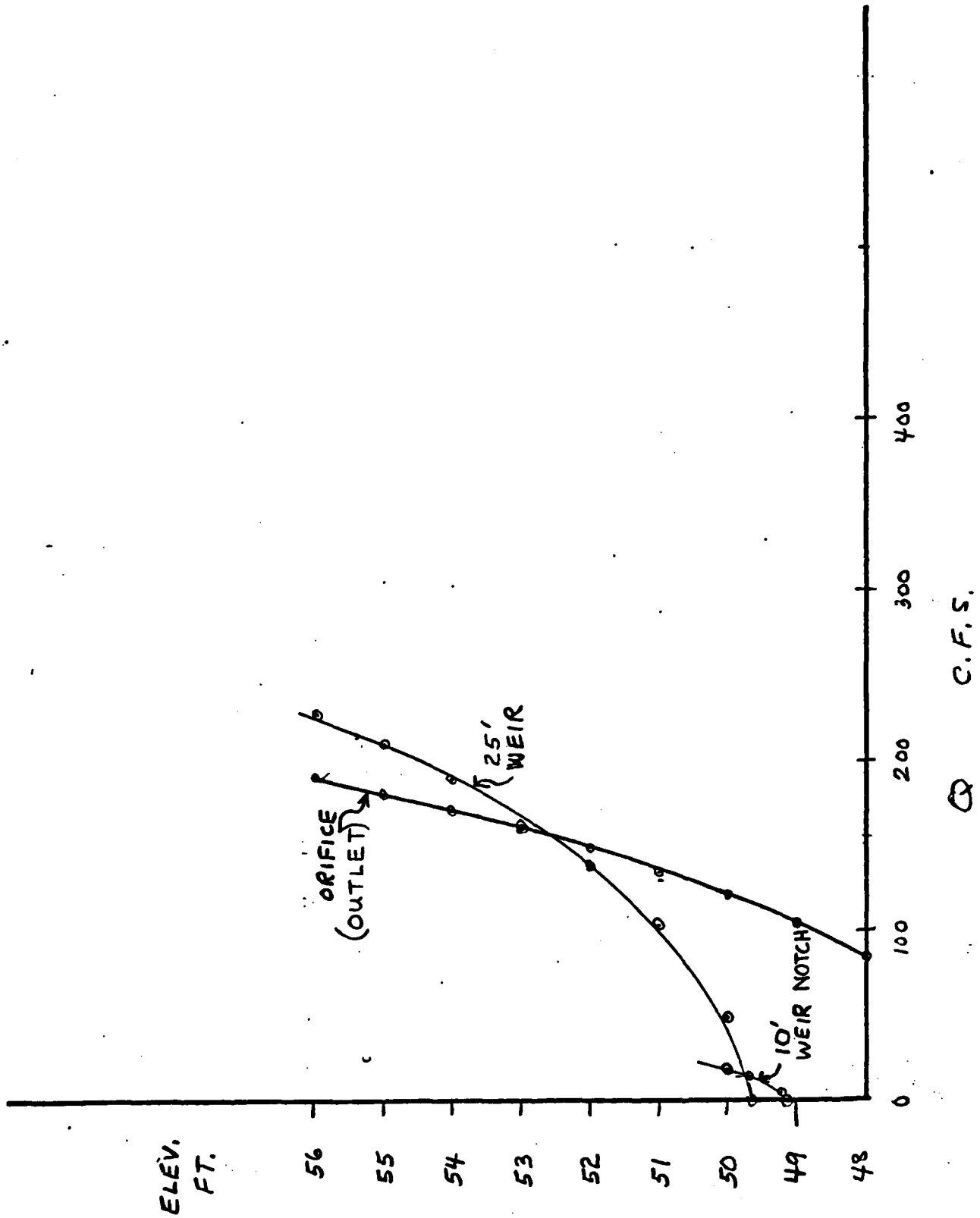
$Q = 60.4\ H^{0.5}$, where H = Pool Elevation minus 46.0

---

[1] Computed by Rummel, Klepper & Kahl

BY GES DATE 7/30/80 SUBJECT Columbia LNG SHEET NO. 4 OF
CHKD. BY DATE JOB NO. 580-21-11D

WEIR AND PIPE FLOW CURVE
FOR SECONDARY DAM



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**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  06 FEB 80
**********
     1                A1       SNYDER UNIT HYDROGRAPH, FLOOD ROUTING AND DAM OVERTOPPING ANALYSIS FOR
     2                A2       20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% AND 100% PMF AT COLUMBIA LNG PRIMARY DAM
     3                A3       NDI-I.D. MD116  COMM.NO. 580-21-11D
     4                B    150       0      30       0       0       0       0       0      -4       0
     5                B1     5
     6                J      1       9       1
     7                J1   0.2     0.3     0.4     0.5     0.6     0.7     0.8     0.9     1.0
     8                K      0       1                       0       0       1       0
     9                K1       CALCULATION OF SNYDER UNIT HYDROGRAPH TO COLUMBIA LNG DAM
    10                M      1       1   0.194           0.194       0                       1
    11                P      0      25     112     123     132
    12                T                                                       1    0.05
    13                W    2.5    0.35
    14                X   -1.5   -0.05     2.0
    15                K      1       2                                       1
    16                K1       ROUTED FLOWS THROUGH COLUMBIA LNG DAM
    17                Y                               1       1
    18                Y1     1                                               547      -1
    19                Y4 76.16      77   77.80      79      80      84      86      88      90
    20                Y5     0      19      87     101     111     145     160     172     184
    21                $S     0    3.45     112     392     547     896
    22                $E    25      30      50      70   76.16      90
    23                $$ 76.16
    24                $D  87.5    2.63     1.5      50
    25                $L   610     660     705
    26                $V    88    88.5      89
    27                K     99
```

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**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  06 FEB 80
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SNYDER UNIT HYDROGRAPH, FLOOD ROUTING AND DAM OVERTOPPING ANALYSIS FOR
20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% AND 100% PMF AT COLUMBIA LNG PRIMARY DAM
NDI-I.D. MD116 COMM. NO. 580-21-11D

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
150	0	30	0	0	0	0	0	-4	0
			JOPER	NWT	LROPT	TRACE			
			5	0	0	0			

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 9 LRTIO= 1

RTIOS= 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

CALCULATION OF SNYDER UNIT HYDROGRAPH TO COLUMBIA LNG DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
1	0	0	0	0	0	1	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	1	0.19	0.00	0.19	0.00	0.000	0	1	0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.00	25.00	112.00	123.00	132.00	0.00	0.00	0.00

TRSPC COMPUTED BY THE PROGRAM IS 0.800

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0	0.00	0.00	1.00	0.00	0.00	1.00	1.00	0.05	0.00	0.00

UNIT HYDROGRAPH DATA
TP= 2.50 CP=0.35 NTA= 0

RECESSION DATA
STRTQ= -1.50 QRCSN= -0.05 RTIOR= 2.00

UNIT HYDROGRAPH 63 END-OF-PERIOD ORDINATES, LAG= 2.51 HOURS, CP= 0.35 VOL= 1.00

1.	5.	10.	14.	17.	17.	16.	14.	13.	12.
11.	10.	9.	8.	8.	7.	6.	6.	5.	5.
5.	4.	4.	3.	3.	3.	3.	2.	2.	2.
2.	2.	2.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.							

END-OF-PERIOD FLOW

HR. MN	PERIOD	RAIN	EXCS	LOSS	COMP Q	MO. DA	HR. MN	PERIOD	RAIN	EXCS	LOSS	COMP Q

SUM 26.40 24.54 1.86 6188.
(671.)(623.)(47.)(175.22)

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ROUTED FLOWS THROUGH COLUMBIA LNG DAM

ISTAG	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
2	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.000	0.00	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	547.	-1

STAGE	76.16	77.00	77.80	79.00	80.00	84.00	86.00	88.00	90.00
FLOW	0.00	19.00	87.00	101.00	111.00	145.00	160.00	172.00	184.00

CAPACITY=	0.	3.	112.	392.	547.	896.
ELEVATION=	25.	30.	50.	70.	76.	90.

CREL	SPWID	COGW	EXPW	ELEVL	COGL	CAREA	EXPL
76.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COGD	EXPD	DAMWID
87.5	2.6	1.5	30.

CREST LENGTH AT OR BELOW ELEVATION	610.	660.	705.
	88.0	88.5	89.0

PEAK OUTFLOW IS 30. AT TIME 24.00 HOURS

PEAK OUTFLOW IS 54. AT TIME 22.50 HOURS

PEAK OUTFLOW IS 78. AT TIME 22.50 HOURS

PEAK OUTFLOW IS 90. AT TIME 23.00 HOURS

PEAK OUTFLOW IS 95. AT TIME 23.50 HOURS

PEAK OUTFLOW IS 101. AT TIME 24.00 HOURS

PEAK OUTFLOW IS 107. AT TIME 24.50 HOURS

PEAK OUTFLOW IS 113. AT TIME 25.00 HOURS

PEAK OUTFLOW IS 118. AT TIME 25.50 HOURS

********** ********** ********** ********** **********

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS								
				RATIO 1	RATIO 2	RATIO 3	RATIO 4	RATIO 5	RATIO 6	RATIO 7	RATIO 8	RATIO 9
				0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
HYDROGRAPH AT	1	0.19	1	63.	95.	127.	158.	190.	221.	253.	285.	316.
	(	0.50)	(	1.79)(	2.69)(	3.58)(	4.48)(	5.38)(	6.27)(	7.17)(	8.06)(	8.96)
ROUTED TO	2	0.19	1	30.	54.	78.	90.	95.	101.	107.	113.	118.
	(	0.50)	(	0.85)(	1.54)(	2.21)(	2.54)(	2.70)(	2.87)(	3.03)(	3.19)(	3.34)

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	76.16	76.16	87.50
STORAGE	547.	547.	833.
OUTFLOW	0.	0.	169.

RATIO OF PMF	MAXIMUM RESERVOIR W.S. ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
0.20	77.13	0.00	571.	30.	0.00	24.00	0.00
0.30	77.42	0.00	579.	54.	0.00	22.50	0.00
0.40	77.69	0.00	586.	78.	0.00	22.50	0.00
0.50	78.04	0.00	594.	90.	0.00	23.00	0.00
0.60	78.52	0.00	606.	95.	0.00	23.50	0.00
0.70	79.05	0.00	620.	101.	0.00	24.00	0.00
0.80	79.62	0.00	634.	107.	0.00	24.50	0.00
0.90	80.21	0.00	649.	113.	0.00	25.00	0.00
1.00	80.83	0.00	665.	118.	0.00	25.50	0.00

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**********************************
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  06 FEB 80
**********************************
    1                A1       SNYDER UNIT HYDROGRAPH, FLOOD ROUTING AND DAM OVERTOPPING ANALYSES FOR
    2                A2       20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% AND 100% PMF AT COLUMBIA LNG SECONDARY
    3                A3       POND NDI-I.D. MD116  COMM. NO. 580-21-11D
    4                B    150         0        30         0         0         0         0         2        -1         0
    5                B1     5
    6                J      1         1         1
    7                J1   1.0
    8                K      0         1                             0         0         1         0
    9                K1       CALCULATION OF SNYDER UNIT HYDROGRAPH TO COLUMBIA LNG DAM
   10                M      1         1    0.0184               0.0184         0                             1
   11                P      0        25       112       123       132
   12                T                                                                  1      0.05
   13                W  0.946      0.35
   14                X   -1.5     -0.05       2.0
   15                K      1         2                                                 1
   16                K1       ROUTED FLOWS THROUGH COLUMBIA LNG DAM
   17                Y                                           1         1
   18                Y1     1                                                      15.8        -1
   19                Y4  49.2      49.7        50        51        52      52.5        53        54        55        56
   20                Y5     0     15.48        50       104       139       155       160       171       181       191
   21                $S     0     0.067       4.0      16.1     39.42     77.9
   22                $E    28        30        40        50        60        70
   23                $$  49.2
   24                $D  54.8      2.63       1.5        10
   25                $L    25       175       295
   26                $V    55      55.5        56
   27                K     99
```

Comment: Analyses neglects inflow from Primary Dam and computes Inflow Hydrograph for surface water runoff only.

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FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 06 FEB 80
****

SNYDER UNIT HYDROGRAPH, FLOOD ROUTING AND DAM OVERTOPPING ANALYSES FOR
20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% AND 100% PMF AT COLUMBIA LNG SECONDARY
POND NDI-I.D. MD116 COMM. NO. 580-21-11D

JOB SPECIFICATION

NO	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
150	0	30	0	0	0	0	2	-1	0
			JOPER	NWT	LROPT	TRACE			
			5	0	0	0			

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 1 LRTIO= 1

RTIOS= 1.00

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

CALCULATION OF SNYDER UNIT HYDROGRAPH TO COLUMBIA LNG DAM

ISTAG	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
1	0	0	0	0	0	1	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
1	1	0.02	0.00	0.02	0.00	0.000	0	1	0

PRECIP DATA

SPFE	PMS	R6	R12	R24	R48	R72	R96
0.00	25.00	112.00	123.00	132.00	0.00	0.00	0.00

TRSPC COMPUTED BY THE PROGRAM IS 0.800

LOSS DATA

LROPT	STRKR	DLTKR	RTIOL	ERAIN	STRKS	RTIOK	STRTL	CNSTL	ALSMX	RTIMP
0	0.00	0.00	1.00	0.00	0.00	1.00	1.00	0.05	0.00	0.00

UNIT HYDROGRAPH DATA
TP= 0.95 CP=0.35 NTA= 0

RECESSION DATA
STRTQ= -1.50 QRCSN= -0.05 RTIOR= 2.00

APPROXIMATE CLARK COEFFICIENTS FROM GIVEN SNYDER CP AND TP ARE TC= 1.68 AND R= 3.92 INTERVALS

UNIT HYDROGRAPH 22 END-OF-PERIOD ORDINATES, LAG= 0.94 HOURS, CP= 0.35 VOL= 1.00

2.	4.	4.	3.	2.	2.	1.	1.	1.	1.
1.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0	0								

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS RATIO 1 1.00
HYDROGRAPH AT	1	0.02	1	54.
		(0.05)		(1.53)(
ROUTED TO	2	0.02	1	52.
		(0.05)		(1.48)(

SUMMARY OF DAM SAFETY ANALYSIS

PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	49.75	49.20	54.80
STORAGE	16.	13.	27.
OUTFLOW	21.	0.	179.

RATIO OF PMF	MAXIMUM RESERVOIR W.S. ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
1.00	50.04	0.00	16.	52.	0.00	17.00	0.00

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**********
FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION      JULY 1978
  LAST MODIFICATION  06 FEB 80
**********
    1              A1       INPUT HYDROGRAPH, FLOOD ROUTING AND DAM OVERTOPPING ANALYSES FOR
    2              A2       20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% AND 100% PMF AT COLUMBIA LNG SECONDARY
    3              A3       POND NDI-I.D. MD116  COMM. NO. 580-21-11D
    4              B    100       0      30       0       0       0       0       0      -4       0
    5              B1     5
    6              J      1       9       1
    7              J1   0.2     0.3     0.4     0.5     0.6     0.7     0.8     0.9     1.0
    8              K      0       1                       0       0       1       0
    9              K1       DIRECT INPUT OF HYDROGRAPH ORDINATES TO  COLUMBIA LNG DAM
   10              M     -1       1  0.0183          0.0183       0
   11              N      2       2       3       3       4       4       4       4       8       8
   12              N      9      13      17      25      29      37      45      64      97     118
   13              N    137     136     134     132     129     126     125     124     123     124
   14              N    123     121     121     120     119     119     122     118     118     118
   15              N    118     118     118     115     117     113     113     113     113     109
   16              N    109     109     105     105     105     101     101     101      97      97
   17              N     96      92      92      88      88      84      76      68      60      52
   18              N     48      40      36      32      28      28      24      20      20      20
   19              N     16      16      16      16      16      16      16      16      16      12
   20              N     12      12      12      12      12      12      12      12       8       8
   21              K      1       2                                       1
   22              K1       ROUTED FLOWS THROUGH COLUMBIA LNG DAM
   23              Y                               1       1
   24              Y1     1                                       15.8      -1
   25              Y4  49.2    49.7      50      51      52    52.5      53      54      55      56
   26              Y5     0   15.48      50     104     139     155     160     171     181     191
   27              $S     0   0.067     4.0    16.1   39.42   77.9
   28              $E    28      30      40      50      60      70
   29              $$  49.2
   30              $D  54.8    2.63     1.5      10
   31              $L    25     175     295
   32              $V    55    55.5      56
   33              K     99
```

Comment: Analyses includes Inflow Hydrograph from surface water runoff and Outflow Hydrograph from Primary Dam in the form of Combined Inflow Hydrograph to Secondary Dam.

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FLOOD HYDROGRAPH PACKAGE (HEC-1)
DAM SAFETY VERSION JULY 1978
LAST MODIFICATION 06 FEB 80
****

INPUT HYDROGRAPH, FLOOD ROUTING AND DAM OVERTOPPING ANALYSES FOR
20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% AND 100% PMF AT COLUMBIA LNG SECONDARY
POND NDI-I.D. MD116 COMM. NO. 580-21-11D

JOB SPECIFICATION

NQ	NHR	NMIN	IDAY	IHR	IMIN	METRC	IPLT	IPRT	NSTAN
100	0	30	0	0	0	0	0	-4	0

JOPER	NWT	LROPT	TRACE
5	0	0	0

MULTI-PLAN ANALYSES TO BE PERFORMED
NPLAN= 1 NRTIO= 9 LRTIO= 1

RTIOS= 0.20 0.30 0.40 0.50 0.60 0.70 0.80 0.90 1.00

********** ********** ********** ********** **********

SUB-AREA RUNOFF COMPUTATION

DIRECT INPUT OF HYDROGRAPH ORDINATES TO COLUMBIA LNG DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
1	0	0	0	0	0	1	0	0

HYDROGRAPH DATA

IHYDG	IUHG	TAREA	SNAP	TRSDA	TRSPC	RATIO	ISNOW	ISAME	LOCAL
-1	1	0.02	0.00	0.02	0.00	0.000	0	0	0

********** ********** ********** ********** **********

HYDROGRAPH ROUTING

ROUTED FLOWS THROUGH COLUMBIA LNG DAM

ISTAQ	ICOMP	IECON	ITAPE	JPLT	JPRT	INAME	ISTAGE	IAUTO
2	1	0	0	0	0	1	0	0

ROUTING DATA

QLOSS	CLOSS	AVG	IRES	ISAME	IOPT	IPMP	LSTR
0.0	0.000	0.00	1	1	0	0	0

NSTPS	NSTDL	LAG	AMSKK	X	TSK	STORA	ISPRAT
1	0	0	0.000	0.000	0.000	16.	-1

STAGE	49.20	49.70	50.00	51.00	52.00	52.50	53.00	54.00	55.00	56.00
FLOW	0.00	15.48	50.00	104.00	139.00	155.00	160.00	171.00	181.00	191.00
CAPACITY=	0.	0.	4.	16.	39.	116.				
ELEVATION=	28.	30.	40.	50.	60.	70.				

CREL	SPWID	COGW	EXPW	ELEVL	COGL	CAREA	EXPL
49.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0

DAM DATA

TOPEL	COGD	EXPD	DAMWID
54.8	2.6	1.5	10.

CREST LENGTH	25.	175	295.
AT OR BELOW ELEVATION	55.0	55.5	56.0

PEAK OUTFLOW IS 28. AT TIME 11.00 HOURS

PEAK OUTFLOW IS 41. AT TIME 11.00 HOURS

PEAK OUTFLOW IS 54. AT TIME 11.50 HOURS

PEAK OUTFLOW IS 67. AT TIME 11.50 HOURS

PEAK OUTFLOW IS 80. AT TIME 11.50 HOURS

PEAK OUTFLOW IS 93. AT TIME 11.50 HOURS

PEAK OUTFLOW IS 106. AT TIME 12.00 HOURS

PEAK OUTFLOW IS 118. AT TIME 12.00 HOURS

PEAK OUTFLOW IS 131. AT TIME 12.00 HOURS

********** ********** ********** ********** **********

PEAK FLOW AND STORAGE (END OF PERIOD) SUMMARY FOR MULTIPLE PLAN-RATIO ECONOMIC COMPUTATIONS
FLOWS IN CUBIC FEET PER SECOND (CUBIC METERS PER SECOND)
AREA IN SQUARE MILES (SQUARE KILOMETERS)

OPERATION	STATION	AREA	PLAN	RATIOS APPLIED TO FLOWS								
				RATIO 1	RATIO 2	RATIO 3	RATIO 4	RATIO 5	RATIO 6	RATIO 7	RATIO 8	RATIO 9
				0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
HYDROGRAPH AT	1	0.02	1	27.	41.	55	68	82.	96	110.	123	137.
	(	0.05)	(	0.78)(	1.16)(	1.55)(	1.94)(	2.33)(	2.72)(	3.10)(	3.49)(	3.88).
ROUTED TO	2	0.02	1	28.	41.	54	67.	80	93.	106.	118.	131.
	(	0.05)	(	0.78)(	1.17)(	1.52)(	1.89)(	2.26)(	2.64)(	3.00)(	3.35)(	3.71)

SUMMARY OF DAM SAFETY ANALYSIS

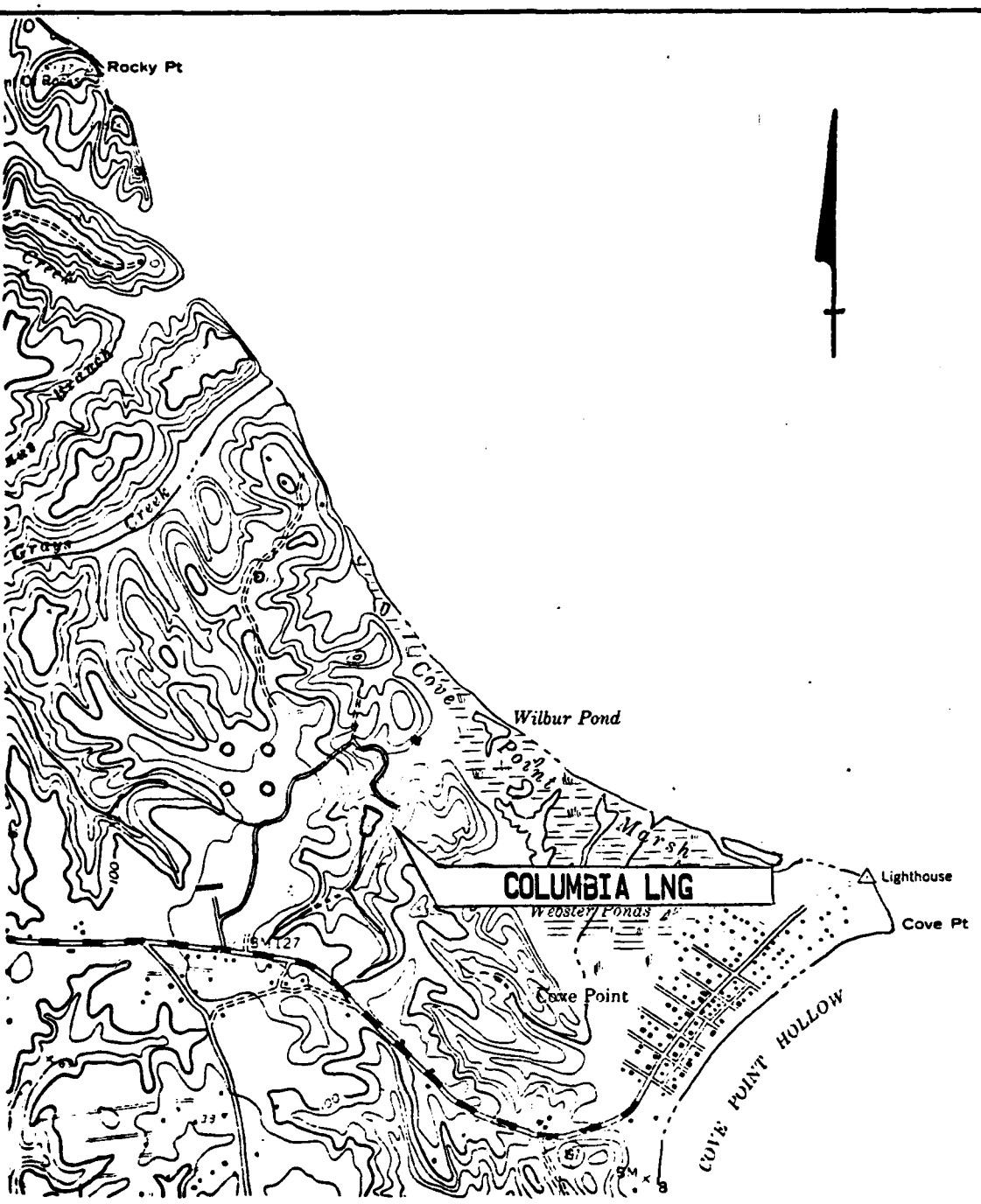
PLAN 1 .....

	INITIAL VALUE	SPILLWAY CREST	TOP OF DAM
ELEVATION	49.75	49.20	54.80
STORAGE	16.	15.	27.
OUTFLOW	21.	0.	179.

RATIO OF PMF	MAXIMUM RESERVOIR W.S ELEV	MAXIMUM DEPTH OVER DAM	MAXIMUM STORAGE AC-FT	MAXIMUM OUTFLOW CFS	DURATION OVER TOP HOURS	TIME OF MAX OUTFLOW HOURS	TIME OF FAILURE HOURS
0.20	49.81	0.00	16.	28.	0.00	11.00	0.00
0.30	49.93	0.00	16.	41.	0.00	11.00	0.00
0.40	50.07	0.00	16.	54.	0.00	11.50	0.00
0.50	50.31	0.00	17.	67.	0.00	11.50	0.00
0.60	50.55	0.00	17.	80.	0.00	11.50	0.00
0.70	50.80	0.00	18.	93.	0.00	11.50	0.00
0.80	51.06	0.00	19.	106.	0.00	12.00	0.00
0.90	51.41	0.00	19.	118.	0.00	12.00	0.00
1.00	51.77	0.00	20.	131.	0.00	12.00	0.00

APPENDIX E

PLATES



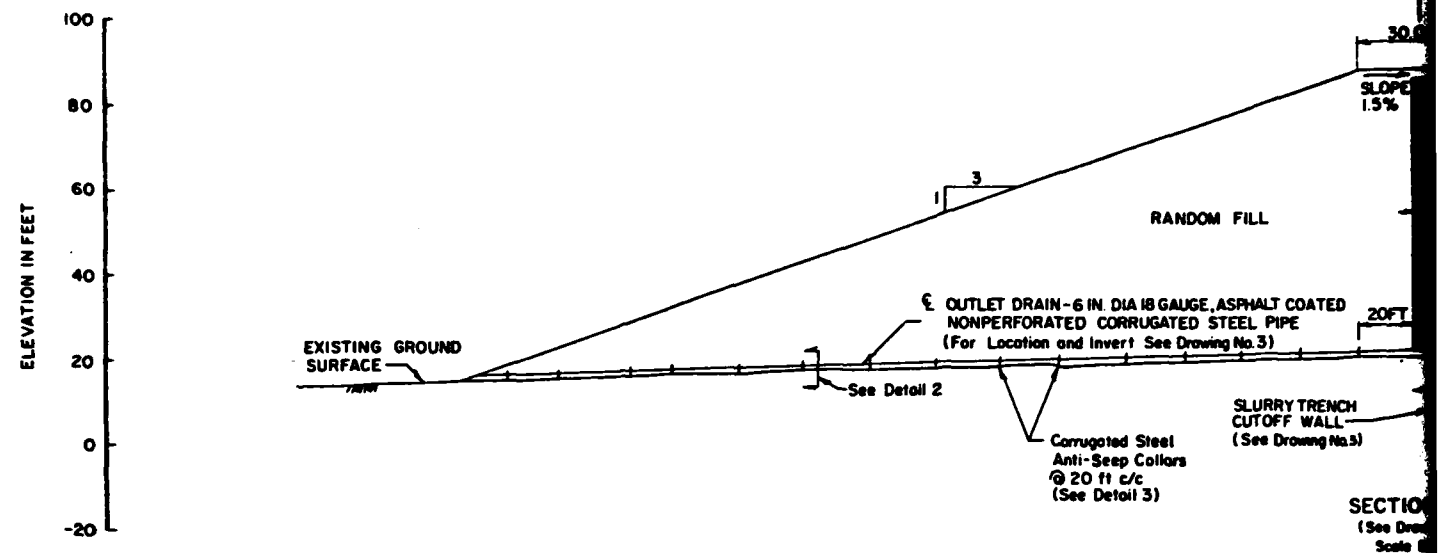
SCALE

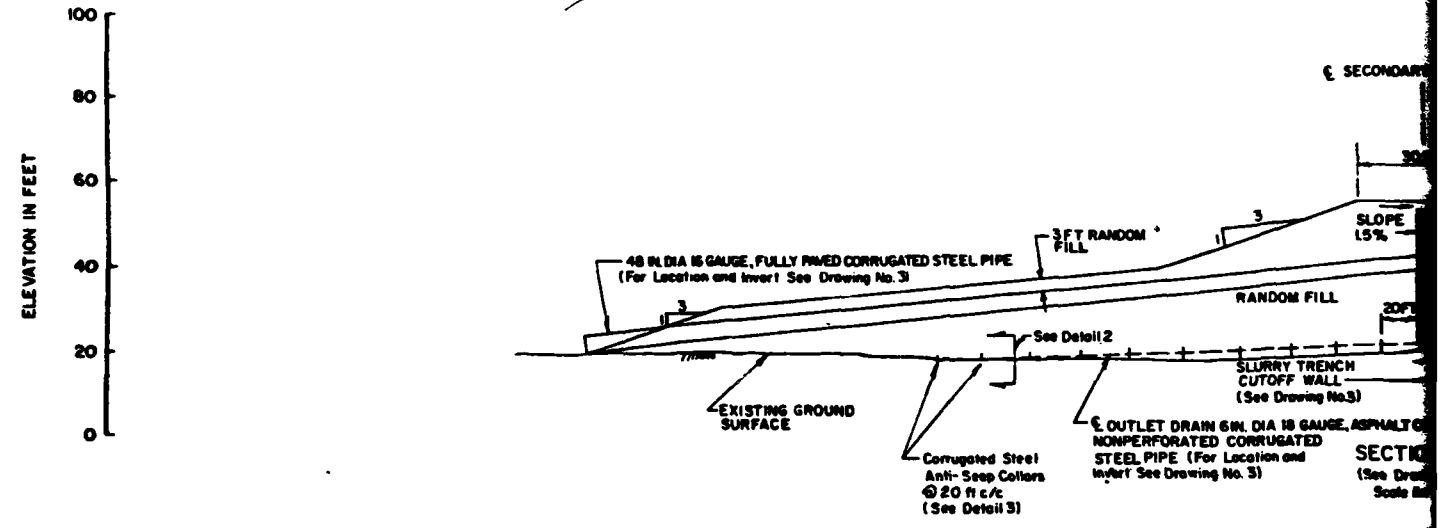
0 1/2 Mi. 1 Mi.

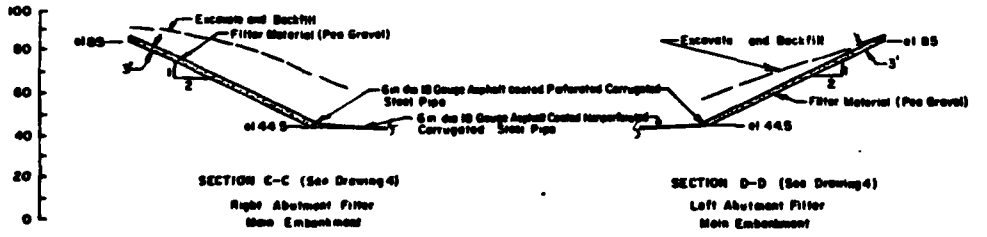
COLUMBIA LNG

LOCATION MAP

PLATE E-1

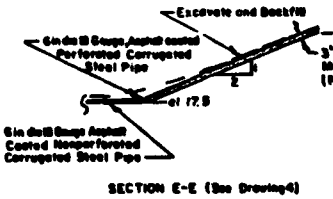




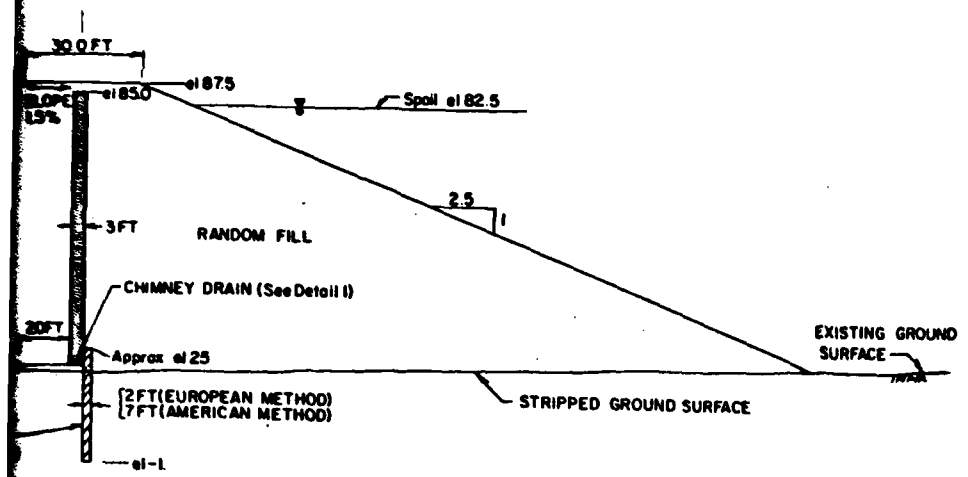


SECTION C-C (See Drawing 4)
Right Abutment Filter
Main Embankment

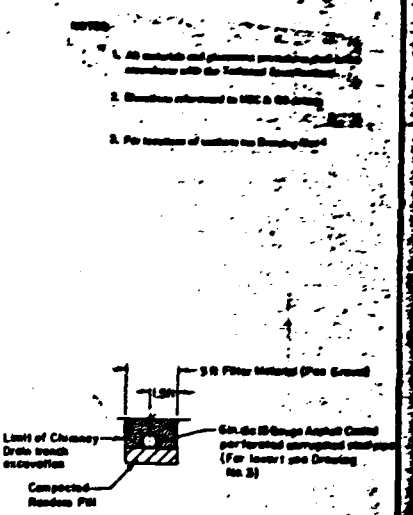
SECTION D-D (See Drawing 4)
Left Abutment Filter
Main Embankment



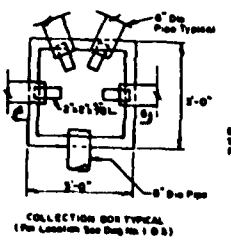
SECTION E-E (See Drawing 4)
Left Abutment Filter-Secondary Embankment



SECTION A-A

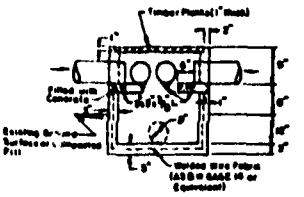


DETAIL 1

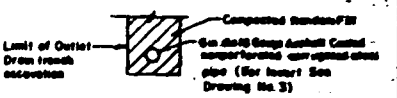


COLLECTION BOX TYPICAL

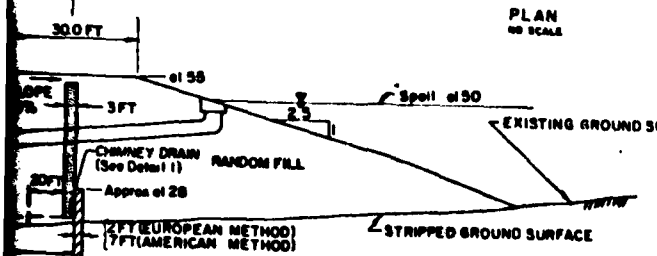
PLAN



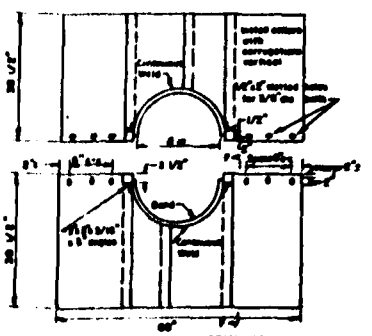
SECTION G-G



DETAIL 2

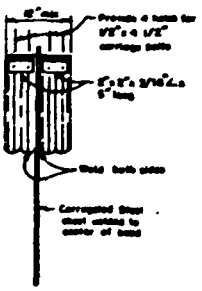


SECTION B-B

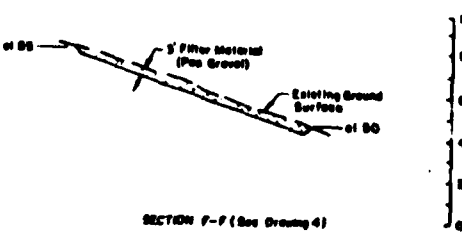


ELEVATION OF UNASSEMBLED ANTISEEPAGE COLLAR

DETAIL 3



SECTION F-F



SECTION F-F (See Drawing 4)

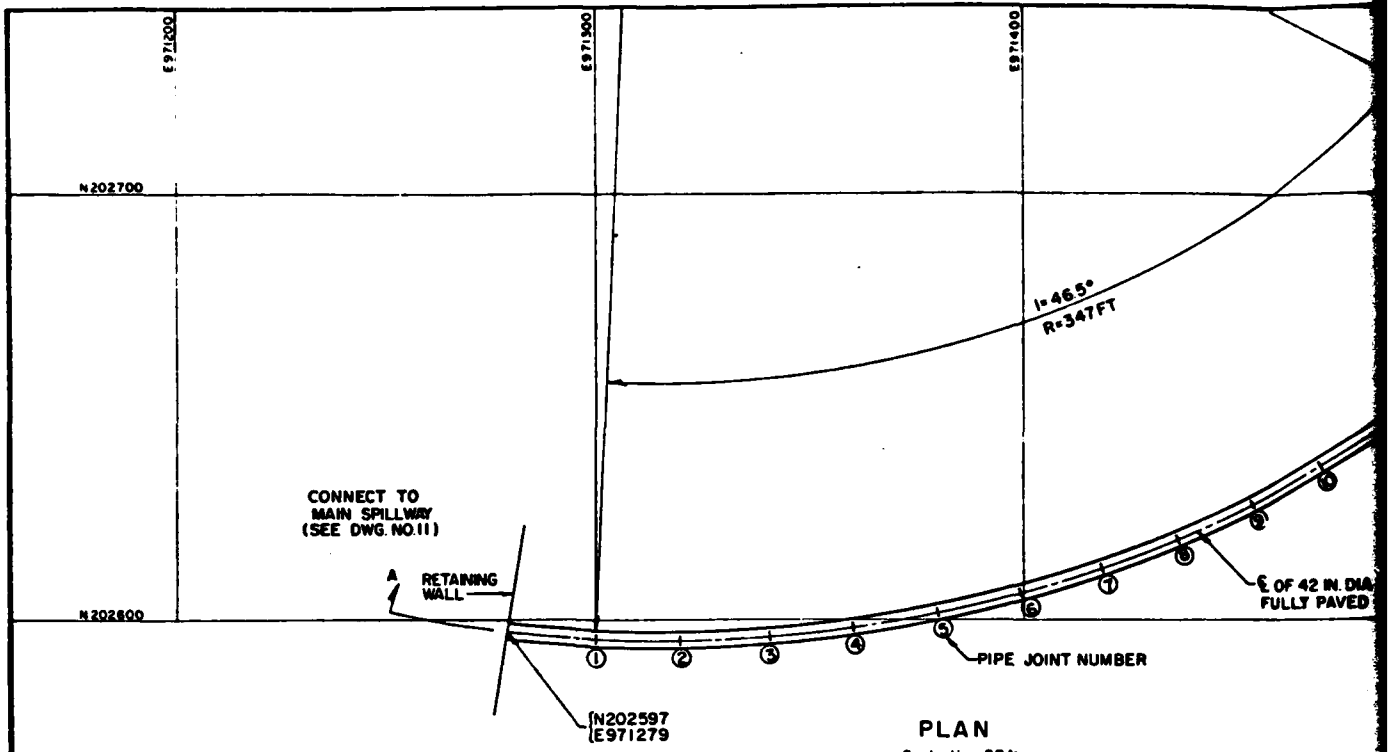
COLUMBIA LNG CORPORATION
SPOIL EMBANKMENTS
COVE POINT, MARYLAND

EMBANKMENT SECTIONS AND DETAILS

WOODWARD-MOORHOUSE & ASSOCIATES, INC.
CONSULTING ENGINEERS AND GEOLOGISTS
NEW YORK, NEW YORK

DR BY: BRS	SCALE: AS SHOWN	PROJ NO: 71-738 D
CK'D BY: HB	DATE: 10 MAY 73	DRAWING NO. 5

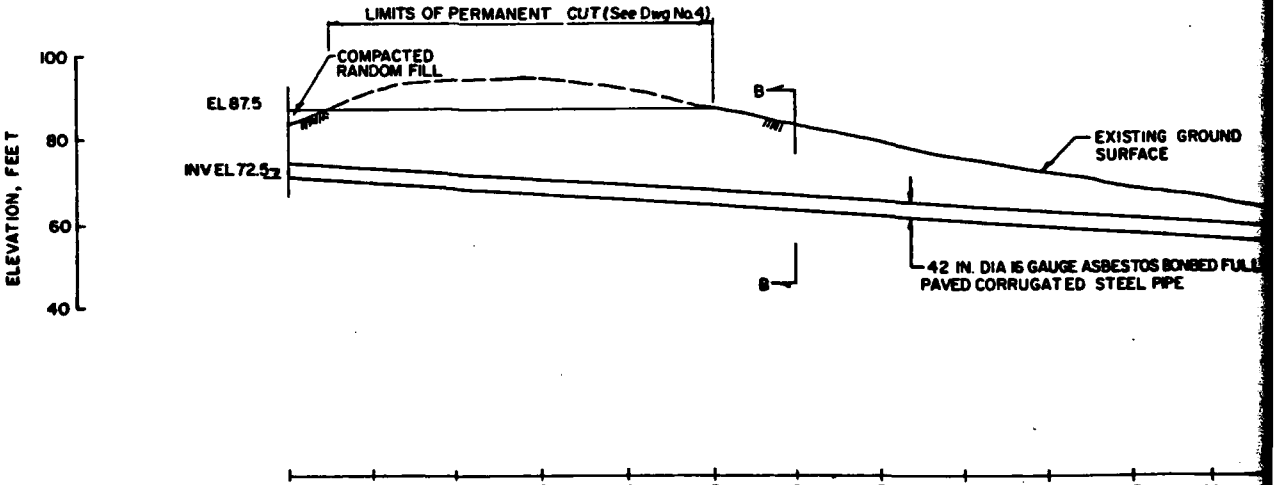
PLATE E-2



PLAN

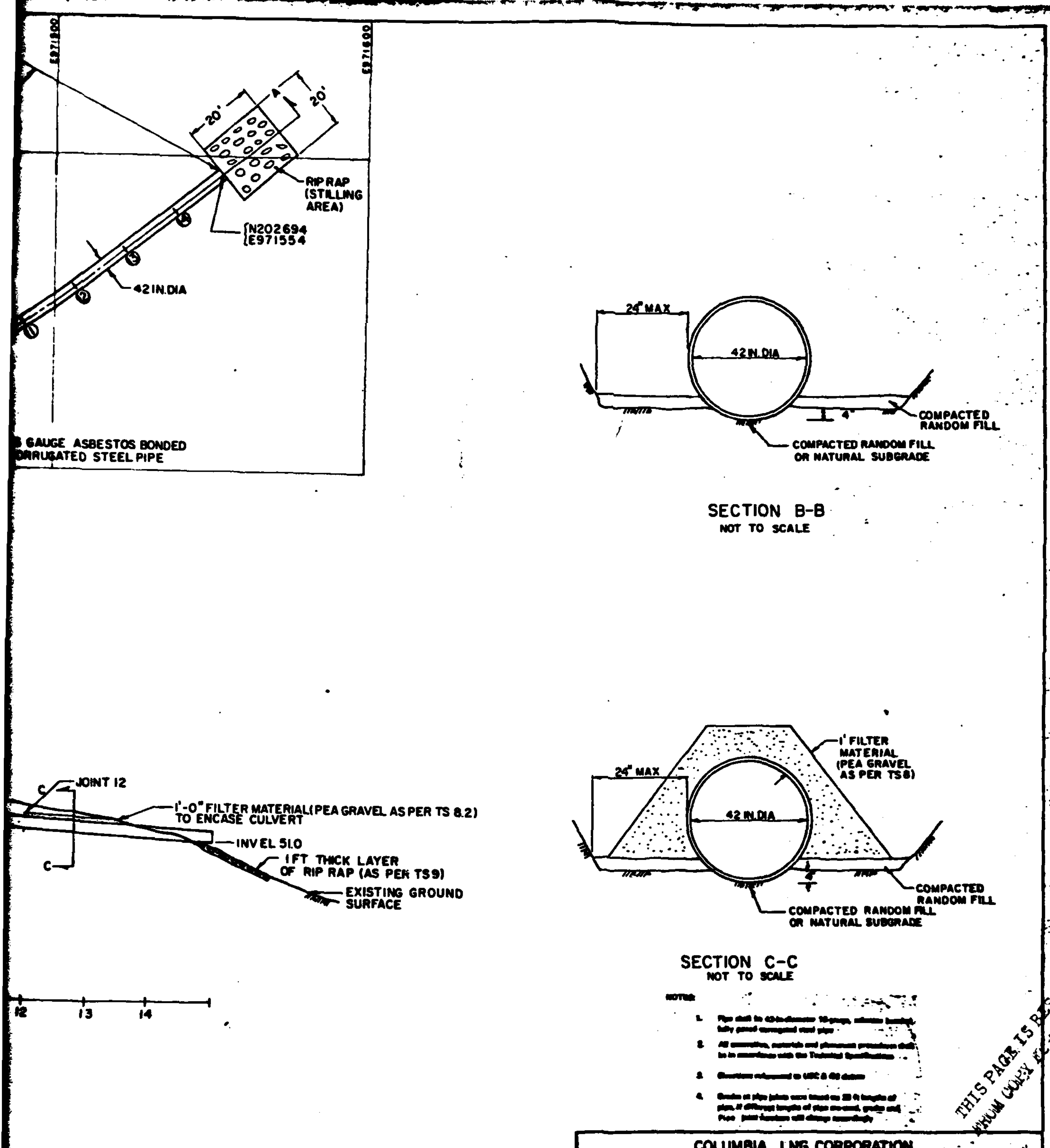
Scale 1 in. = 20 ft

(For Location See Dwg. No. 4)



SECTION A-A

Scale 1 in. = 20 ft



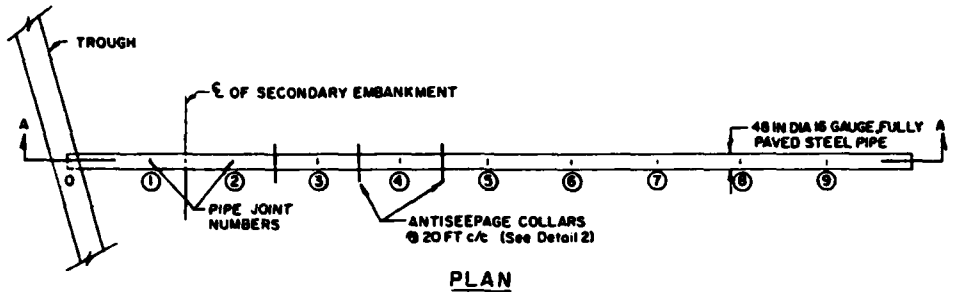
COLUMBIA LNG CORPORATION
SPOIL EMBANKMENTS
COVE POINT, MARYLAND

MAIN SPILLWAY-OUTLET PIPE

WOODWARD-MOORHOUSE & ASSOCIATES, INC.
CONSULTING ENGINEERS AND GEOLOGISTS
NEW YORK, NEW YORK

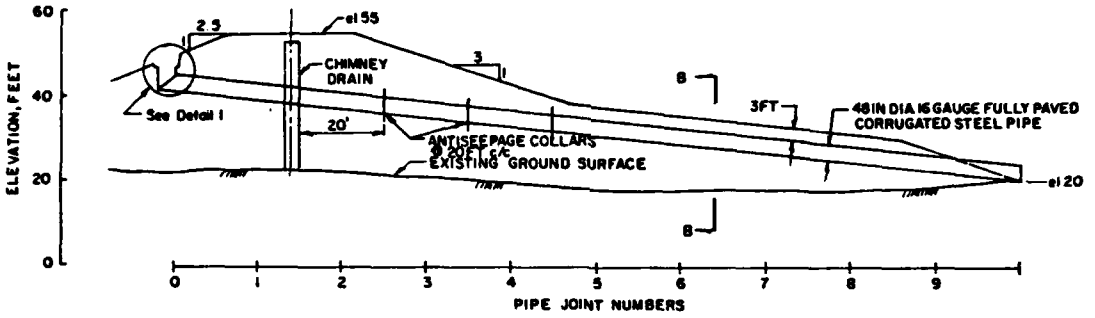
DR. BY DRS	SCALE: AS SHOWN	PROJ. NO. 71-738 D
CK'D BY.	DATE: 15 MAY 73	DRAWING NO. 12

PLATE



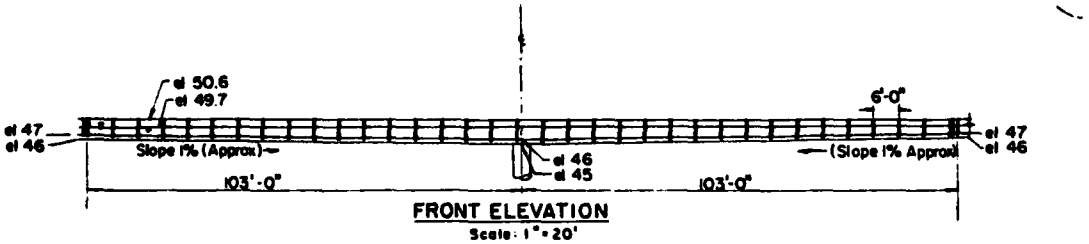
PLAN

Scale 1" = 20'



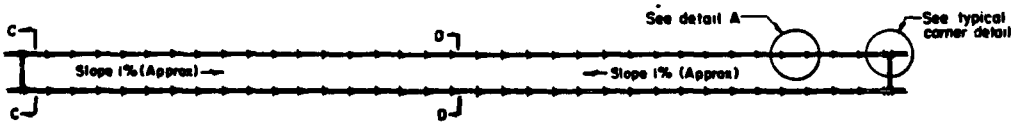
SECTION A-A

Scale 1" = 20'



FRONT ELEVATION

Scale: 1" = 20'



PLAN
TROUGH STRUCTURE

Scale 1" = 20'

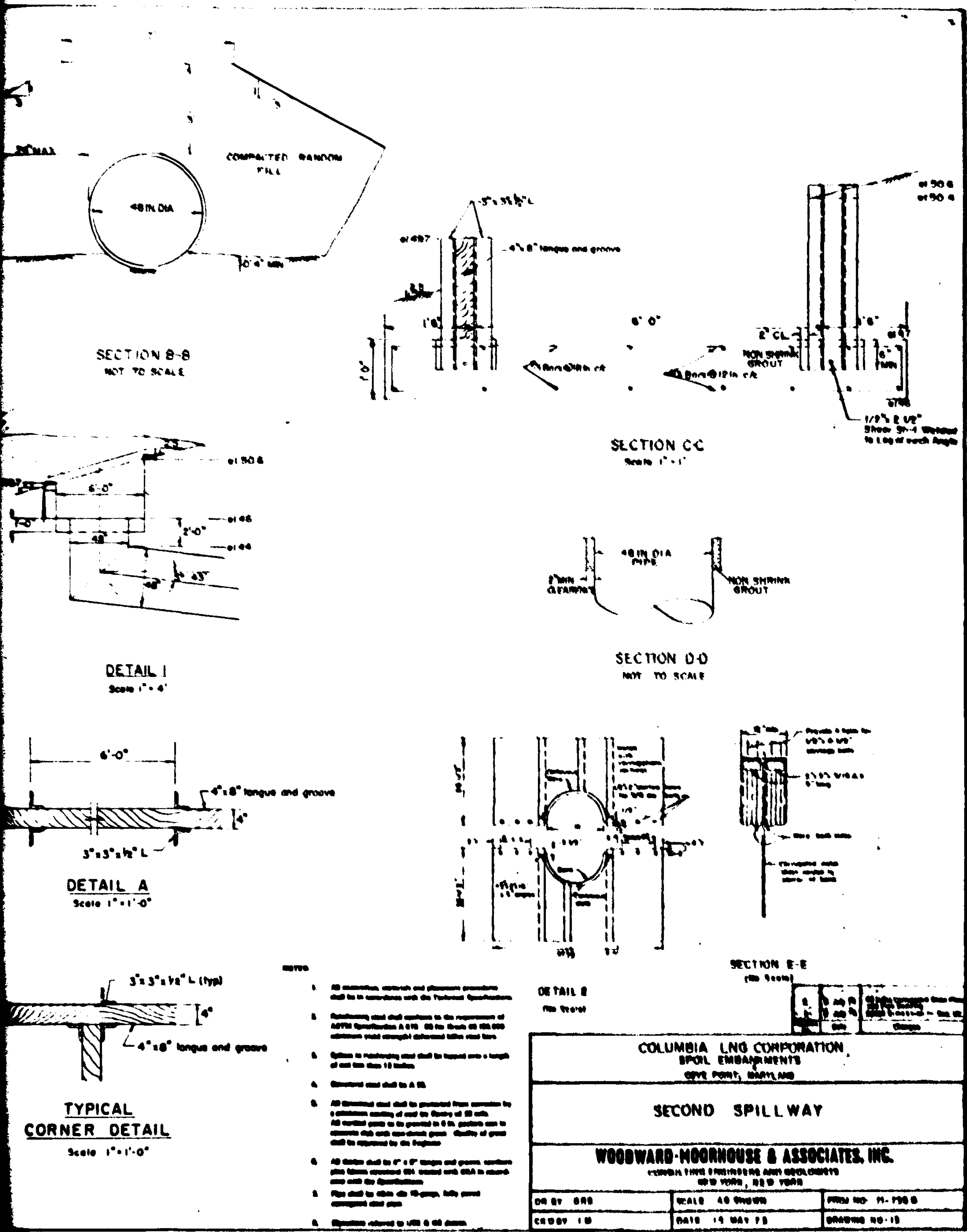

COMPACTED RANDOM FILL
48 IN DIA
SECTION B-B
NOT TO SCALE
4"x 8" tongue and groove
6'-0"
2" CL
NON SHRINK GROUT
SECTION CC
el 50.6
el 46
el 44
2'-0"
DETAIL I
48 IN DIA PIPE
NON SHRINK GROUT
SECTION D-D
NOT TO SCALE
6'-0"
4"x 8" tongue and groove
3"x 3"x 1/2" L
DETAIL A
Scale 1" = 1'-0"
SECTION E-E
DETAIL 2
3"x 3"x 1/2" L (typ)
4"x 8" tongue and groove
TYPICAL CORNER DETAIL
Scale 1" = 1'-0"
NOTES
COLUMBIA LNG CORPORATION
SPOIL EMBANKMENTS
COVE POINT, MARYLAND
SECOND SPILLWAY
WOODWARD-MOORHOUSE & ASSOCIATES, INC.
NEW YORK, NEW YORK

PLATE E

APPENDIX F

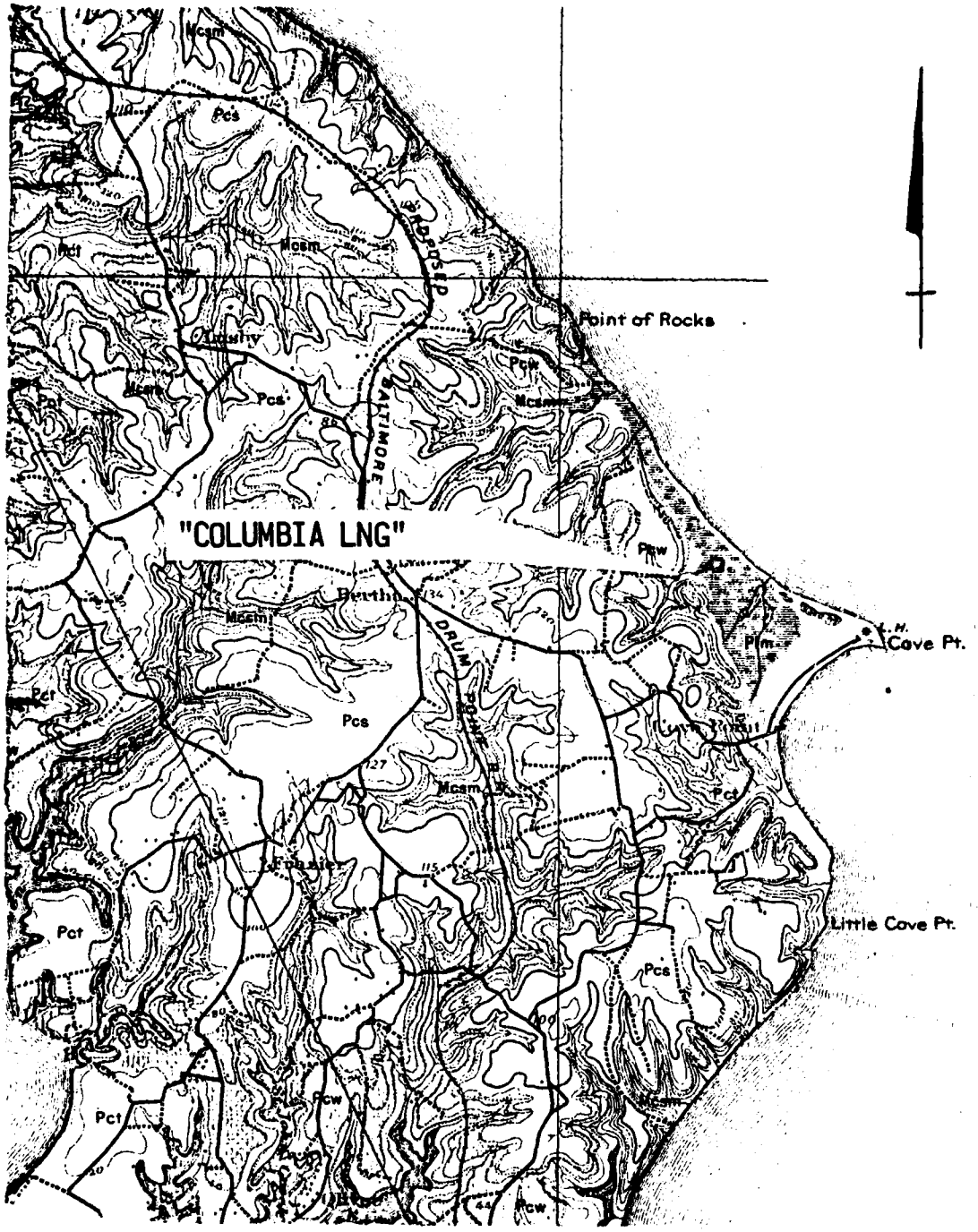
GEOLOGY

COLUMBIA LNG

APPENDIX F

REGIONAL GEOLOGY

The Columbia LNG Main and Secondary Dams are situtated on the sediments of the Pleistocene Columbia Group, specifically the Wicomico Formation, which include sand, clay, and gravel. The average thickness of the Wicomico Formation is 20 feet, and the average total thickness of the Columbia Group is 70 feet. The sediments of the Columbia Group lie unconformably on the sediments of the Miocene Chespaeake Group. The Columbia LNG Plant is located in the Coastal Plain Physiographic Province.



SCALE

0 1 Mi. 2 Mi.

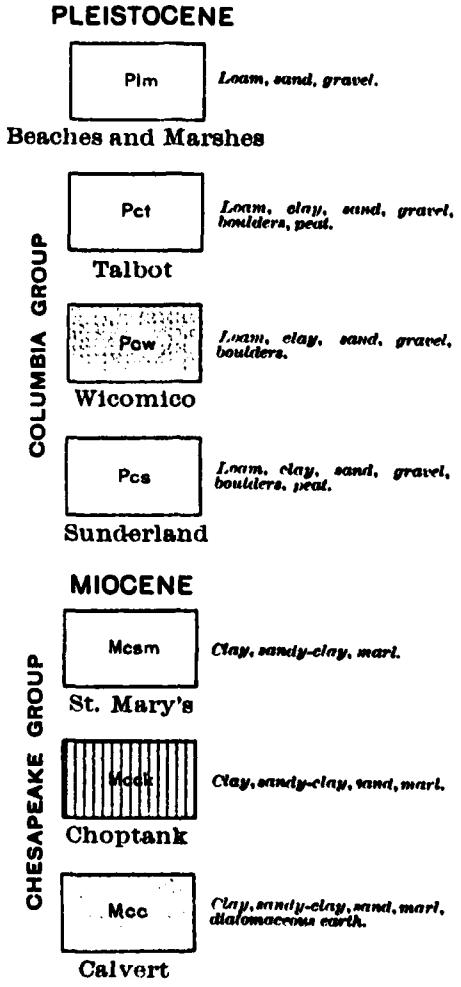
REFERENCE:

GEOLOGIC MAP OF CALVERT COUNTY,
PREPARED BY STATE OF MARYLAND,
MARYLAND GEOLOGICAL SURVEY,
1968

COLUMBIA LNG

GEOLOGY MAP

RUMMEL, KLEPPER & KAHL



REFERENCE:

GEOLOGIC MAP OF CALVERT COUNTY, PREPARED BY STATE OF MARYLAND, MARYLAND GEOLOGICAL SURVEY, DATED 1902.

COLUMBIA LNG

GEOLOGY MAP LEGEND

RUMMEL, KLEPPER & KAHL


FILMED
2-8