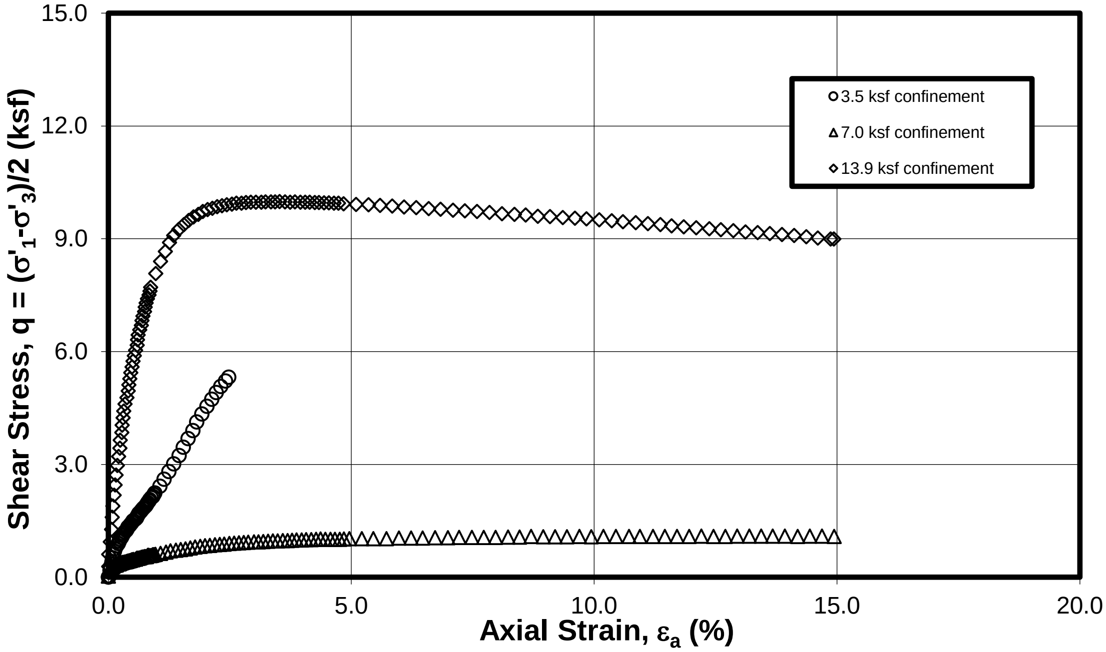
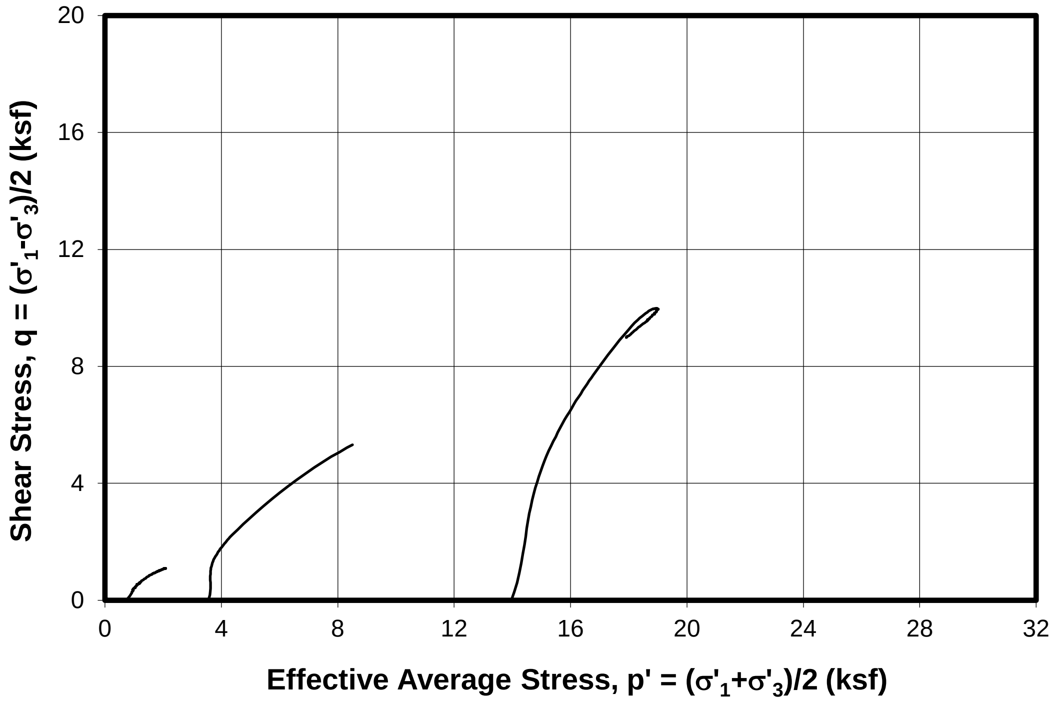
Part 7 of 19 of Appendices for Resource Report No. 13 LNG

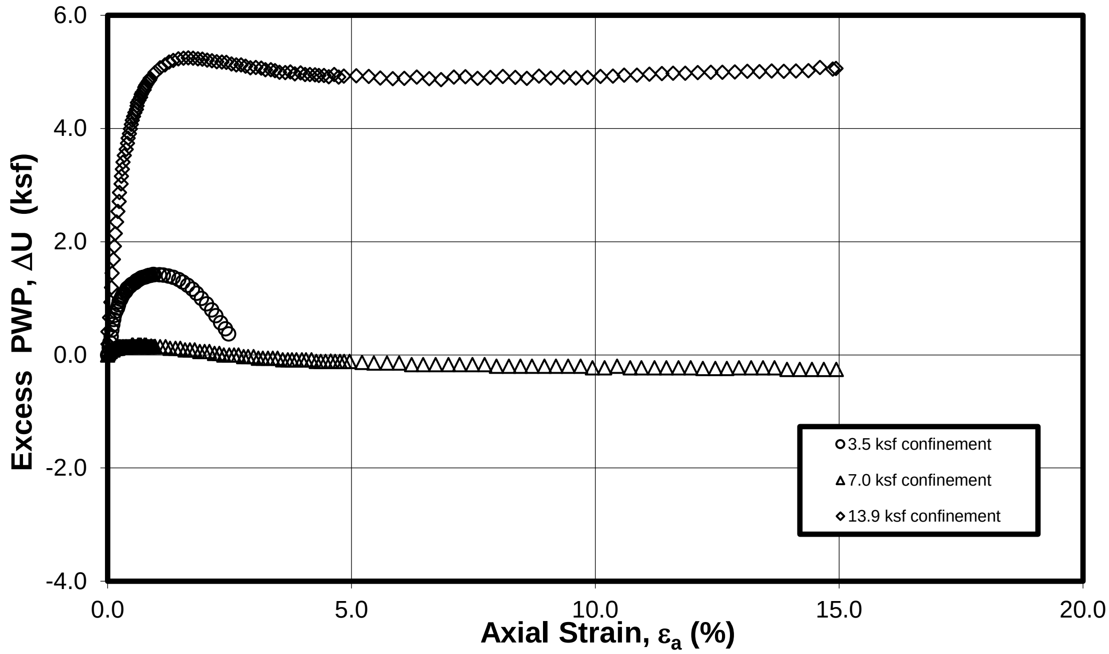
APPENDIX G5

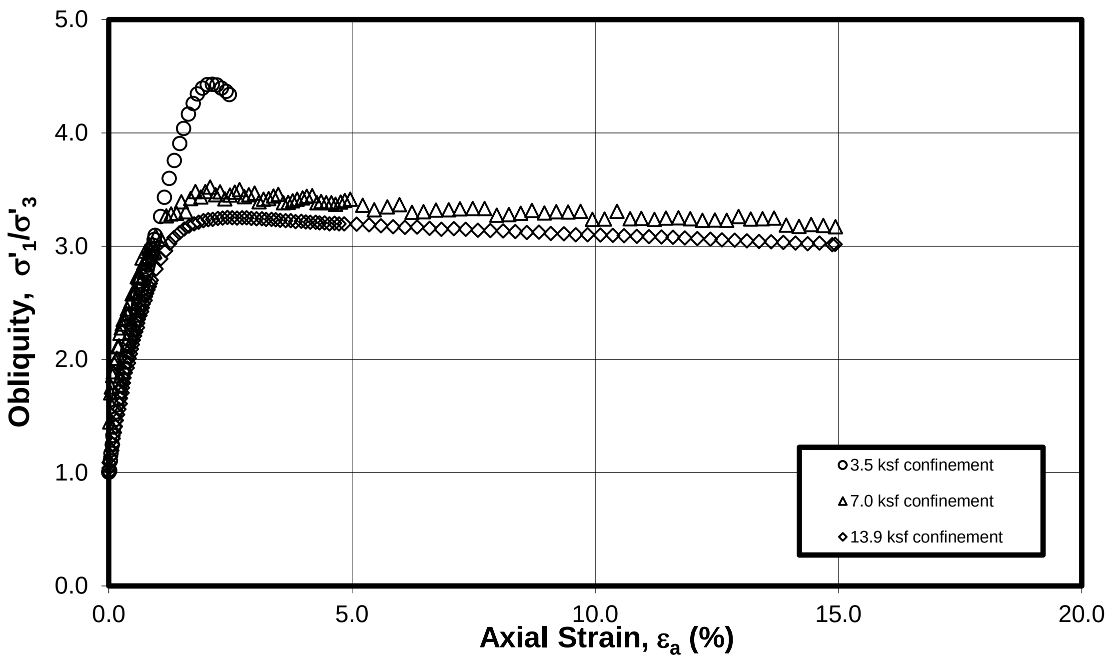
Consolidated-Undrained Triaxial Compression Test Results



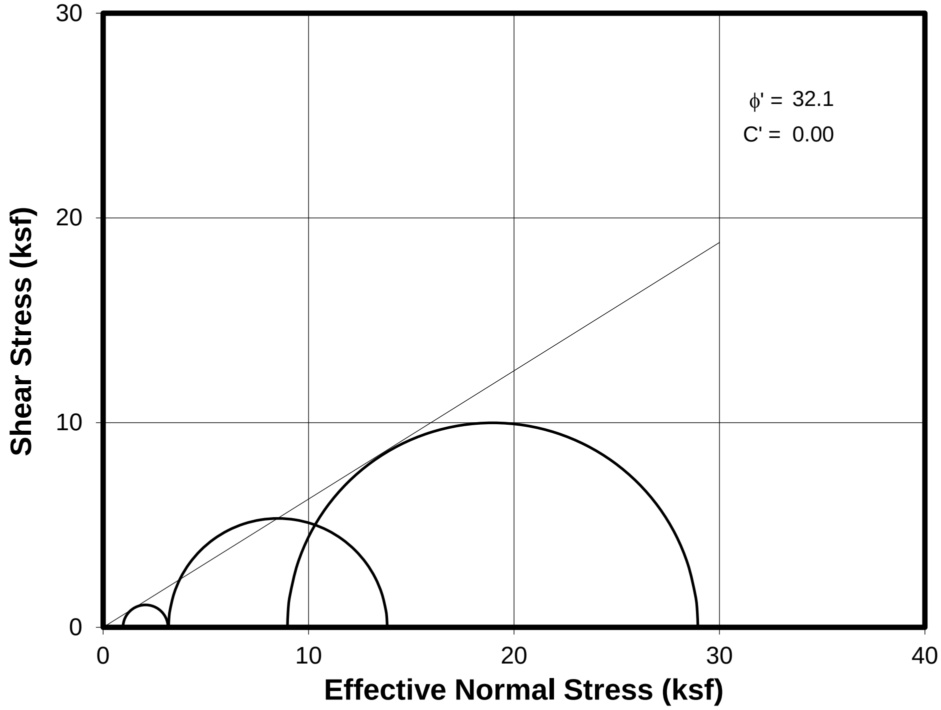


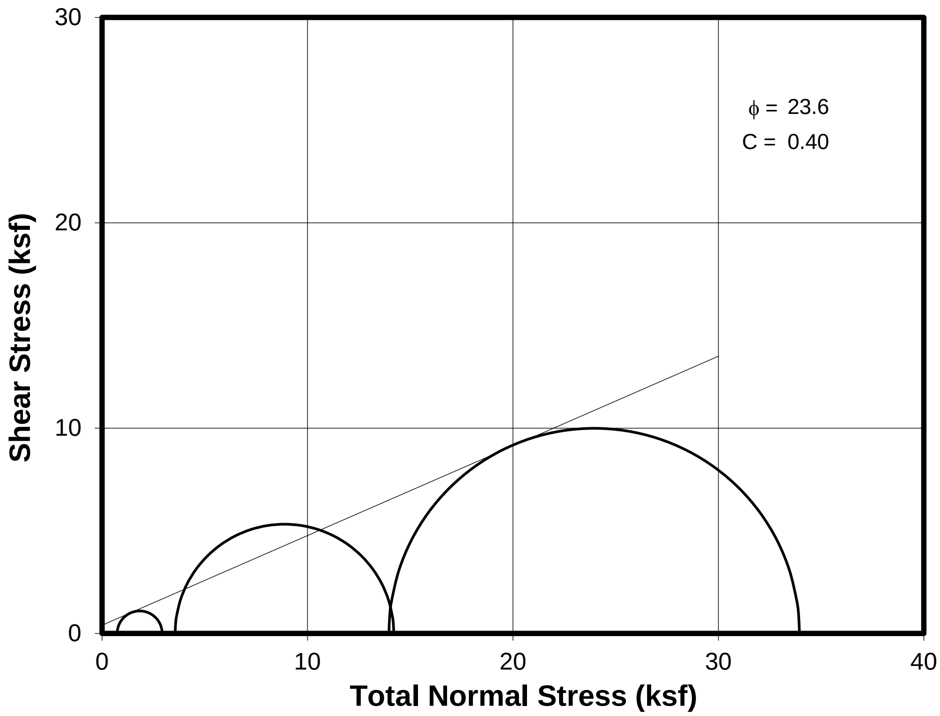
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-176, SAMPLE S-30, DEPTH 120.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



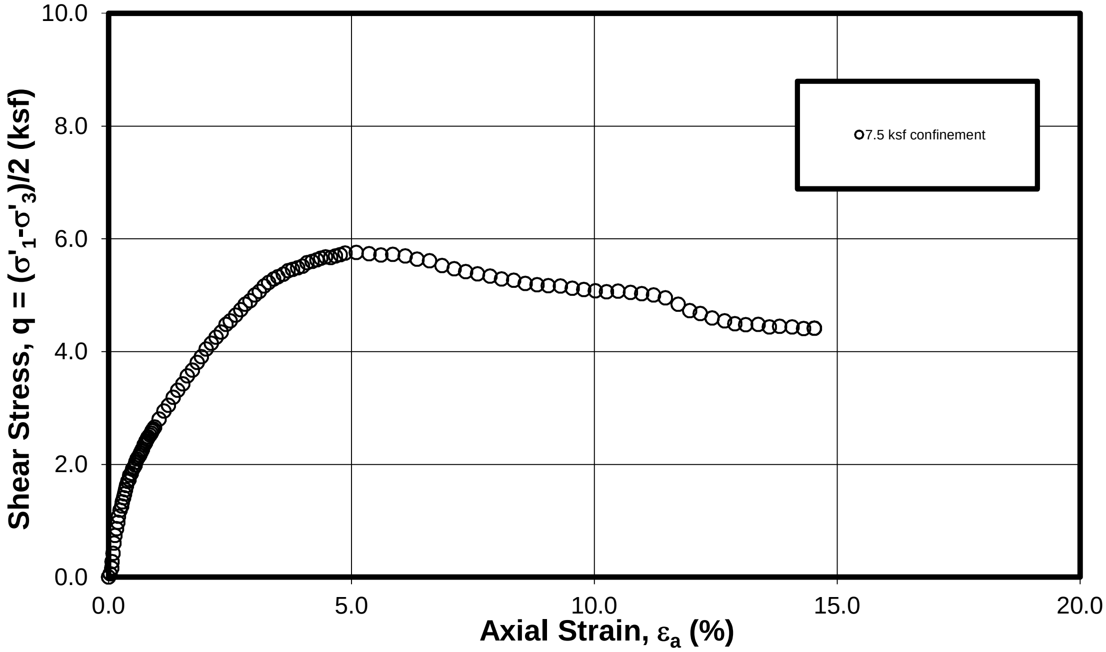


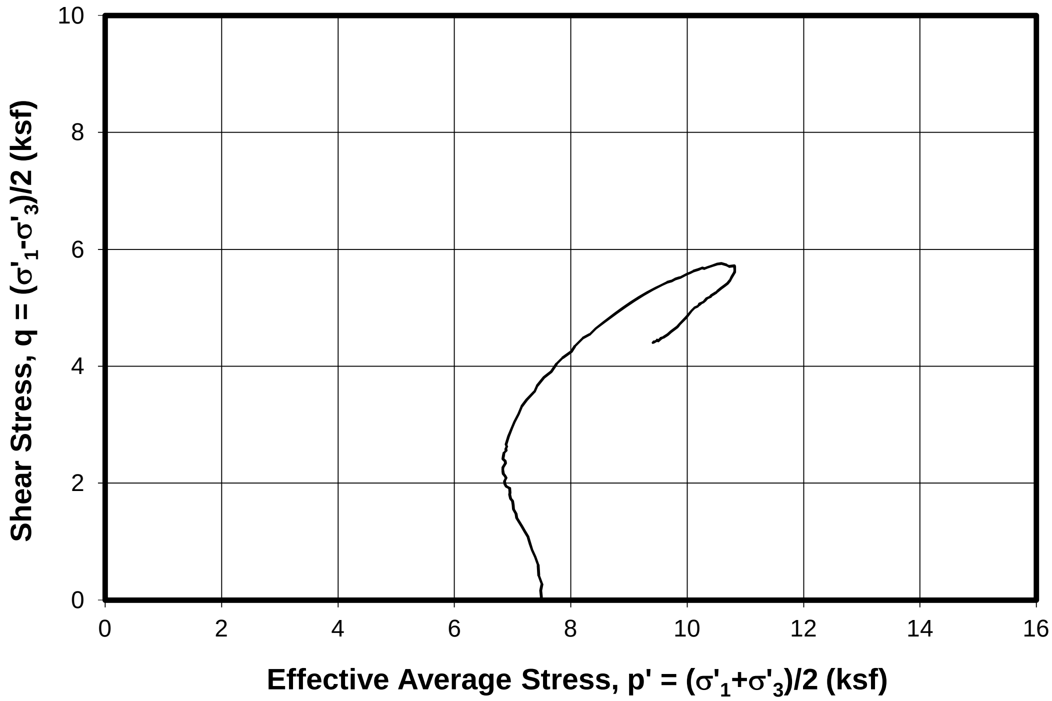
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-176, SAMPLE S-30, DEPTH 120.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA





CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-176, SAMPLE S-30, DEPTH 120.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA





CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
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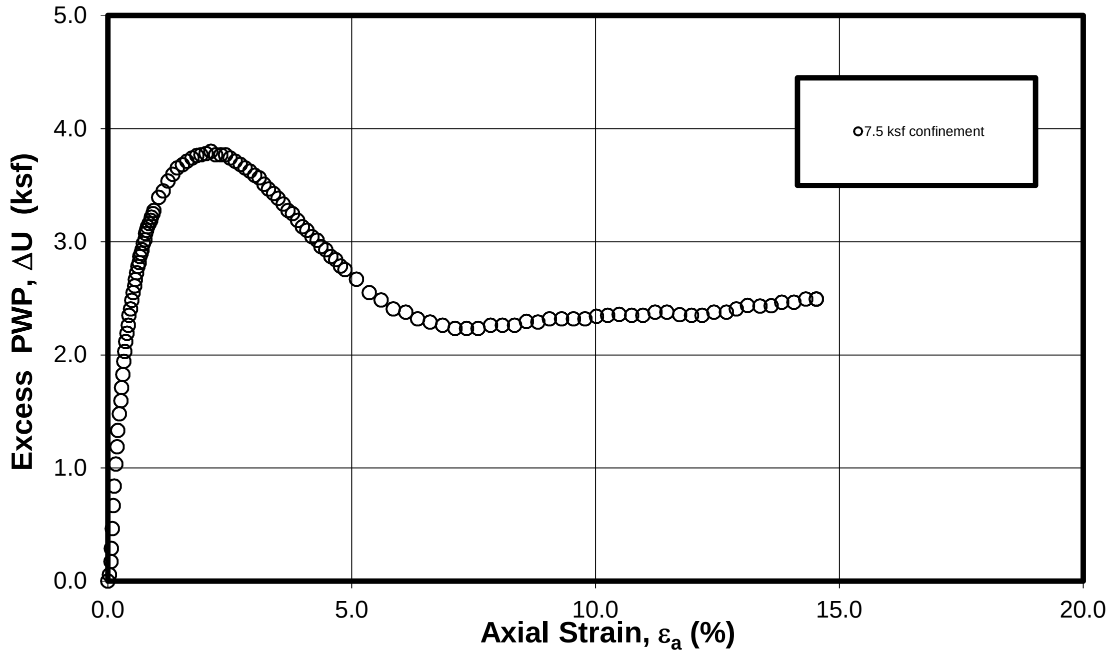
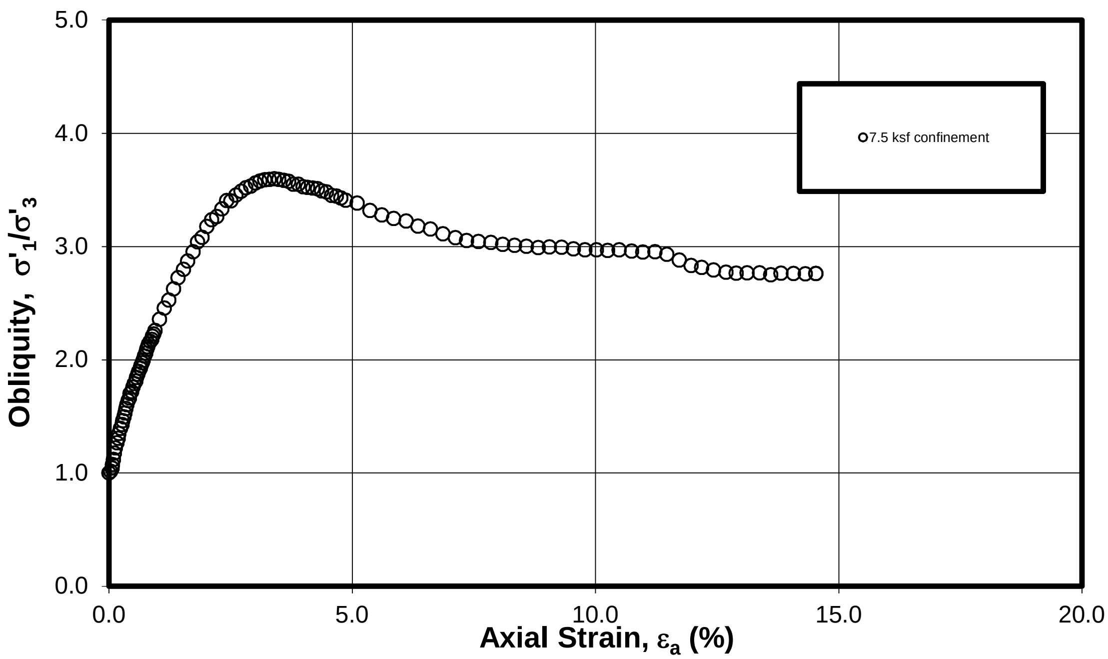
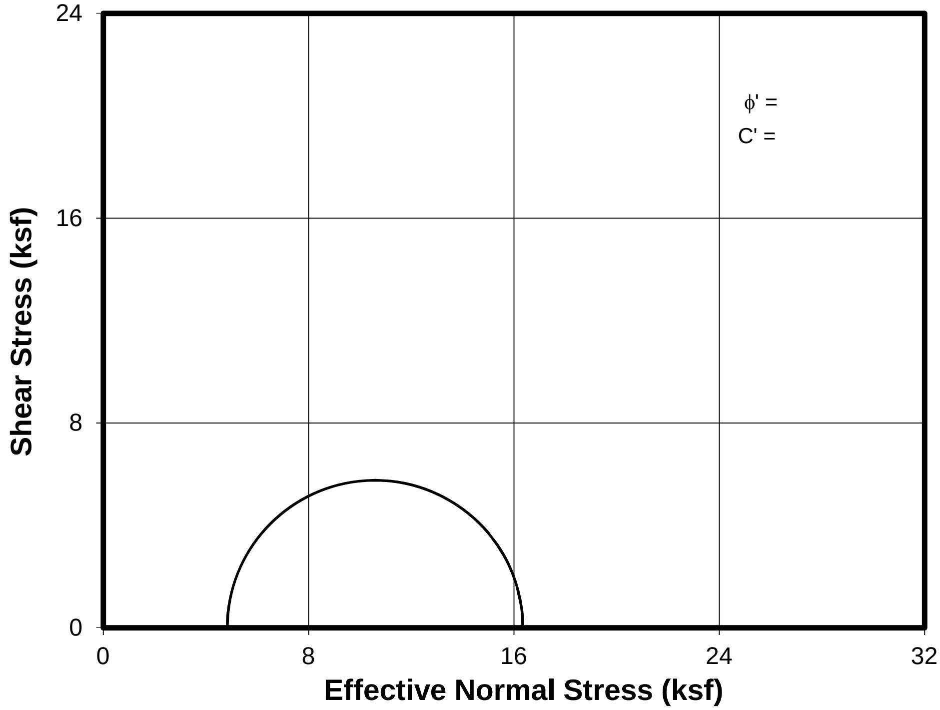
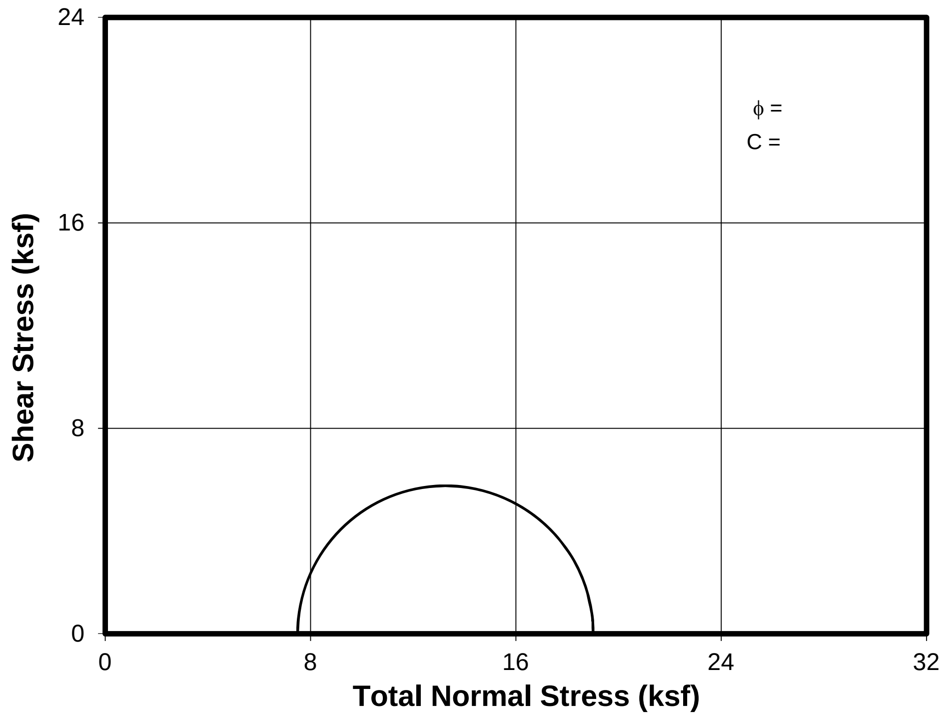
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



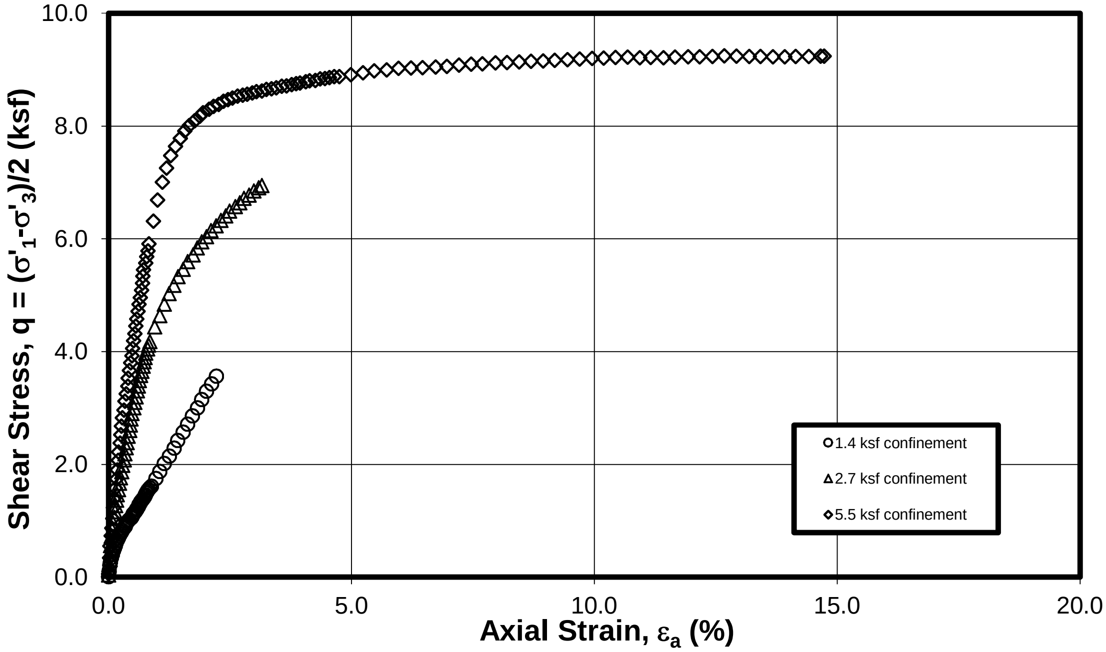


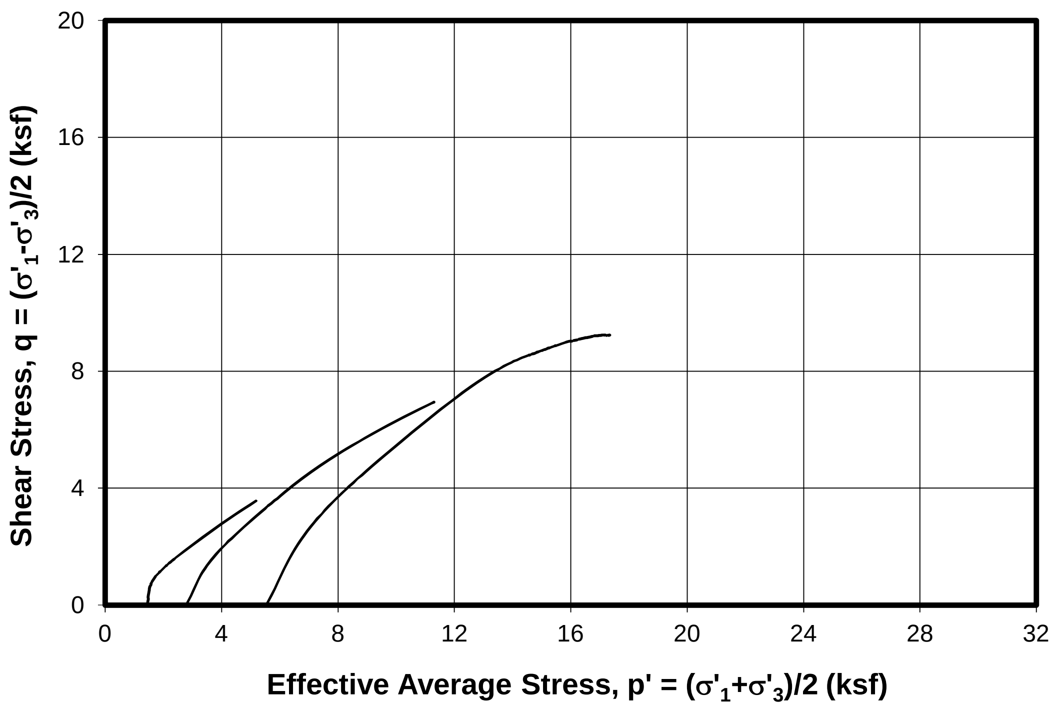
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-176, SAMPLE S-34, DEPTH 130.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



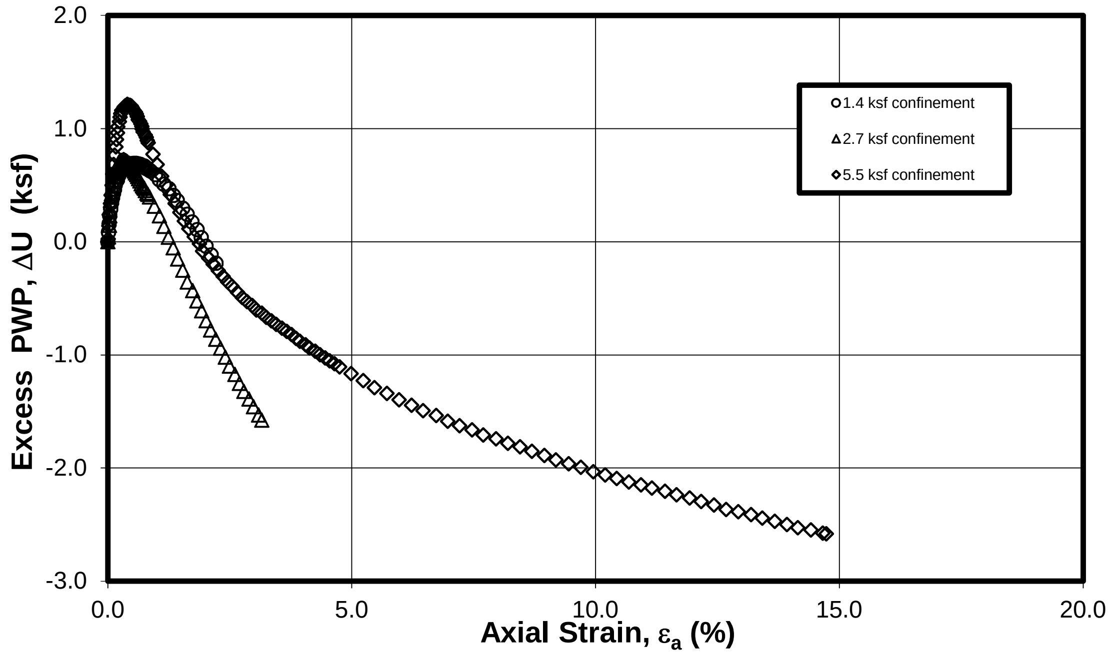


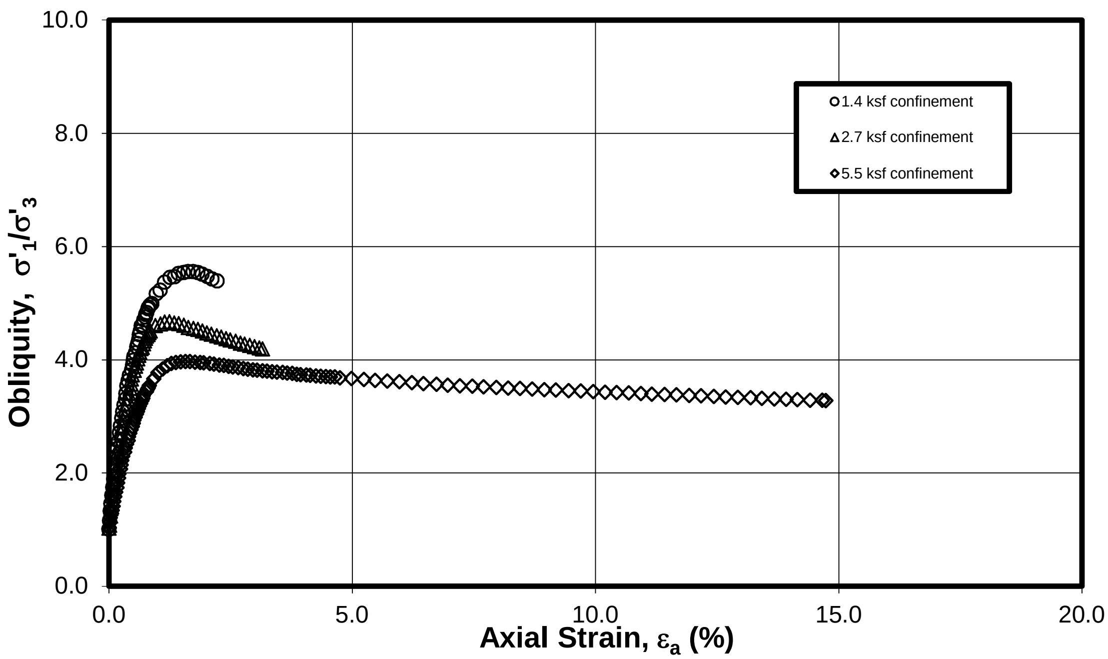
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-176, SAMPLE S-34, DEPTH 130.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



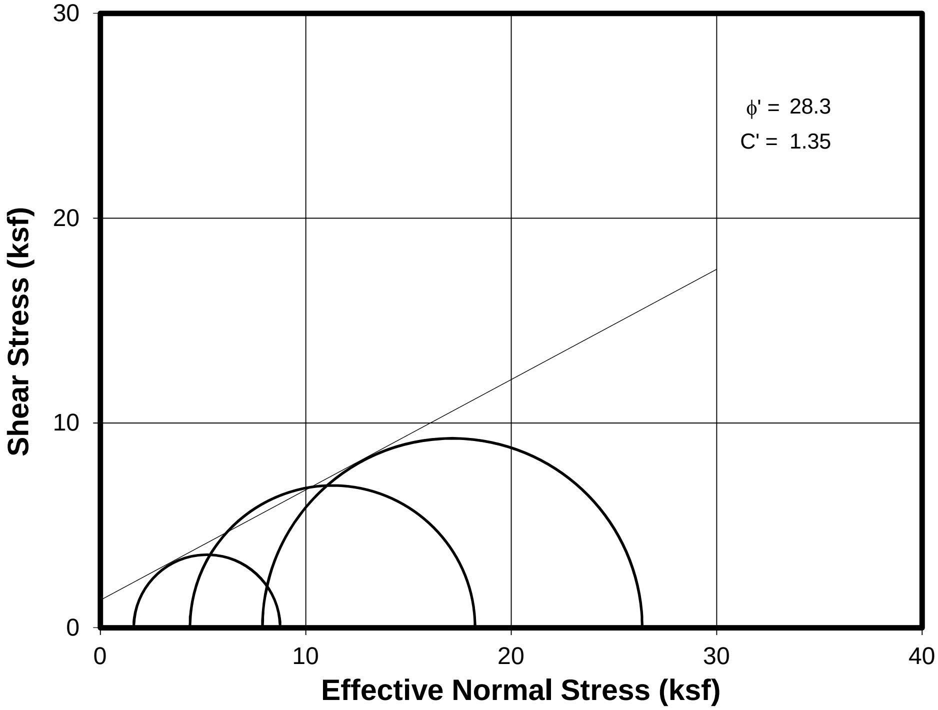


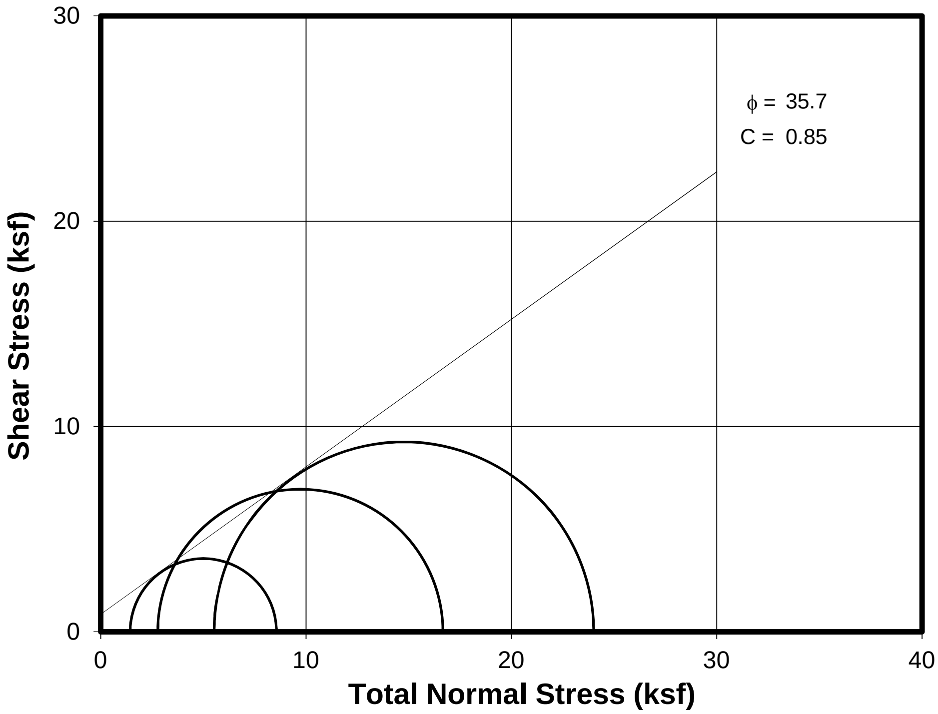
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-190, SAMPLE S-16, DEPTH 47.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



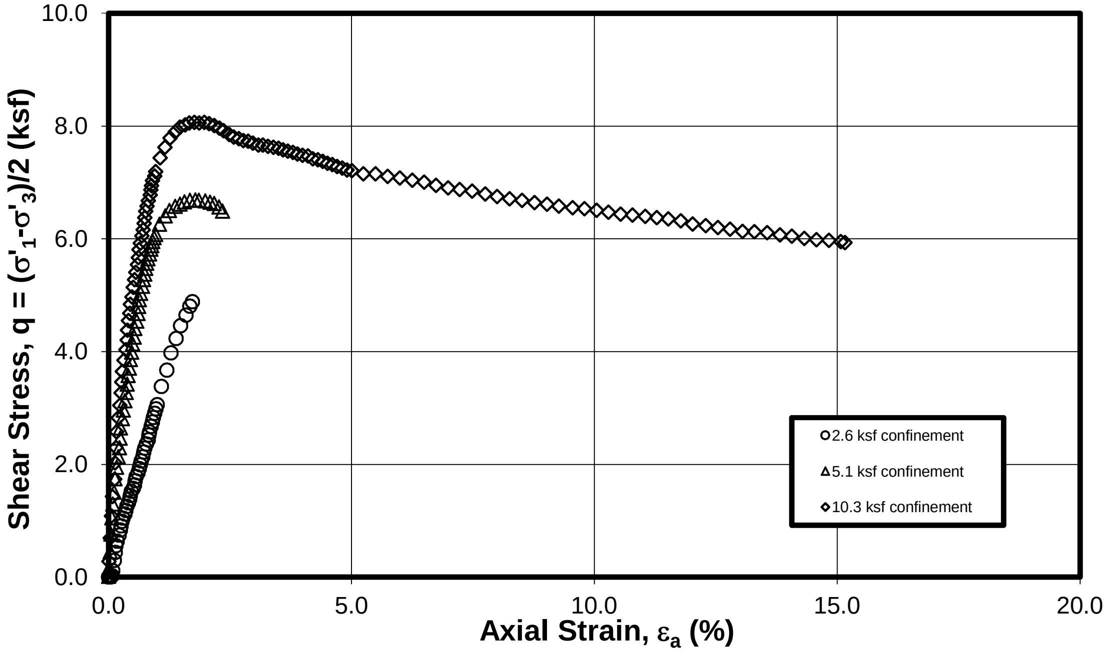


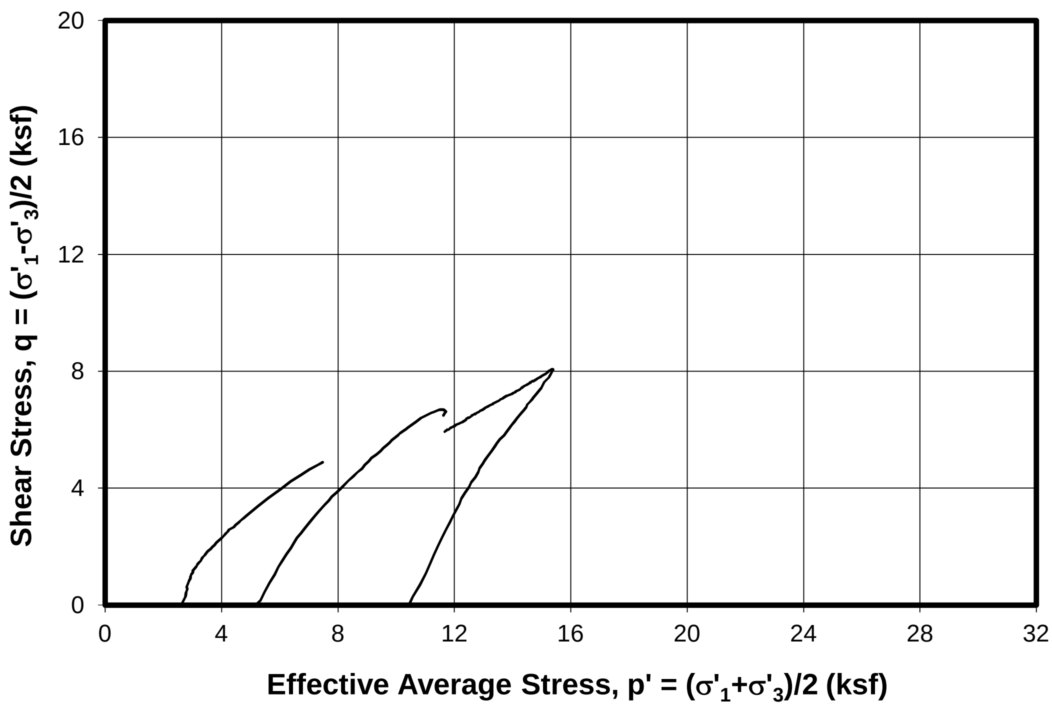
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-190, SAMPLE S-16, DEPTH 47.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA





CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-190, SAMPLE S-16, DEPTH 47.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA





CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
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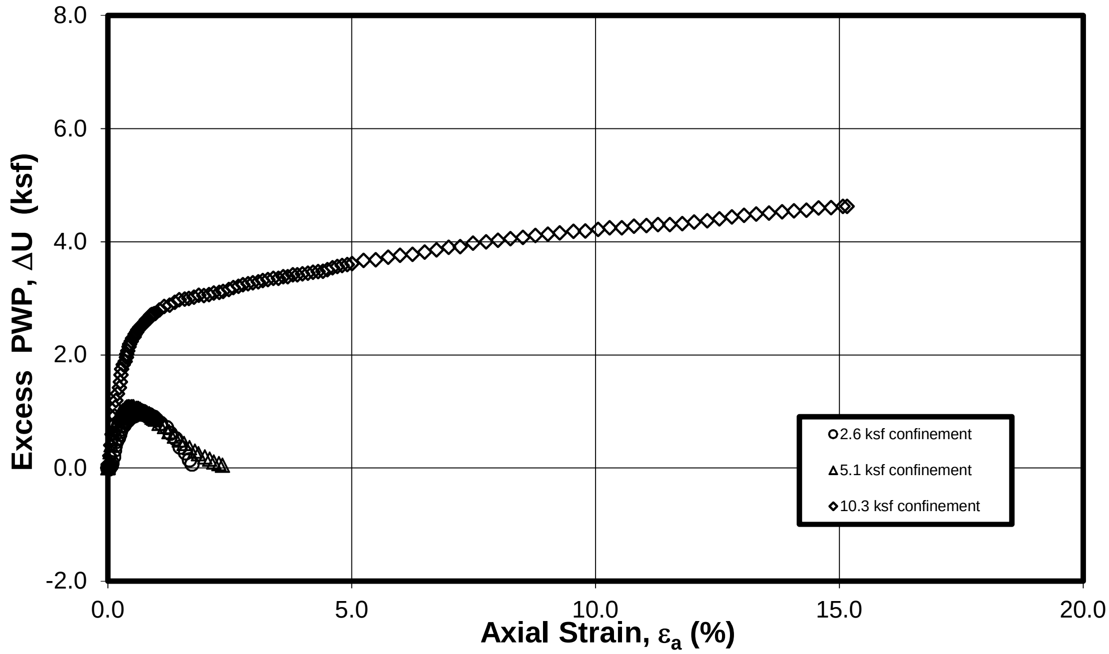
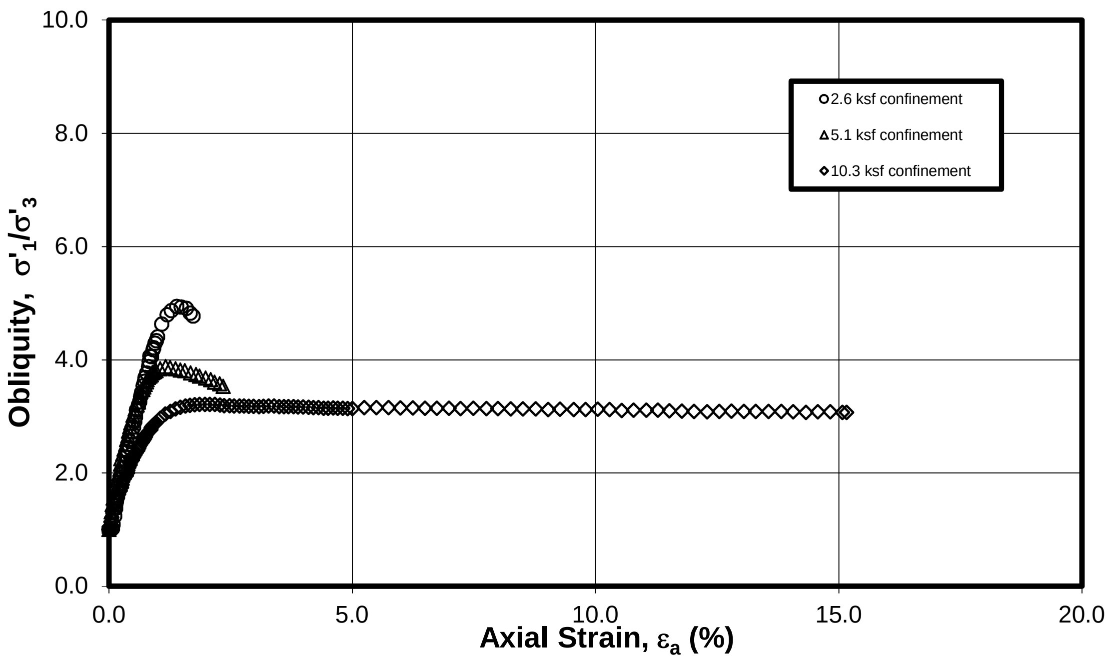
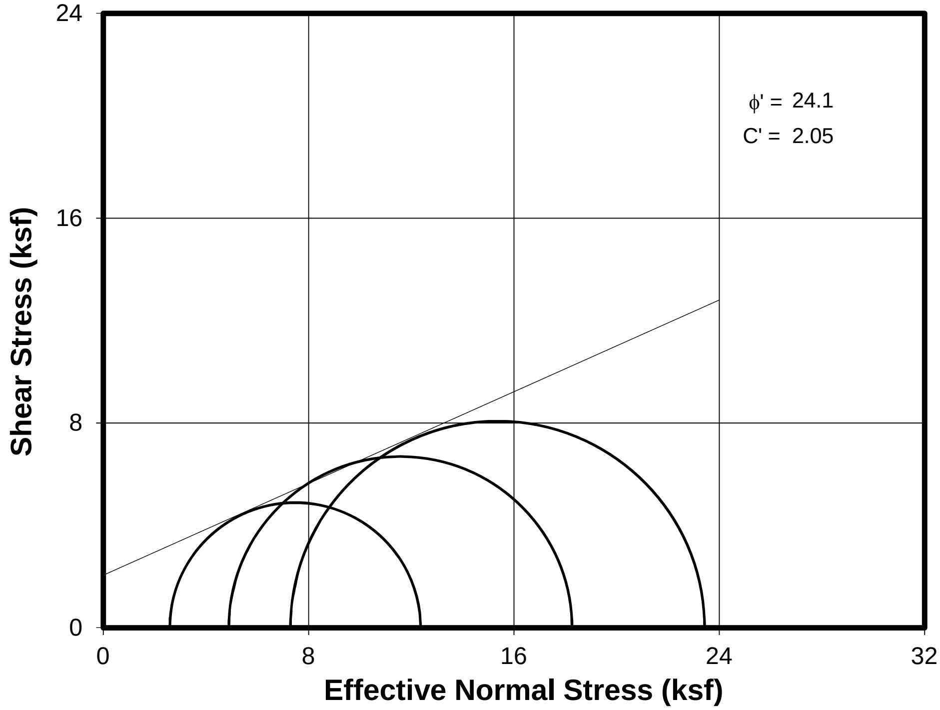
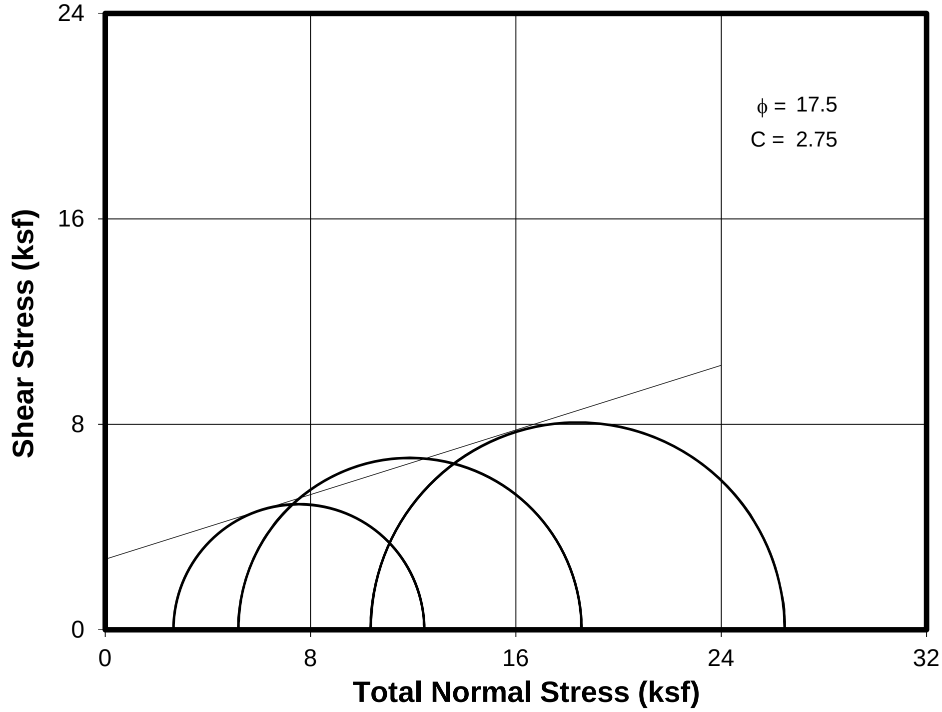
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



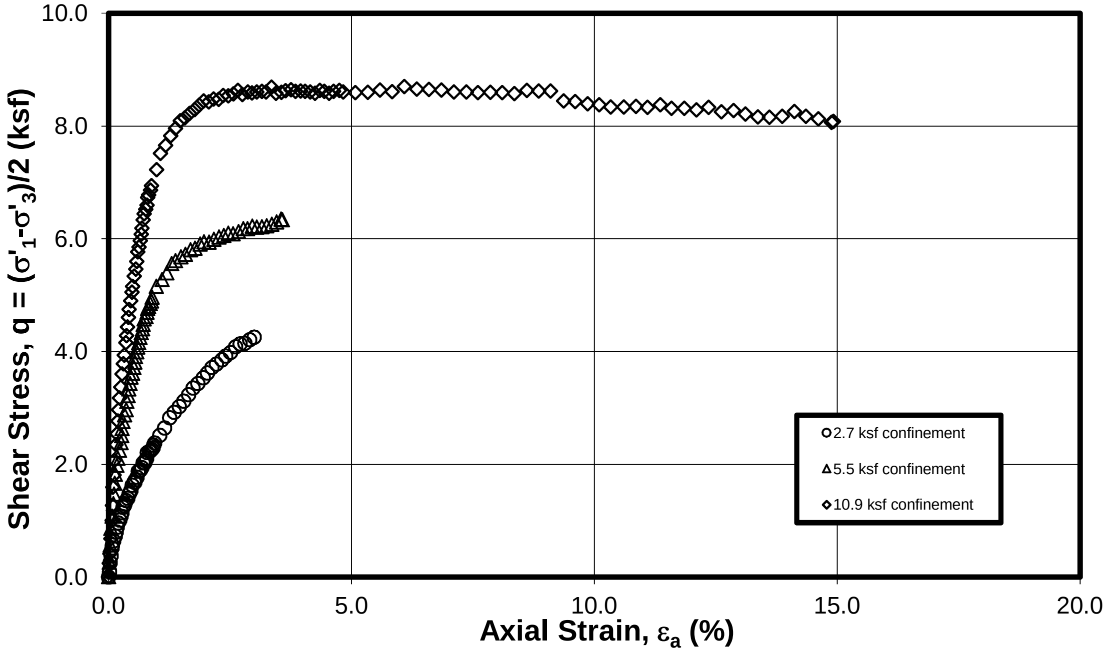


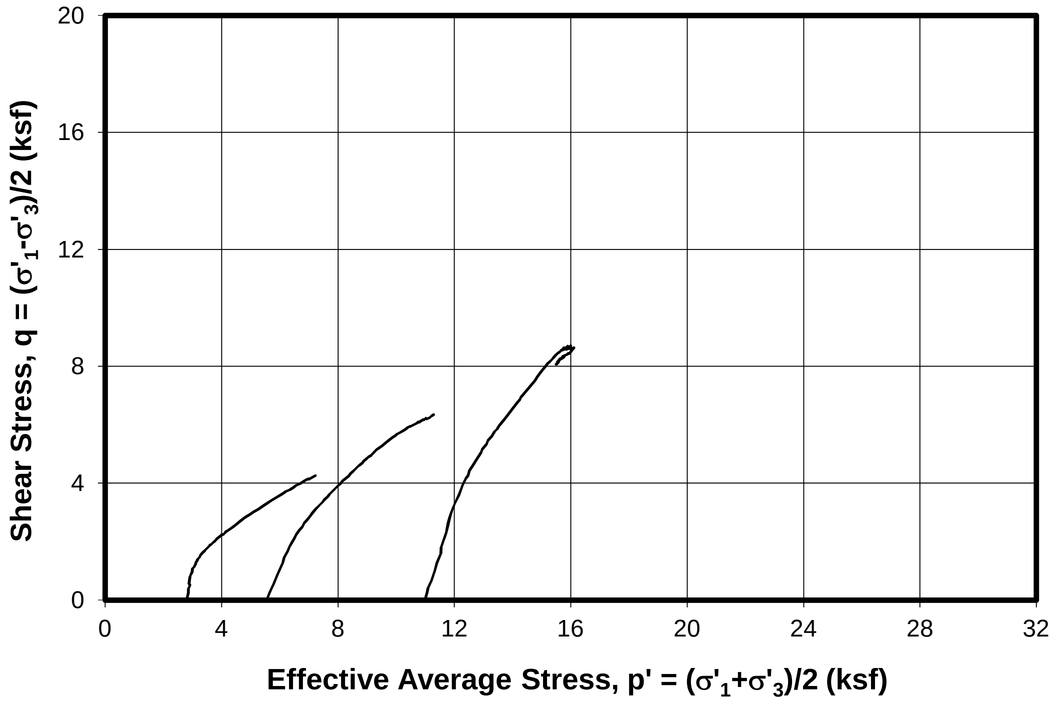
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-190, SAMPLE S-26, DEPTH 89.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



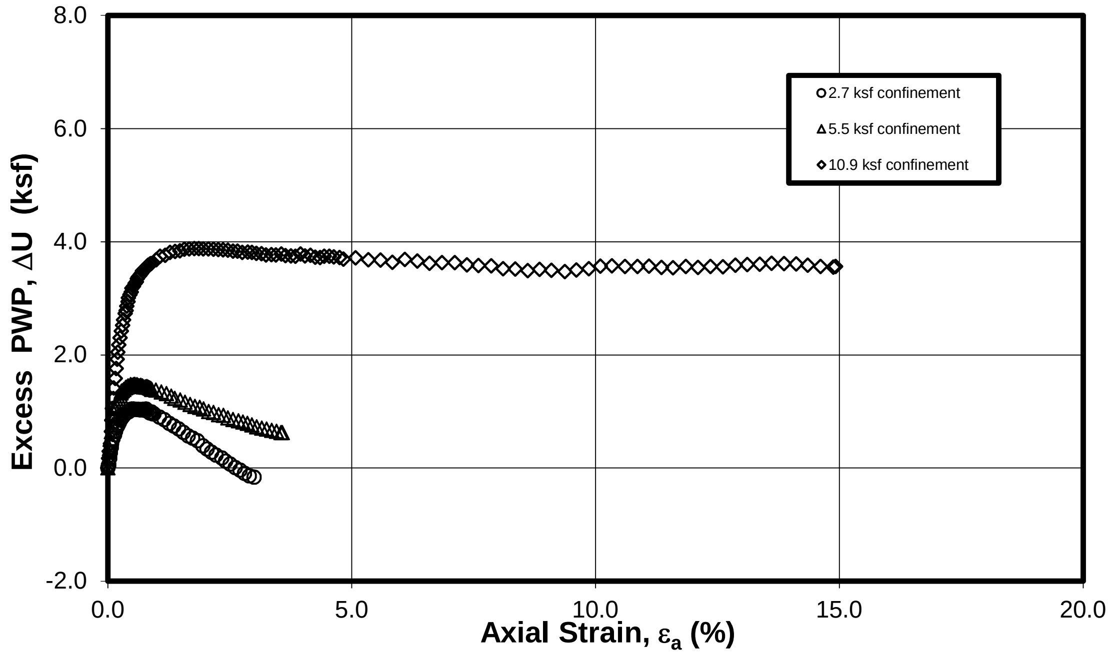


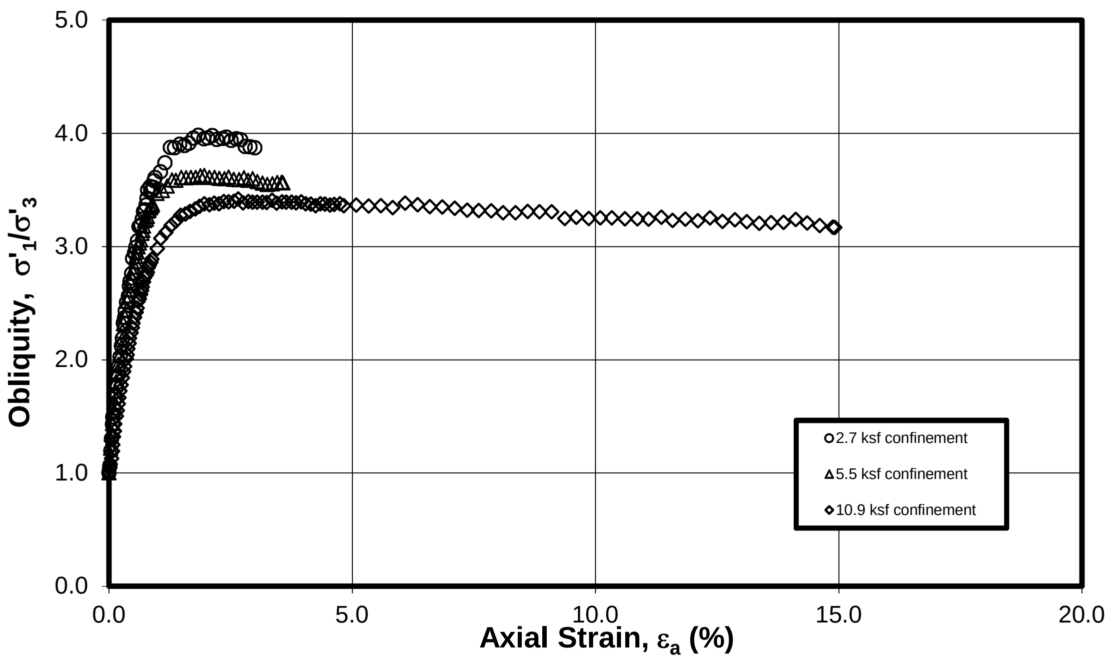
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-190, SAMPLE S-26, DEPTH 89.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



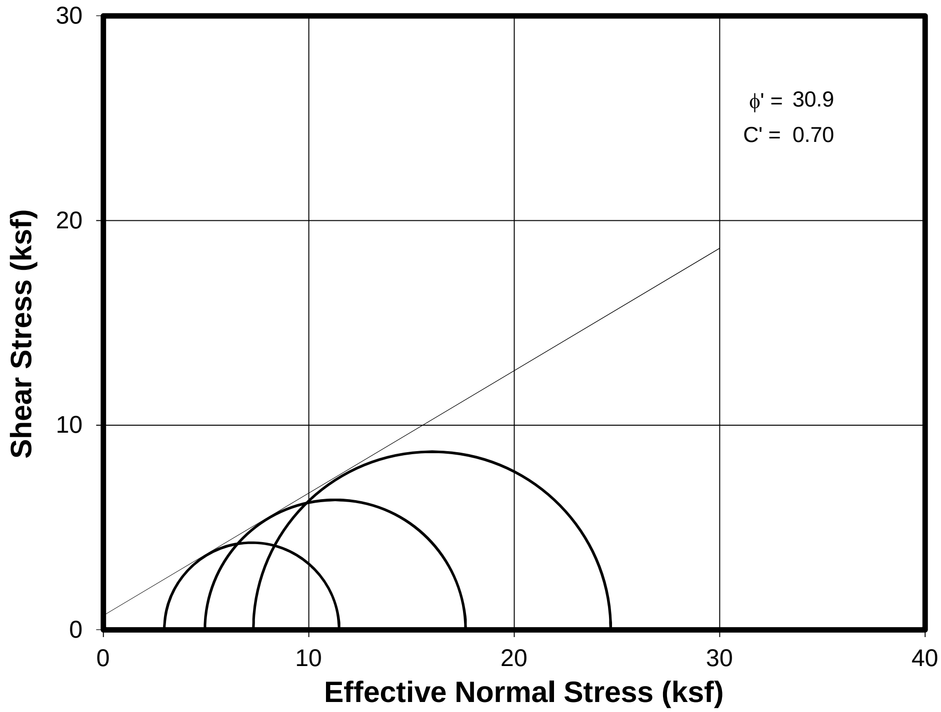


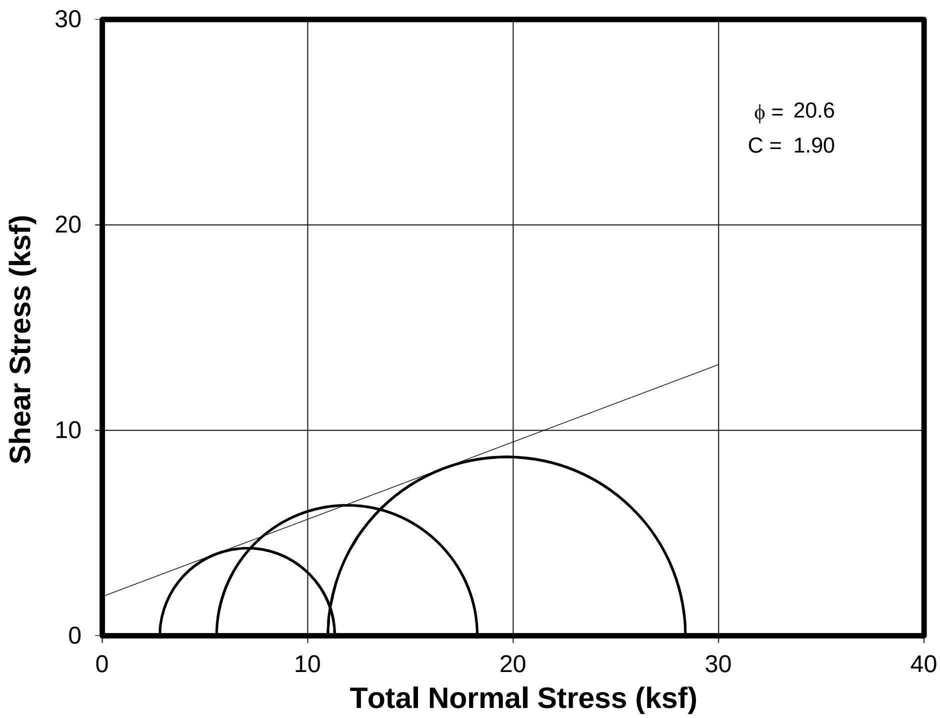
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-190, SAMPLE S-27, DEPTH 95.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



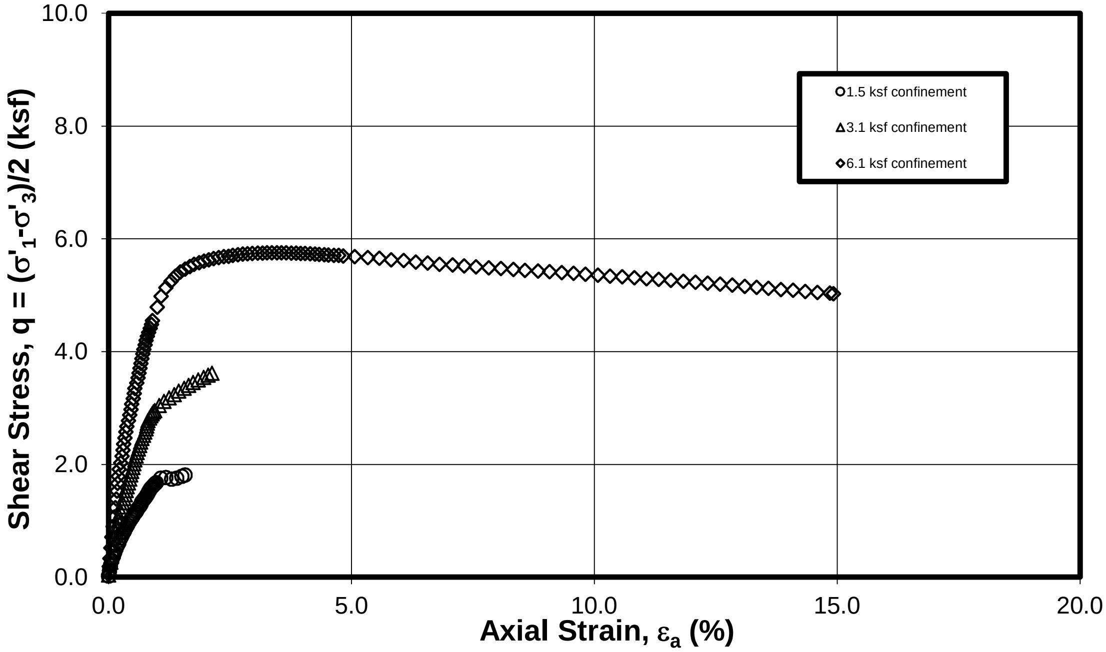


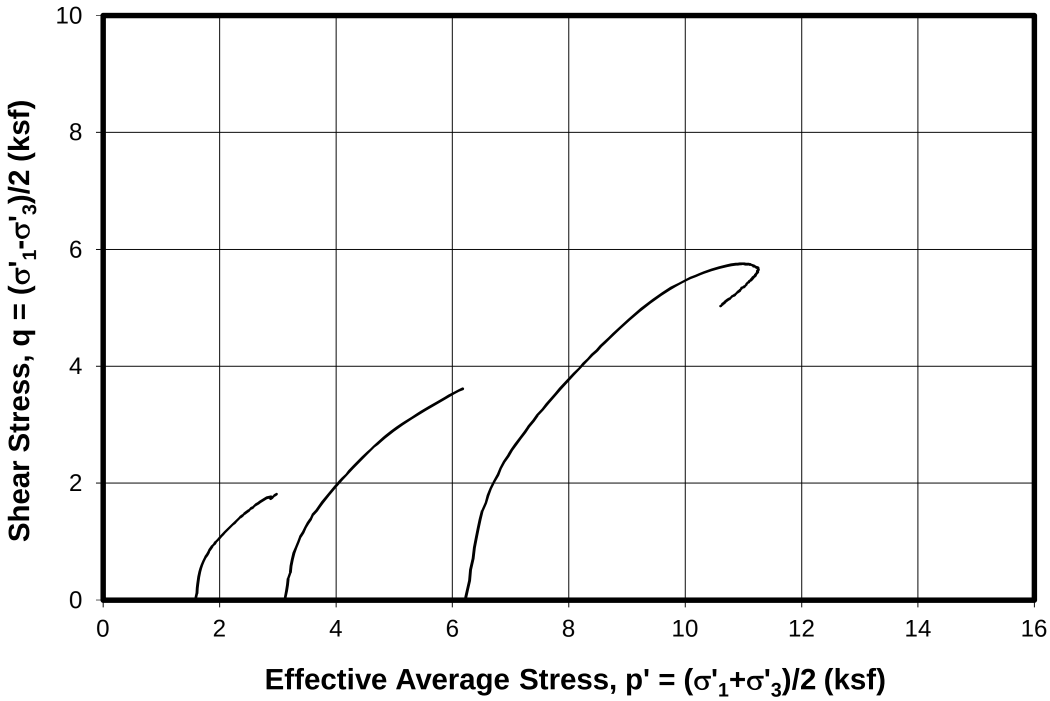
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-190, SAMPLE S-27, DEPTH 95.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



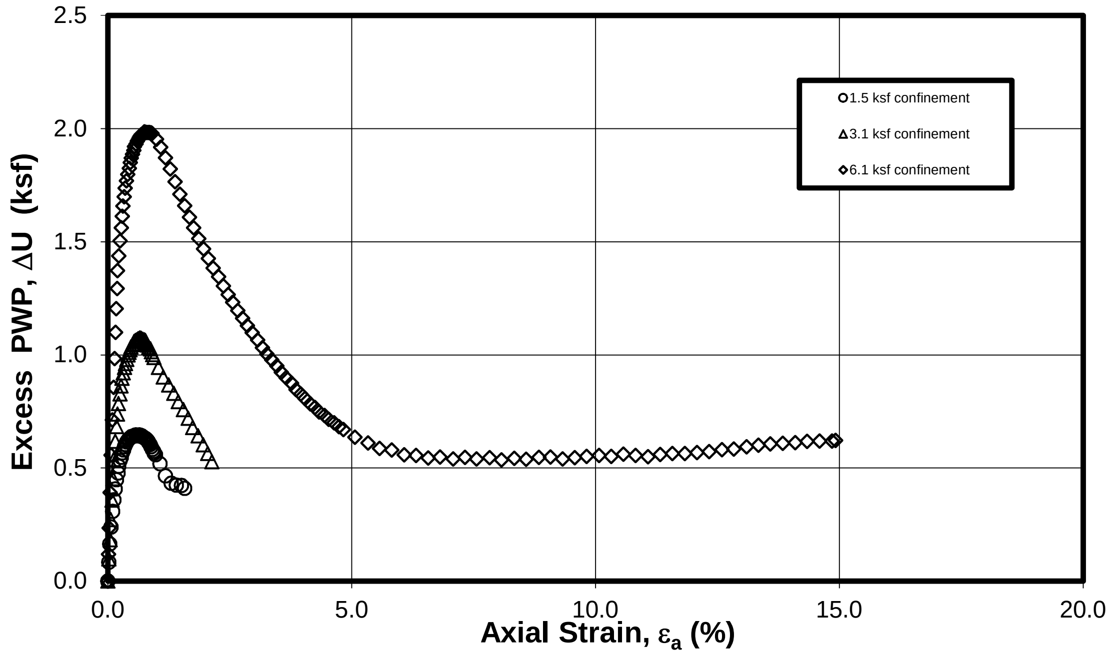


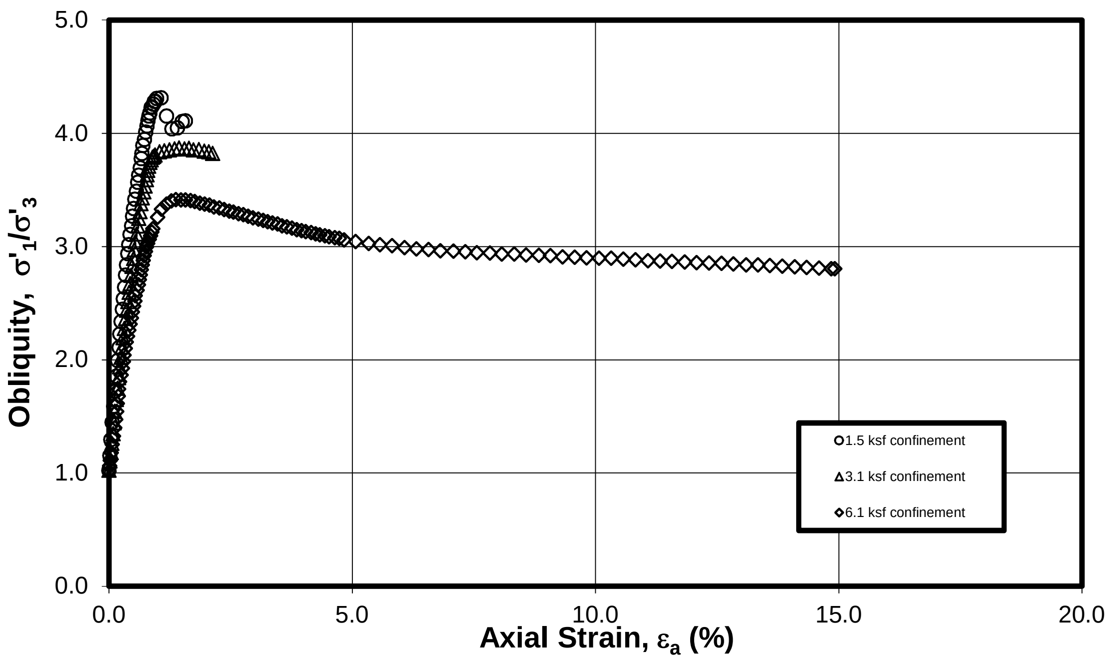
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-190, SAMPLE S-27, DEPTH 95.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



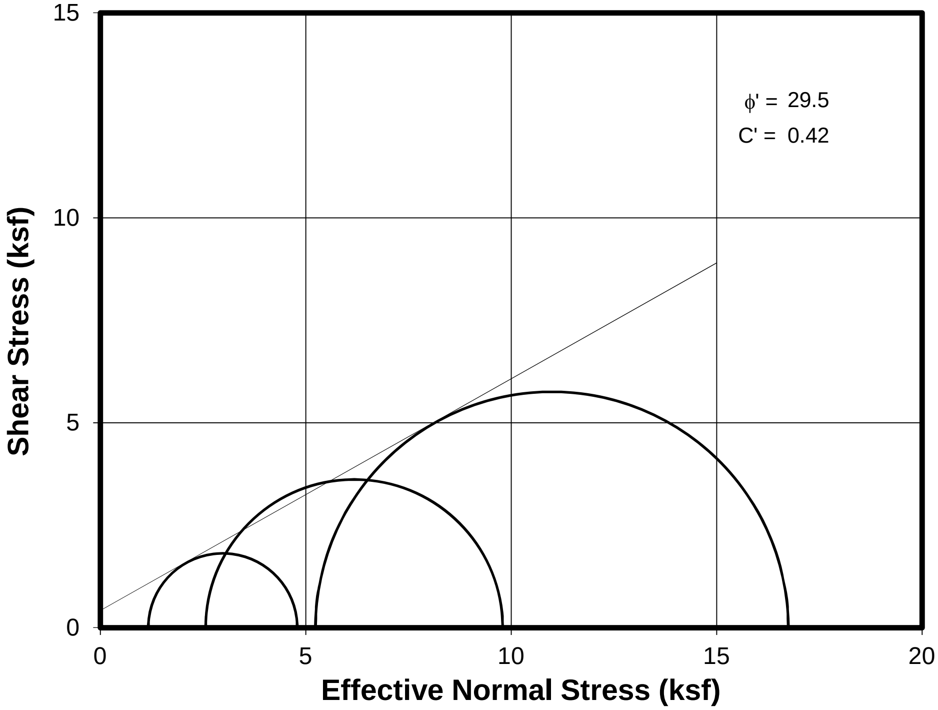


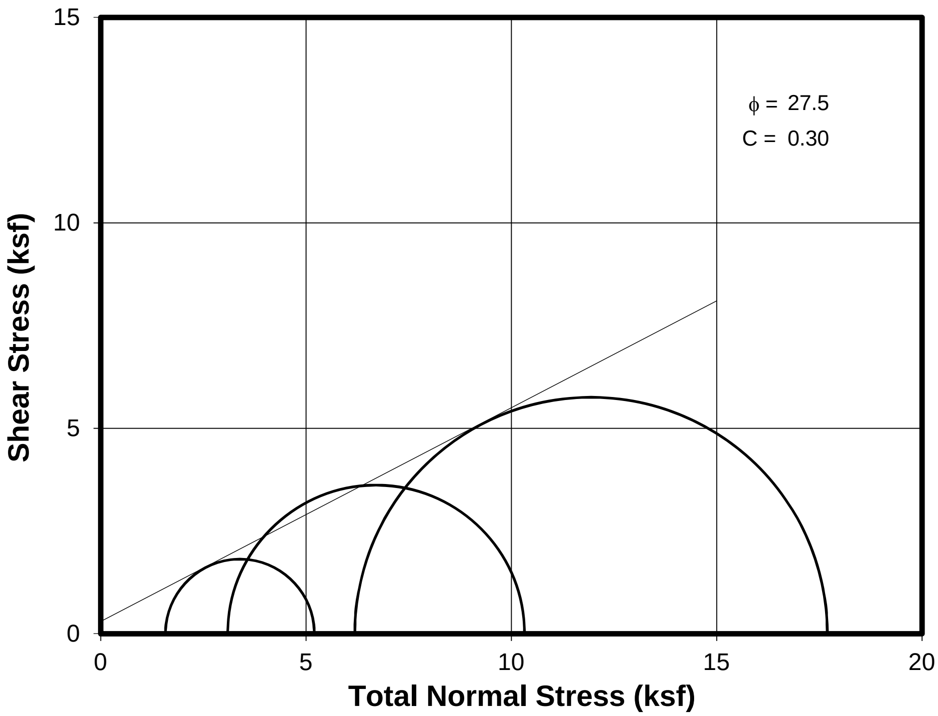
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-191, SAMPLE S-17, DEPTH 53.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



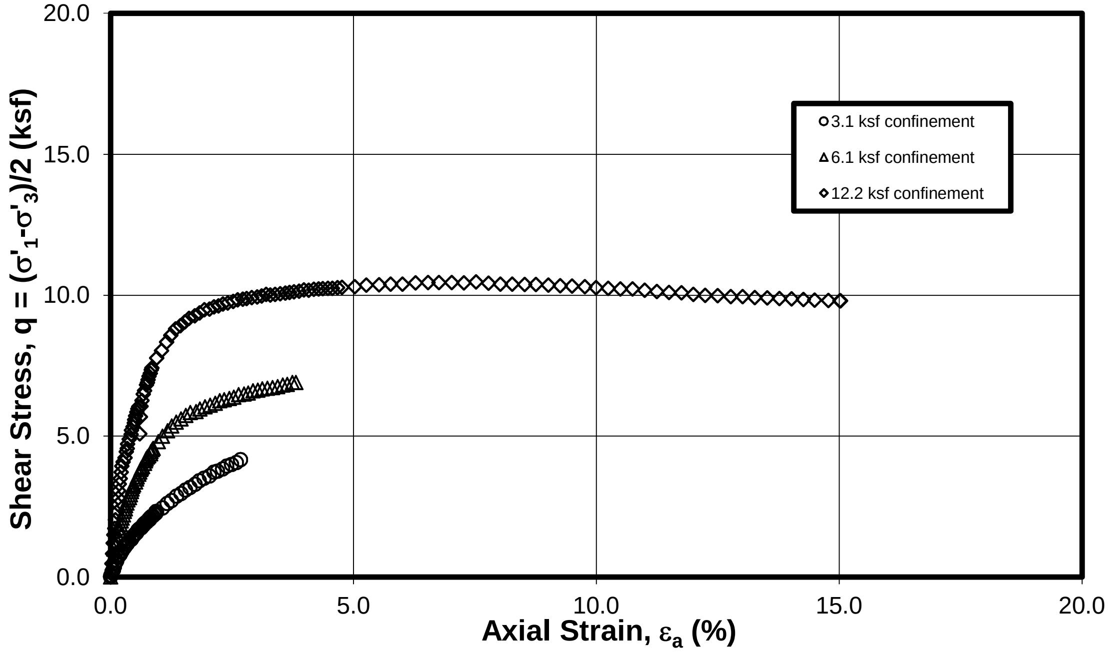


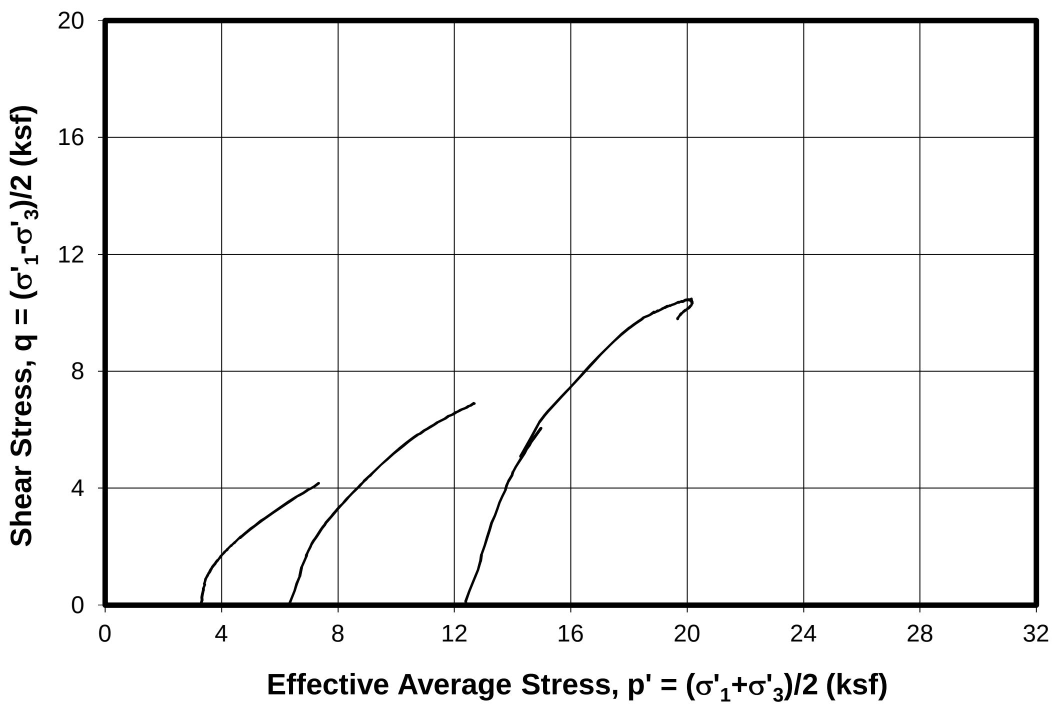
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-191, SAMPLE S-17, DEPTH 53.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA





CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-191, SAMPLE S-17, DEPTH 53.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA





CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
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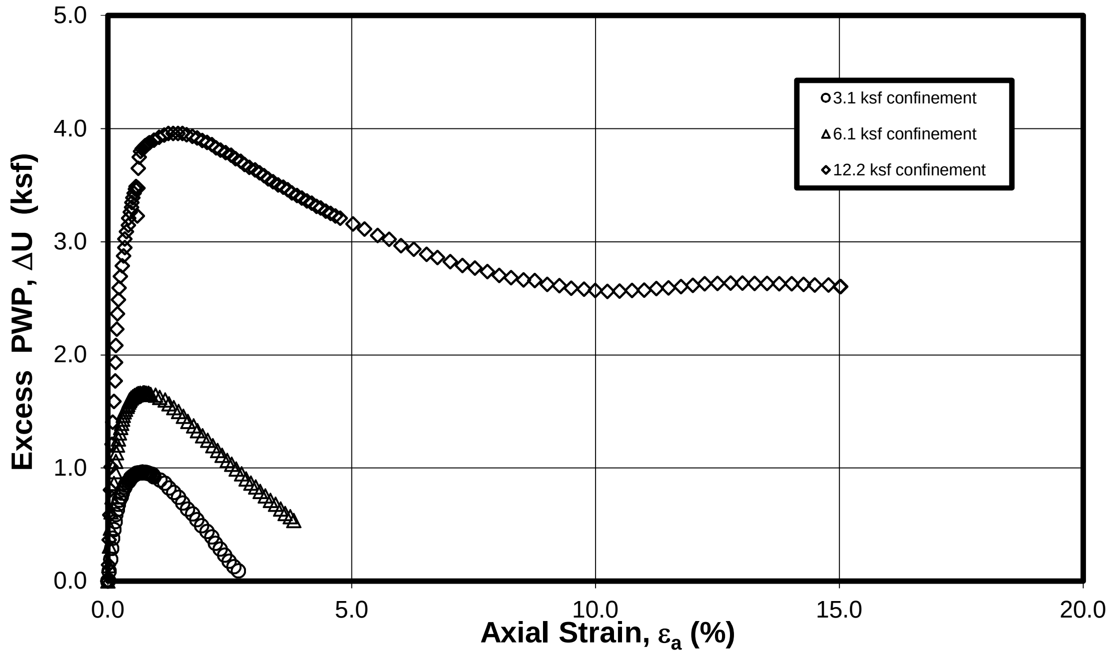
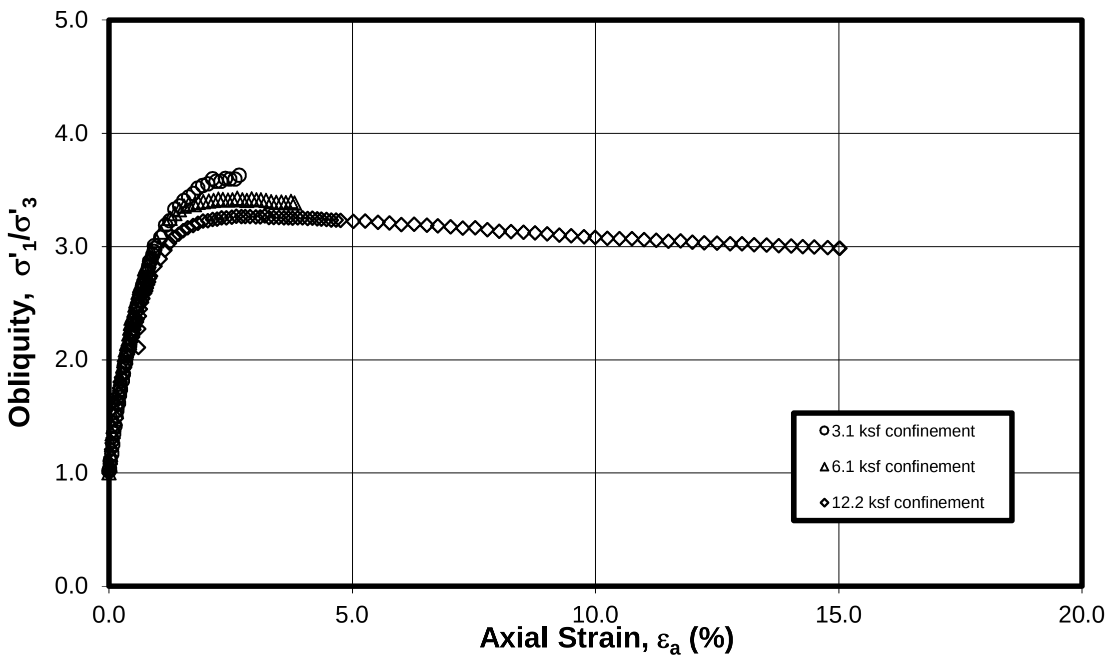
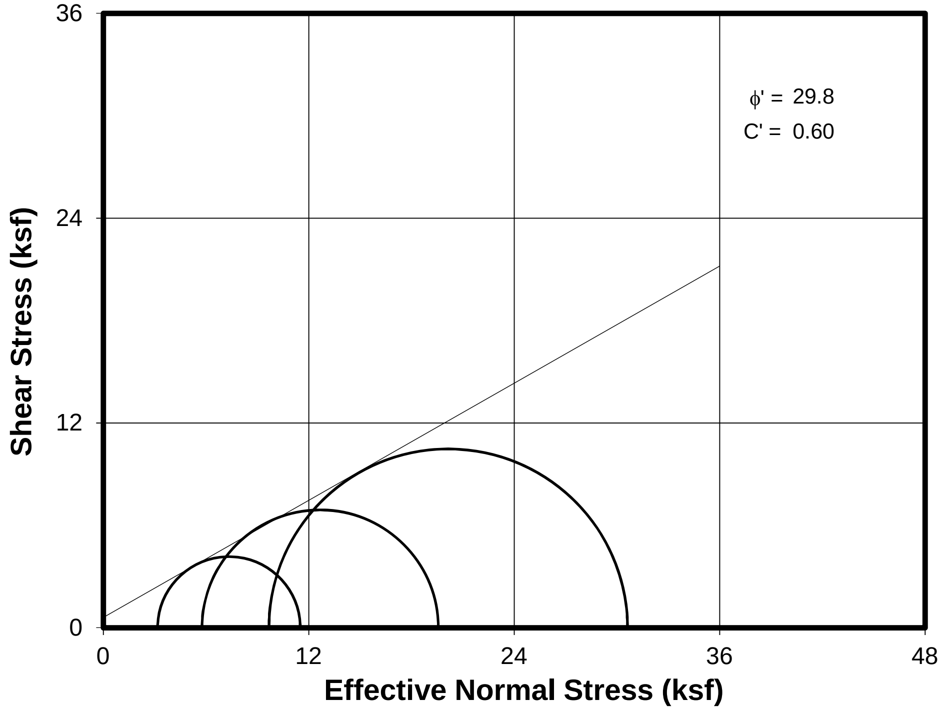
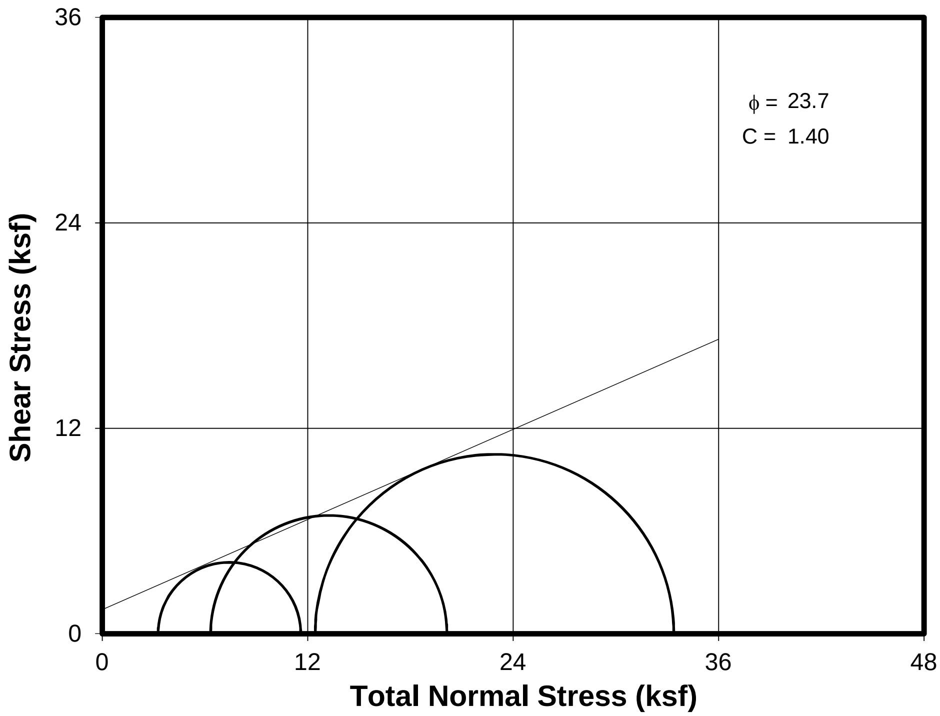
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



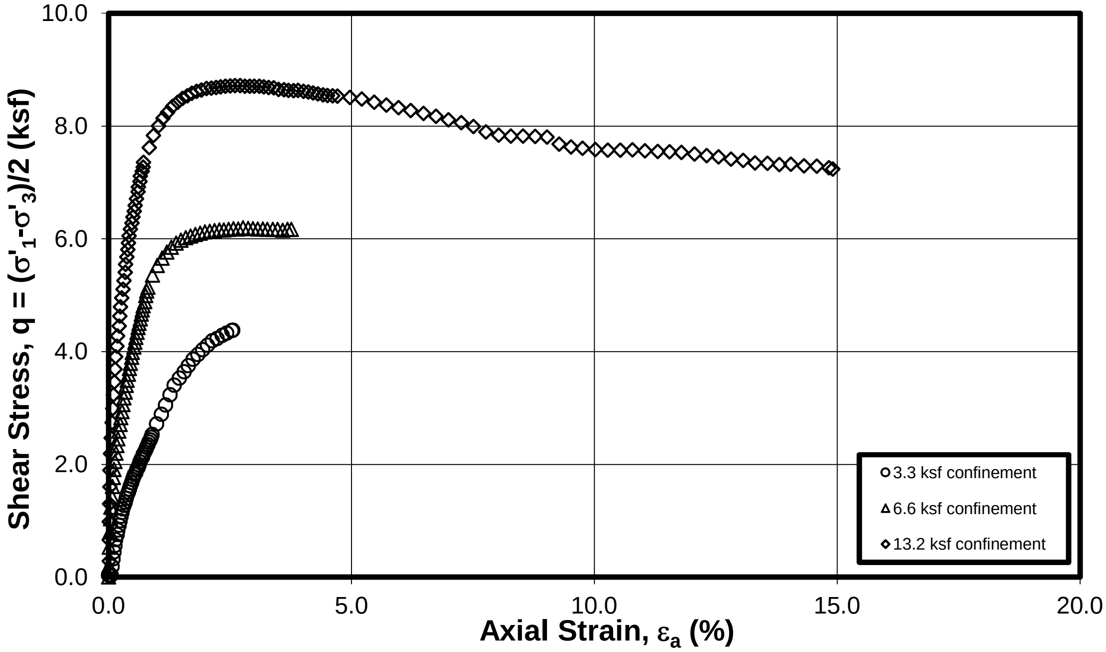


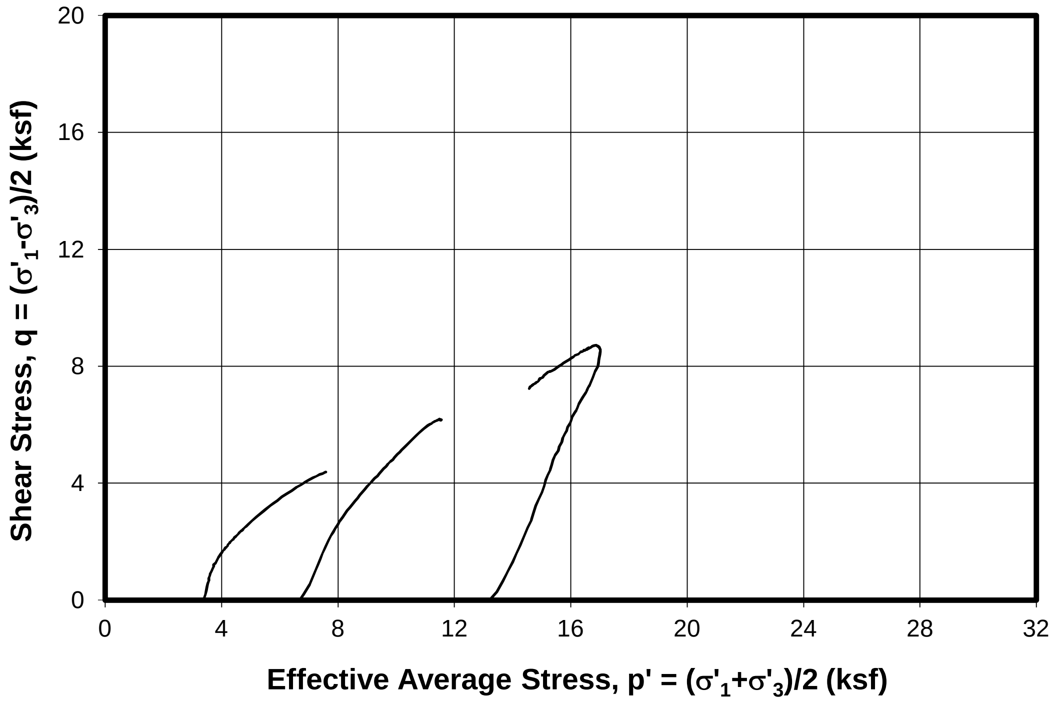
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-191, SAMPLE S-32, DEPTH 106.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



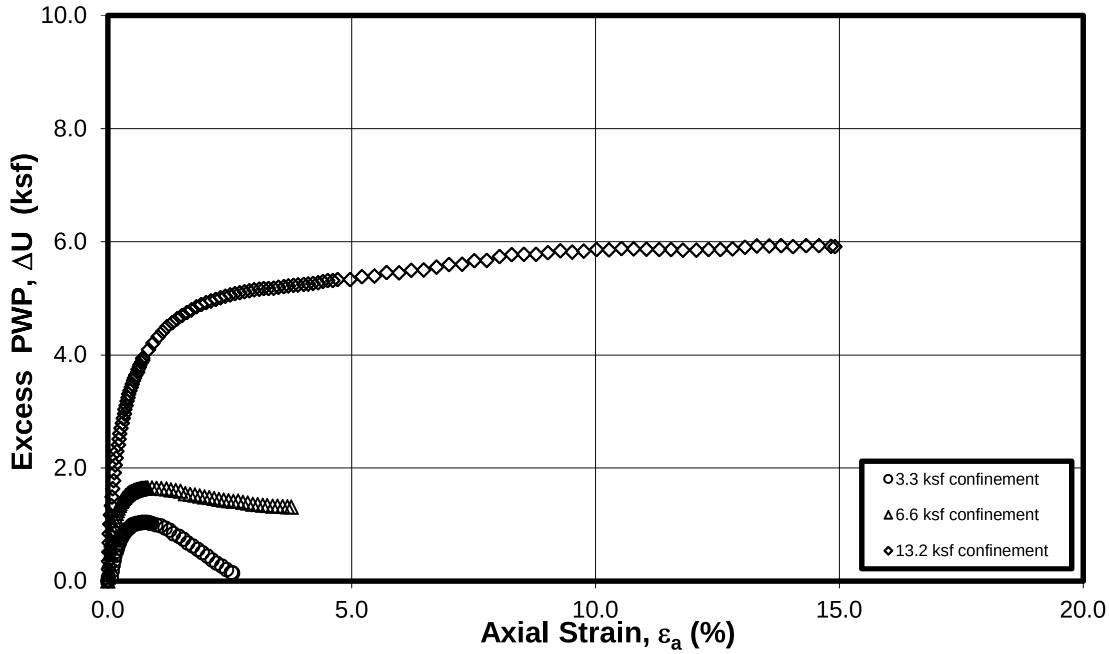


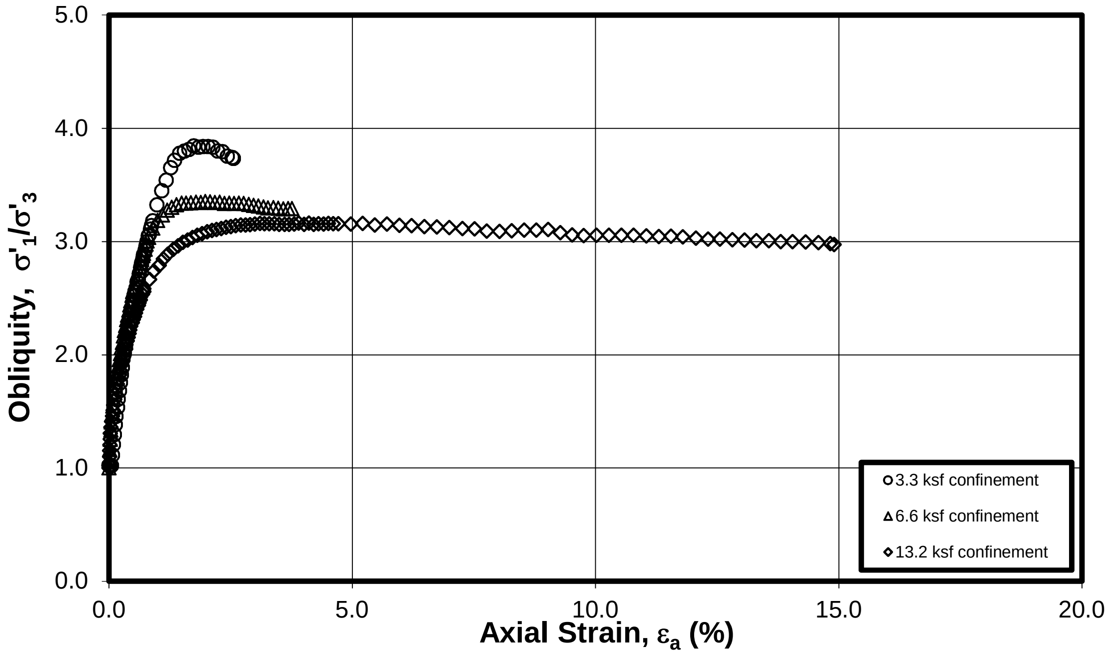
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-191, SAMPLE S-32, DEPTH 106.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



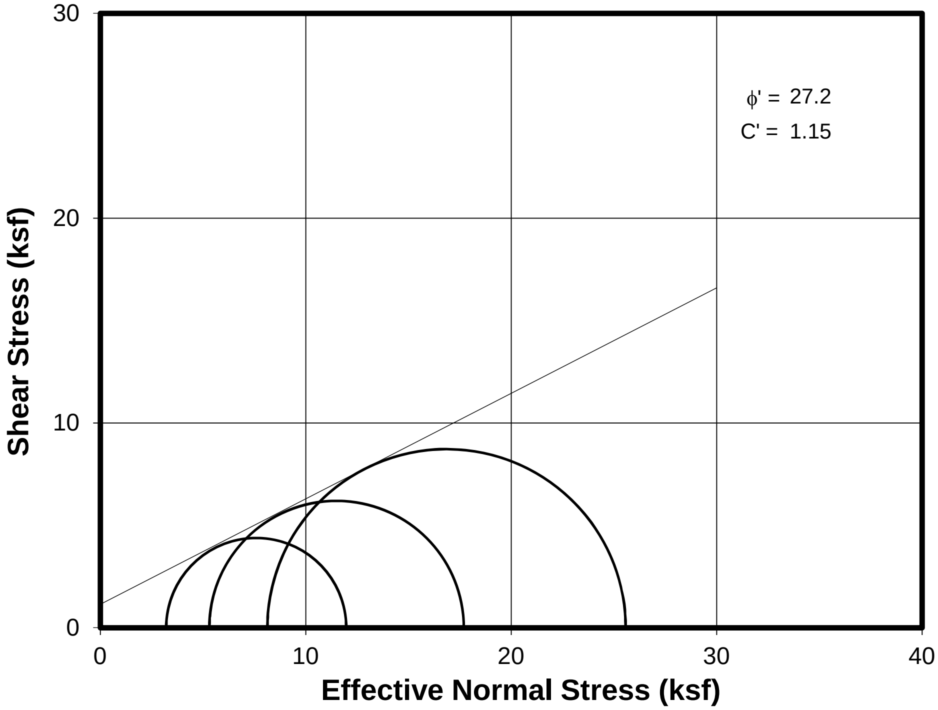


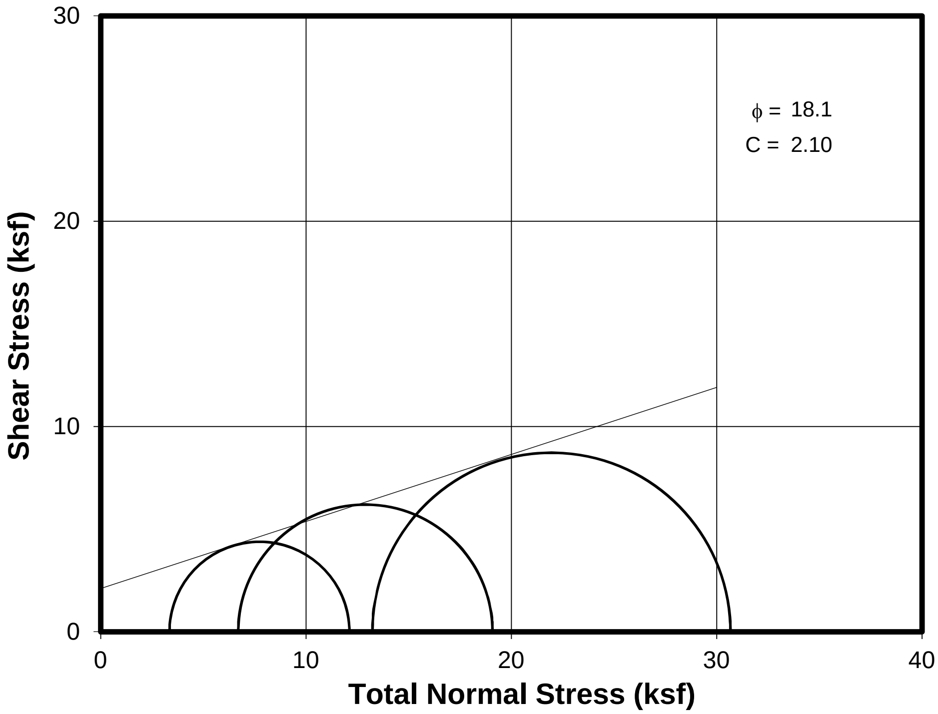
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-191, SAMPLE S-36, DEPTH 114.2 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



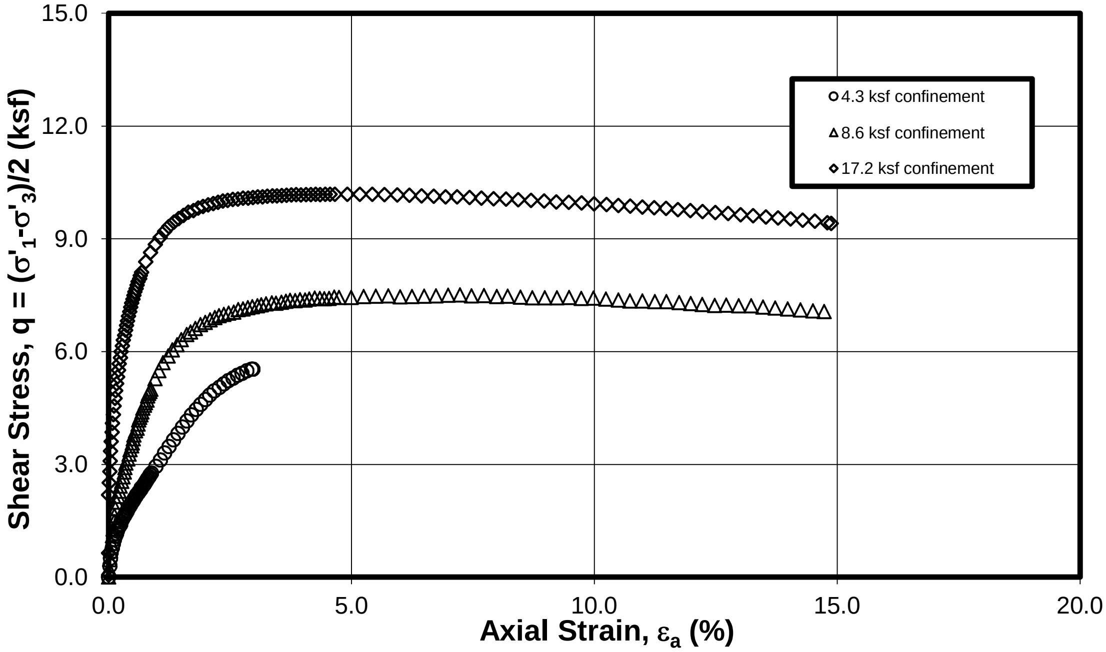


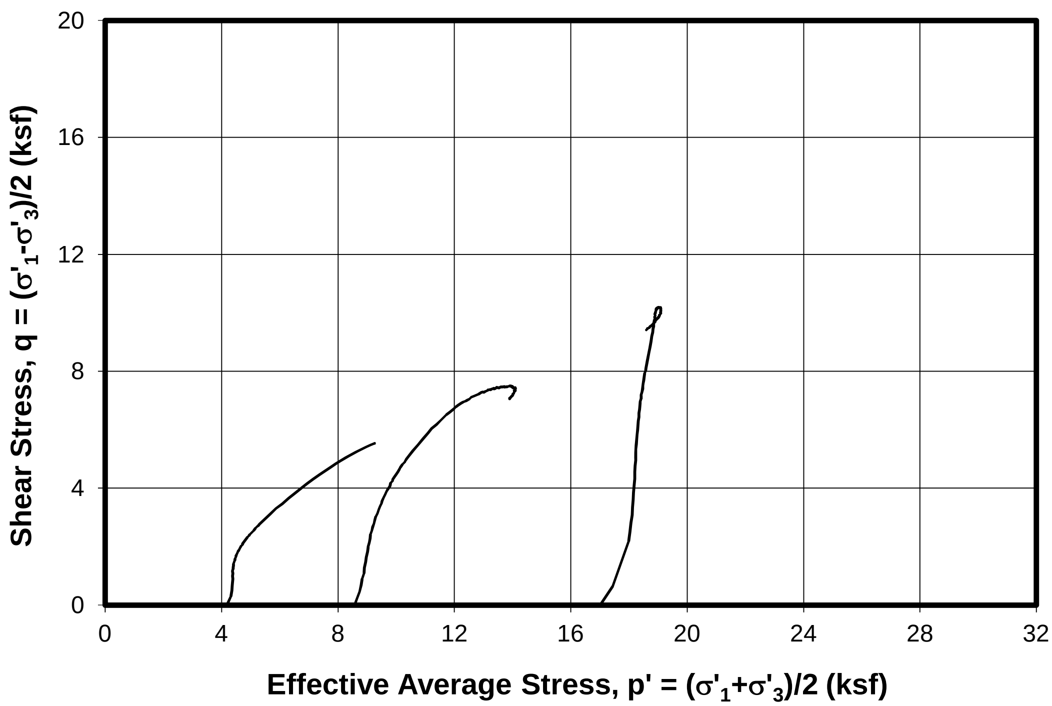
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-191, SAMPLE S-36, DEPTH 114.2 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



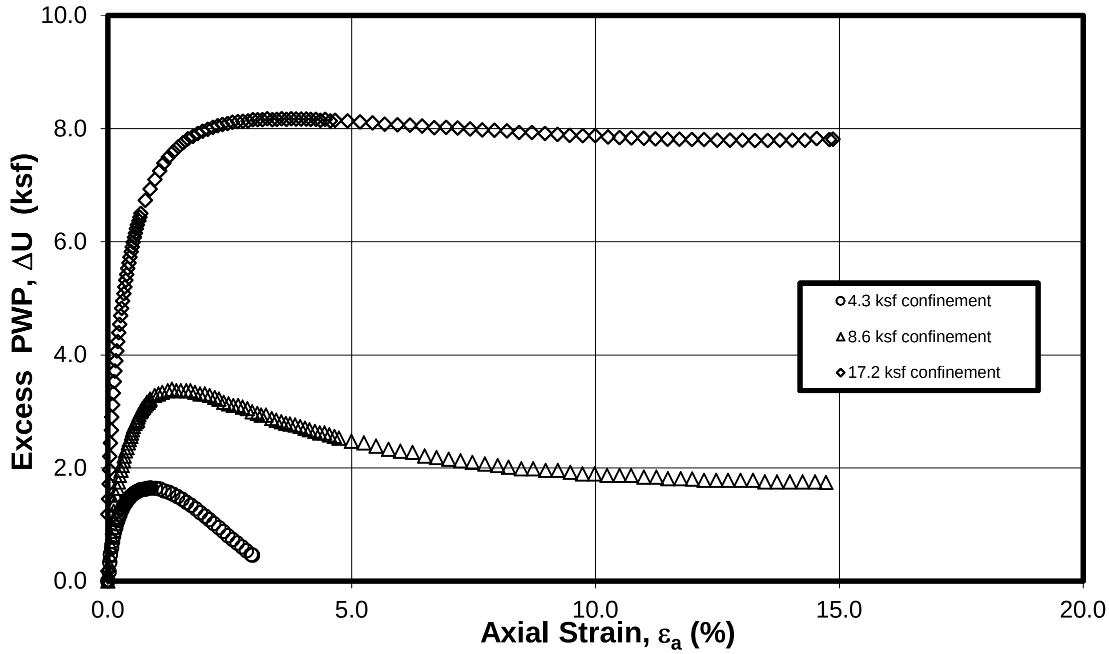


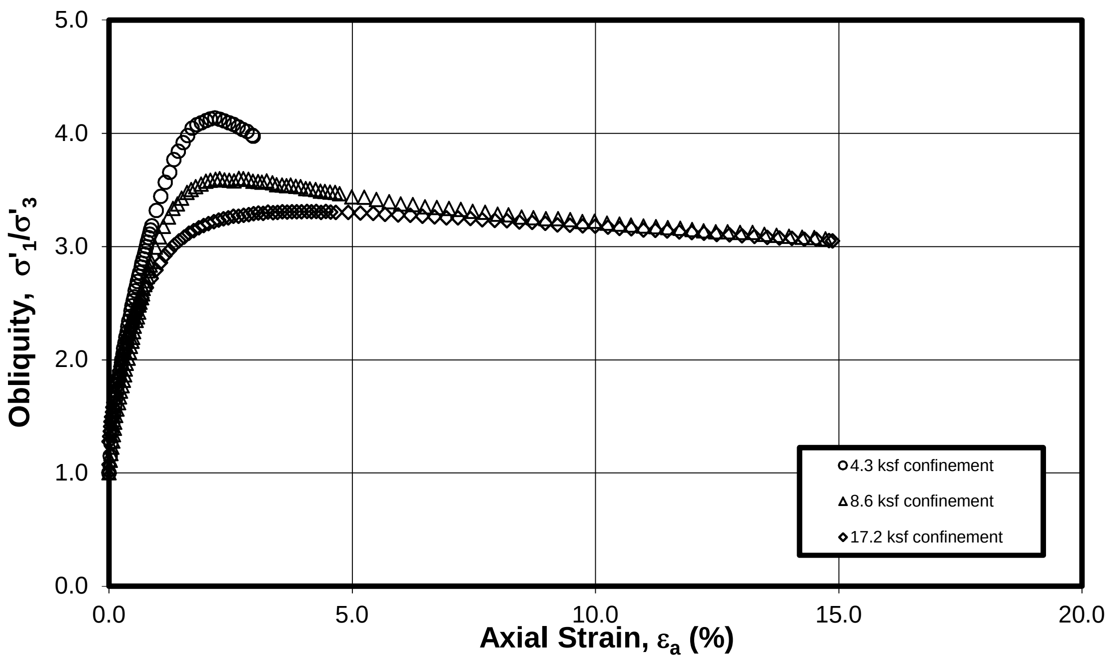
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-191, SAMPLE S-36, DEPTH 114.2 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



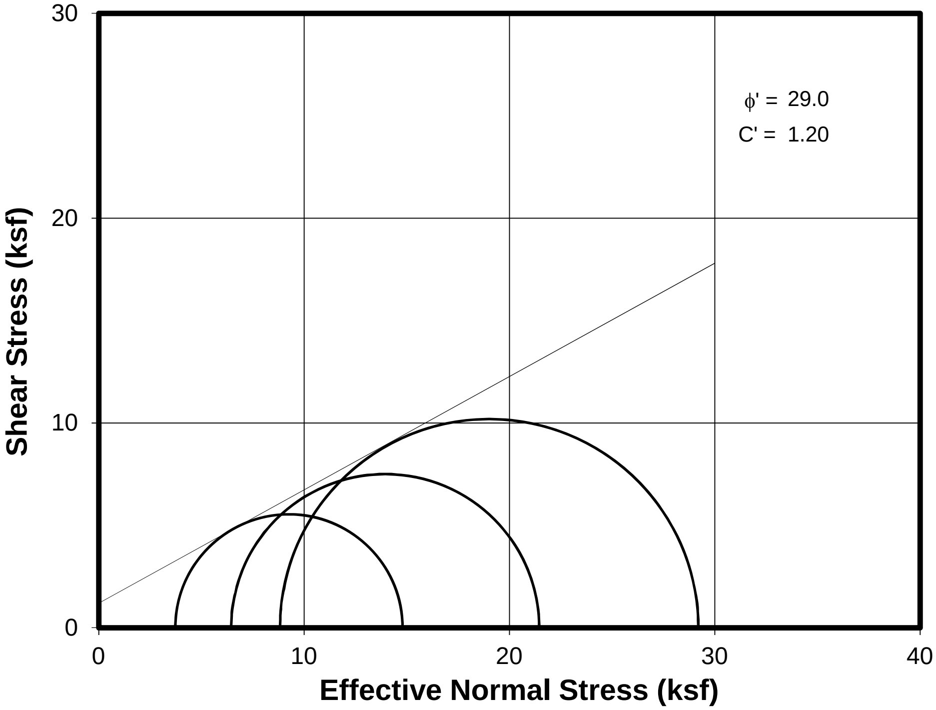


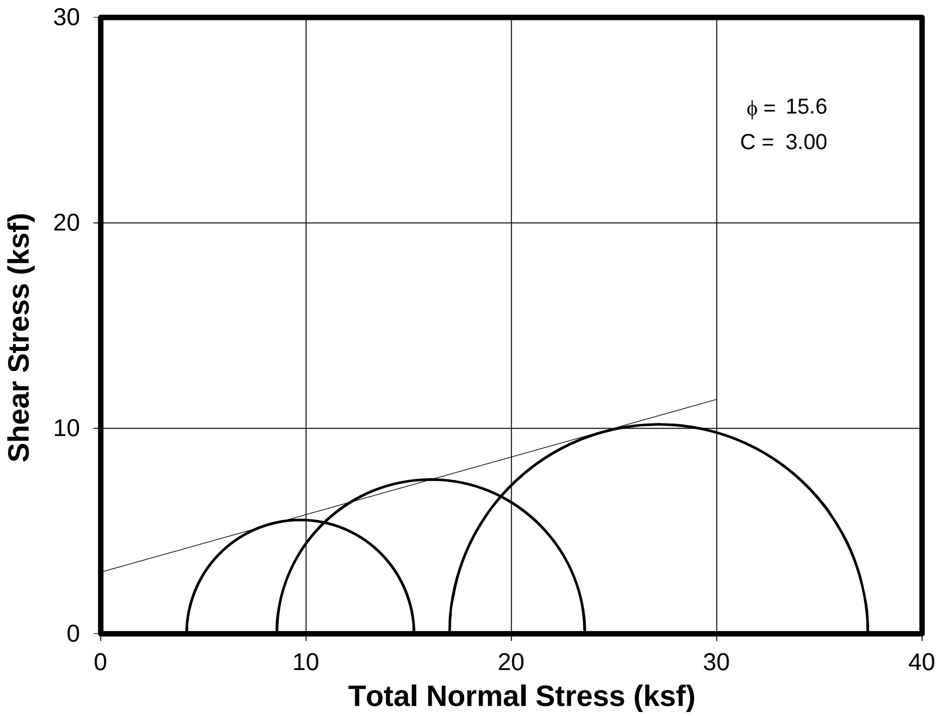
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-192, SAMPLE S-24, DEPTH 92.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



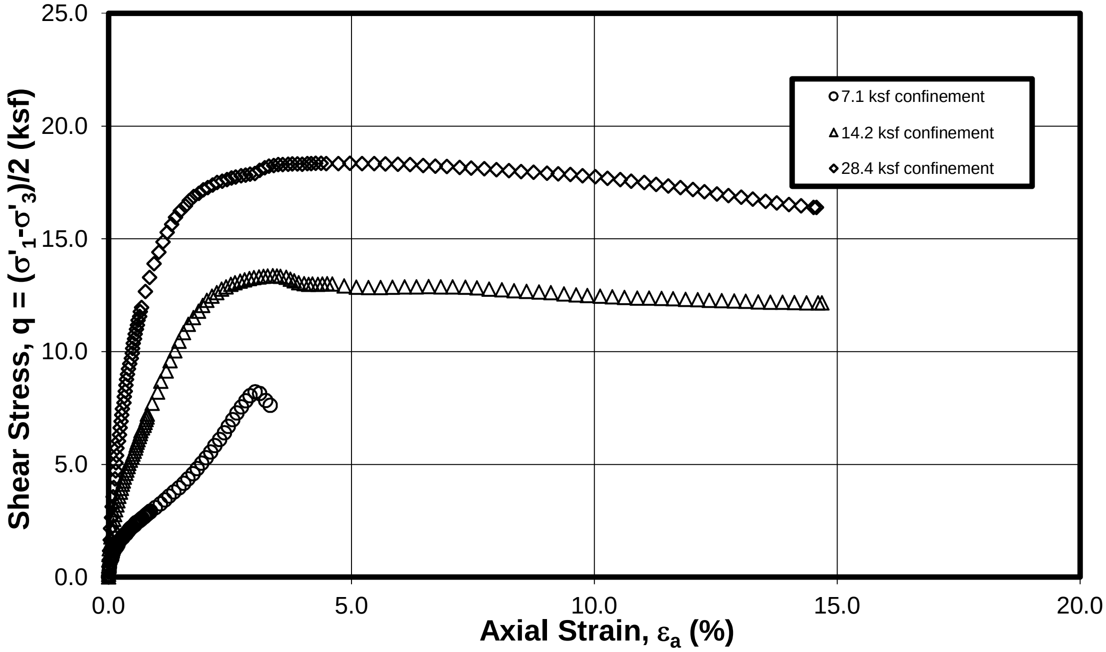


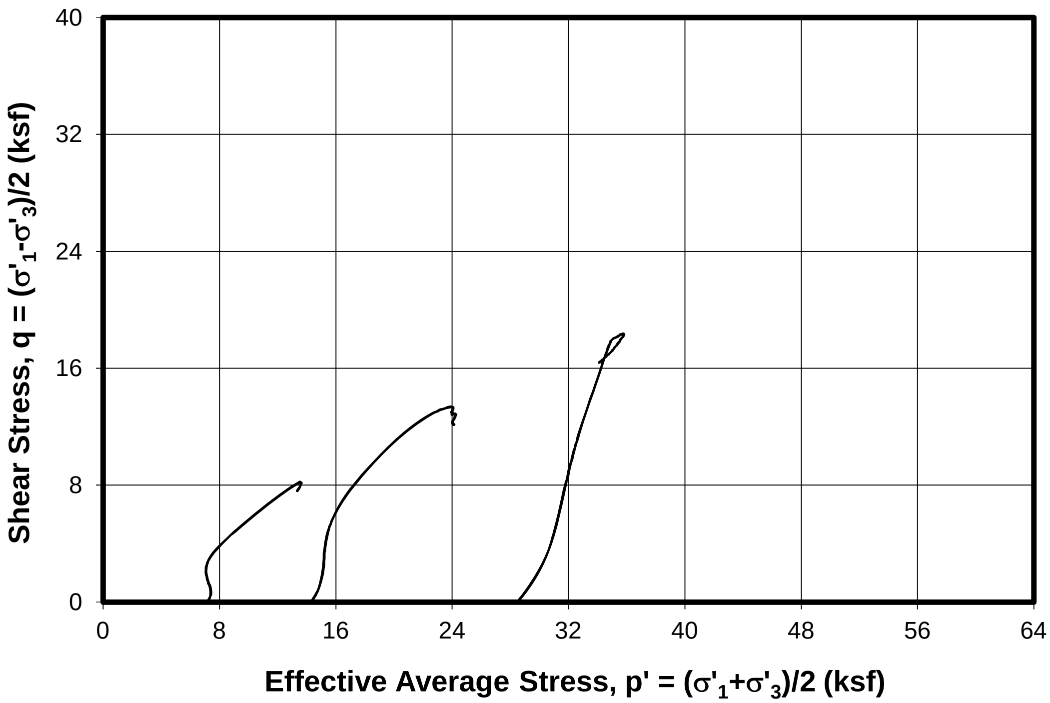
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-192, SAMPLE S-24, DEPTH 92.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



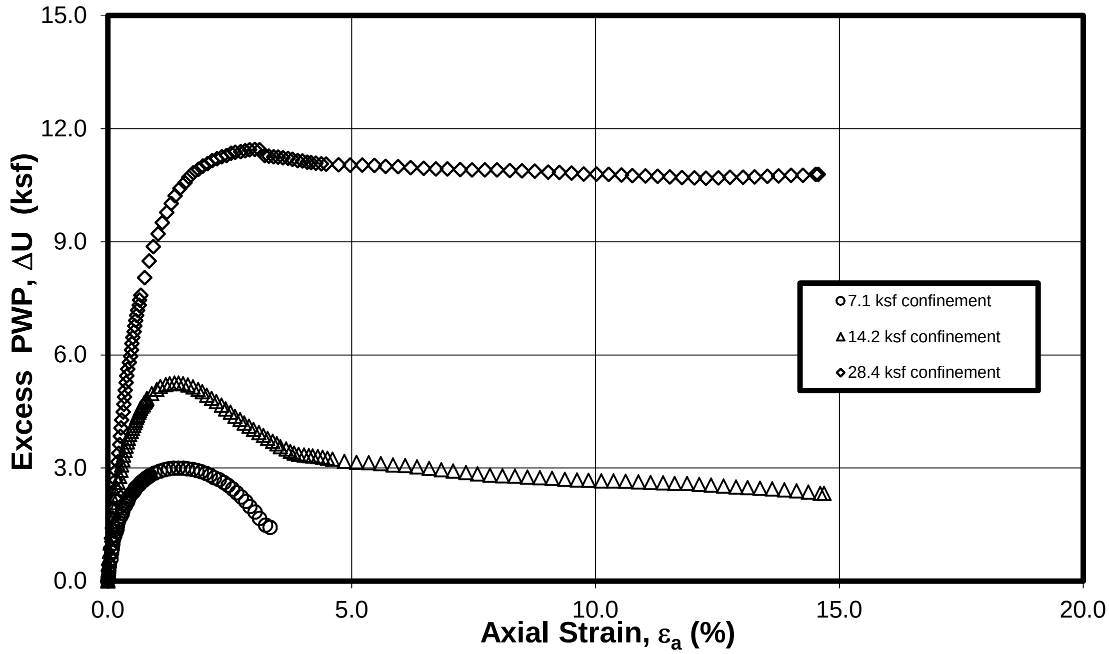


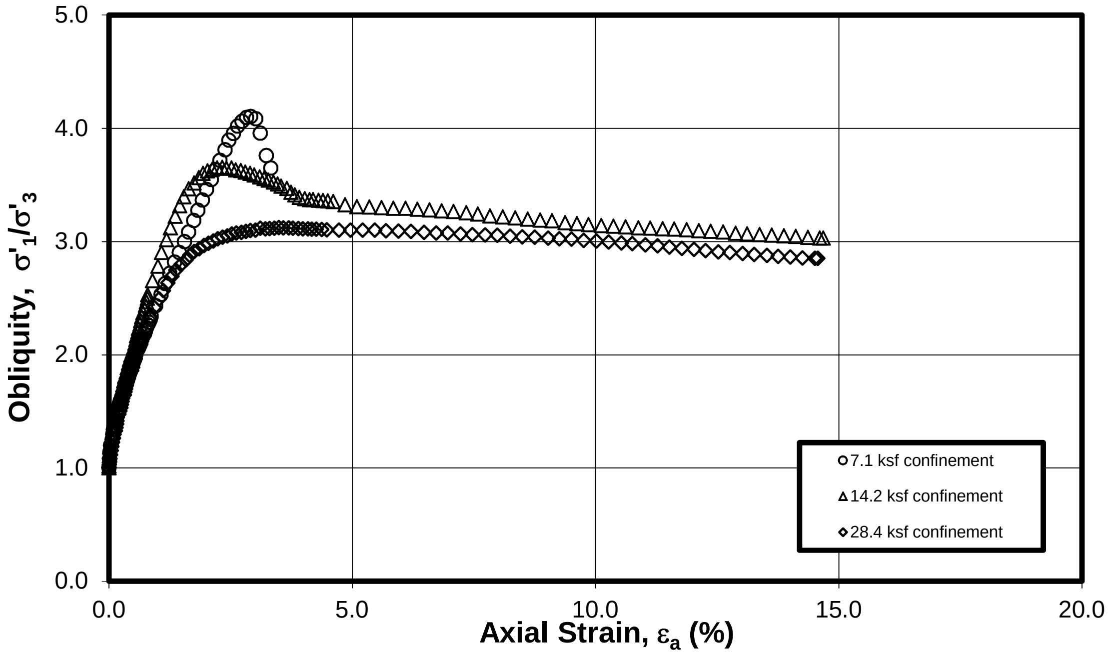
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-192, SAMPLE S-24, DEPTH 92.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



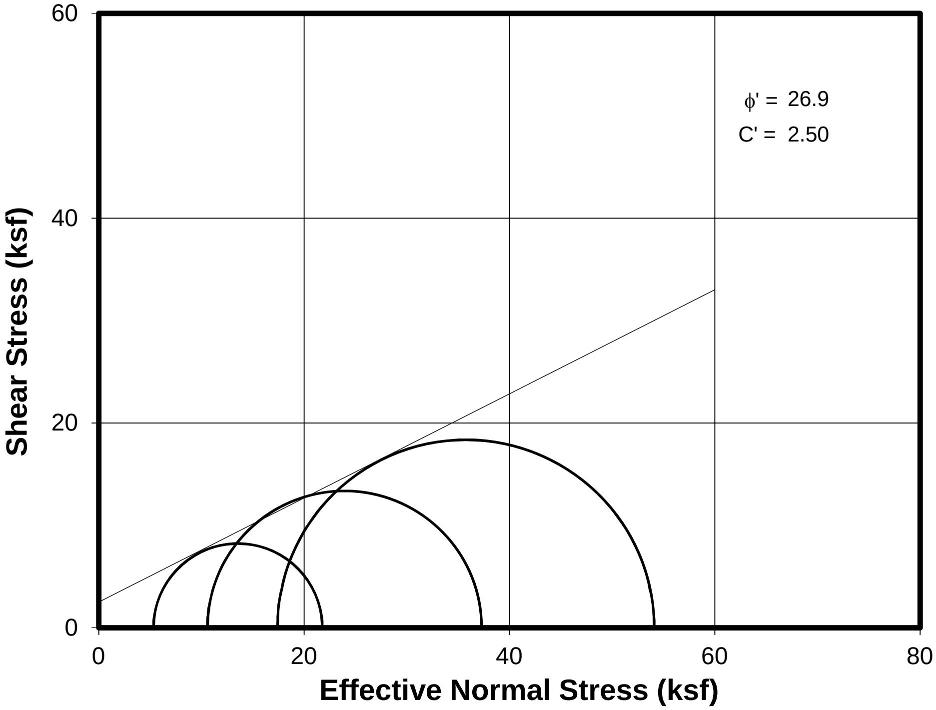


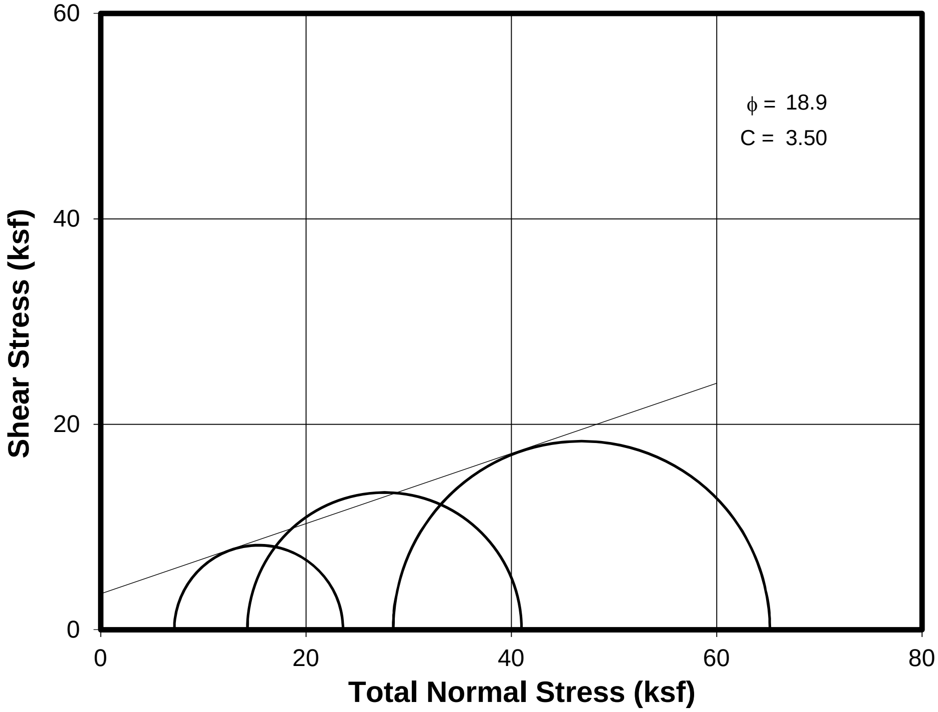
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-192, SAMPLE S-38, DEPTH 190.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



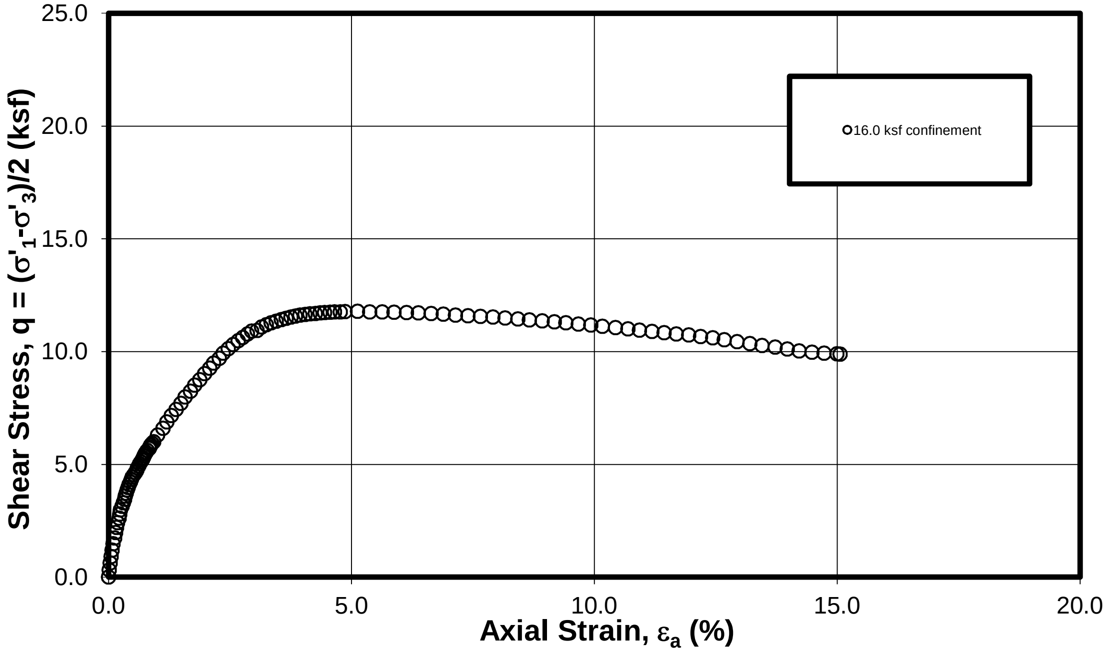


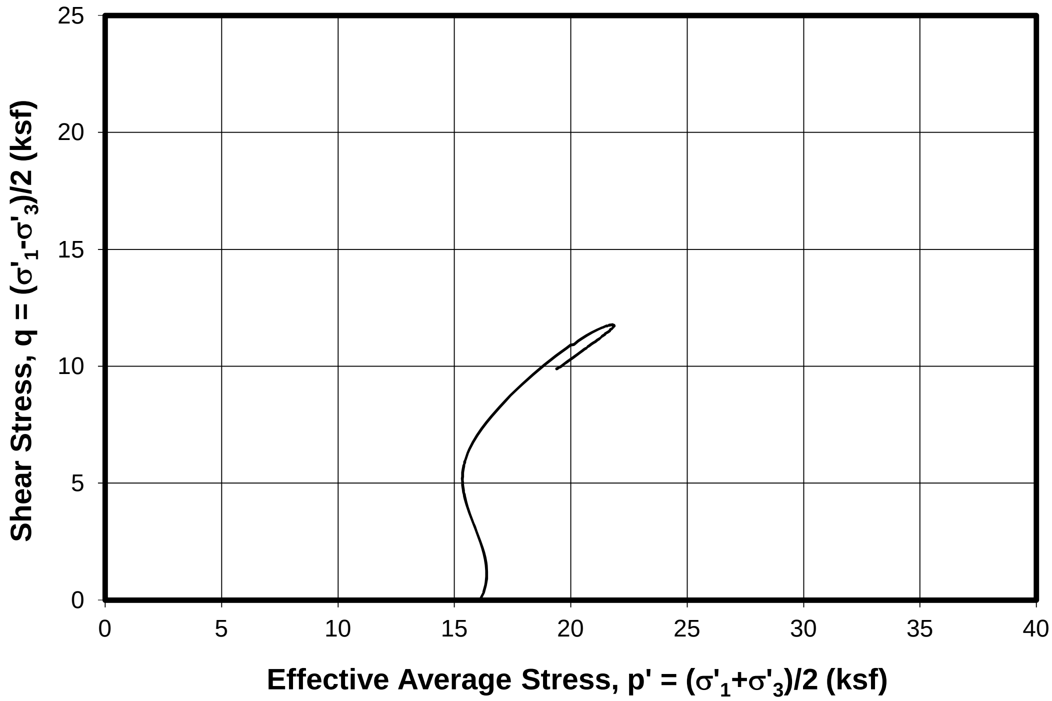
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-192, SAMPLE S-38, DEPTH 190.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



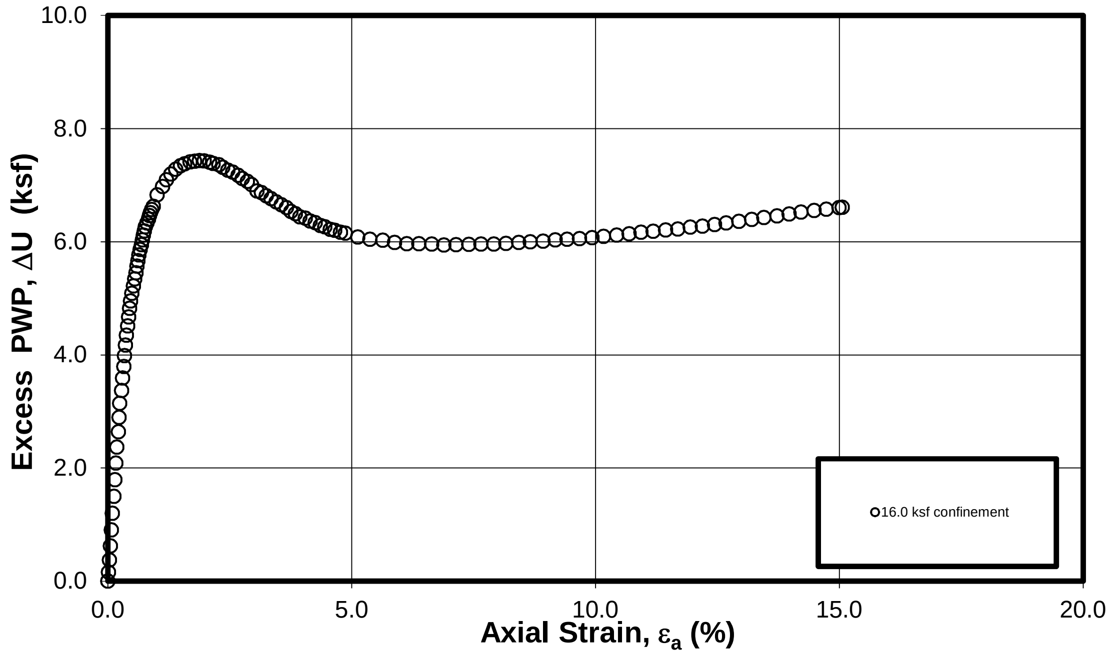


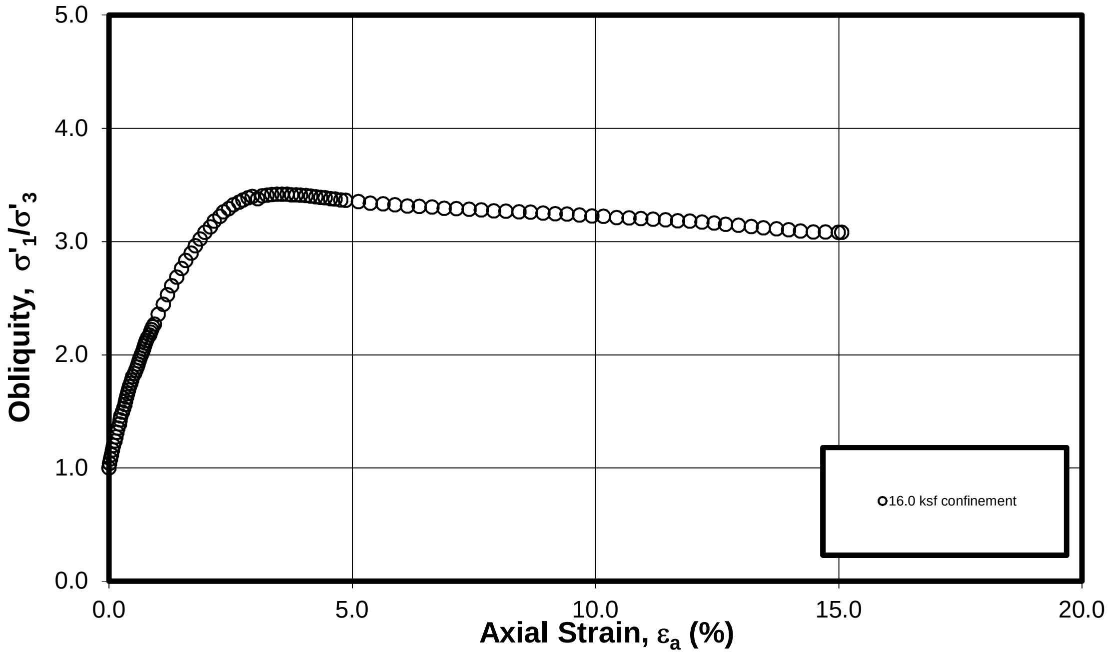
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-192, SAMPLE S-38, DEPTH 190.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



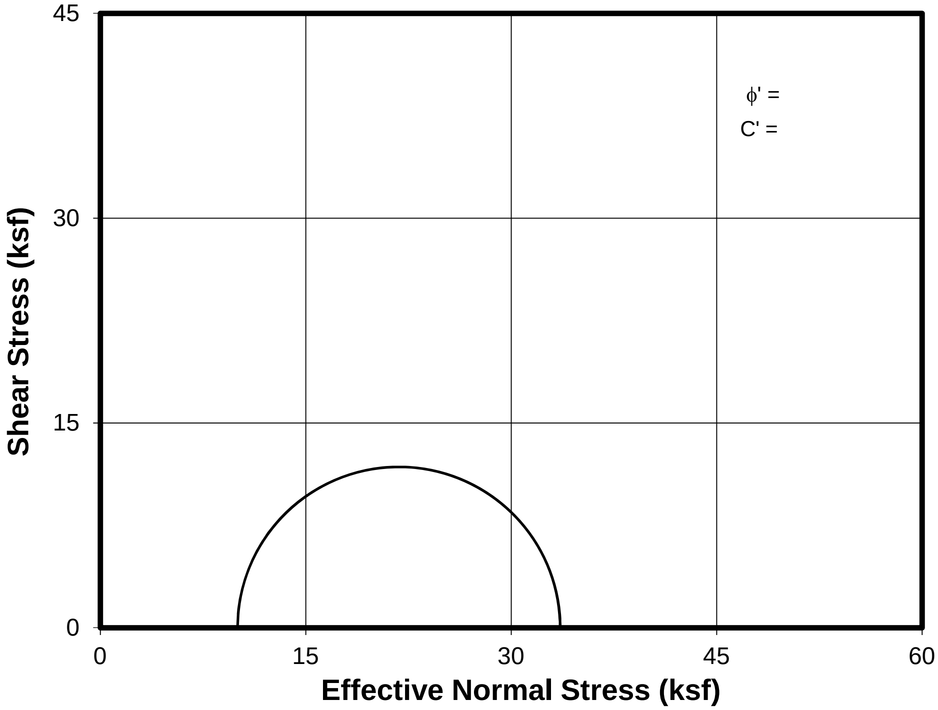


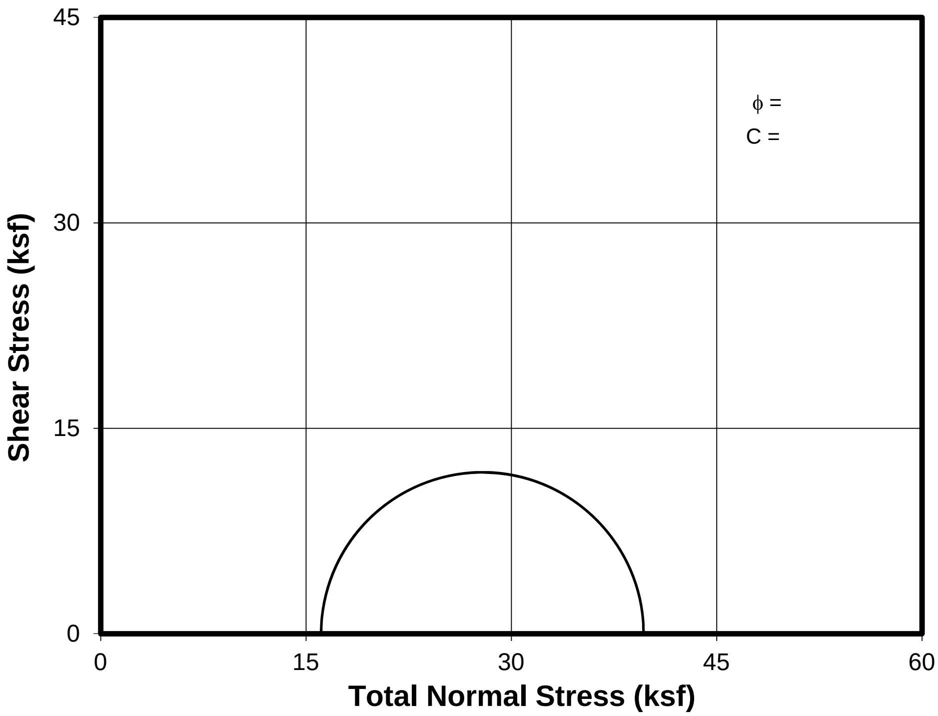
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-192, SAMPLE S-45, DEPTH 219.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



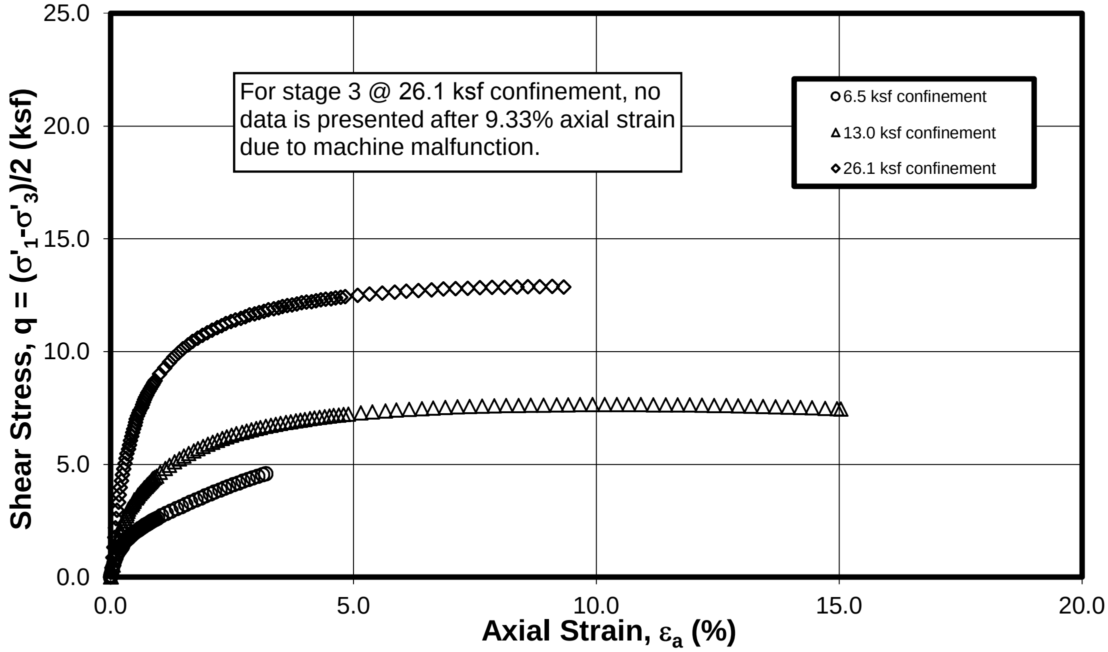


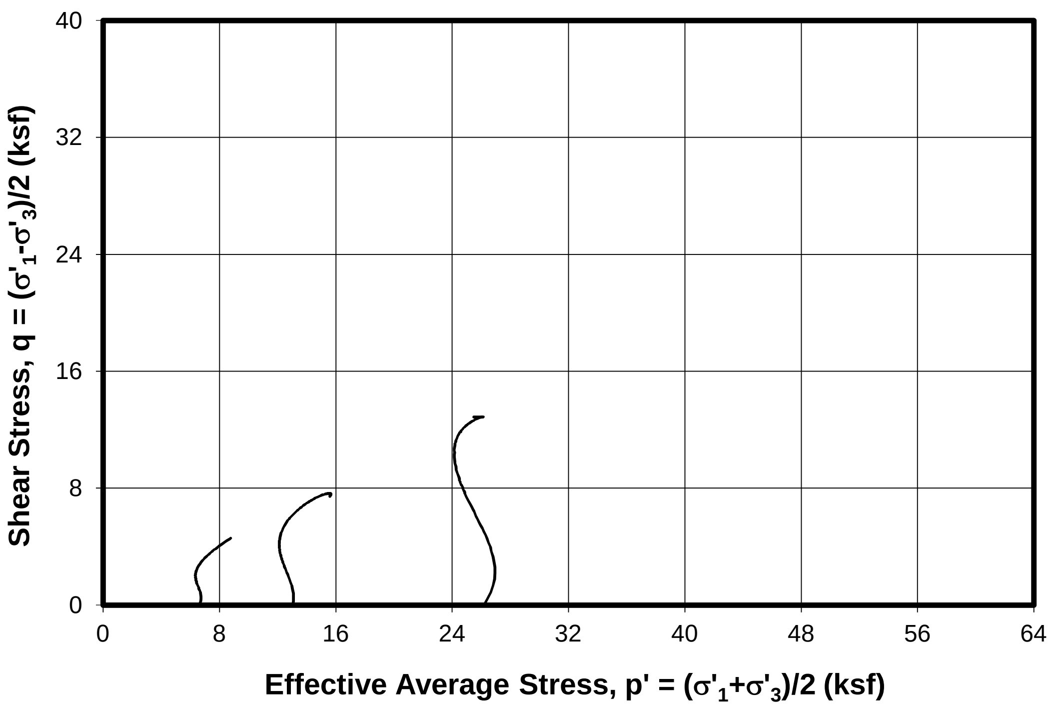
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-192, SAMPLE S-45, DEPTH 219.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



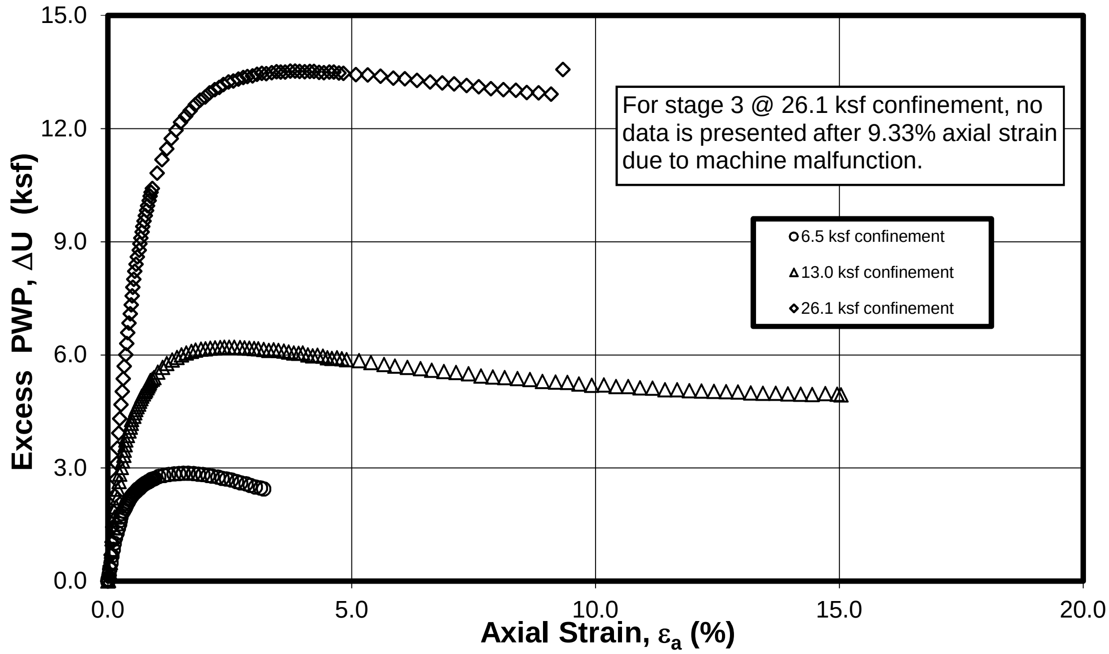


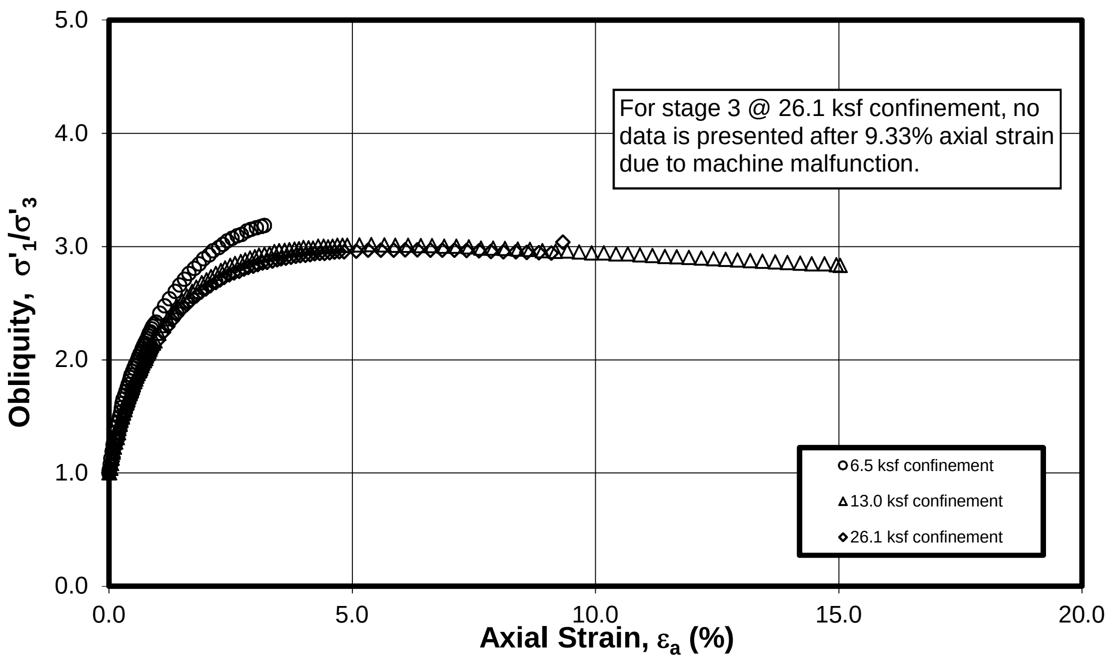
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-192, SAMPLE S-45, DEPTH 219.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



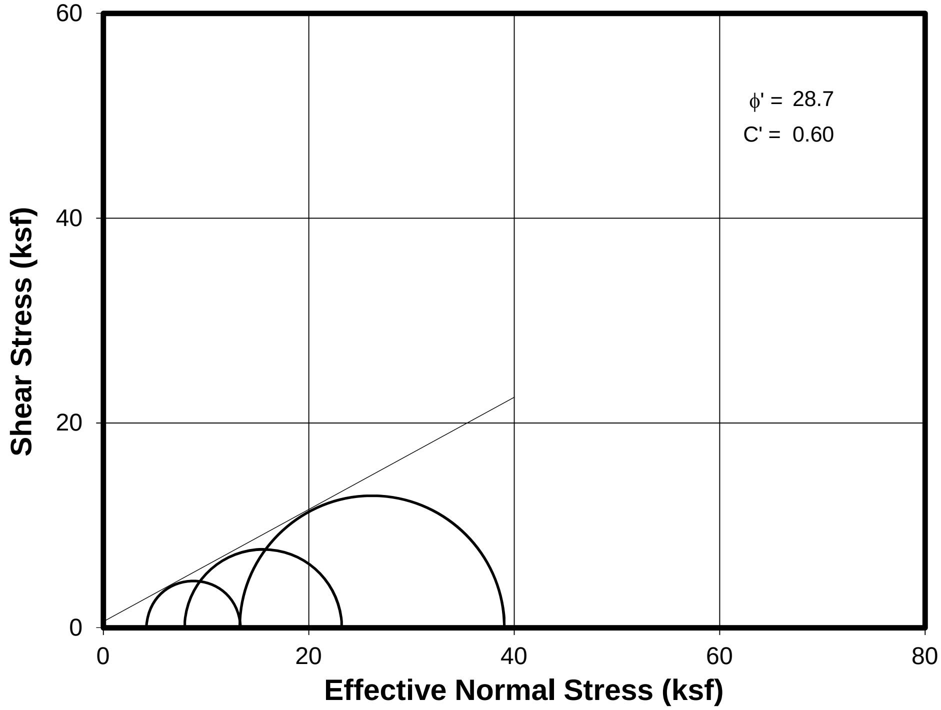


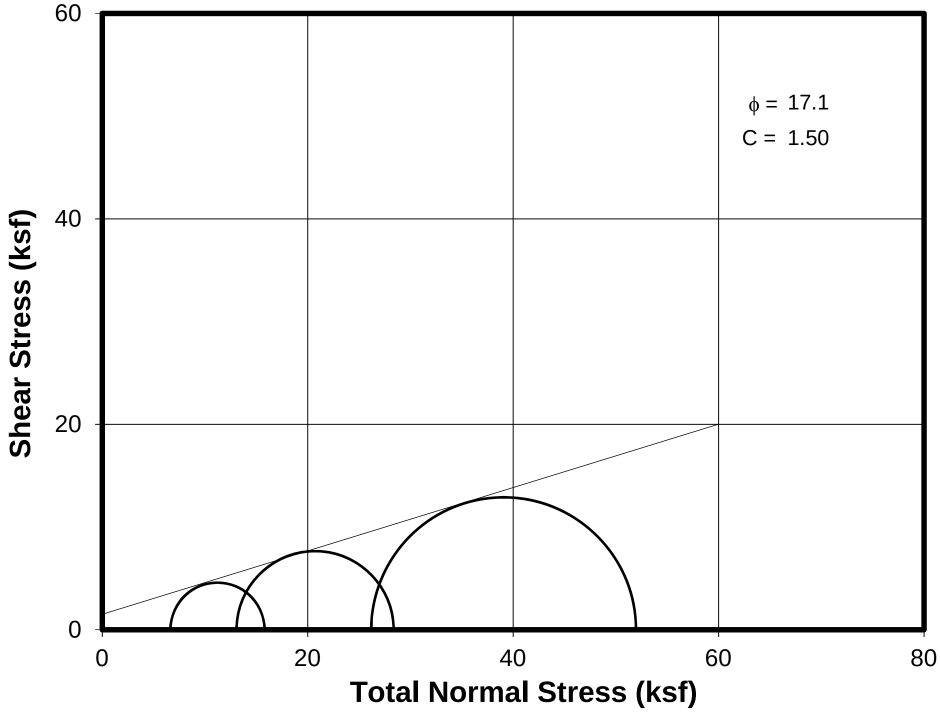
CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-195, SAMPLE S-34, DEPTH 152.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA





CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-195, SAMPLE S-34, DEPTH 152.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

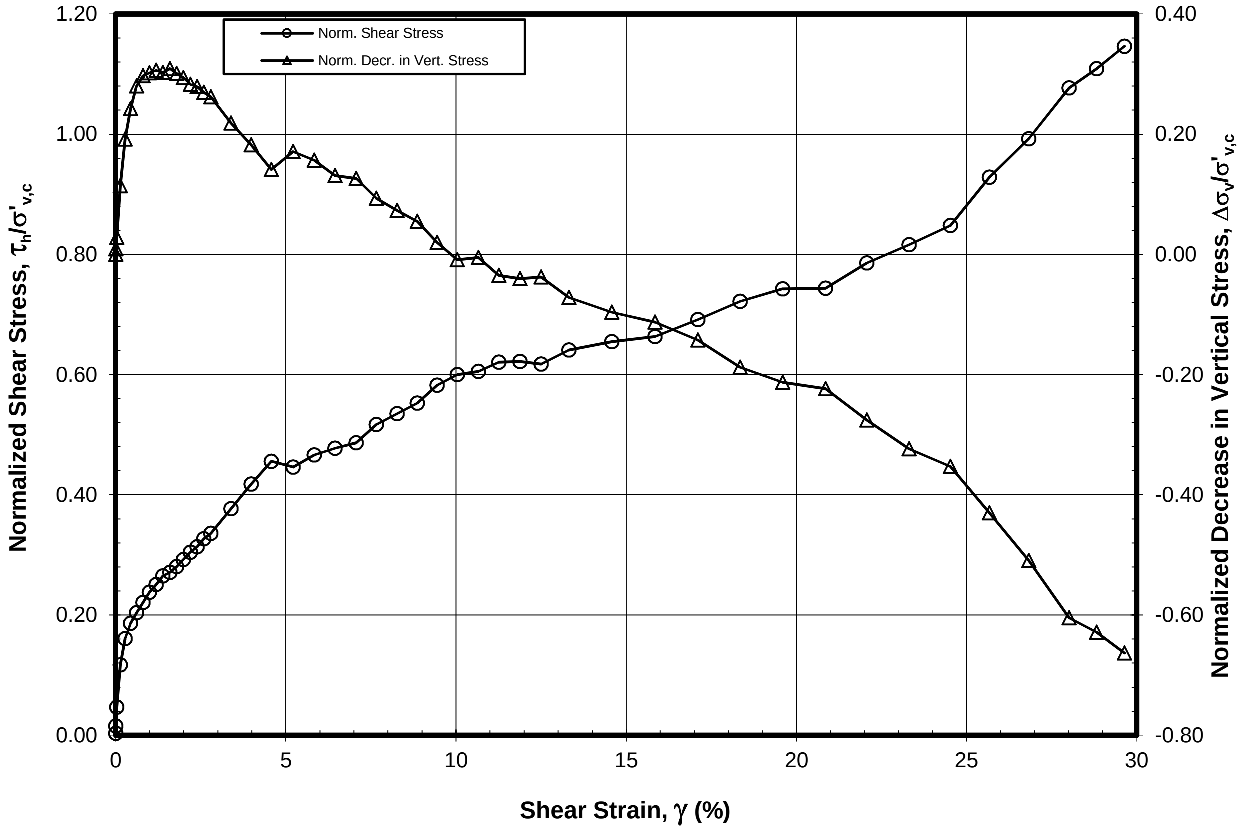


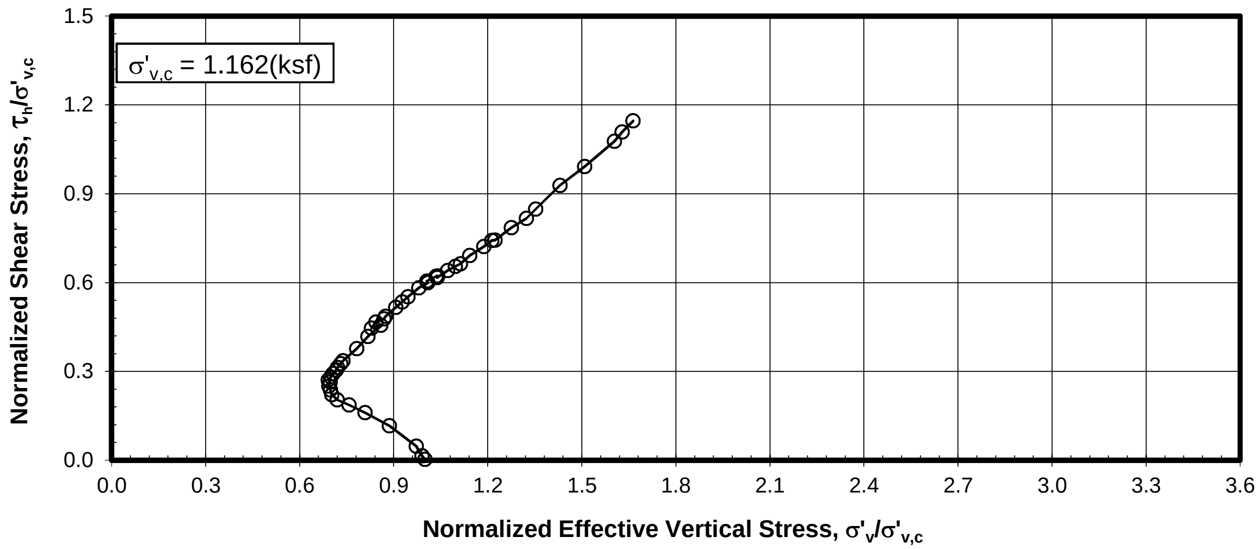


CONSOLIDATED-UNDRAINED TRIAXIAL COMPRESSION TESTS
BORING B-195, SAMPLE S-34, DEPTH 152.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

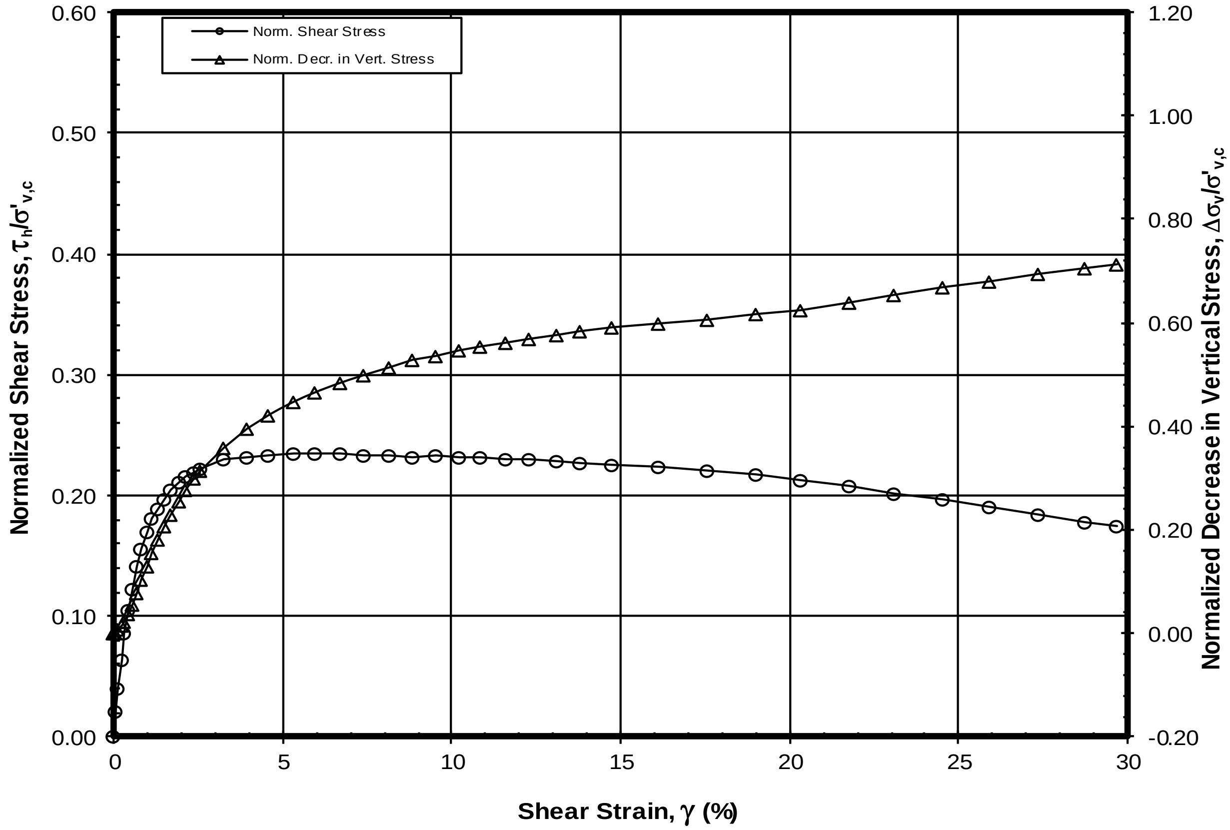
APPENDIX G6

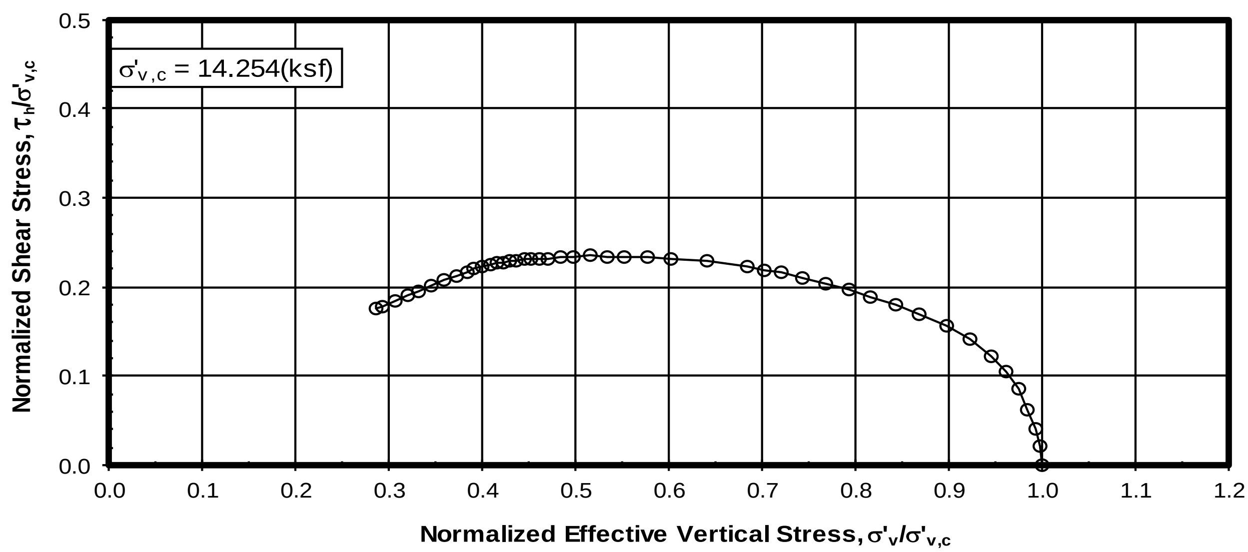
Direct Simple Shear and Direct Shear Test Results



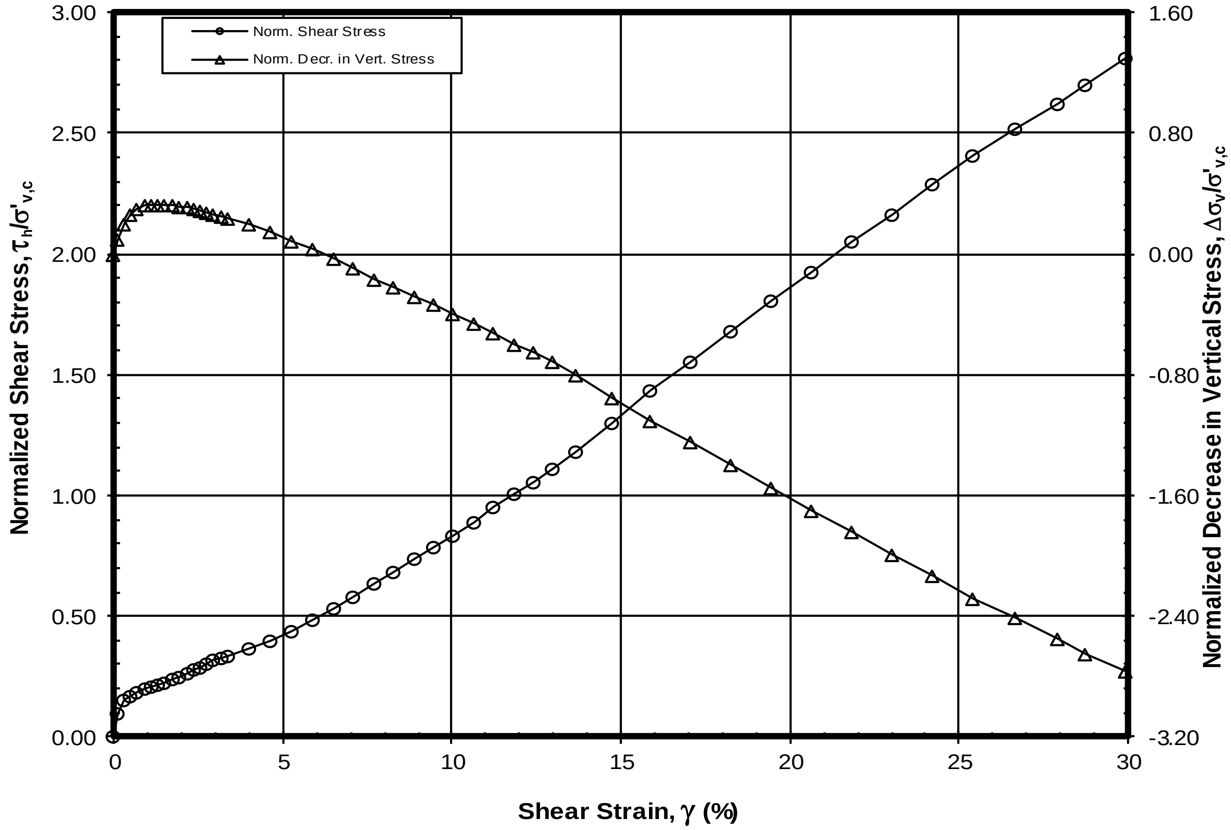


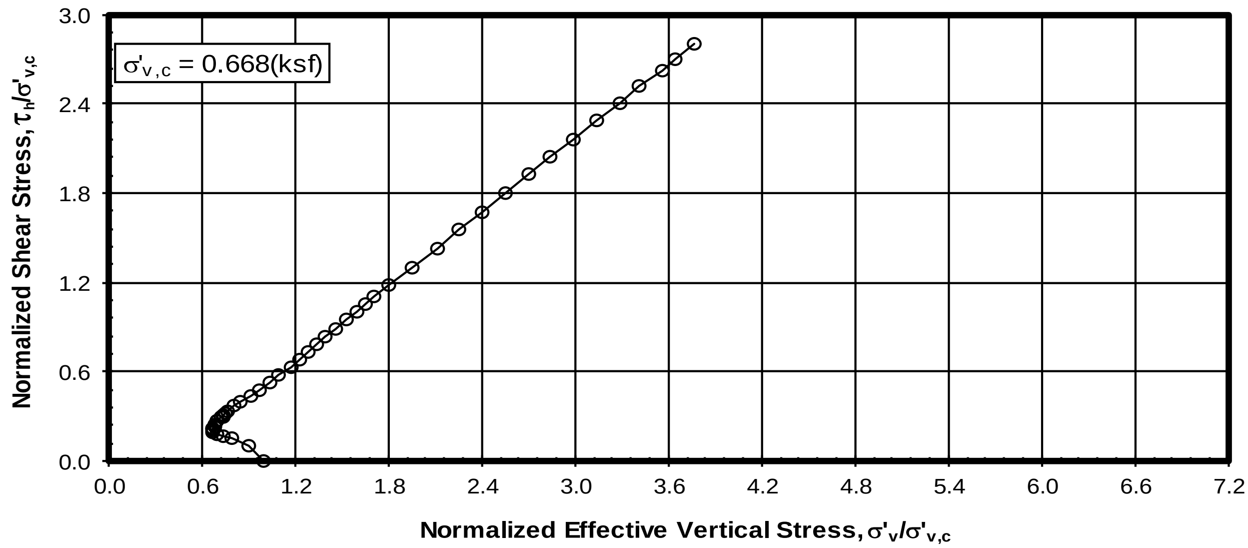
Ko-CONSOLIDATED UNDRAINED DIRECT SIMPLE SHEAR TESTS
BORING B-176, SAMPLE S-8, DEPTH 19.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



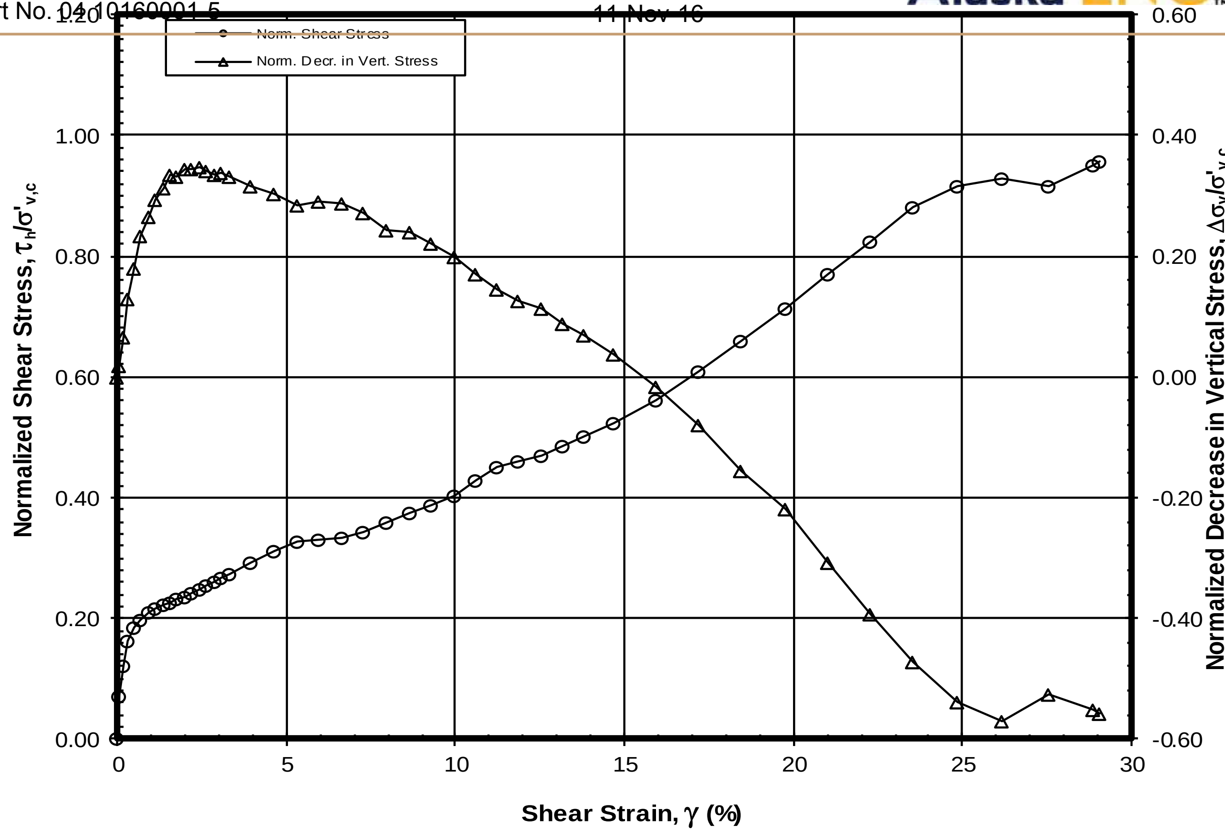


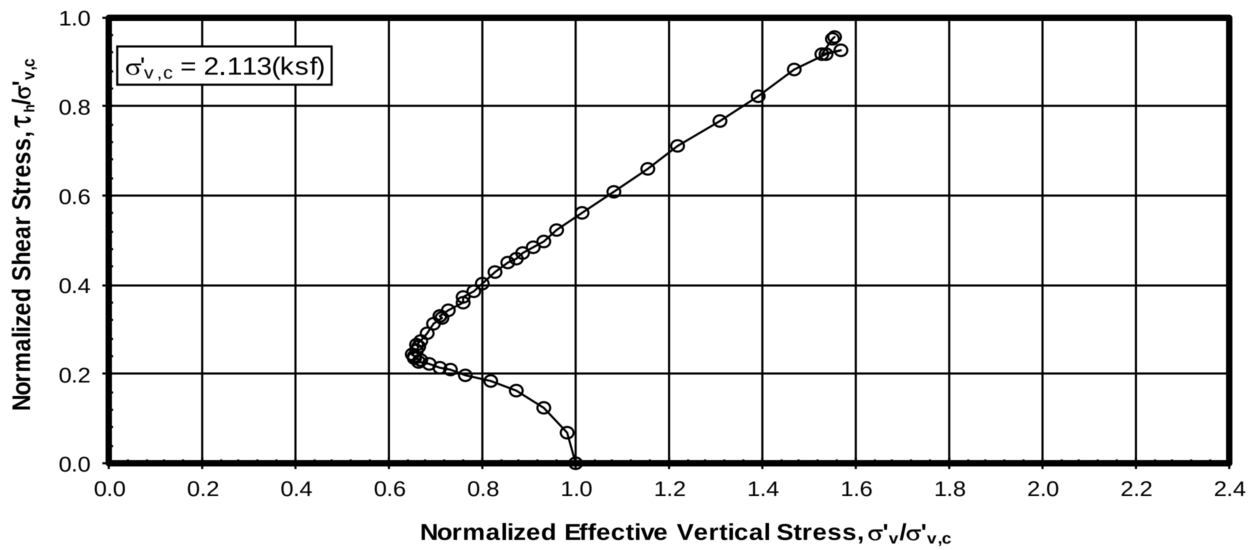
Ko-CONSOLIDATED UNDRAINED DIRECT SIMPLE SHEAR TESTS
BORING B-189, SAMPLE S-34, DEPTH 171.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



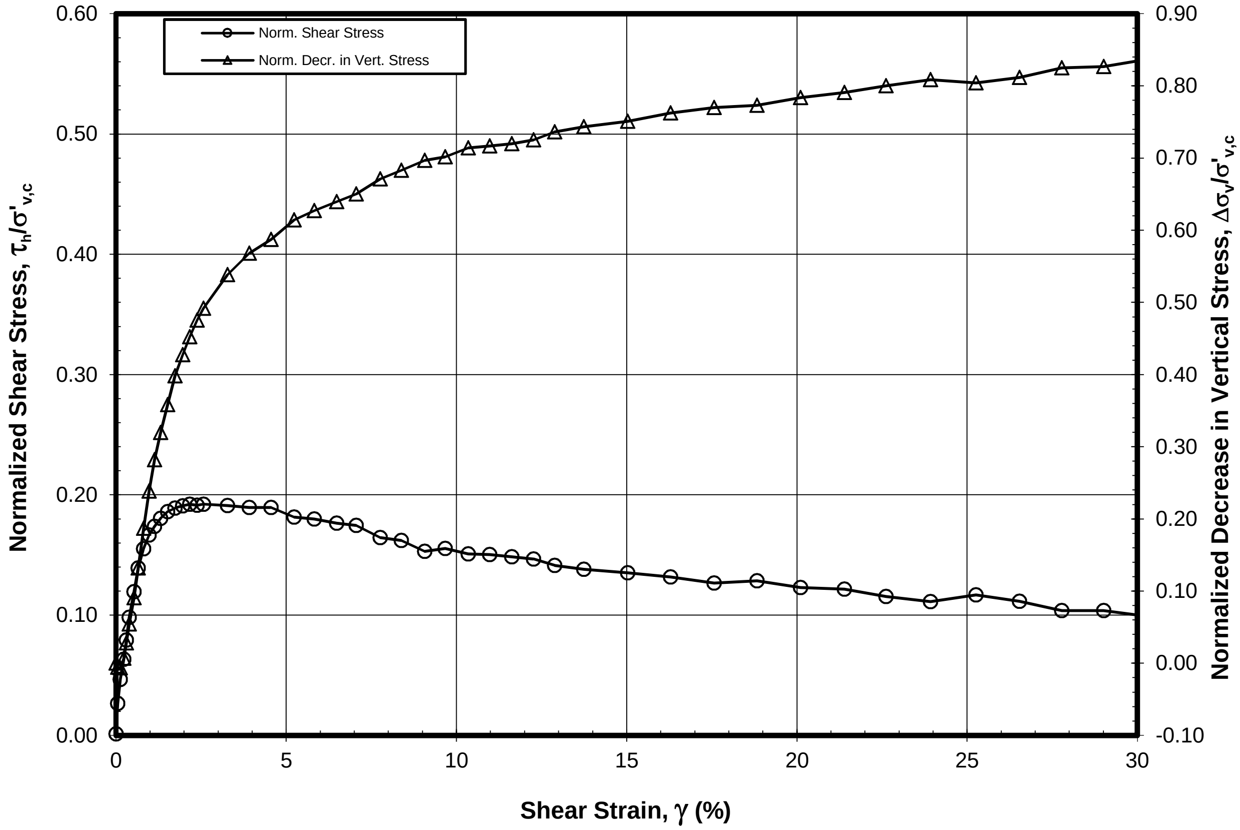


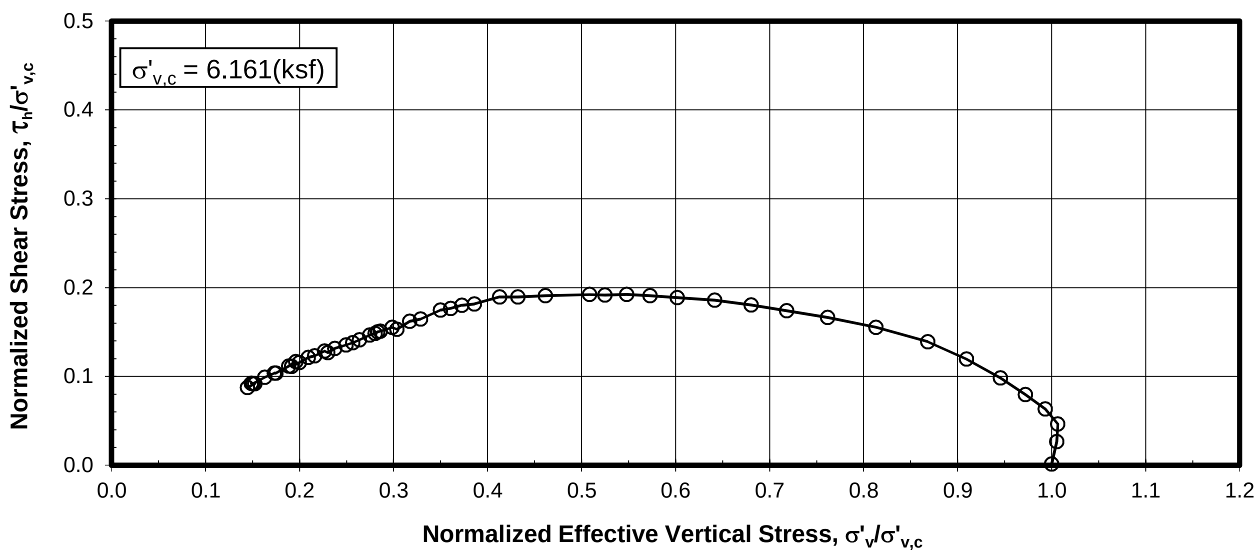
Ko-CONSOLIDATED UNDRAINED DIRECT SIMPLE SHEAR TESTS
BORING B-190, SAMPLE S-5, DEPTH 11.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



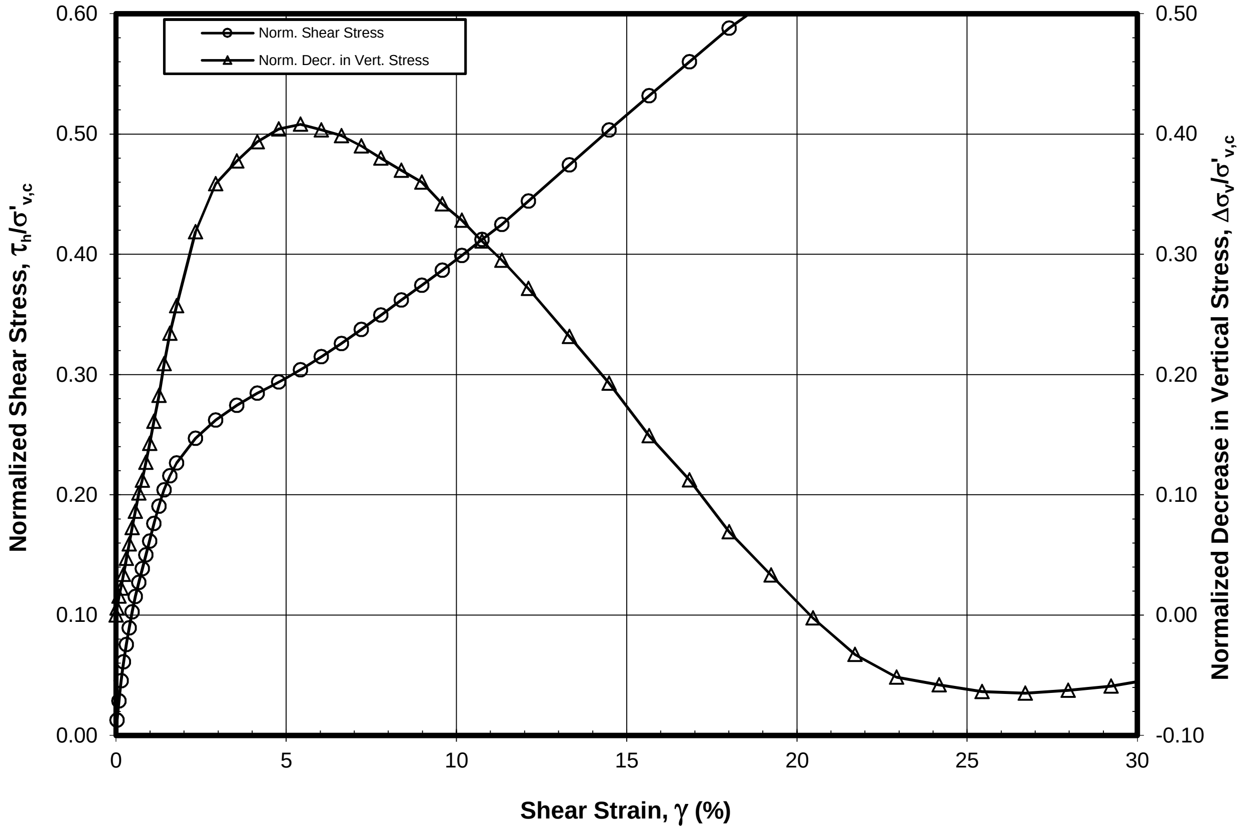


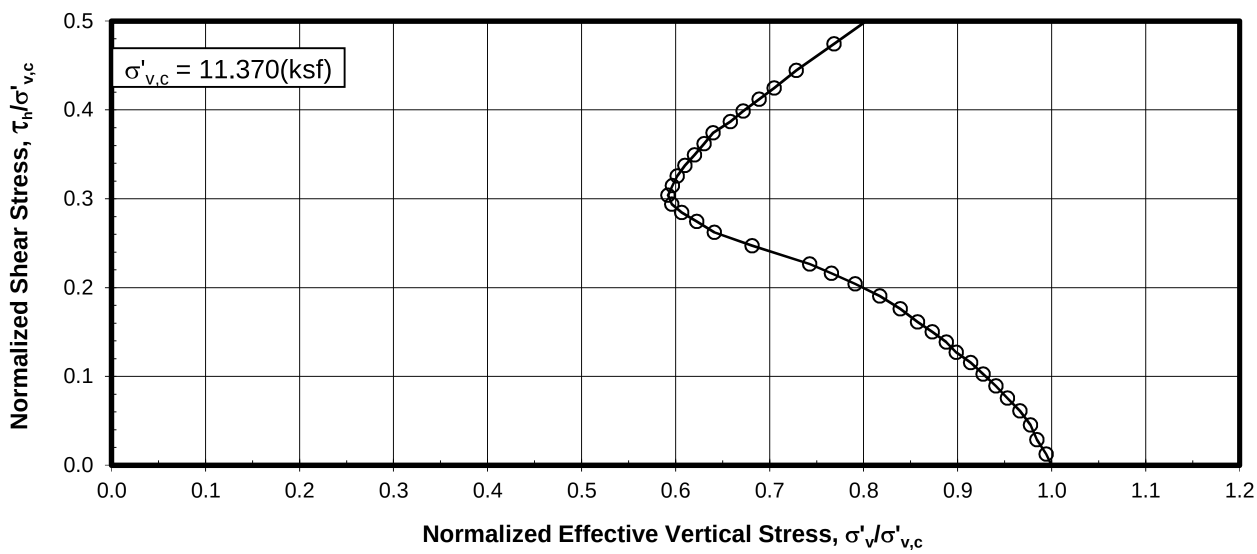
Ko-CONSOLIDATED UNDRAINED DIRECT SIMPLE SHEAR TESTS
BORING B-191, SAMPLE S-12, DEPTH 36.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



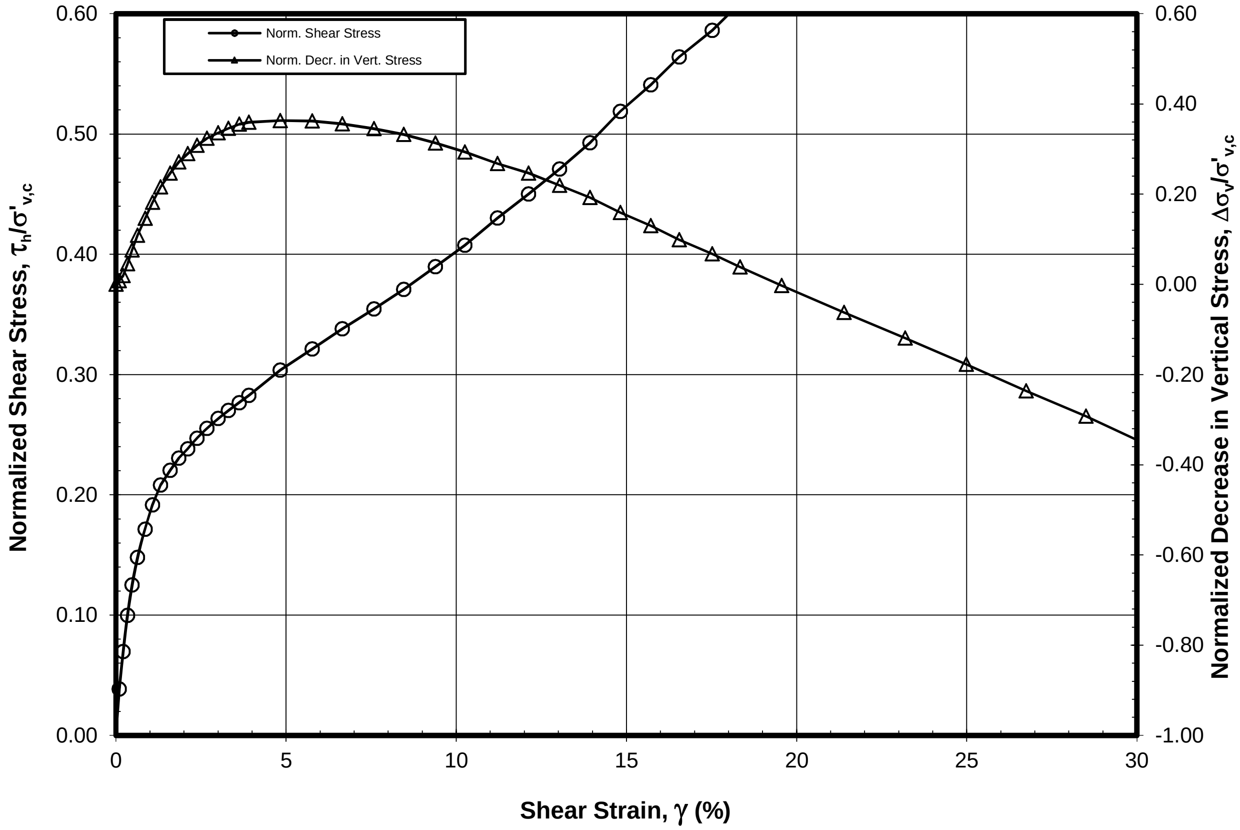


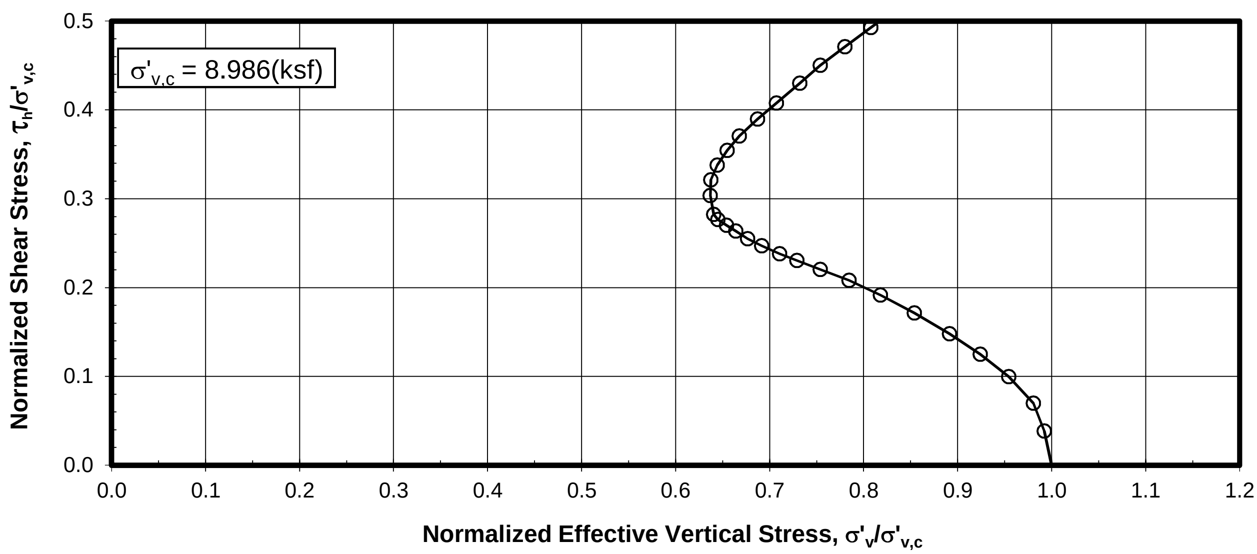
Ko-CONSOLIDATED UNDRAINED DIRECT SIMPLE SHEAR TESTS
BORING B-192, SAMPLE S-16, DEPTH 56.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



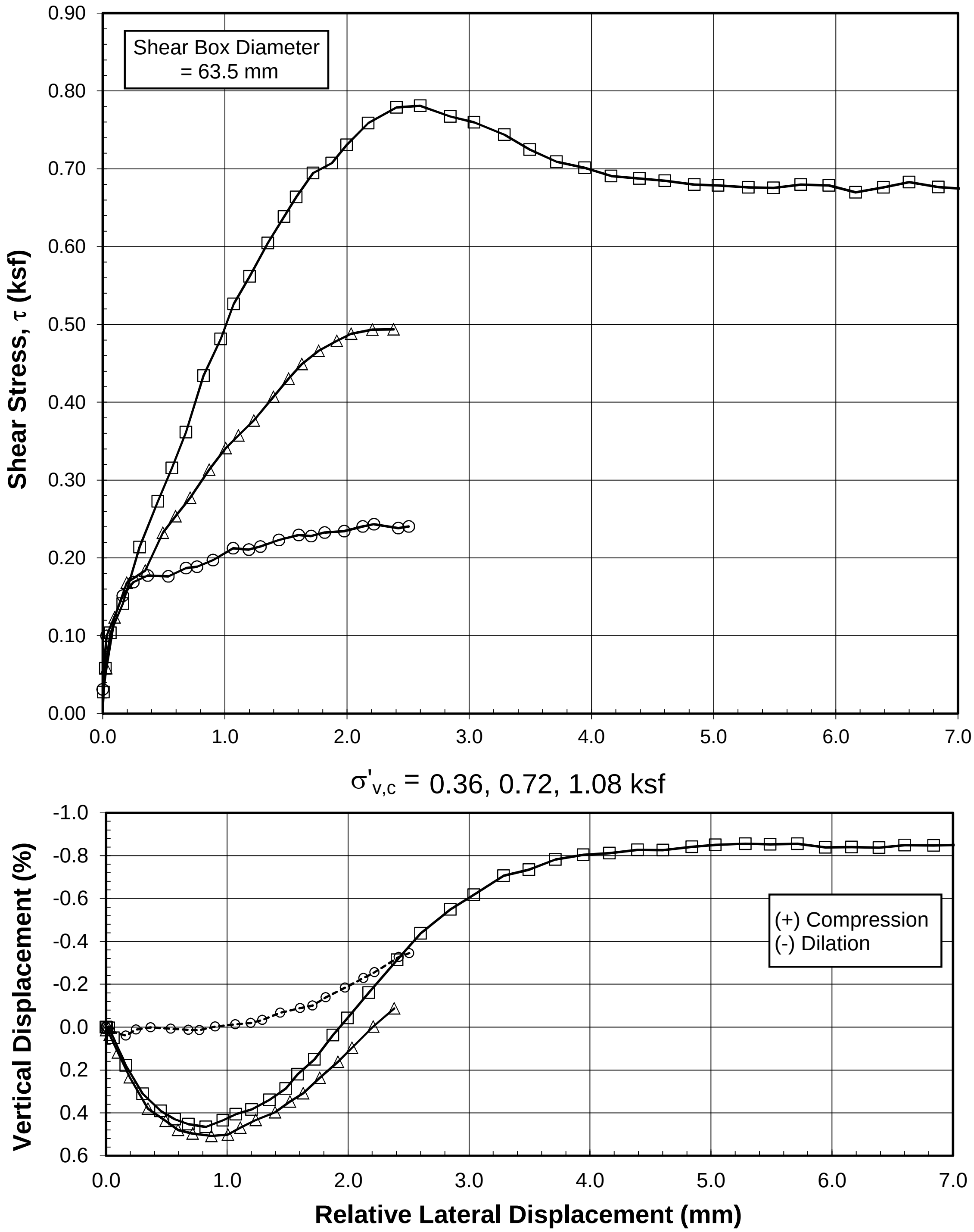


Ko-CONSOLIDATED UNDRAINED DIRECT SIMPLE SHEAR TESTS
BORING B-192, SAMPLE S-31, DEPTH 141.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

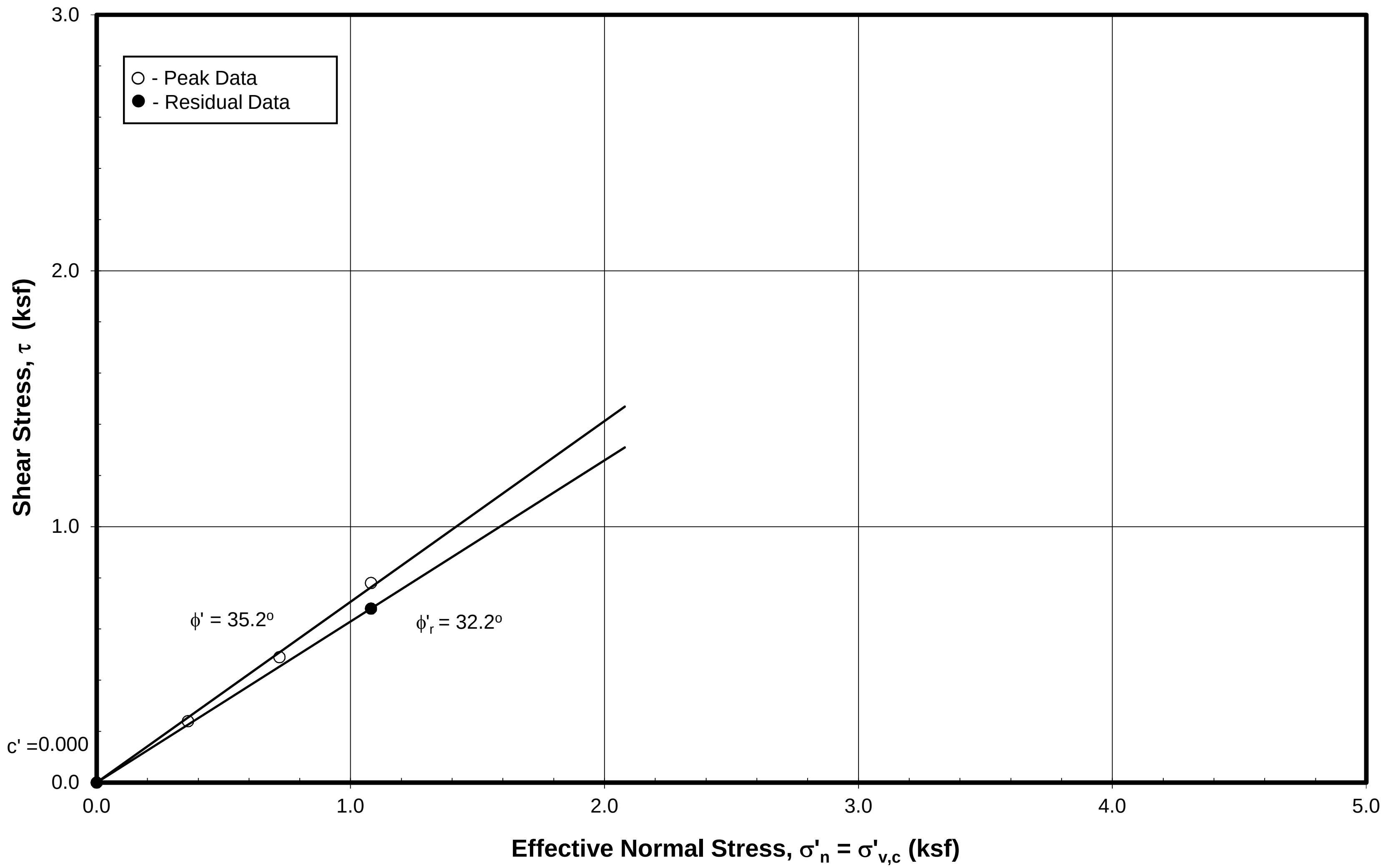




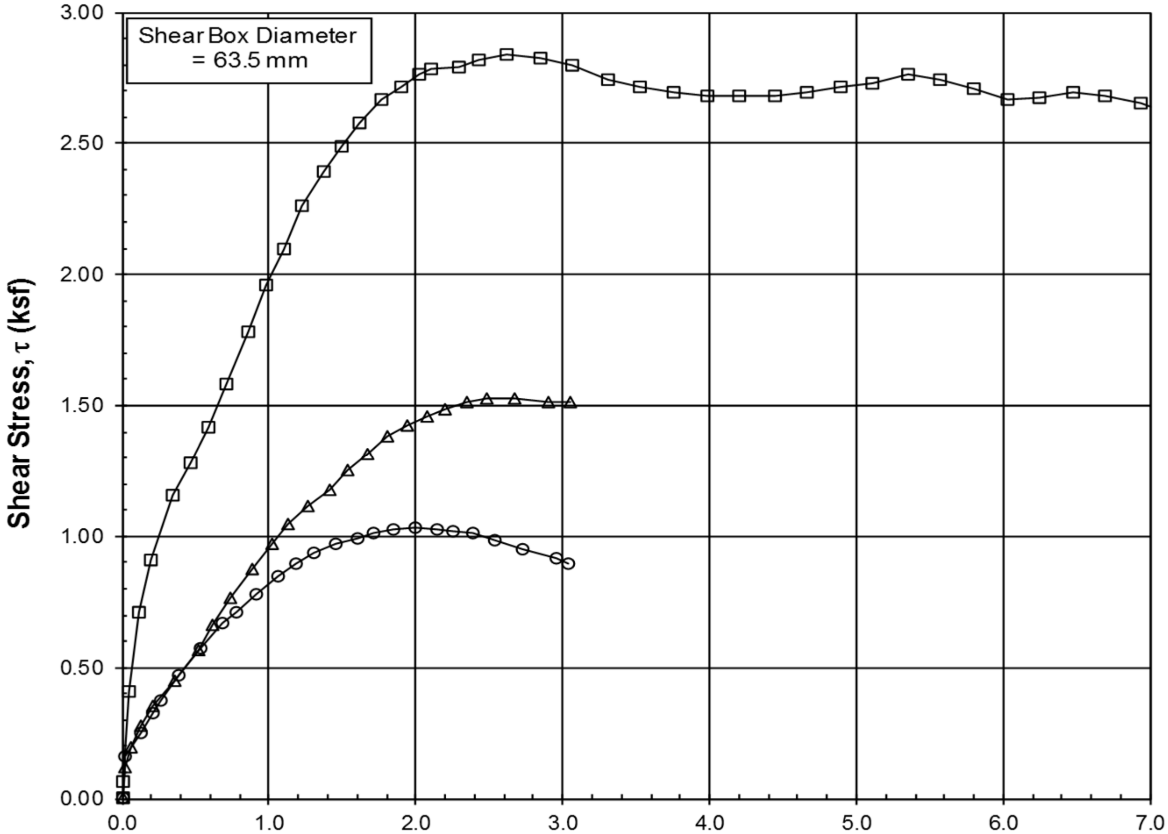
Ko-CONSOLIDATED UNDRAINED DIRECT SIMPLE SHEAR TESTS
BORING B-195, SAMPLE S-22, DEPTH 81.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



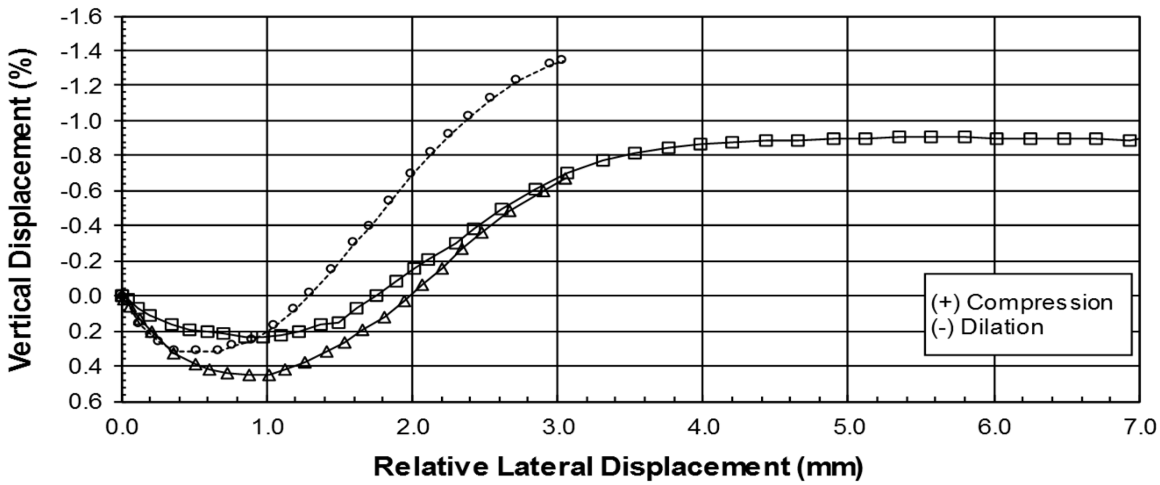
DIRECT SHEAR TESTS
BORING B-176, SAMPLE S-3, DEPTH 7.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



DIRECT SHEAR TESTS
BORING B-176, SAMPLE S-3, DEPTH 7.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



$\sigma'_{v,c}$ = 0.9, 1.8, 3.6 ksf



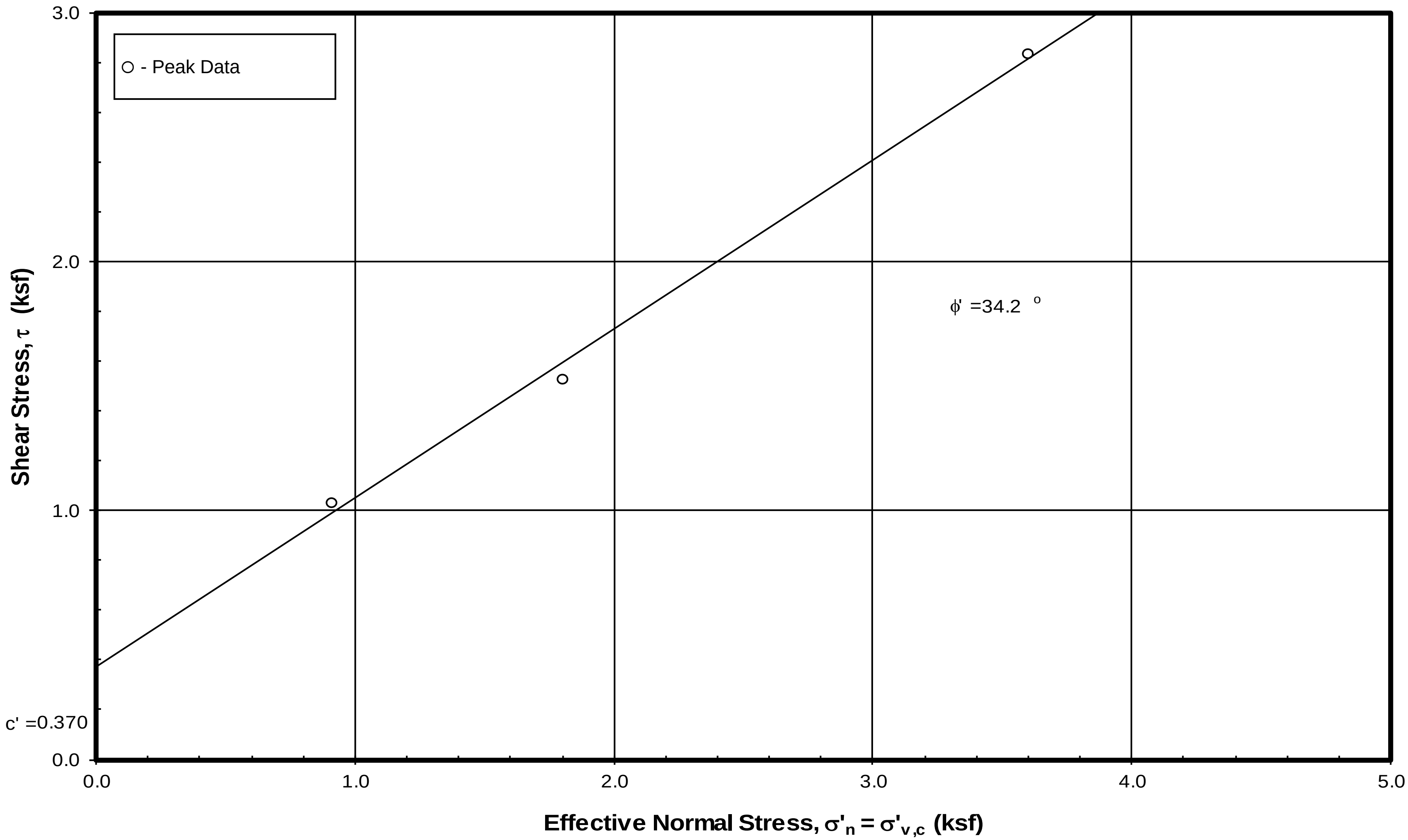
DIRECT SHEAR TESTS

BORING B-189, SAMPLE S-8, DEPTH 15.0 FT

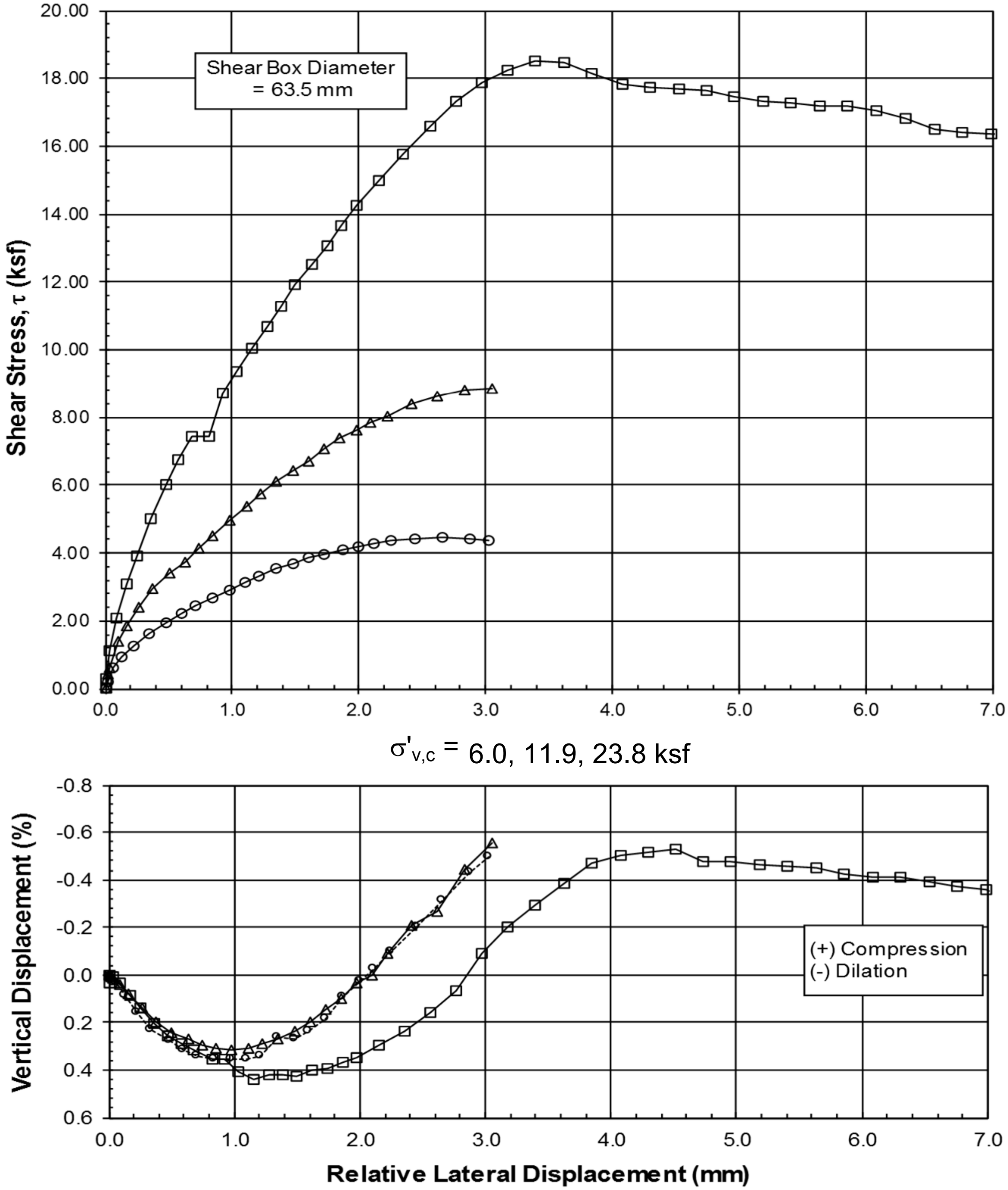
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

NIKISKI, ALASKA



DIRECT SHEAR TESTS
BORING B-189, SAMPLE S-8, DEPTH 15.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



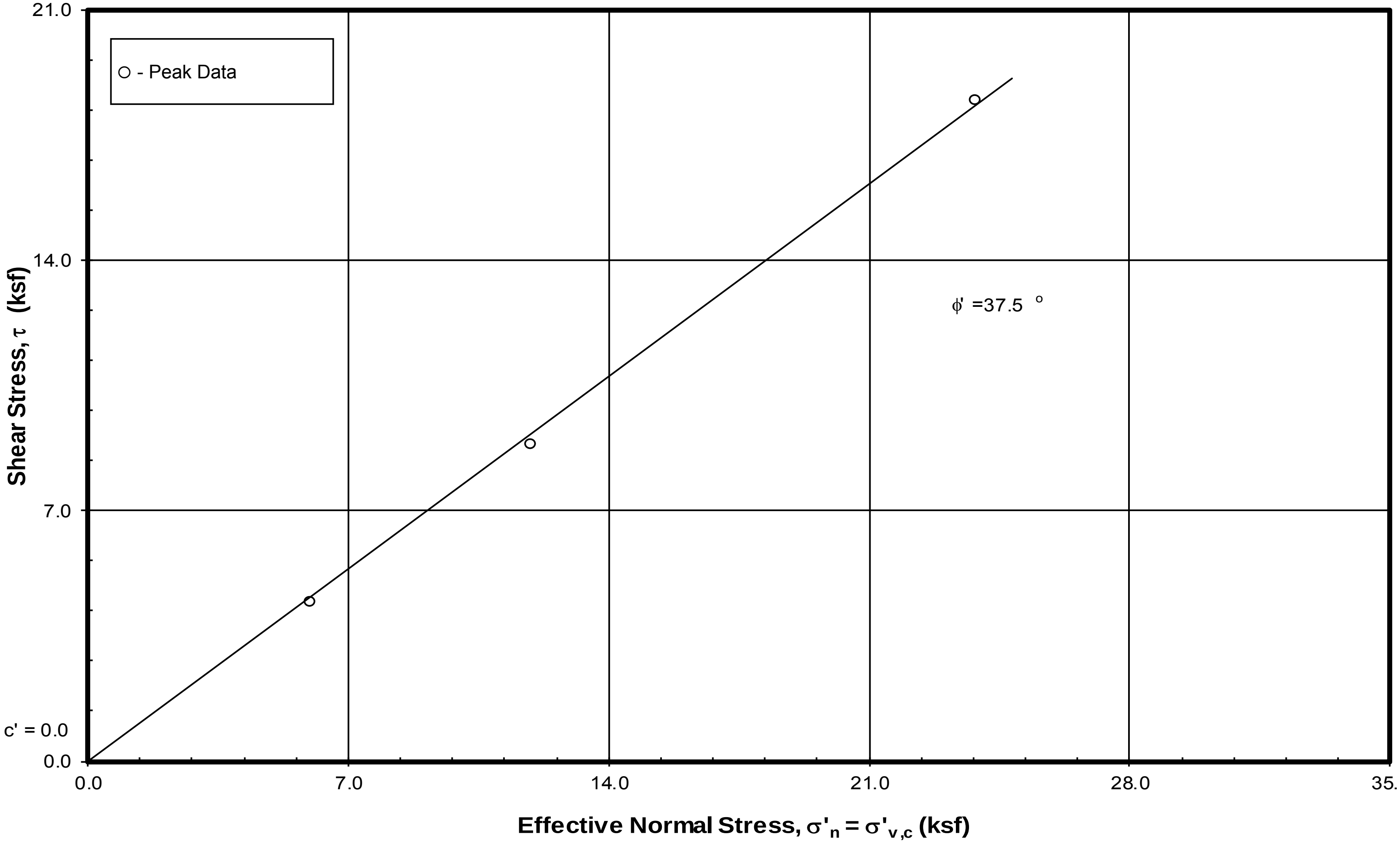
DIRECT SHEAR TESTS

BORING B-189, SAMPLE S-30, DEPTH 131.0 FT

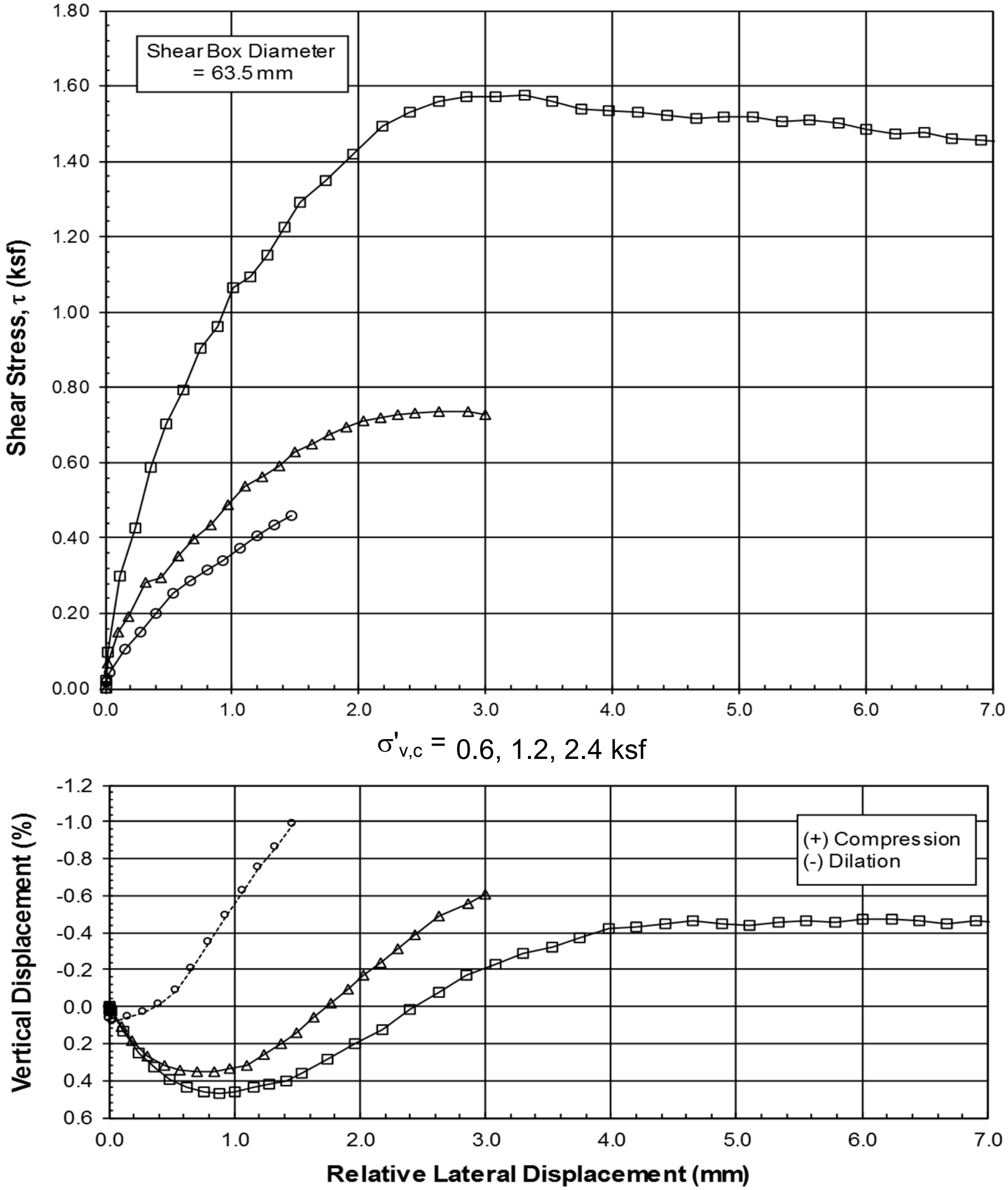
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

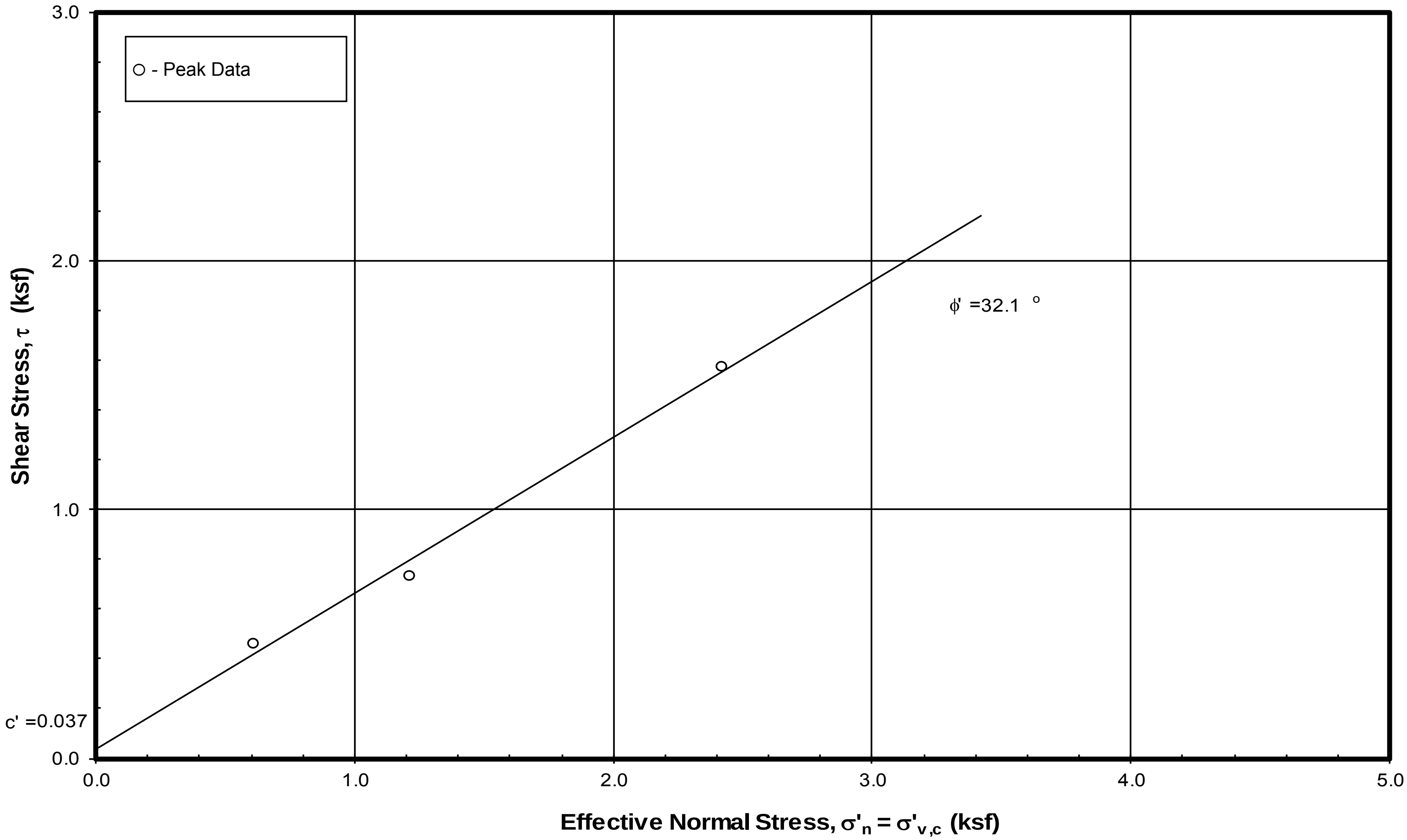
NIKISKI, ALASKA



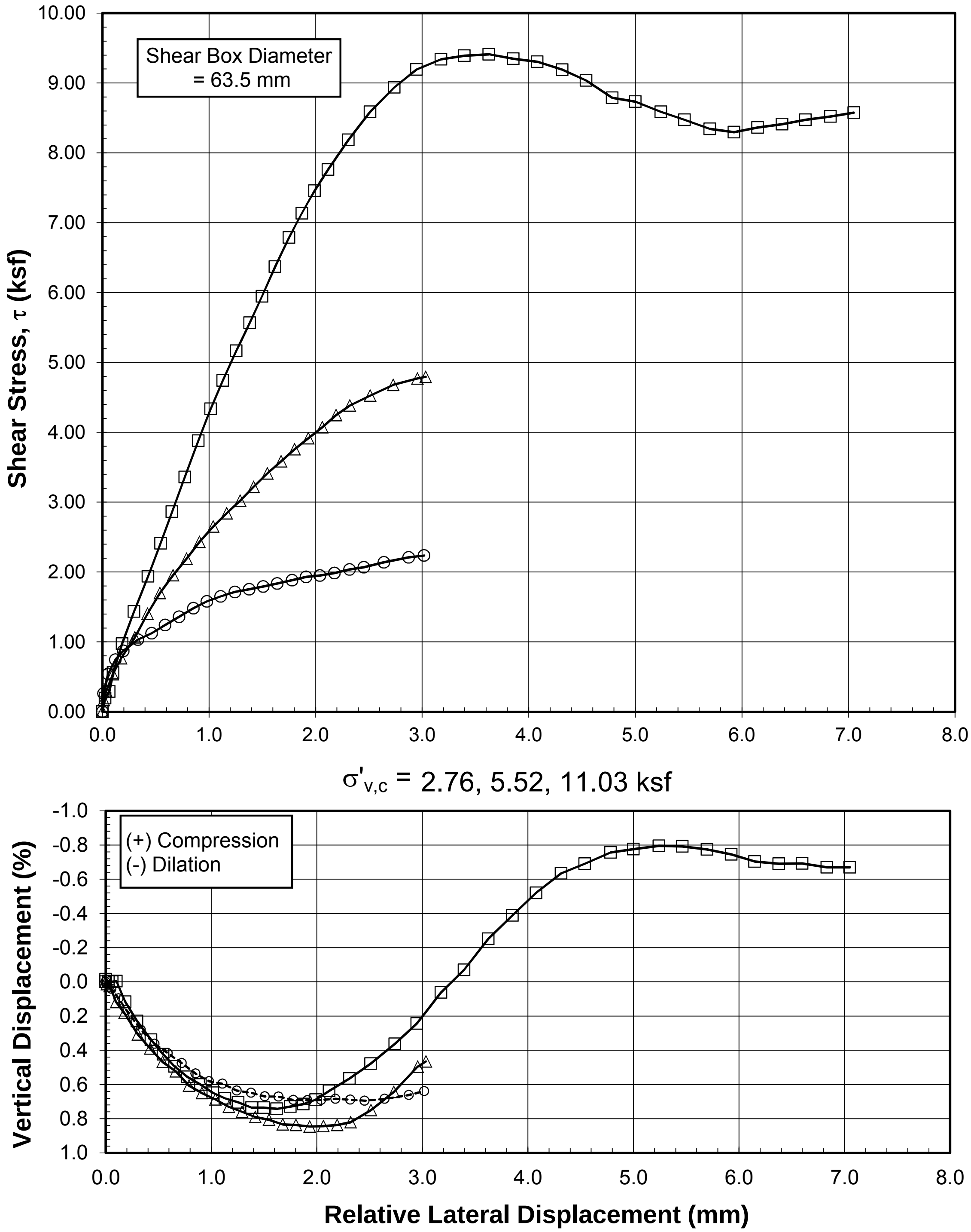
DIRECT SHEAR TESTS
BORING B-189, SAMPLE S-30, DEPTH 131.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



DIRECT SHEAR TESTS
BORING B-191, SAMPLE S-9, DEPTH 21.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



DIRECT SHEAR TESTS
BORING B-191, SAMPLE S-9, DEPTH 21.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



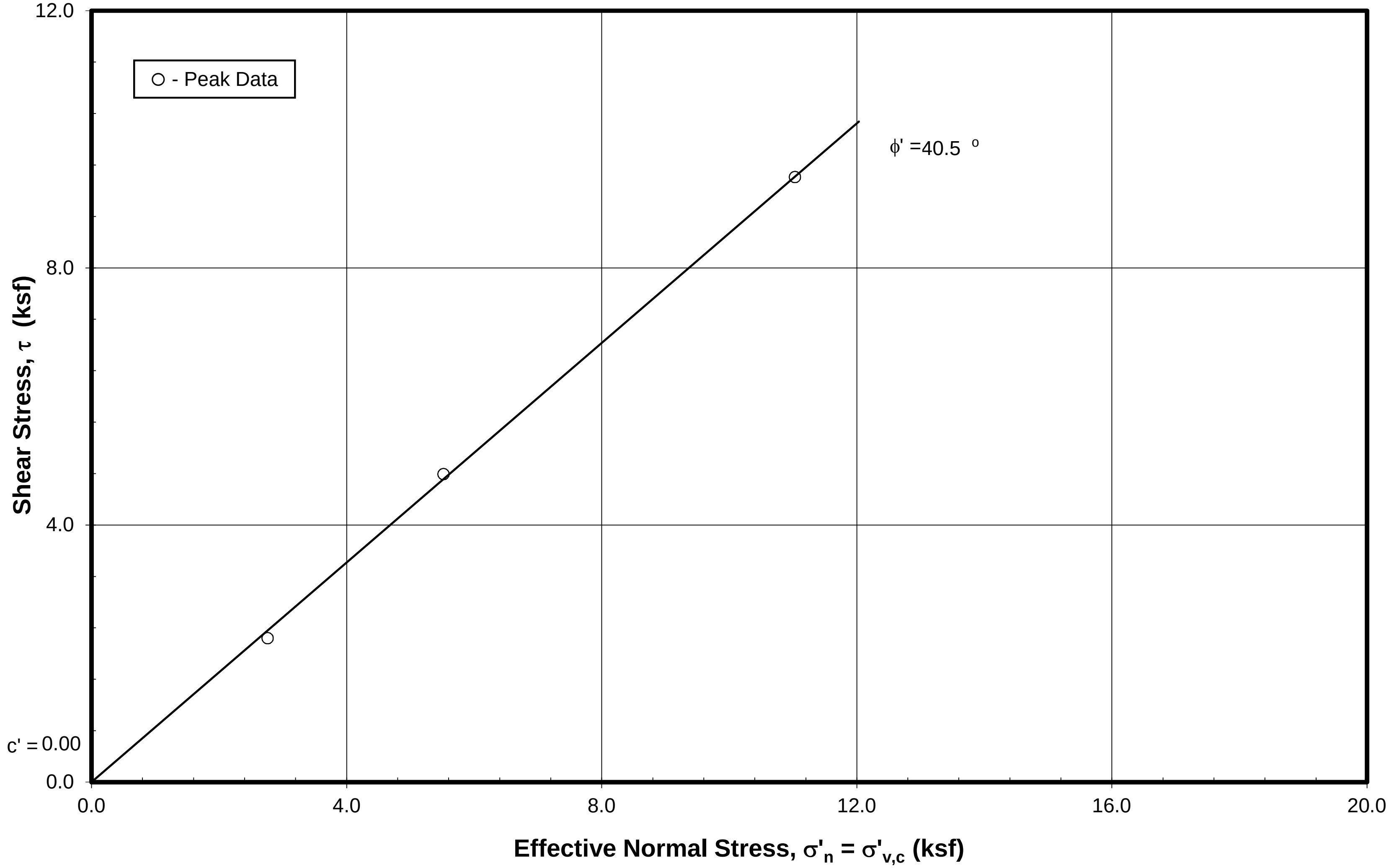
DIRECT SHEAR TESTS

BORING B-192, SAMPLE S-14, DEPTH 46.0 FT

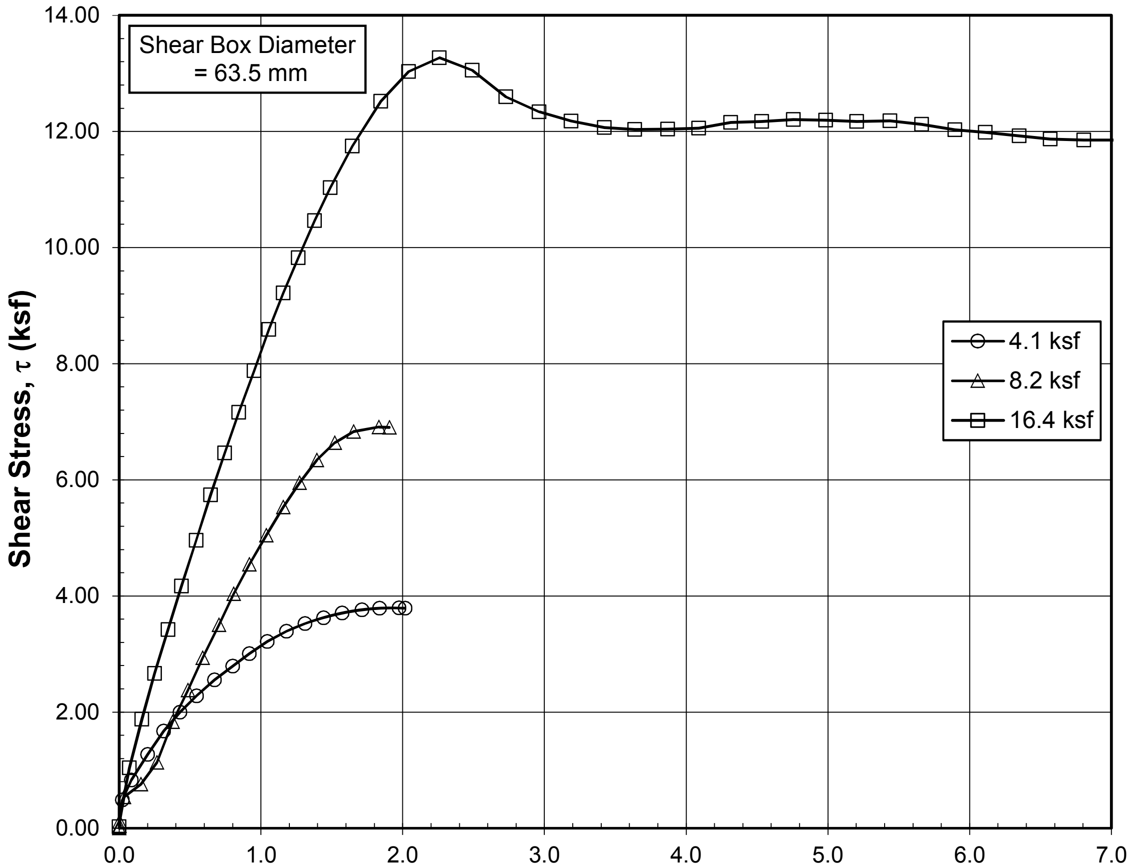
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

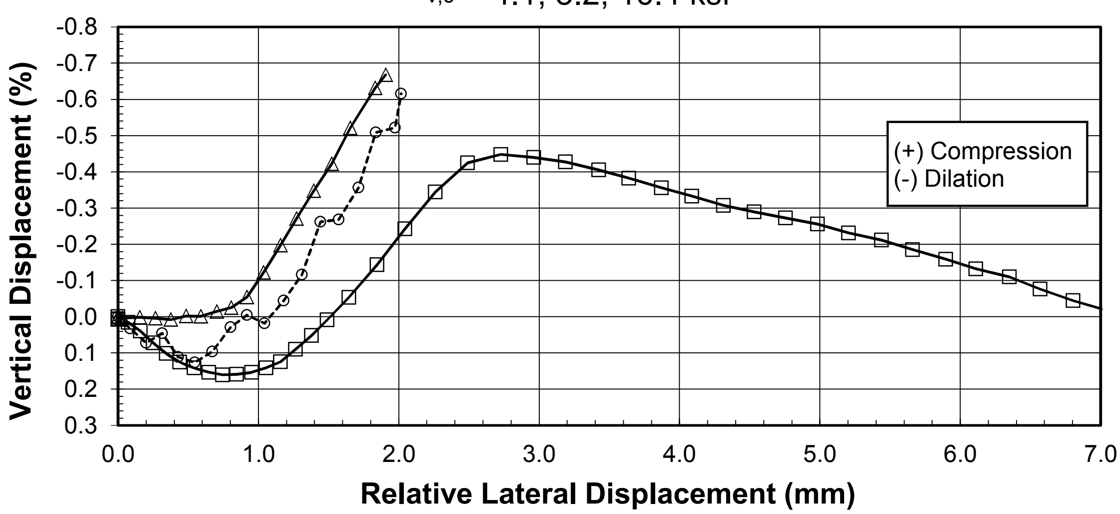
NIKISKI, ALASKA



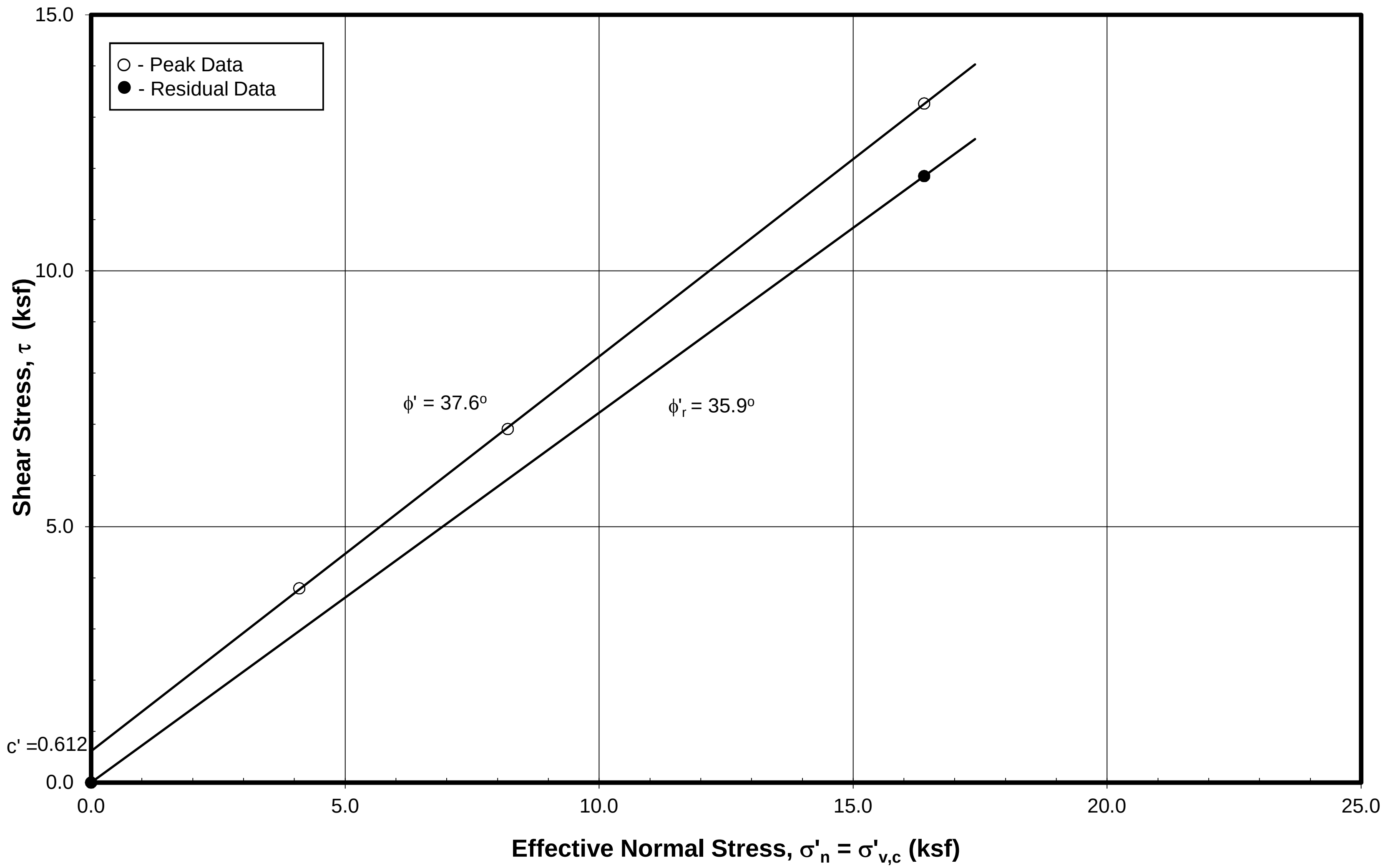
DIRECT SHEAR TESTS
BORING B-192, SAMPLE S-14, DEPTH 46.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



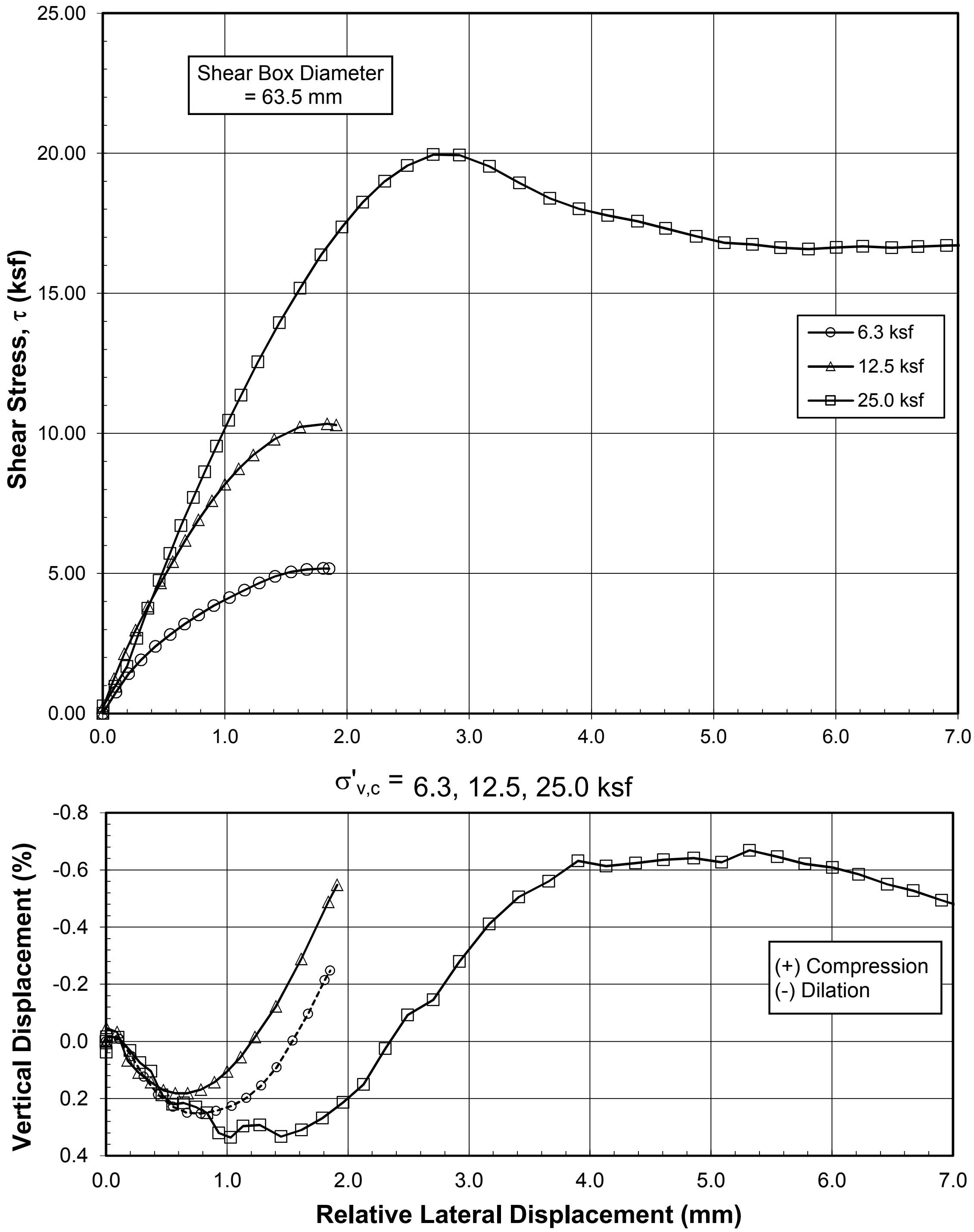
σ'v,c = 4.1, 8.2, 16.4 ksf



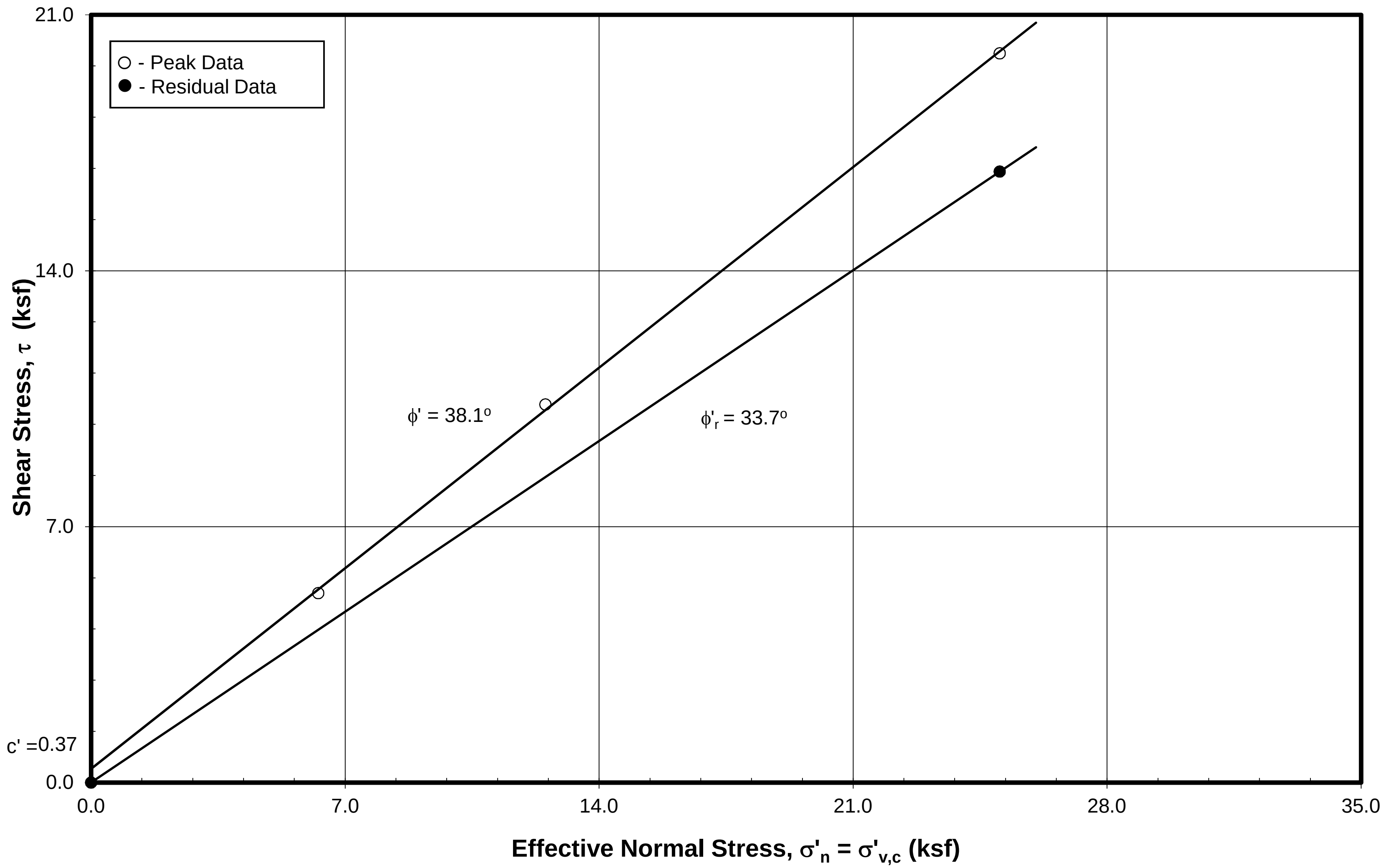
DIRECT SHEAR TESTS
BORING B-192, SAMPLE S-22, DEPTH 86.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



DIRECT SHEAR TESTS
BORING B-192, SAMPLE S-22, DEPTH 86.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



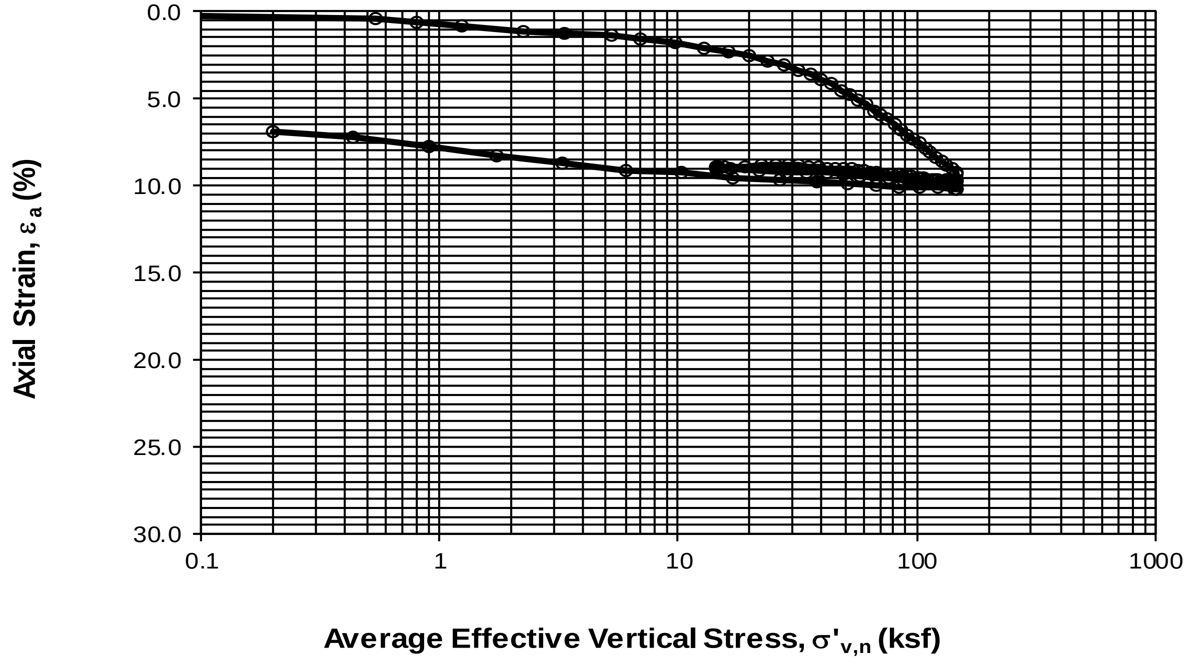
DIRECT SHEAR TESTS
BORING B-192, SAMPLE S-33, DEPTH 161.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



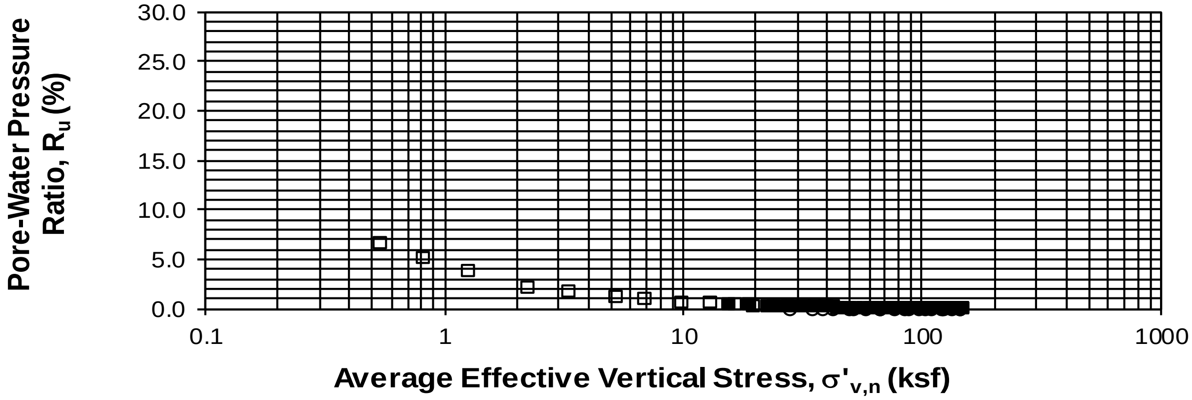
DIRECT SHEAR TESTS
BORING B-192, SAMPLE S-33, DEPTH 161.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

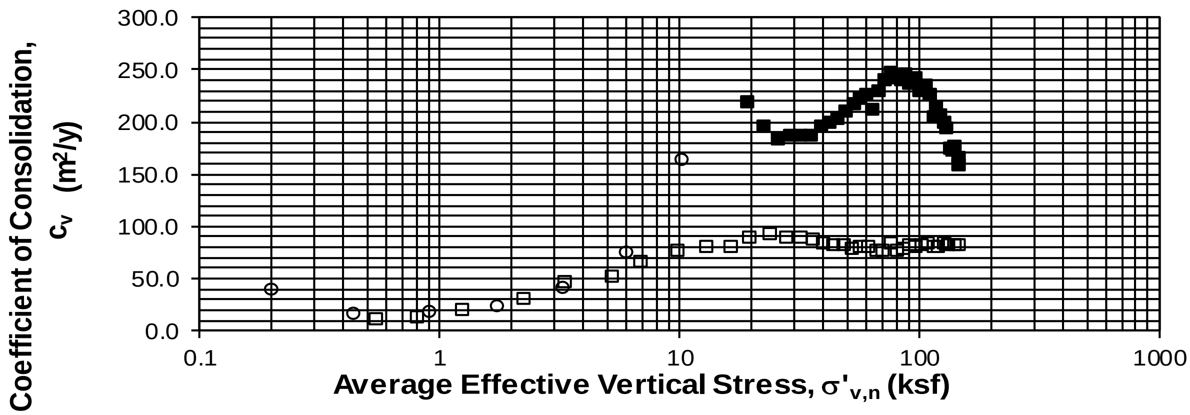
APPENDIX G7

Consolidation Test Results

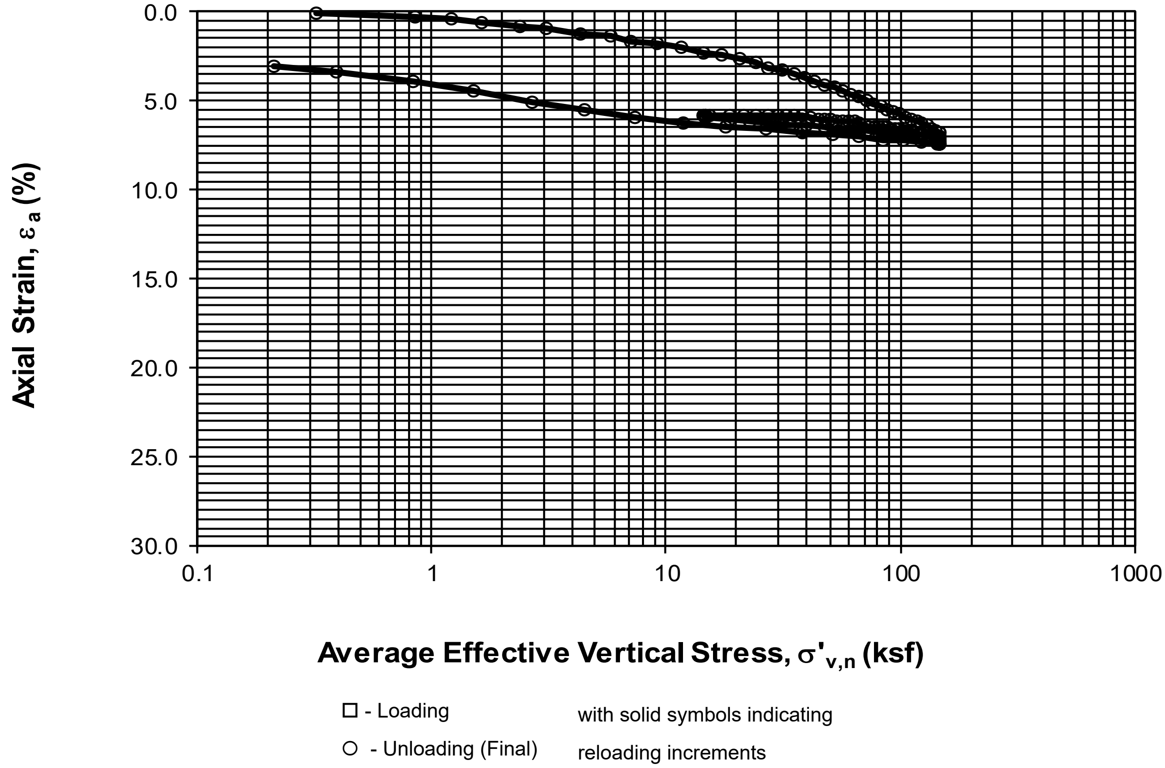


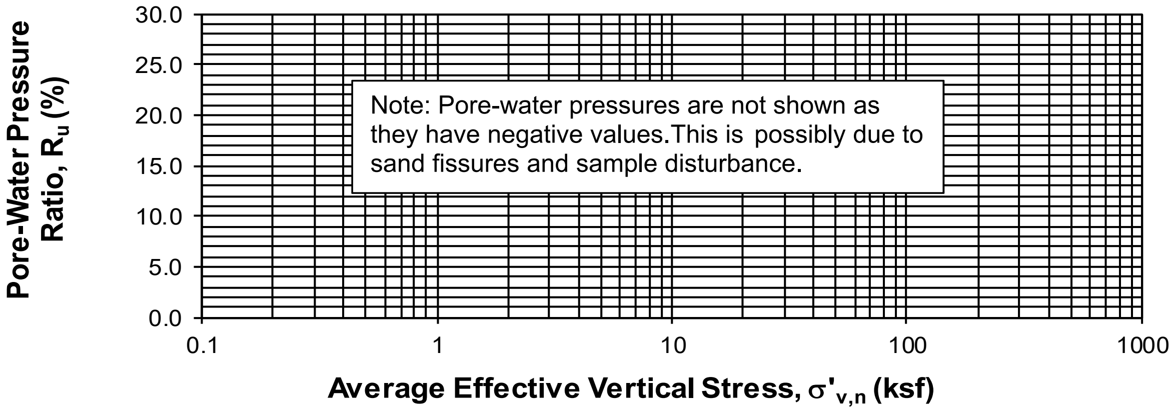
□ - Loading
○ - Unloading (Final)
with solid symbols indicating reloading increments

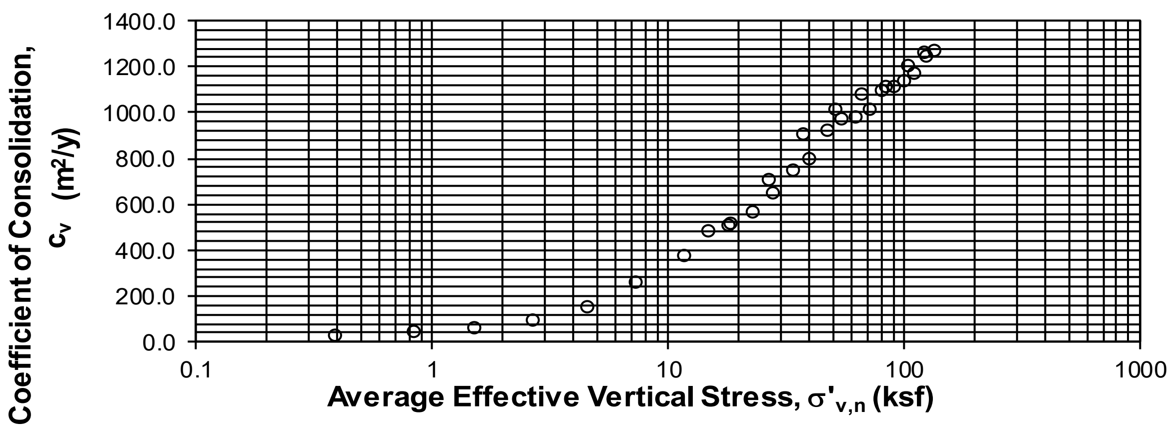




1-D CONSOLIDATION TESTS - CRS
BORING B-146, SAMPLE S-20, DEPTH 80.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA







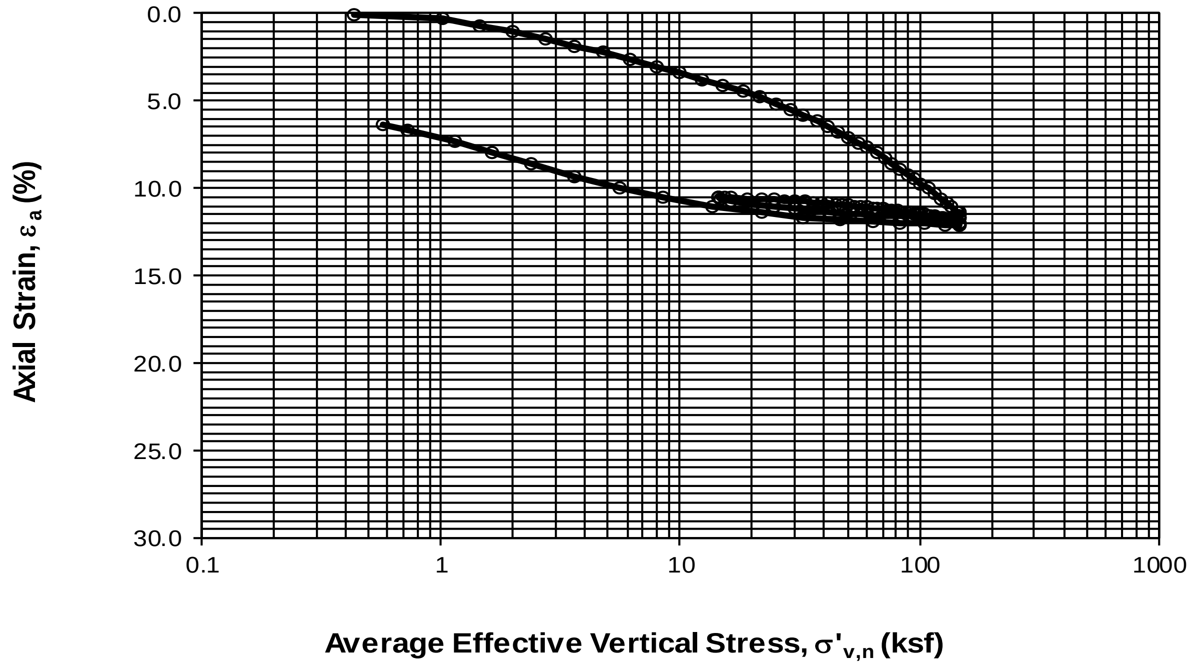
1-D CONSOLIDATION TESTS - CRS

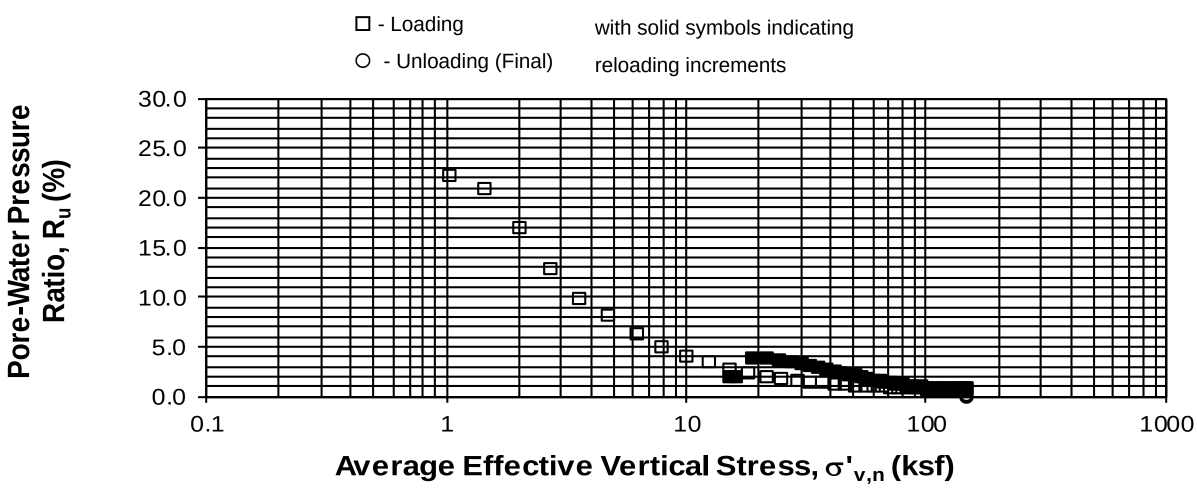
BORING B-146, SAMPLE S-30, DEPTH 121.8 FT

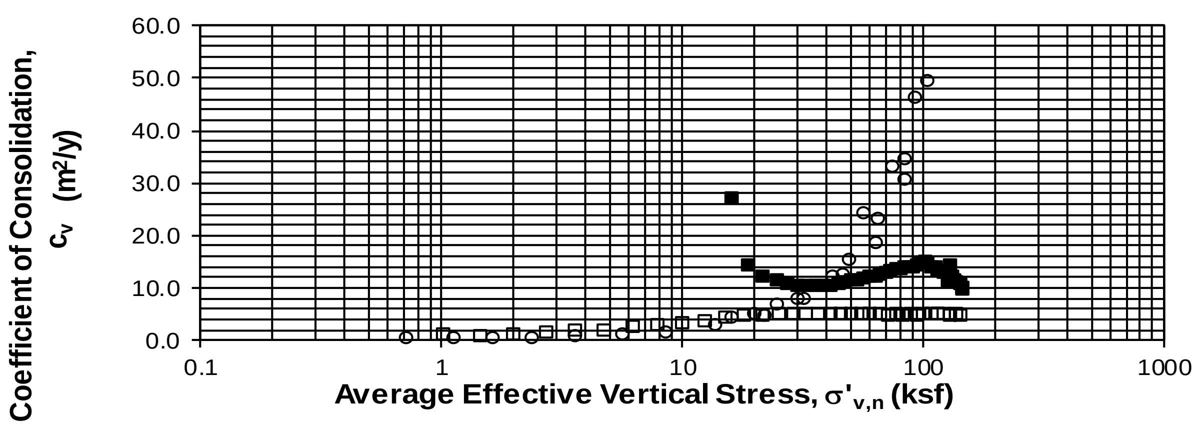
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

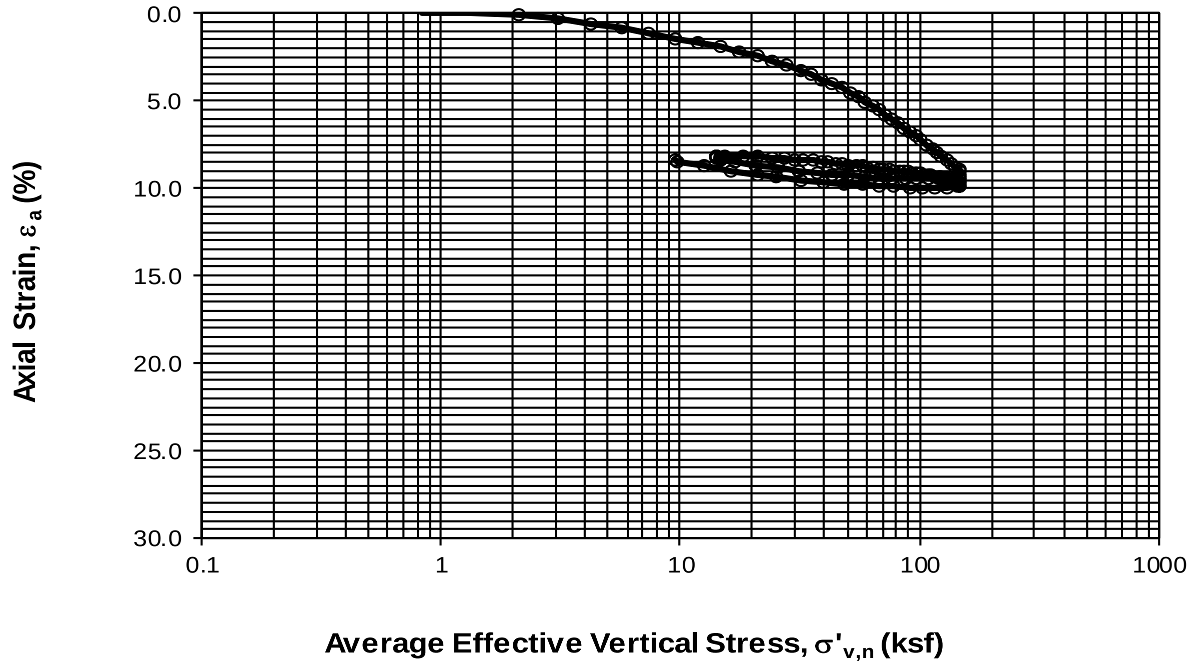
NIKISKI, ALASKA

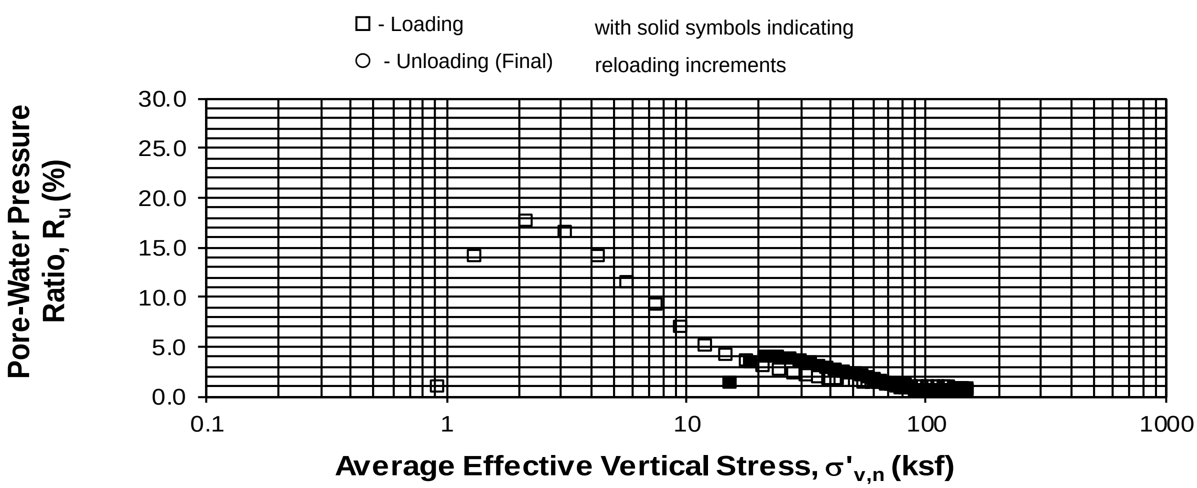


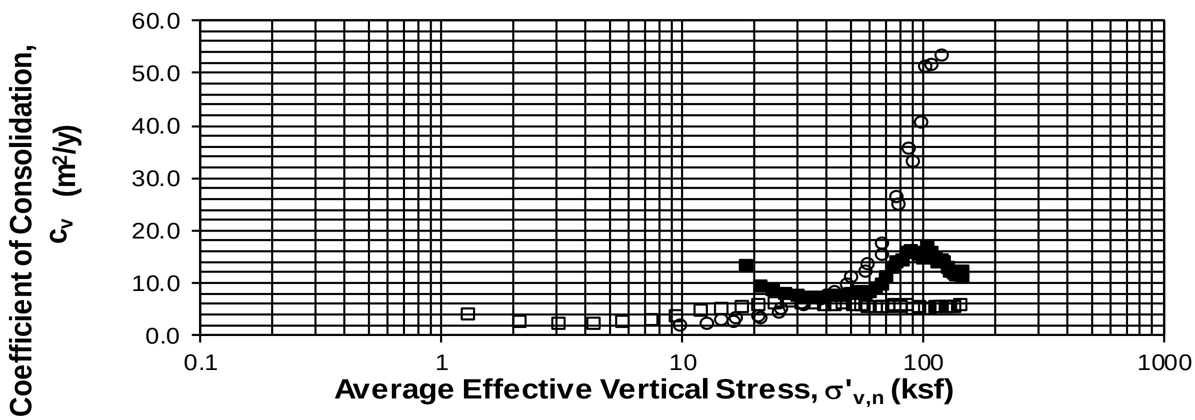




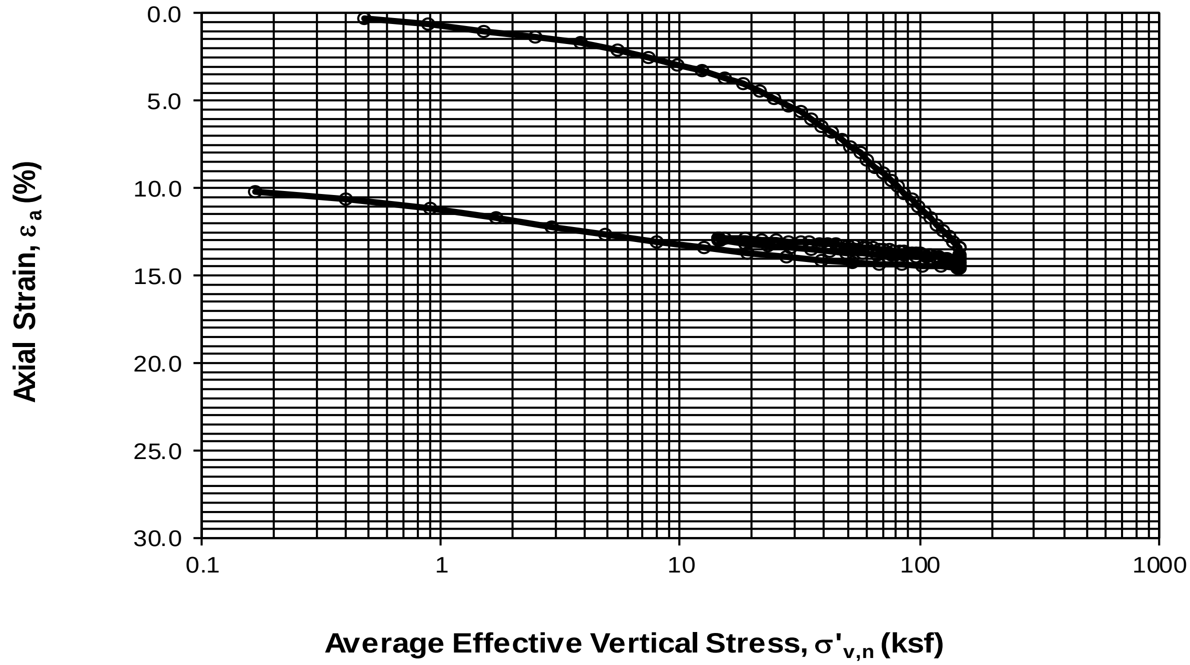
1-D CONSOLIDATION TESTS - CRS
BORING B-146, SAMPLE S-39, DEPTH 198.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



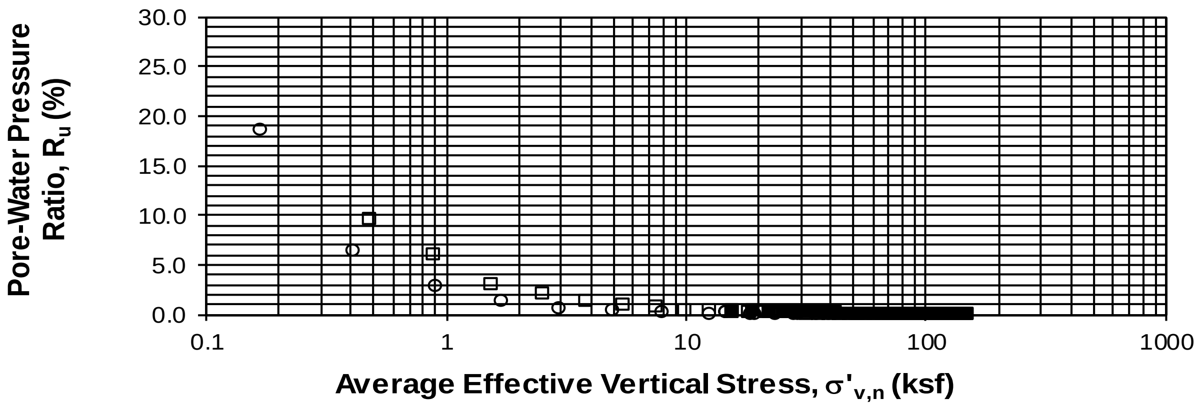


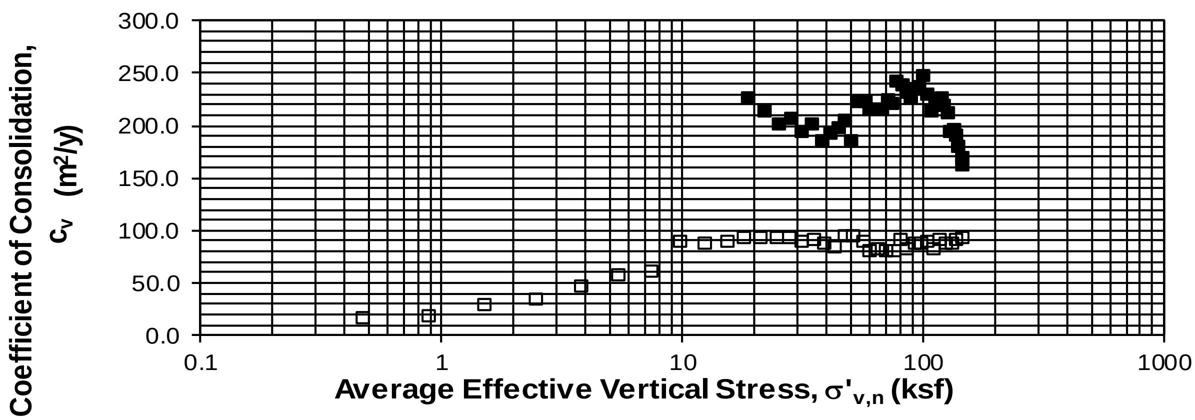


1-D CONSOLIDATION TESTS - CRS
BORING B-148, SAMPLE S-42, DEPTH 199.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

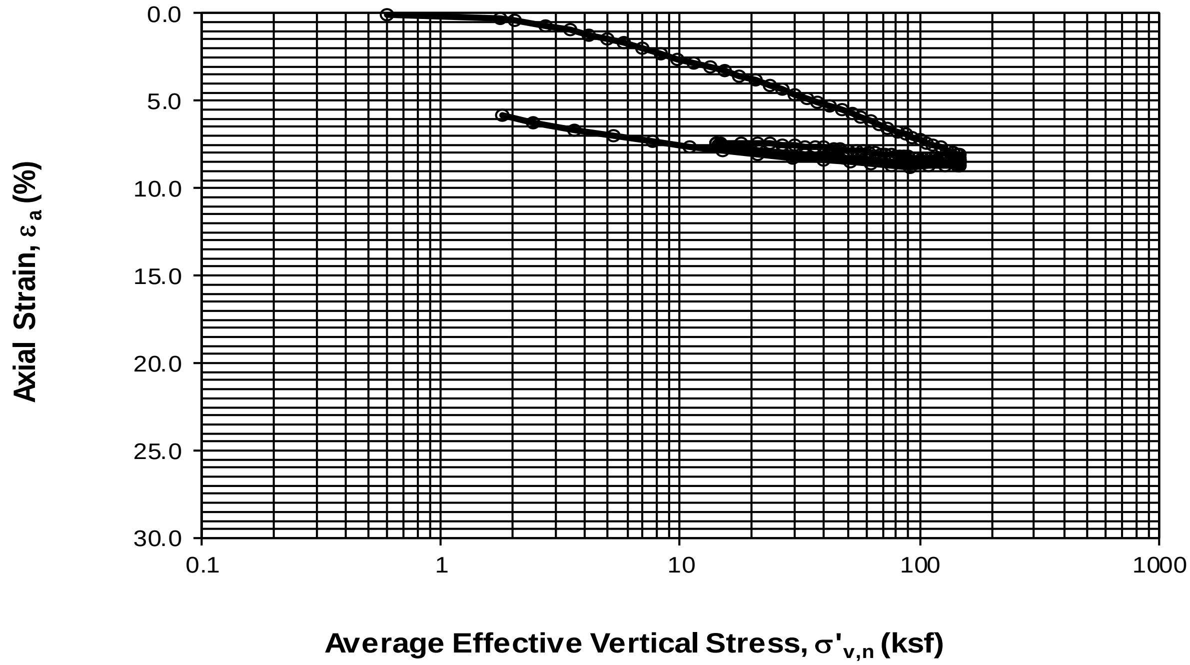


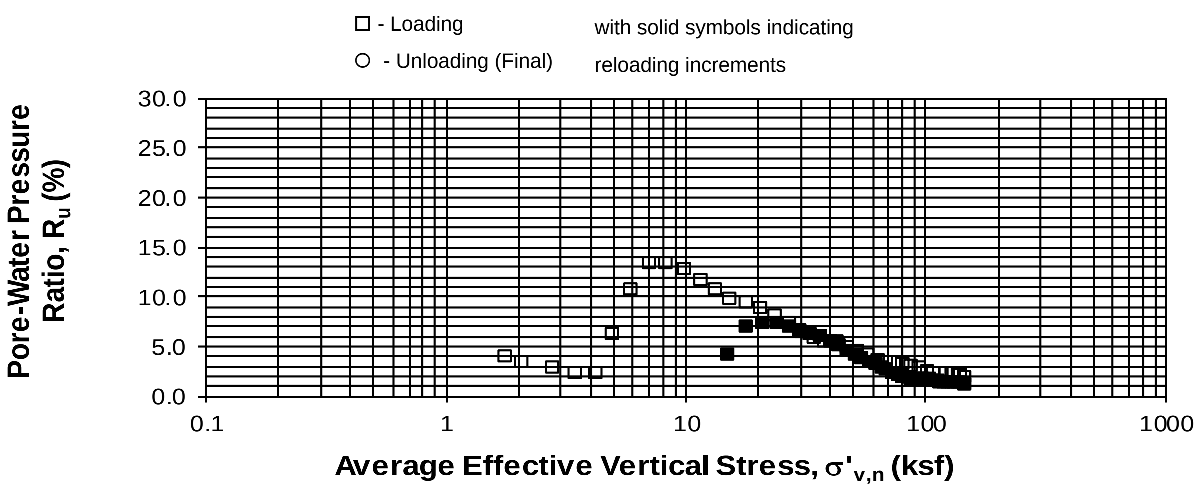
□ - Loading
○ - Unloading (Final)
with solid symbols indicating reloading increments

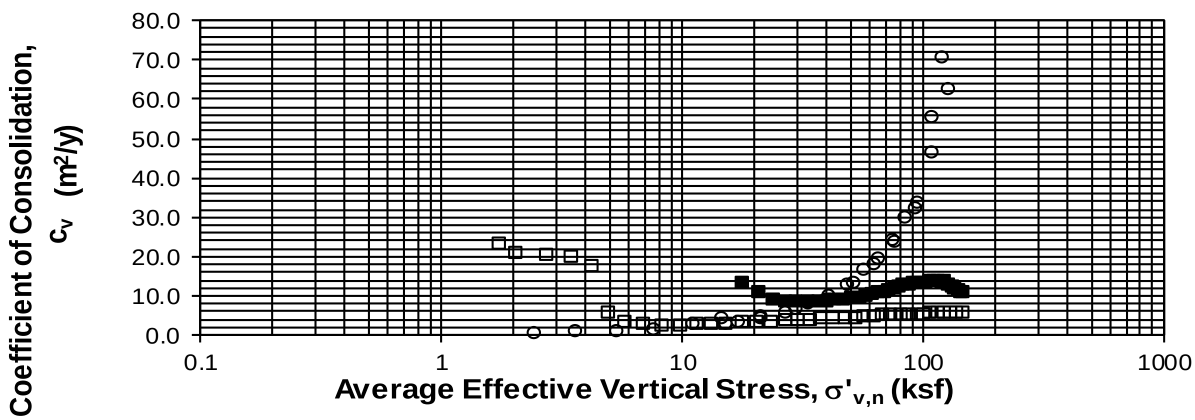




1-D CONSOLIDATION TESTS - CRS
BORING B-149, SAMPLE S-21, DEPTH 76.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA







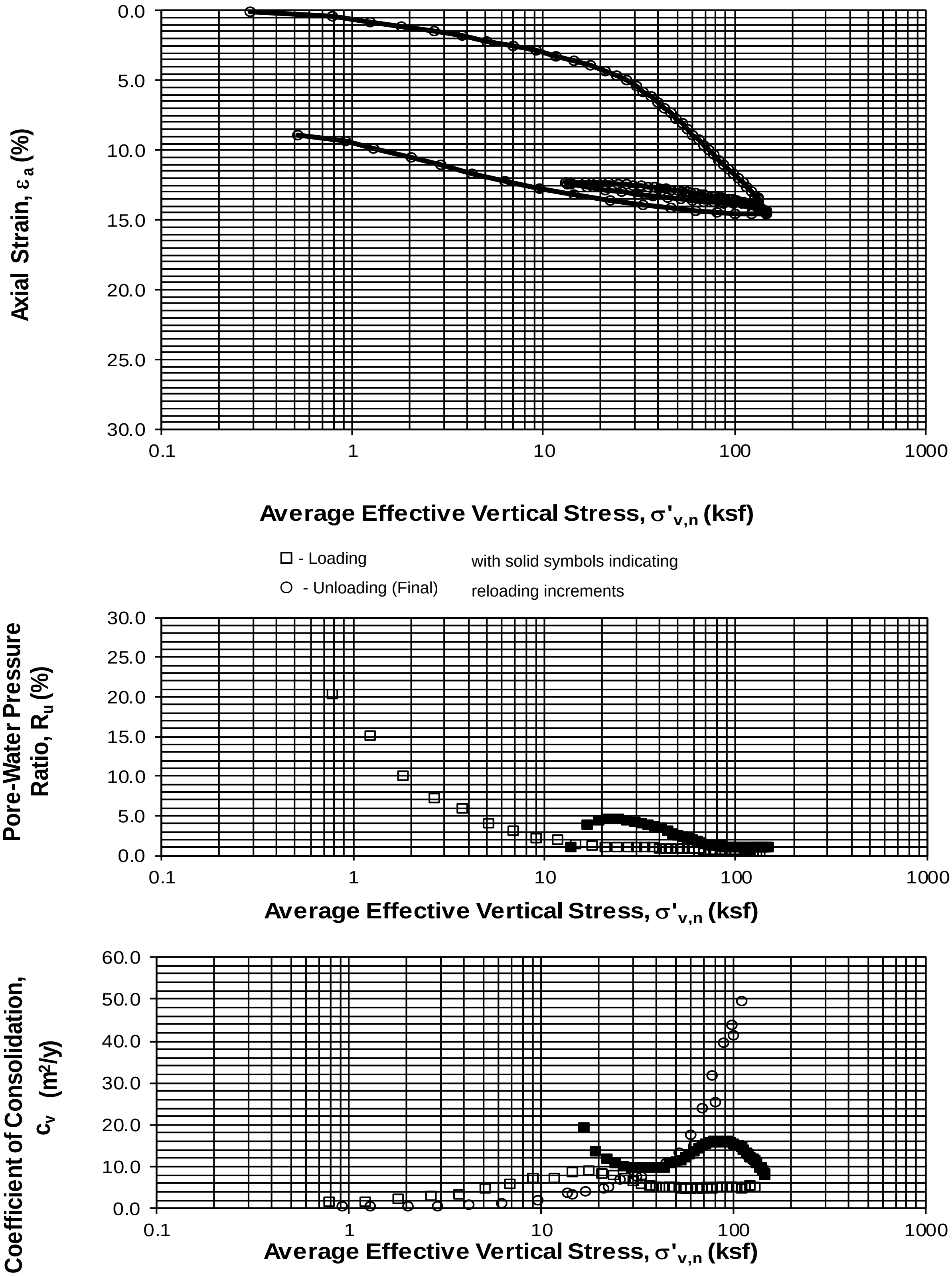
1-D CONSOLIDATION TESTS - CRS

BORING B-149, SAMPLE S-31, DEPTH 131.5 FT

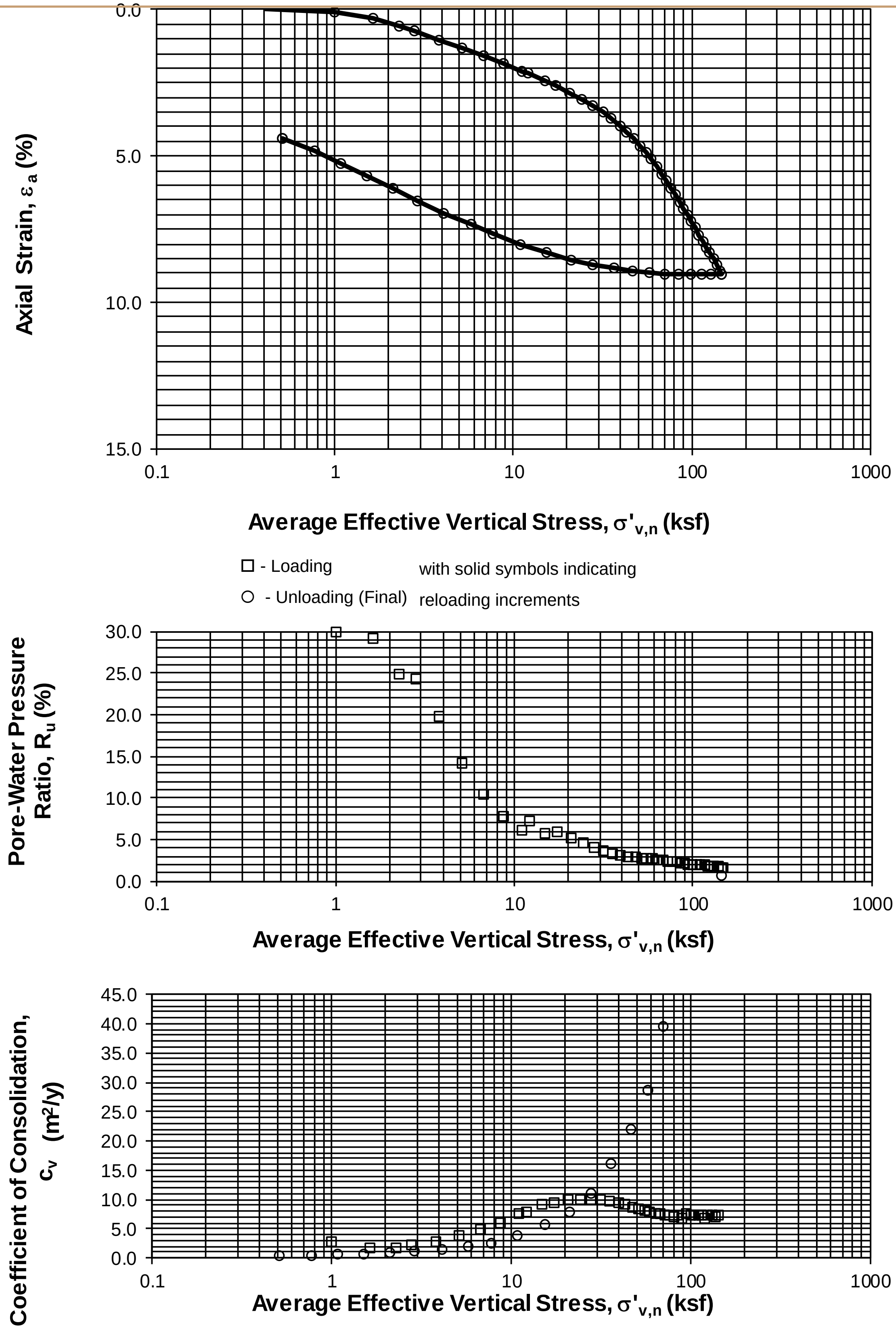
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

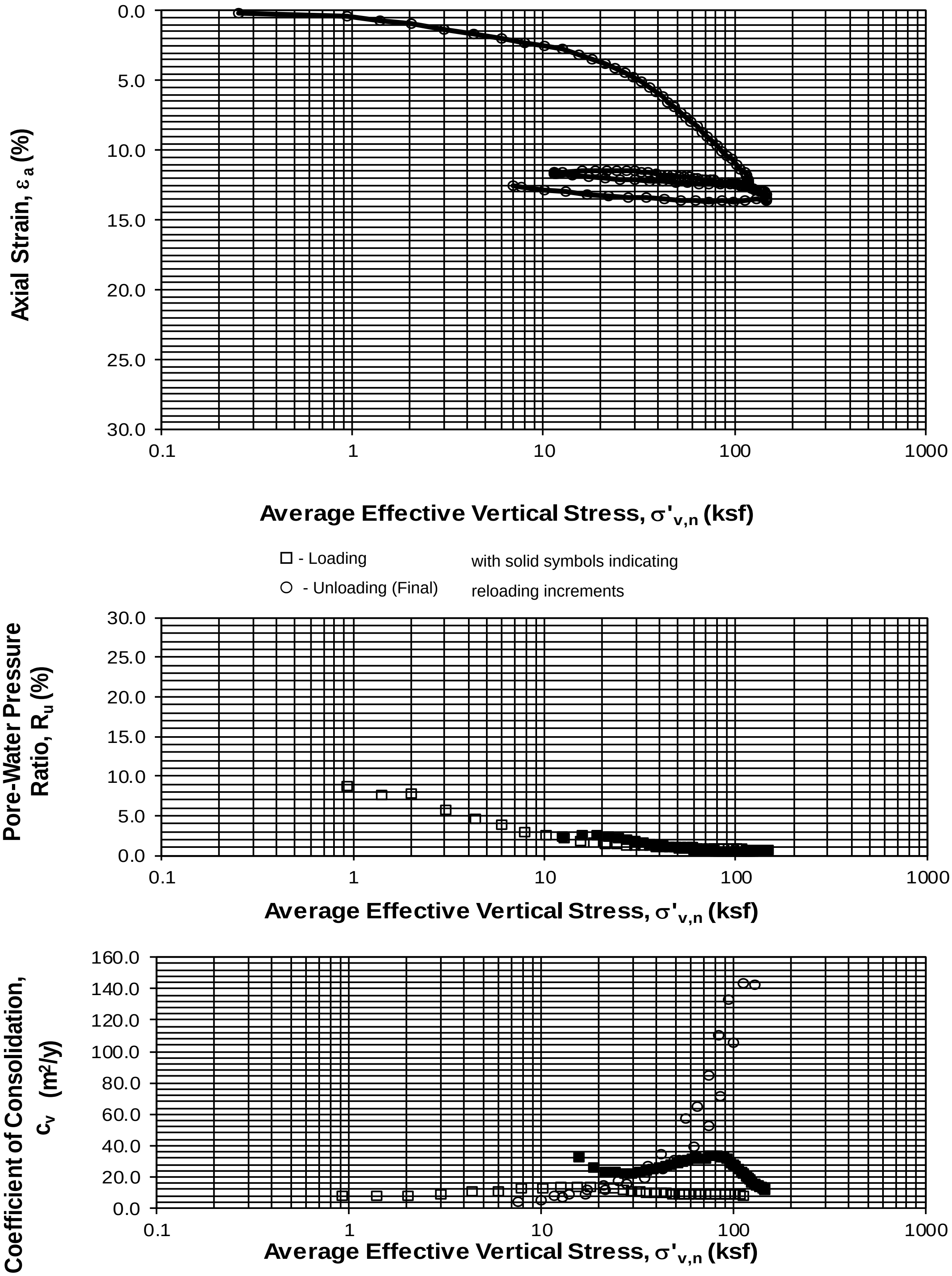
NIKISKI, ALASKA



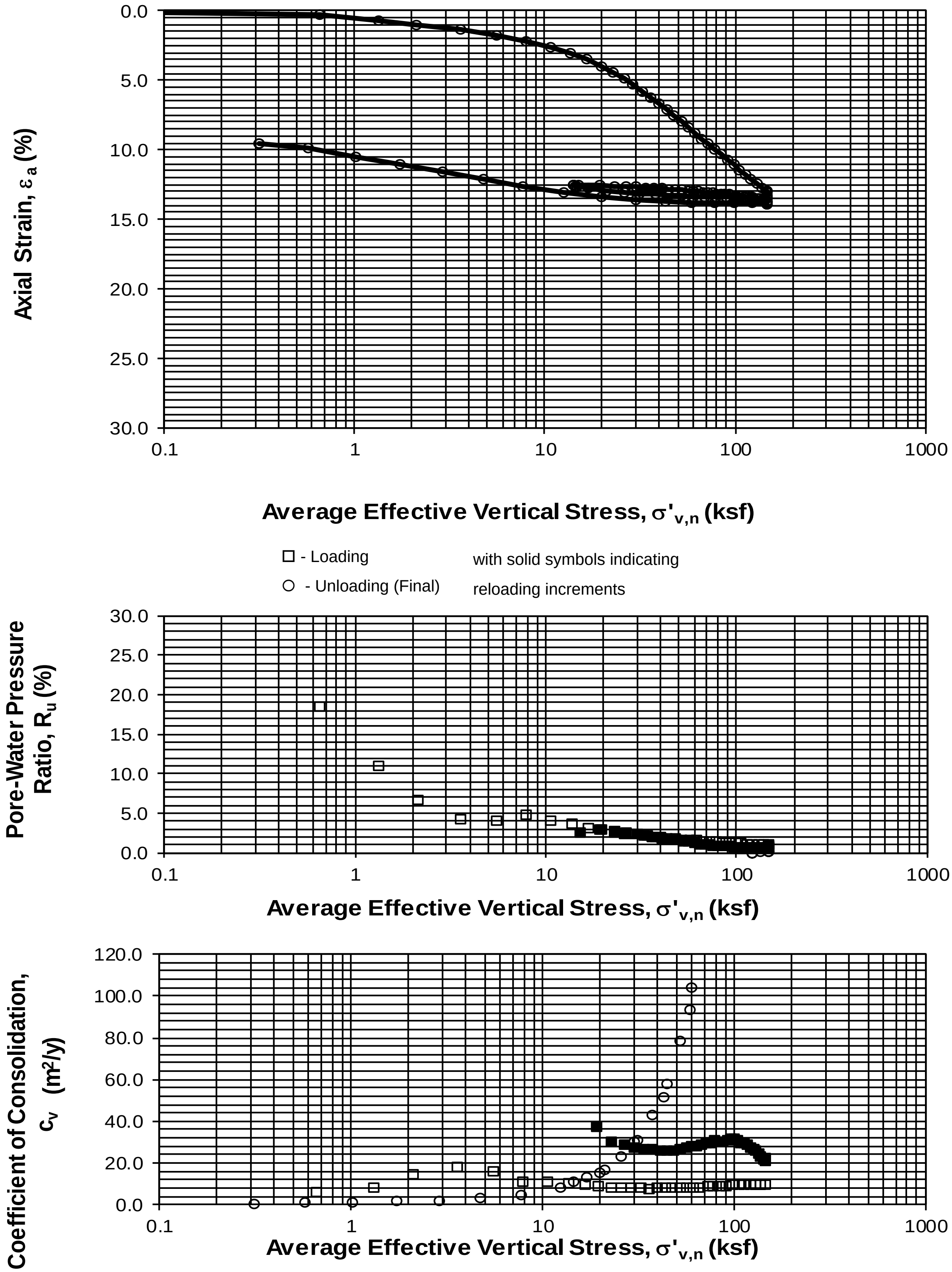
1-D CONSOLIDATION TESTS - CRS
BORING B-149, SAMPLE S-38, DEPTH 193.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



1-D CONSOLIDATION TESTS - CRS
BORING B-149, SAMPLE S-43, DEPTH 219.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



1-D CONSOLIDATION TESTS - CRS
BORING B-150, SAMPLE S-19, DEPTH 66.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



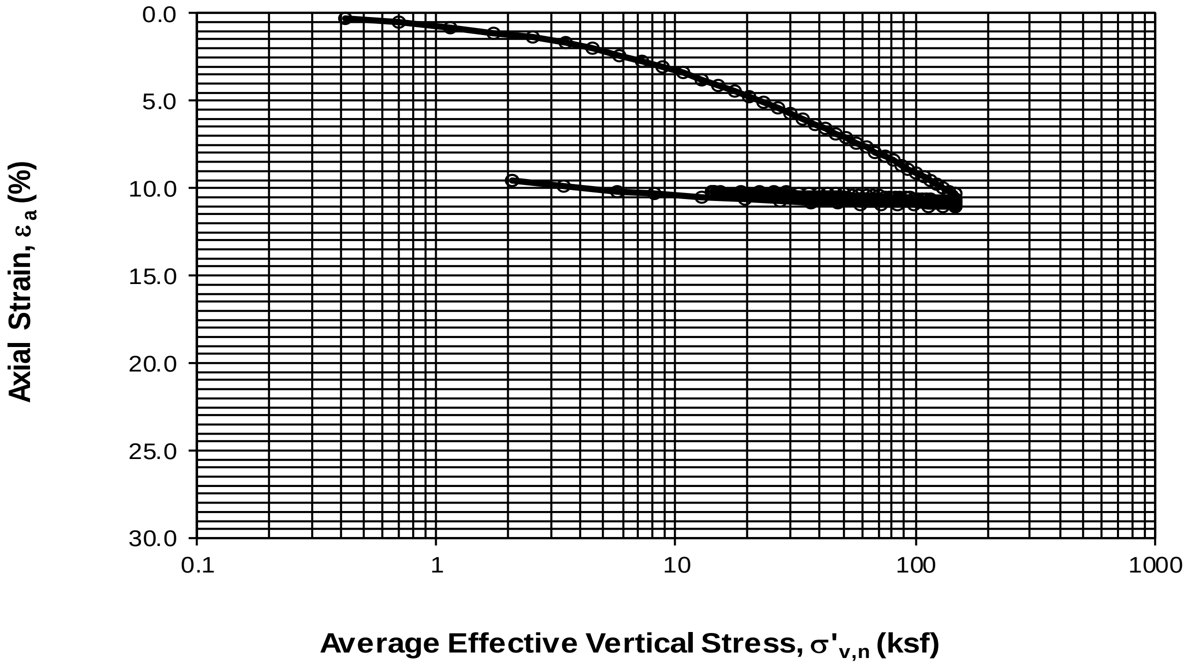
1-D CONSOLIDATION TESTS - CRS

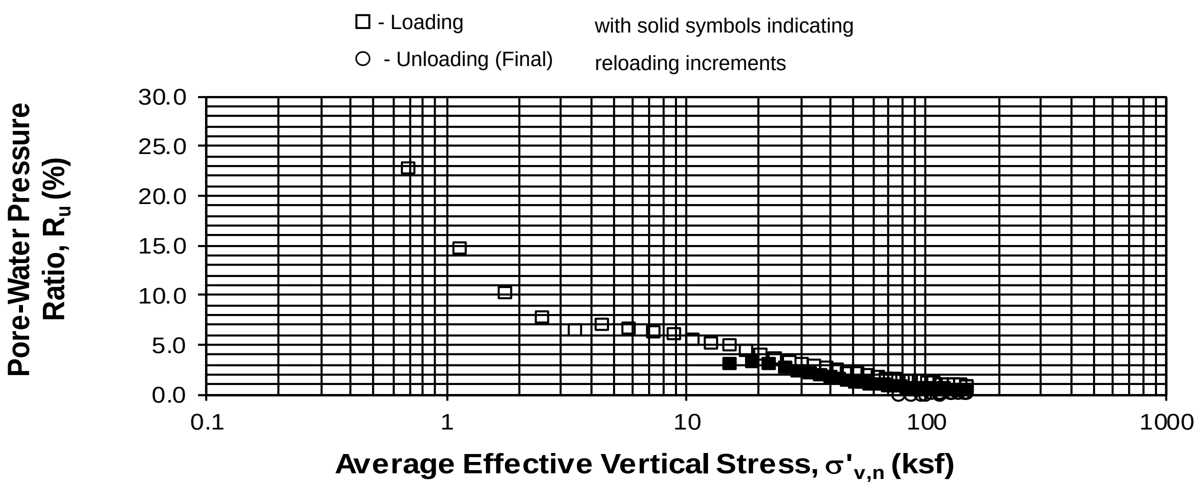
BORING B-150, SAMPLE S-30, DEPTH 119.2 FT

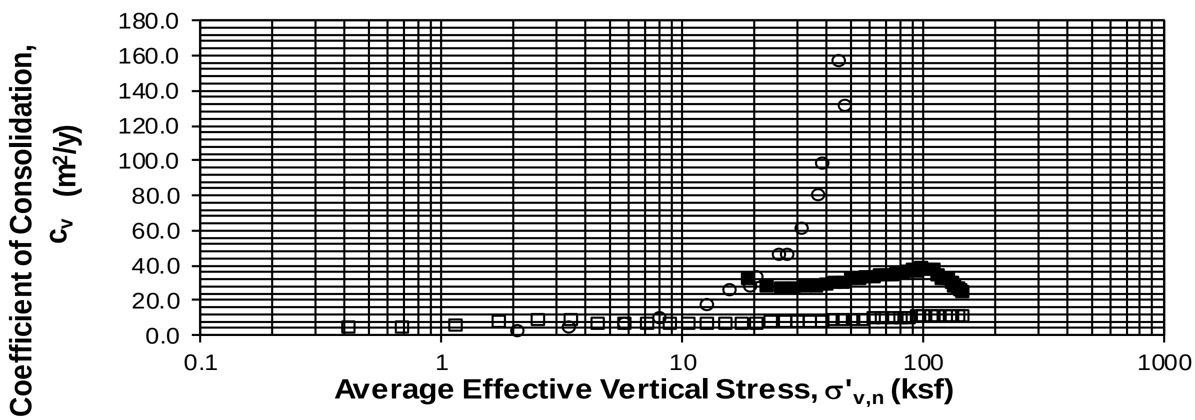
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

NIKISKI, ALASKA

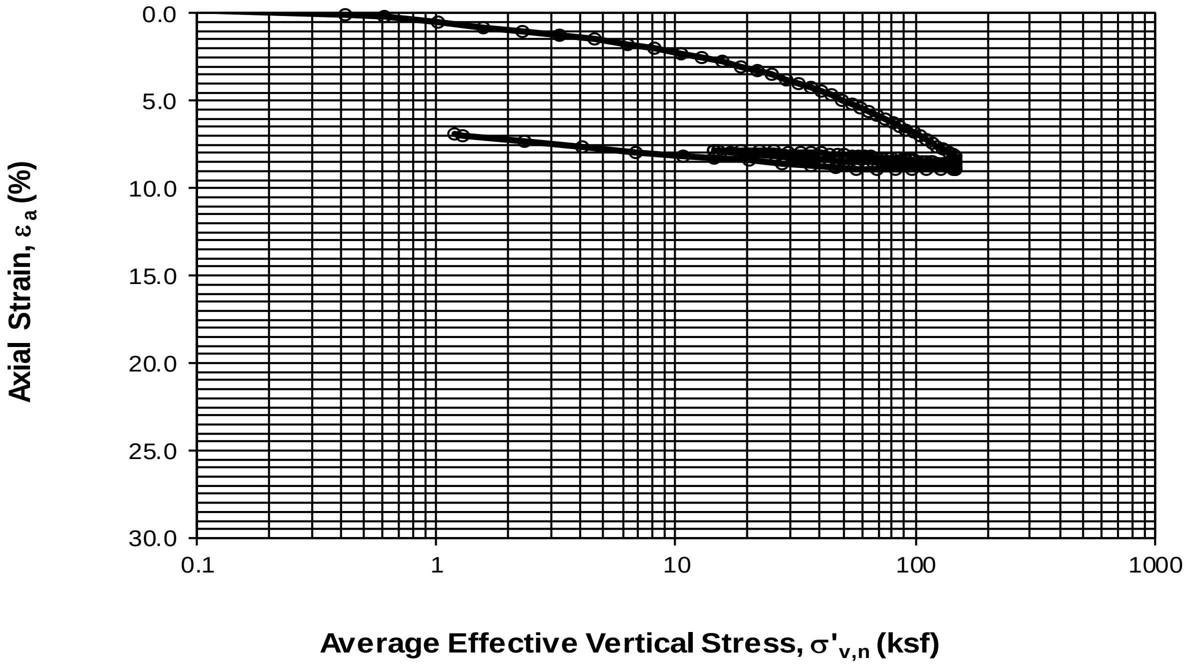




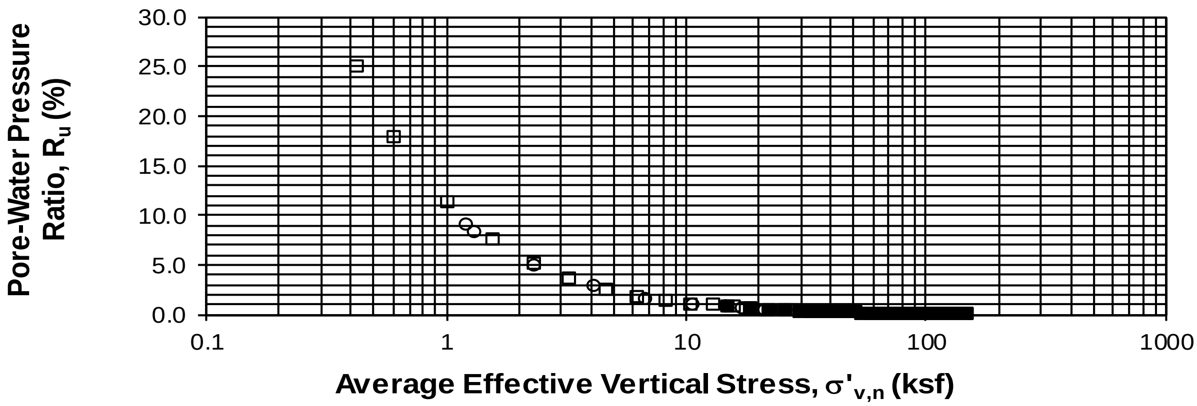


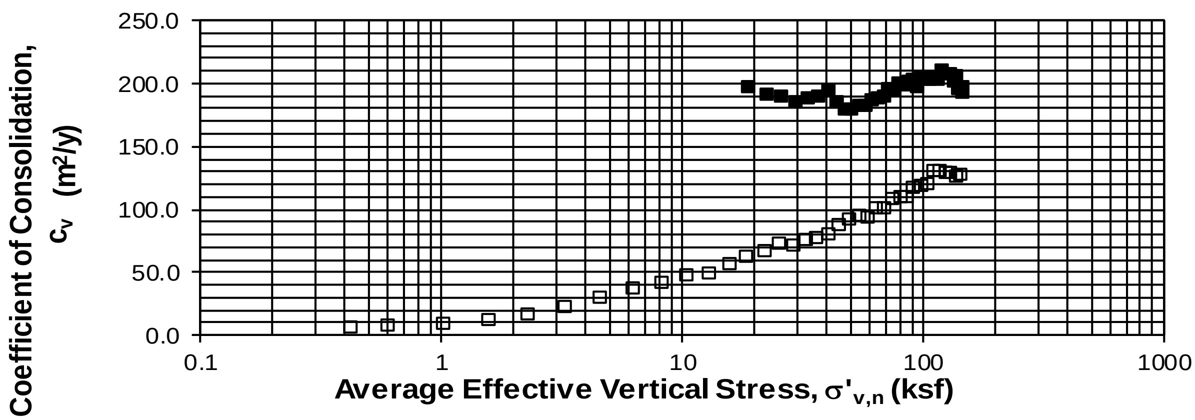
1-D CONSOLIDATION TESTS - CRS
BORING B-151, SAMPLE S-35, DEPTH 151.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G7-11

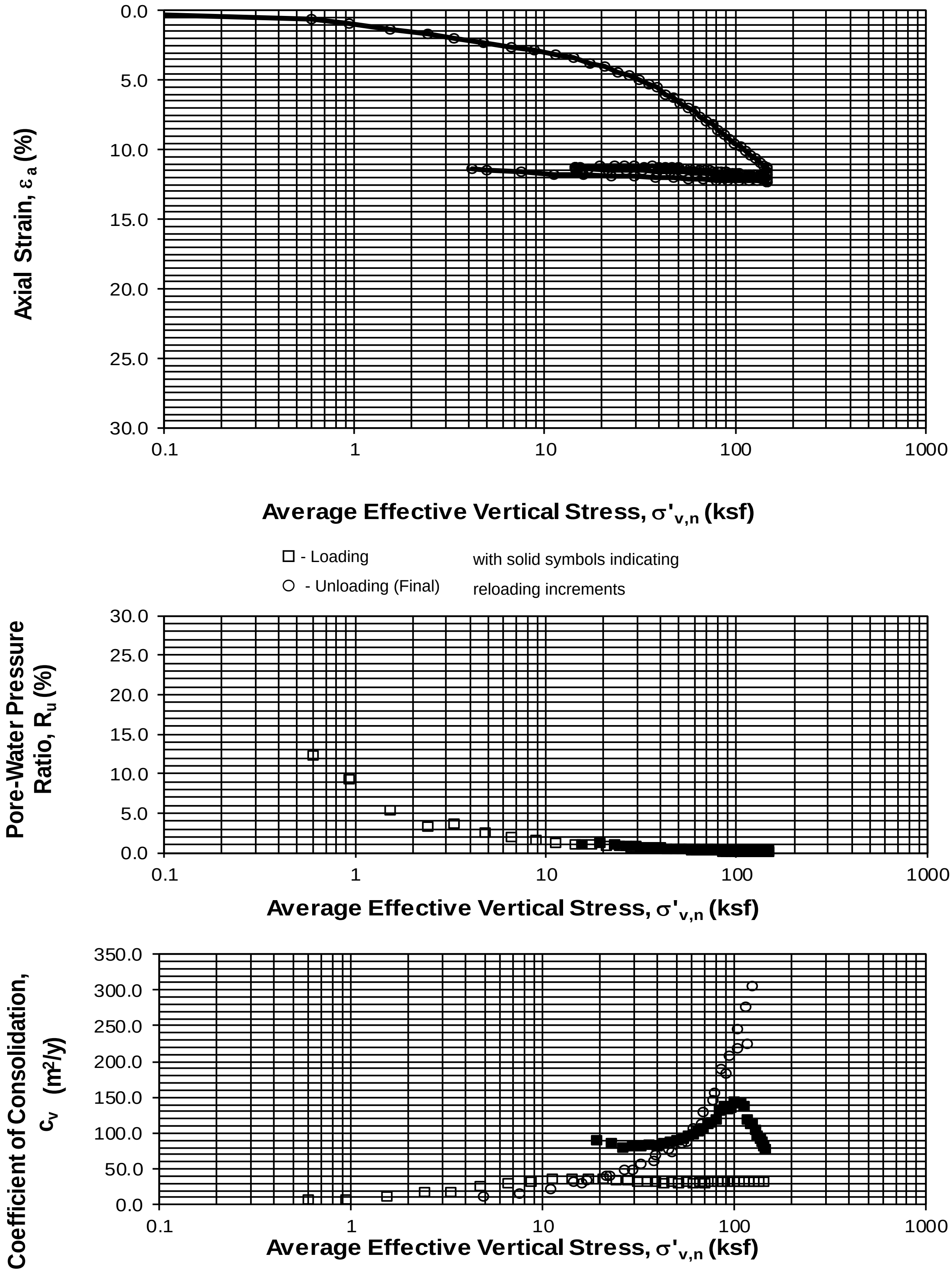


□ - Loading
○ - Unloading (Final)
with solid symbols indicating reloading increments



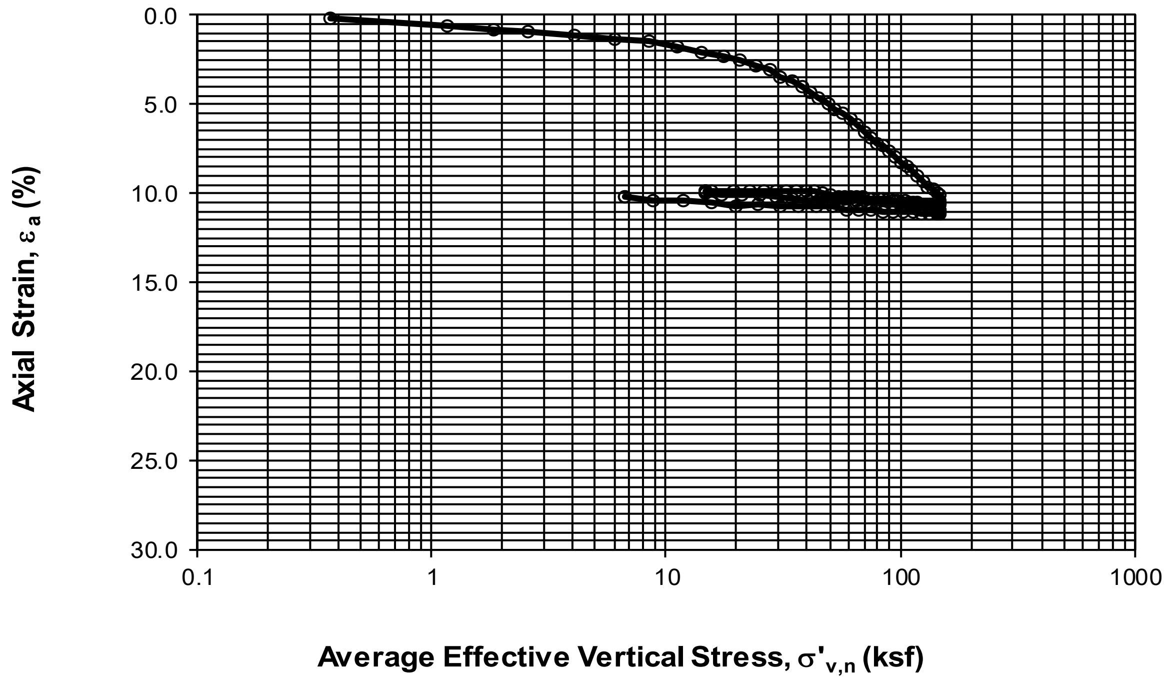


1-D CONSOLIDATION TESTS - CRS
BORING B-151, SAMPLE S-40, DEPTH 191.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

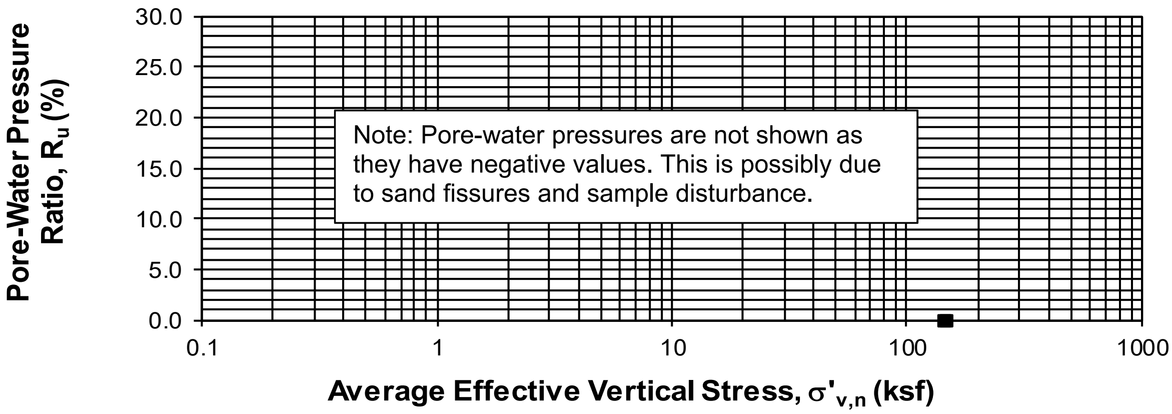


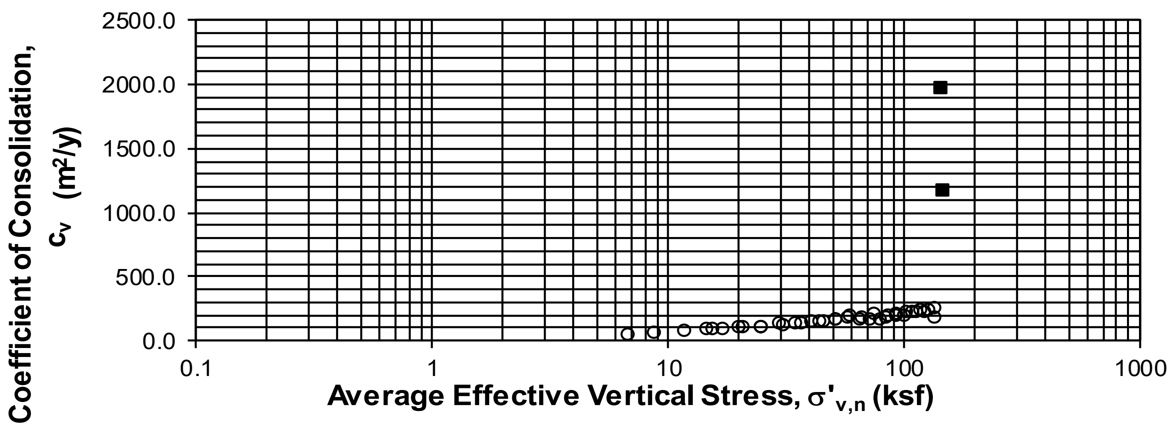
1-D CONSOLIDATION TESTS - CRS
BORING B-152, SAMPLE S-21, DEPTH 70.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G7-13

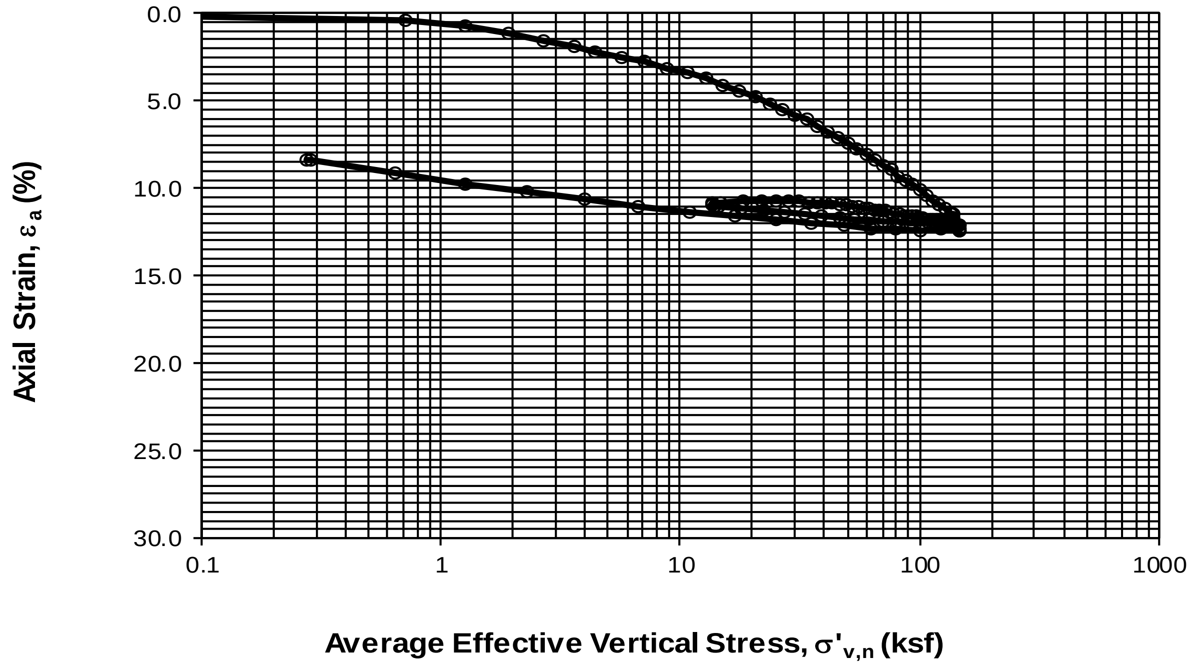


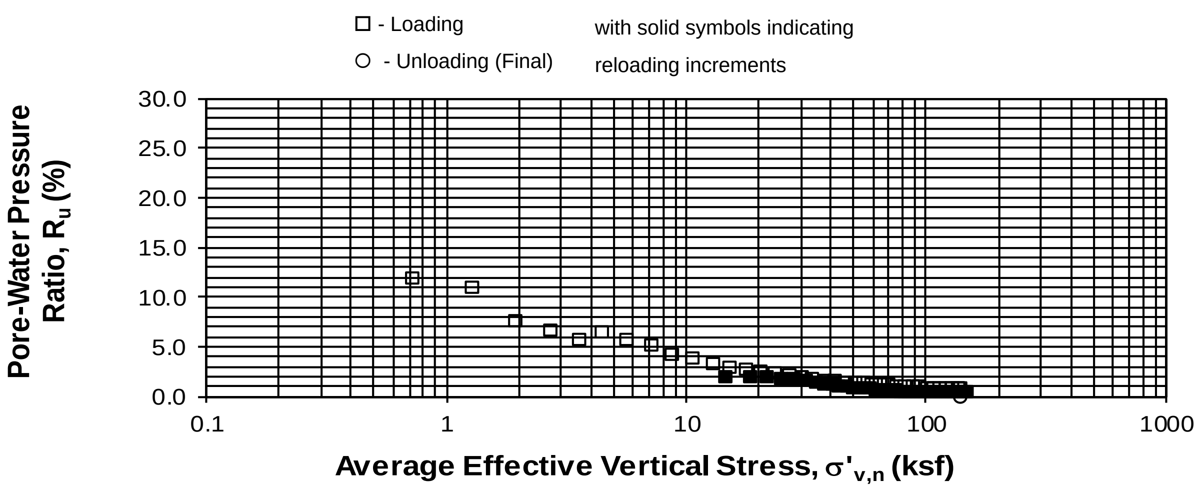
□ - Loading
○ - Unloading (Final)
with solid symbols indicating reloading increments

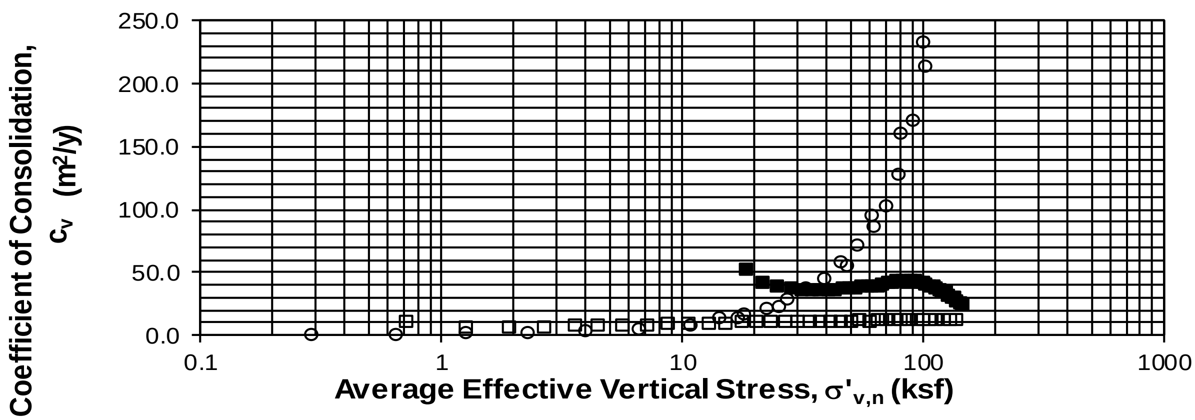




1-D CONSOLIDATION TESTS - CRS
BORING B-153, SAMPLE S-19, DEPTH 67.4 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

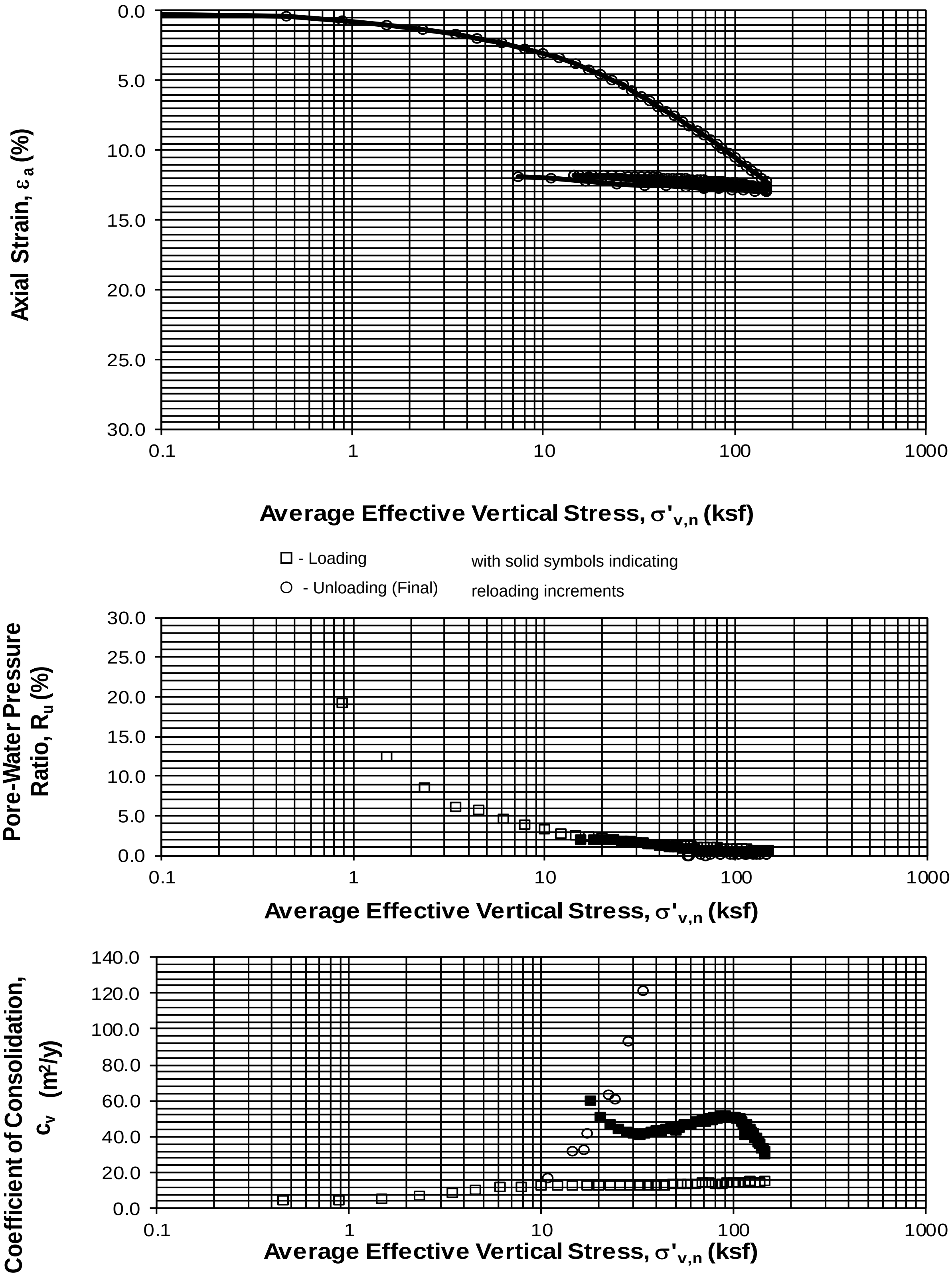




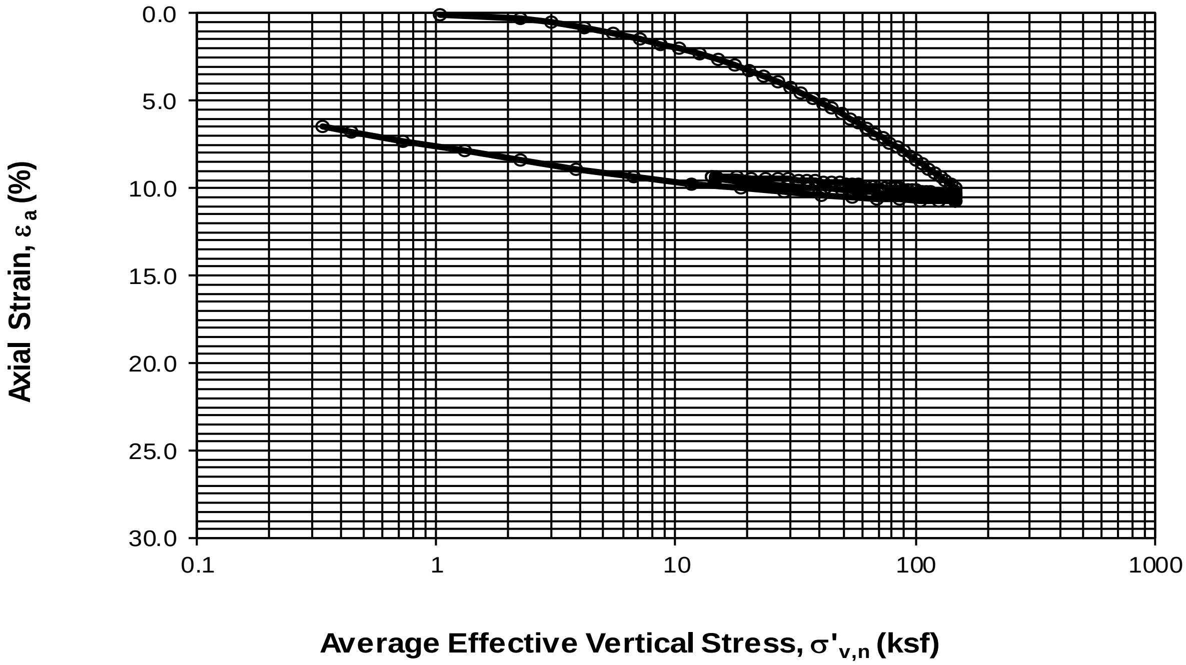


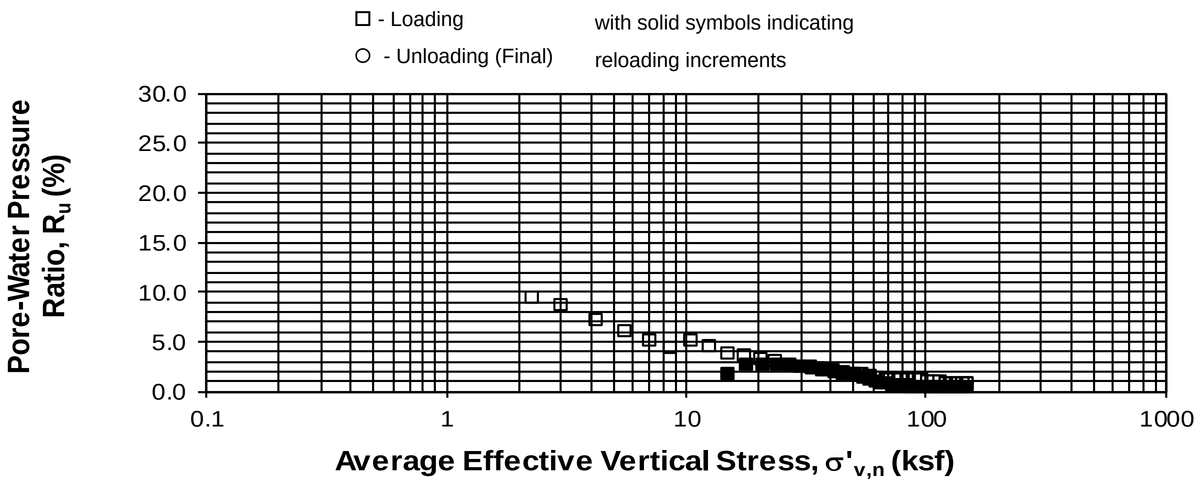
1-D CONSOLIDATION TESTS - CRS
BORING B-154, SAMPLE S-27, DEPTH 92.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

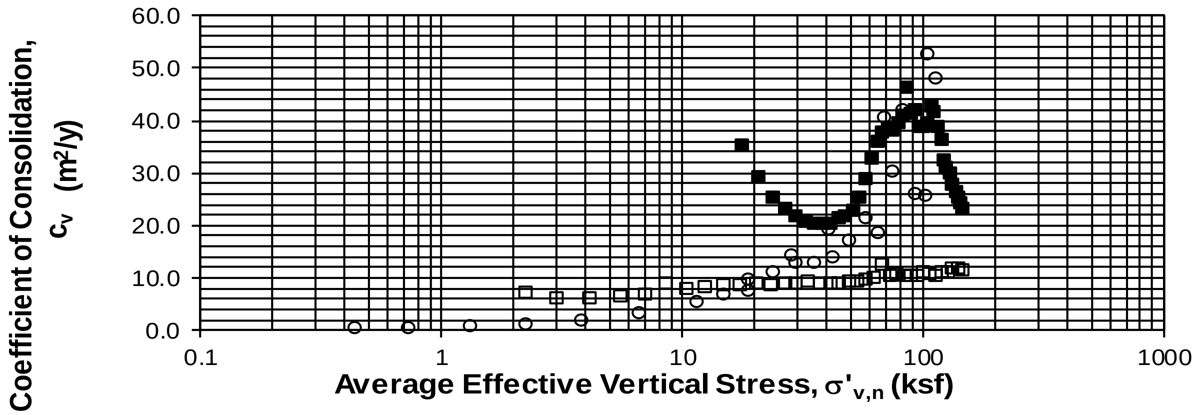
PLATE G7-15



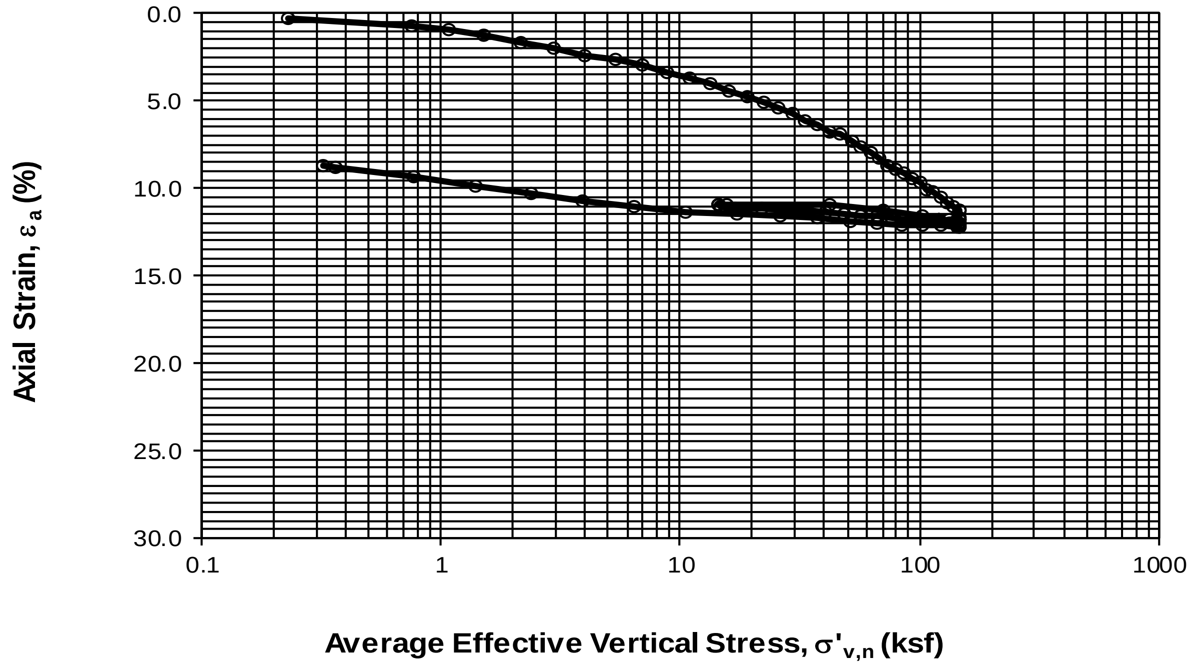
1-D CONSOLIDATION TESTS - CRS
BORING B-156, SAMPLE S-27, DEPTH 102.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

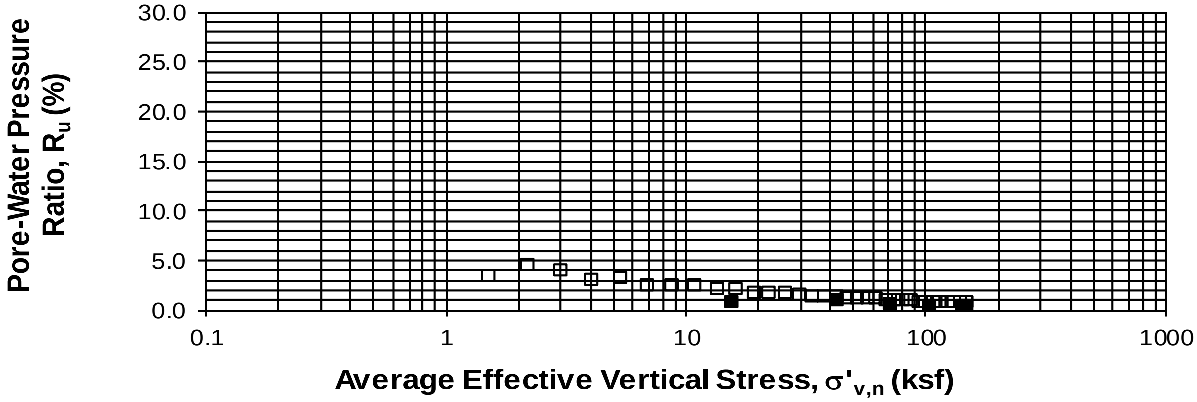


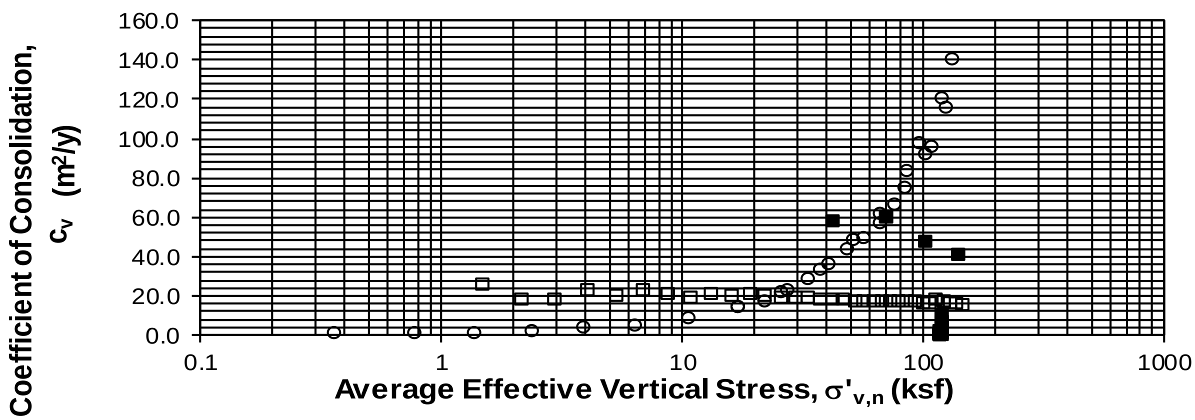




1-D CONSOLIDATION TESTS - CRS
BORING B-157, SAMPLE S-30, DEPTH 101.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA







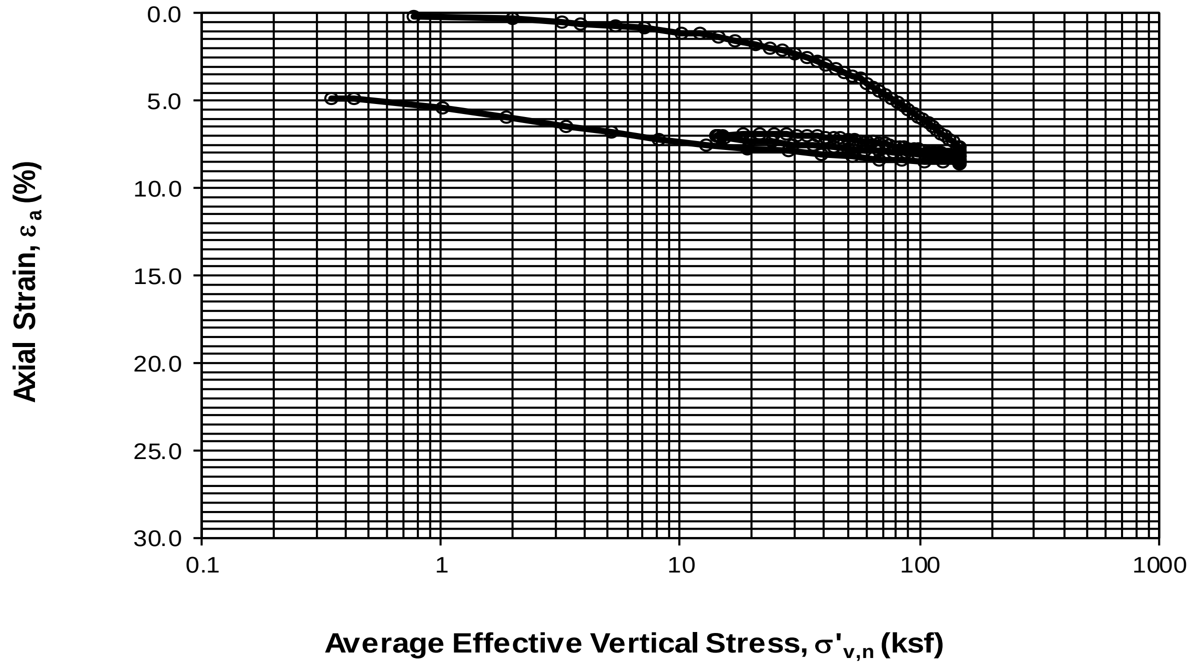
1-D CONSOLIDATION TESTS - CRS

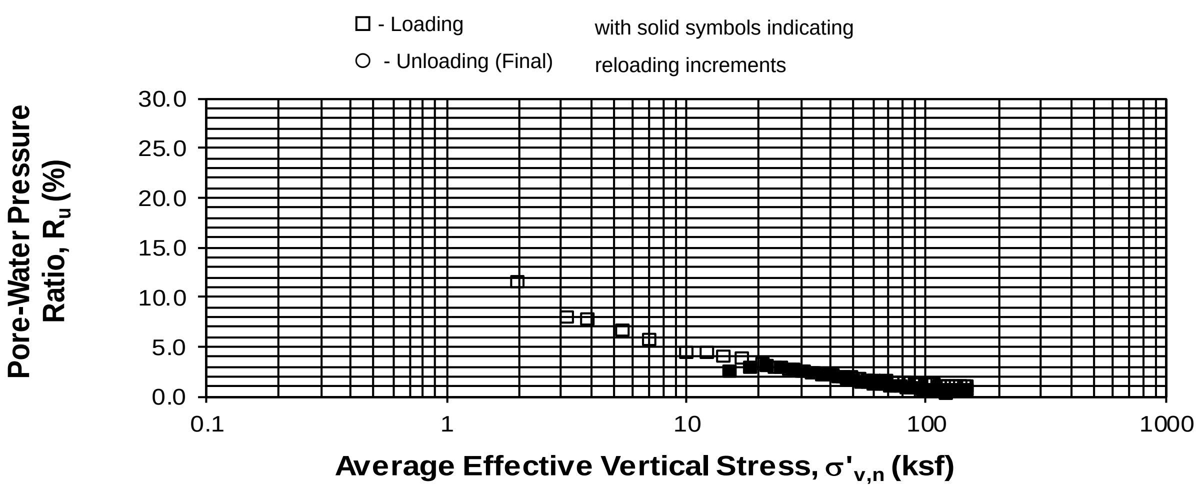
BORING B-161, SAMPLE S-28, DEPTH 113.0 FT

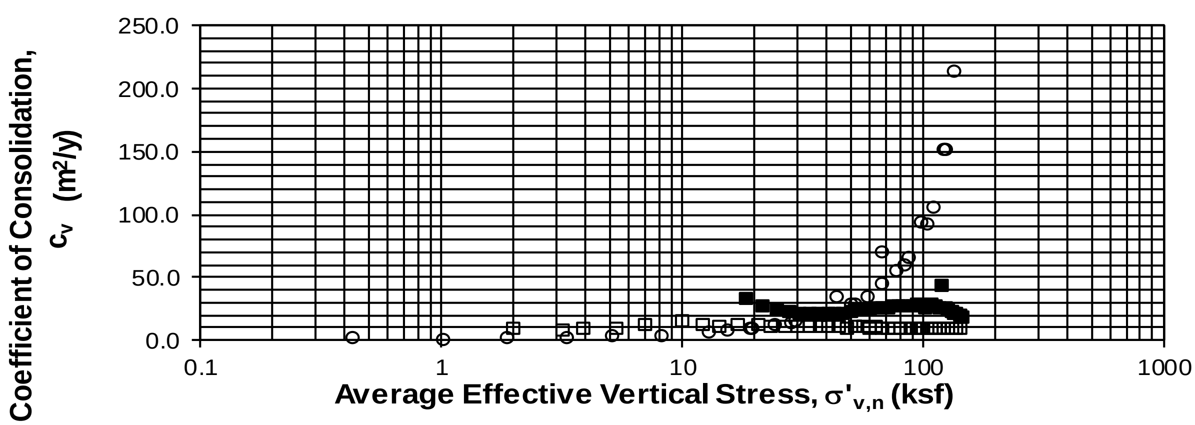
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

NIKISKI, ALASKA







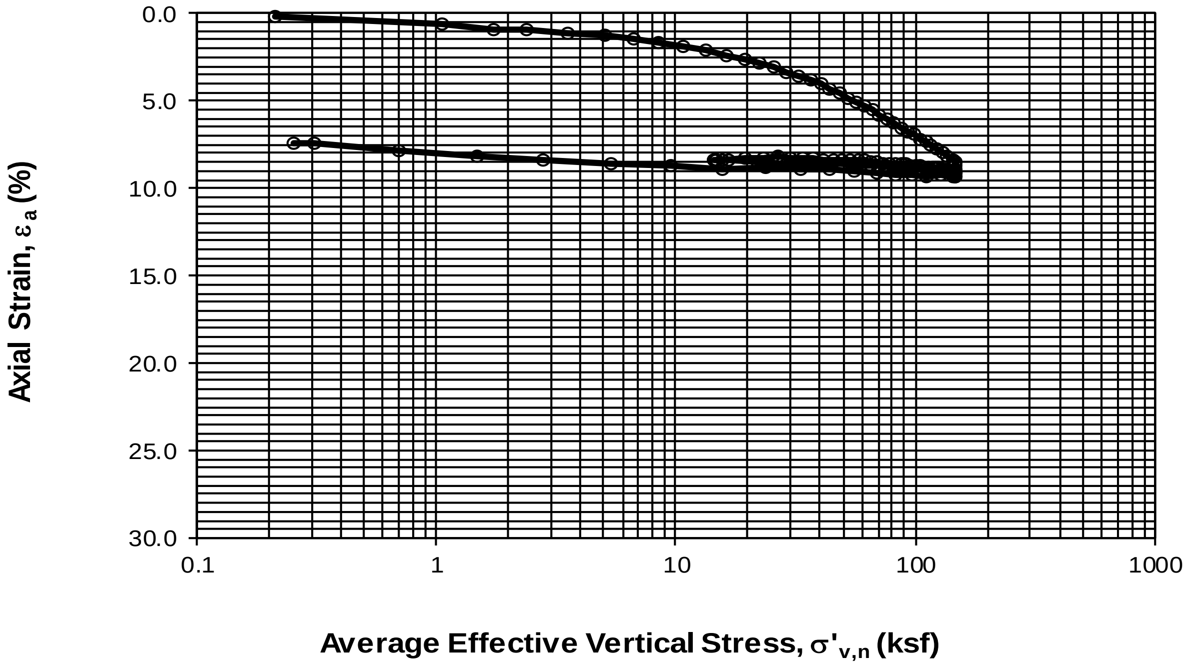
1-D CONSOLIDATION TESTS - CRS

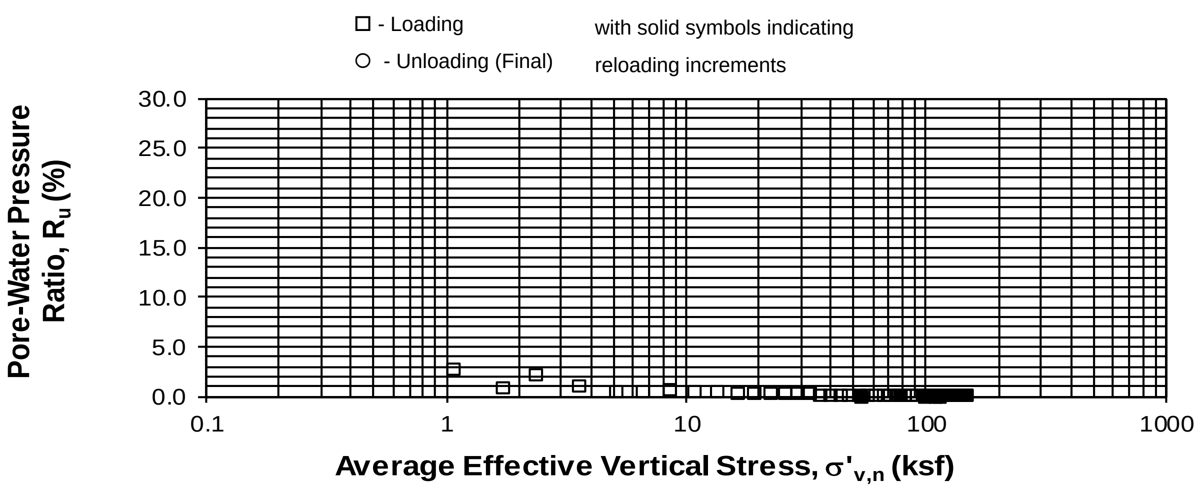
BORING B-168, SAMPLE S-30, DEPTH 131.0 FT

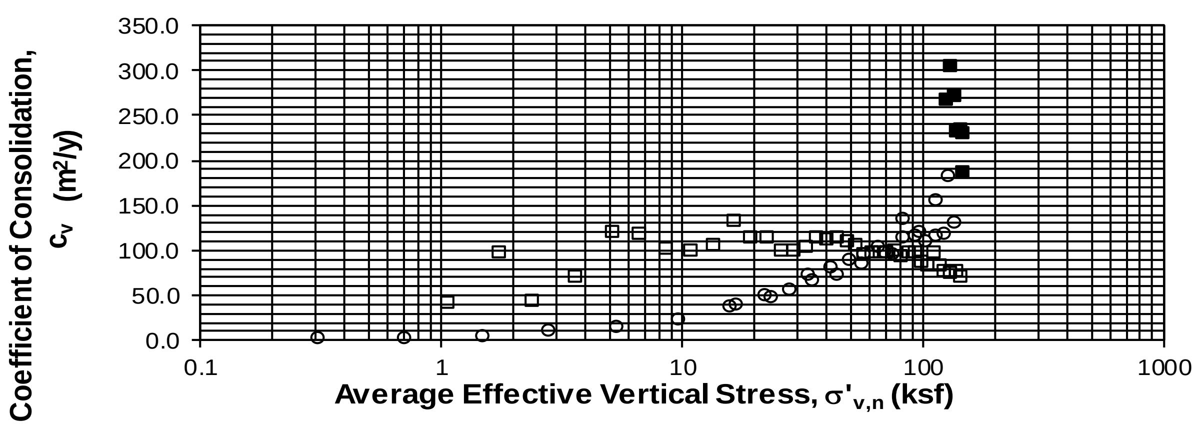
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

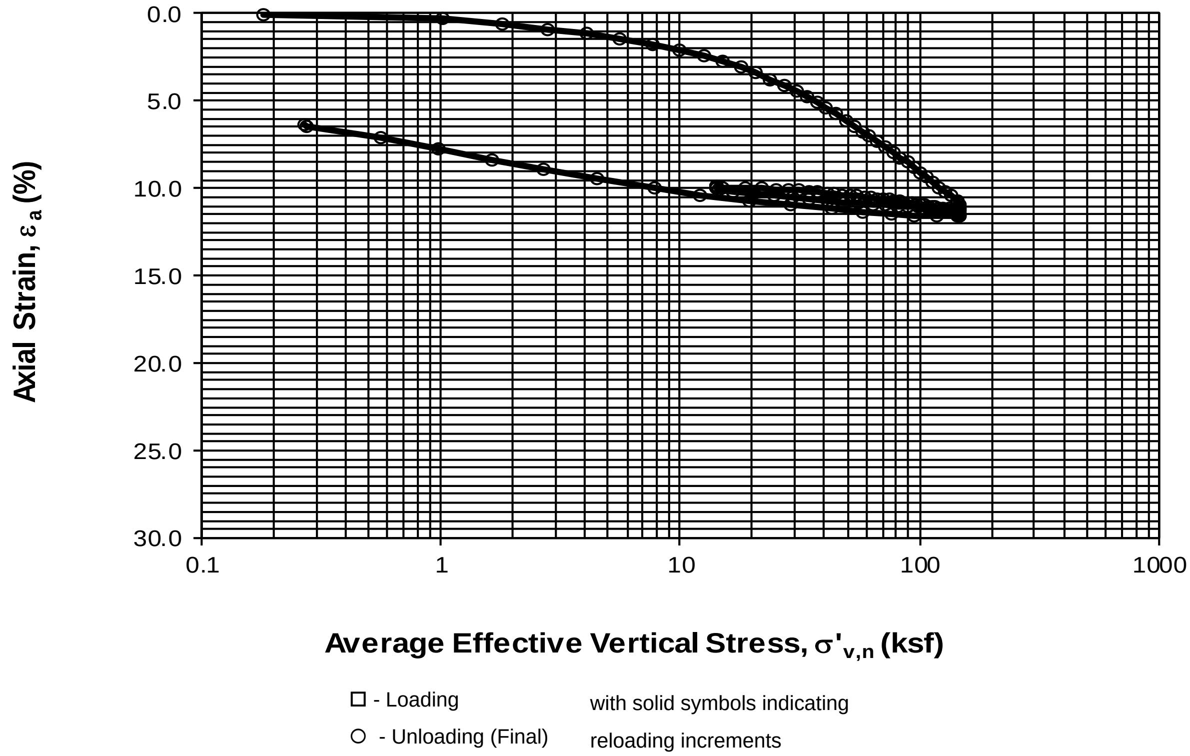
NIKISKI, ALASKA

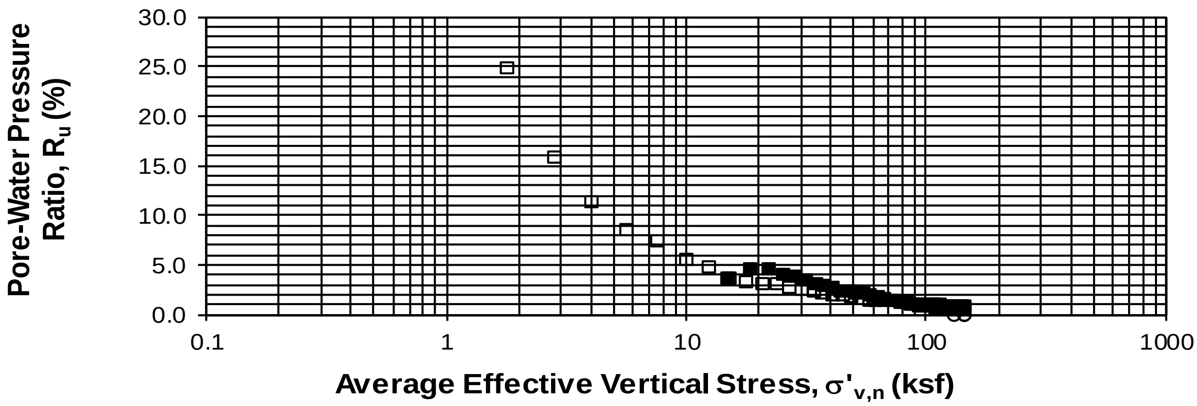


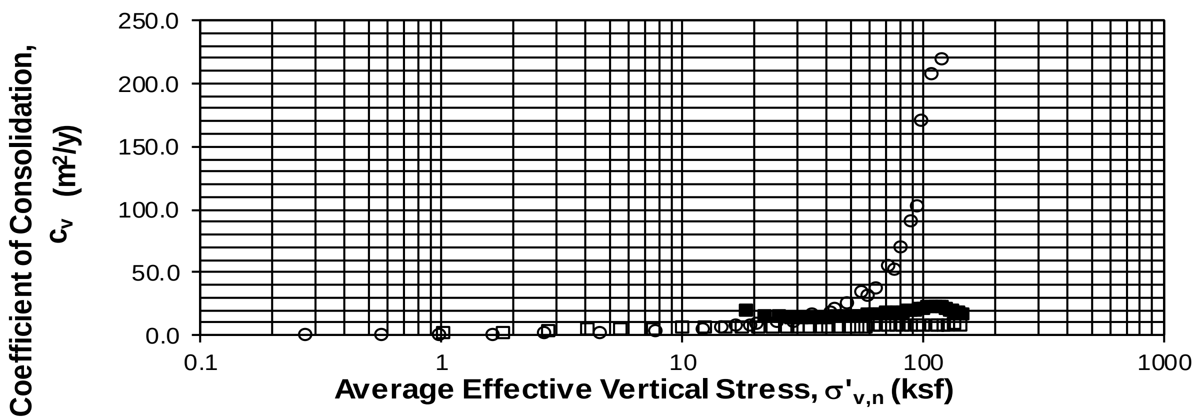




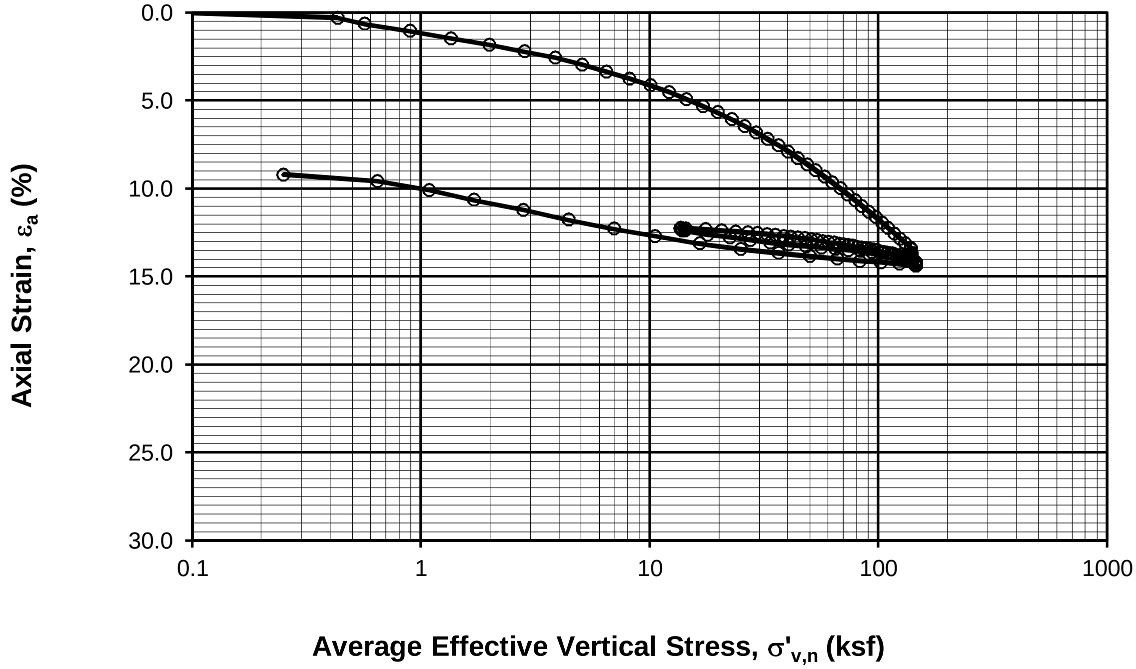
1-D CONSOLIDATION TESTS - CRS
BORING B-170, SAMPLE S-30, DEPTH 132.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

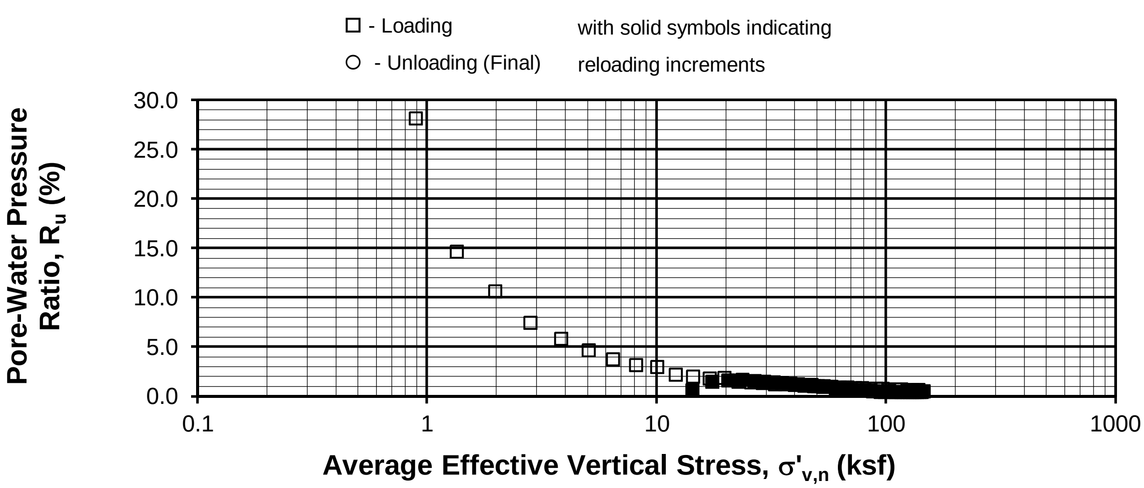


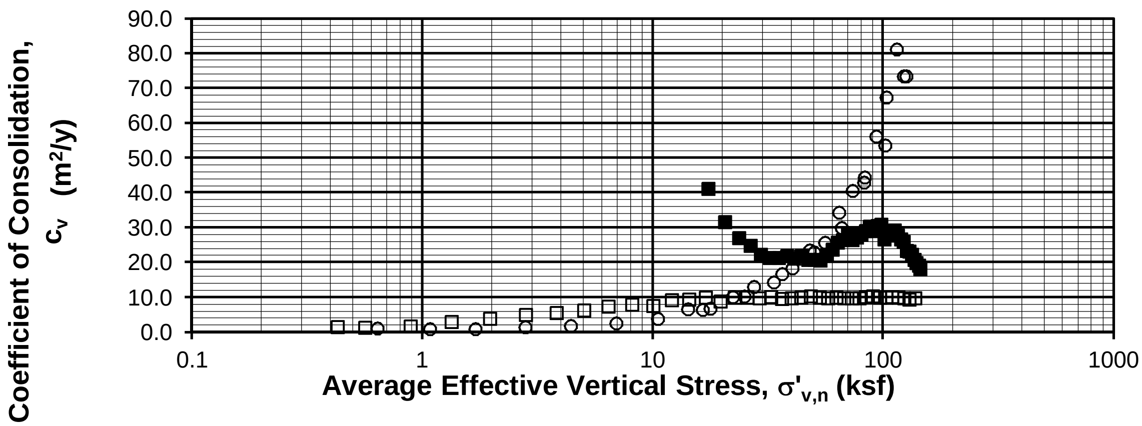




1-D CONSOLIDATION TESTS - CRS
BORING B-173, SAMPLE S-32, DEPTH 152.4 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

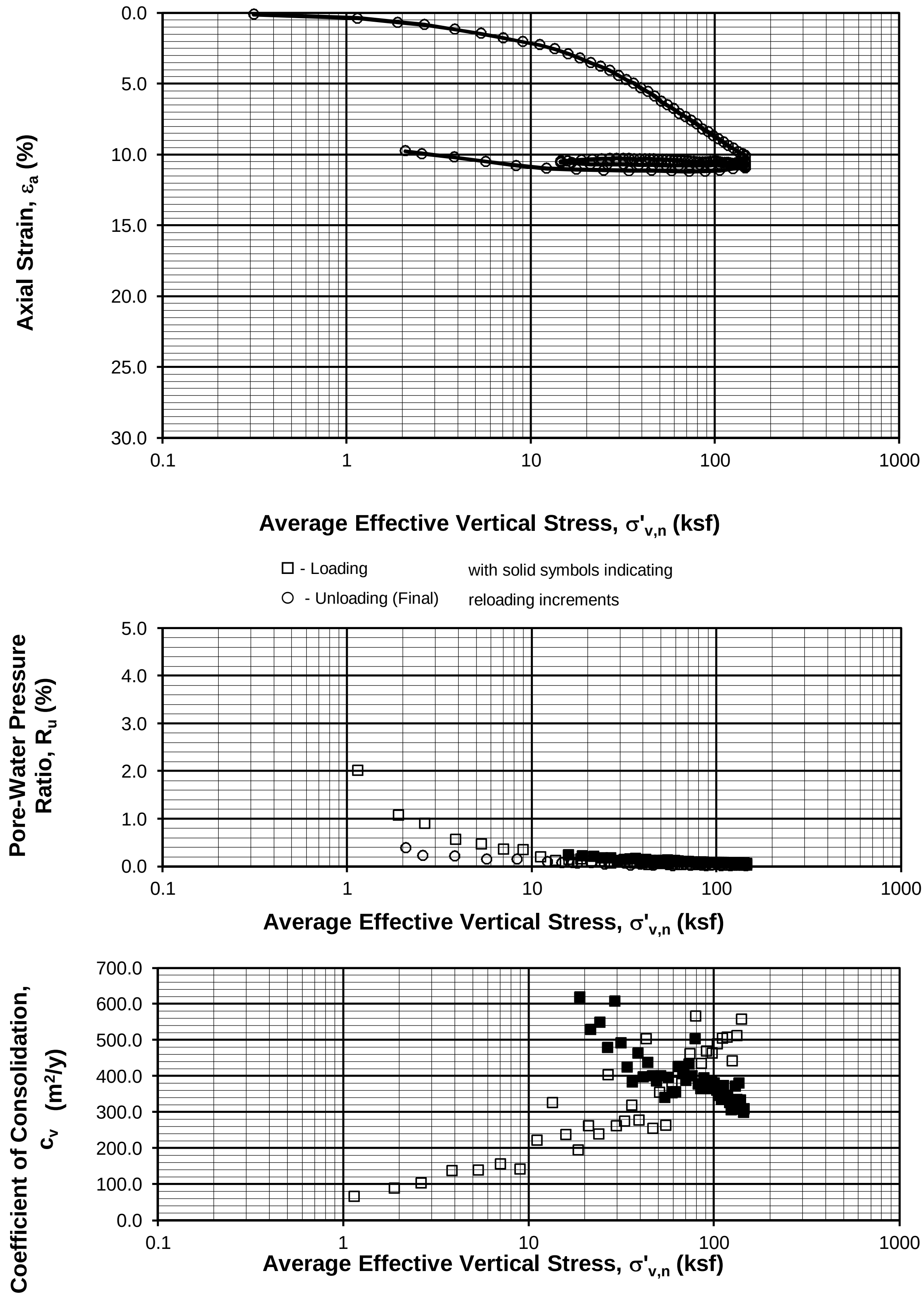




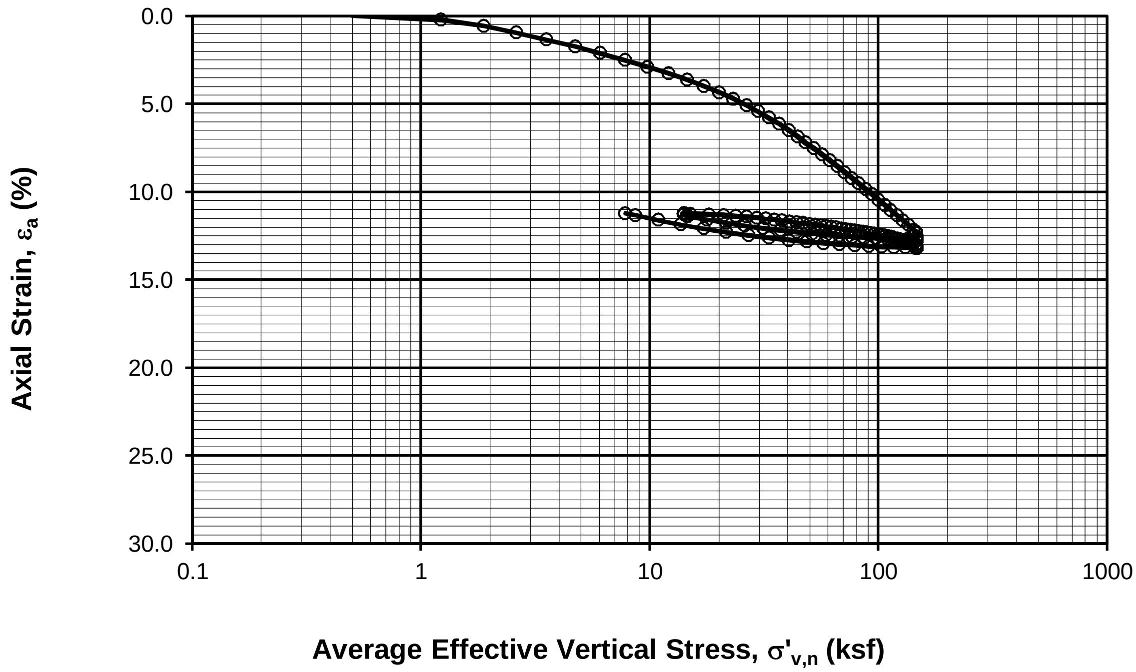


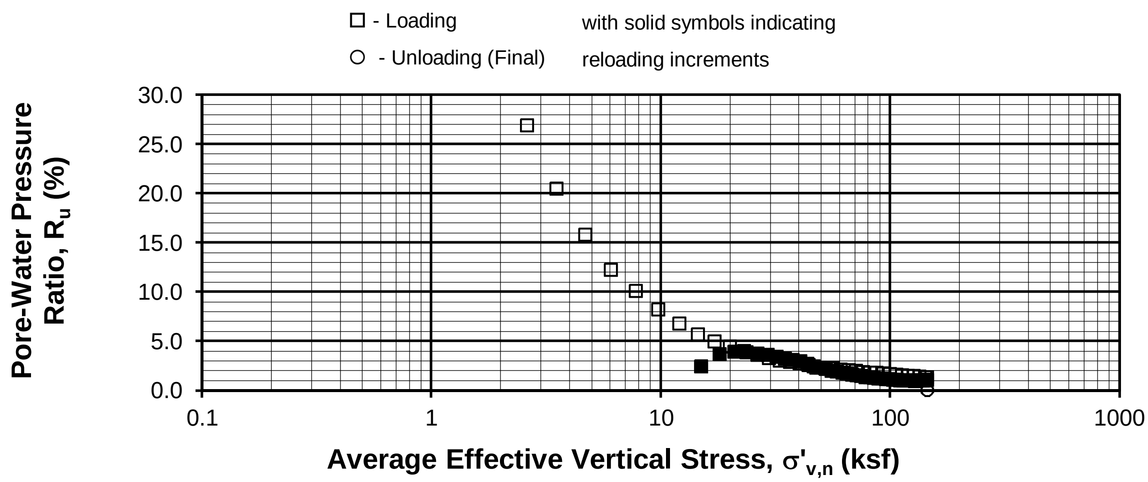
1-D CONSOLIDATION TESTS - CRS
BORING B-183, SAMPLE S-25, DEPTH 80.4 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

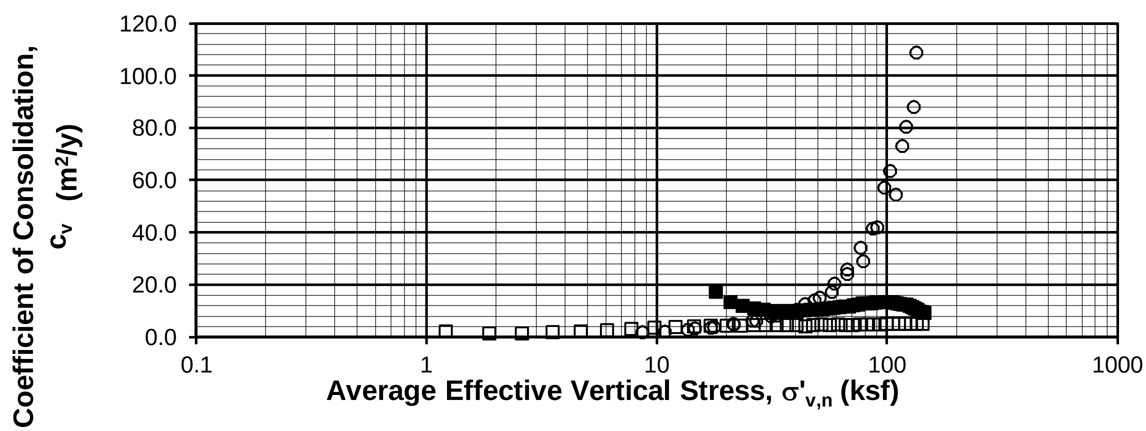
PLATE G7-22



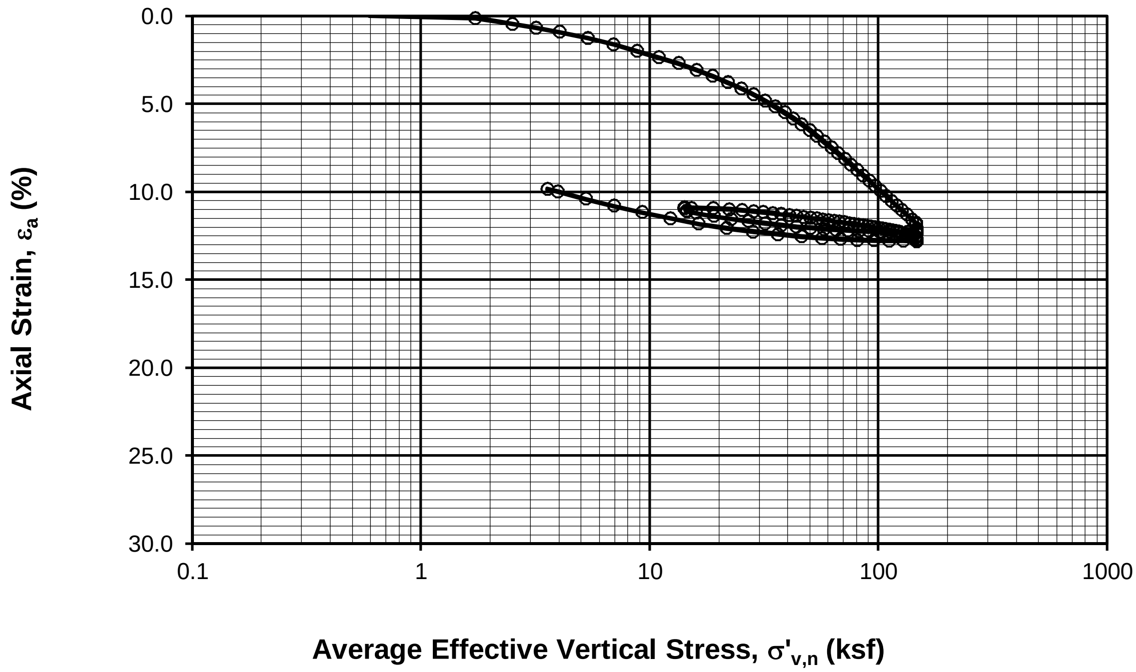
1-D CONSOLIDATION TESTS - CRS
BORING B-192, SAMPLE S-24, DEPTH 92.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

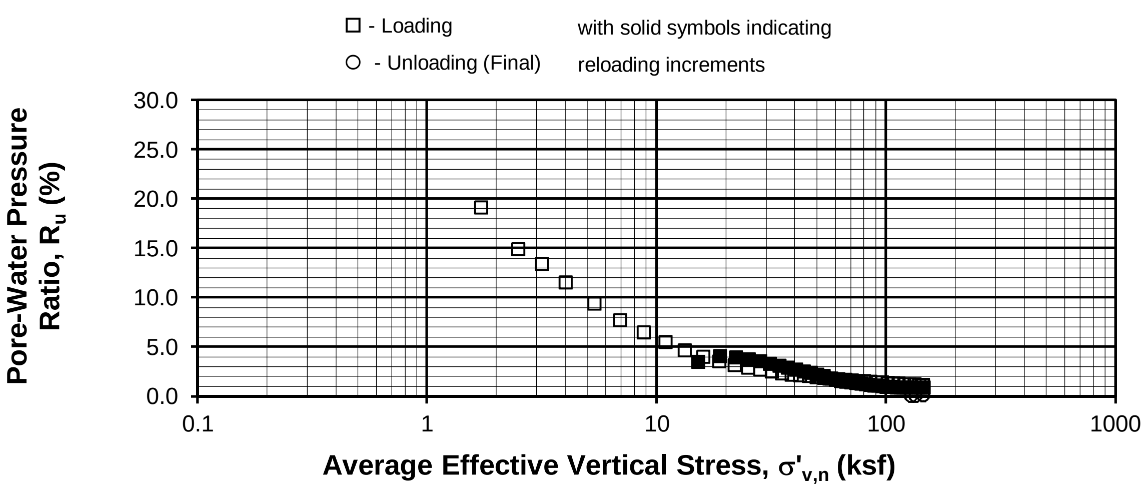


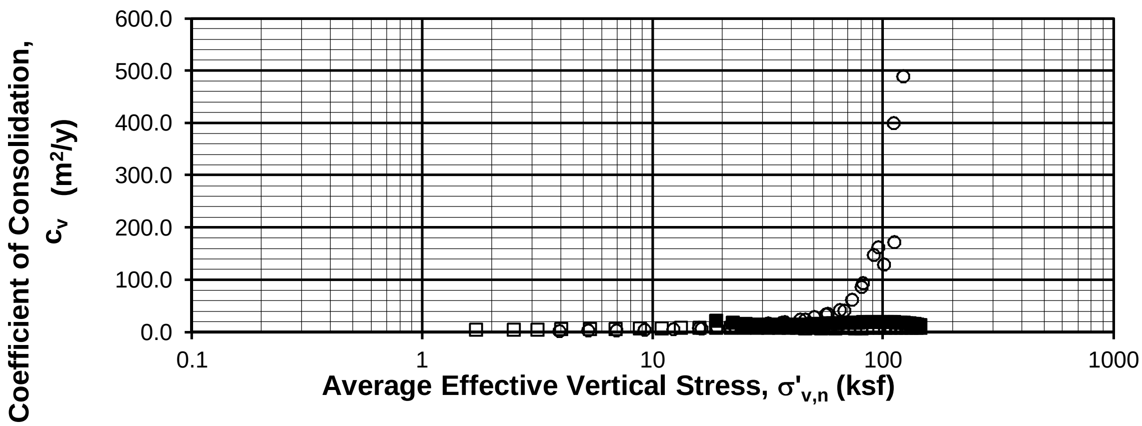




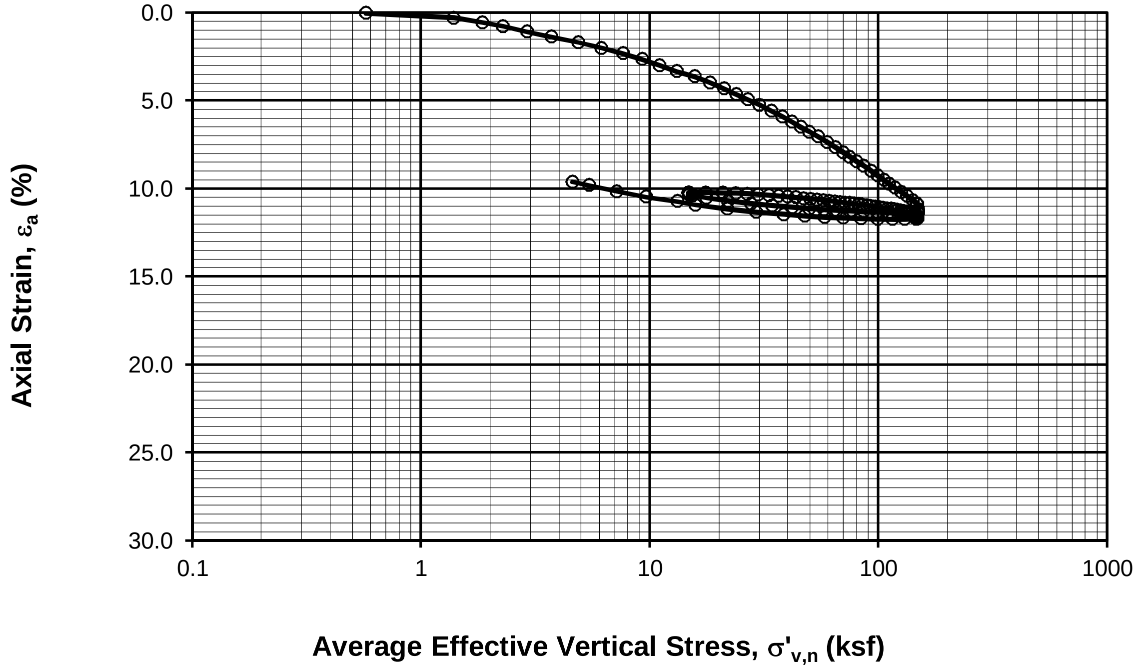
1-D CONSOLIDATION TESTS - CRS
BORING B-195, SAMPLE S-34, DEPTH 152.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

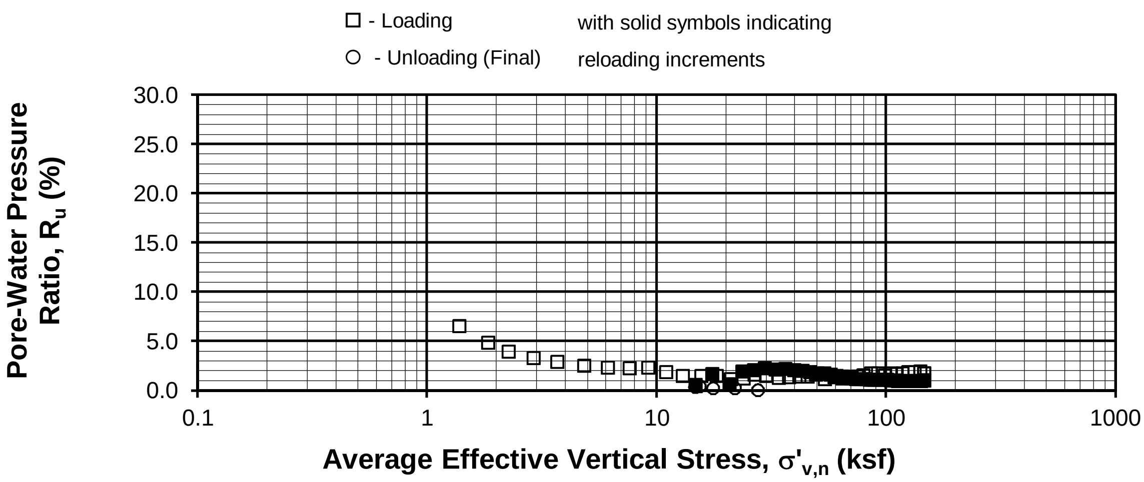


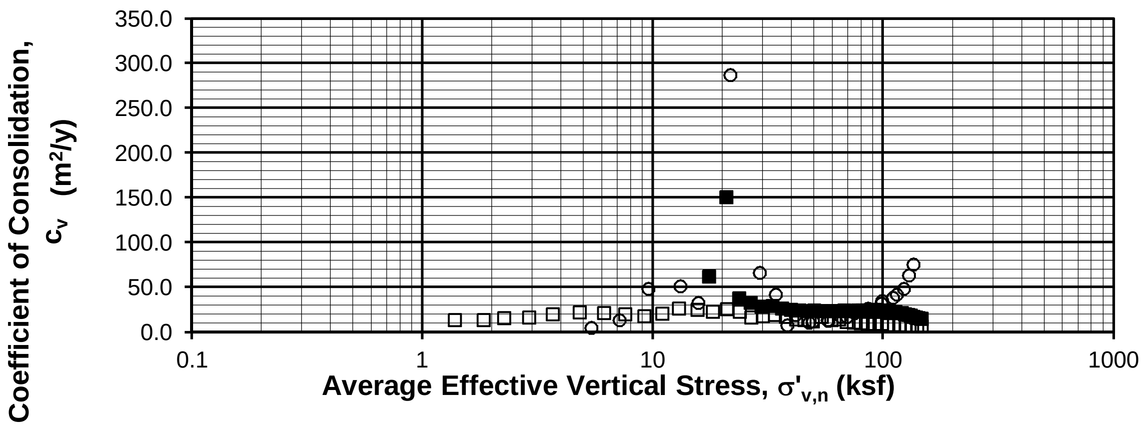




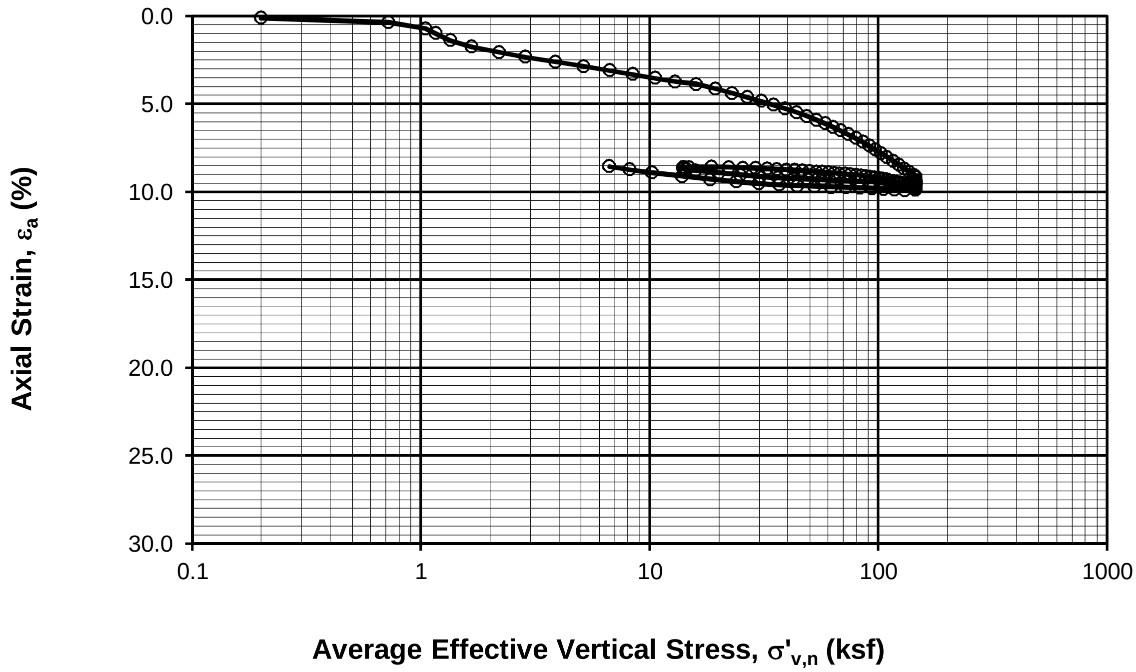
1-D CONSOLIDATION TESTS - CRS
BORING B-195, SAMPLE S-44, DEPTH 200.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



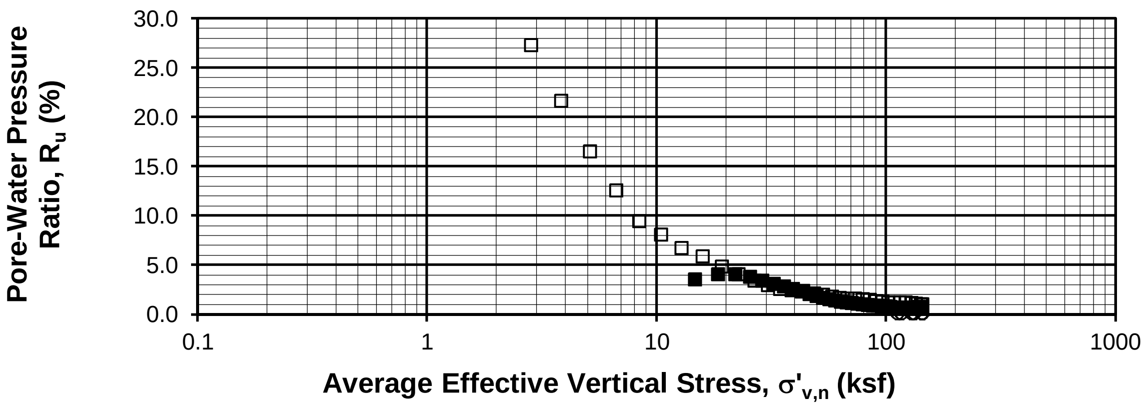


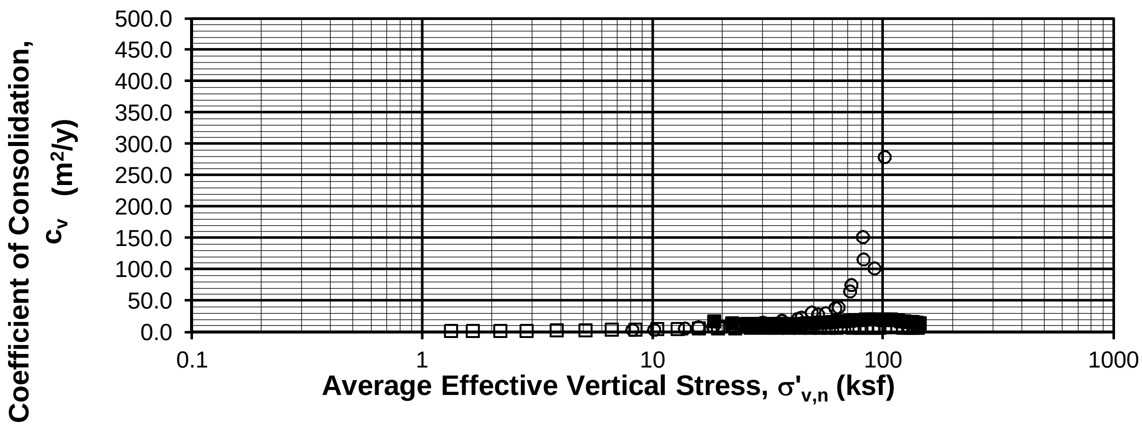


1-D CONSOLIDATION TESTS - CRS
BORING B-197, SAMPLE S-40, DEPTH 185.2 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

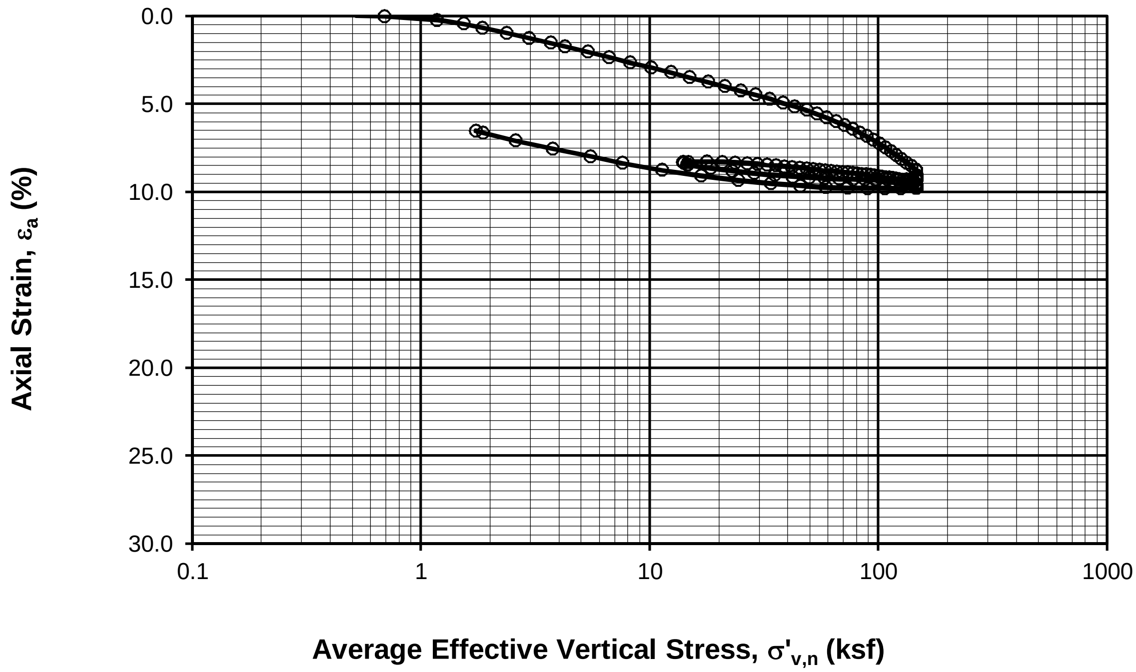


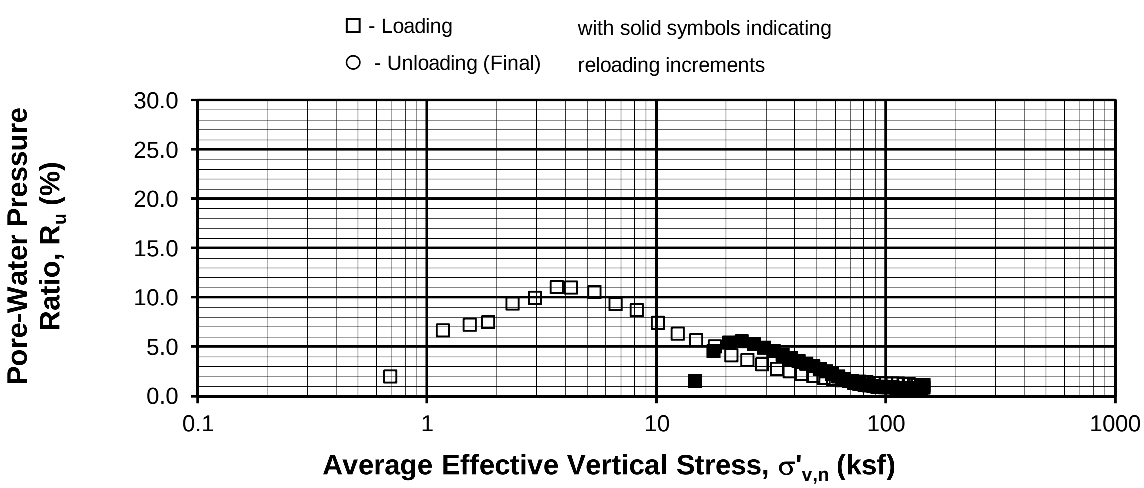
□ - Loading
○ - Unloading (Final)
with solid symbols indicating reloading increments

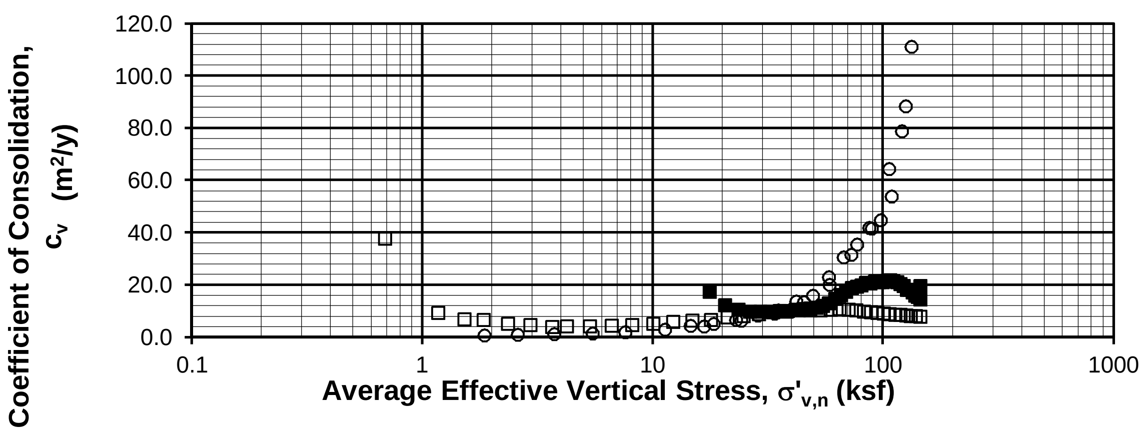




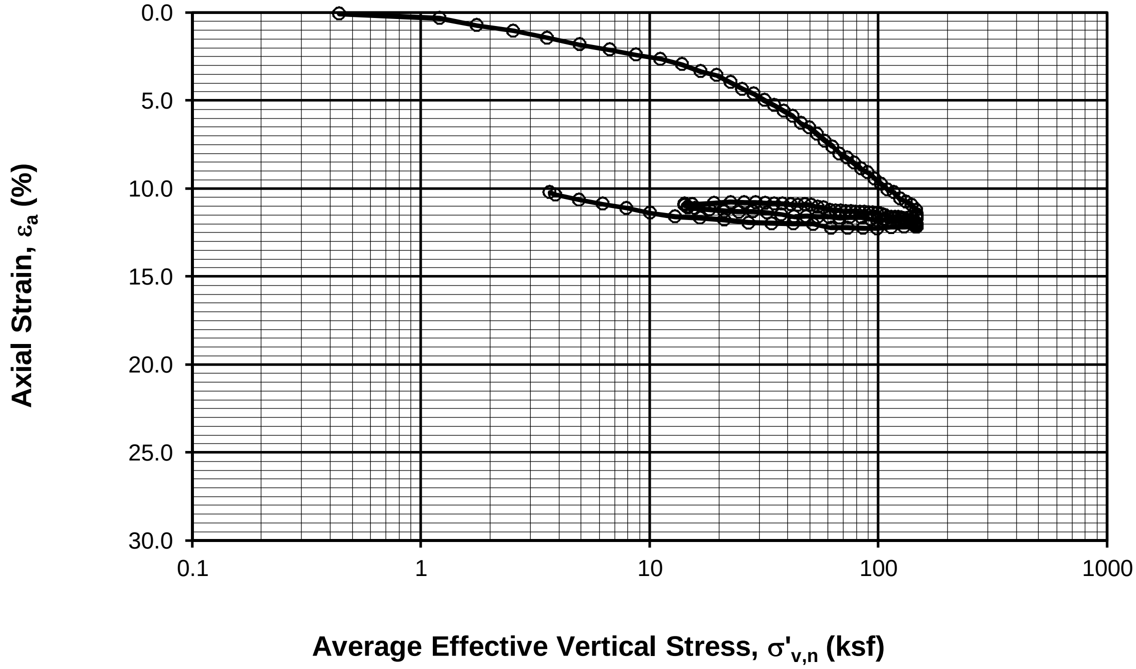
1-D CONSOLIDATION TESTS - CRS
BORING B-197, SAMPLE S-45, DEPTH 210.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

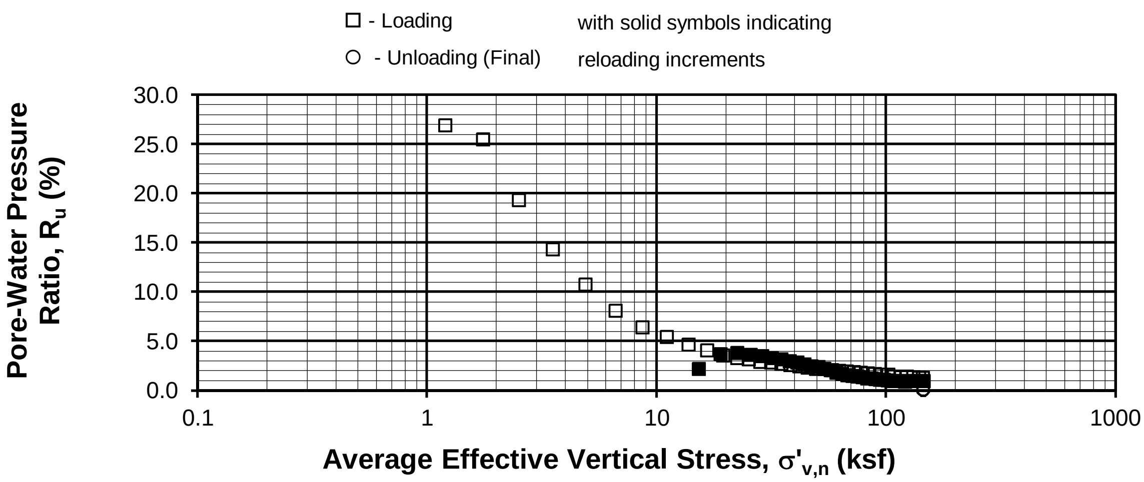


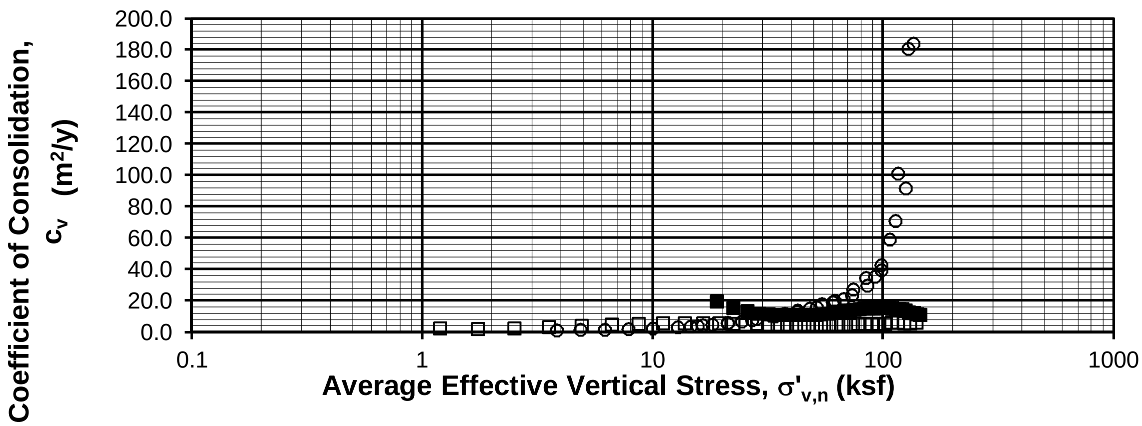




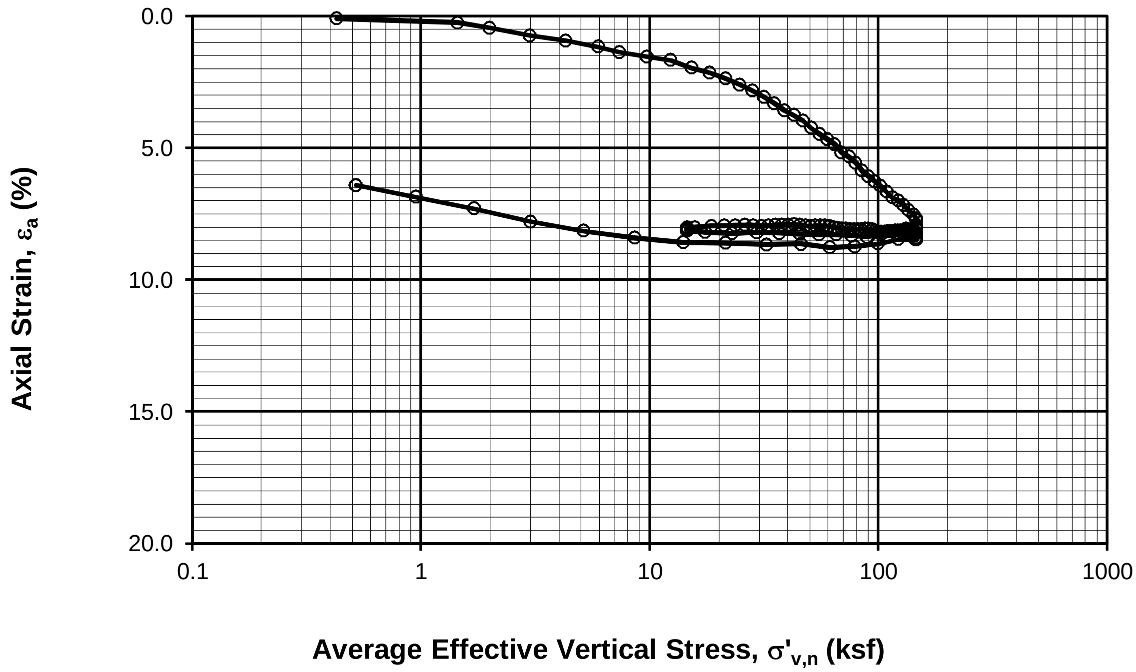
1-D CONSOLIDATION TESTS - CRS
BORING B-197, SAMPLE S-49, DEPTH 230.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

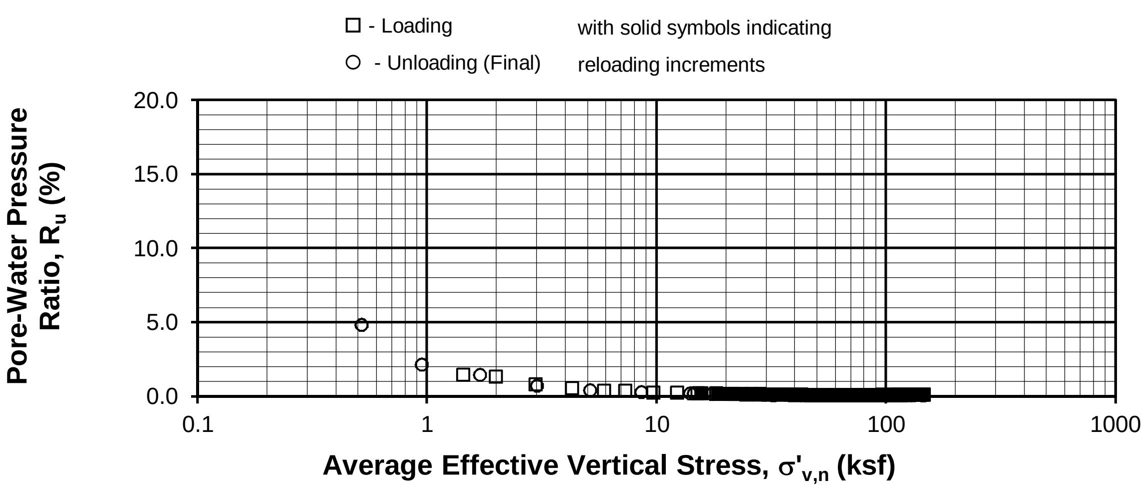


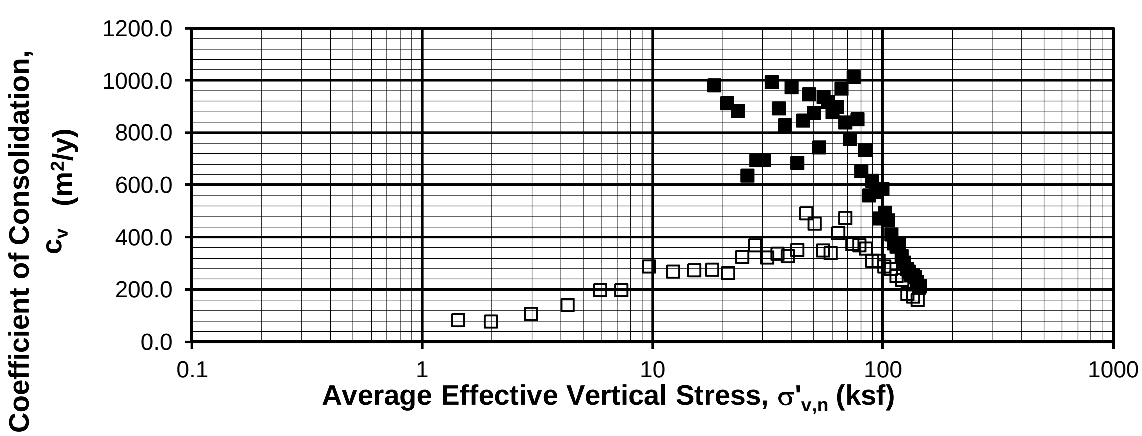




1-D CONSOLIDATION TESTS - CRS
BORING B-198, SAMPLE S-32, DEPTH 152.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA







1-D CONSOLIDATION TESTS - CRS

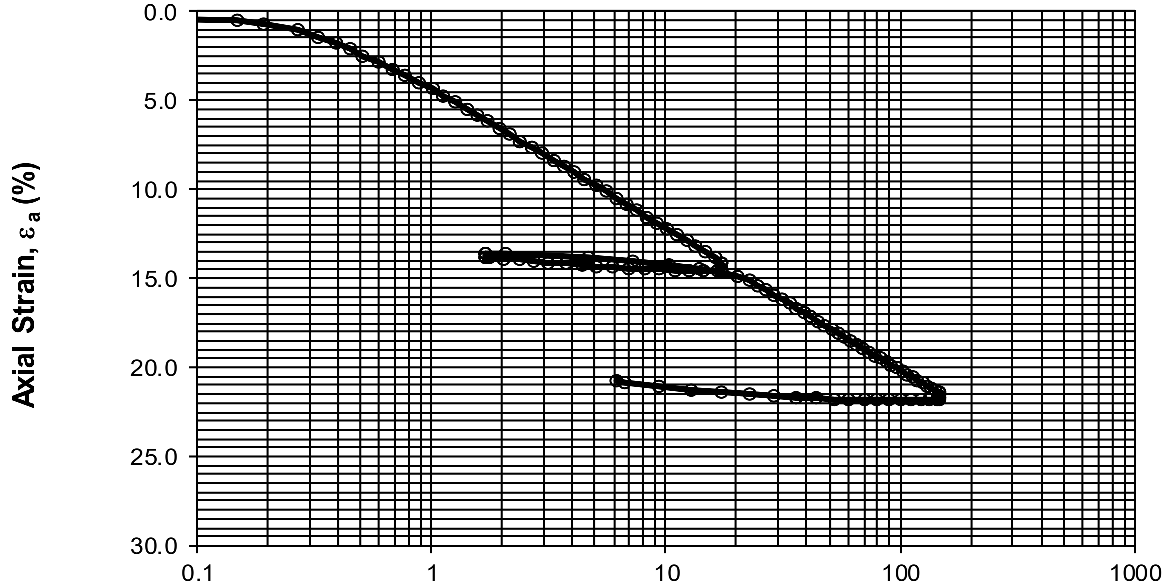
BORING B-198, SAMPLE S-41, DEPTH 205.5 FT

ONSHORE LNG FACILITIES

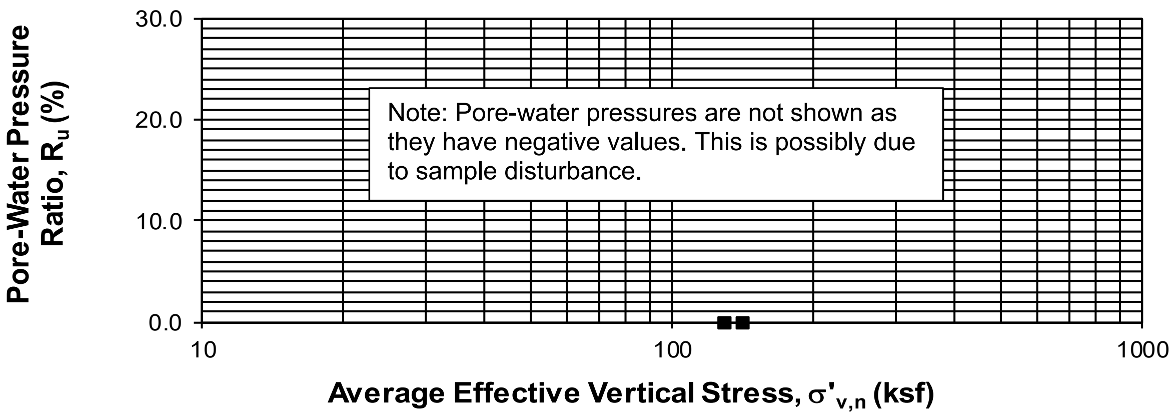
ALASKA LNG PROJECT

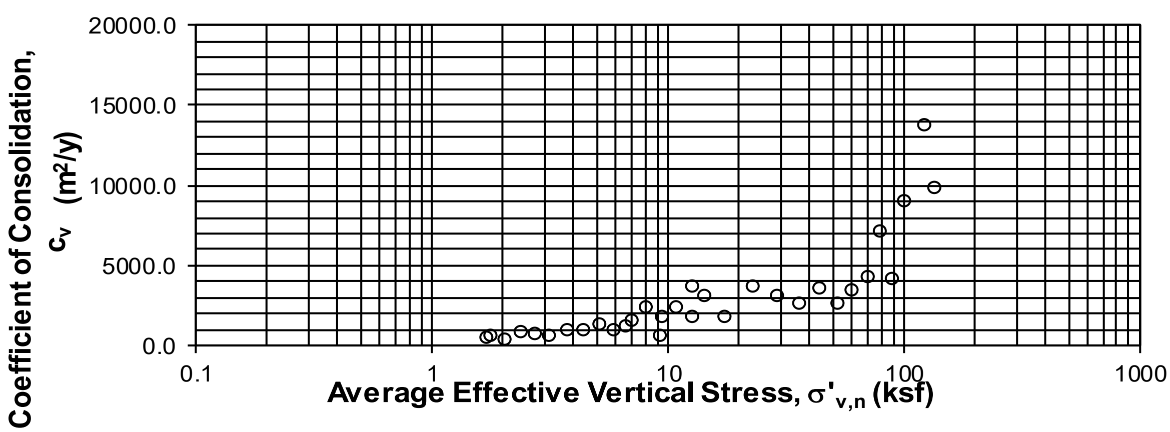
NIKISKI, ALASKA

PLATE G7-30

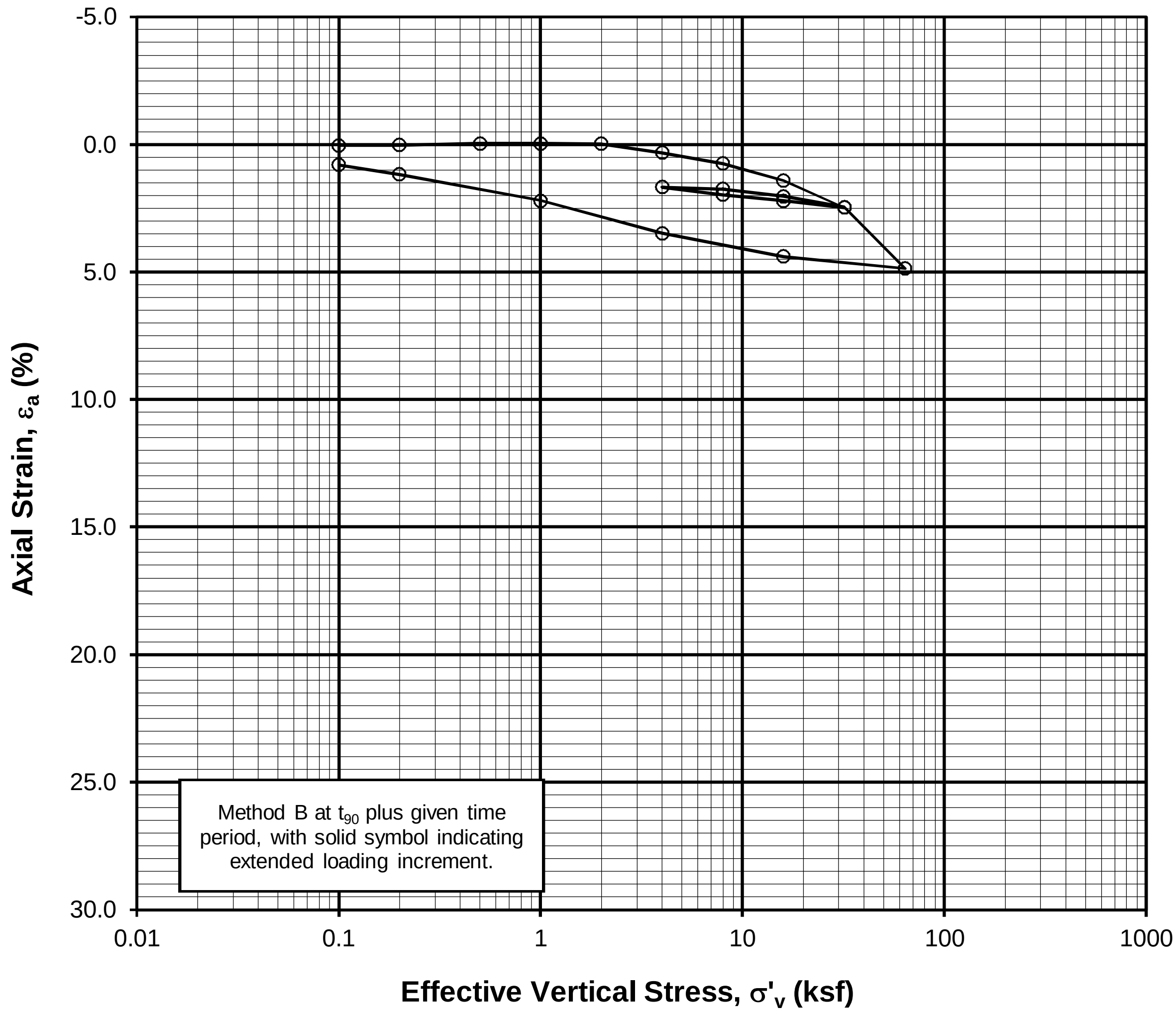


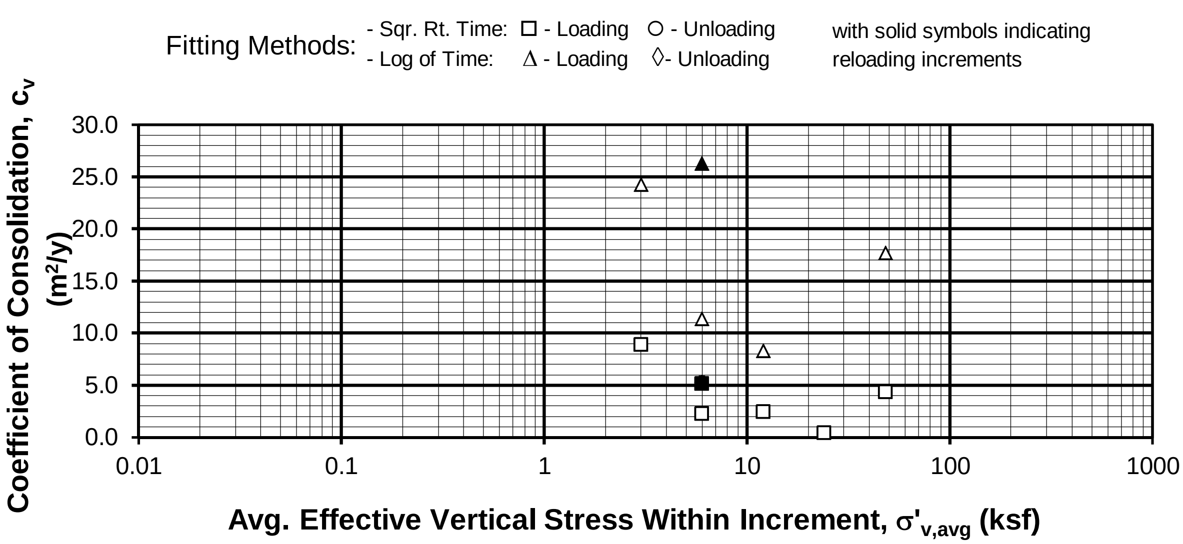
□ - Loading
○ - Unloading (Final)
with solid symbols indicating reloading increments





1-D CONSOLIDATION TESTS - CRS
BORING B-198, SAMPLE S-44, DEPTH 219.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA





1-D CONSOLIDATION TESTS - INC

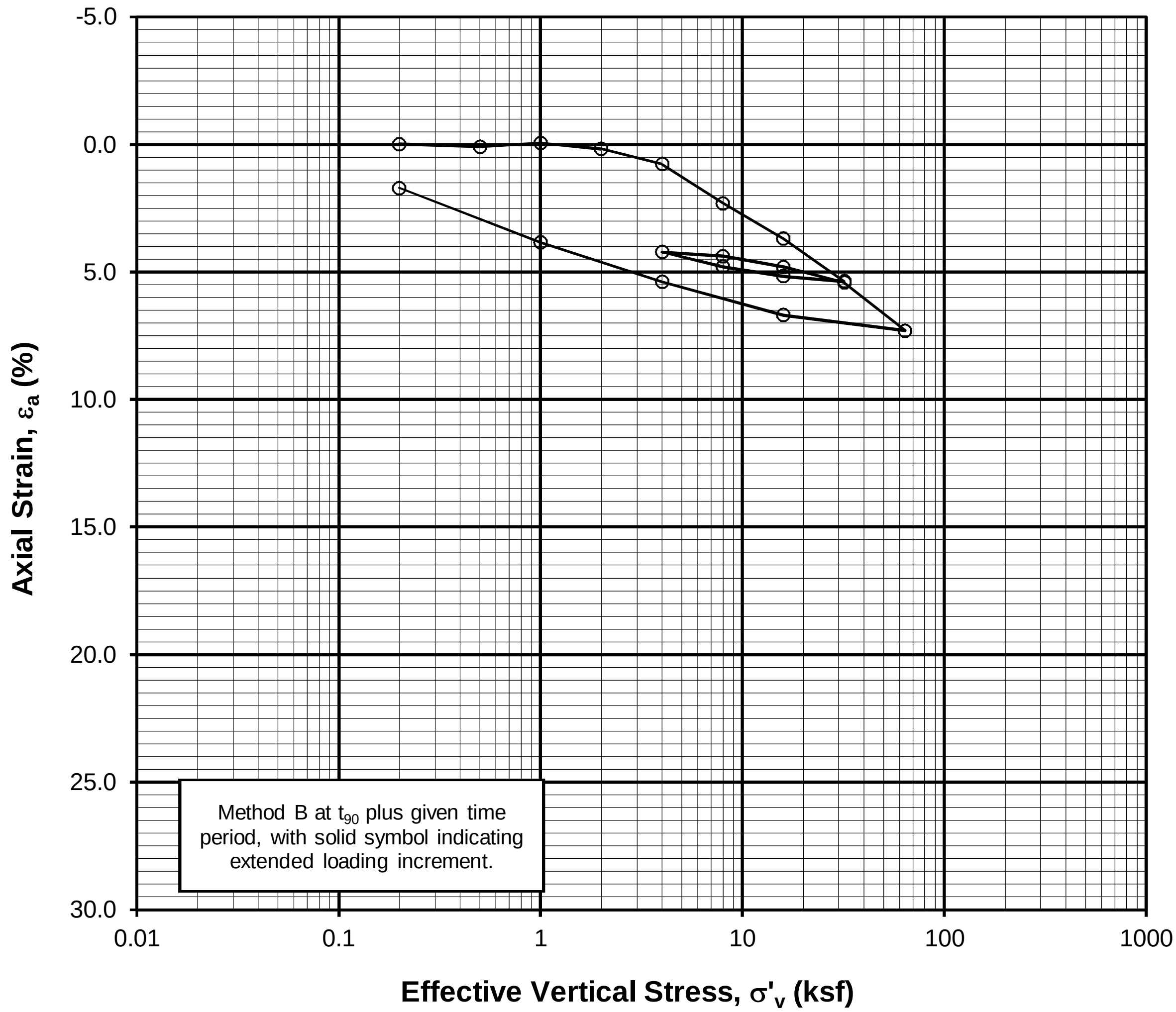
BORING B-146, SAMPLE S-36, DEPTH 179.9 FT

ONSHORE LNG FACILITIES

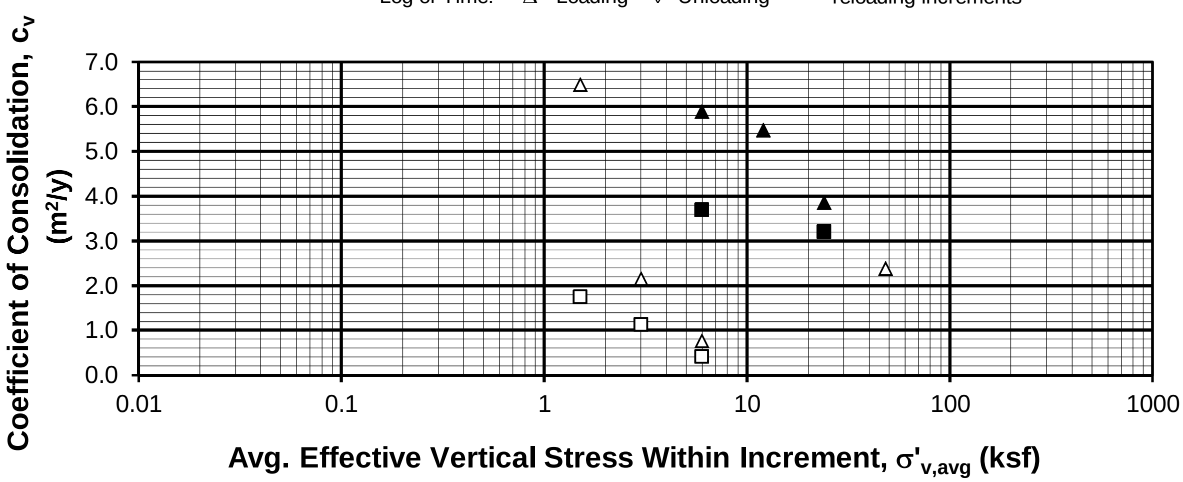
ALASKA LNG PROJECT

NIKISKI, ALASKA

PLATE G7-32



Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloading; - Log of Time: Δ - Loading ◊- Unloading; with solid symbols indicating reloading increments



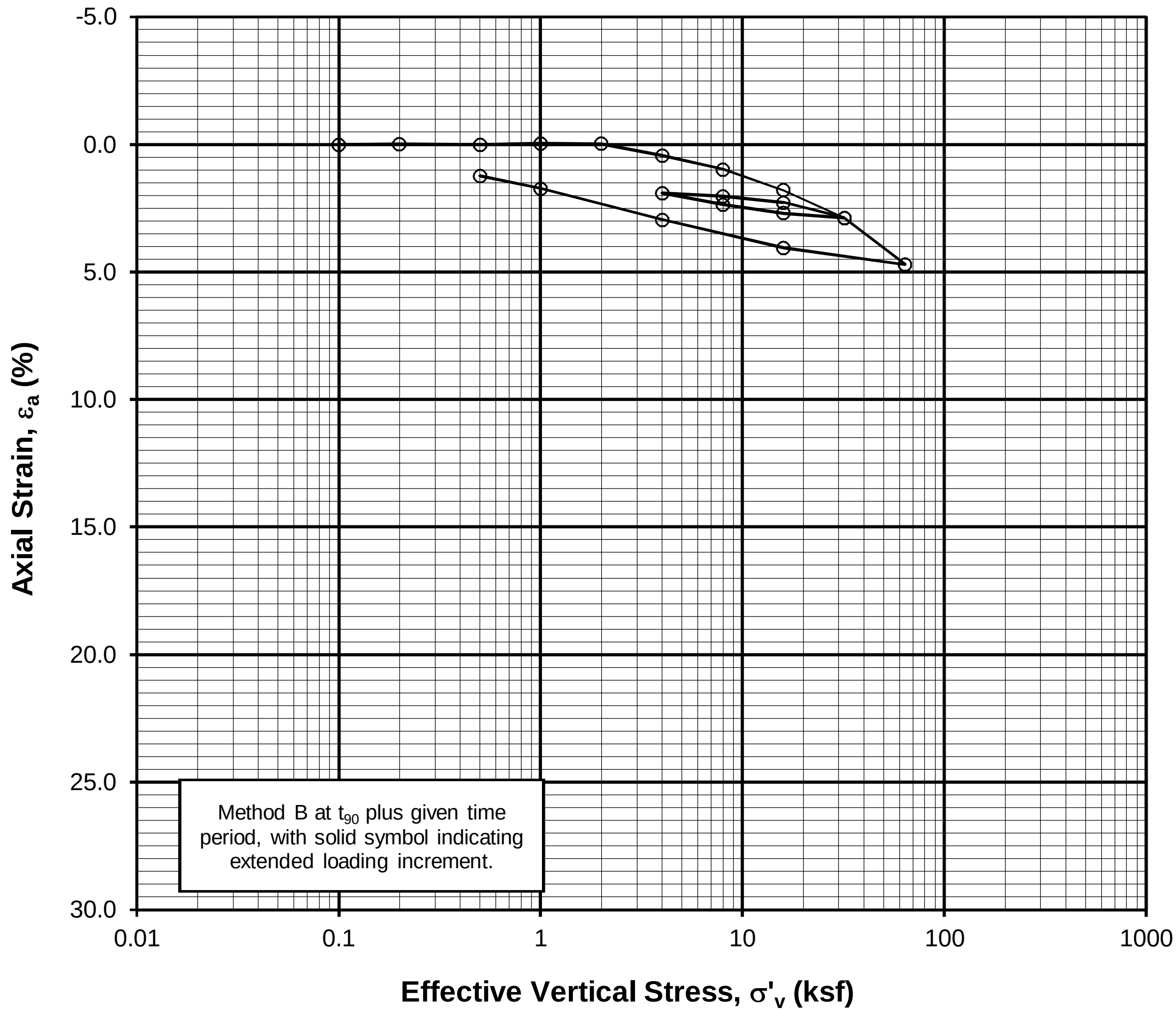
1-D CONSOLIDATION TESTS - INC

BORING B-146, SAMPLE S-40, DEPTH 203.1 FT

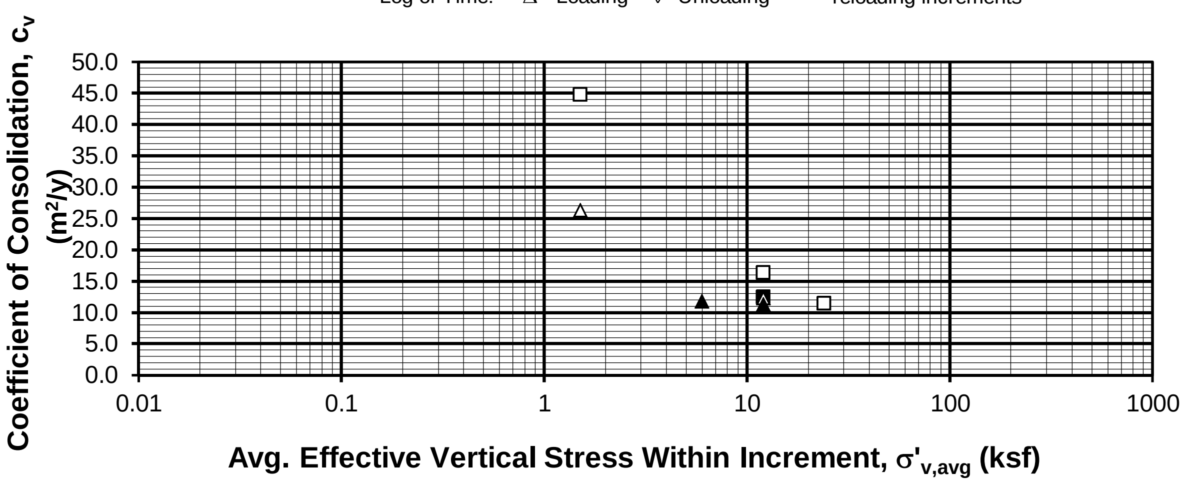
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

NIKISKI, ALASKA



Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloading with solid symbols indicating reloading increments
- Log of Time: Δ - Loading ◊- Unloading



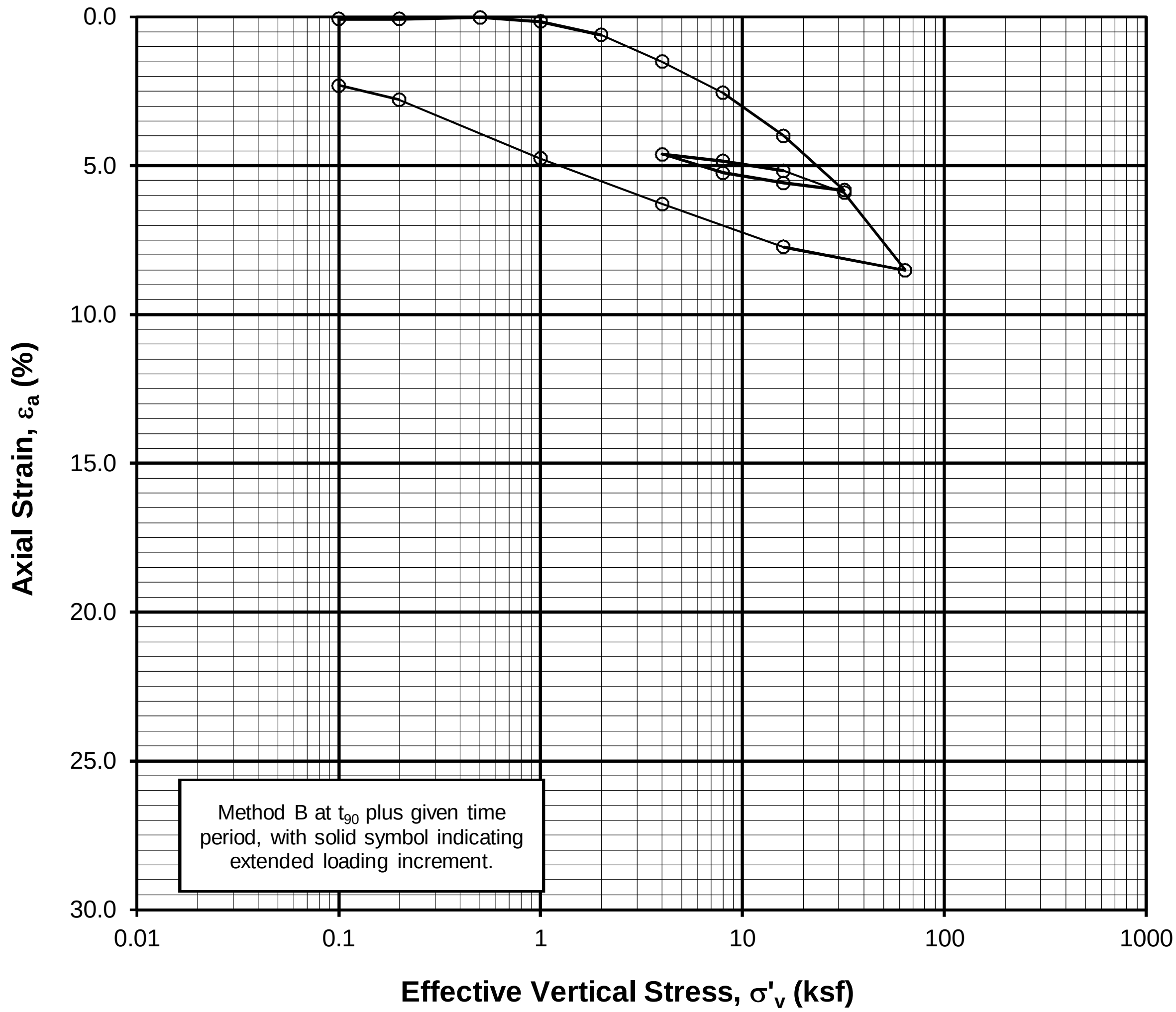
1-D CONSOLIDATION TESTS - INC

BORING B-148, SAMPLE S-40, DEPTH 193.6 FT

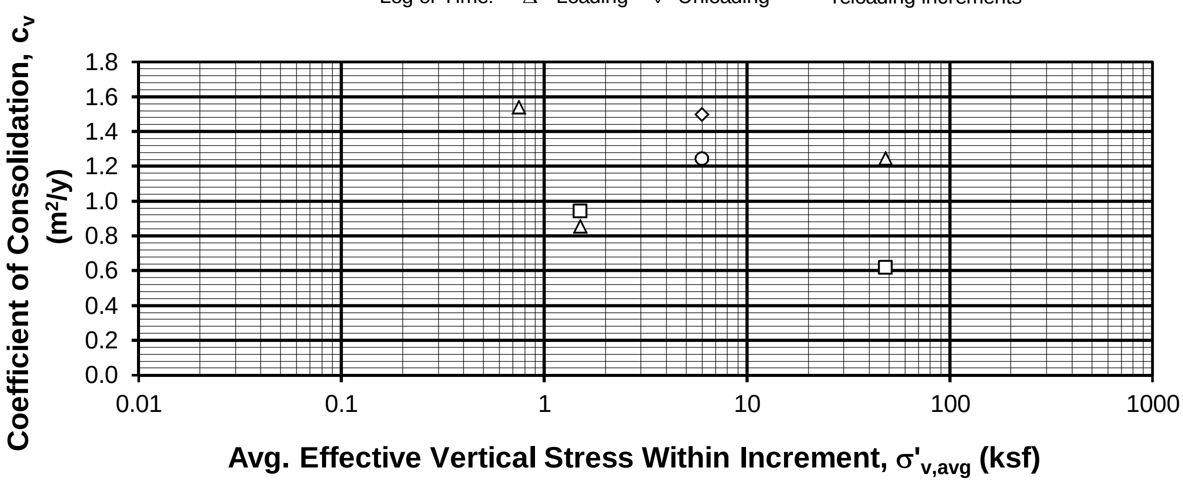
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

NIKISKI, ALASKA



Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloading with solid symbols indicating reloading increments
- Log of Time: Δ - Loading ◊- Unloading



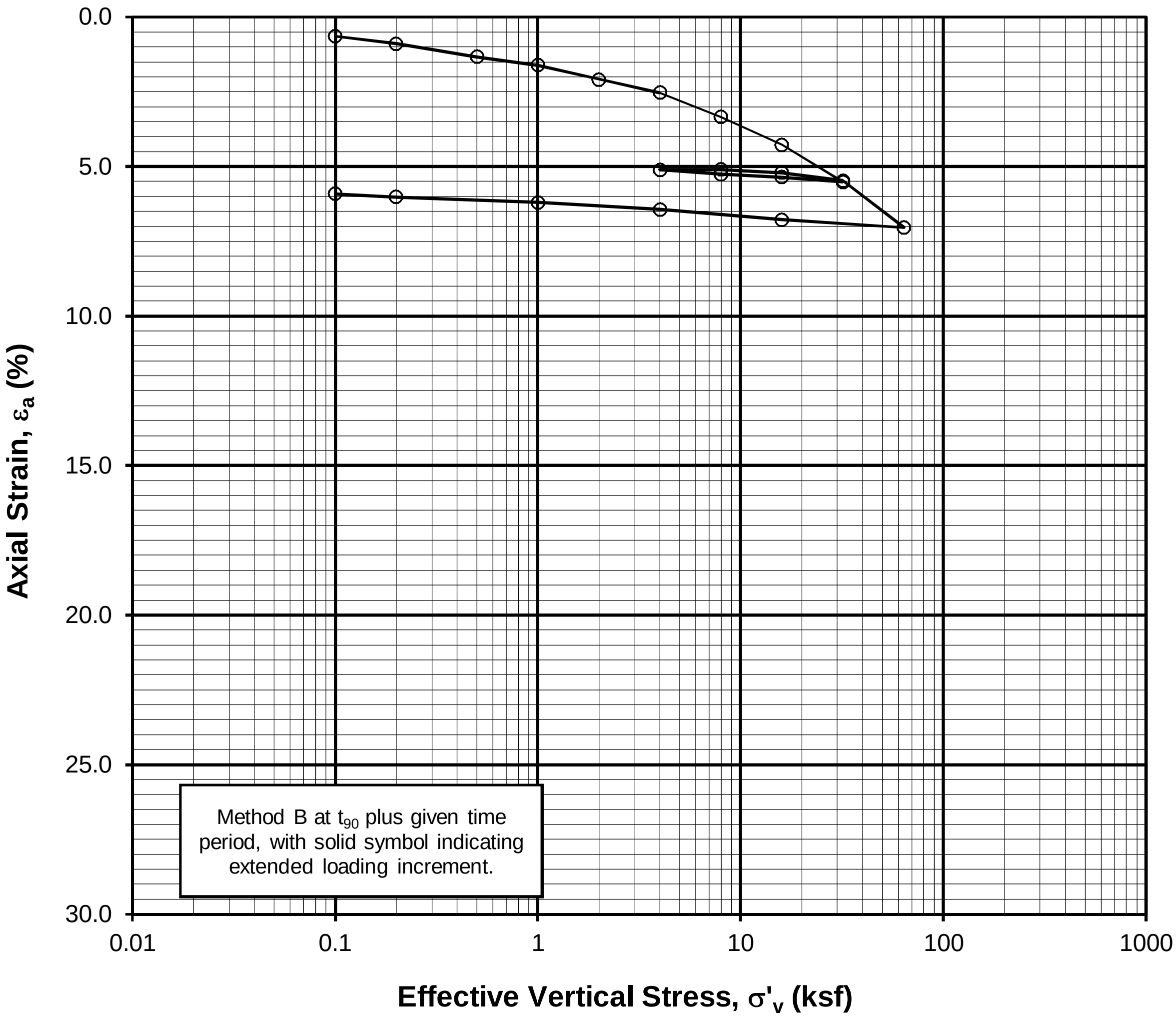
1-D CONSOLIDATION TESTS - INC

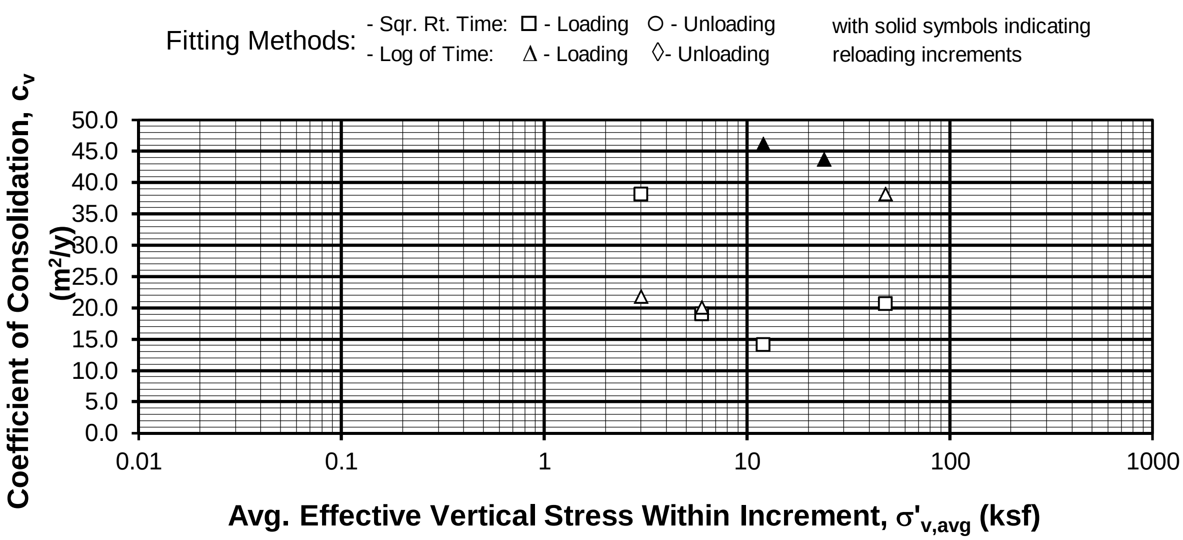
BORING B-149, SAMPLE S-41, DEPTH 206.0 FT

ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

NIKISKI, ALASKA





1-D CONSOLIDATION TESTS - INC

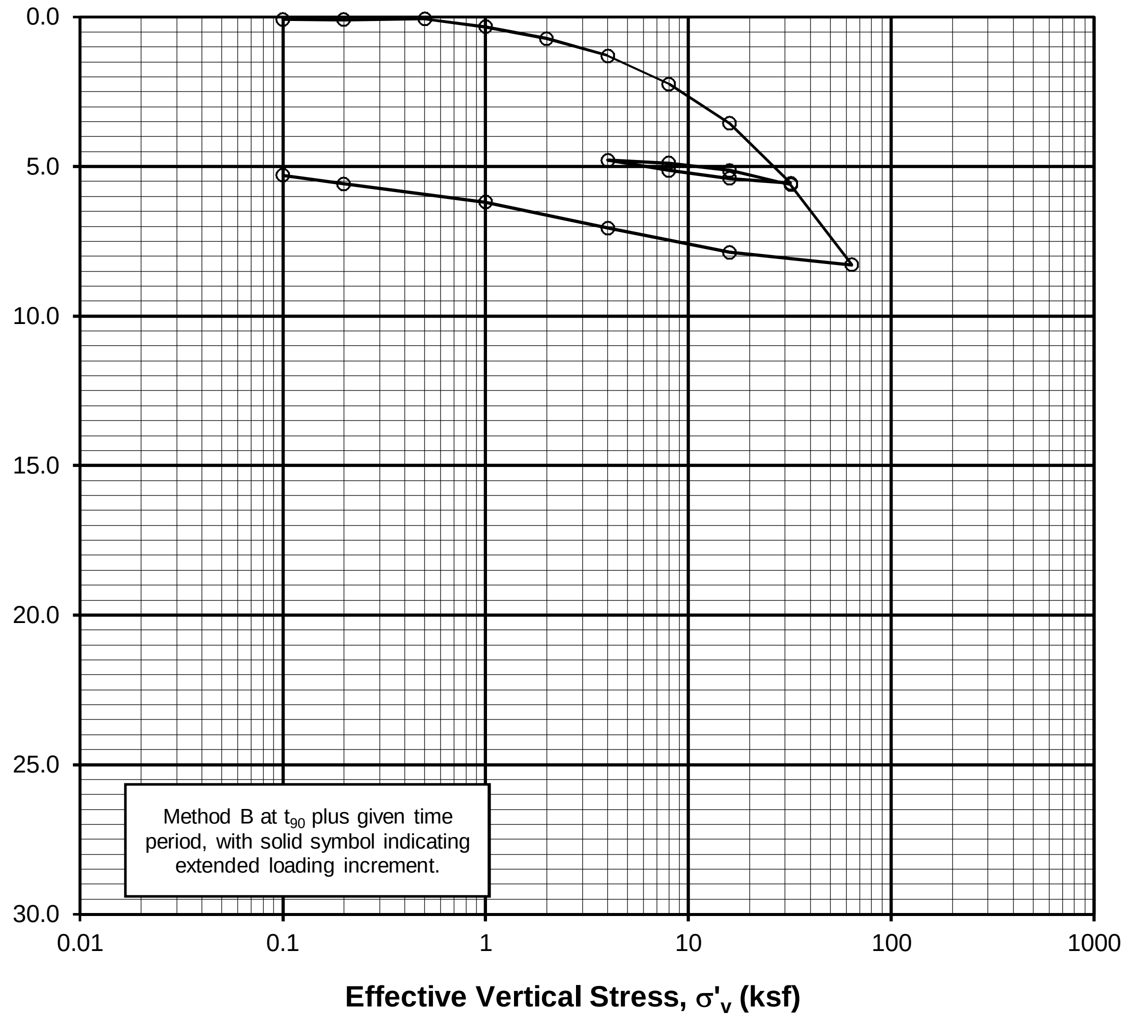
BORING B-151, SAMPLE S-36, DEPTH 159.2 FT

ONSHORE LNG FACILITIES

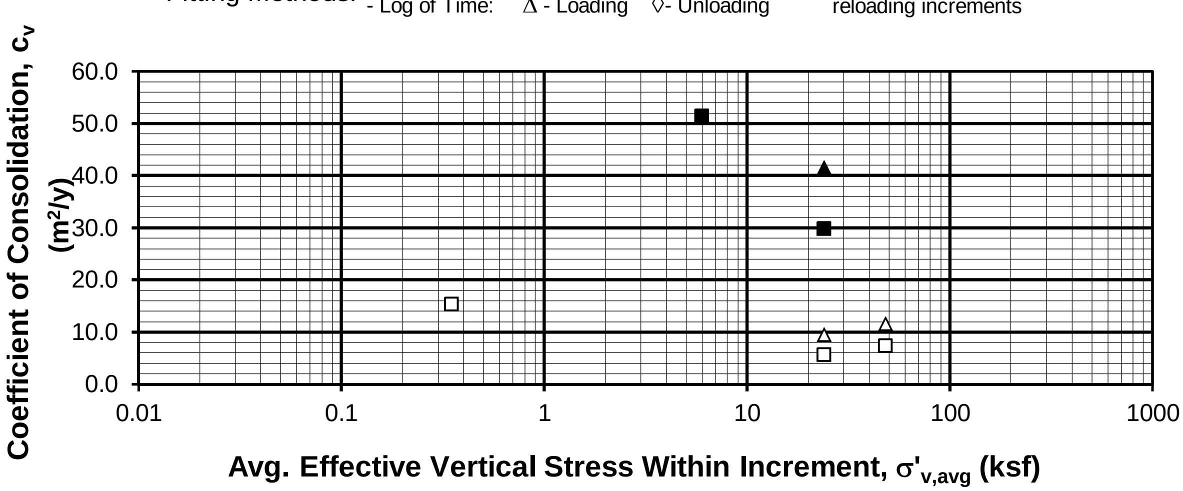
ALASKA LNG PROJECT

NIKISKI, ALASKA

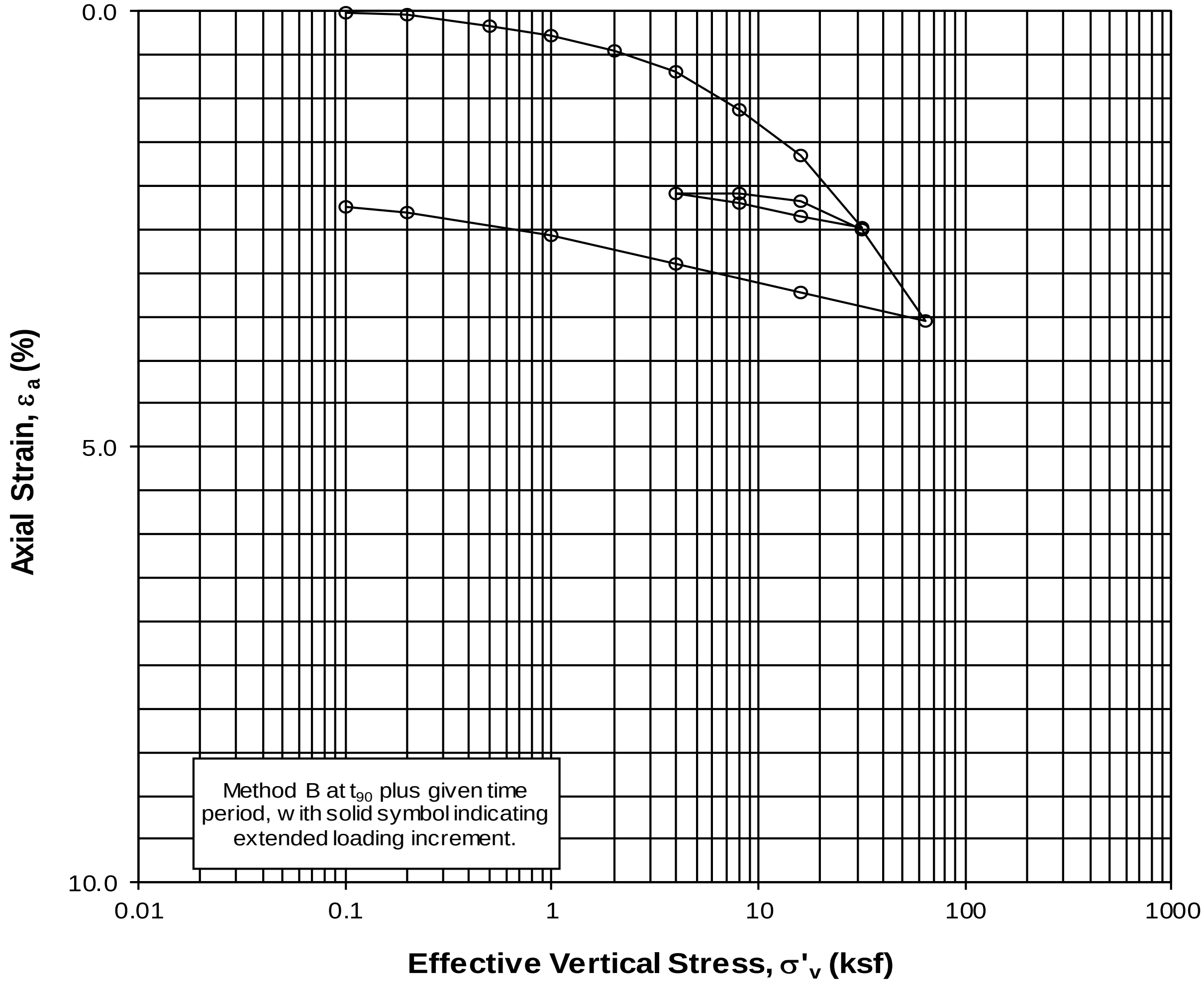
PLATE G7-36



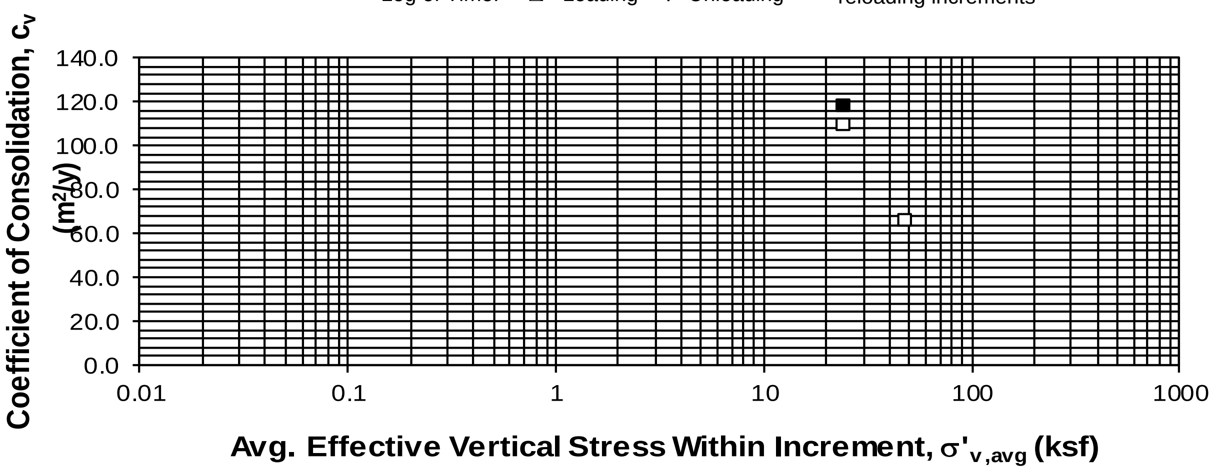
Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloading; - Log of Time: Δ - Loading ◊- Unloading; with solid symbols indicating reloading increments



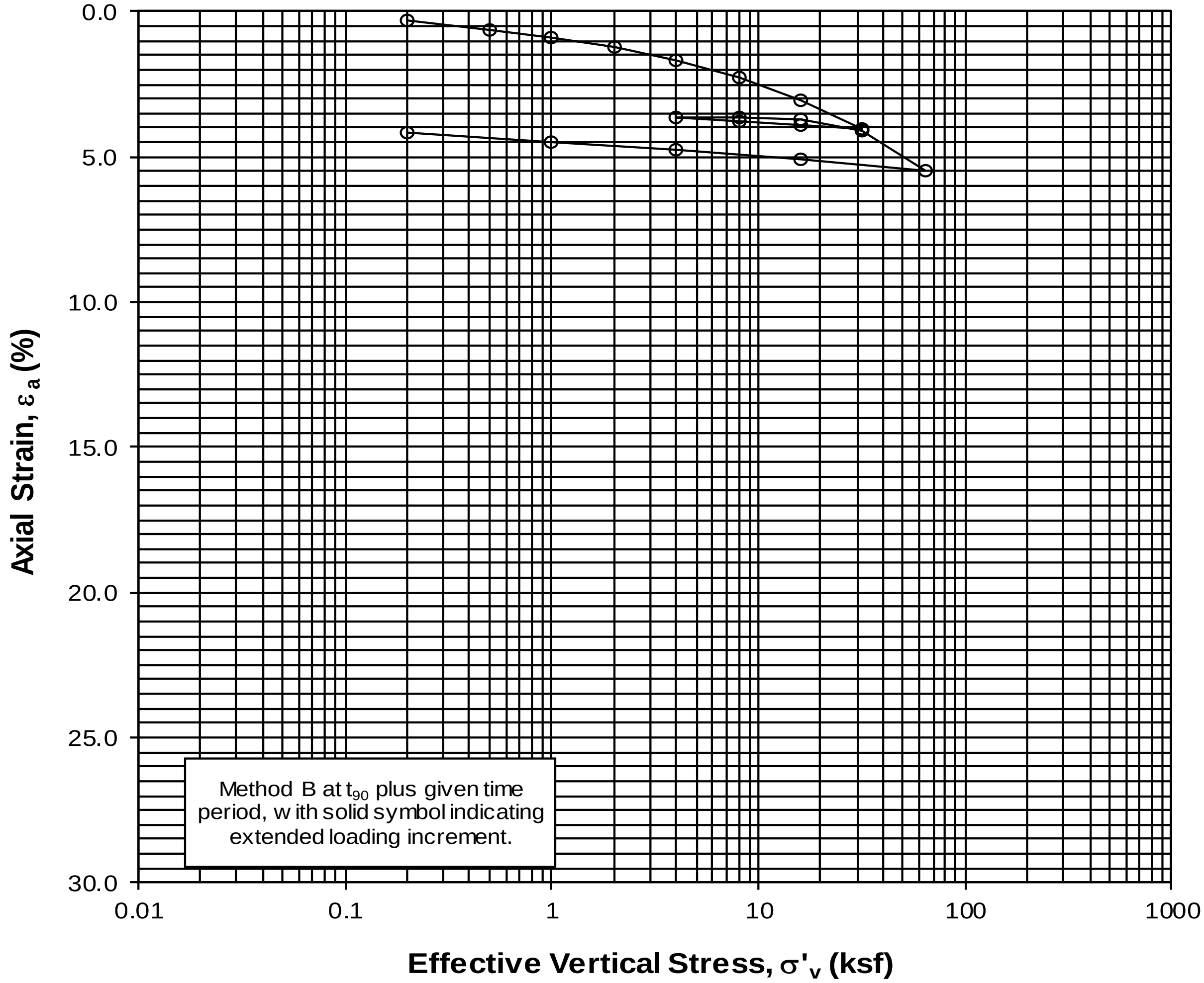
1-D CONSOLIDATION TESTS - INC
BORING B-152, SAMPLE S-28, DEPTH 90.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

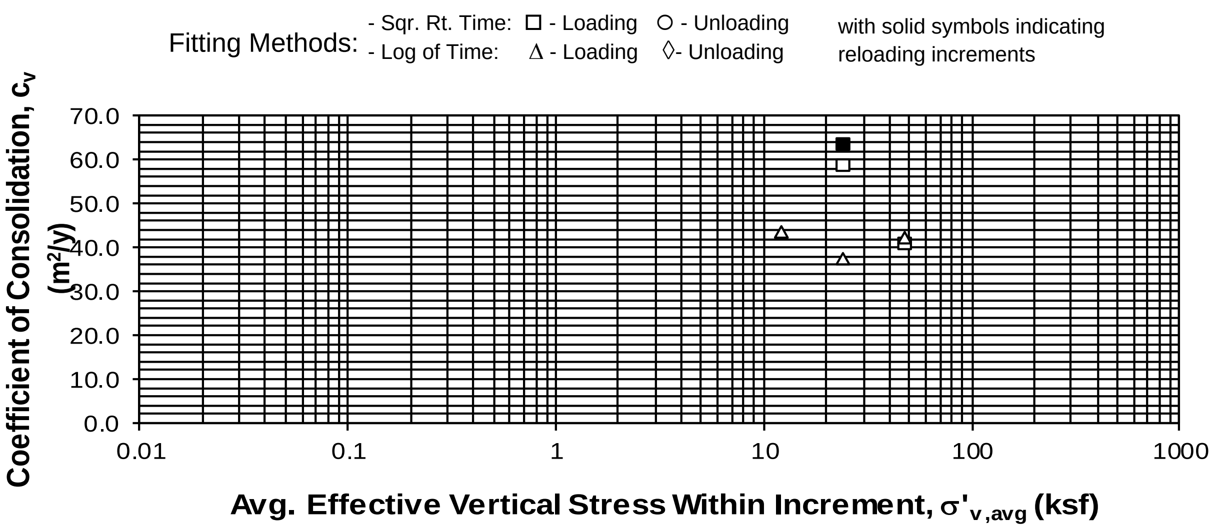


Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloading
- Log of Time: Δ - Loading ◊- Unloading
with solid symbols indicating reloading increments

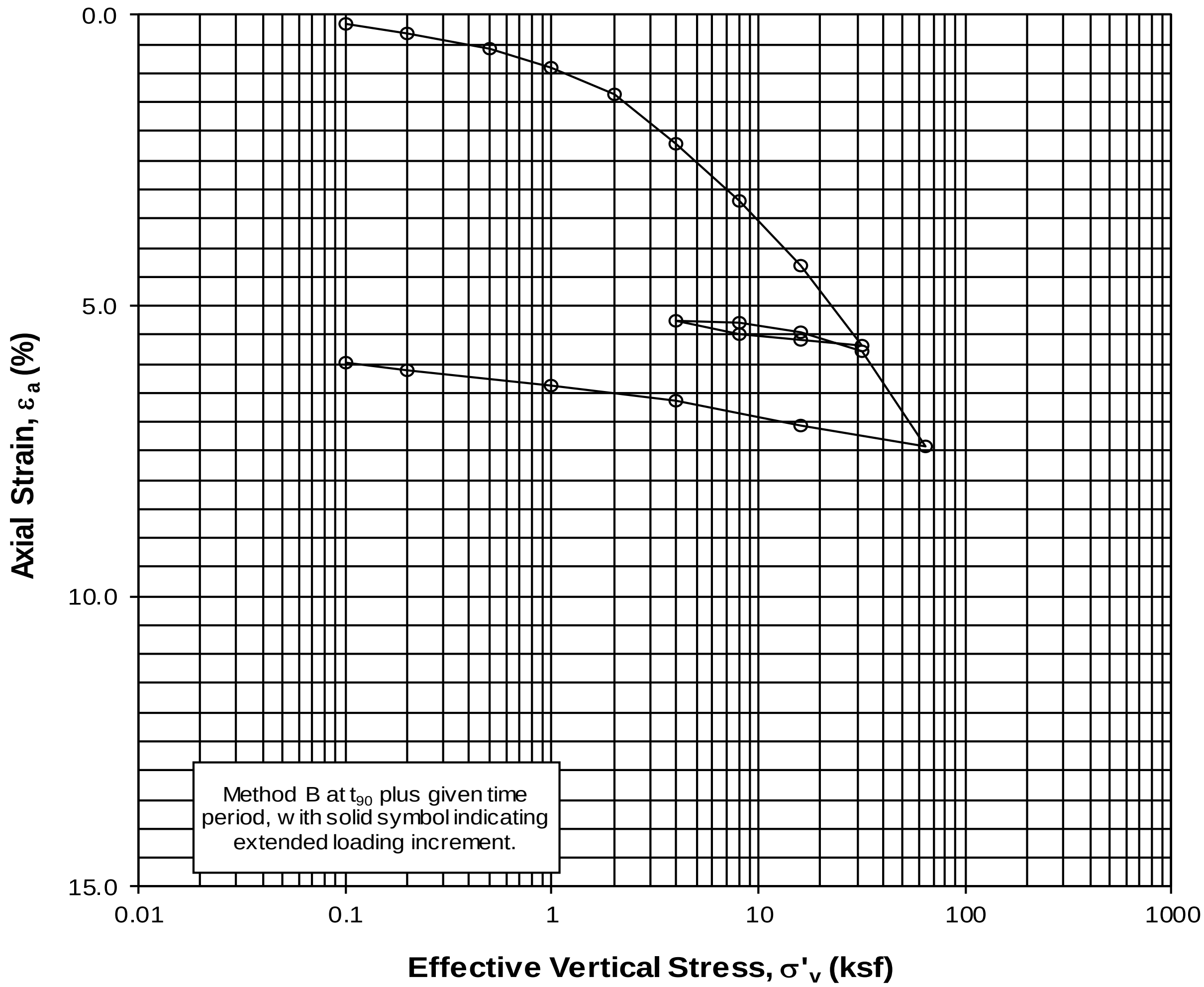


1-D CONSOLIDATION TESTS - INC
BORING B-156, SAMPLE S-28, DEPTH 104.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

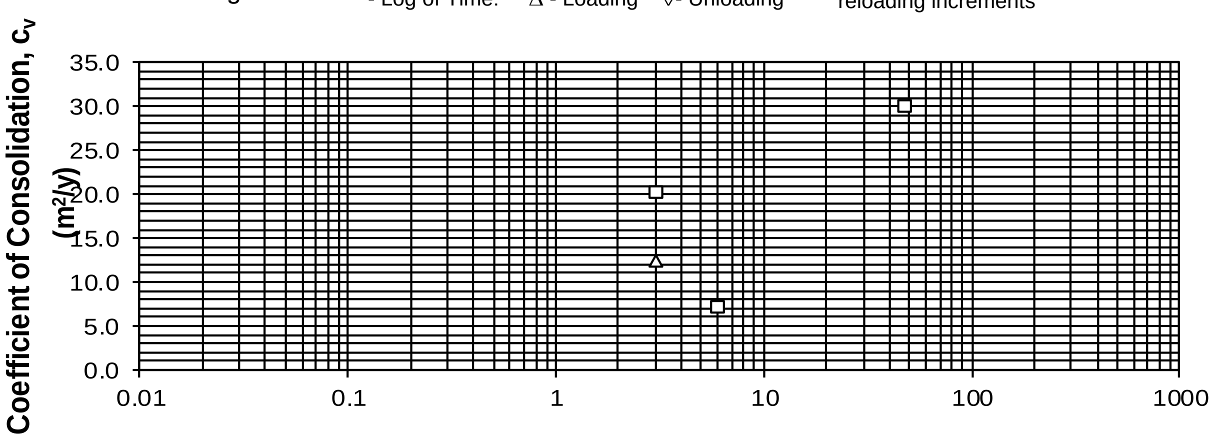




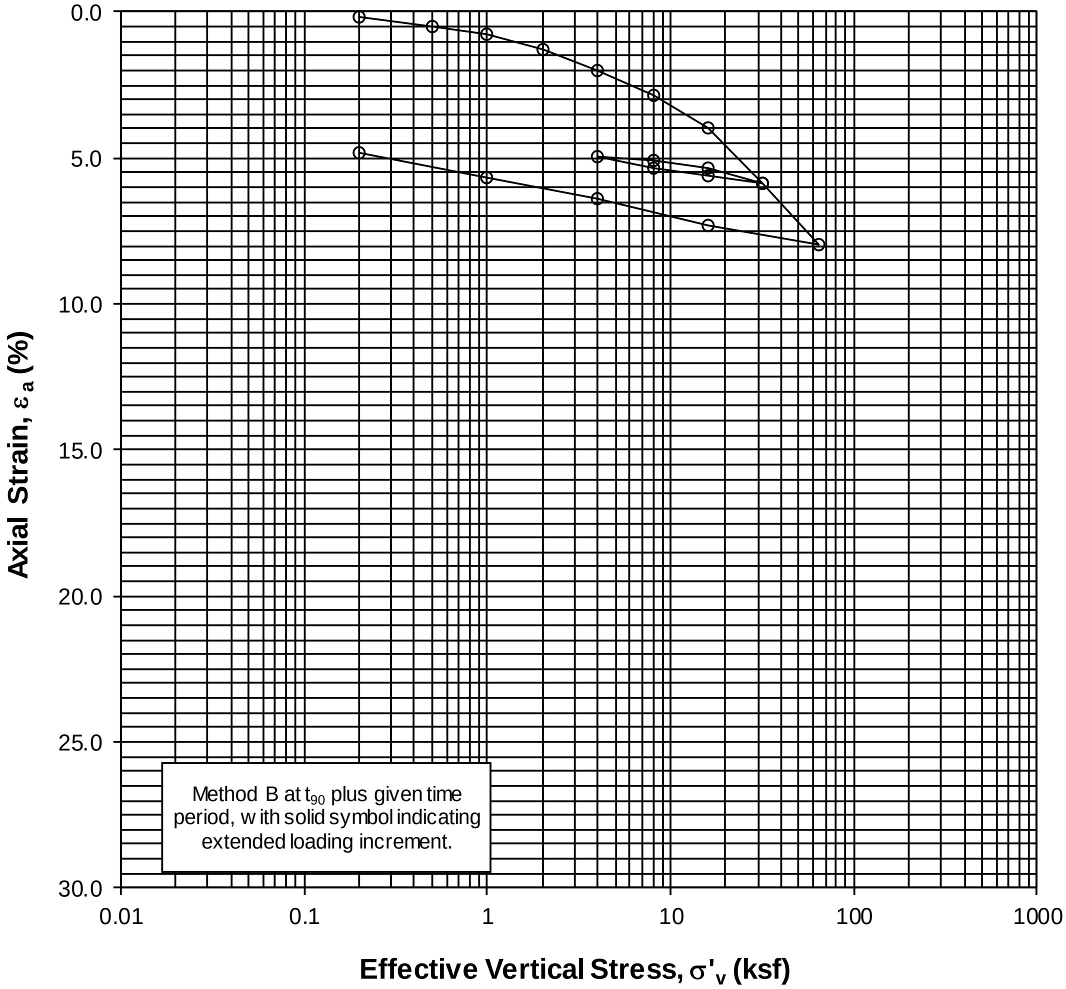
1-D CONSOLIDATION TESTS - INC
BORING B-156, SAMPLE S-32, DEPTH 138.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



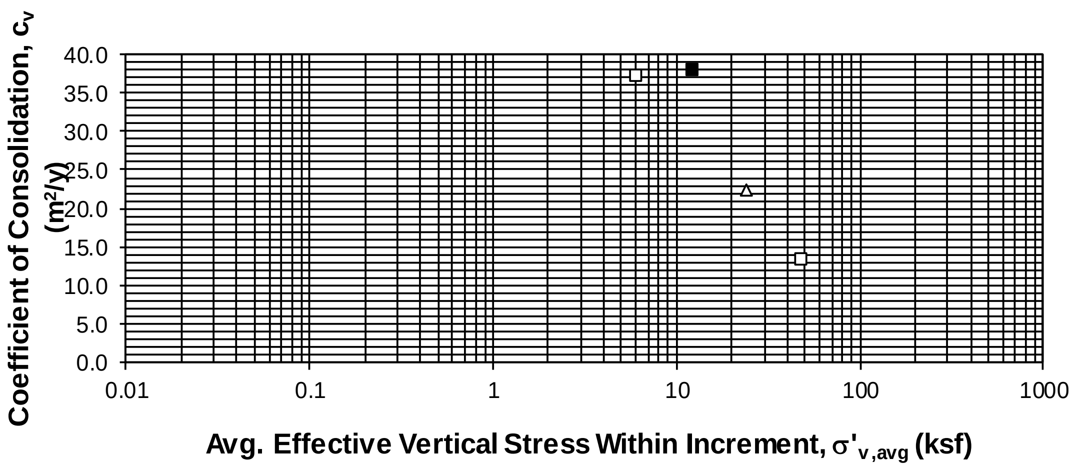
Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloading; - Log of Time: Δ - Loading ◊- Unloading; with solid symbols indicating reloading increments



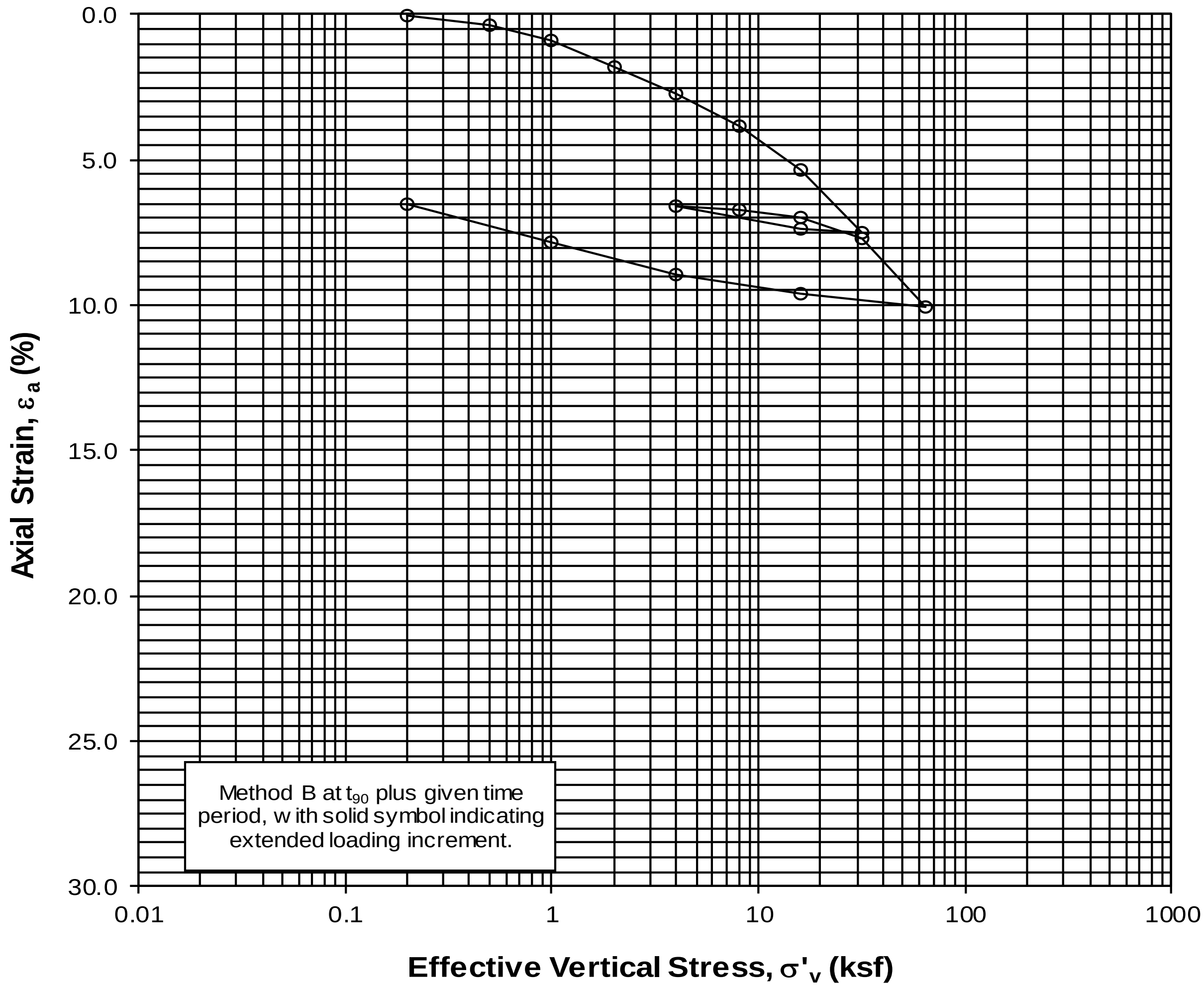
1-D CONSOLIDATION TESTS - INC
BORING B-157, SAMPLE S-28, DEPTH 96.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

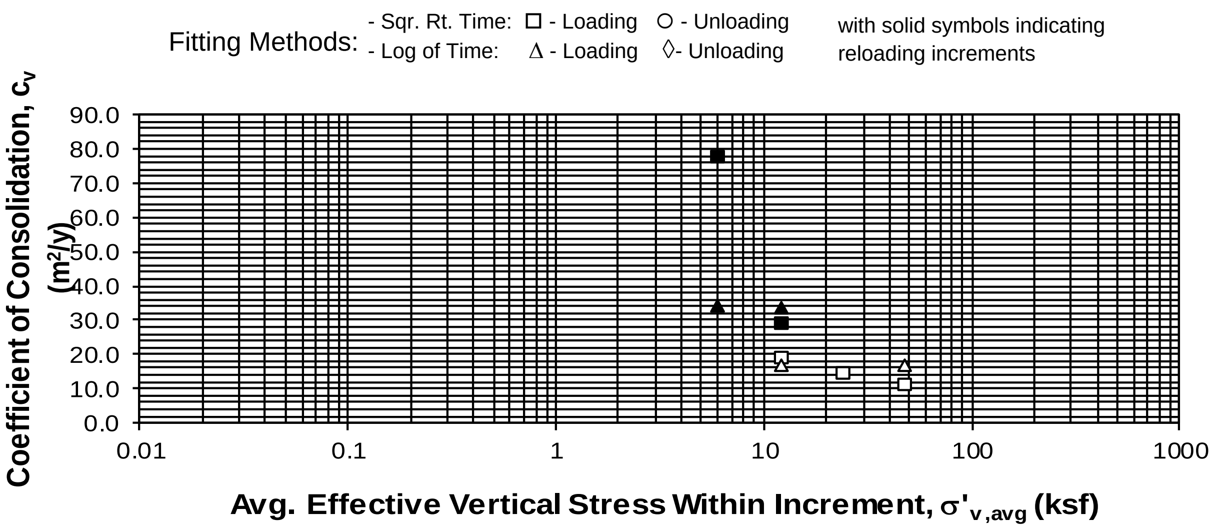


Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloadin with solid symbols indicating
- Log of Time: Δ - Loading ◊- Unloading reloading increments



1-D CONSOLIDATION TESTS - INC
BORING B-157, SAMPLE S-36, DEPTH 141.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA





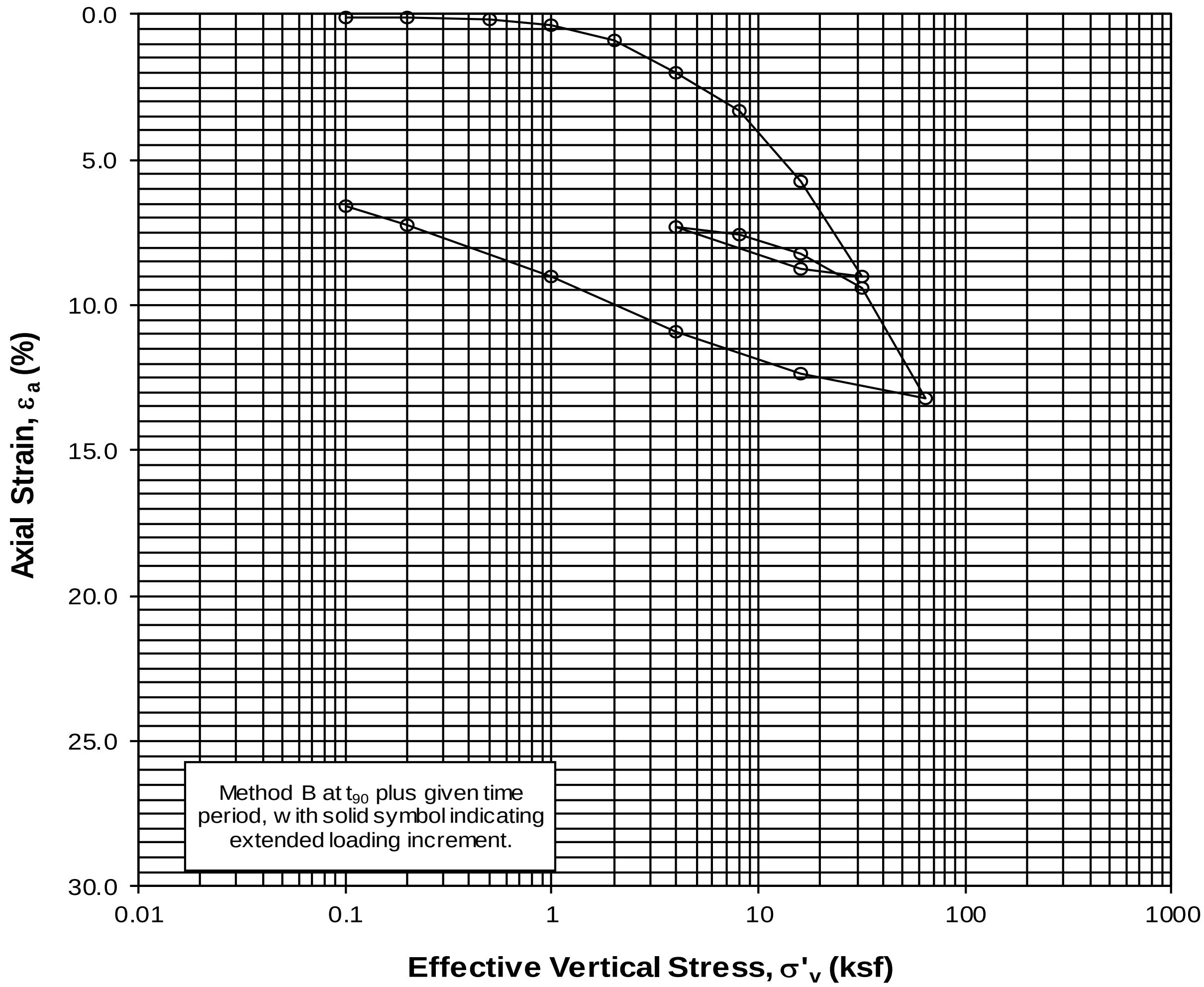
1-D CONSOLIDATION TESTS - INC

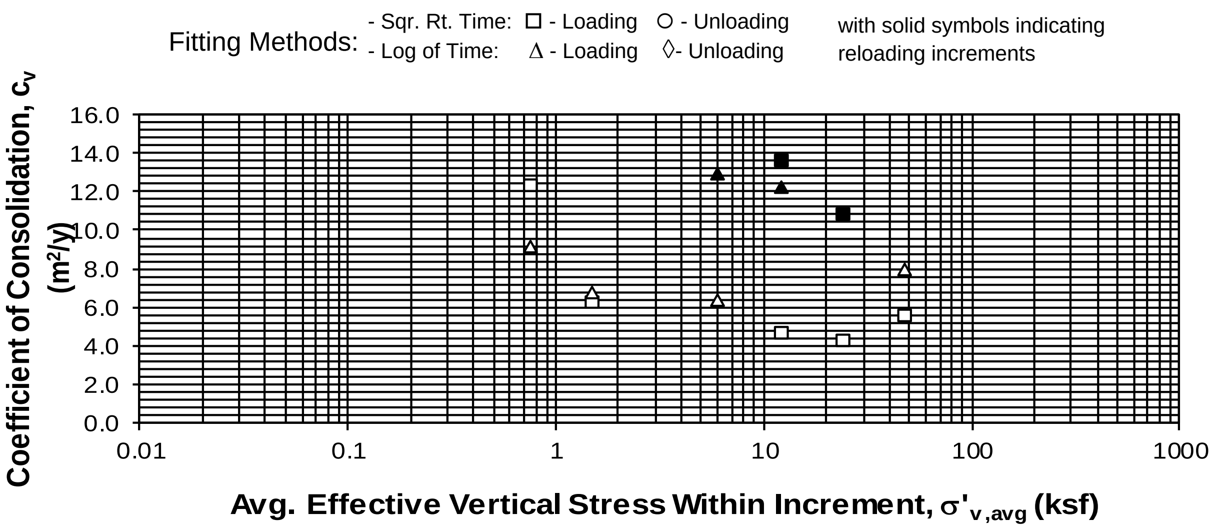
BORING B-162, SAMPLE S-24, DEPTH 89.3 FT

ONSHORE LNG FACILITIES

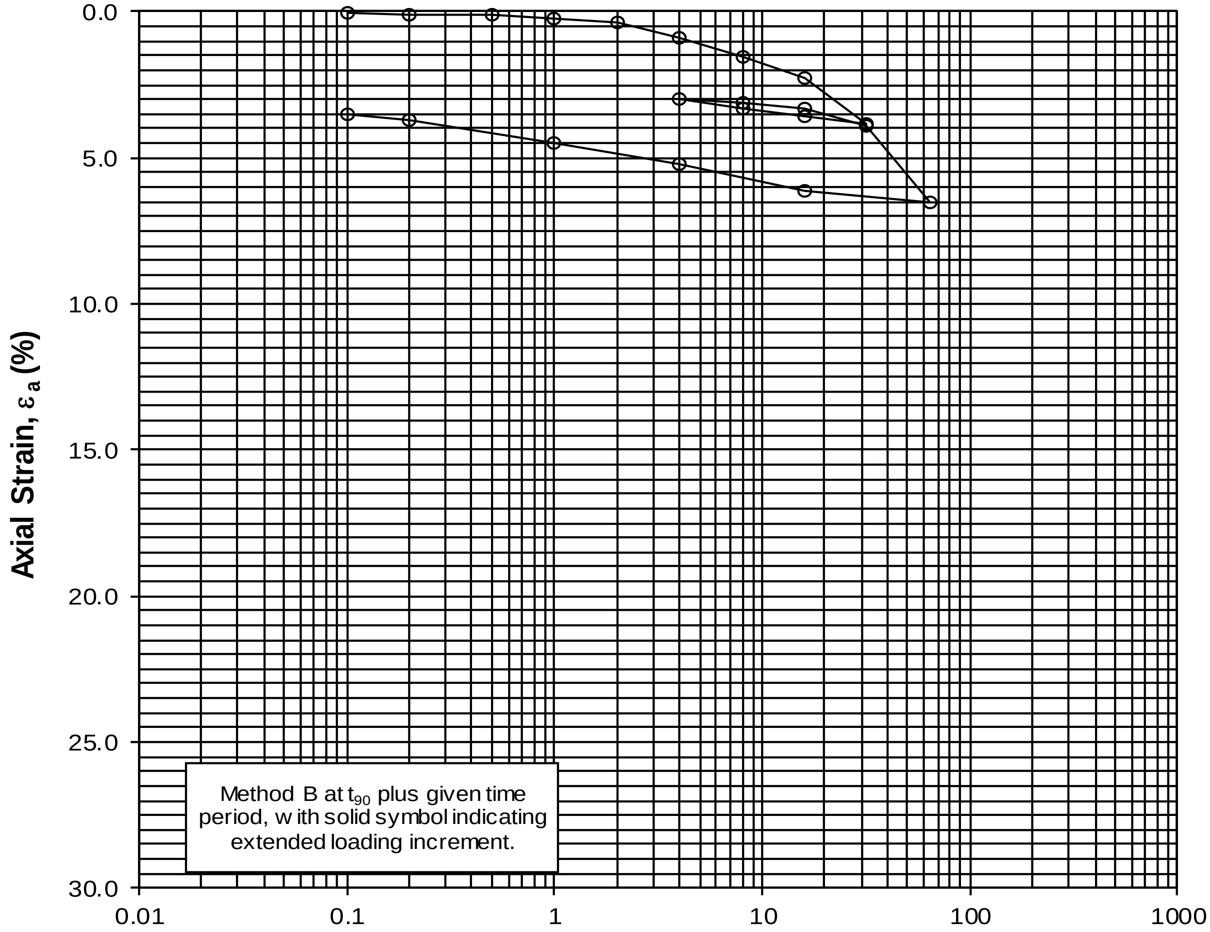
ALASKA LNG PROJECT

NIKISKI, ALASKA

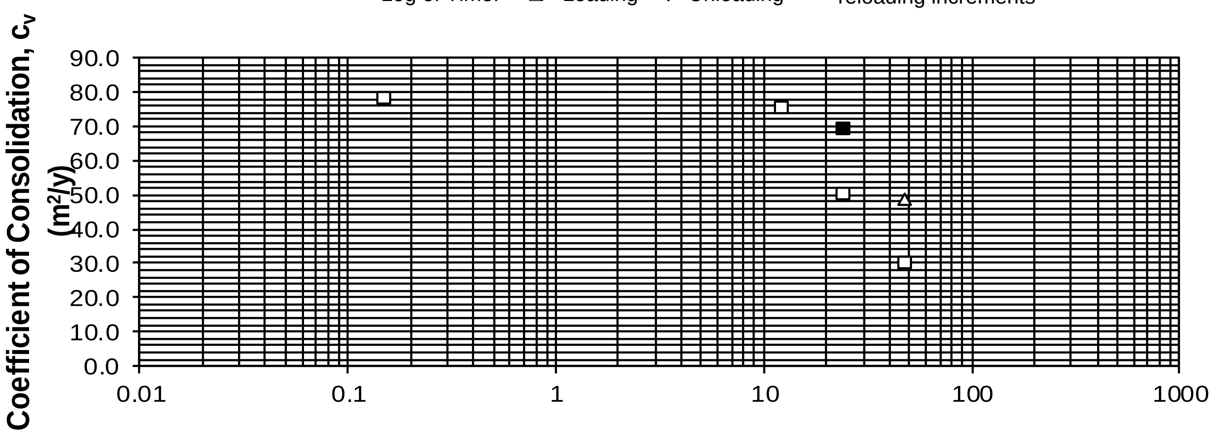




1-D CONSOLIDATION TESTS - INC
BORING B-166, SAMPLE S-24, DEPTH 88.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloading; - Log of Time: Δ - Loading ◊- Unloading; with solid symbols indicating reloading increments



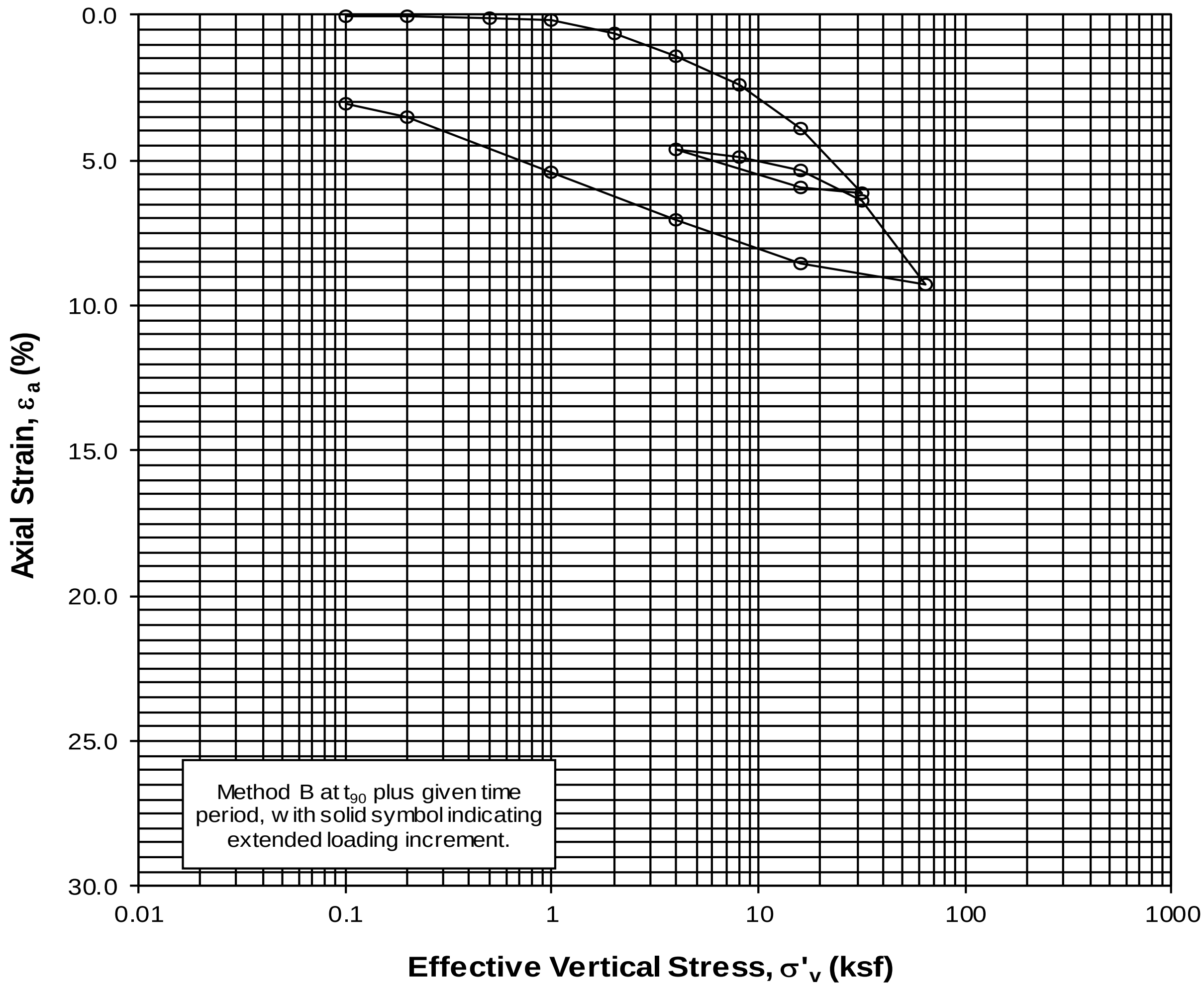
1-D CONSOLIDATION TESTS - INC

BORING B-167, SAMPLE S-15, DEPTH 44.7 FT

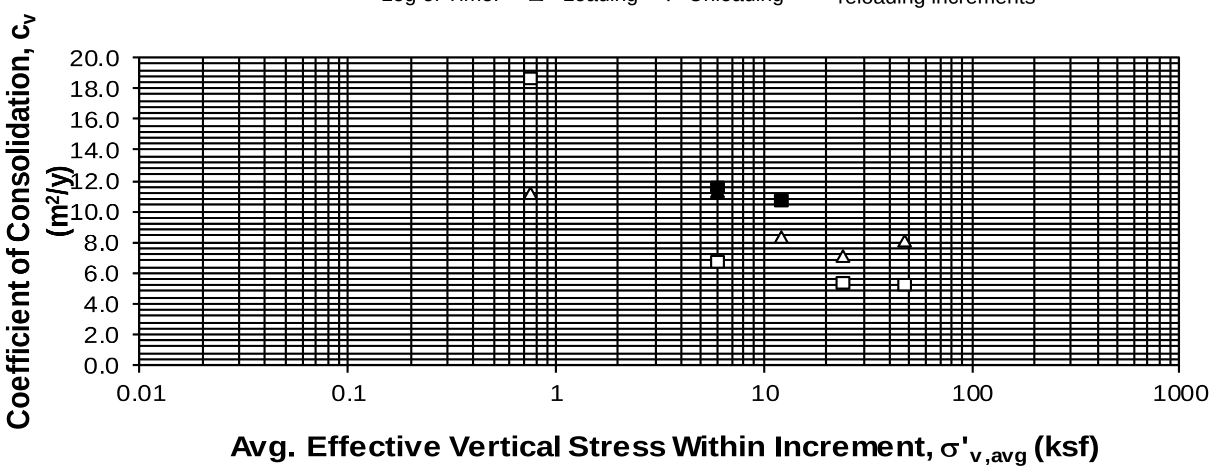
ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

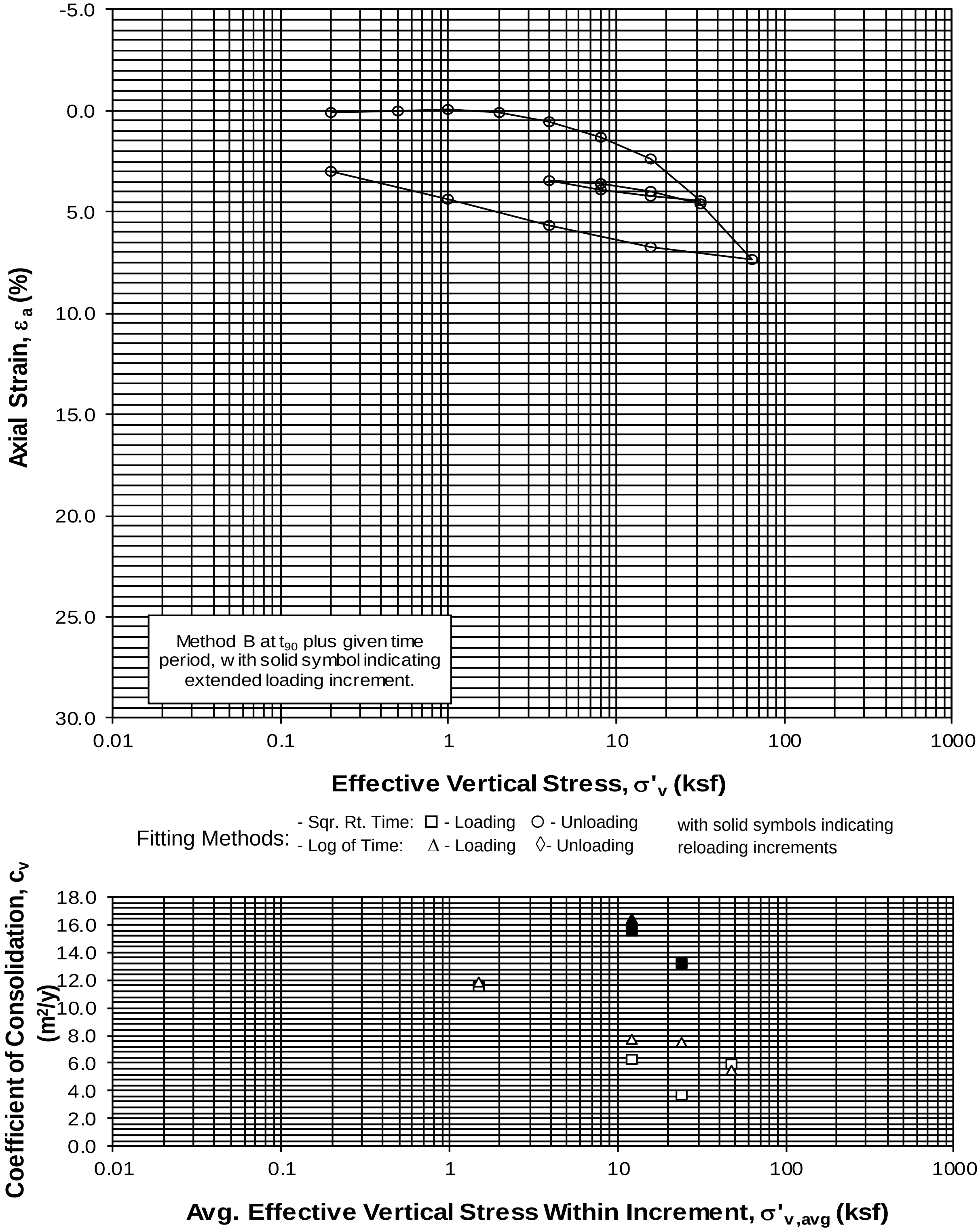
NIKISKI, ALASKA



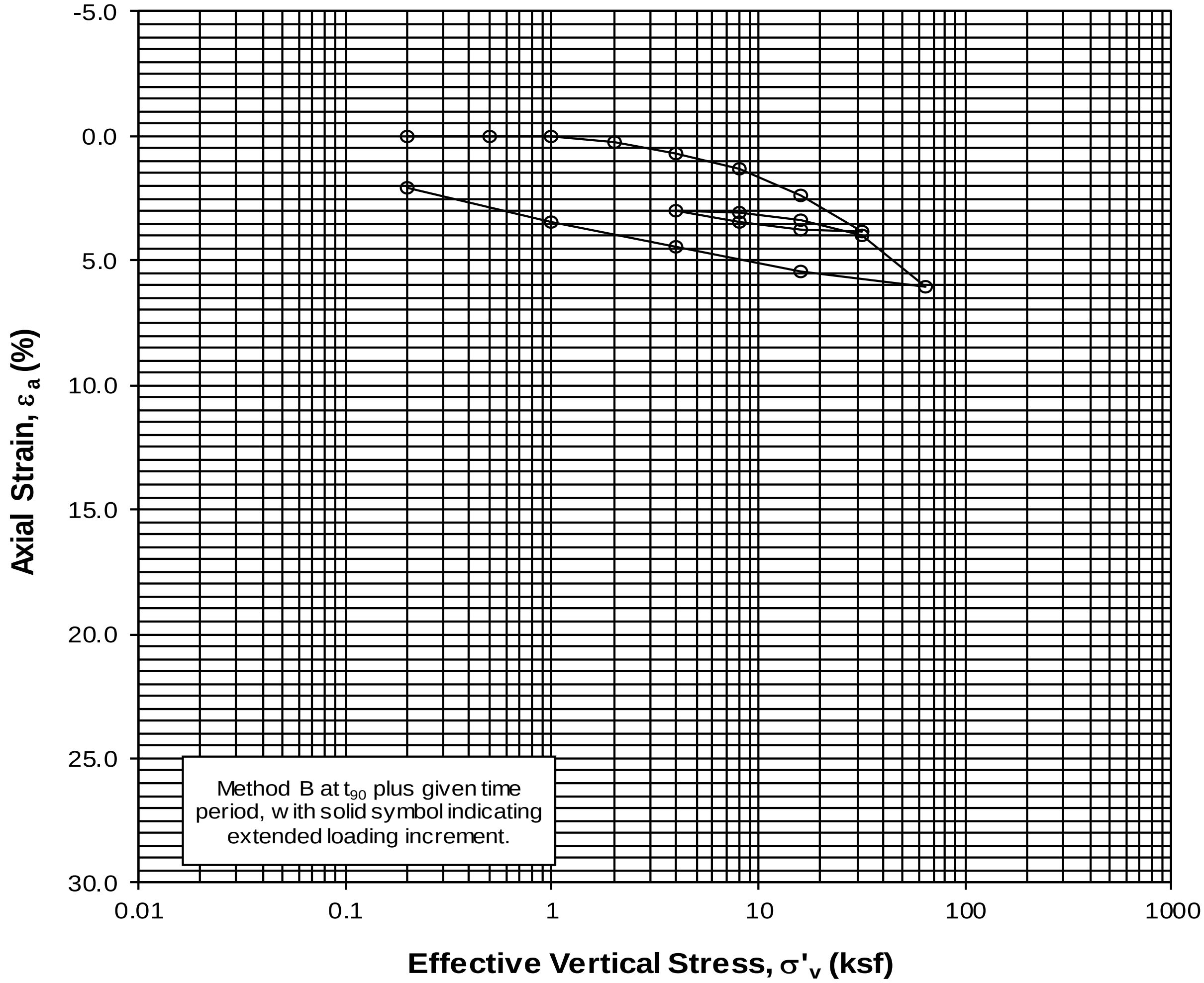
Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloading
- Log of Time: Δ - Loading ◊- Unloading
with solid symbols indicating reloading increments



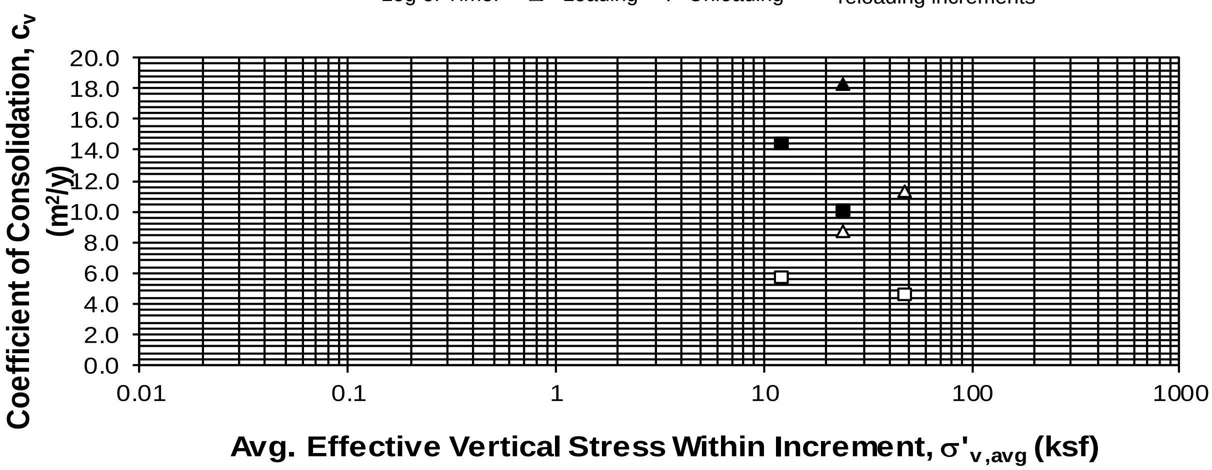
1-D CONSOLIDATION TESTS - INC
BORING B-172, SAMPLE S-31, DEPTH 151.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



1-D CONSOLIDATION TESTS - INC
BORING B-197, SAMPLE S-38, DEPTH 177.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



Fitting Methods: - Sqr. Rt. Time: □ - Loading ○ - Unloading; - Log of Time: Δ - Loading ◊- Unloading; with solid symbols indicating reloading increments



1-D CONSOLIDATION TESTS - INC
BORING B-198, SAMPLE S-35, DEPTH 170.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

APPENDIX G8

Corrosion Test Results

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT: B-146, S-3 @ 7'

FOR: FUGRO CONSULTANTS, INC.
HOUSTON, TEXAS

REPORTED TO: J. SOCHAN

LAB NUMBER: 0811014

REPORT DATE: 08-17-16
CLIENT NUMBER:
JOB NUMBER: 1016-0001
REPORT NUMBER:
DATE SAMPLED:
TIME SAMPLED:
SAMPLED BY: CLIENT
DATE RECEIVED: 08-11-16
TIME RECEIVED: 0700
RECEIVED BY: SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.4	SU	ASTM D4972 •	1000/08-15-16	SD
Sulfate, Soluble	< 100*	mg/kg	ASTM D-516 **	1000/08-17-16	SD
Chloride, Soluble	< 100*	mg/kg	ASTM D-512 **	1200/08-17-16	SD
Electrical Resistivity @ 15.5°C	19,083	ohm-cm	ASTM G-187	0700/08-16-16	SD

SO4CL 075-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT: B-146, S-5 @ 12'

FOR: FUGRO CONSULTANTS, INC.
HOUSTON, TEXAS

REPORTED TO: J. SOCHAN

LAB NUMBER: 0811015

REPORT DATE: 08-17-16
CLIENT NUMBER:
JOB NUMBER: 1016-0001
REPORT NUMBER:
DATE SAMPLED:
TIME SAMPLED:
SAMPLED BY: CLIENT
DATE RECEIVED: 08-11-16
TIME RECEIVED: 0700
RECEIVED BY: SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.8	SU	ASTM D4972 •	1000/08-15-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/08-17-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1200/08-17-16	SD
Electrical Resistivity @ 15.5°C	21,803	ohm-cm	ASTM G-187	0700/08-16-16	SD

SO4CL 075-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT: B-148, S-4a @ 7.8'

FOR: FUGRO CONSULTANTS, INC.
HOUSTON, TEXAS

REPORTED TO: J. SOCHAN

LAB NUMBER: 0811016

REPORT DATE: 08-17-16
CLIENT NUMBER:
JOB NUMBER: 1016-0001
REPORT NUMBER:
DATE SAMPLED:
TIME SAMPLED:
SAMPLED BY: CLIENT
DATE RECEIVED: 08-11-16
TIME RECEIVED: 0700
RECEIVED BY: SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.1	SU	ASTM D4972 •	1000/08-15-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/08-17-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1200/08-17-16	SD
Electrical Resistivity @ 15.5°C	QNS ¥	ohm-cm	ASTM G-187	0700/08-16-16	SD

¥ QUANTITY NON SUFFICIENT

SO4CL

Respectfully submitted,

* Dry weight basis

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT:	B-152, S-6 @ 13.5'	REPORT DATE:	10-04-16
		CLIENT NUMBER:	
		JOB NUMBER:	1016-0001
FOR:	FUGRO CONSULTANTS, INC. HOUSTON, TEXAS	REPORT NUMBER:	
		DATE SAMPLED:	
		TIME SAMPLED:	
REPORTED TO:	J. SOCHAN	SAMPLED BY:	CLIENT
		DATE RECEIVED:	09-16-16
		TIME RECEIVED:	0930
LAB NUMBER:	0916061	RECEIVED BY:	SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.3	SU	ASTM D4972 •	1100/10-03-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/10-04-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1300/10-04-16	SD
Electrical Resistivity @ 15.5°C	57,070	ohm-cm	ASTM G-187	0700/10-04-16	SD

50% OF SAMPLE CONTAINED ROCKS

SO4CL 096-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT HOUSTON, TEXAS 77081
PHONE (713) 369-5400 FAX (713) 369-5518

RESULTS OF TESTS

PROJECT:	B-153, S-3 @ 7'	REPORT DATE:	10-04-16
		CLIENT NUMBER:	
		JOB NUMBER:	1016-0001
FOR:	FUGRO CONSULTANTS, INC. HOUSTON, TEXAS	REPORT NUMBER:	
		DATE SAMPLED:	
		TIME SAMPLED:	
REPORTED TO:	J. SOCHAN	SAMPLED BY:	CLIENT
		DATE RECEIVED:	09-16-16
		TIME RECEIVED:	0930
LAB NUMBER:	0916062	RECEIVED BY:	SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.1	SU	ASTM D4972 •	1100/10-03-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/10-04-16	SD
Chloride, Soluble	<100 *	mg/kg	ASTM D-512 **	1300/10-04-16	SD
Electrical Resistivity @ 15.5°C	37,315	ohm-cm	ASTM G-187	0700/10-04-16	SD

50% OF SAMPLE CONTAINED ROCKS

SO4CL 096-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT: B-157, S-7 @ 16’

FOR: FUGRO CONSULTANTS, INC.
HOUSTON, TEXAS

REPORTED TO: J. SOCHAN

LAB NUMBER: 0916063

REPORT DATE: 10-04-16
CLIENT NUMBER:
JOB NUMBER: 1016-0001
REPORT NUMBER:
DATE SAMPLED:
TIME SAMPLED:
SAMPLED BY: CLIENT
DATE RECEIVED: 09-16-16
TIME RECEIVED: 0930
RECEIVED BY: SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.3	SU	ASTM D4972 •	1100/10-03-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/10-04-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1300/10-04-16	SD
Electrical Resistivity @ 15.5°C	22,300	ohm-cm	ASTM G-187	0700/10-04-16	SD

50% OF SAMPLE CONTAINED ROCKS

SO4CL 096-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT:	**B-158, S-4 @ 9.5'**	**REPORT DATE:**	**10-04-16**
		CLIENT NUMBER:	
		JOB NUMBER:	**1016-0001**
FOR:	**FUGRO CONSULTANTS, INC.** **HOUSTON, TEXAS**	**REPORT NUMBER:**	
		DATE SAMPLED:	
		TIME SAMPLED:	
REPORTED TO:	**J. SOCHAN**	**SAMPLED BY:**	**CLIENT**
		DATE RECEIVED:	**09-16-16**
		TIME RECEIVED:	**0930**
LAB NUMBER:	**0916064**	**RECEIVED BY:**	**SD**

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.3	SU	ASTM D4972 •	1100/10-03-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/10-04-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1300/10-04-16	SD
Electrical Resistivity @ 15.5°C	28,535	ohm-cm	ASTM G-187	0700/10-04-16	SD

50% OF SAMPLE CONTAINED ROCKS

SO4CL 096-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

**THE RESULTS RELATE AS TO THE LOCATION TESTED AND NO OTHER REFERENCE SHALL BE MADE.
THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400
HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT: B-162, S-3 @ 5.5'

FOR: FUGRO CONSULTANTS, INC.
HOUSTON, TEXAS

REPORTED TO: J. SOCHAN

LAB NUMBER: 0628067

REPORT DATE: 07-07-16
CLIENT NUMBER:
JOB NUMBER: 1016-0001
REPORT NUMBER:
DATE SAMPLED:
TIME SAMPLED:
SAMPLED BY: CLIENT
DATE RECEIVED: 06-28-16
TIME RECEIVED: 1000
RECEIVED BY: SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	4.6	SU	ASTM D4972 •	0900/07-06-16	SD
Sulfate, Soluble	220 *	mg/kg	ASTM D-516 **	1030/07-06-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1200/07-06-16	SD
Electrical Resistivity @ 15.5°C	5,843	ohm-cm	ASTM G-187	0700/07-07-16	SD

SO4CL 059-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

**THE RESULTS RELATE AS TO THE LOCATION TESTED AND NO OTHER REFERENCE SHALL BE MADE.
THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400
HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT: B-165, S-3 @ 6'

FOR: FUGRO CONSULTANTS, INC.
HOUSTON, TEXAS

REPORTED TO: J. SOCHAN

LAB NUMBER: 0713035

REPORT DATE: 07-20-16
CLIENT NUMBER:
JOB NUMBER: 1016-0001
REPORT NUMBER:
DATE SAMPLED:
TIME SAMPLED:
SAMPLED BY: CLIENT
DATE RECEIVED: 07-13-16
TIME RECEIVED: 1000
RECEIVED BY: SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	4.5	SU	ASTM D4972 •	1130/07-20-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1100/07-20-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1300/07-20-16	SD
Electrical Resistivity @ 15.5°C	10,035	ohm-cm	ASTM G-187	0700/07-20-16	SD

SO4CL 065-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

**THE RESULTS RELATE AS TO THE LOCATION TESTED AND NO OTHER REFERENCE SHALL BE MADE.
THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT:	B-169, S-5-OPST @ 11'	REPORT DATE:	10-04-16
		CLIENT NUMBER:	
		JOB NUMBER:	1016-0001
FOR:	FUGRO CONSULTANTS, INC. HOUSTON, TEXAS	REPORT NUMBER:	
		DATE SAMPLED:	
		TIME SAMPLED:	
REPORTED TO:	J. SOCHAN	SAMPLED BY:	CLIENT
		DATE RECEIVED:	09-16-16
		TIME RECEIVED:	0930
LAB NUMBER:	0916065	RECEIVED BY:	SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.4	SU	ASTM D4972 •	1100/10-03-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/10-04-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1300/10-04-16	SD
Electrical Resistivity @ 15.5°C	46,095	ohm-cm	ASTM G-187	0700/10-04-16	SD

50% OF SAMPLE CONTAINED ROCKS

SO4CL 096-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

**THE RESULTS RELATE AS TO THE LOCATION TESTED AND NO OTHER REFERENCE SHALL BE MADE.
THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400
HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT:	B-171, S-2 @ 3.5’	REPORT DATE:	07-07-16
		CLIENT NUMBER:	
		JOB NUMBER:	1016-0001
FOR:	FUGRO CONSULTANTS, INC. HOUSTON, TEXAS	REPORT NUMBER:	
		DATE SAMPLED:	
		TIME SAMPLED:	
REPORTED TO:	J. SOCHAN	SAMPLED BY:	CLIENT
		DATE RECEIVED:	06-28-16
		TIME RECEIVED:	1000
LAB NUMBER:	0628068	RECEIVED BY:	SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	5.4	SU	ASTM D4972 •	0900/07-06-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1030/07-06-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1200/07-06-16	SD
Electrical Resistivity @ 15.5°C	33,075	ohm-cm	ASTM G-187	0700/07-07-16	SD

SO4CL 059-16

Respectfully submitted,

* Dry weight basis

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.

THE RESULTS RELATE AS TO THE LOCATION TESTED AND NO OTHER REFERENCE SHALL BE MADE.
THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400
HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT: B-173, S-3 @ 6.5'

FOR: FUGRO CONSULTANTS, INC.
HOUSTON, TEXAS

REPORTED TO: J. SOCHAN

LAB NUMBER: 0628069

REPORT DATE: 07-07-16
CLIENT NUMBER:
JOB NUMBER: 1016-0001
REPORT NUMBER:
DATE SAMPLED:
TIME SAMPLED:
SAMPLED BY: CLIENT
DATE RECEIVED: 06-28-16
TIME RECEIVED: 1000
RECEIVED BY: SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	5.7	SU	ASTM D4972 •	0900/07-06-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1030/07-06-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1200/07-06-16	SD
Electrical Resistivity @ 15.5°C	36,383	ohm-cm	ASTM G-187	0700/07-07-16	SD

SO4CL 059-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

**THE RESULTS RELATE AS TO THE LOCATION TESTED AND NO OTHER REFERENCE SHALL BE MADE.
THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT: B-189, S-6 @ 11'

FOR: FUGRO CONSULTANTS, INC.
HOUSTON, TEXAS

REPORTED TO: J. SOCHAN

LAB NUMBER: 0916066

REPORT DATE: 10-04-16
CLIENT NUMBER:
JOB NUMBER: 1016-0001
REPORT NUMBER:
DATE SAMPLED:
TIME SAMPLED:
SAMPLED BY: CLIENT
DATE RECEIVED: 09-16-16
TIME RECEIVED: 0930
RECEIVED BY: SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.3	SU	ASTM D4972 •	1100/10-03-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/10-04-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1300/10-04-16	SD
Electrical Resistivity @ 15.5°C	42,803	ohm-cm	ASTM G-187	0700/10-04-16	SD

50% OF SAMPLE CONTAINED ROCKS

SO4CL 096-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

**THE RESULTS RELATE AS TO THE LOCATION TESTED AND NO OTHER REFERENCE SHALL BE MADE.
THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT: B-195, S-3 @ 7'

FOR: FUGRO CONSULTANTS, INC.
HOUSTON, TEXAS

REPORTED TO: J. SOCHAN

LAB NUMBER: 0916067

REPORT DATE: 10-04-16
CLIENT NUMBER:
JOB NUMBER: 1016-0001
REPORT NUMBER:
DATE SAMPLED:
TIME SAMPLED:
SAMPLED BY: CLIENT
DATE RECEIVED: 09-16-16
TIME RECEIVED: 0930
RECEIVED BY: SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.3	SU	ASTM D4972 •	1100/10-03-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/10-04-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1300/10-04-16	SD
Electrical Resistivity @ 15.5°C	34,960	ohm-cm	ASTM G-187	0700/10-04-16	SD

50% OF SAMPLE CONTAINED ROCKS

SO4CL 096-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT
PHONE (713) 369-5400

HOUSTON, TEXAS 77081
FAX (713) 369-5518

RESULTS OF TESTS

PROJECT:	B-197, S-5 @ 11'	REPORT DATE:	10-04-16
		CLIENT NUMBER:	
		JOB NUMBER:	1016-0001
FOR:	FUGRO CONSULTANTS, INC. HOUSTON, TEXAS	REPORT NUMBER:	
		DATE SAMPLED:	
		TIME SAMPLED:	
REPORTED TO:	J. SOCHAN	SAMPLED BY:	CLIENT
		DATE RECEIVED:	09-16-16
		TIME RECEIVED:	0930
LAB NUMBER:	0916068	RECEIVED BY:	SD

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.5	SU	ASTM D4972 •	1100/10-03-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/10-04-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1300/10-04-16	SD
Electrical Resistivity @ 15.5°C	48,150	ohm-cm	ASTM G-187	0700/10-04-16	SD

50% OF SAMPLE CONTAINED ROCKS

SO4CL 096-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

**THE RESULTS RELATE AS TO THE LOCATION TESTED AND NO OTHER REFERENCE SHALL BE MADE.
THIS REPORT SHALL NOT BE REPRODUCED EXCEPT IN FULL WITHOUT THE WRITTEN APPROVAL OF THE LABORATORY.**

END OF REPORT

FUGRO CONSULTANTS, INC.

6100 HILLCROFT **HOUSTON, TEXAS 77081**
PHONE (713) 369-5400 **FAX (713) 369-5518**

RESULTS OF TESTS

PROJECT:	**B-198, S-3 @ 6'**	**REPORT DATE:**	**10-04-16**
		CLIENT NUMBER:	
		JOB NUMBER:	**1016-0001**
FOR:	**FUGRO CONSULTANTS, INC.** **HOUSTON, TEXAS**	**REPORT NUMBER:**	
		DATE SAMPLED:	
		TIME SAMPLED:	
REPORTED TO:	**J. SOCHAN**	**SAMPLED BY:**	**CLIENT**
		DATE RECEIVED:	**09-16-16**
		TIME RECEIVED:	**0930**
LAB NUMBER:	**0916069**	**RECEIVED BY:**	**SD**

PARAMETER	RESULTS	UNITS	METHOD	TIME/DATE	ANALYST
pH, Method A	6.5	SU	ASTM D4972 •	1100/10-03-16	SD
Sulfate, Soluble	< 100 *	mg/kg	ASTM D-516 **	1000/10-04-16	SD
Chloride, Soluble	< 100 *	mg/kg	ASTM D-512 **	1300/10-04-16	SD
Electrical Resistivity @ 15.5°C	52,675	ohm-cm	ASTM G-187	0700/10-04-16	SD

50% OF SAMPLE CONTAINED ROCKS

SO4CL 096-16

Respectfully submitted,

*** Dry weight basis**

Steve DeGregorio
Chemist

SD

• CALCIUM CHLORIDE pH RESULTS NOT REPORTED

**** WATER EXTRACTION PERFORMED BY USING A 1:10 RATIO OF SAMPLE AND REAGENT WATER FOLLOWED BY CENTRIFUGE AND VACUUME FILTRATION. THE WATER EXTRACT IS THEN ANALYZED USING THE ASTM D-512 AND D-516 METHODS.**

END OF REPORT

APPENDIX G9

Frost Heave Test Results by Laval University

Frost heave data for AKLNG soils tested in 2016

Submitted to

Fugro Consultants Inc.

By

Jean-Marie Konrad, ing. PhD.

October 2016

Scope of work

To conduct frost heave tests on AKLNG soils using a procedure derived from ASTM D 5918-06. The soil samples were shipped by Fugro Consultants on September 15, 2016 (see Appendix C).

Test program

Eight (8) frost heave tests were conducted at Laval University under the supervision of Professor Konrad.

Test no (Sample)	Ho mm	ρ_d Kg/m^3	w_0 %	Sr_0 %	w_c %	Sr_c %	% Fines < 0.075mm
1 (B147-B148-B149)	127	2003	8.6	70.9	9.2	74.4	6.1
2 (B152)	135	1949	9.0	66.6	9.9	73.6	4.8
3 (B156-B157)	135	1959	8.5	63.9	10.6	80.0	5.3
4 (B169)	130	1956	8.7	64.9	11.4	85.4	3.7
5 (B170-B171)	135	1954	8.8	65.4	10.5	78.4	3.7
6 (B172)	130	1955	8.7	65.0	10.6	78.7	11.7
7 (B197)	134	1975	8.5	65.4	10.3	80.4	7.8
8 (<5mm,20%Fines)	124	1960	12.0	88.3	11.3	84.8	20.2

Table 1. Summary of test program

Ho : initial height of specimen; ρ_d : dry density; wo: initial moisture content, Sro : initial degree of saturation, wc: moisture content after water percolation through the sample, Src: degree of saturation before freezing, %fines : fines (< 0.075mm) content.

Note

Specimen no 8 (<5mm) was reconstituted using specimen B 169 for particles smaller than 5mm to which fines (<0.075 mm) from samples 1(B147-148-149), 2(B 152) and 3(B 156-157) were added in order to achieve a total fines content of about 20%. The aim was to verify the influence of fines content on frost-susceptibility.

Grain size distribution of specimen used in each freeze test is summarized in Figure 1.

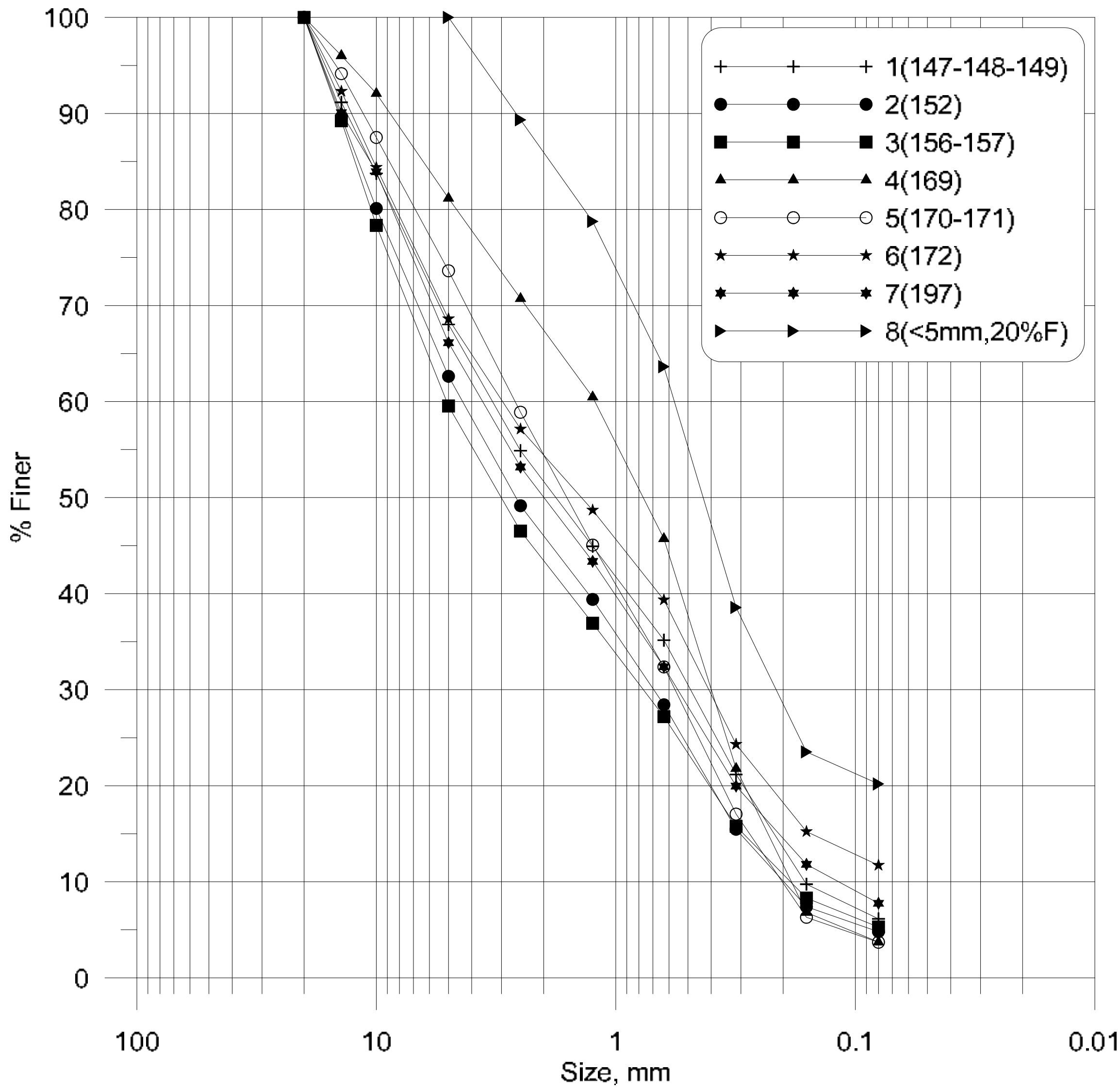


Figure 1. Grain size distribution of specimen tested

Sample Preparation Procedure

The samples were laboratory-compacted soils. The dry density and moisture content required for the test were determined from in situ conditions and similar to the tests performed on the AKLNG soils taken in 2015. Five layers were directly compacted into the freezing cell at the desired dry density. The sample was subjected to water percolation from the base in an upward direction in order to increase the degree of saturation prior to freeze.

Freeze Procedure

ASTM D 5918-06 was used as a guidance since the freeze cells have an inside diameter of 100 mm (4 in.) rather than 146 mm (5.75 in.). Furthermore, given the small quantity of material received, it was not possible to obtain 150 mm (6 in.) high samples. As indicated in the table above, the sample's height varied between 124 mm and 135 mm, which is sufficiently close to the recommended sample height.

Two freeze-thaw cycles were imposed on compacted soil specimens which are frozen and thawed by applying specified constant temperatures in steps at the top and bottom of the specimen with water freely available at the base. As recommended by ASTM 5918-06, a surcharge of 3.5 kPa (0.5 lb/in^2) is applied to the top. It is noted that the smaller the surcharge, the higher the heave rate which means that this testing condition leads to a conservative assessment of frost-susceptibility. In the field, the applied surcharge increases with increasing depth and heave rate due to freezing would decrease.

Conditioning the Specimen

The first 24 h is a conditioning period. Both the top and bottom plates are held at +3 °C (37.4 °F) and the temperature evolution is monitored with time.

First Freezing Period

The first freeze starts by lowering the top plate at -3 °C (26.6 °F) and allowing freezing to proceed until thermal equilibrium is attained after about 24 to 28 hours.

First Thawing Period

The first thaw starts at the beginning of the third 24-hour period by raising the top plate temperature to +3 °C for another 24 hours in order to allow temperatures across the specimen to reach a uniform distribution prior to the second freeze.

Second Freeze Period

The second freeze starts at the beginning of the fourth 24-hour period by lowering the top plate at -3 °C (26.6 °F) and allowing freezing to proceed until thermal equilibrium is attained after about 24 hours. After this step-freezing phase, the samples are frozen to mid-height and a ramped-freeze is initiated in order to induce a constant frost penetration rate until the sample is completely frozen. The ramp-rate is set to about -3 °C/day at the top and bottom plates.

Samples are not thawed at the end of the second freeze in order to take a photograph to record ice lenses (if any) and to slice the frozen samples in 1 cm-high disks to determine the water content profile after the second freeze.

Measurements During Freeze-Thaw Test

All temperatures sensors installed in the freeze cell are automatically recorded every 10 minutes by an acquisition system and transferred to a computer. An LVDT records the sample's heave and a Mariotte burette records the water volume intake. The position of each thermistor embedded in the freeze cell wall is given in Appendix B.

Bearing Ratio of thawed sample

No bearing ratio was determined on the thawed sample since it was agreed to focus our laboratory investigation of frost heave. Since water content profile in the frozen soil is a better indicator of frost induced water migration in low frost-susceptible soils, the samples were cut in slices after testing was complete in order to determine the moisture content profiles.

Test Results

The results of each freeze-thaw test are presented using 12 graphs:

1) One graph showing the Grain Size Distribution of the sample obtained after the second freeze;

2) One graph showing the evolution of sample height and temperatures during the first conditioning phase;

3) 3 graphs to summarize the sample's response during the first freeze:

   a. Heave vs. time

   b. Temperature profile at different times

   c. Frost depth vs. time

4) 2 graphs showing the evolution of sample height and temperatures during the first thawing phase;

5) 3 graphs to summarizes the sample's response during the second freeze:

   a. Heave vs. time

   b. Temperature profile at different times

   c. Frost depth vs. time

6) 2 graphs showing a photograph of the sample after the second freeze and a water content profile at the same scale.

The test results are presented in Appendix A.

Frost-Susceptibility classification

The frost-susceptibility of the AKLNG soils were determined using ASTM D 5918-06 tentative criteria summarized in Table 2.

Frost-Susceptibility Classification	Symbol	8-h heave rate,mm/day
Negligible	NFS	<1
Very Low	VL	1 to 2
Low	L	2 to 4
Medium	M	4 to 8
High	H	8 to 16
Very High	VH	>16

Table 2.Tentative Frost-susceptibility Criteria (adapted from ASTM 5918-06)

Test Results

Table 3 summarizes the frost heave test results for the AKLNG soils obtained in 2016. Heave rate expressed in mm/day is reported for first and second freeze for each test. Figure 3 presents heave rate as a function of fines content. As anticipated, there is a trend of increasing heave rate with increasing fines content. Figure 4 shows the relationship of heave ratio (total heave/height of sample in percentage) and fines content. Two observations can be made: i) heave ratio increases almost linearly with increasing fines content and ii) the value of heave ratio is very small, less than 0.25% for a fines content of 20%.

The AKLNG soils sampled in 2016 display a very low frost-susceptibility as shown in Figure 5. According to the classification proposed by ASTM D 5918-06, the frost-susceptibility of the 8 soils tested depends upon the fines content (<0.075 mm) and would be classified as Negligible (NFS) for all soils tested, even at a fines content up to 20%.

The ability of freezing-induced water migration towards the freezing front can also be assessed by comparing maximum changes in water content after completion of the second freeze. Usually, frost-susceptible soils are characterized by a substantial increase in water content owing to the presence of ice lenses. It is not uncommon to observe water content increase of several tens of percent (30 to 60%). Table 3 also summarizes the increase in water content after the second freeze and indicates clearly that the AKLNG soils are non-frost-susceptible since the increase in water content is less than 1.7 percent.

Test no (Sample)	Fines % < 0.075 mm	Heave rate 1st Freeze mm/day	Heave rate 2nd Freeze mm/day	Relative Heave h/Ho (%)	ΔW_{max}, %
1 (B147-B148-B149)	6.1	0.18	0.08	0,08	1.0
2 (B152)	4.8	0.06	0.15	0,11	0.5
3 (B156-B157)	5.3	0.23	0.23	0,15	0.5
4 (B169)	3.7	0	0	0,00	0.25
5 (B170-B171)	3.7	0.05	0.06	0,03	0
6 (B172)	11.7	0.12	0.12	0,15	1.5
7 (B197)	7.8	0,145	0.145	0,07	1.2
8 (<5mm,20%Fines)	20.2	0,16	0.31	0,24	1.7

Table 3. Summary of freeze tests results for AKLNG soils.

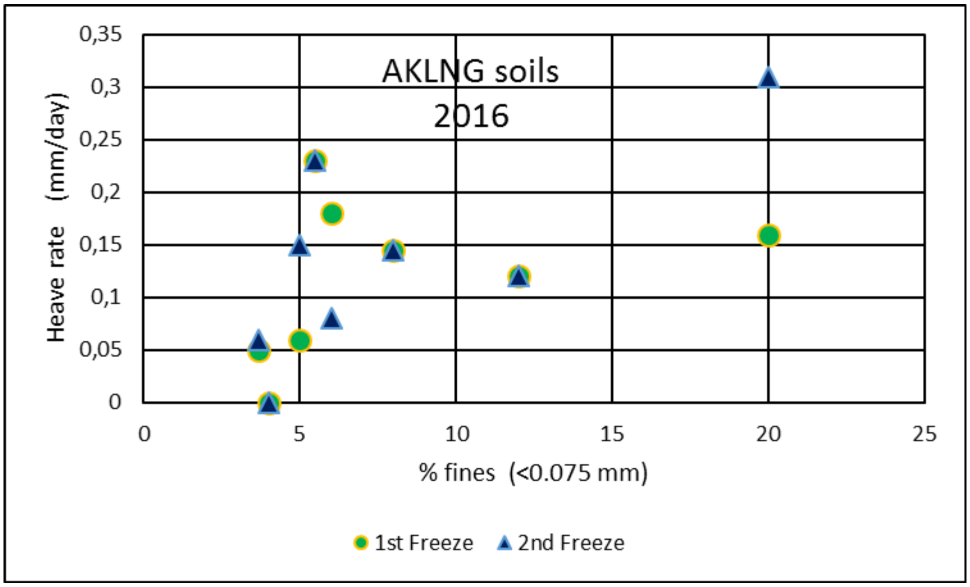


Figure 3 Heave rate vs. fines content for AKLNG soils tested in 2016

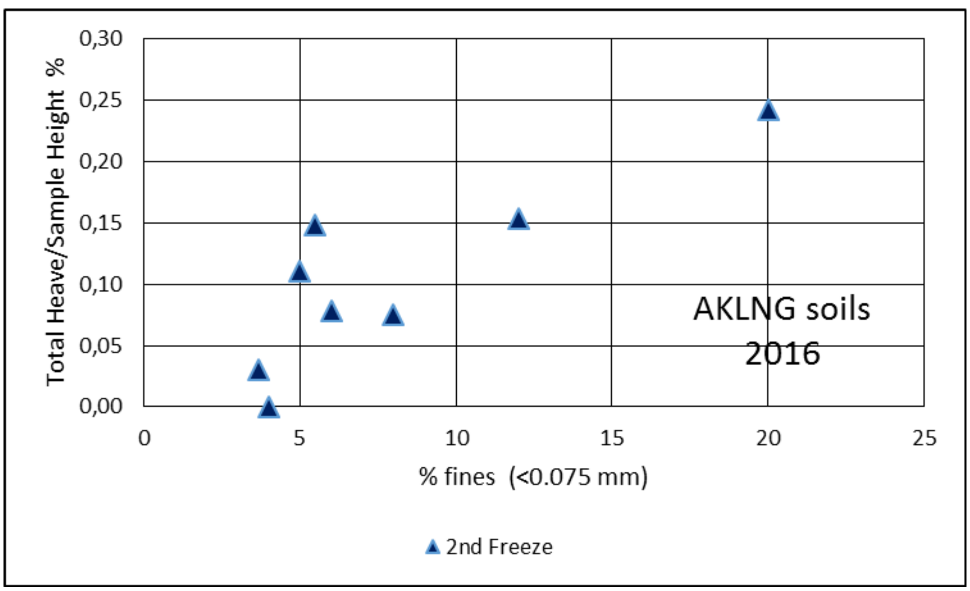


Figure 4. Heave ratio vs. fines content for AKLNG soils (2016)

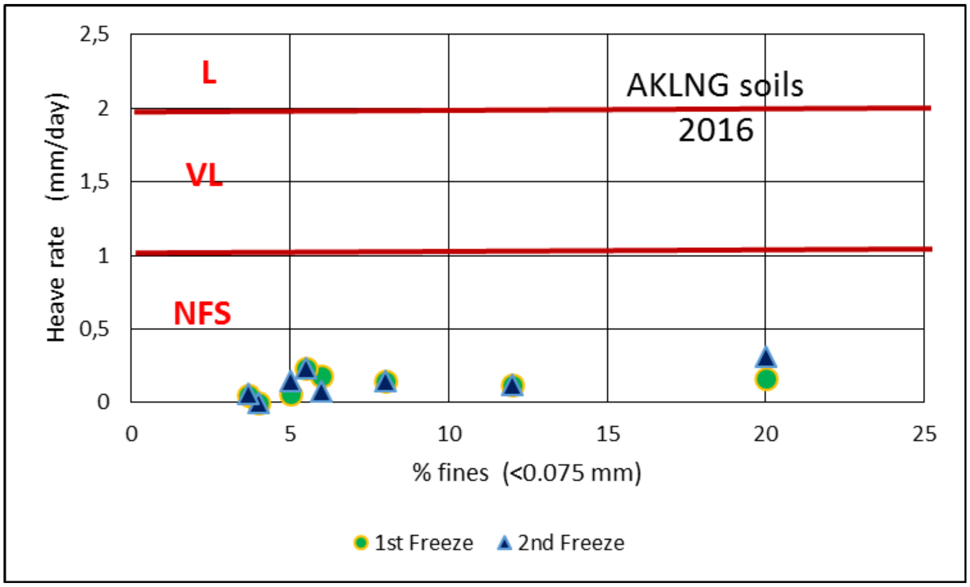


Figure 5. Frost-Susceptibility of tested 2016 AKLNG soils (ASTM 5918-06)

Comparison with frost heave tests on AKLNG soils taken in 2015

A report dated April 2016 summarized frost-heave test results for AKLNG soils obtained in 2015. Figures 6 and 7 compare the frost heave tests for the two sampling campaigns. It is noted that soils tested in 2015 included as-sampled specimens as well as blended specimens adjusted for fines content. Clearly, the AKLNG soils sampled in 2016 display significantly less frost heave than soils tested in 2015.

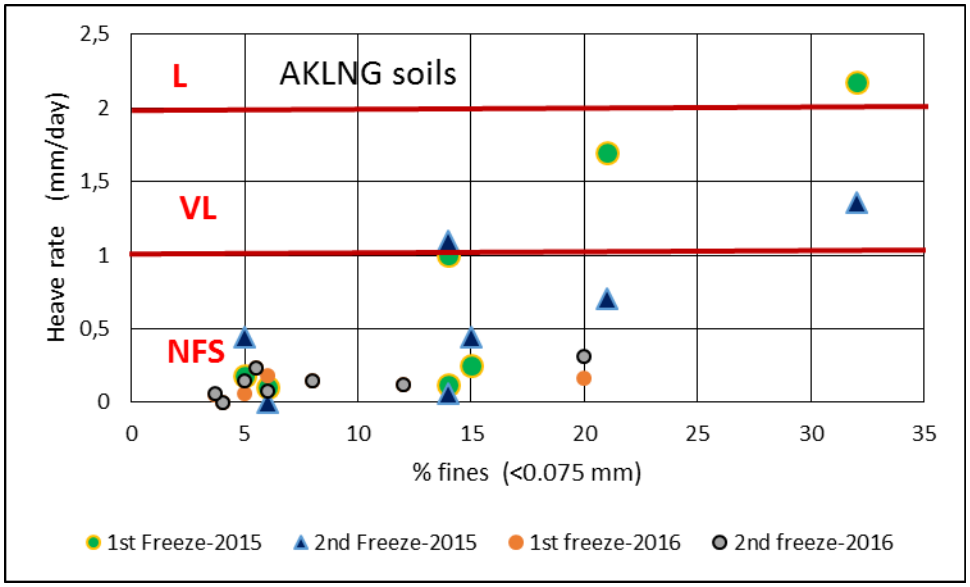


Figure 6 Comparison of frost heave rate for AKLNG soils tested in 2015 and 2016

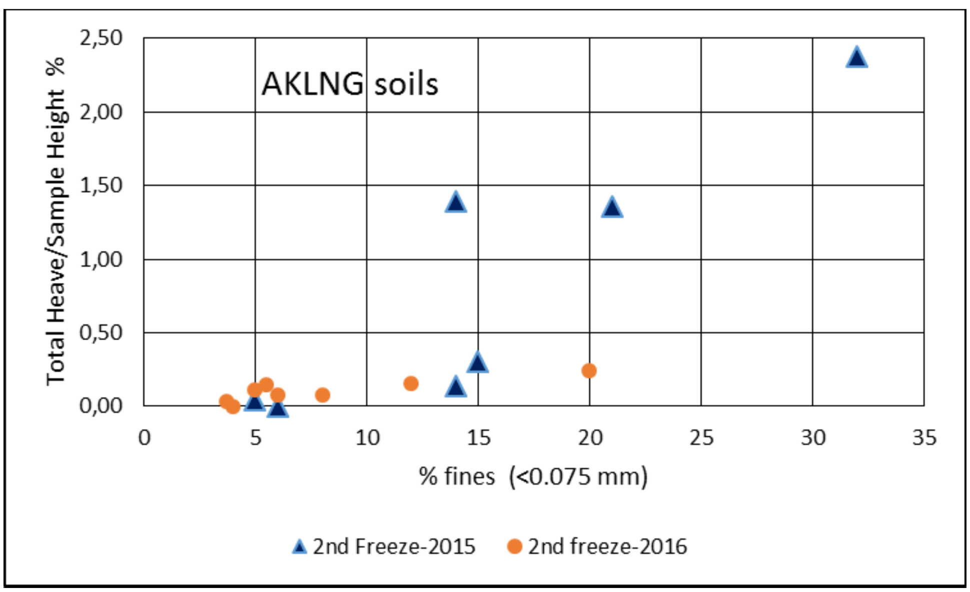


Figure 7. Comparison of Relative heave for AKLNG soils (2015 and 2016)

In conclusion, it can be stated that the AKLNG soils tested in 2016 are non-frost-susceptible with fines up to 20%.

References

Konrad, J.-M. 1999. Canadian Geotechnical J. 36, 403-417

Konrad, J.-M. 2005. Canadian Geotechnical J. 42, 38-50

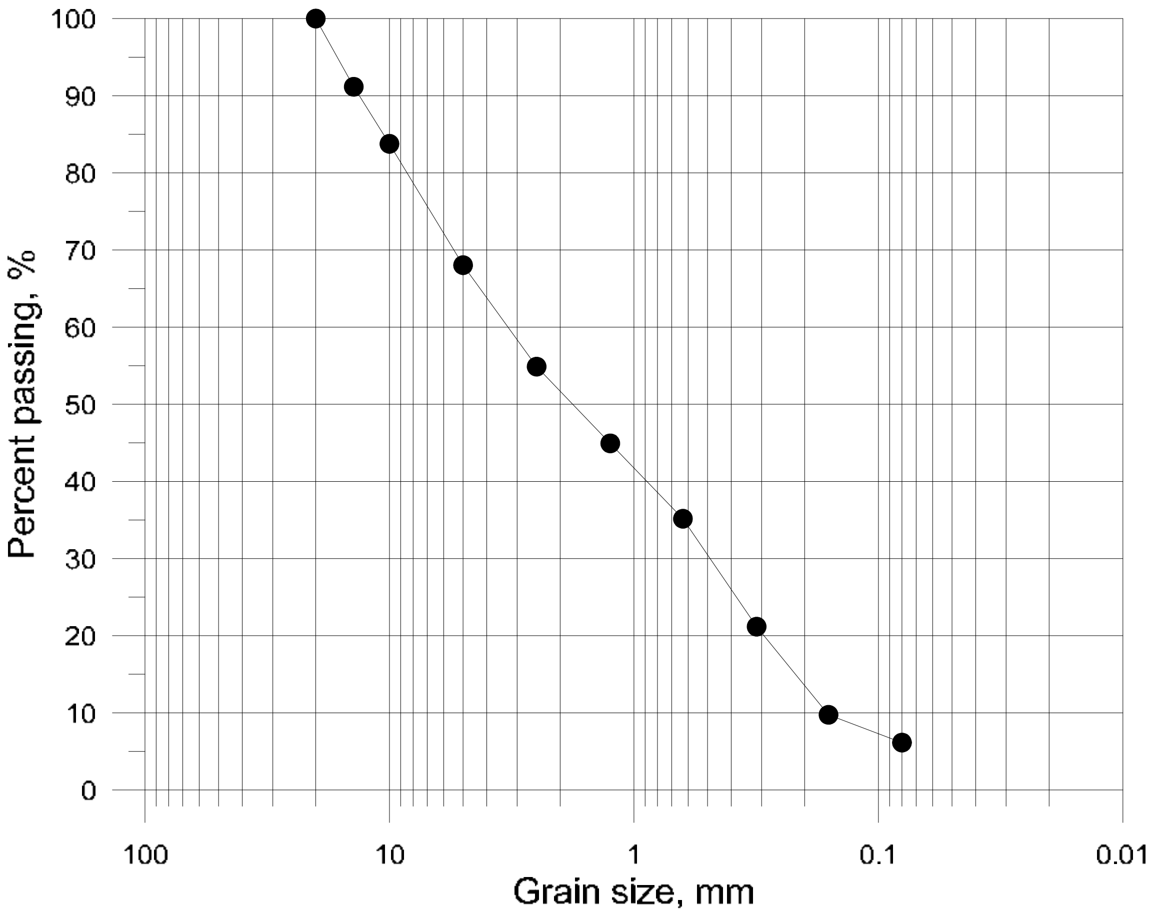
Konrad, J.-M. April 2016. **Frost heave data for AKLNG soils.** Report submitted to Fugro Consultants Inc.

APPENDIX A: Frost-Heave Test results

For AKLNG soils sampled in 2016

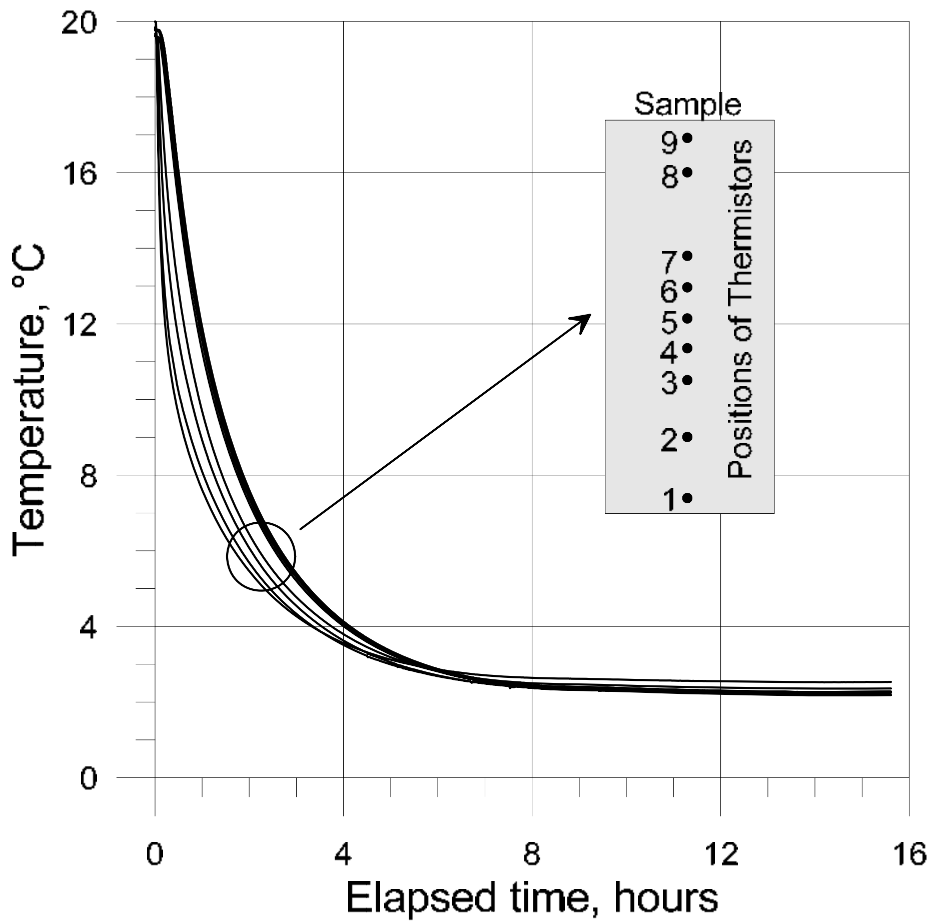
Test 1; samples B-147, B-148, B-149

Sieve analysis



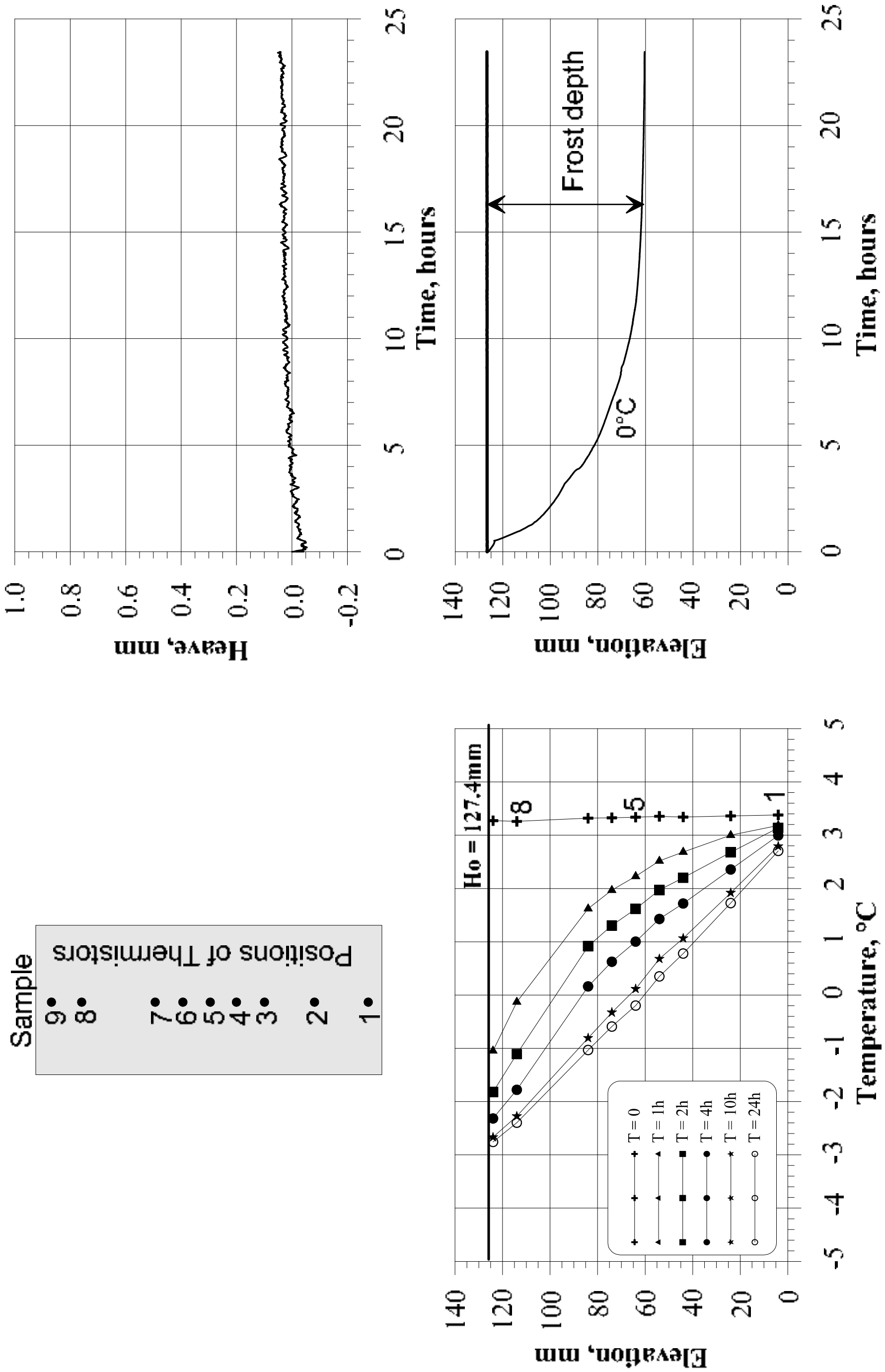
1; B-147, B-148, B-149

Step 1, conditioning



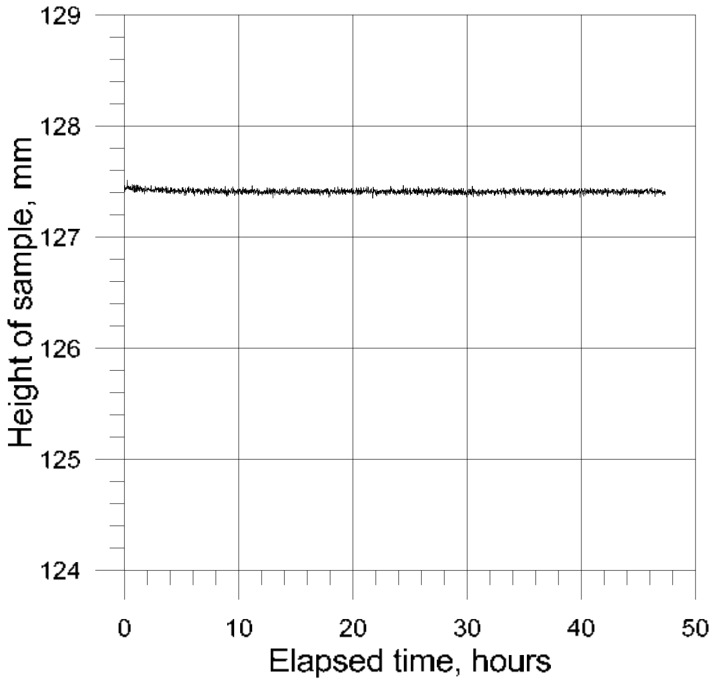
1; B-147, B-148, B-149

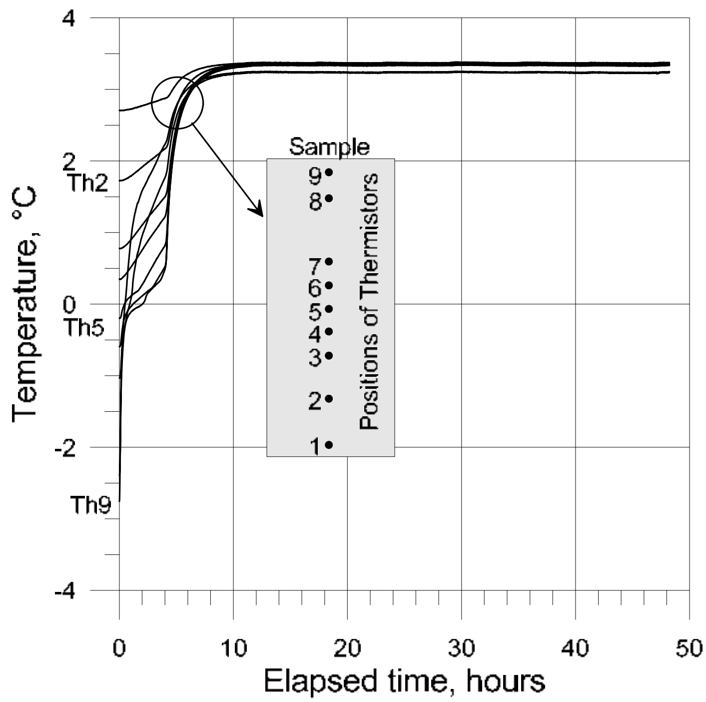
Step 2, 1st freeze



1; B-147, B-148, B-149

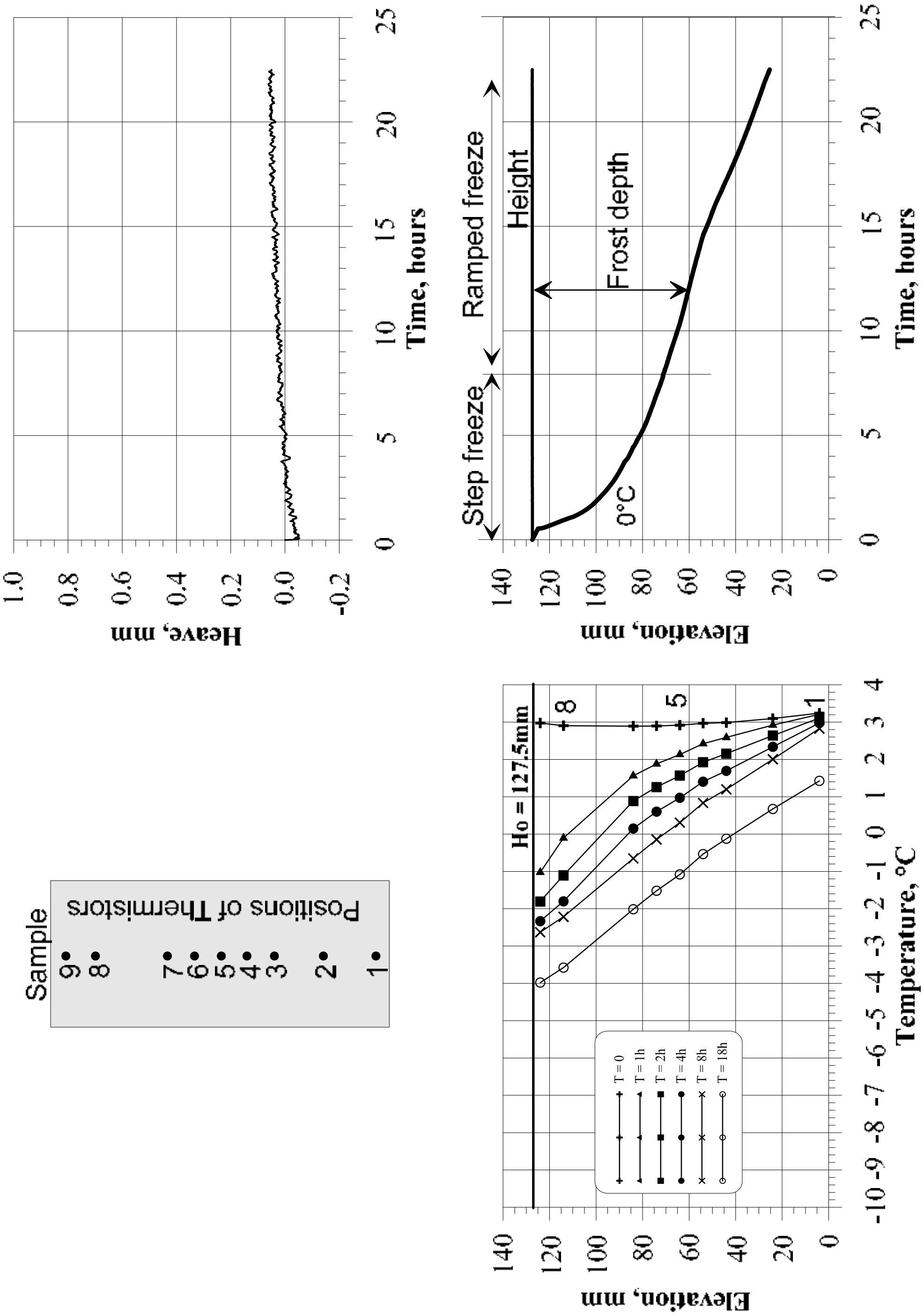
Step 3, Thaw



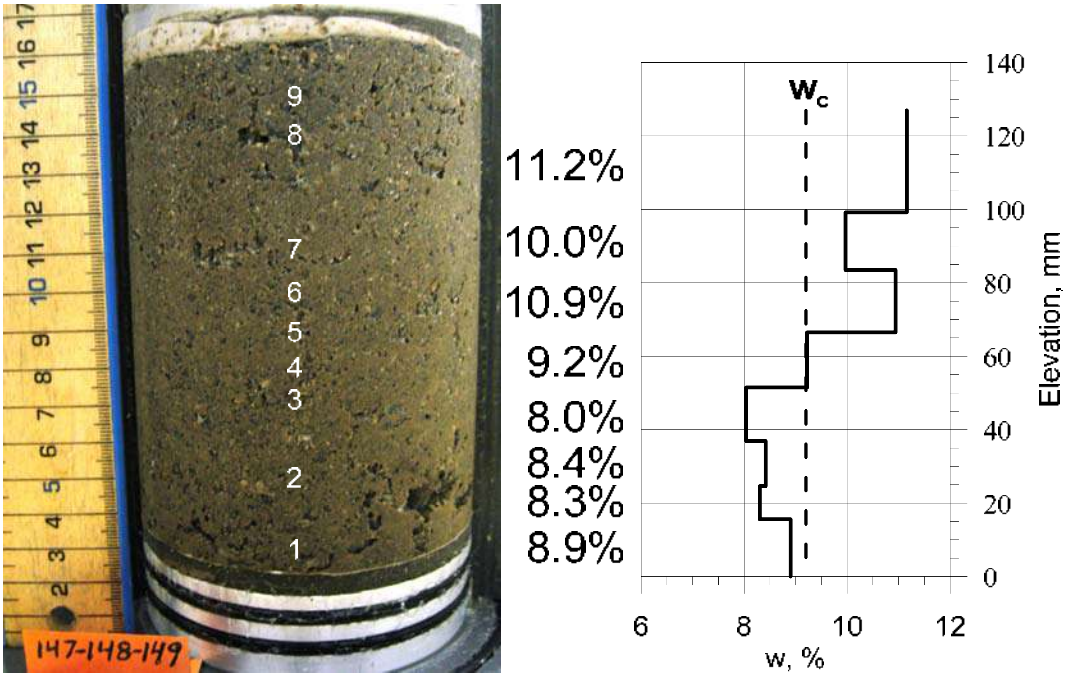


1; B-147, B-148, B-149

Step 4, 2nd freeze+ ramping freeze

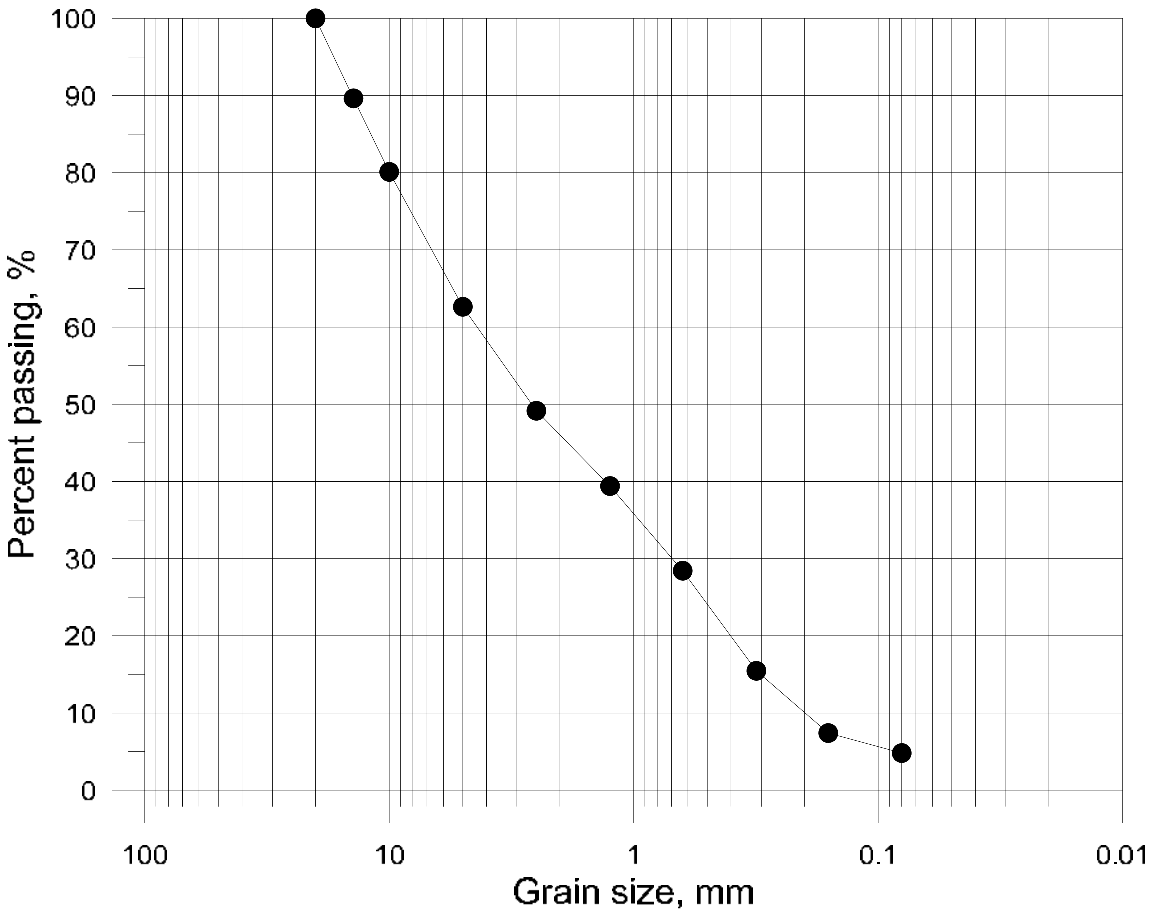


1; B-147, B-148, B-149



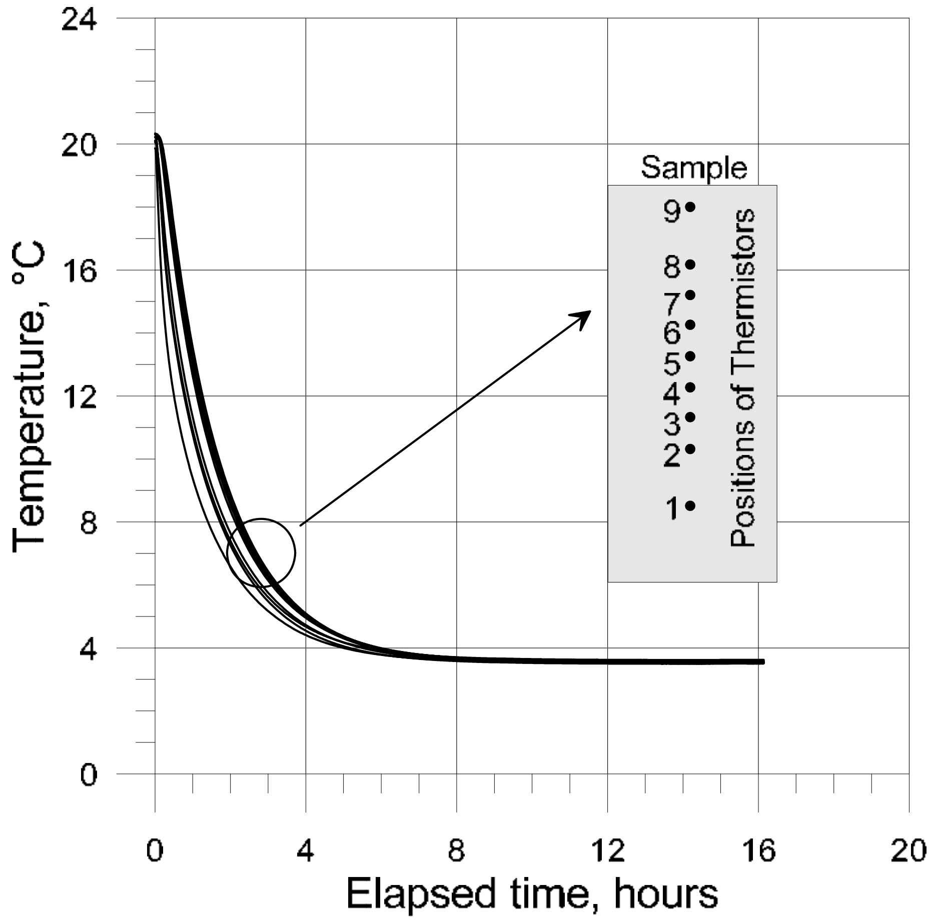
Test 2; sample B-152

Sieve analysis



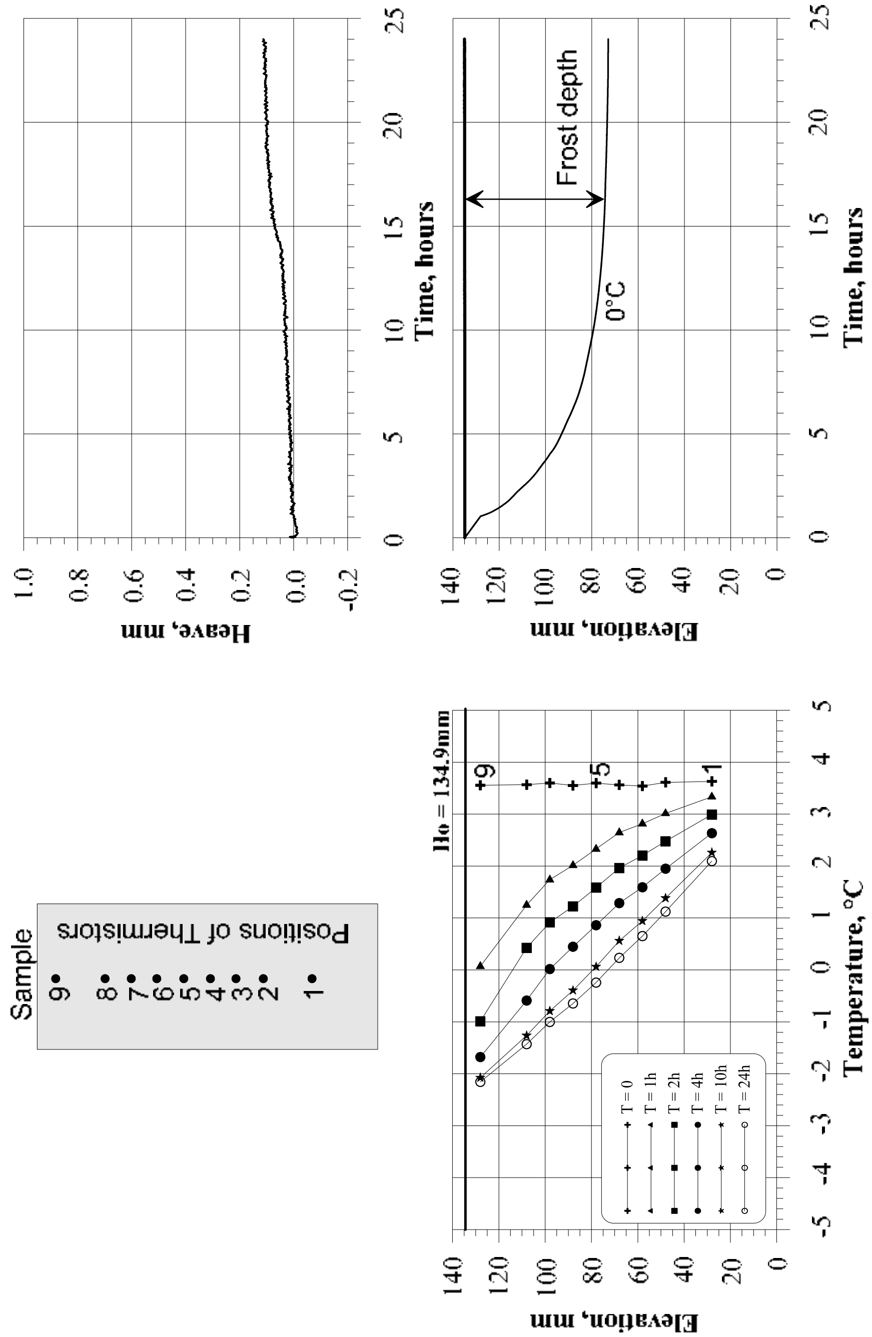
2; B-152

Step 1, conditioning



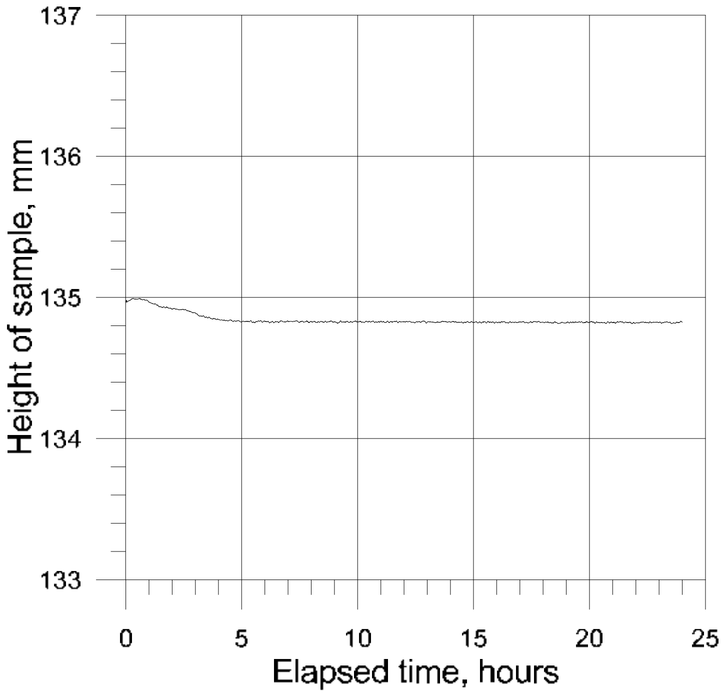
2; B-152

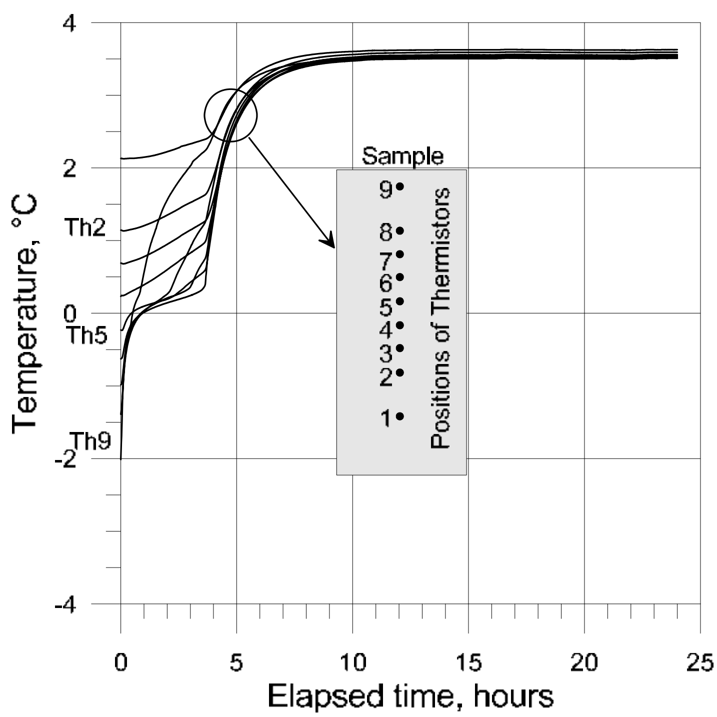
Step 2, 1st freeze



2; B-152

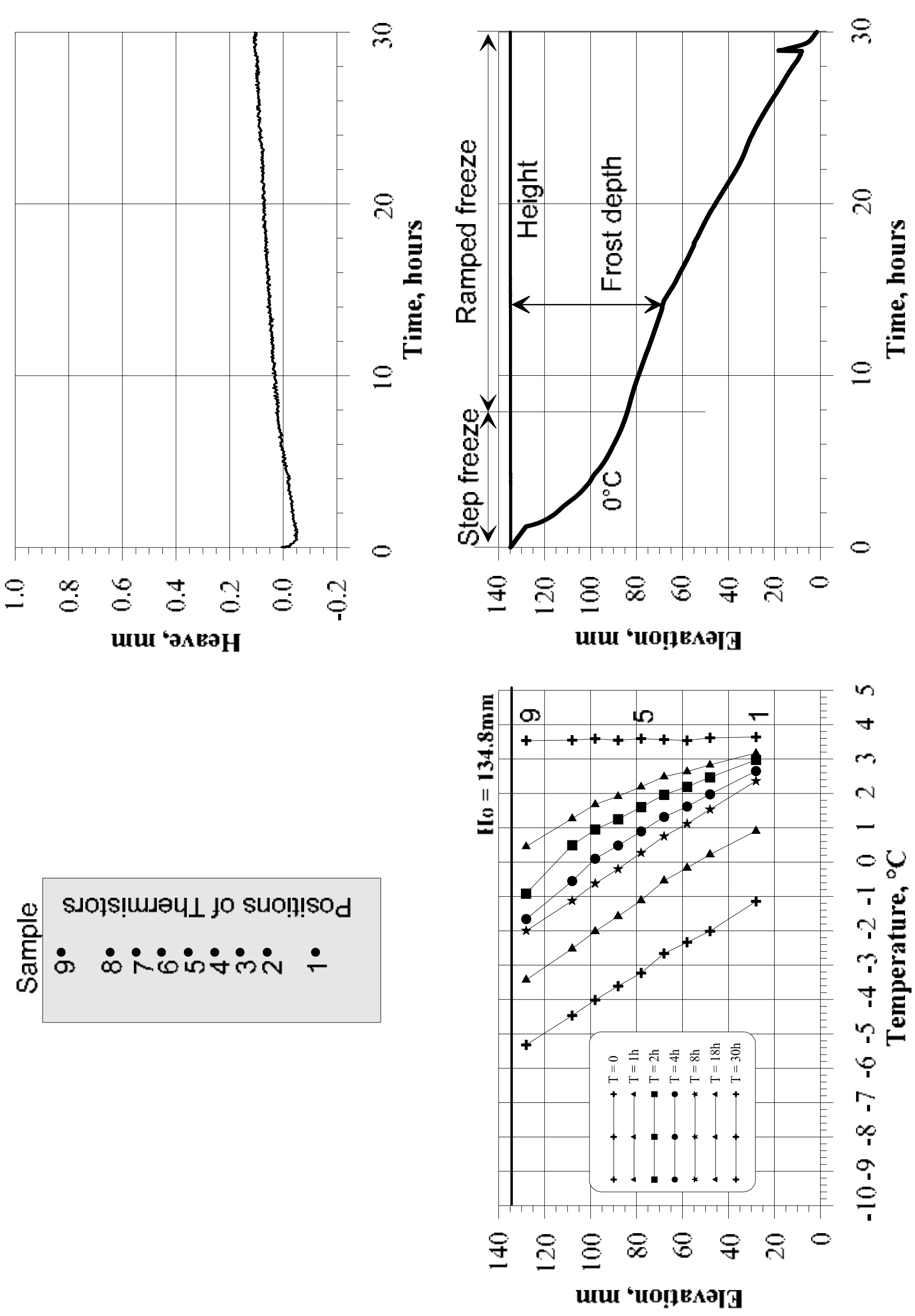
Step 3, Thaw



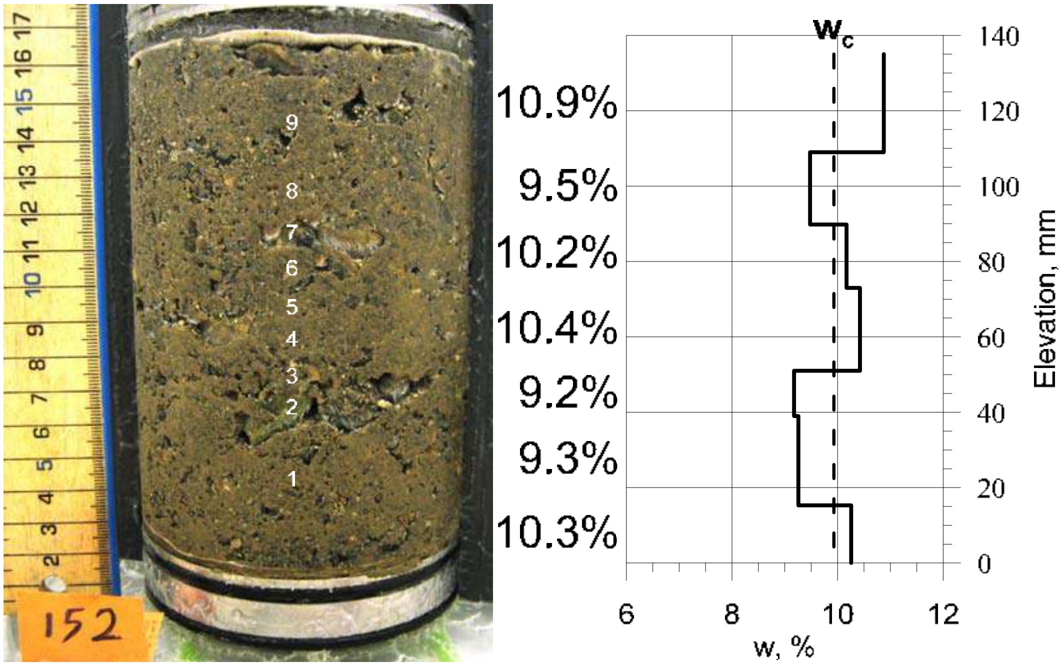


2; B-152

Step 4, 2nd freeze+ ramping freeze

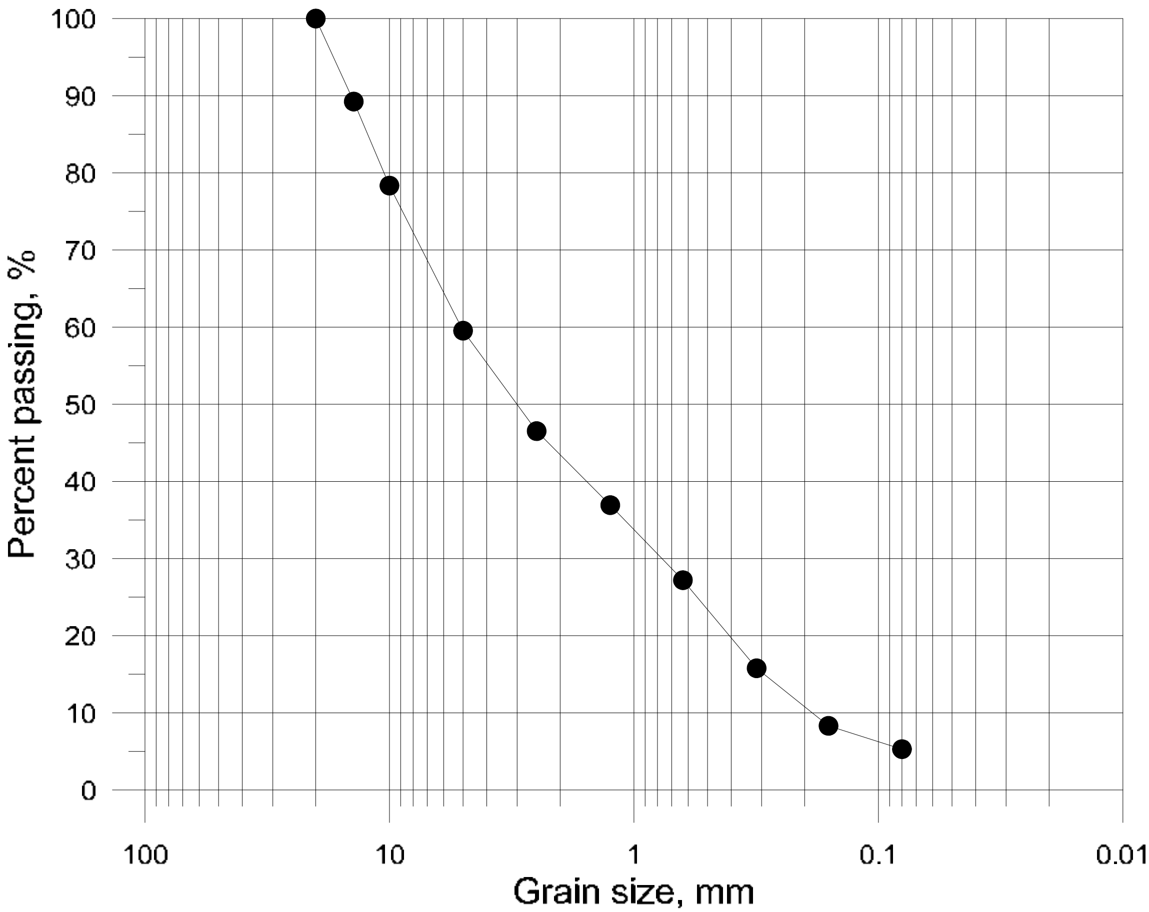


2; B-152


152
9
8
7
6
5
4
3
2
1
10.9%
9.5%
10.2%
10.4%
9.2%
9.3%
10.3%
w_c
140
120
100
80
60
40
20
0
Elevation, mm
6
8
10
12
w, %

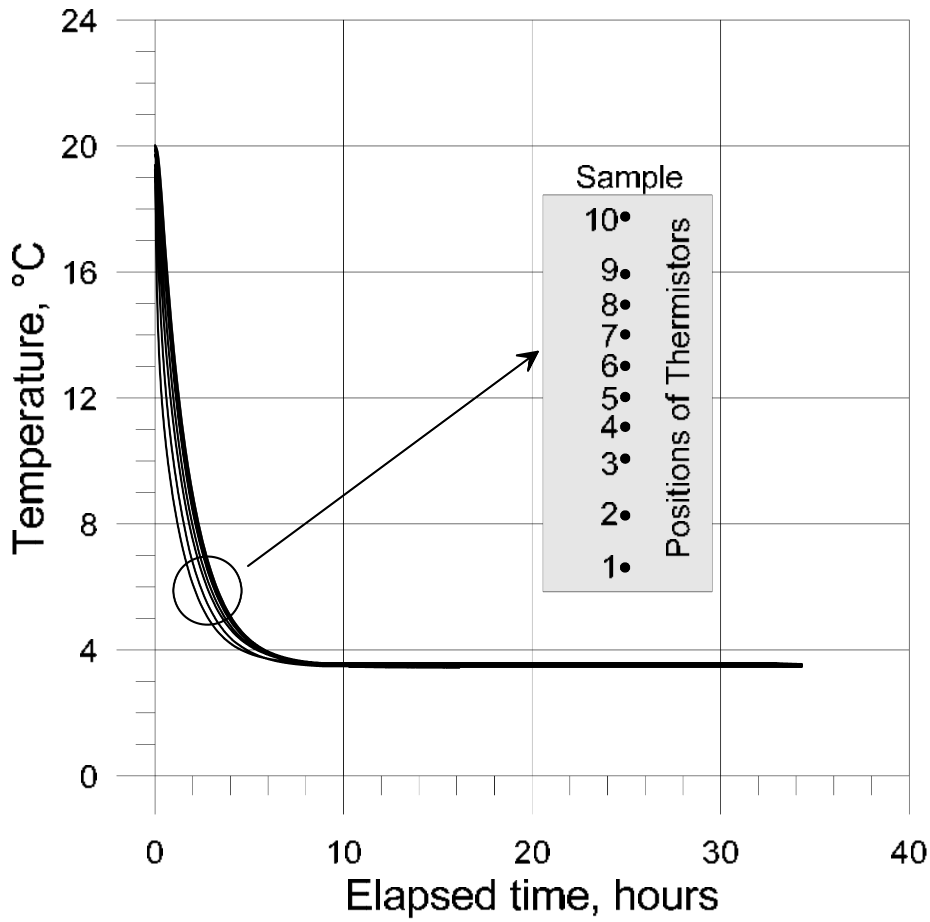
Test 3; samples B-156, B-157

Sieve analysis



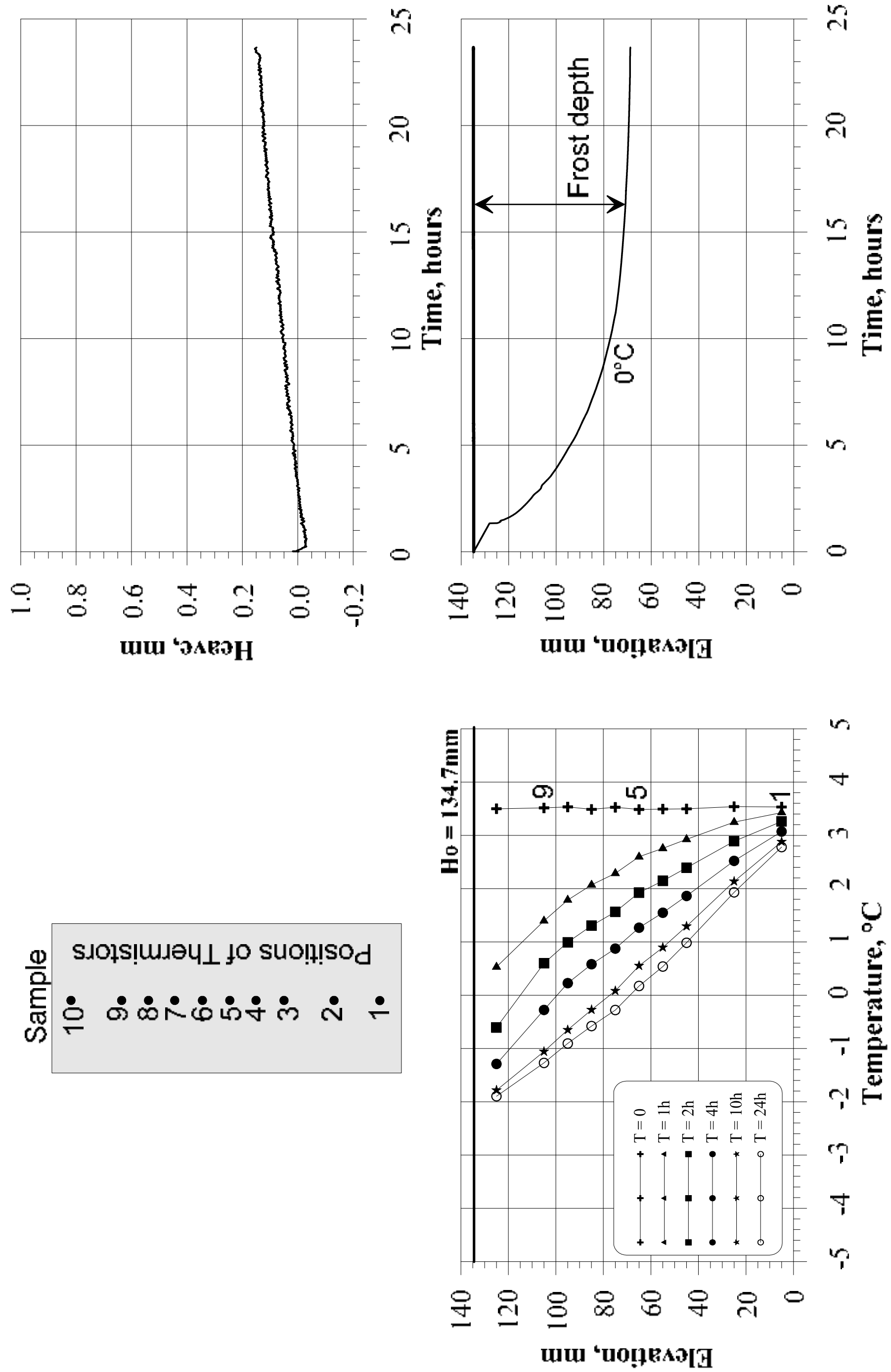
3; B-156, B-157

Step 1, conditioning



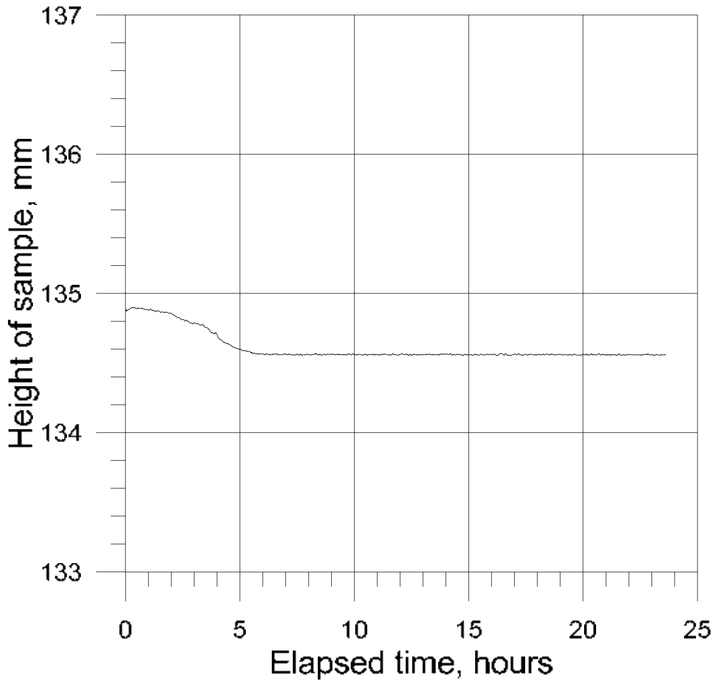
3; B-156, B-157

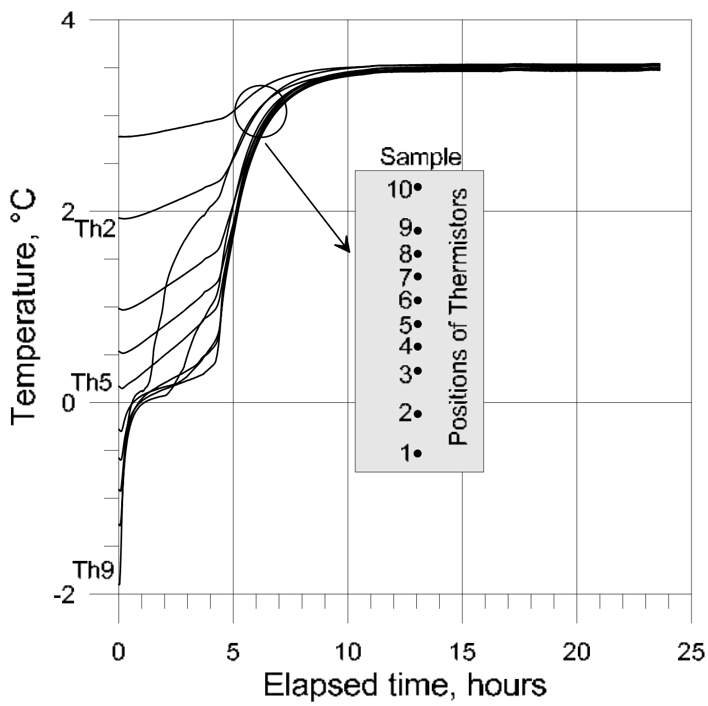
Step 2, 1st freeze



3; B-156, B-157

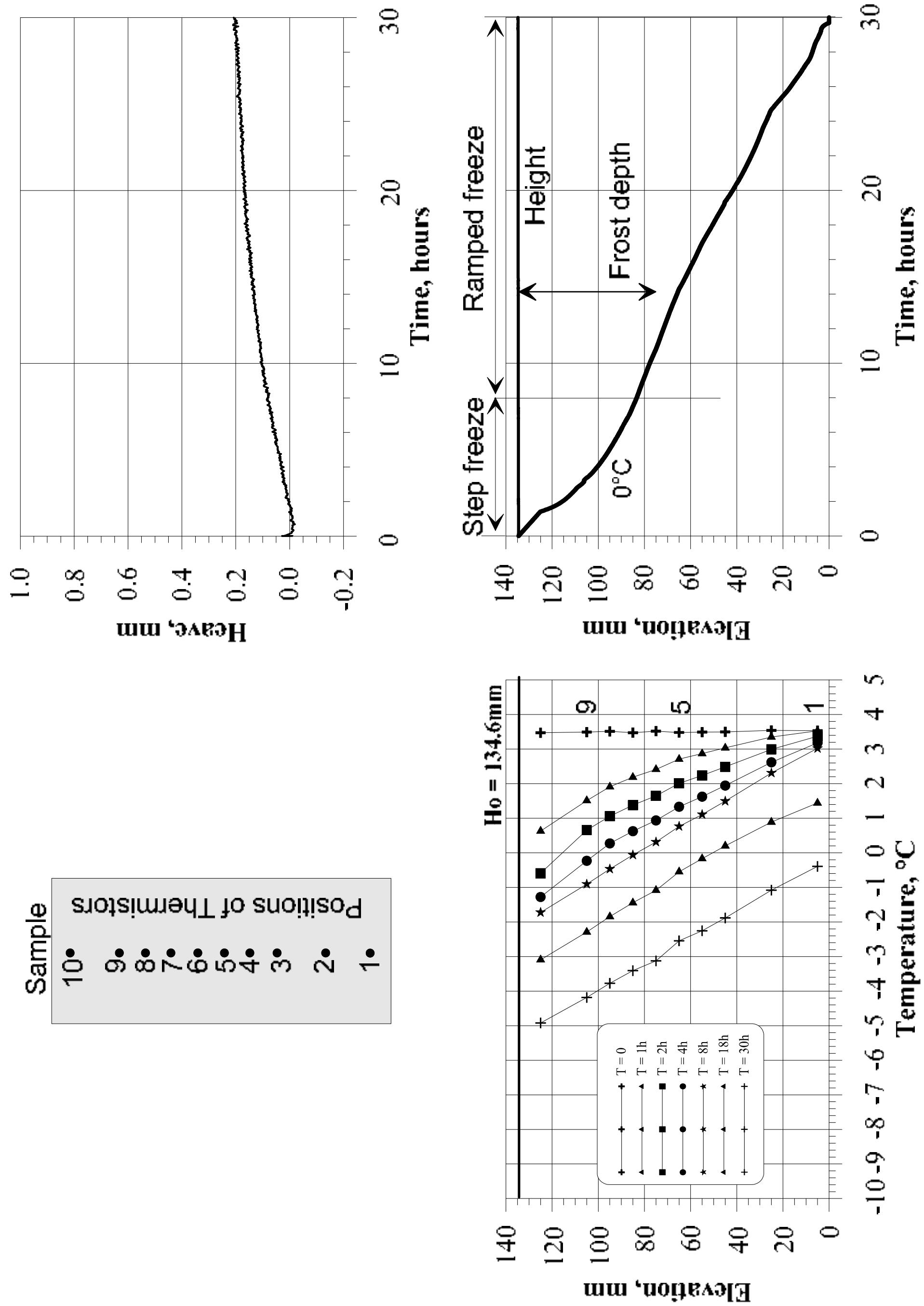
Step 3, Thaw



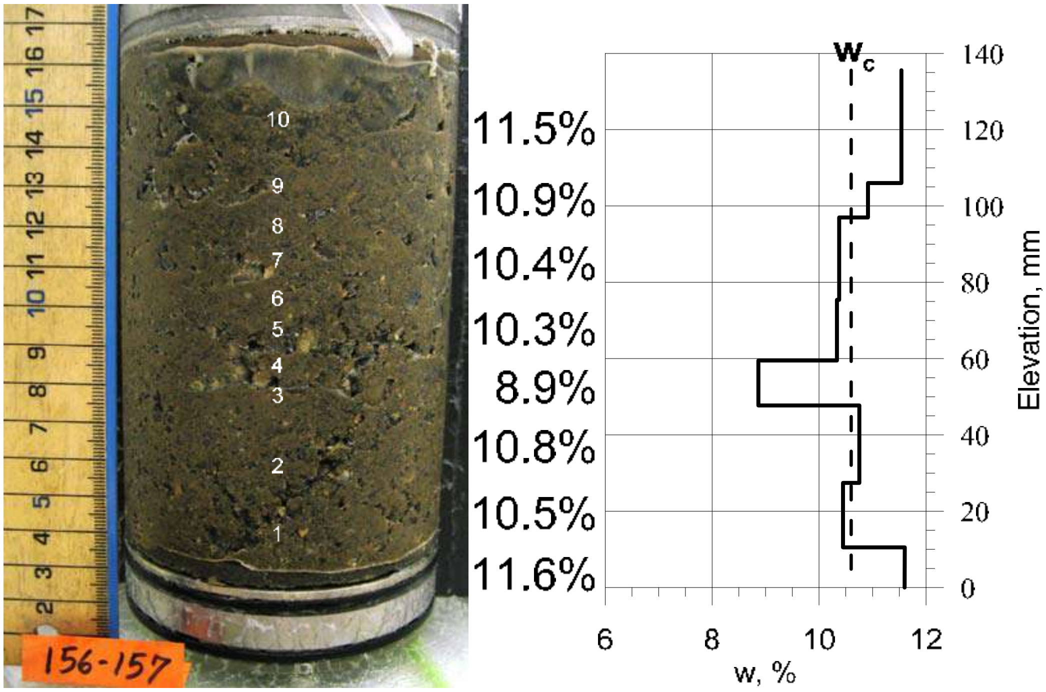


3; B-156, B-157

Step 4, 2nd freeze+ ramping freeze

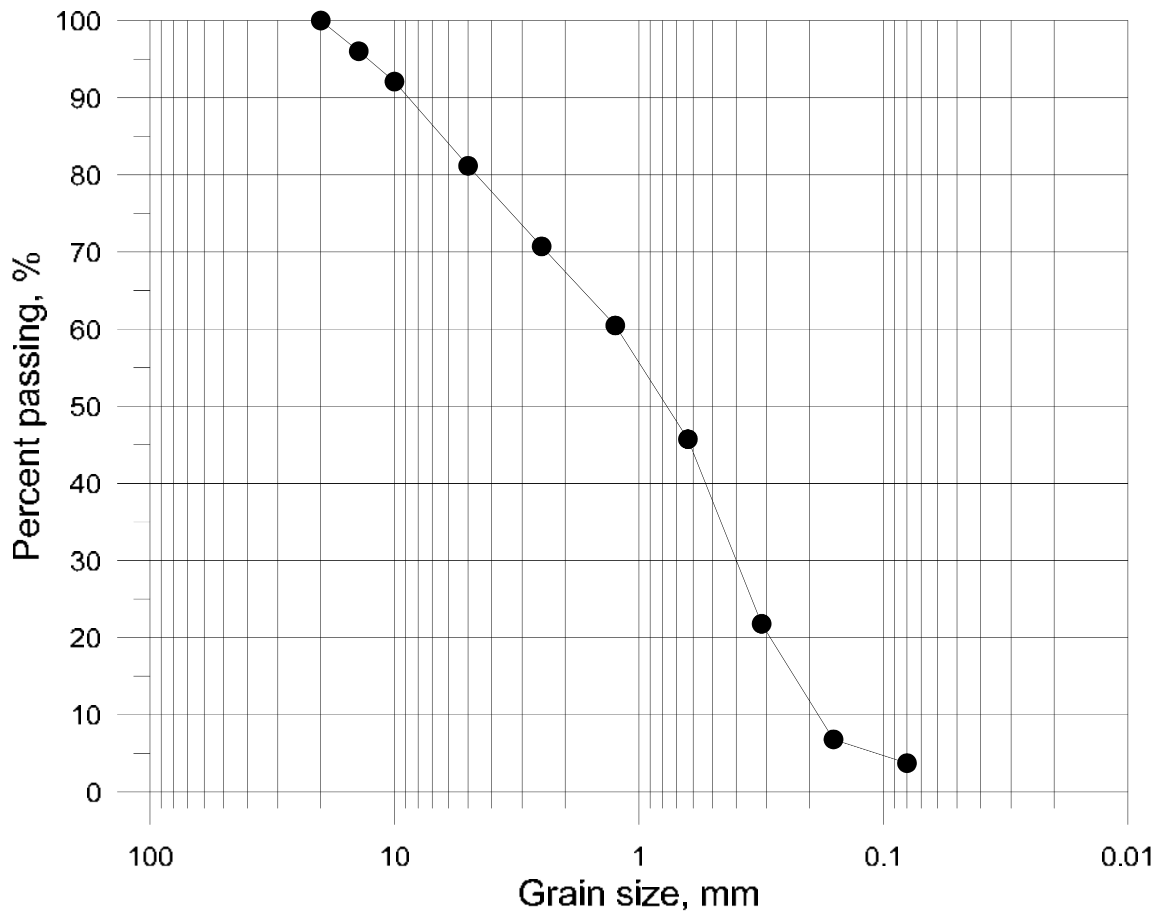


3; B-156, B-157


156-157
10
9
8
7
6
5
4
3
2
1
11.5%
10.9%
10.4%
10.3%
8.9%
10.8%
10.5%
11.6%
w_c
140
120
100
80
60
40
20
0
Elevation, mm
6
8
10
12
w, %

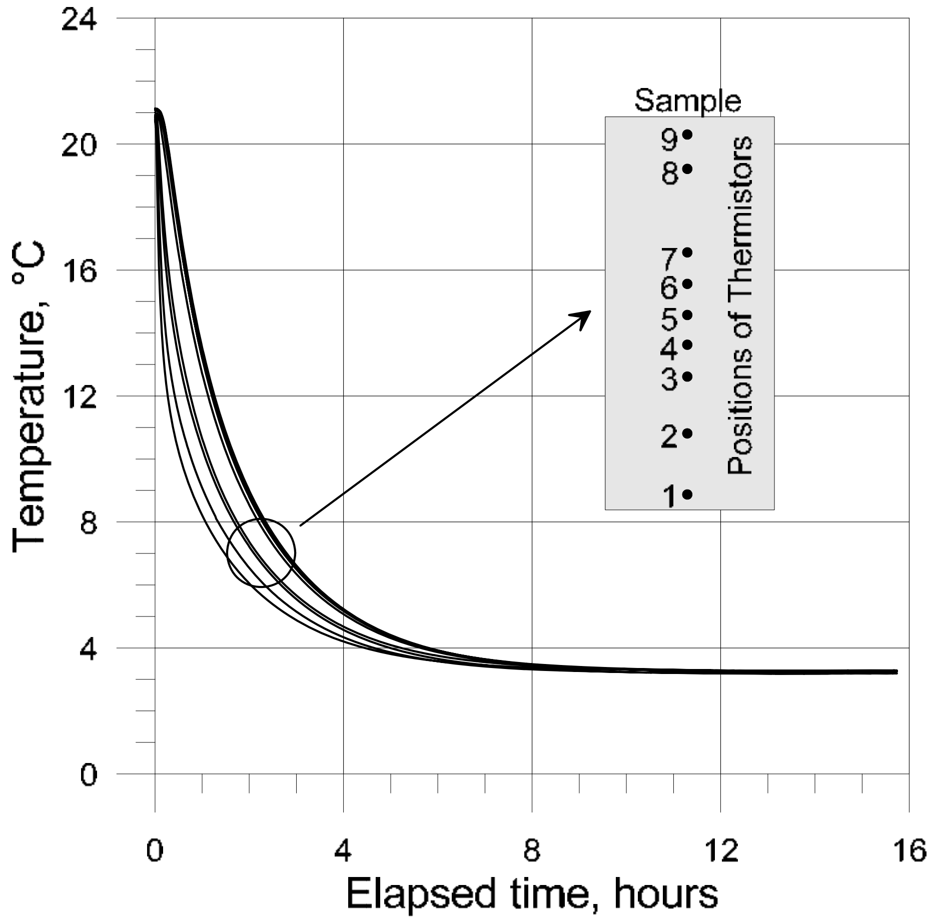
Test 4; sample B-169

Sieve analysis



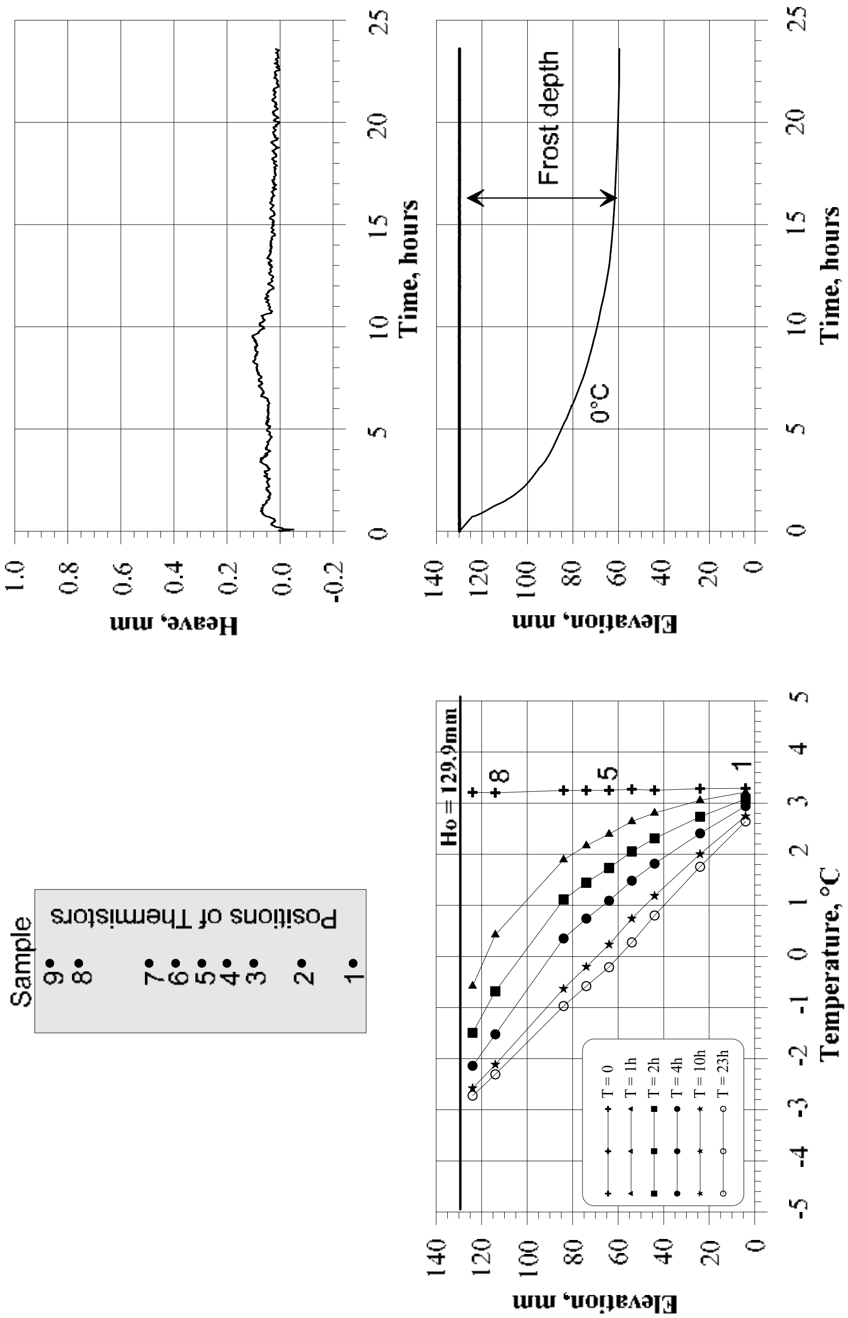
4; B-169

Step 1, conditioning



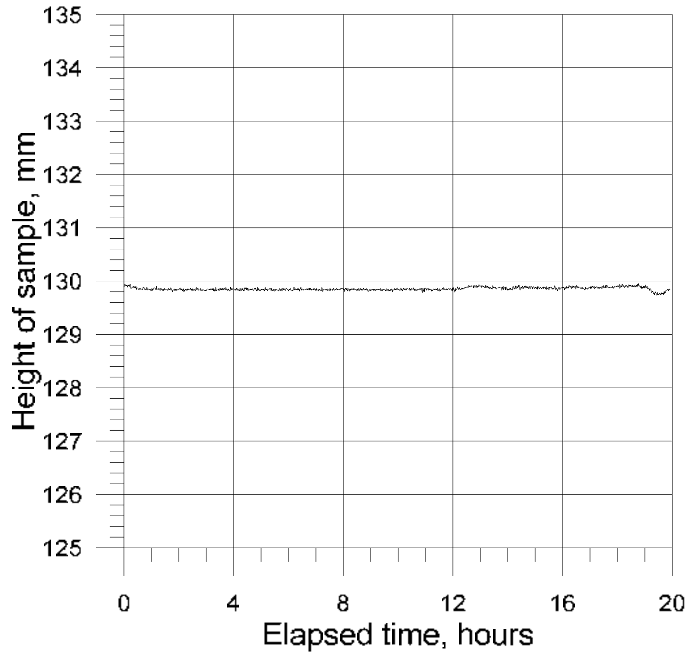
4; B-169

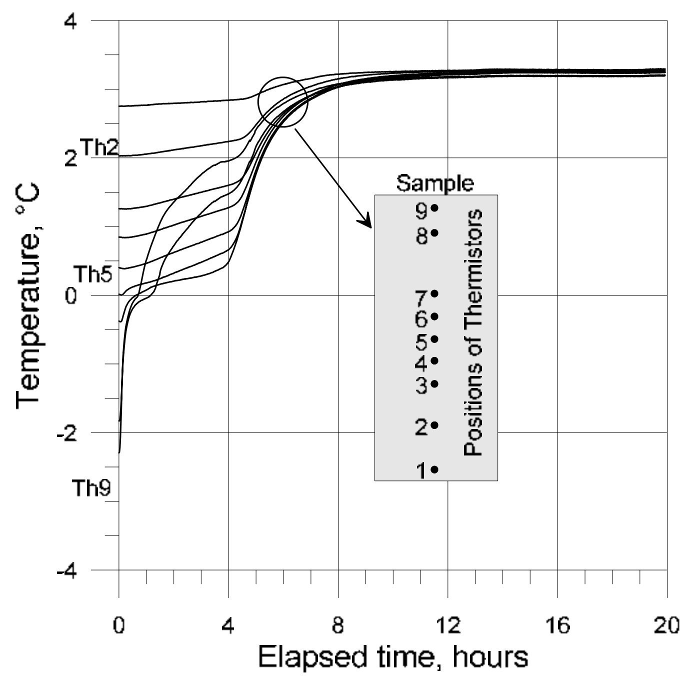
Step 2, 1st freeze



4; B-169

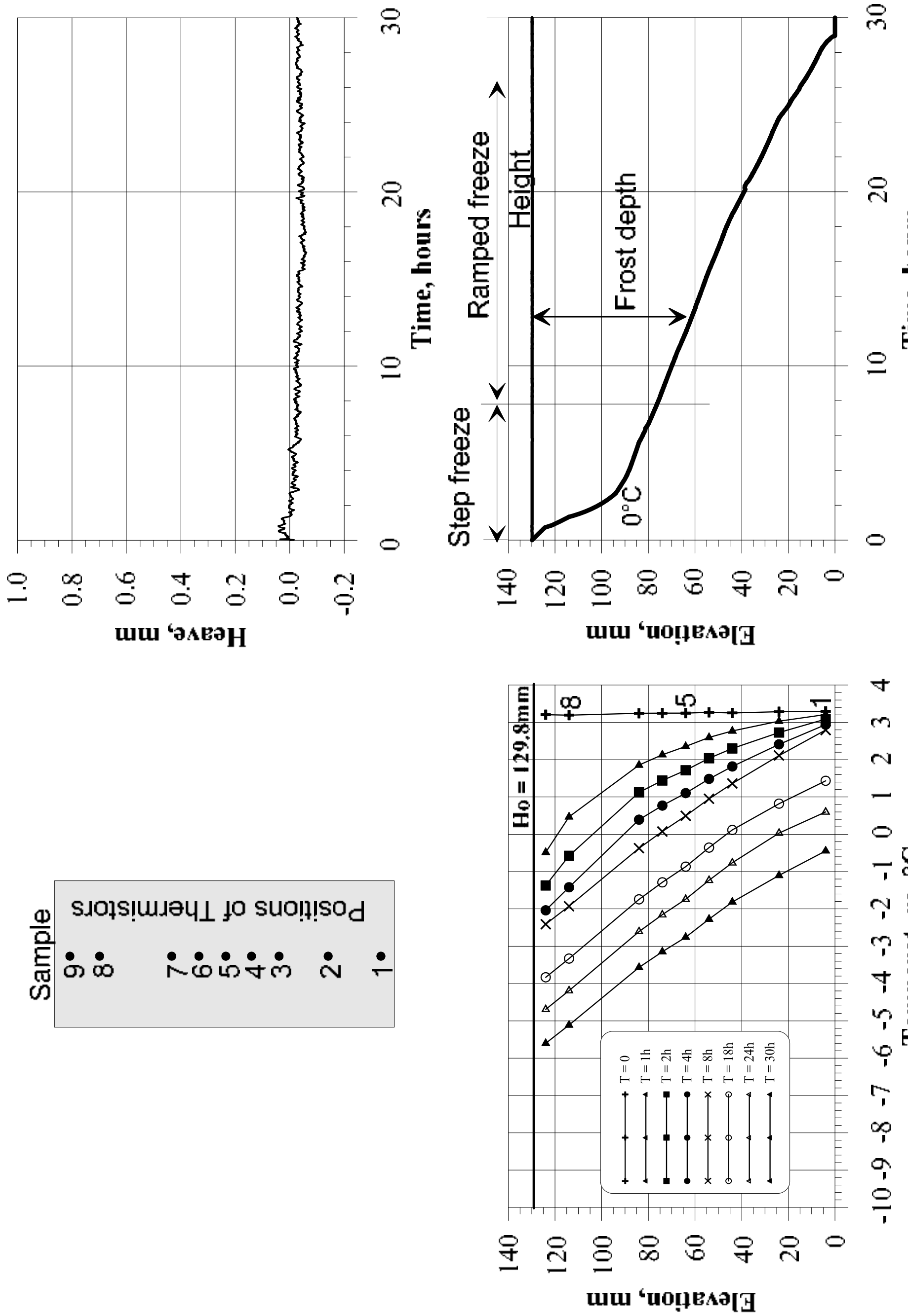
Step 3, Thaw



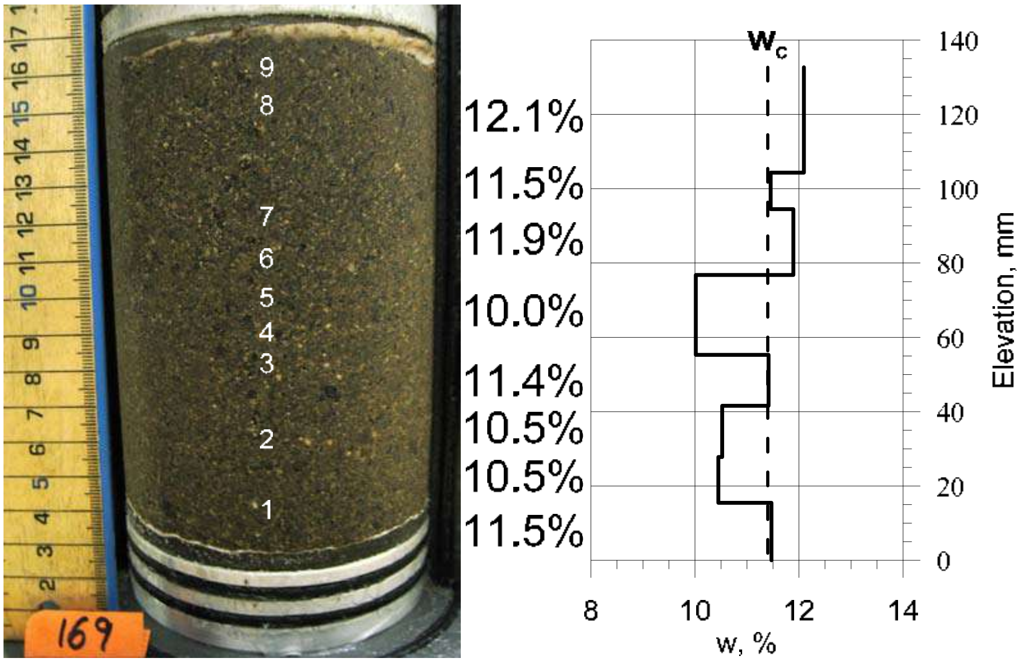


4; B-169

Step 4, 2nd freeze+ ramping freeze

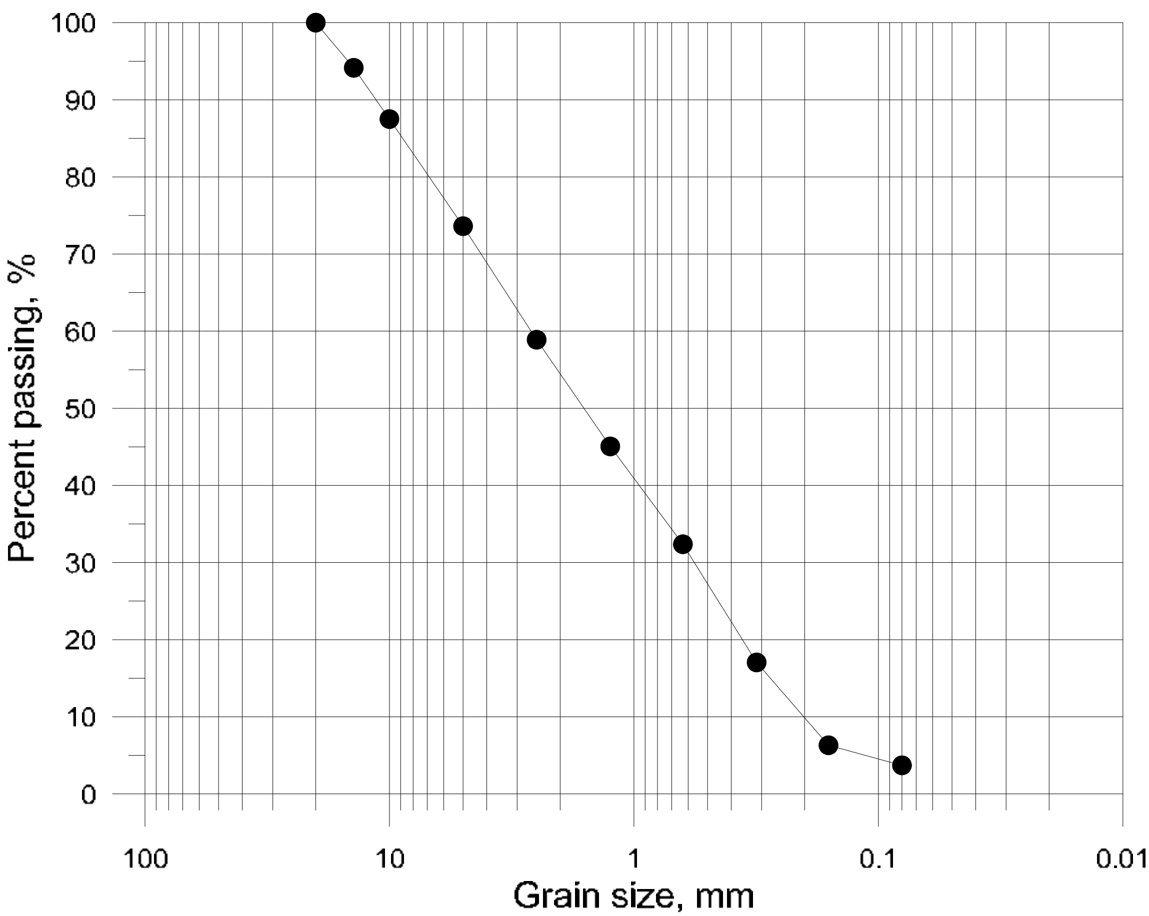


4; B-169


9
8
7
6
5
4
3
2
1
169
12.1%
11.5%
11.9%
10.0%
11.4%
10.5%
10.5%
11.5%
w_c
140
120
100
80
60
40
20
0
Elevation, mm
8
10
12
14
w, %

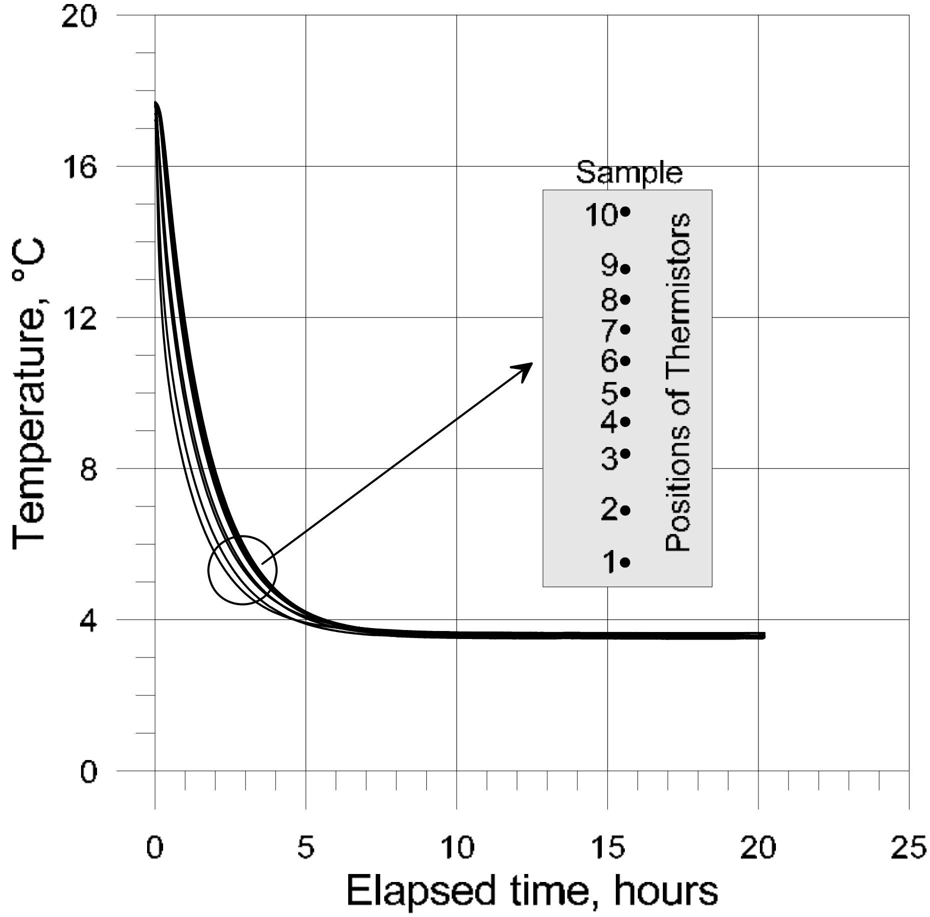
Test 5; samples B-170, B-171

Sieve analysis



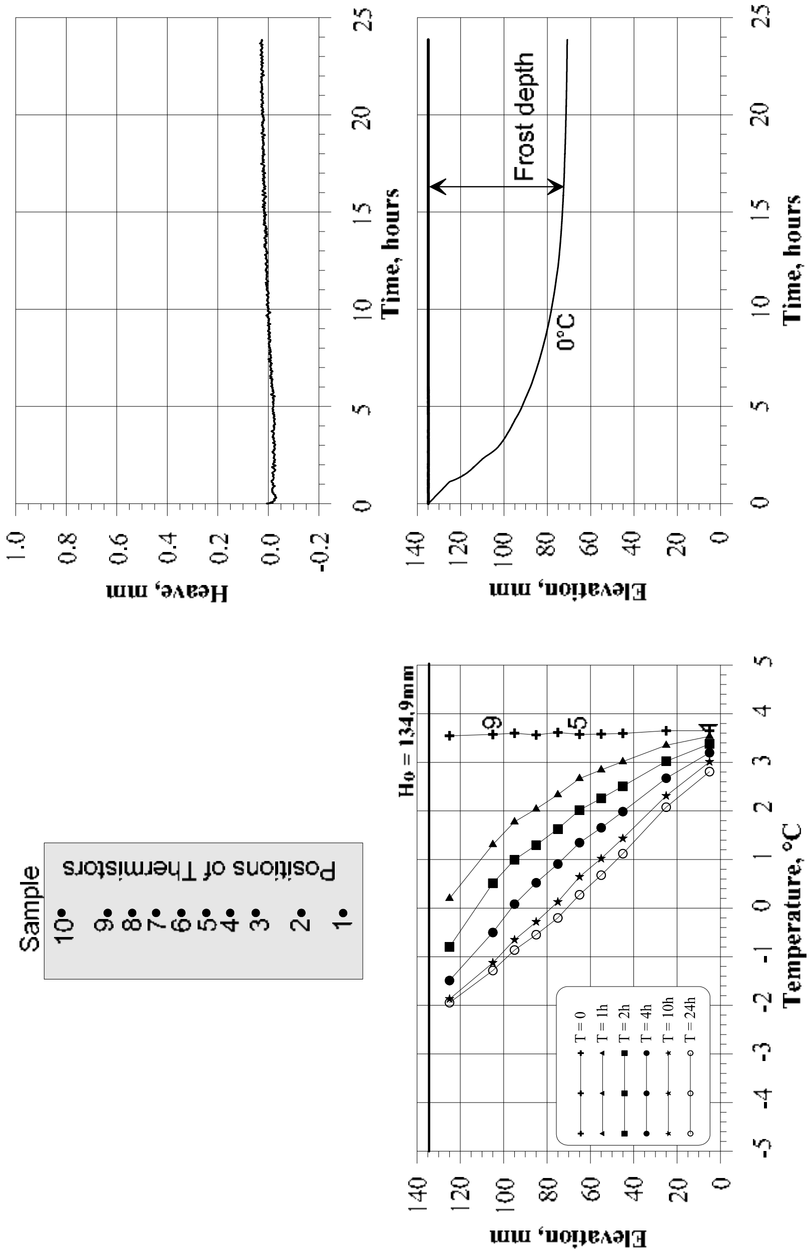
5; B-170, B-171

Step 1, conditioning



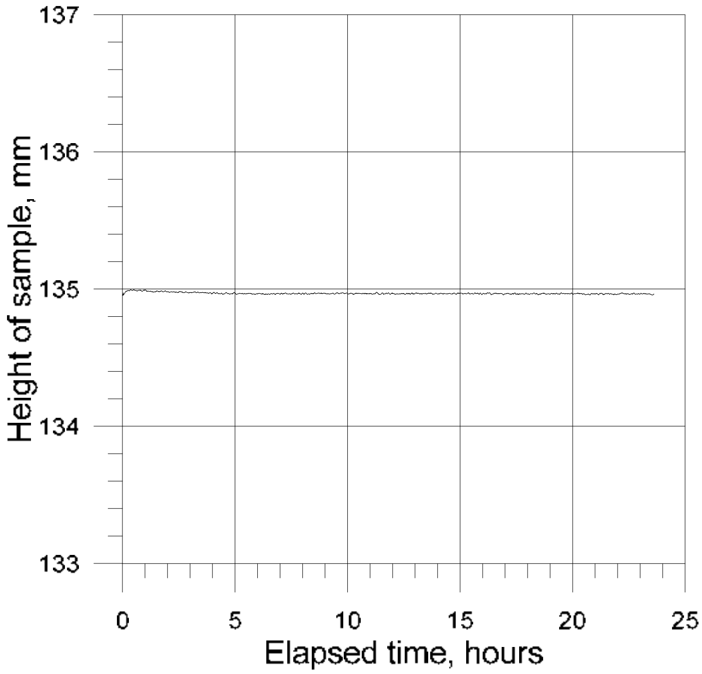
5; B-170, B-171

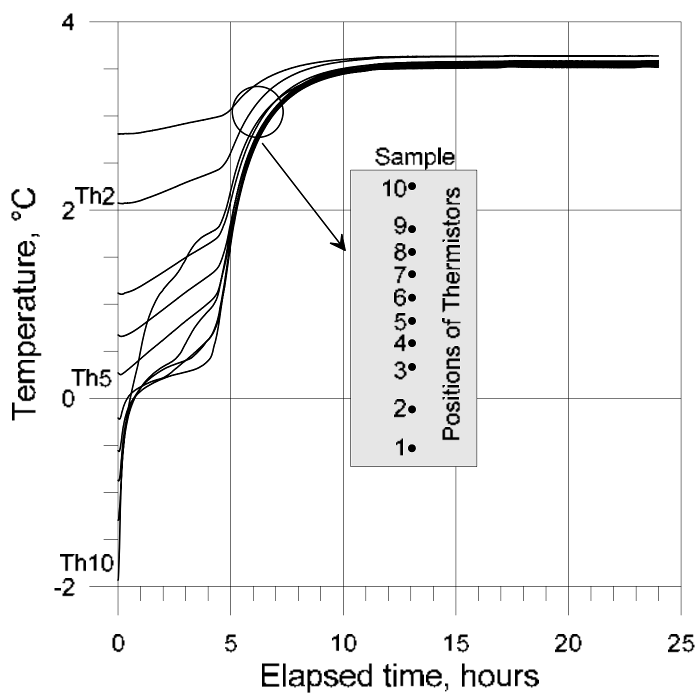
Step 2, 1st freeze



5; B-170, B-171

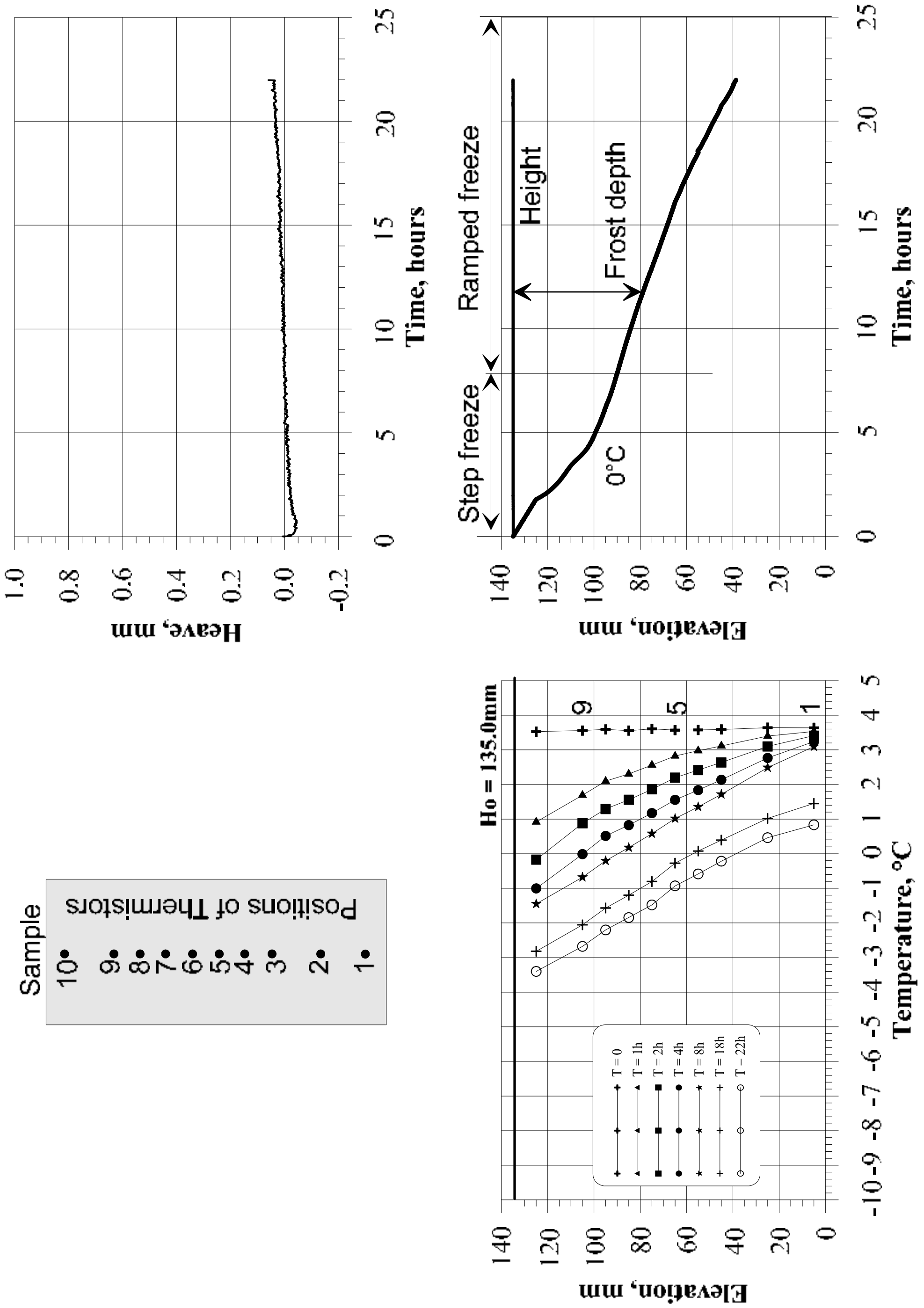
Step 3, Thaw



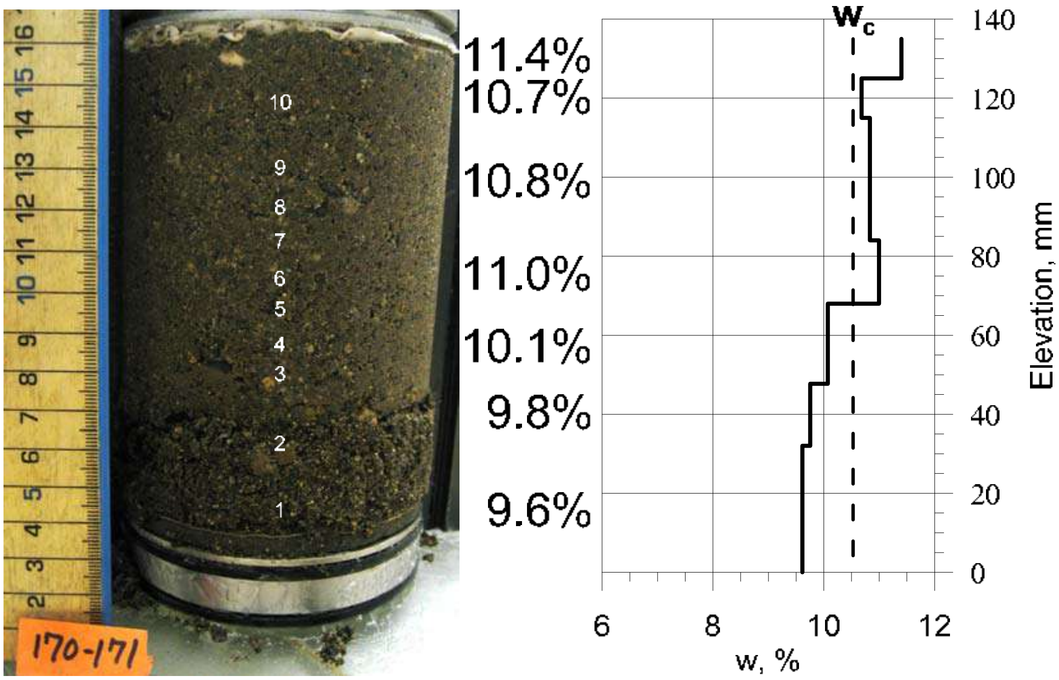


5; B-170, B-171

Step 4, 2nd freeze+ ramping freeze

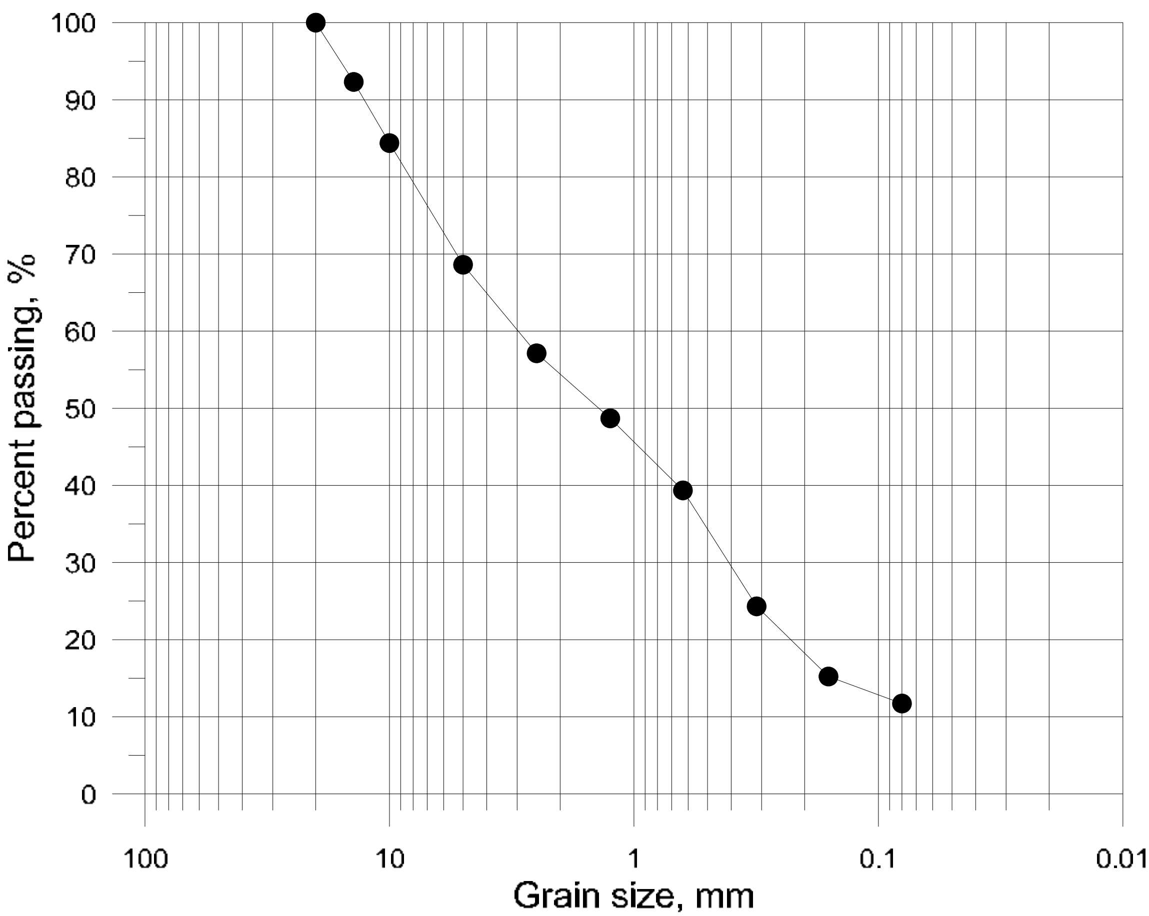


5; B-170, B-171


170-171
10
9
8
7
6
5
4
3
2
1
11.4%
10.7%
10.8%
11.0%
10.1%
9.8%
9.6%
w_c
Elevation, mm
w, %

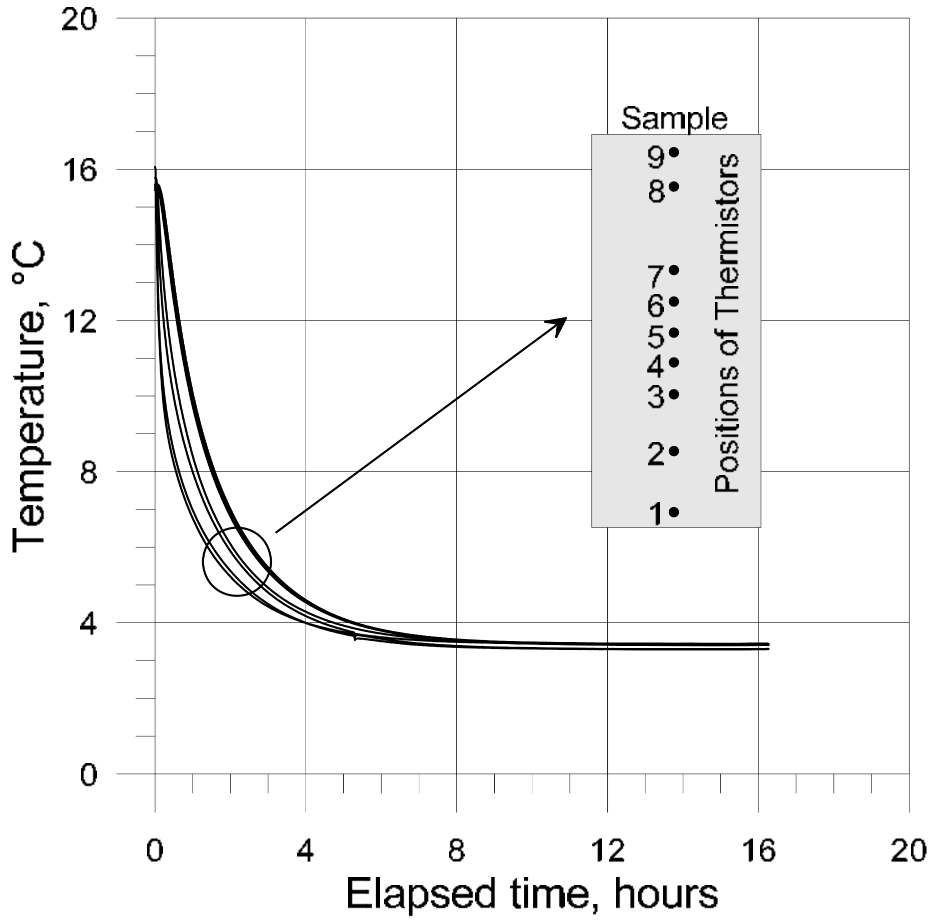
Test 6; sample B-172

Sieve analysis



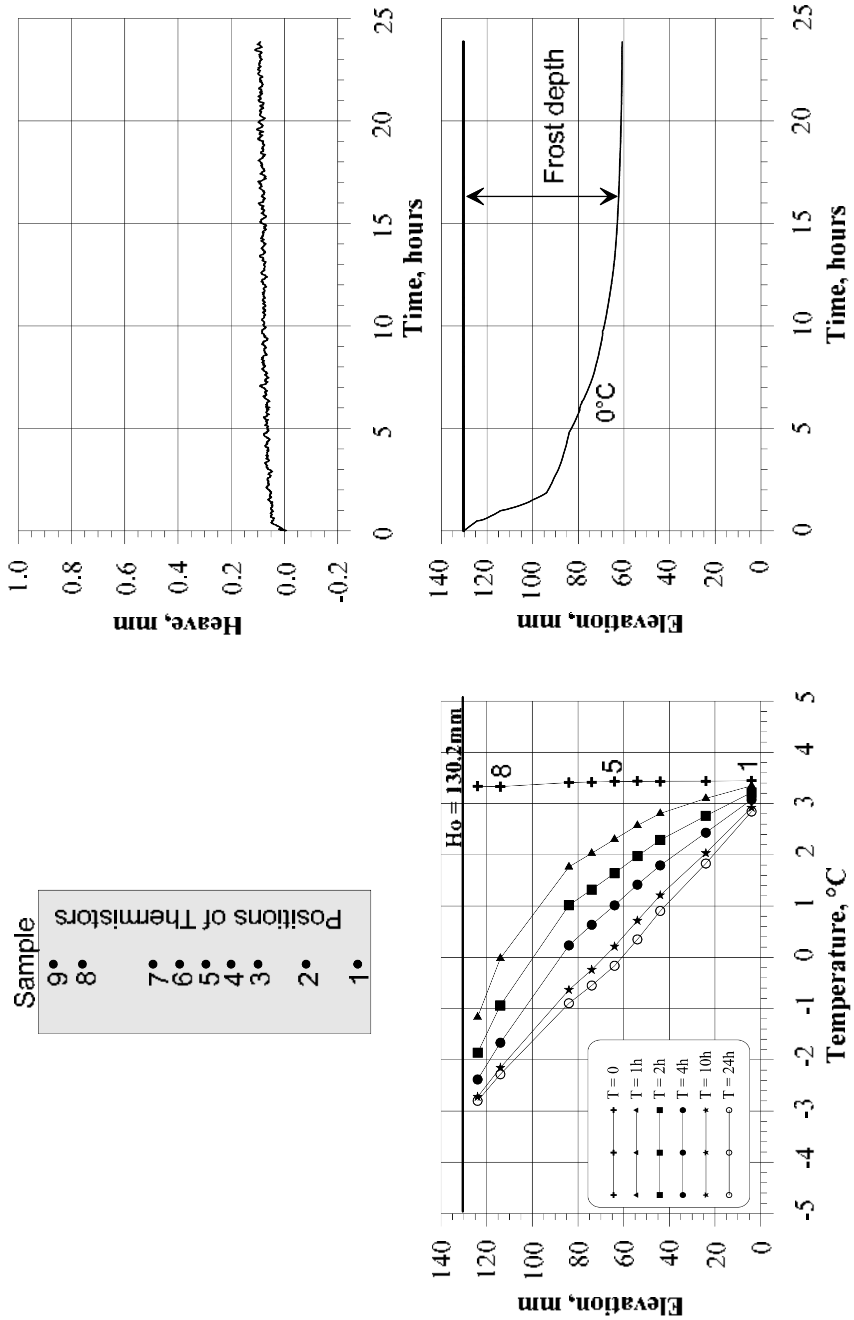
6; B-172

Step 1, conditioning



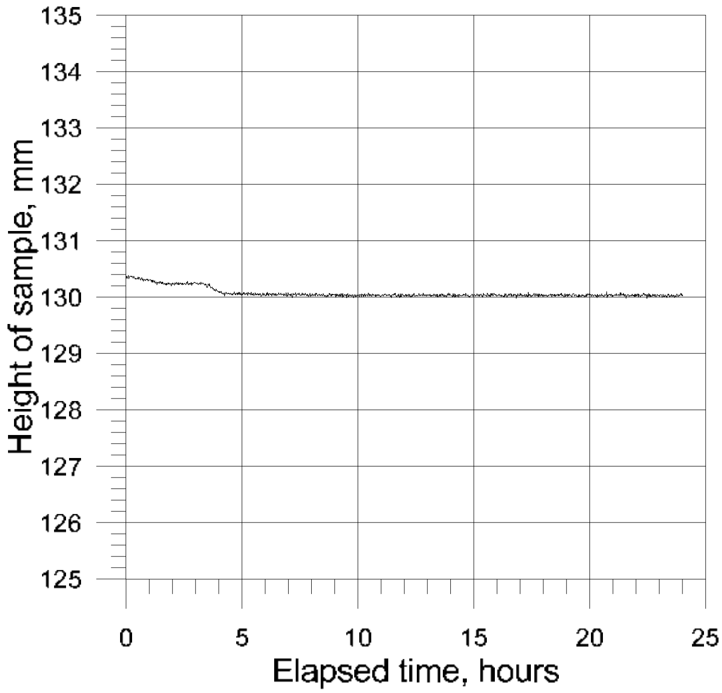
6; B-172

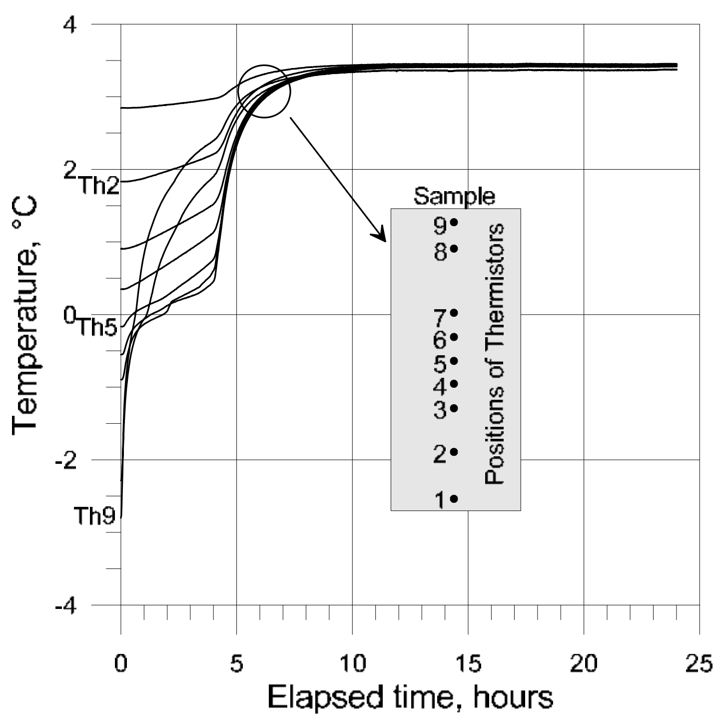
Step 2, 1st freeze



6; B-172

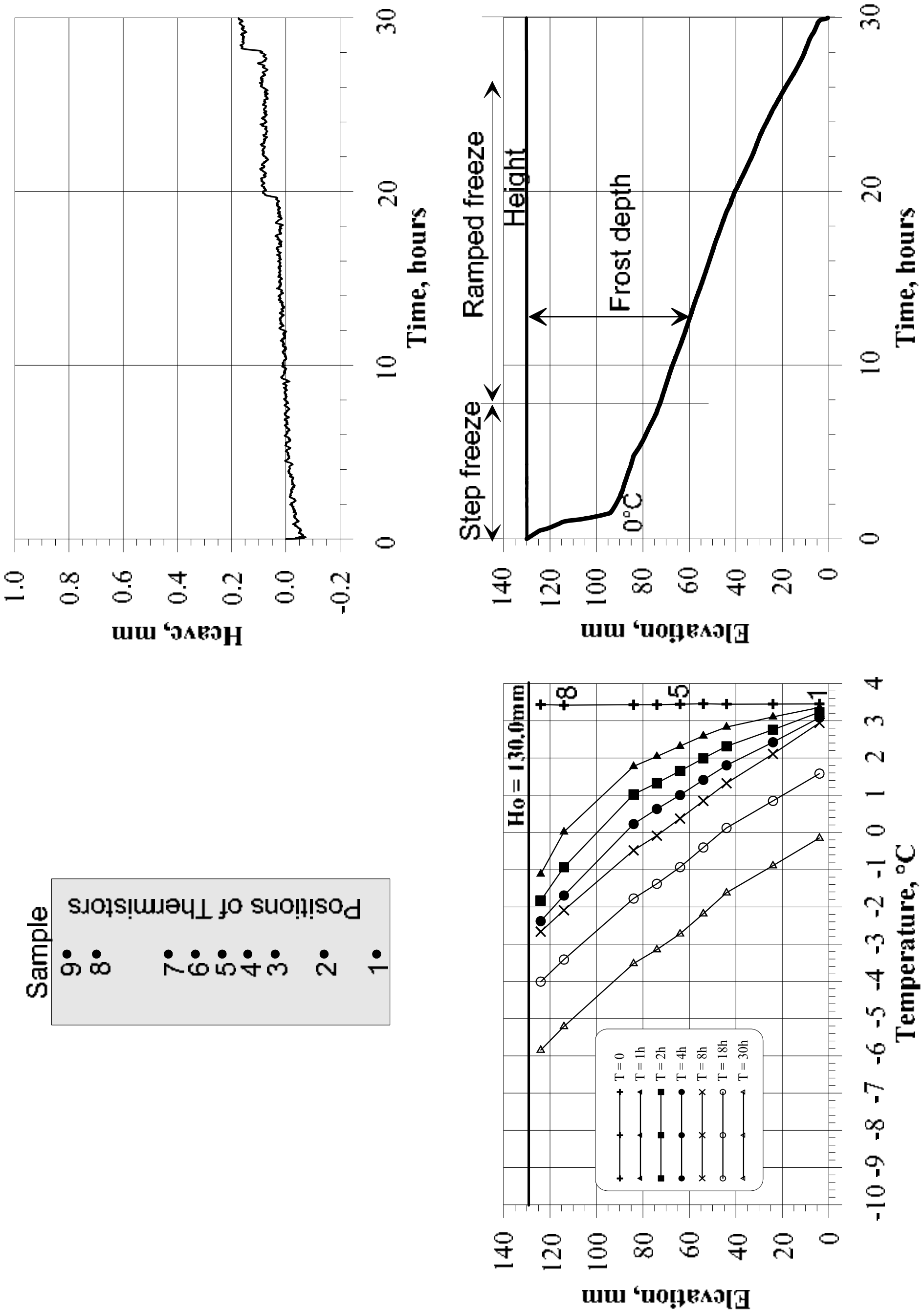
Step 3, Thaw



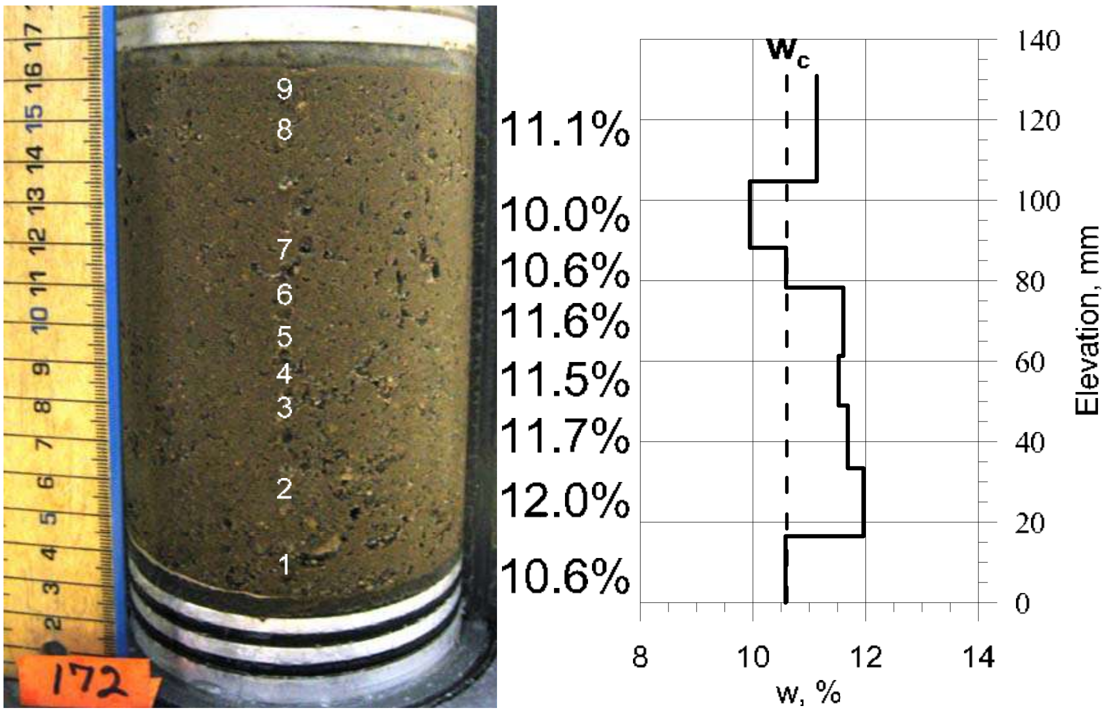


6; B-172

Step 4, 2nd freeze+ ramping freeze

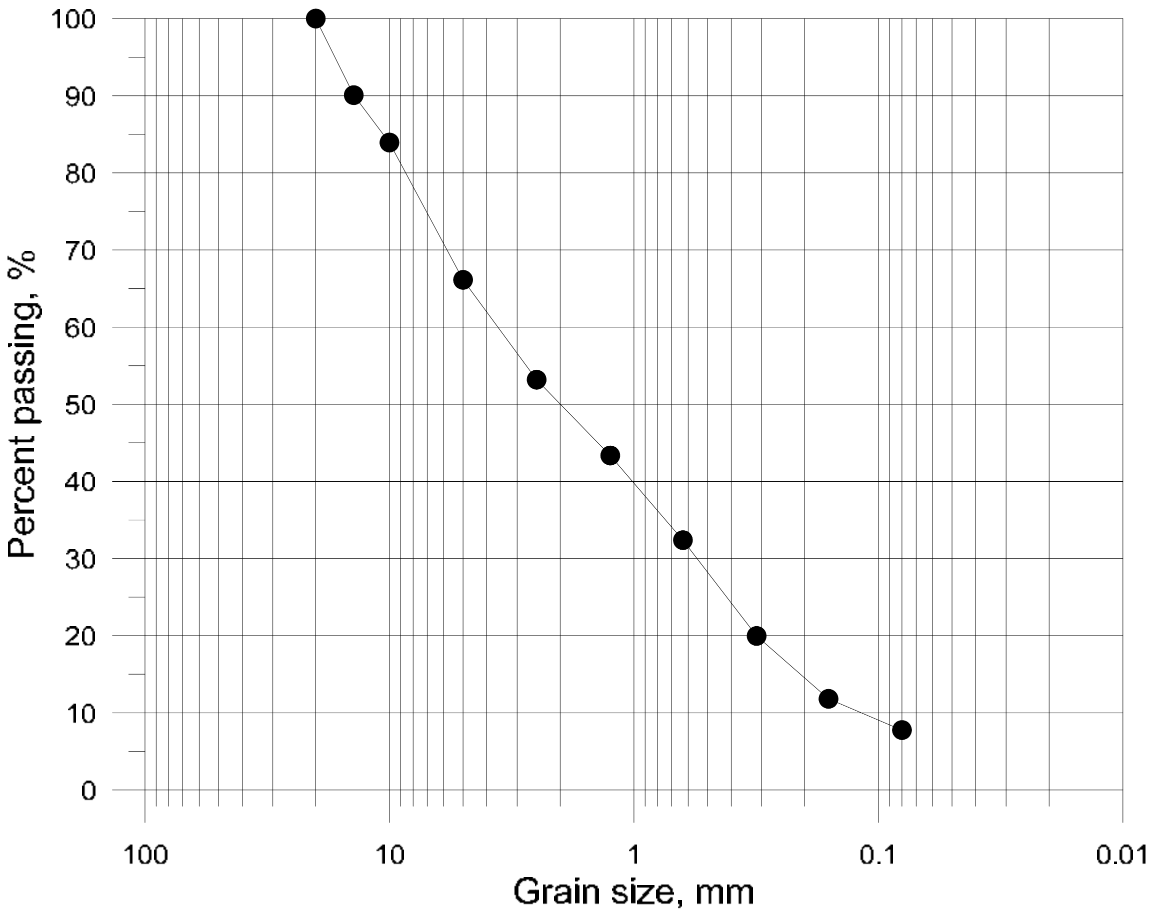


6; B-172


172
9
8
7
6
5
4
3
2
1
11.1%
10.0%
10.6%
11.6%
11.5%
11.7%
12.0%
10.6%
w_c
Elevation, mm
140
120
100
80
60
40
20
0
8
10
12
14
w, %

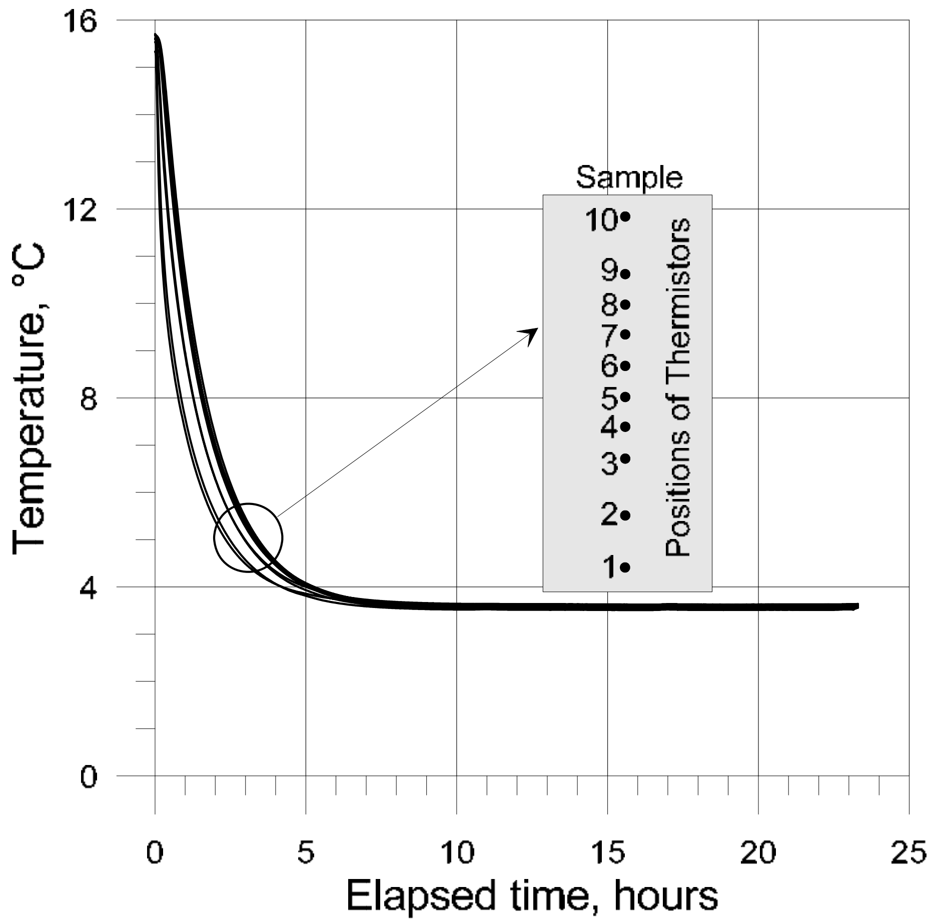
Test 7; sample B-197

Sieve analysis



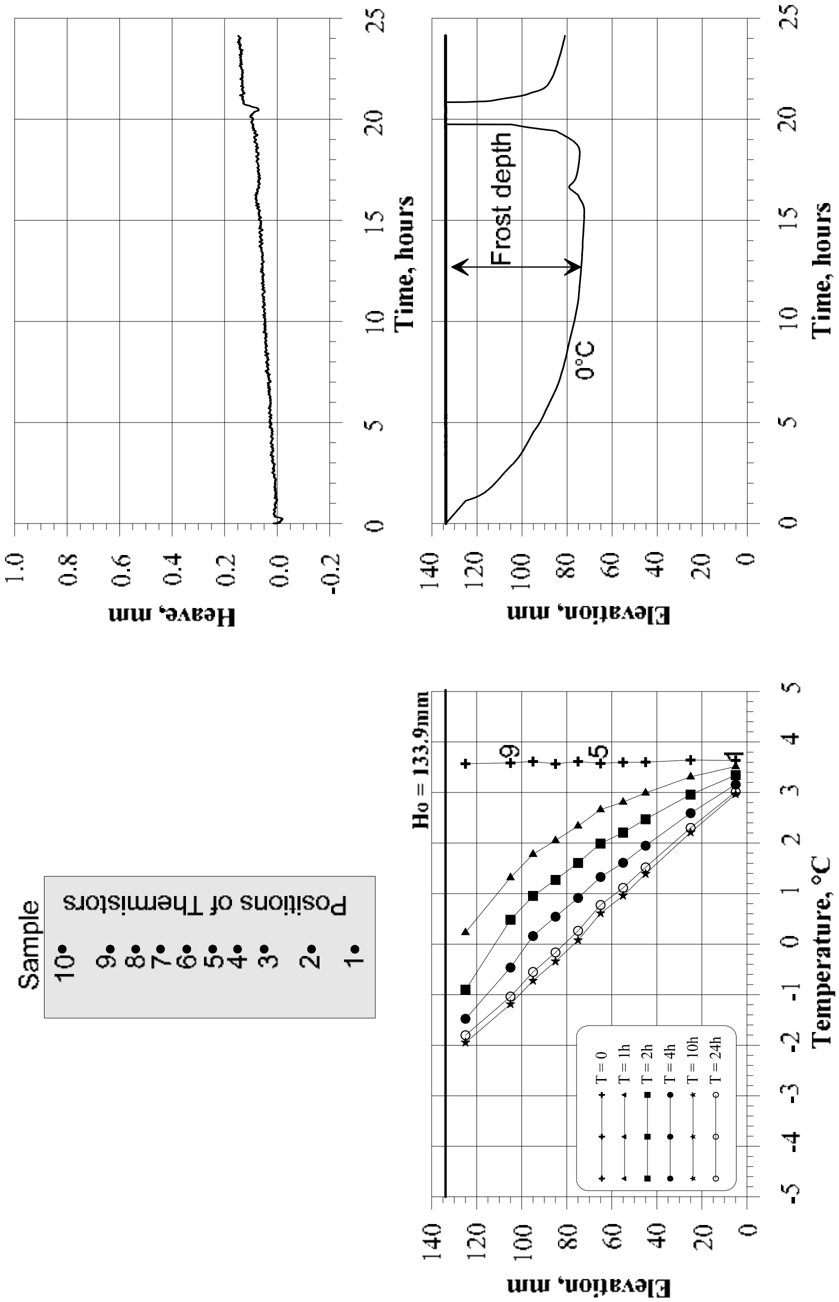
7; B-197

Step 1, conditioning



7; B-197

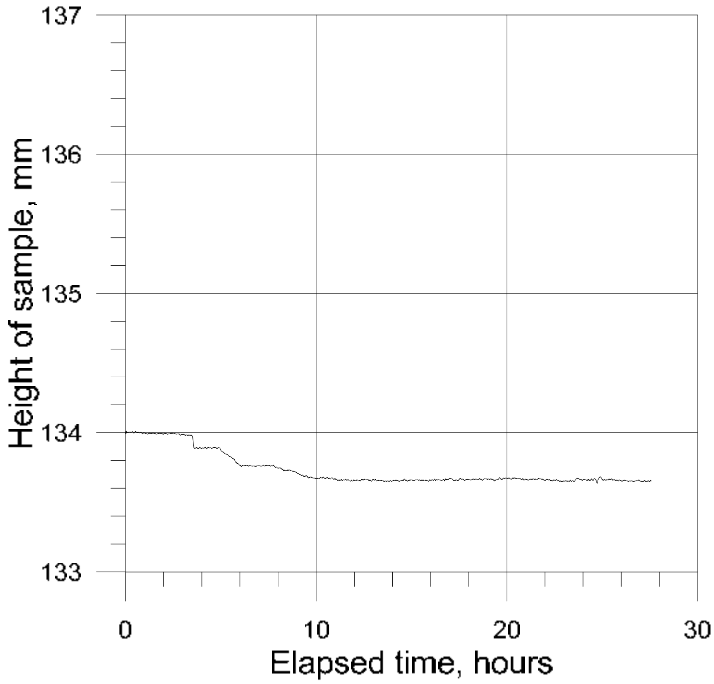
Step 2, 1st freeze

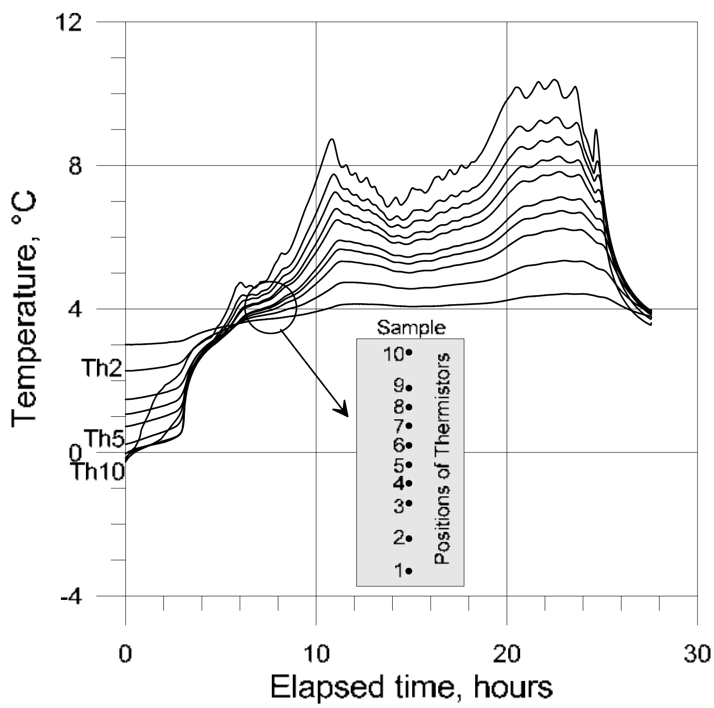


Note: after 20 hours: failure of temperature bath

7; B-197

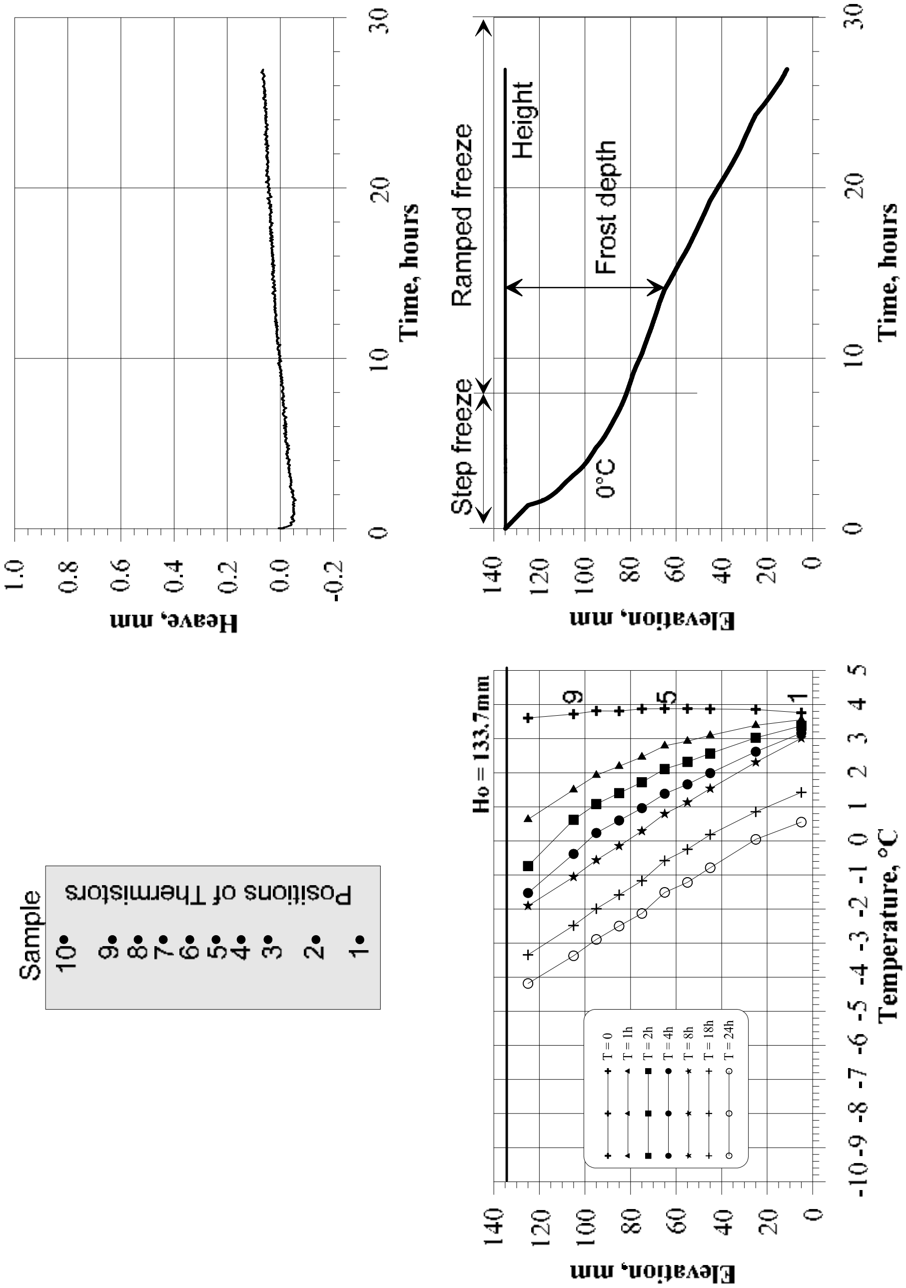
Step 3, Thaw



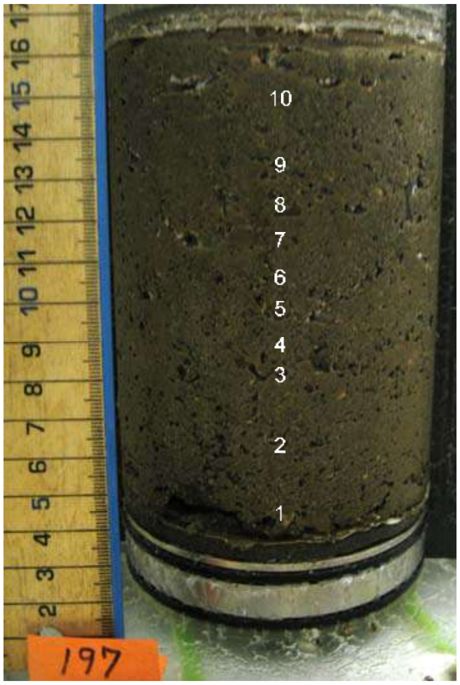


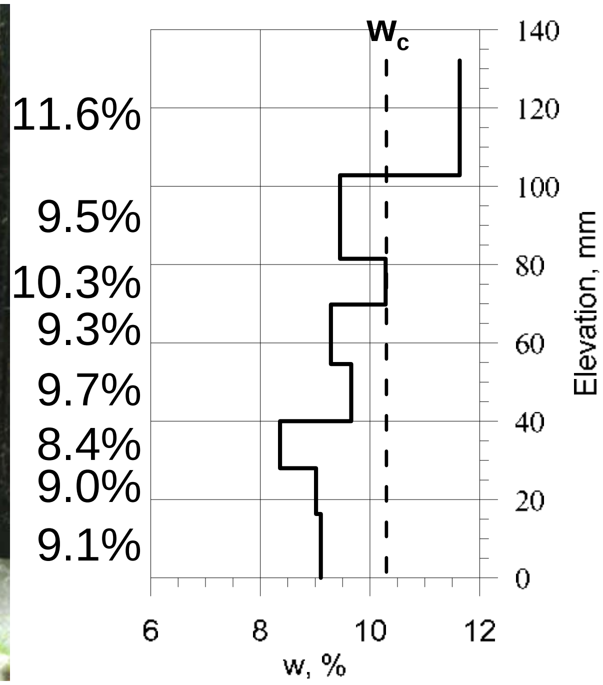
7; B-197

Step 4, 2nd freeze+ ramping freeze



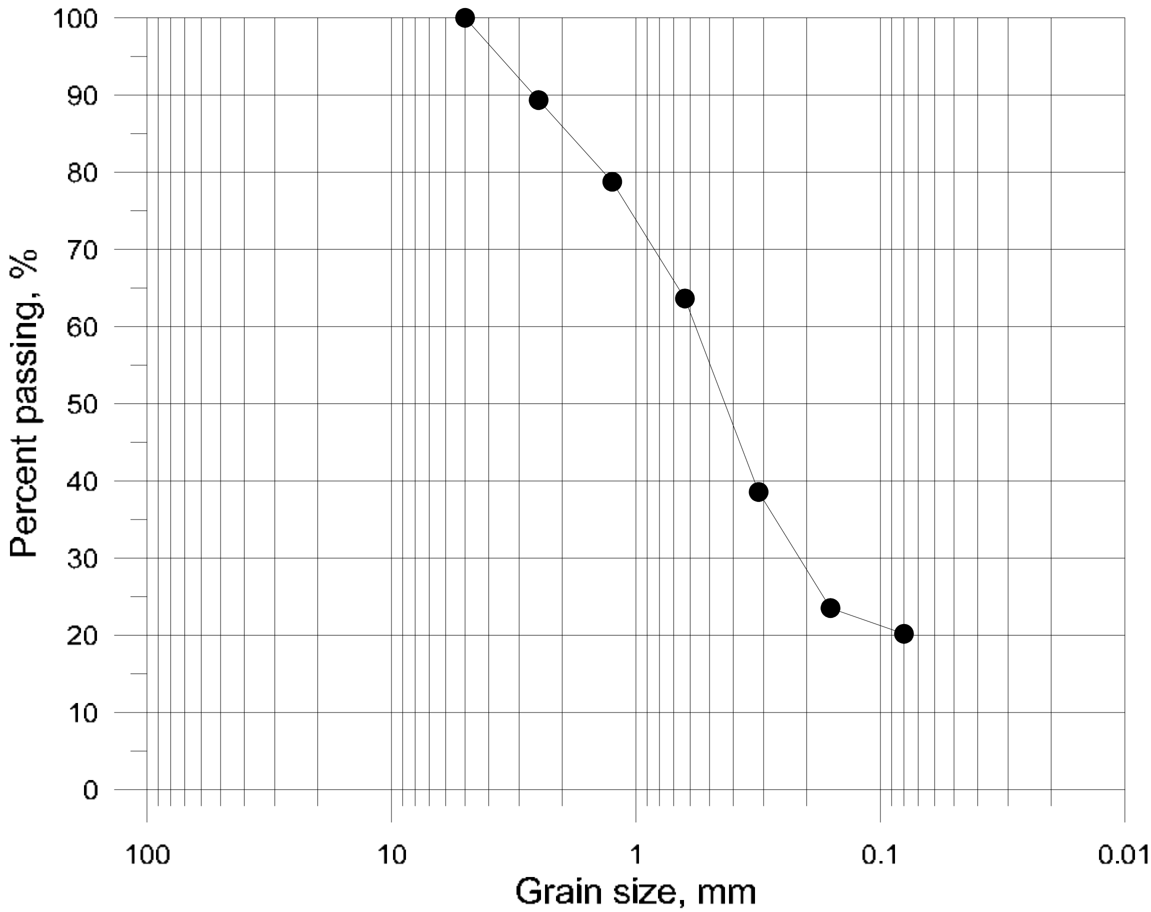
7; B-197


10
9
8
7
6
5
4
3
2
1
197


w_c
11.6%
9.5%
10.3%
9.3%
9.7%
8.4%
9.0%
9.1%
140
120
100
80
60
40
20
0
Elevation, mm
6
8
10
12
w, %

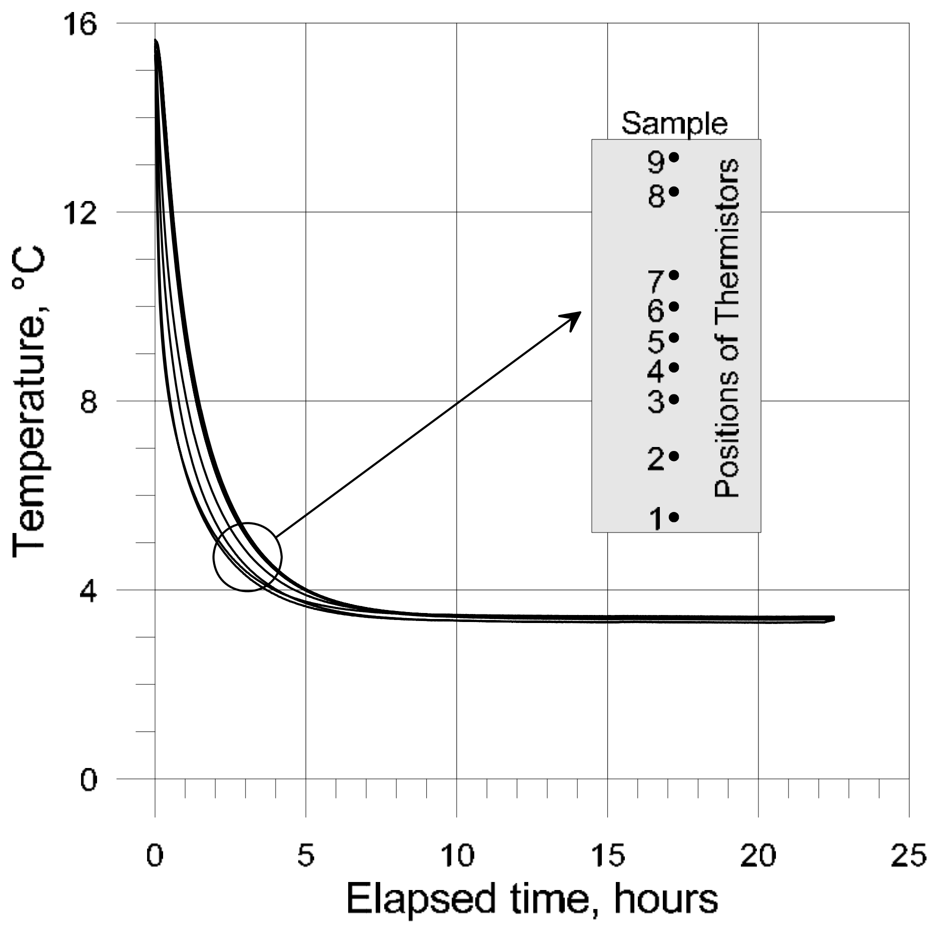
Test 8; 0-5mm, with 20% of <0.075mm (reconstituted from samples B 169 and 1(147-148-149), 2(152), 3(156-157)

Sieve analysis



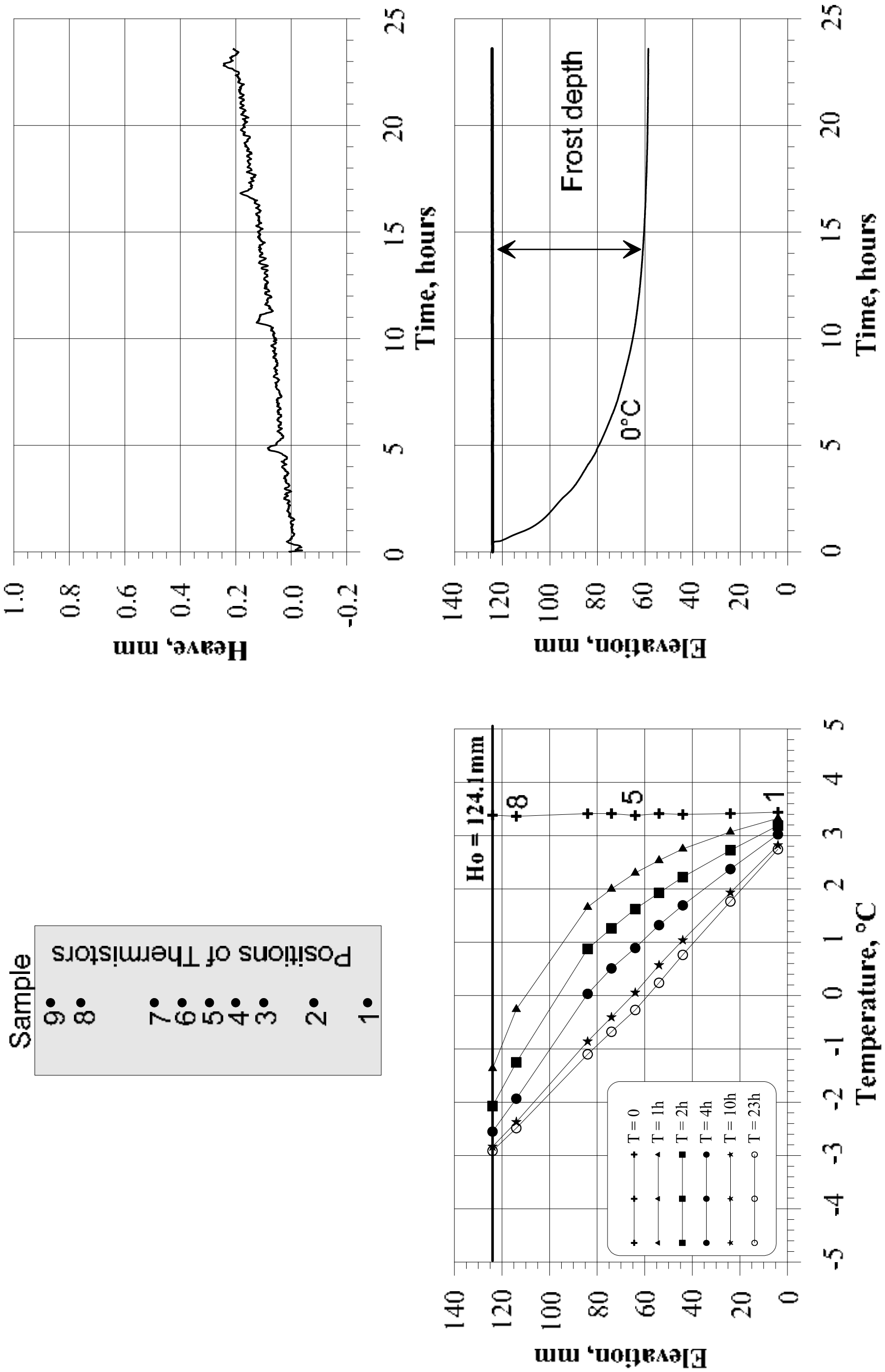
8; 0-5mm, with 20% of <0.075mm

Step 1, conditioning



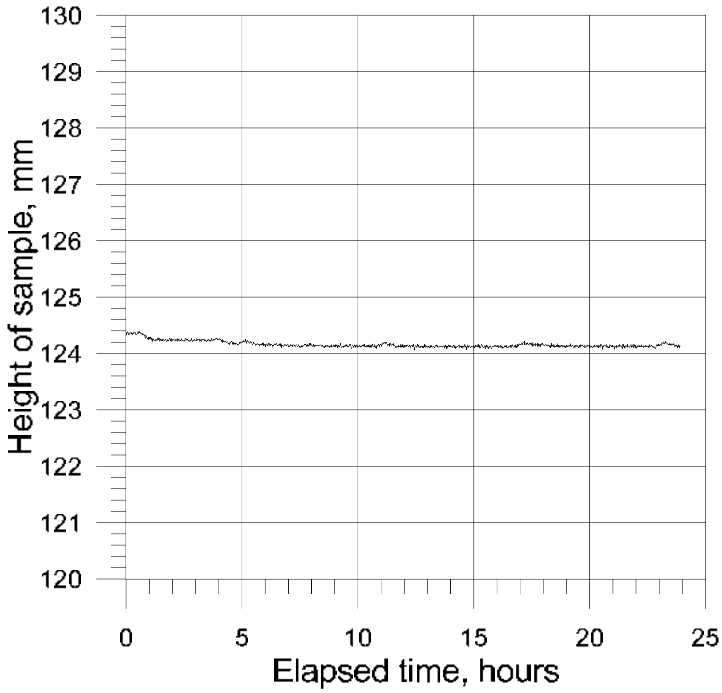
8; 0-5mm, with 20% of <0.075mm

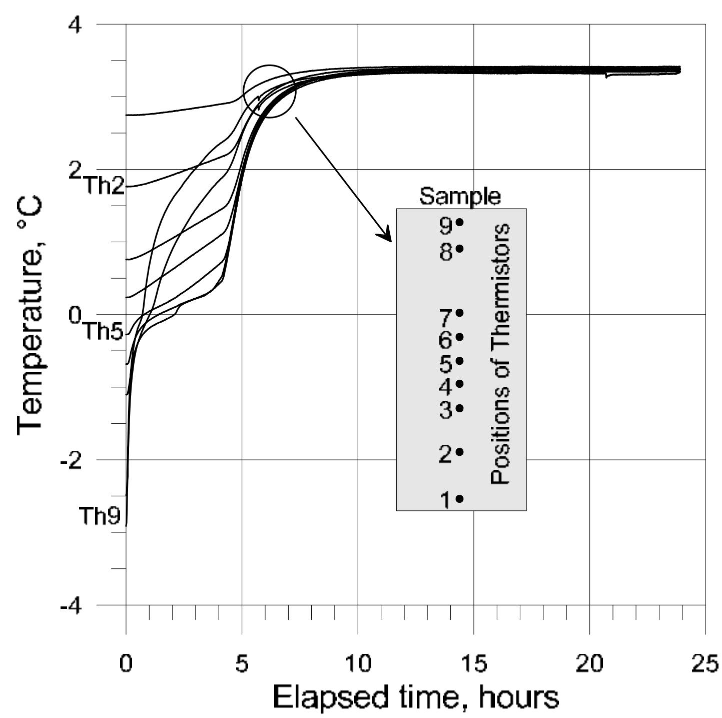
Step 2, 1st freeze



8; 0-5mm, with 20% of <0.075mm

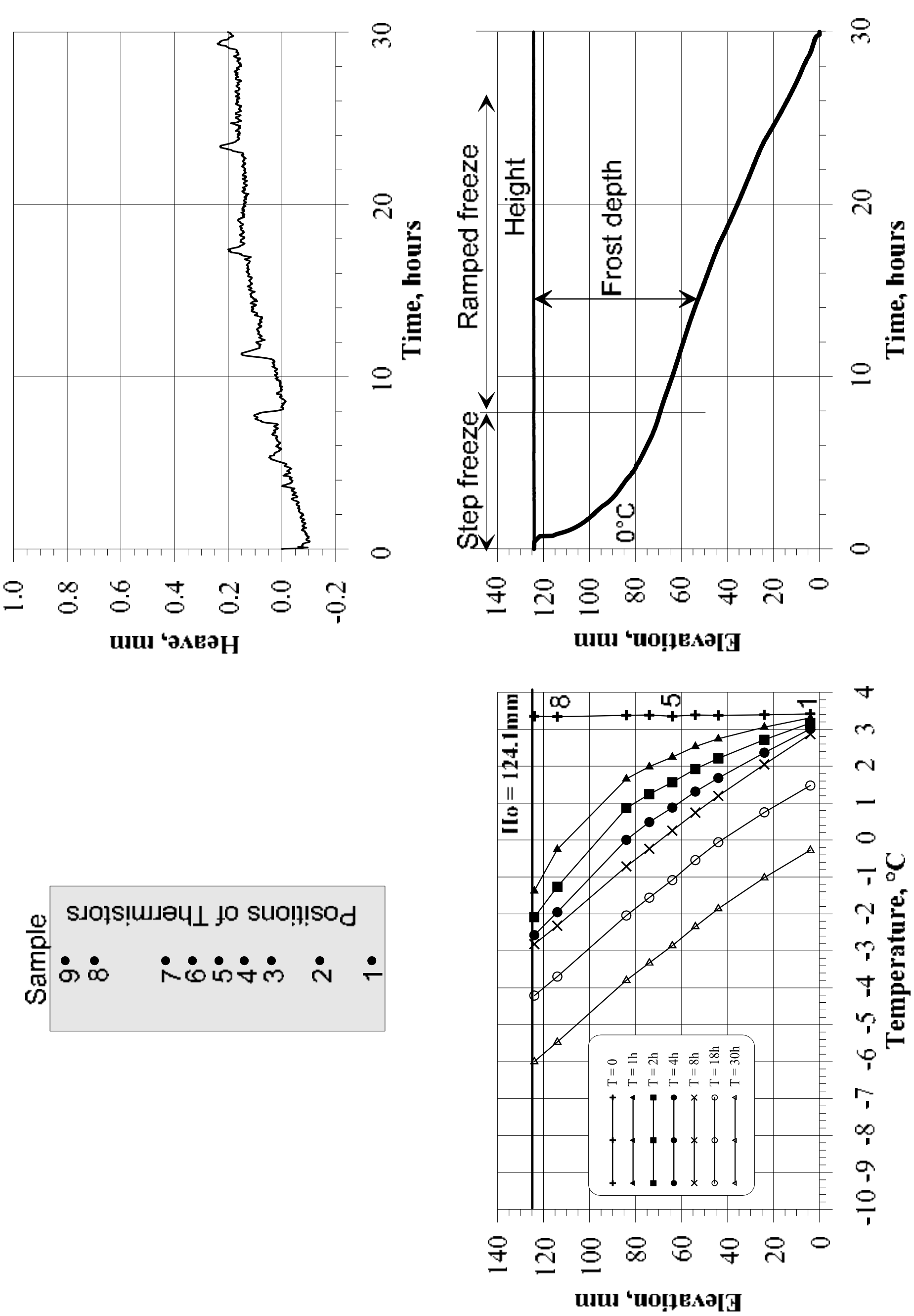
Step 3, Thaw



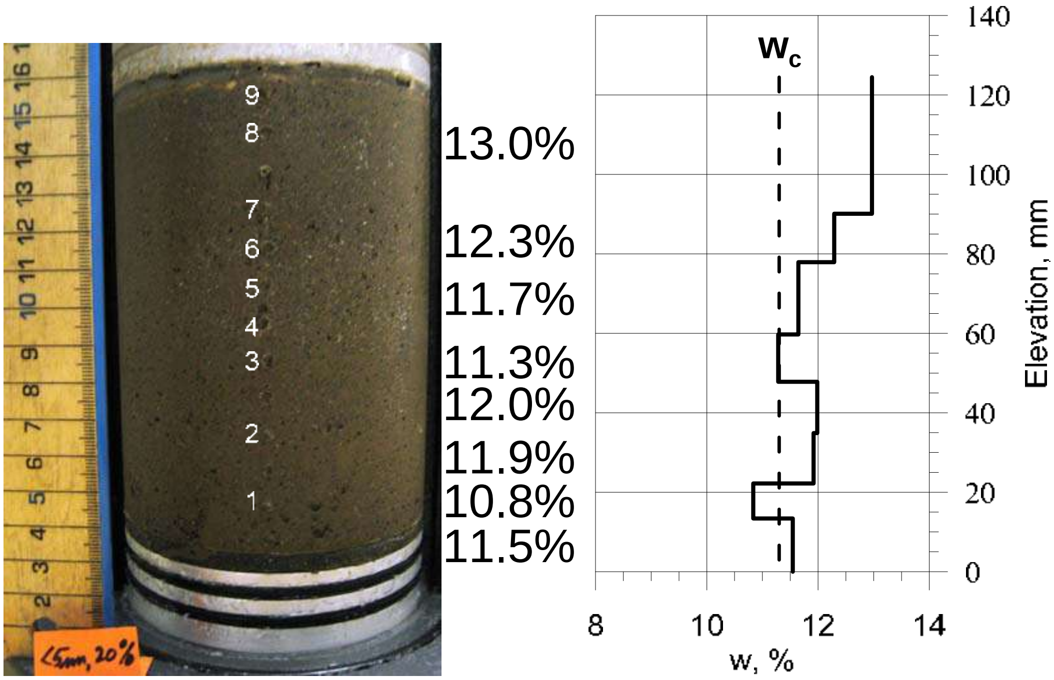


8; 0-5mm, with 20% of <0.075mm

Step 4, 2nd freeze+ ramping freeze



8; 0-5mm, with 20% of <0.075mm



Appendix B : location of thermistors

Elevation of thermistors (mm).

test	1	2	3	4	5	6	7	8
Base	0	0	0	0	0	0	0	0
Th1	4	28	5	4	5	4	5	4
Th2	24	48	25	24	25	24	25	24
Th3	44	58	45	44	45	44	45	44
Th4	54	68	55	54	55	54	55	54
Th5	64	78	65	64	65	64	65	64
Th6	74	88	75	74	75	74	75	74
Th7	84	98	85	84	85	84	85	84
Th8	114	108	95	114	95	114	95	114
Th9	124	128	105	124	105	124	105	124
Th10			125		125		125	

Appendix C: Work statement

Good morning Dr. Konrad,

Thank you for your confirmation of shipment.

As mentioned previously, detailed testing program that we would like you to run is to have 7 frost-heave tests (same as what we did in the 2015 AK LNG project) with the following samples (and see attached).
Due to limit of sample quantities requiring for the test, you may want to combine two or more samples bags within same test number.
Below and attachment are the table showing the samples that can be combined together:

Test No.	Boring No.	Sample No.
1	B-147	S-2
	B-147	S-3
	B-147	S-4
	B-148	S-2
	B-148	S-3
	B-148	S-4b
	B-149	S-4
2	B-152	S-2b
	B-152	S-3
	B-152	S-4
3	B-156	S-2b
	B-156	S-3a
	B-156	S-3c
	B-156	S-4
	B-157	S-2b
	B-157	S-3
	B-157	S-4
	B-157	S-5
4	B-169	S-3
	B-169	S-4
	B-169	S-4-OSPT
5	B-170	S-2
	B-170	S-3
	B-170	S-4-OSPT
	B-171	S-3
6	B-172	S-2
	B-172	S-3
	B-172	S-4
7	B-197	S-3
	B-197	S-4

FROST-HEAVE (CHAMBER) TESTS

Date: Sep. 15, 2016

Project No. 04.10160001

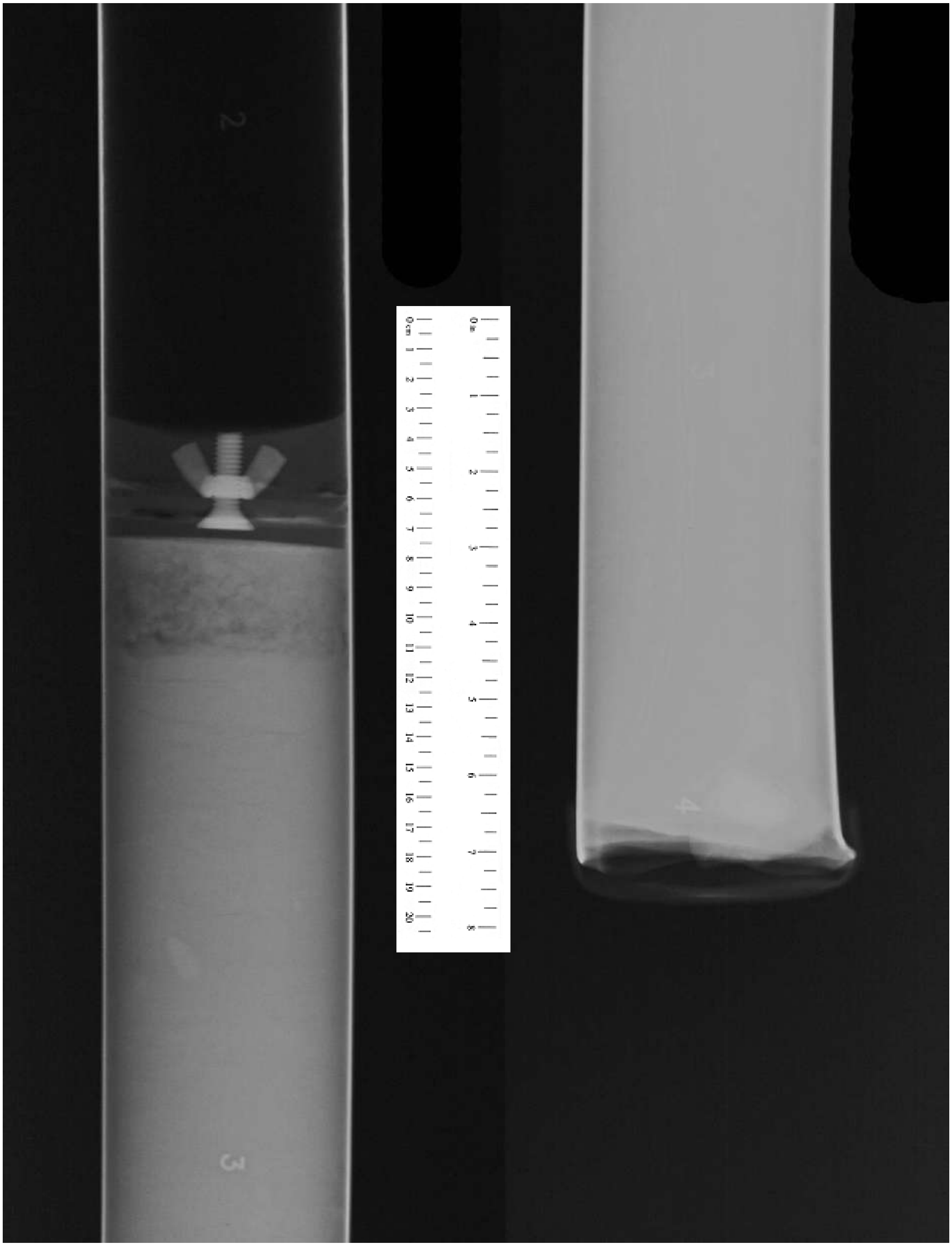
(Fugro Consultants - Laval University)

Test No.	Boring No.	Top Depth (ft)	Bottom Depth (ft)	Sample No.	"Sampler Type (Oversize spoon=O-SPT)"	Sample Type
1	B-147	2,50	4,50	S-2	SPT	BAG
	B-147	5,00	7,00	S-3	SPT	BAG
	B-147	7,50	9,50	S-4	OSPT	BAG
	B-148	2,50	4,50	S-2	SPT	BAG
	B-148	5,00	7,00	S-3	SPT	BAG
	B-148	7,80	8,70	S-4b	SPT	BAG
	B-149	6,00	8,50	S-4	SPT	BAG
2	B-152	2,80	3,50	S-2b	SPT	BAG
	B-152	4,00	5,50	S-3	SPT	BAG
	B-152	6,50	8,50	S-4	SPT	BAG
3	B-156	2,50	3,50	S-2b	SPT	BAG
	B-156	4,00	4,50	S-3a	SPT	BAG
	B-156	5,00	5,50	S-3c	SPT	BAG
	B-156	6,50	8,50	S-4	SPT	BAG
	B-157	2,50	3,50	S-2b	SPT	BAG
	B-157	4,00	5,50	S-3	SPT	BAG

	B-157	6,50	8,50	S-4	SPT	BAG
	B-157	9,00	11,00	S-5	SPT	BAG
4	B-169	4,00	6,00	S-3	SPT	BAG
	B-169	6,50	8,50	S-4	SPT	BAG
	B-169	6,50	11,00	S-4-OSPT	OSPT	BAG
5	B-170	2,00	3,50	S-2	SPT	BAG
	B-170	4,00	6,00	S-3	SPT	BAG
	B-170	6,50	8,50	S-4-OSPT	OSPT	BAG
	B-171	4,00	6,00	S-3	SPT	BAG
6	B-172	2,00	3,50	S-2	SPT	BAG
	B-172	4,00	6,00	S-3	SPT	BAG
	B-172	6,50	8,50	S-4	SPT	BAG
7	B-197	4,00	5,00	S-3	SPT	BAG
	B-197	6,50	8,50	S-4	SPT	BAG

APPENDIX G10

X-Ray Radiography Images



X-RAY RADIOGRAPHY IMAGES

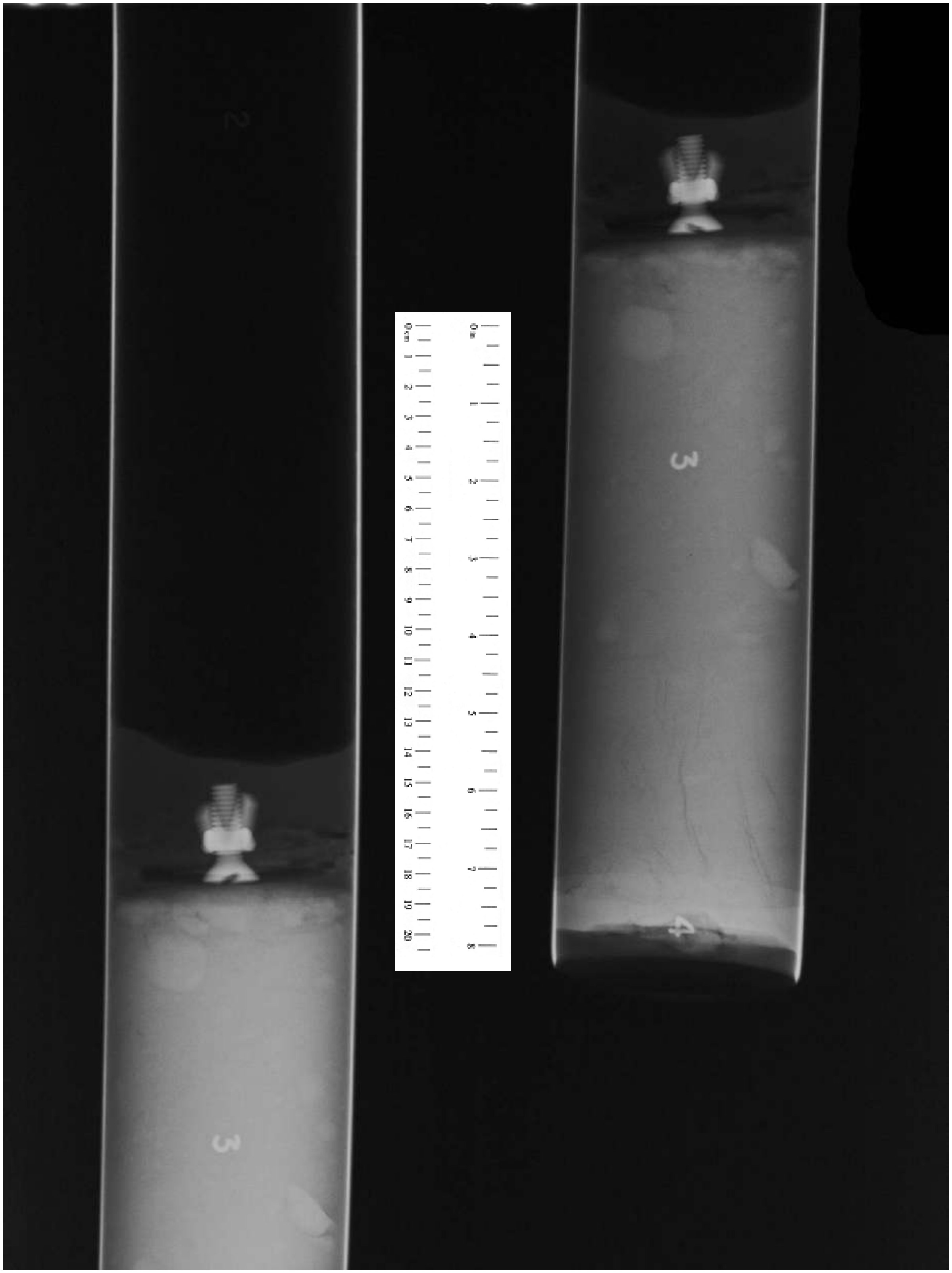
BORING B-146, SAMPLE S-20, DEPTH 79.0 – 80.0 FT

ONSHORE LNG FACILITIES

ALASKA LNG PROJECT

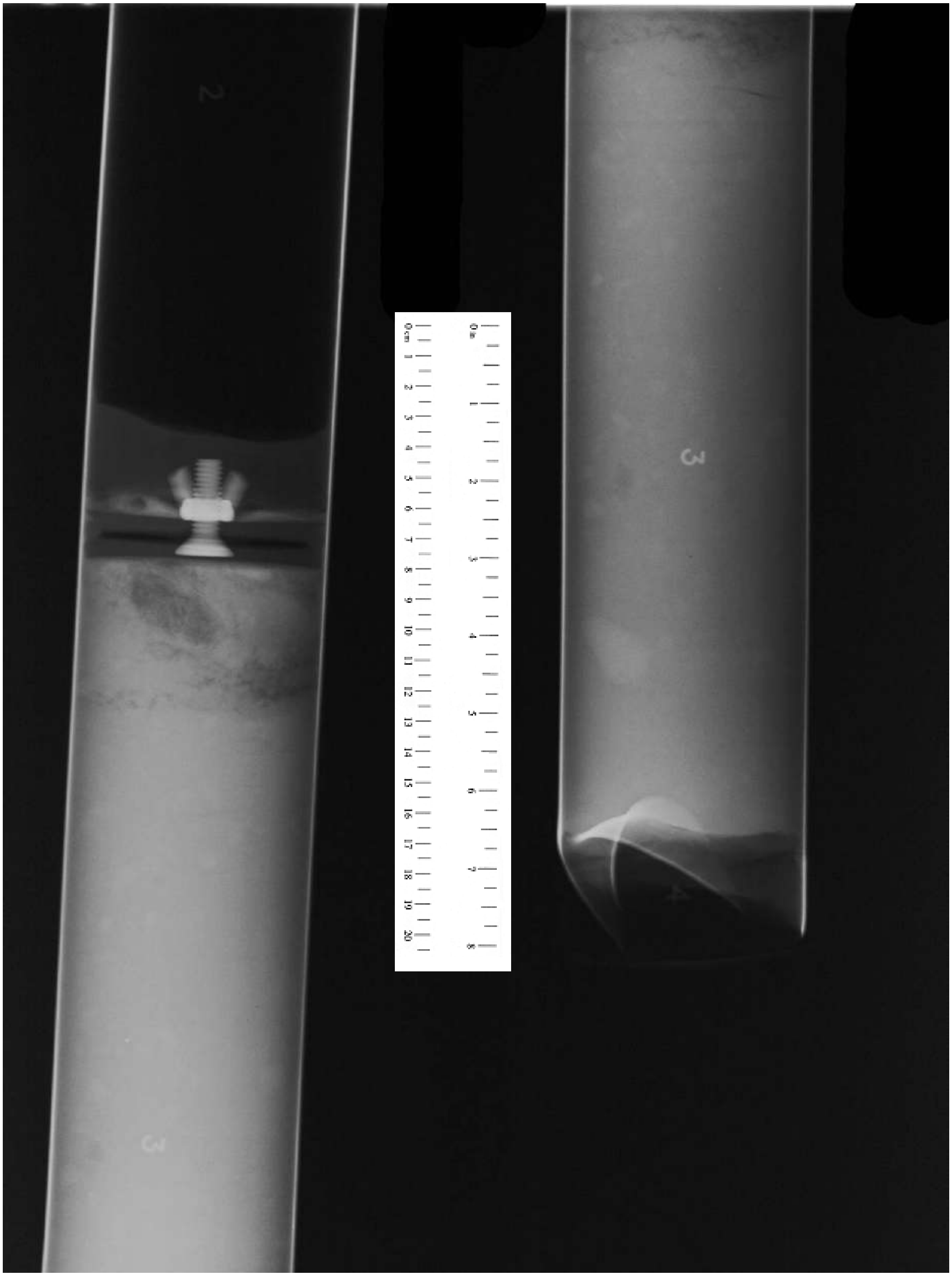
NIKISKI, ALASKA

PLATE G10-1



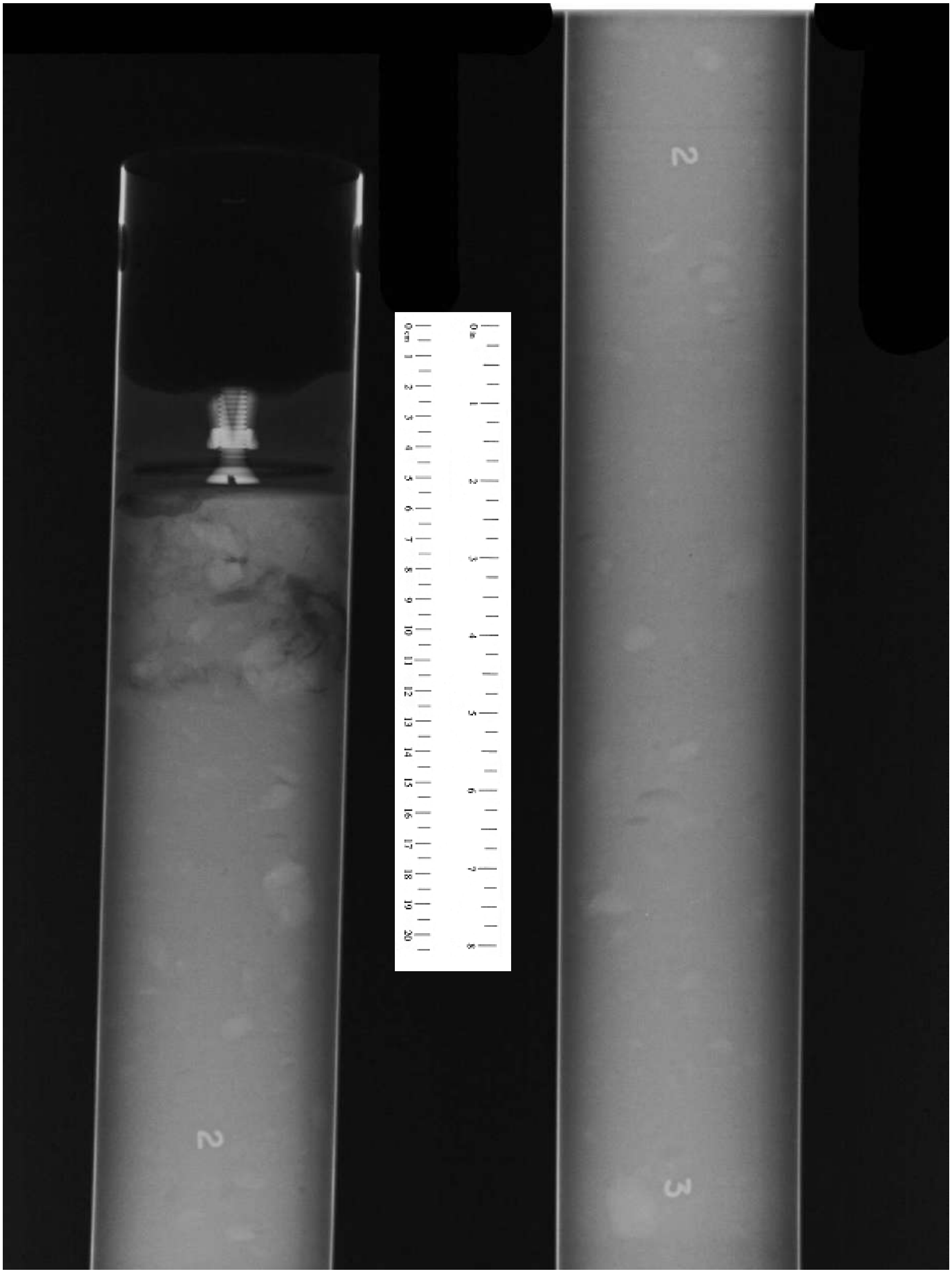
X-RAY RADIOGRAPHY IMAGES
BORING B-146, SAMPLE S-30, DEPTH 121.0 – 121.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-2



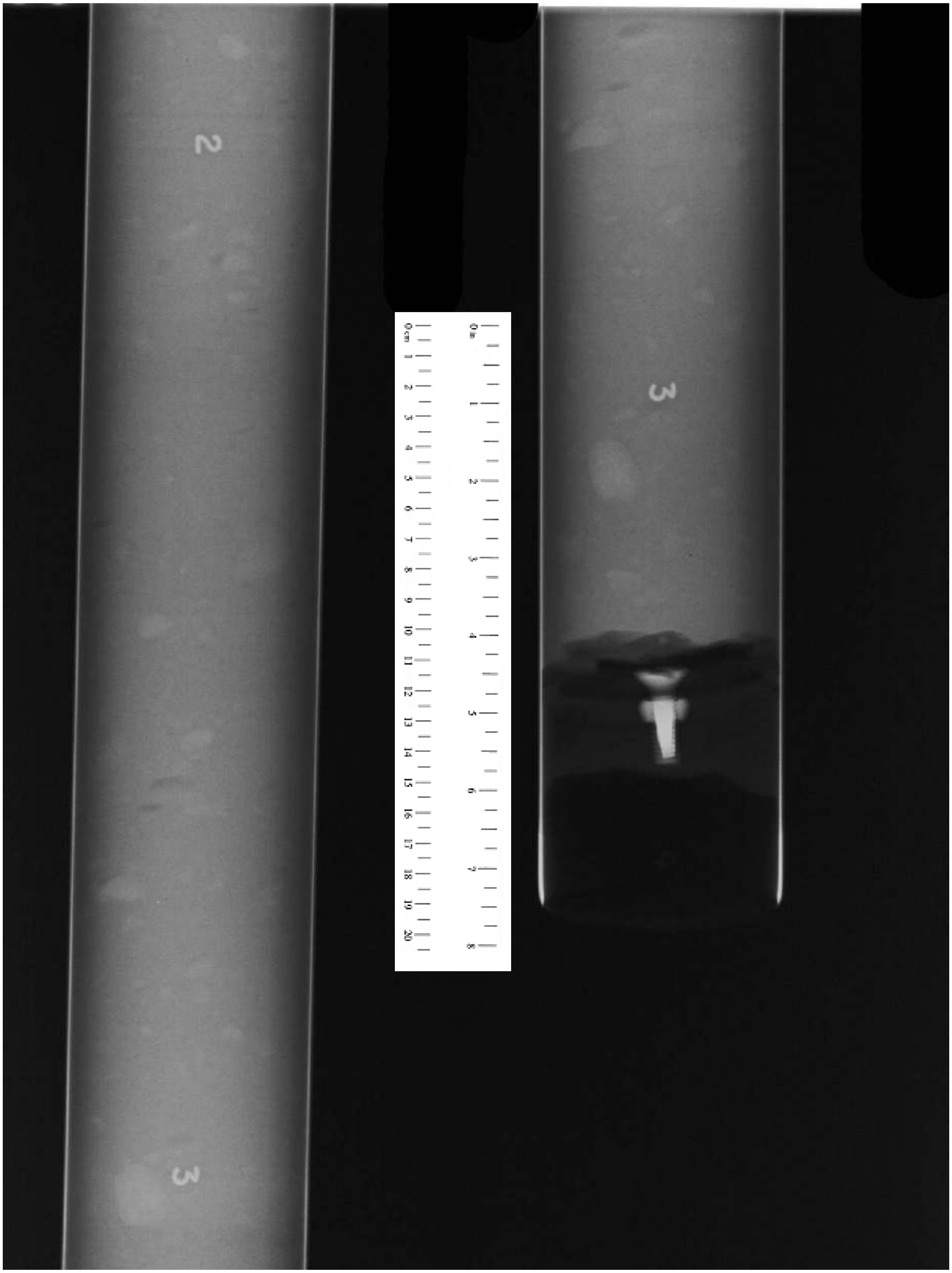
X-RAY RADIOGRAPHY IMAGES
BORING B-146, SAMPLE S-36, DEPTH 179.0 – 179.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-3



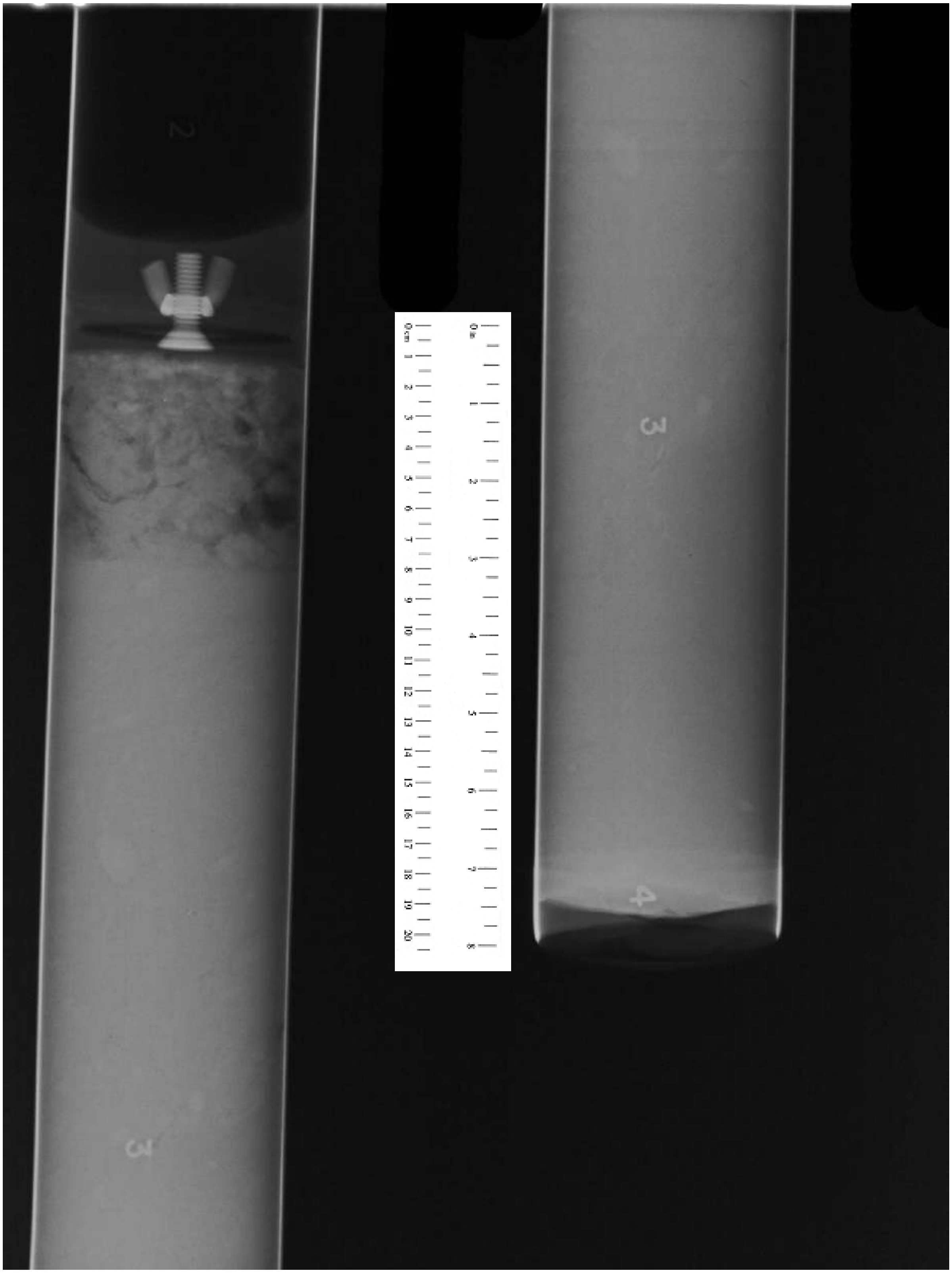
X-RAY RADIOGRAPHY IMAGES
BORING B-146, SAMPLE S-39, DEPTH 197.0 – 198.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-4a



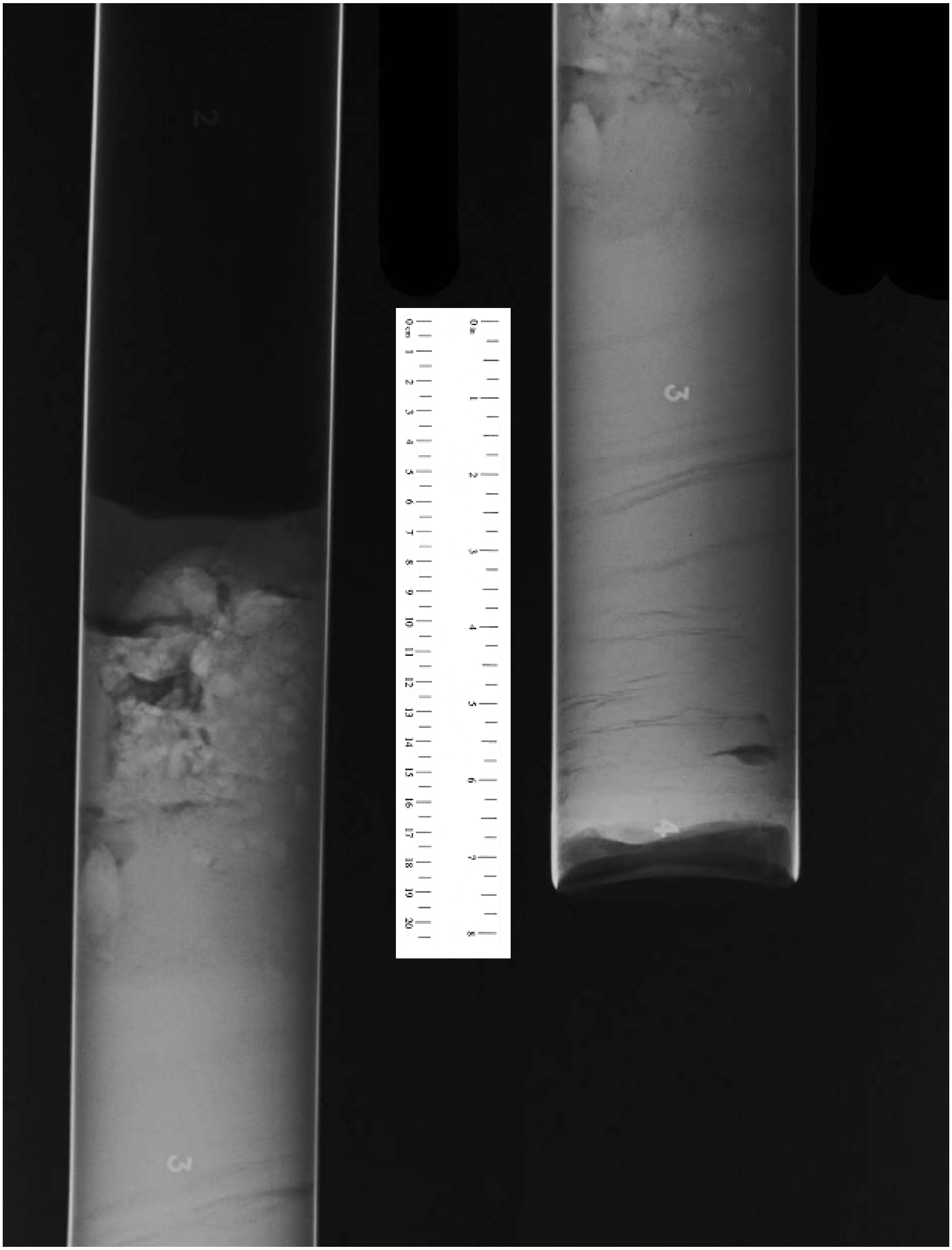
X-RAY RADIOGRAPHY IMAGES
BORING B-146, SAMPLE S-36, DEPTH 197.0 – 198.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-4b

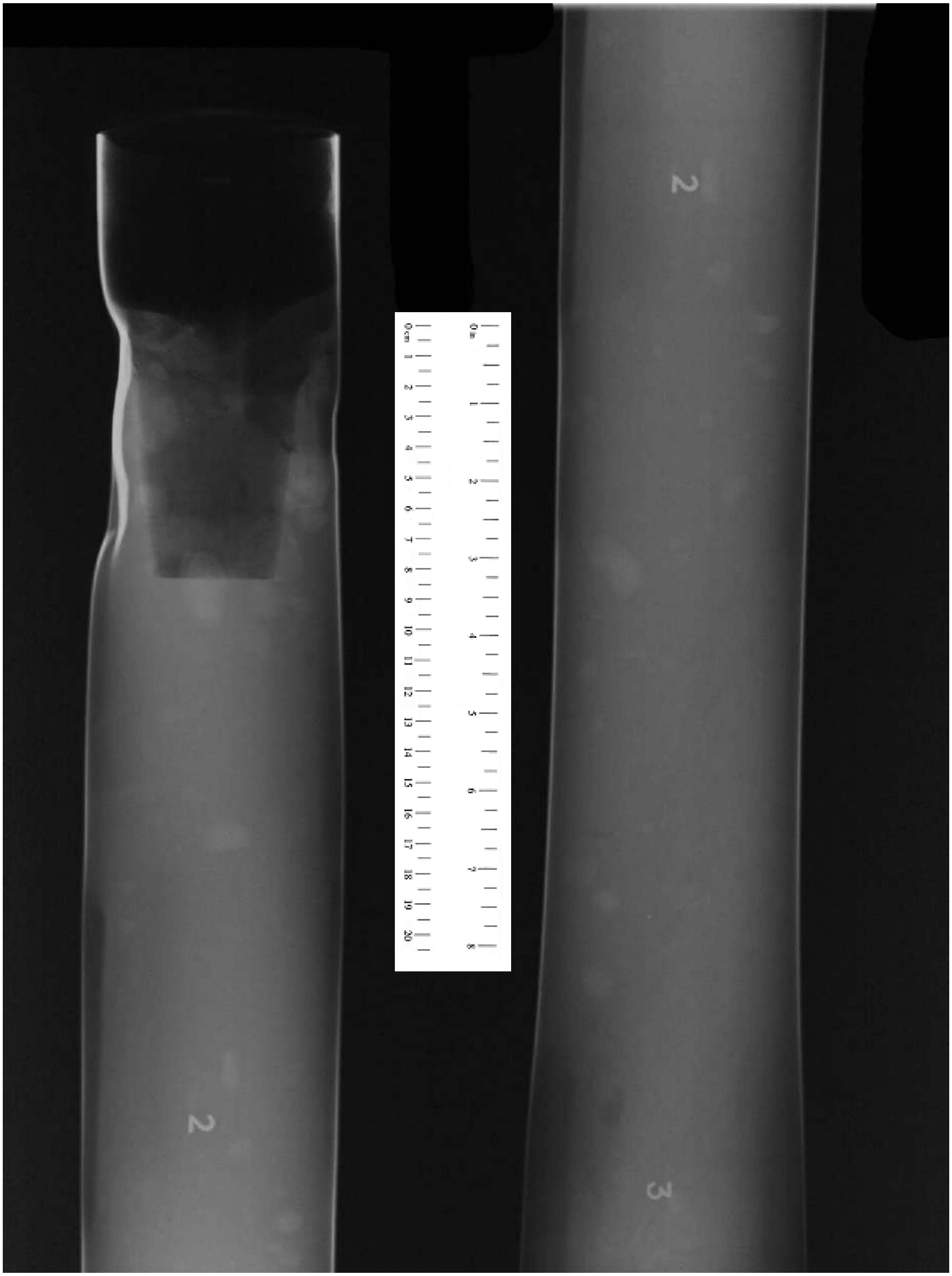


X-RAY RADIOGRAPHY IMAGES
BORING B-146, SAMPLE S-40, DEPTH 202.0 – 203.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-5

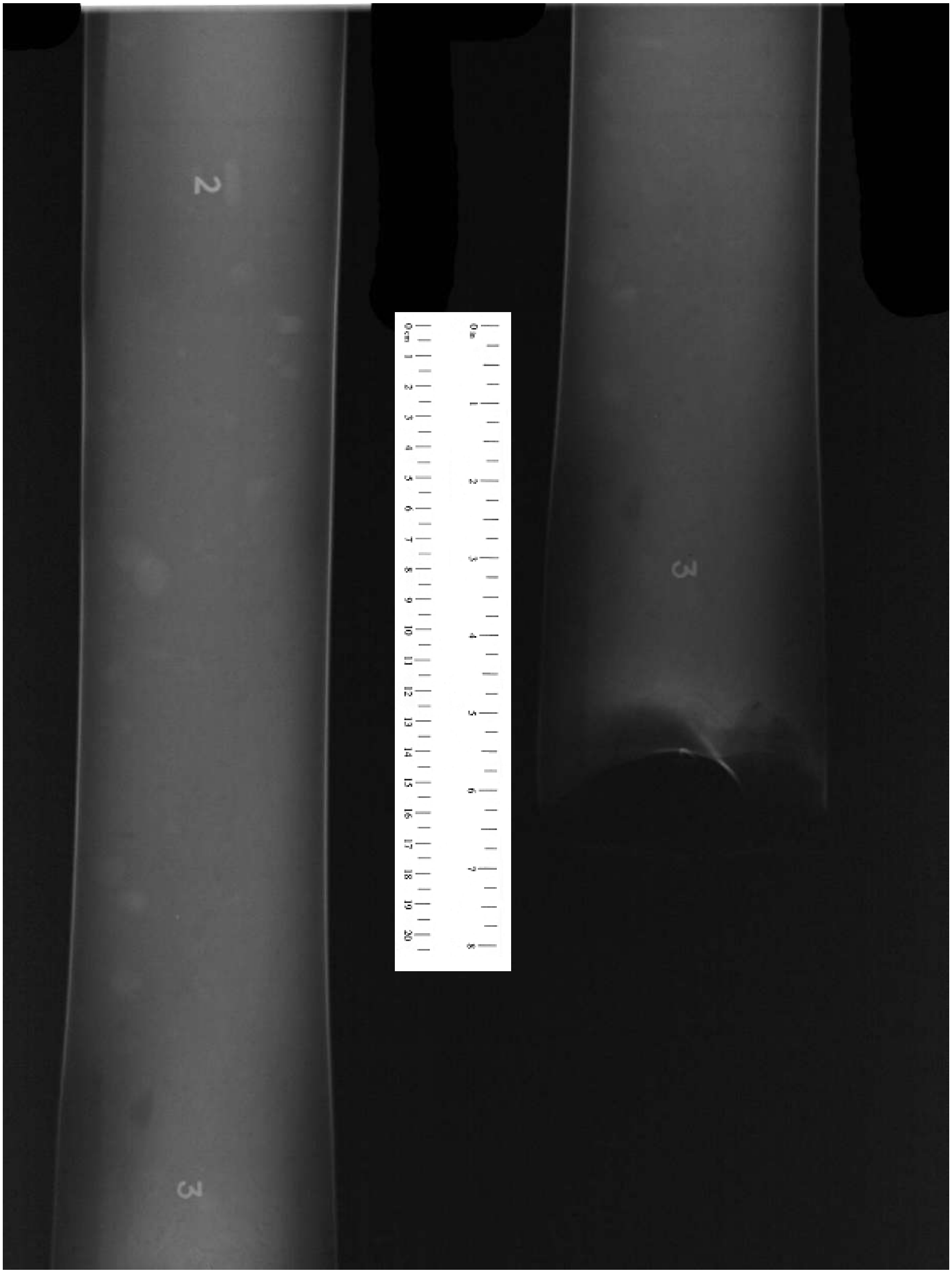


X-RAY RADIOGRAPHY IMAGES
BORING B-147, SAMPLE S-22, DEPTH 82.0 – 82.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



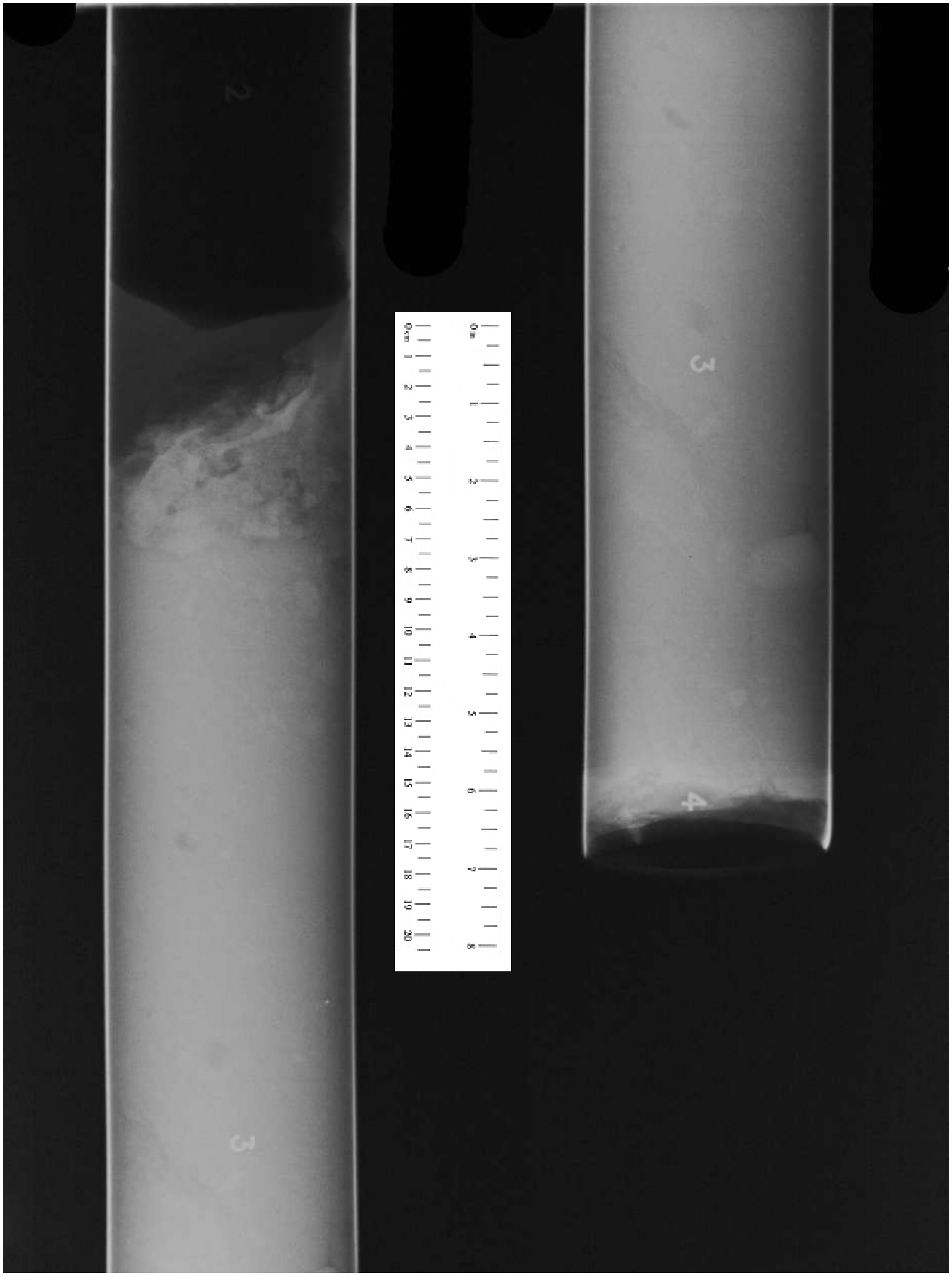
X-RAY RADIOGRAPHY IMAGES
BORING B-148, SAMPLE S-36, DEPTH 172.5 – 174.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-7a



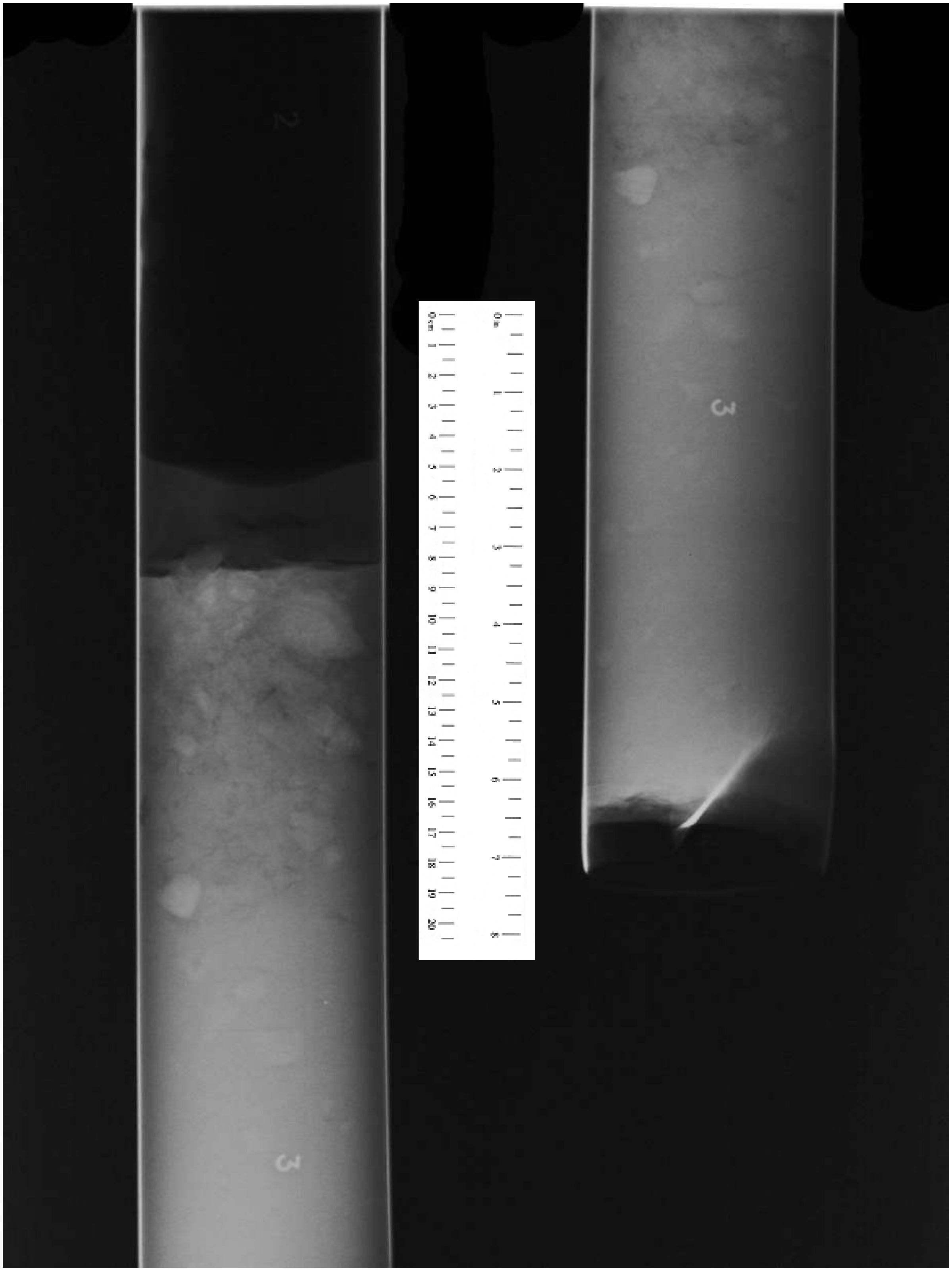
X-RAY RADIOGRAPHY IMAGES
BORING B-148, SAMPLE S-36, DEPTH 172.5 – 174.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-7b

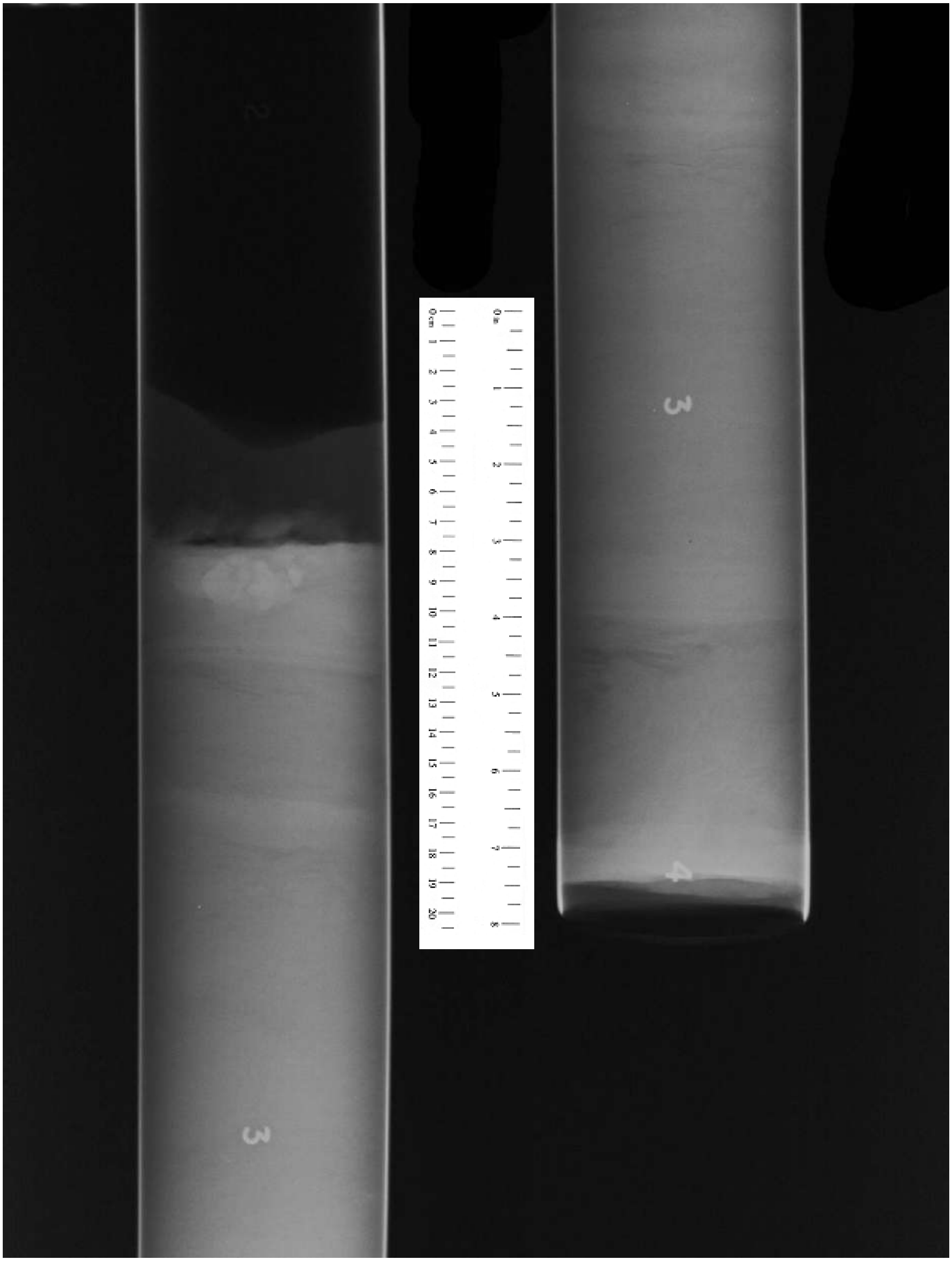


X-RAY RADIOGRAPHY IMAGES
BORING B-148, SAMPLE S-40, DEPTH 192.5 – 193.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-8

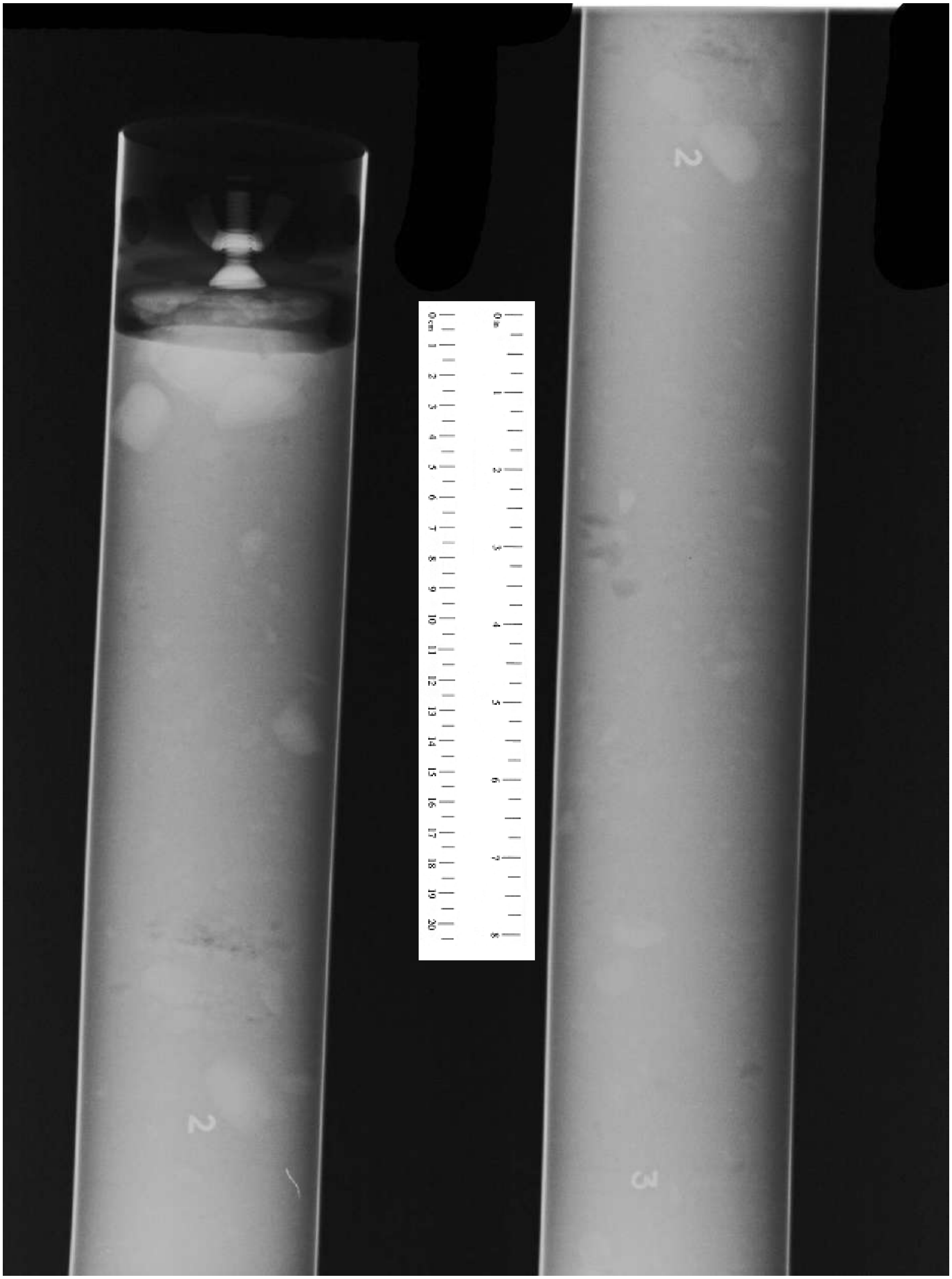


X-RAY RADIOGRAPHY IMAGES
BORING B-148, SAMPLE S-42, DEPTH 199.0 – 199.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



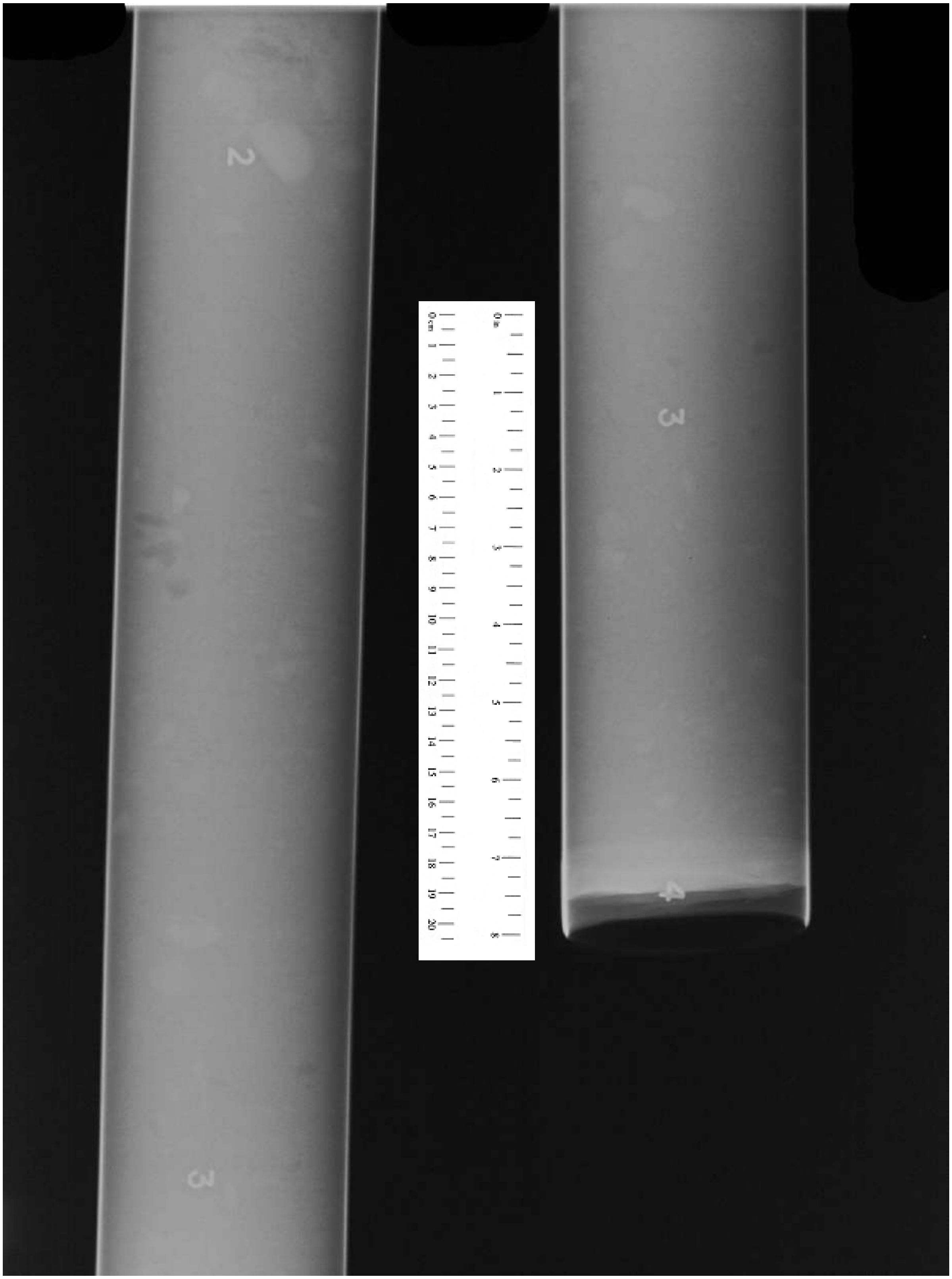
X-RAY RADIOGRAPHY IMAGES
BORING B-149, SAMPLE S-21, DEPTH 76.0 – 77.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-10



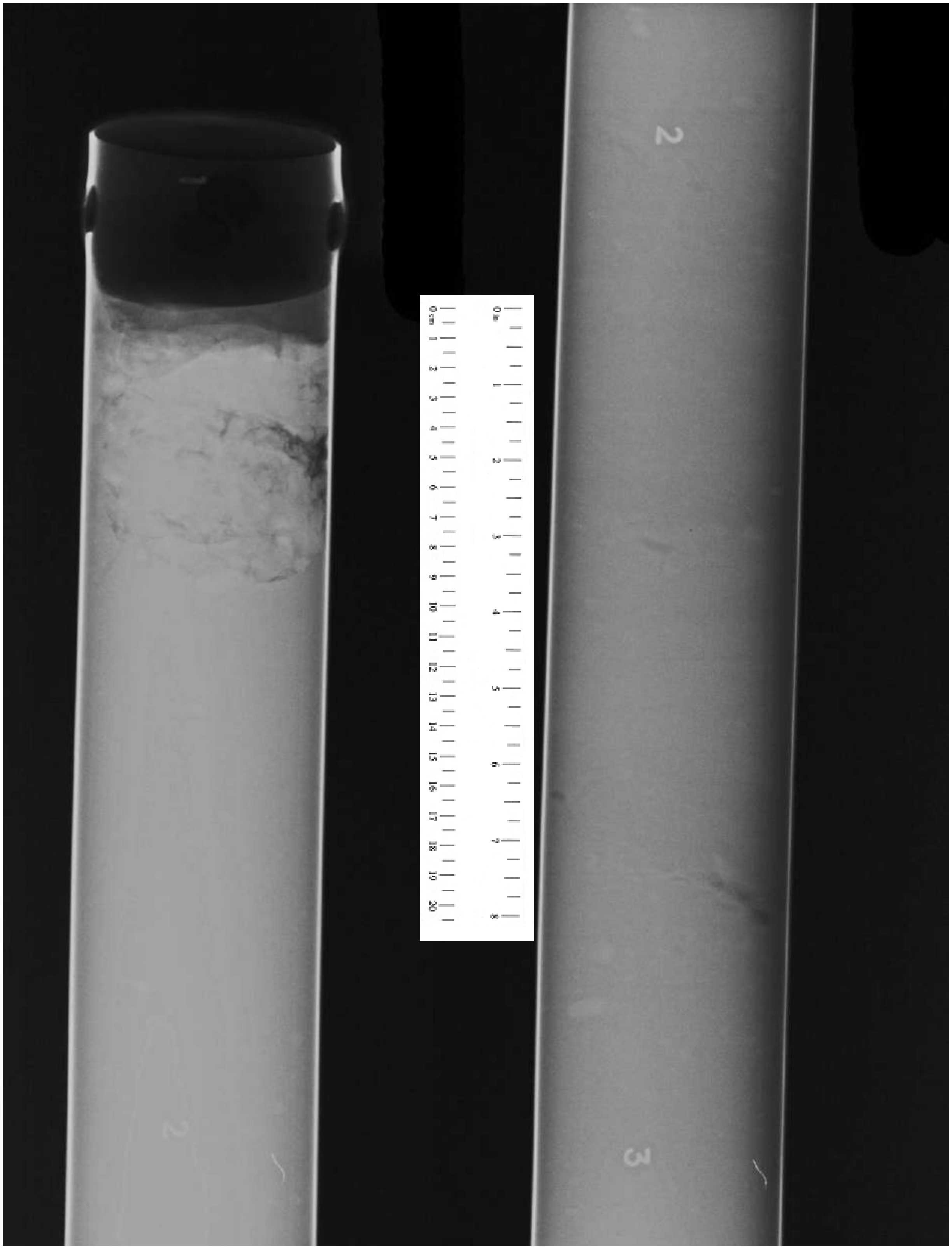
X-RAY RADIOGRAPHY IMAGES
BORING B-149, SAMPLE S-38, DEPTH 191.0 – 193.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-11a



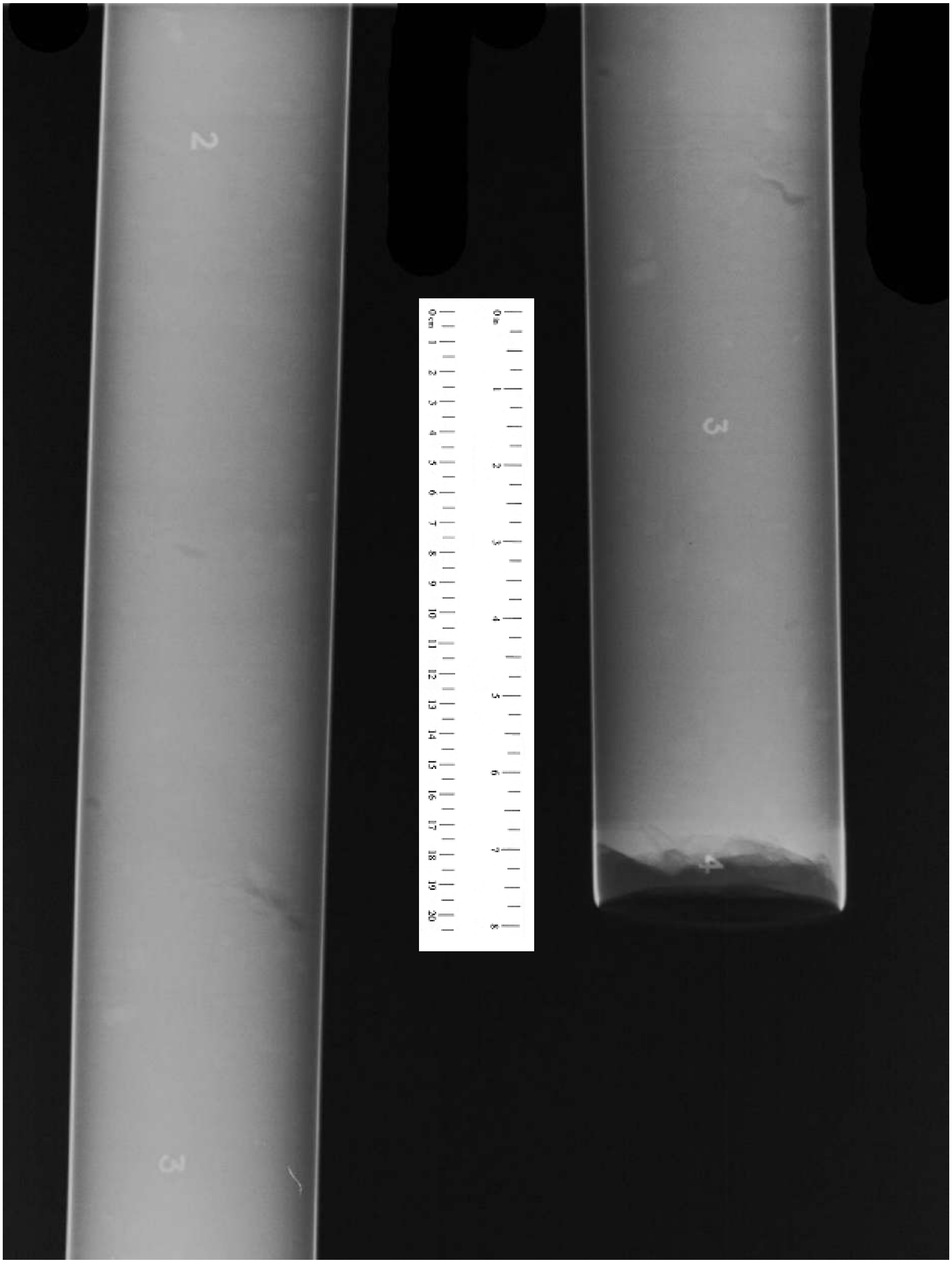
X-RAY RADIOGRAPHY IMAGES
BORING B-149, SAMPLE S-38, DEPTH 191.0 – 193.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-11b



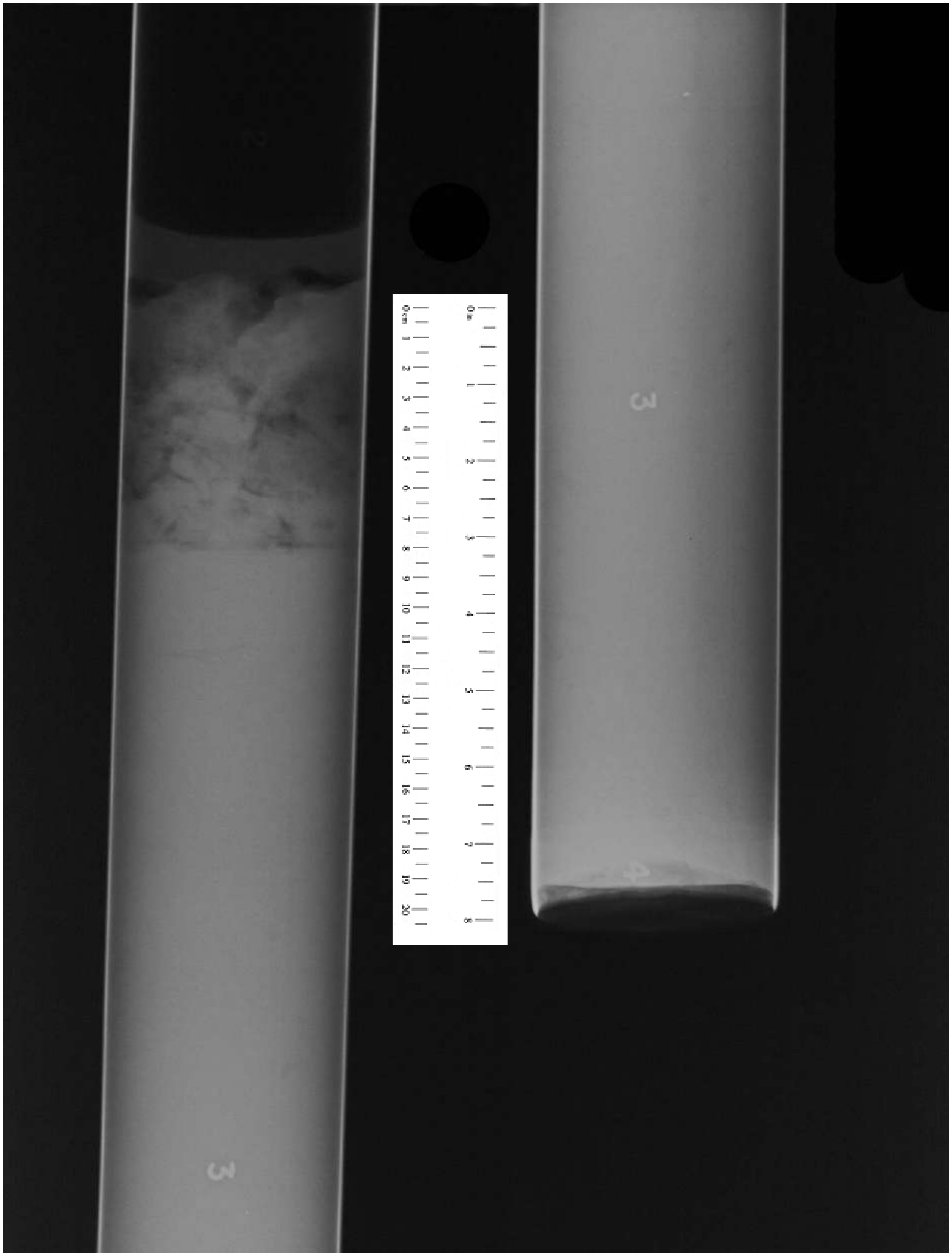
X-RAY RADIOGRAPHY IMAGES
BORING B-149, SAMPLE S-41, DEPTH 204.0 – 206.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-12a

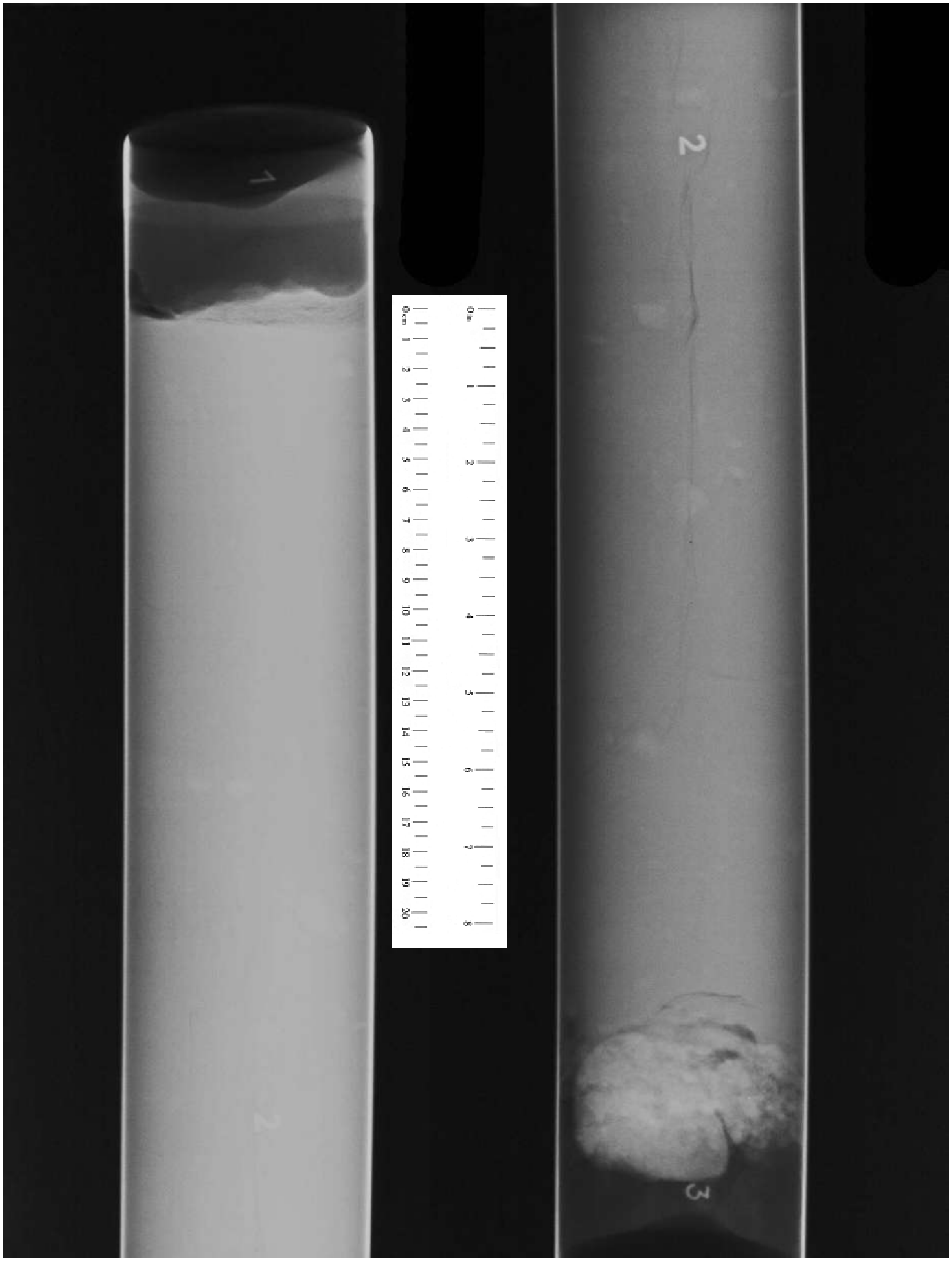


X-RAY RADIOGRAPHY IMAGES
BORING B-149, SAMPLE S-41, DEPTH 204.0 – 206.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

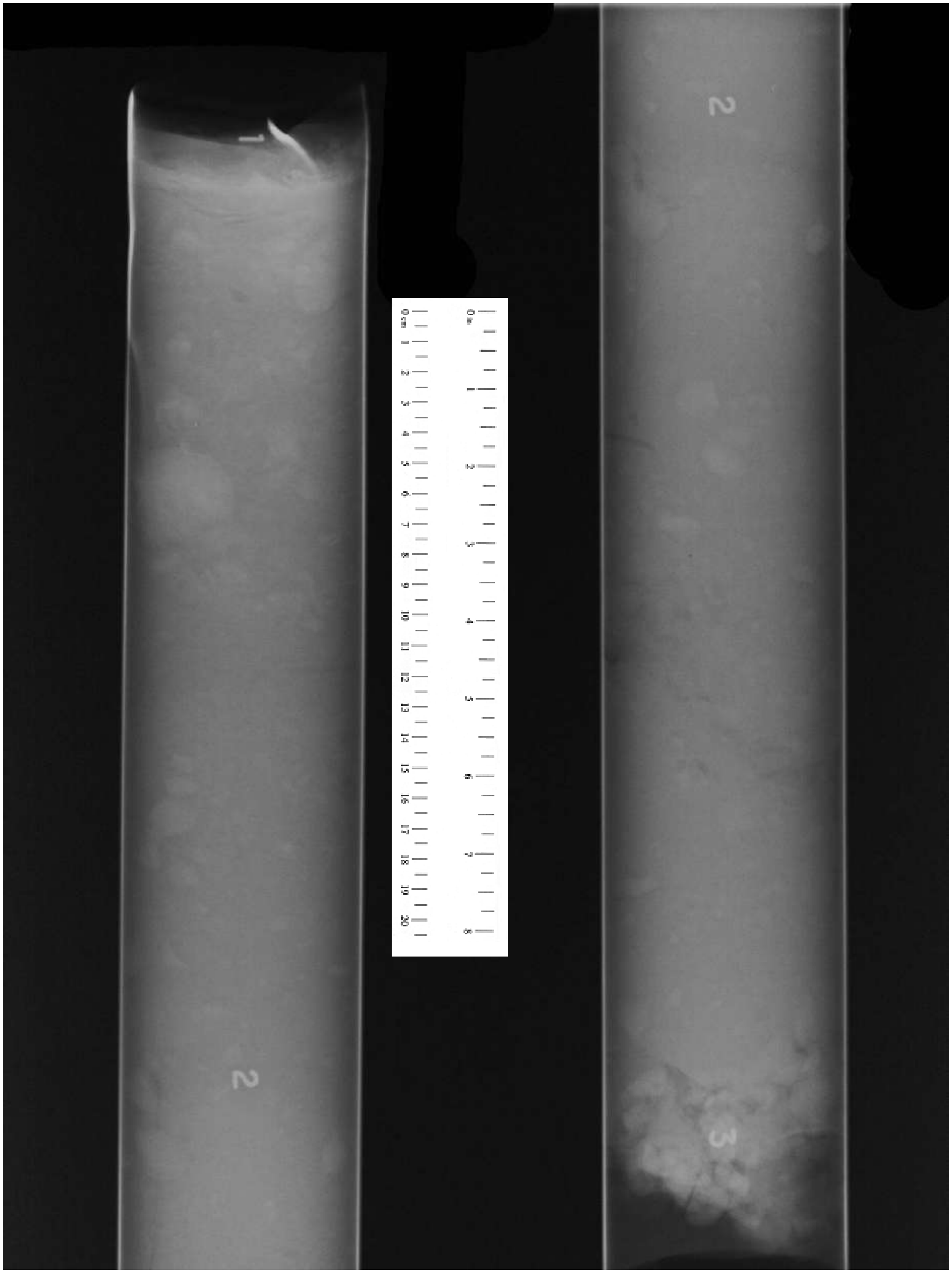
PLATE G10-12b



X-RAY RADIOGRAPHY IMAGES
BORING B-149, SAMPLE S-43, DEPTH 219.0 – 220.2 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

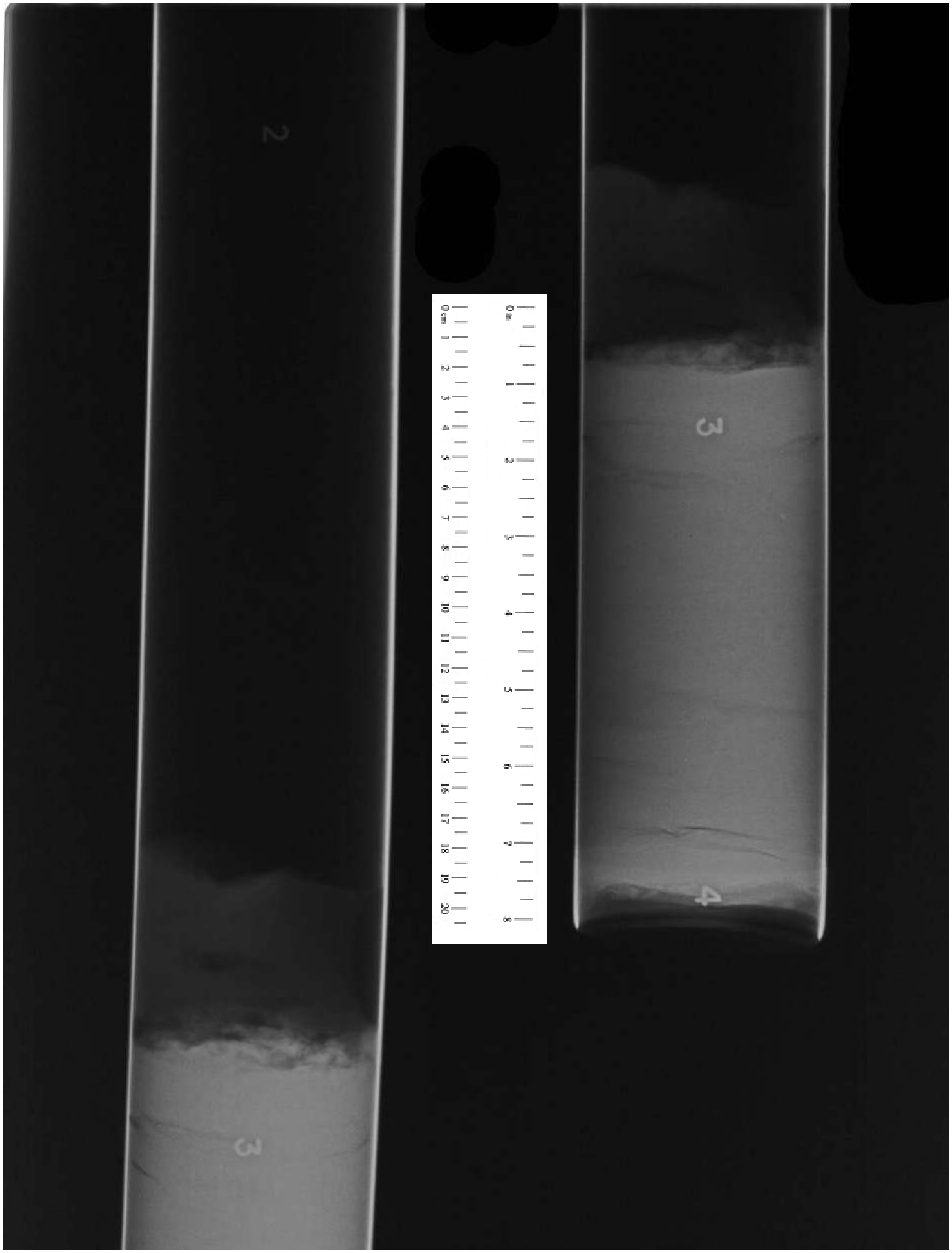


X-RAY RADIOGRAPHY IMAGES
BORING B-150, SAMPLE S-19, DEPTH 65.5 – 67.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

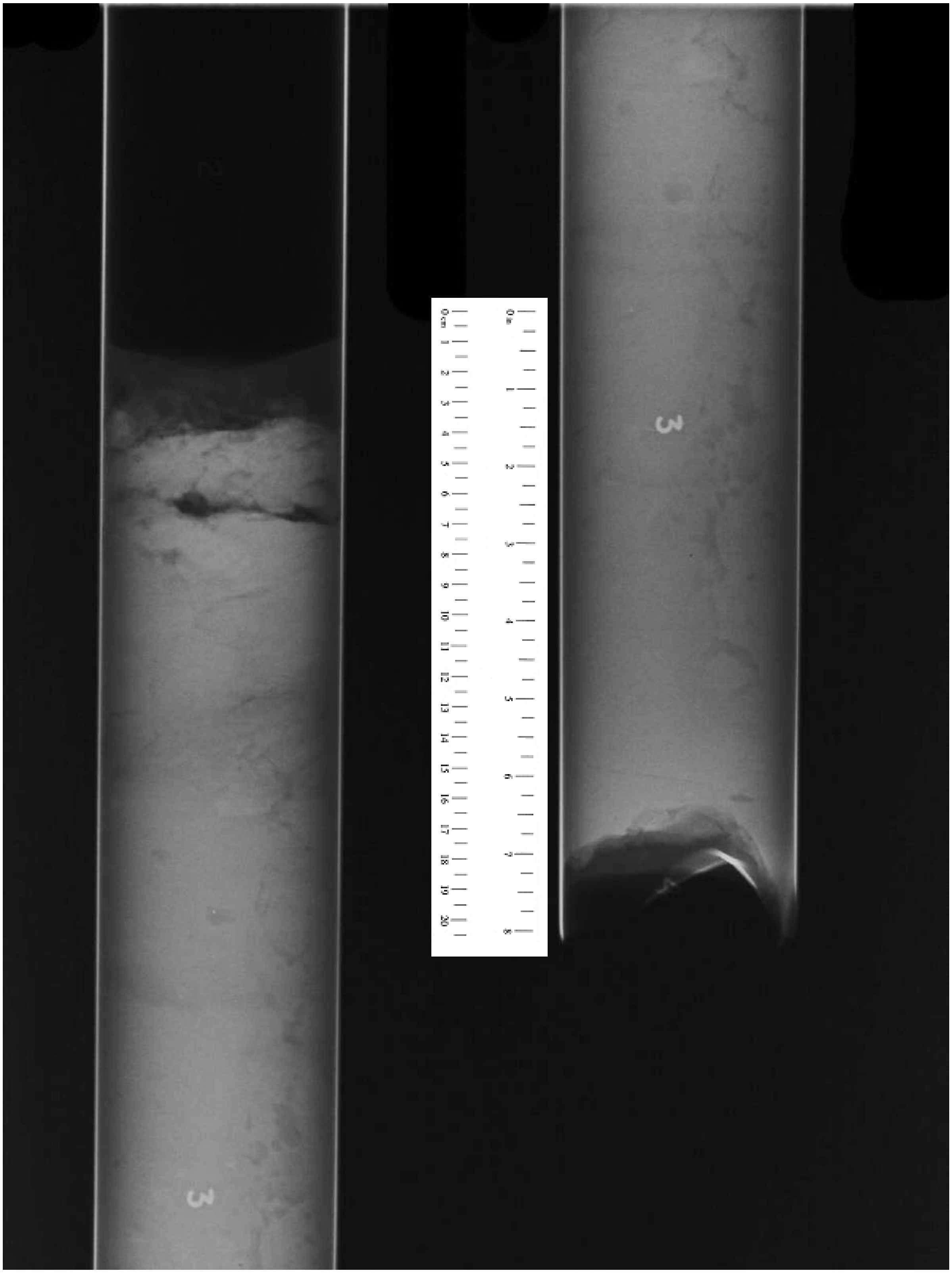


X-RAY RADIOGRAPHY IMAGES
BORING B-150, SAMPLE S-30, DEPTH 118.0 – 120.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

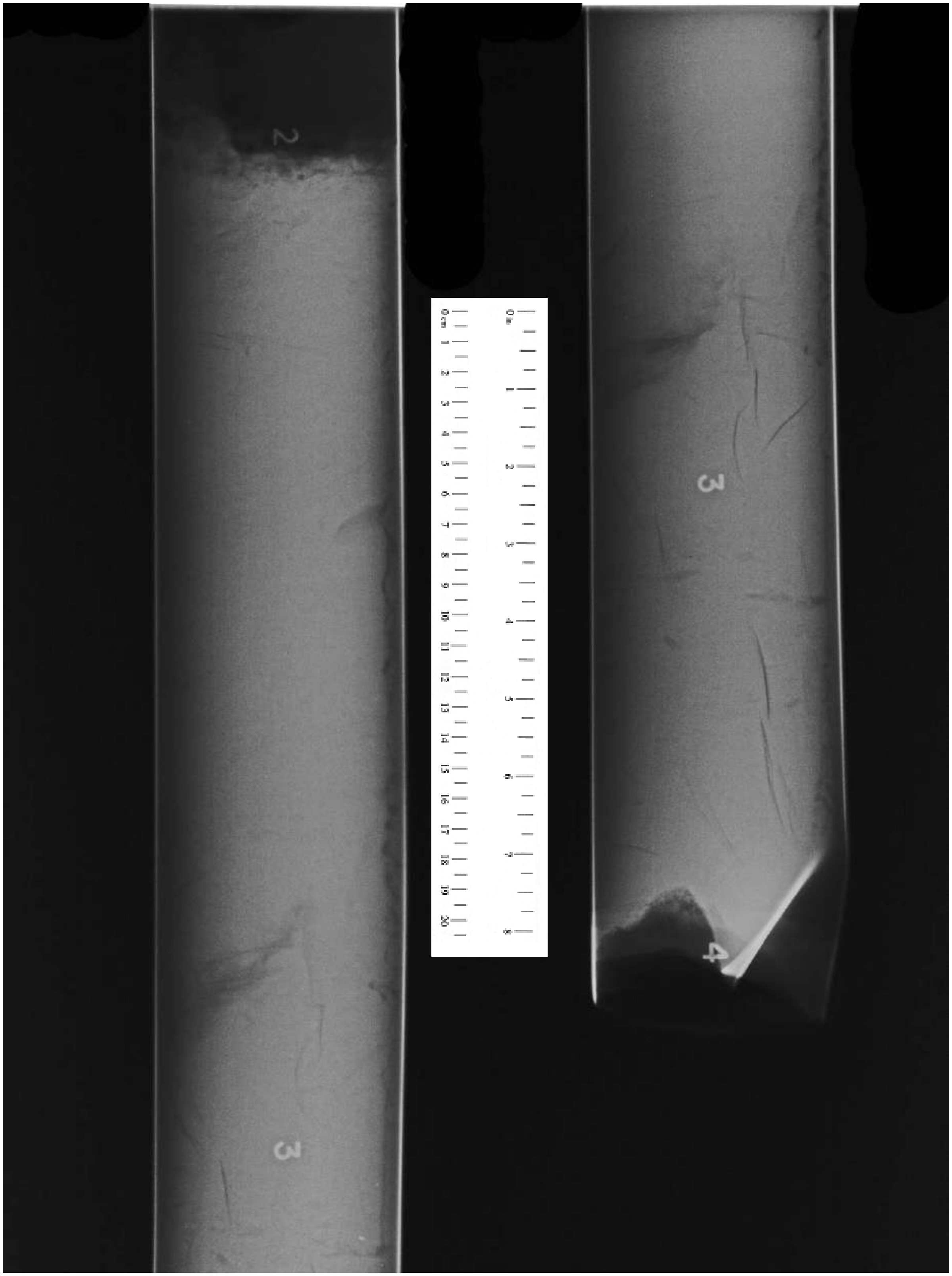
PLATE G10-15



X-RAY RADIOGRAPHY IMAGES
BORING B-151, SAMPLE S-20, DEPTH 66.5 – 67.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

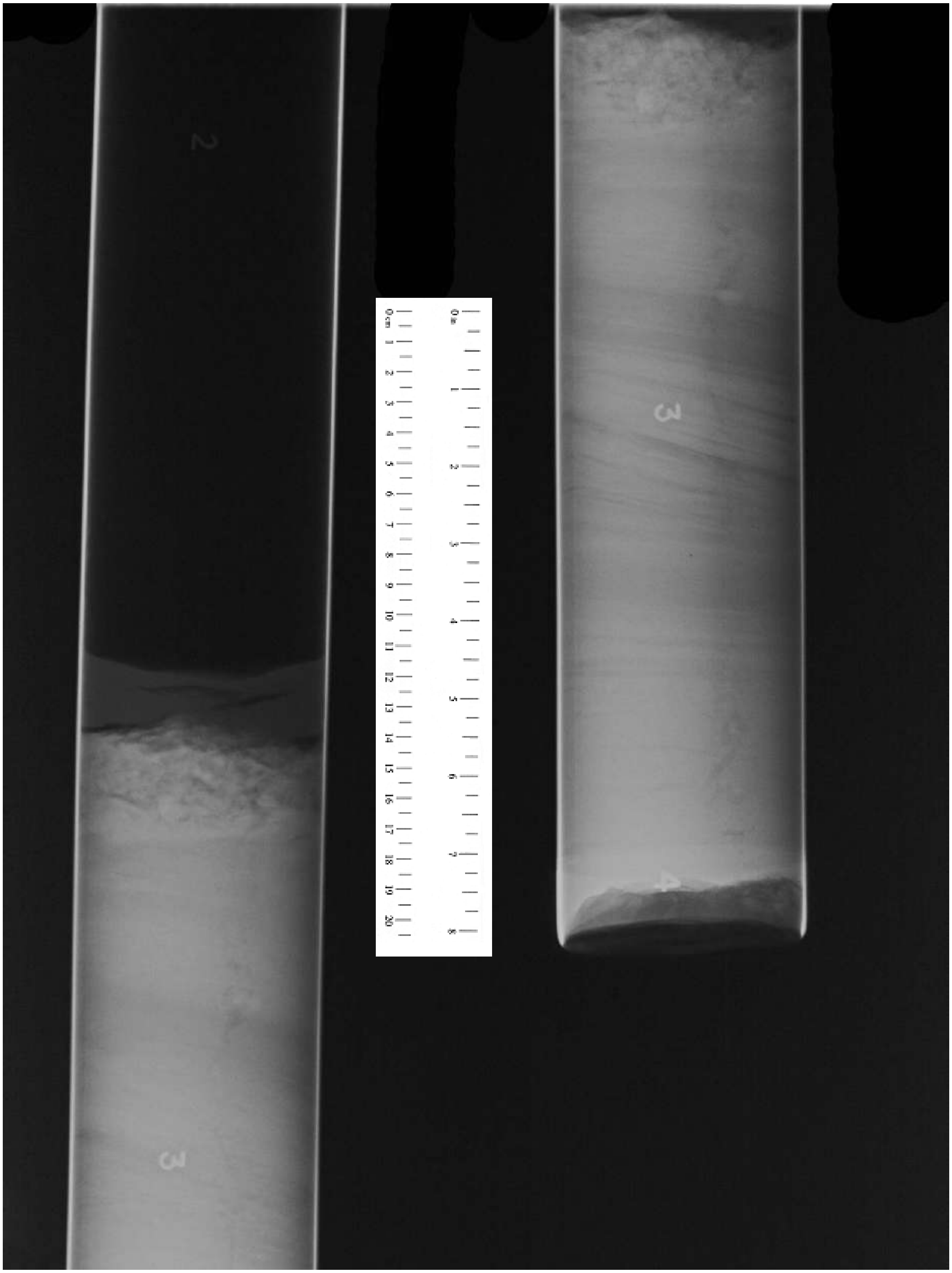


X-RAY RADIOGRAPHY IMAGES
BORING B-151, SAMPLE S-35, DEPTH 150.5 – 151.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

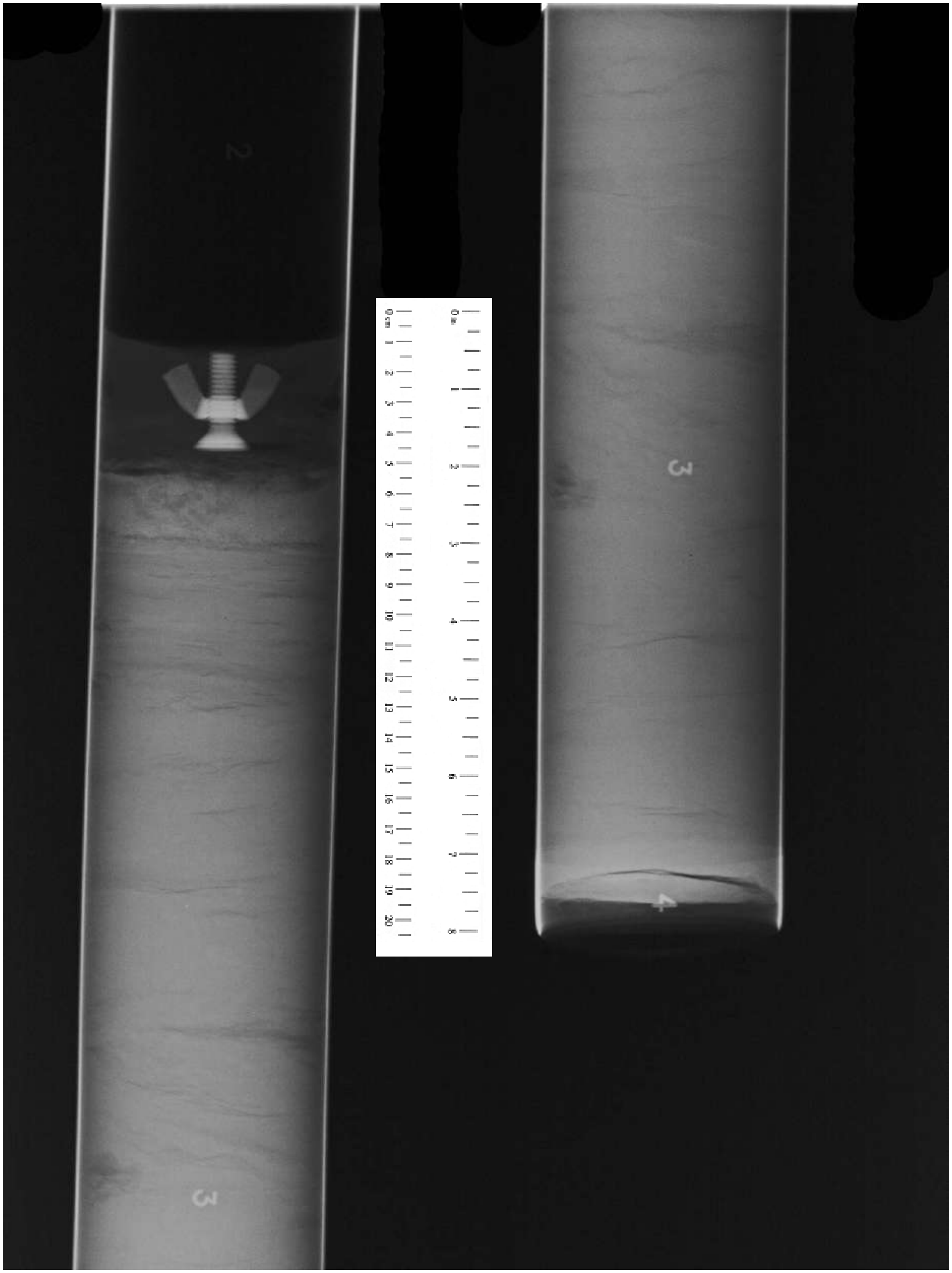


X-RAY RADIOGRAPHY IMAGES
BORING B-151, SAMPLE S-36, DEPTH 159.0 – 160.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

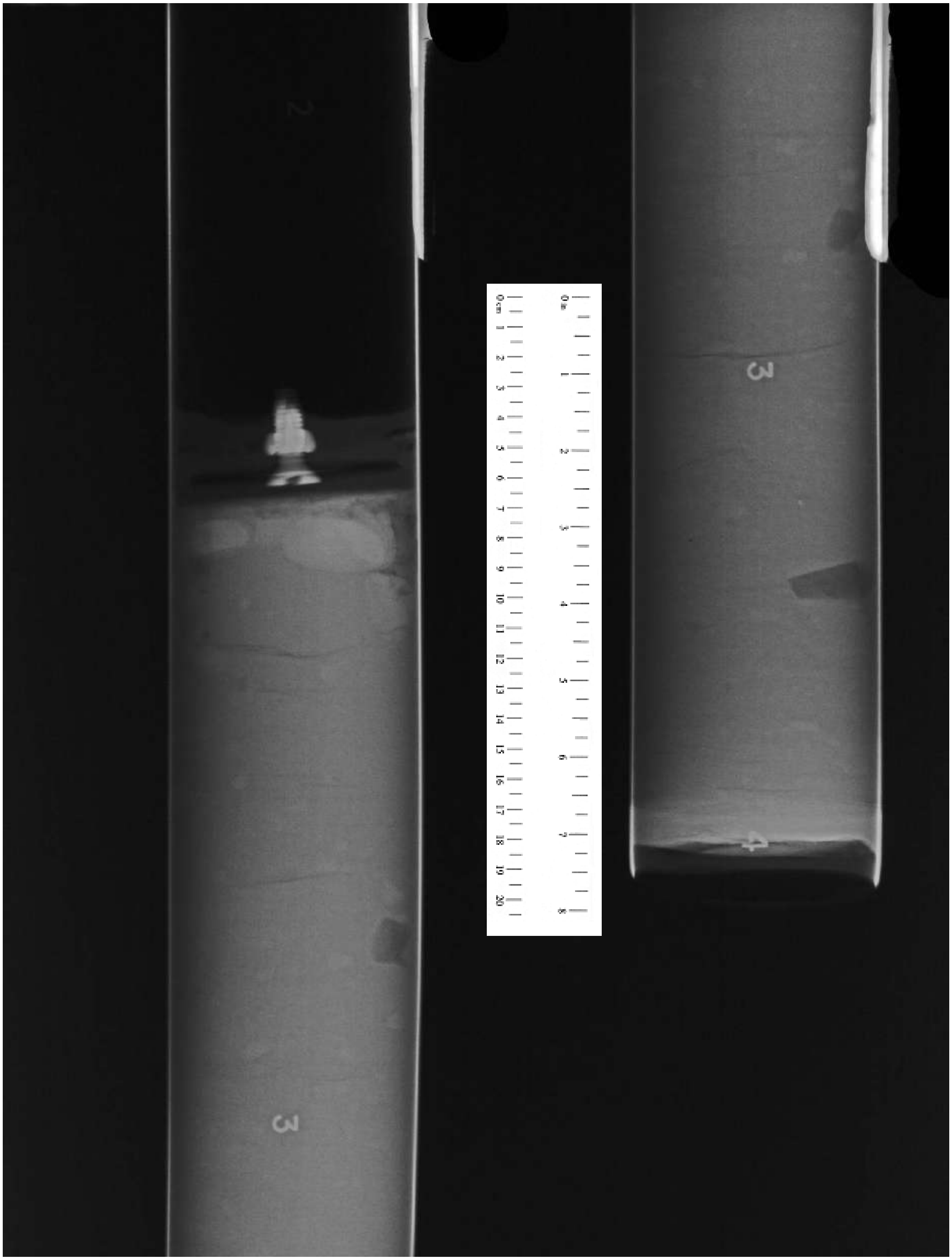
PLATE G10-18



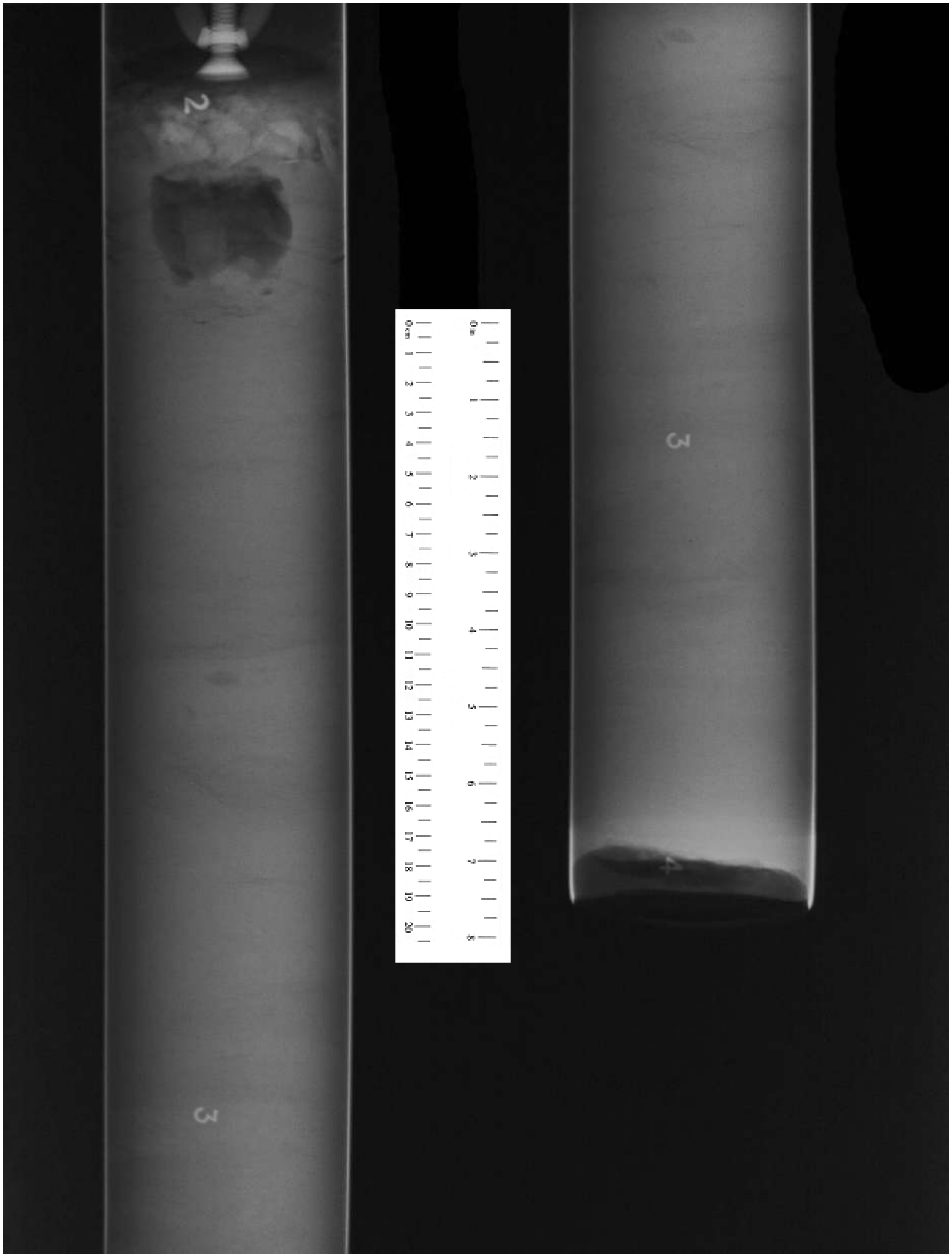
X-RAY RADIOGRAPHY IMAGES
BORING B-151, SAMPLE S-40, DEPTH 191.0 – 191.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



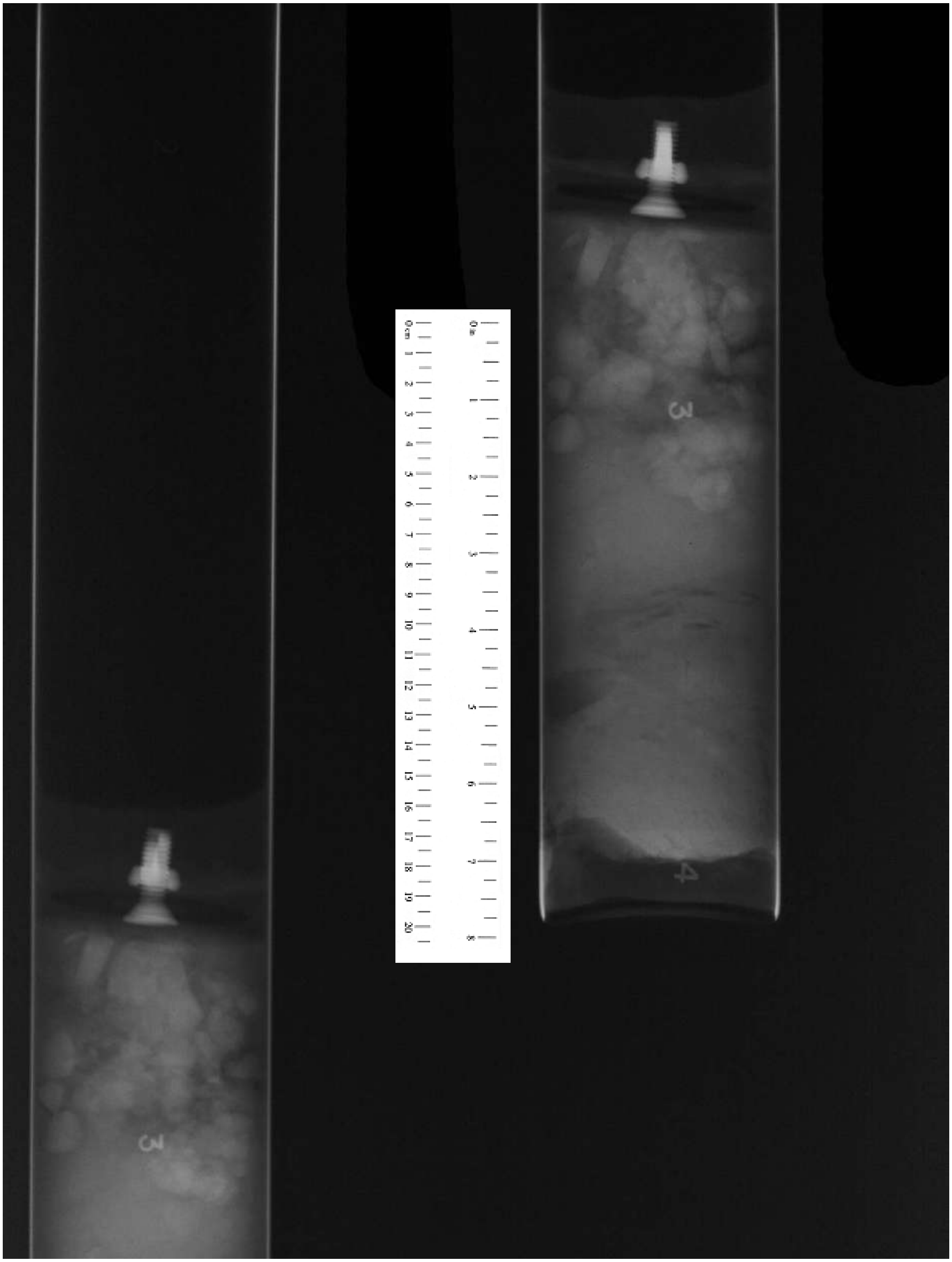
X-RAY RADIOGRAPHY IMAGES
BORING B-152, SAMPLE S-21, DEPTH 69.0 – 70.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
BORING B-152, SAMPLE S-28, DEPTH 90.5 – 91.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

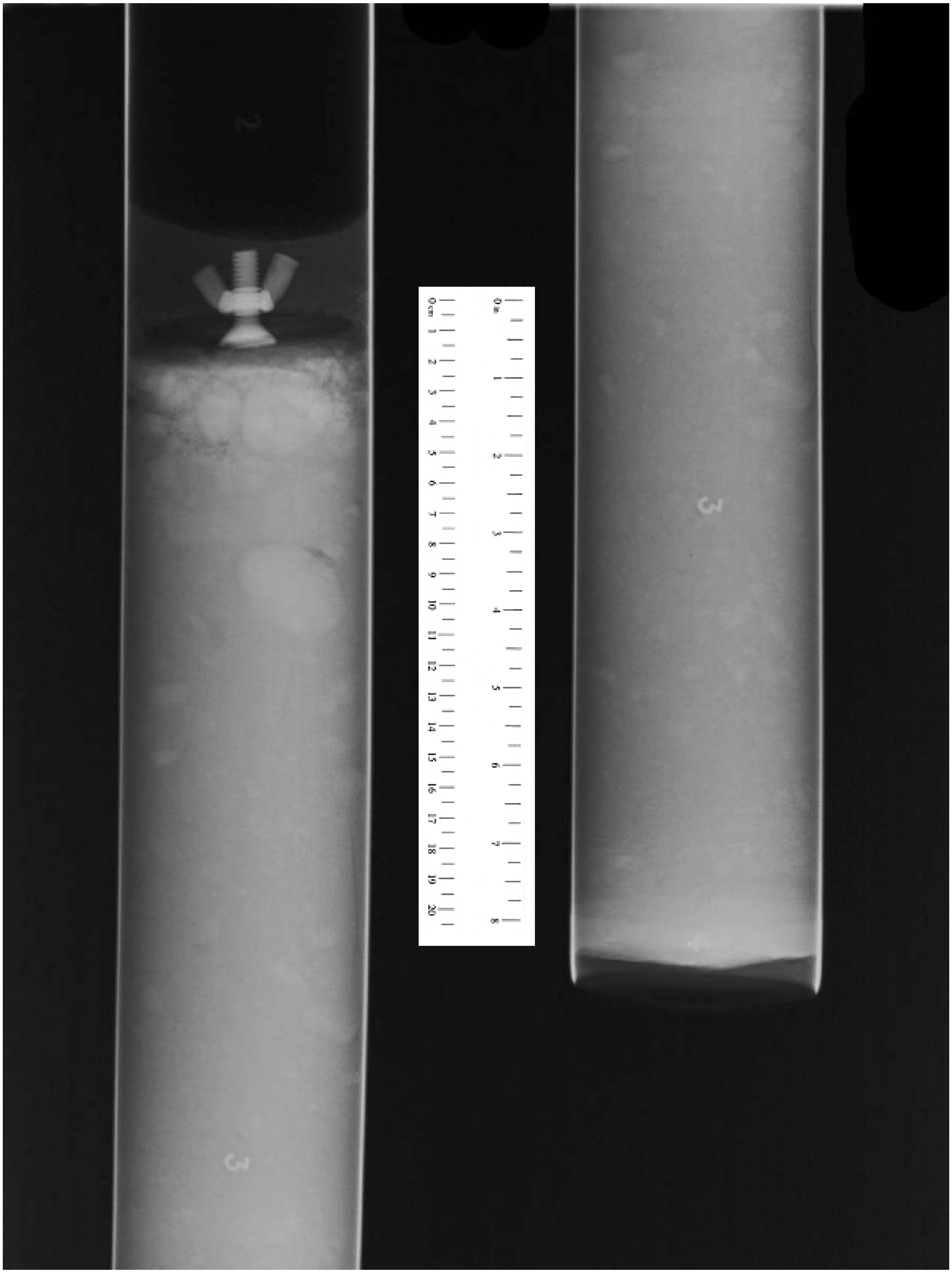


X-RAY RADIOGRAPHY IMAGES
BORING B-153, SAMPLE S-19, DEPTH 66.0 – 67.4 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

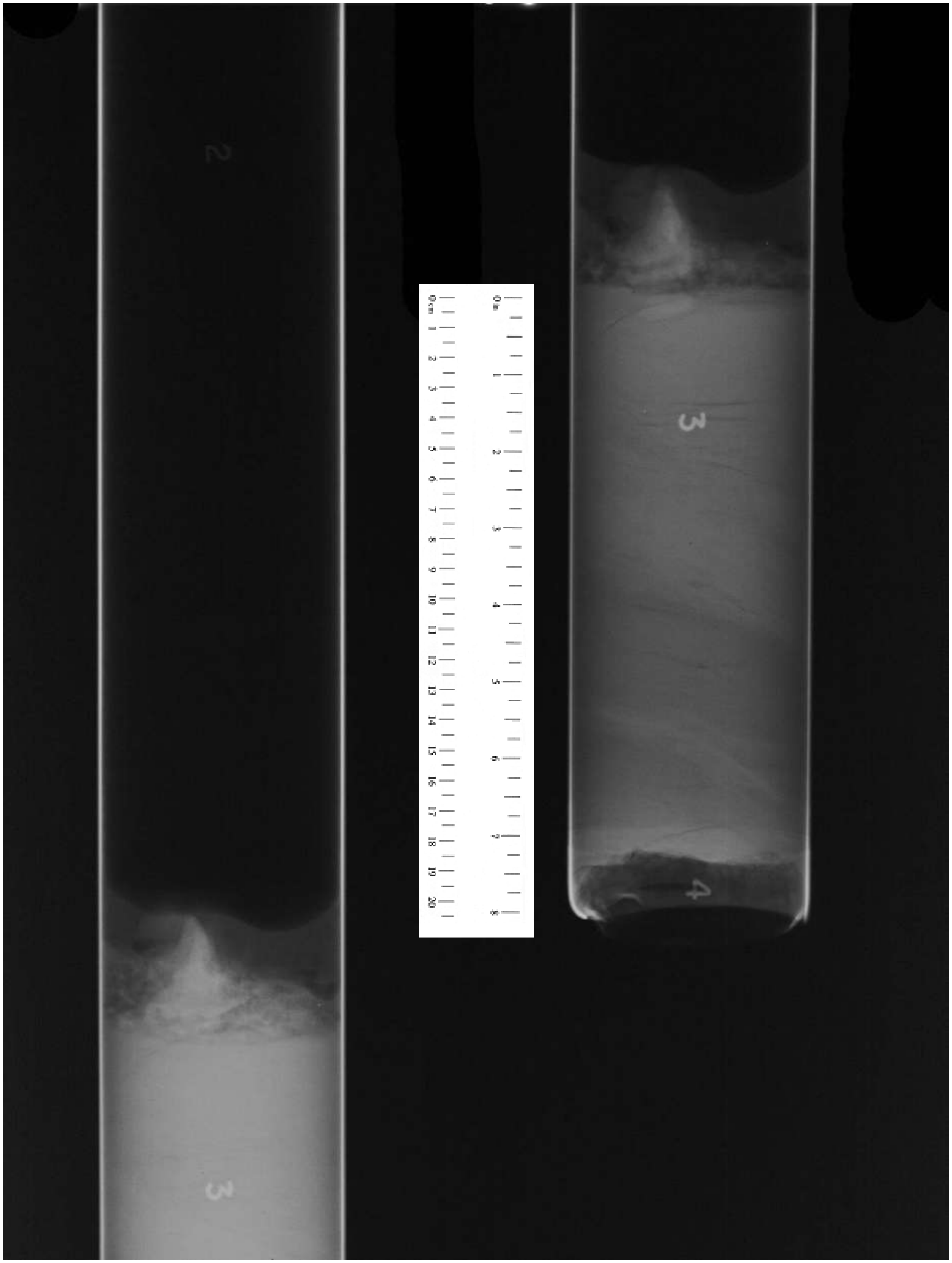


X-RAY RADIOGRAPHY IMAGES
BORING B-153, SAMPLE S-24, DEPTH 86.0 – 86.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

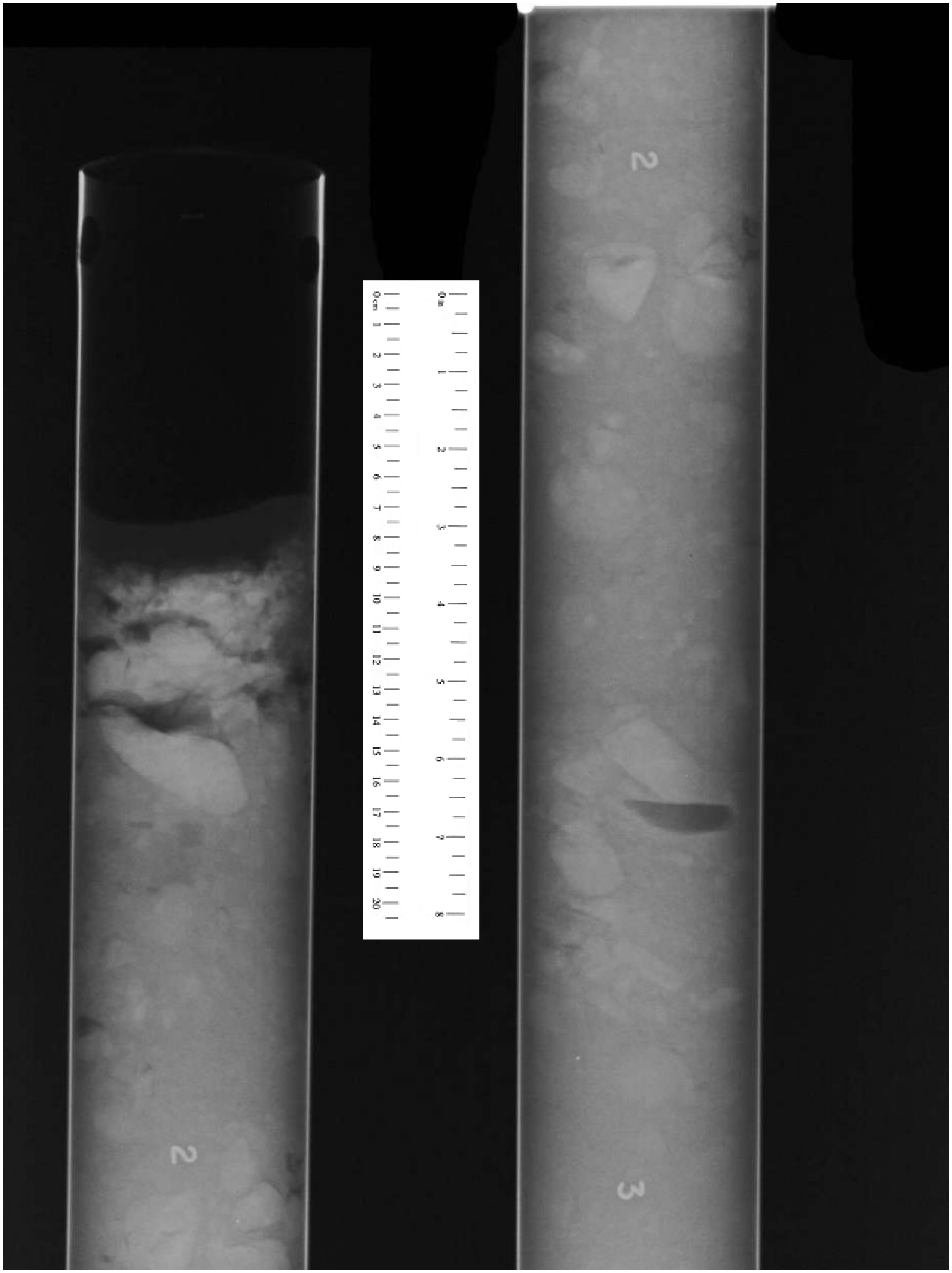
PLATE G10-23



X-RAY RADIOGRAPHY IMAGES
BORING B-154, SAMPLE S-27, DEPTH 91.0 – 92.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

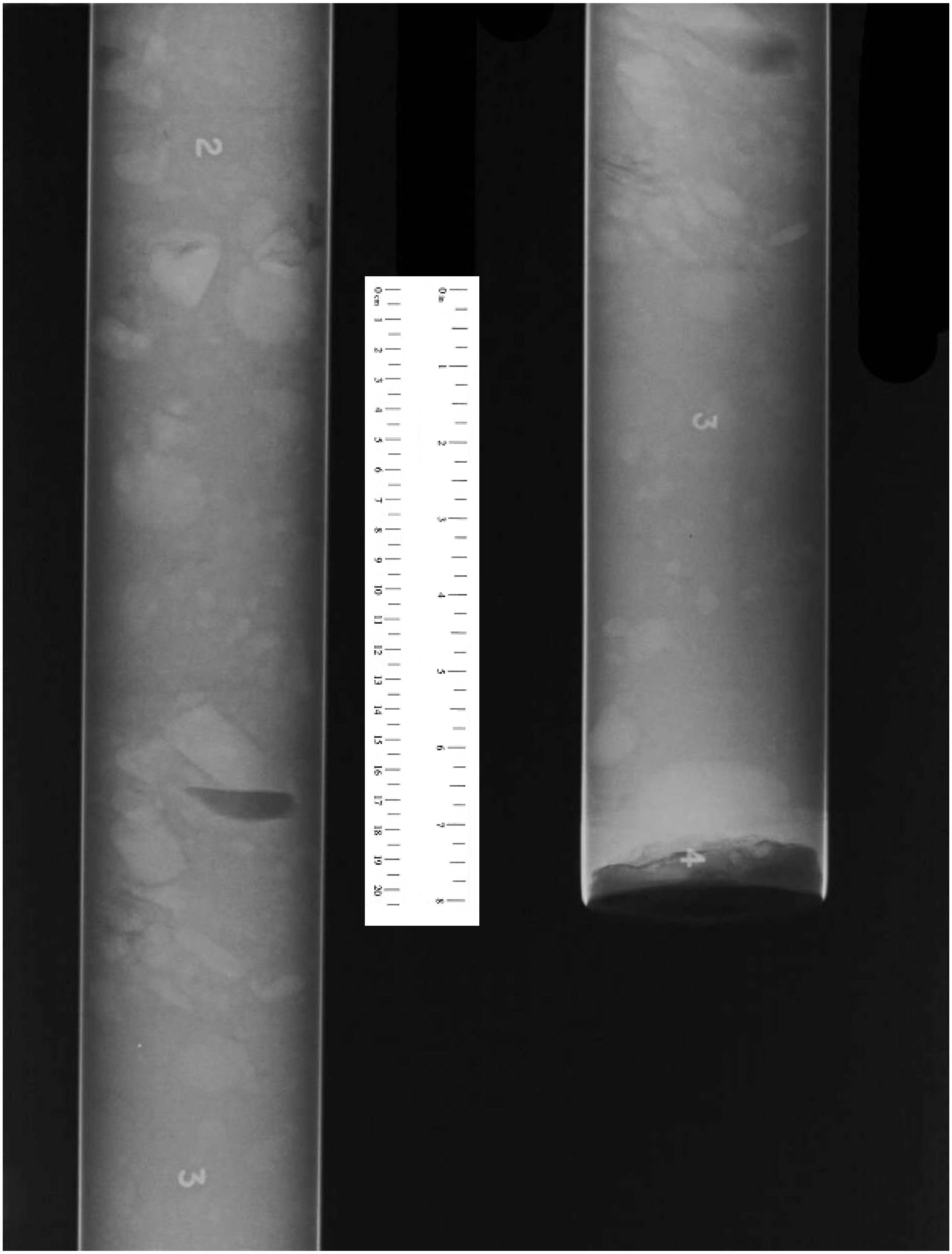


X-RAY RADIOGRAPHY IMAGES
BORING B-156, SAMPLE S-22, DEPTH 83.0 – 83.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



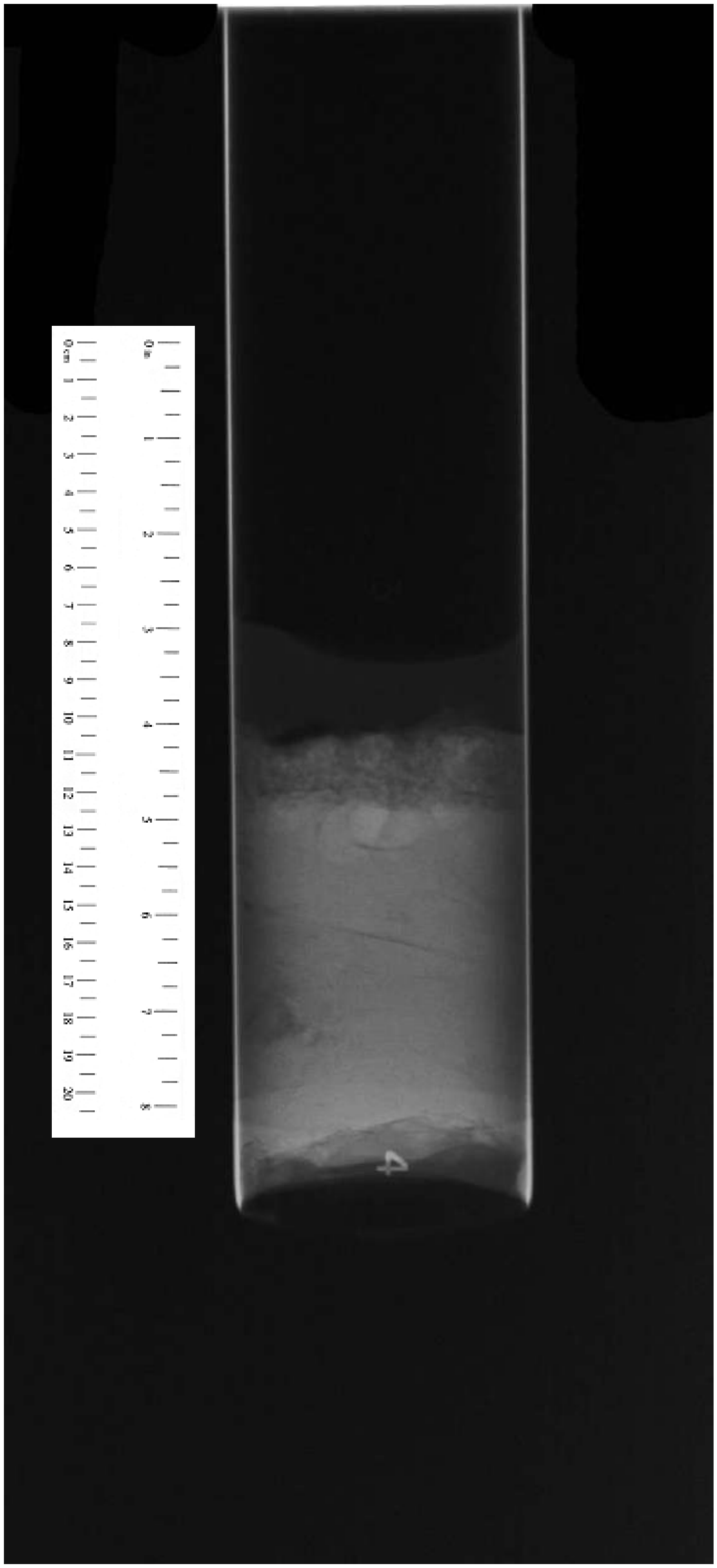
X-RAY RADIOGRAPHY IMAGES
BORING B-156, SAMPLE S-27, DEPTH 100.5 – 102.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-26a



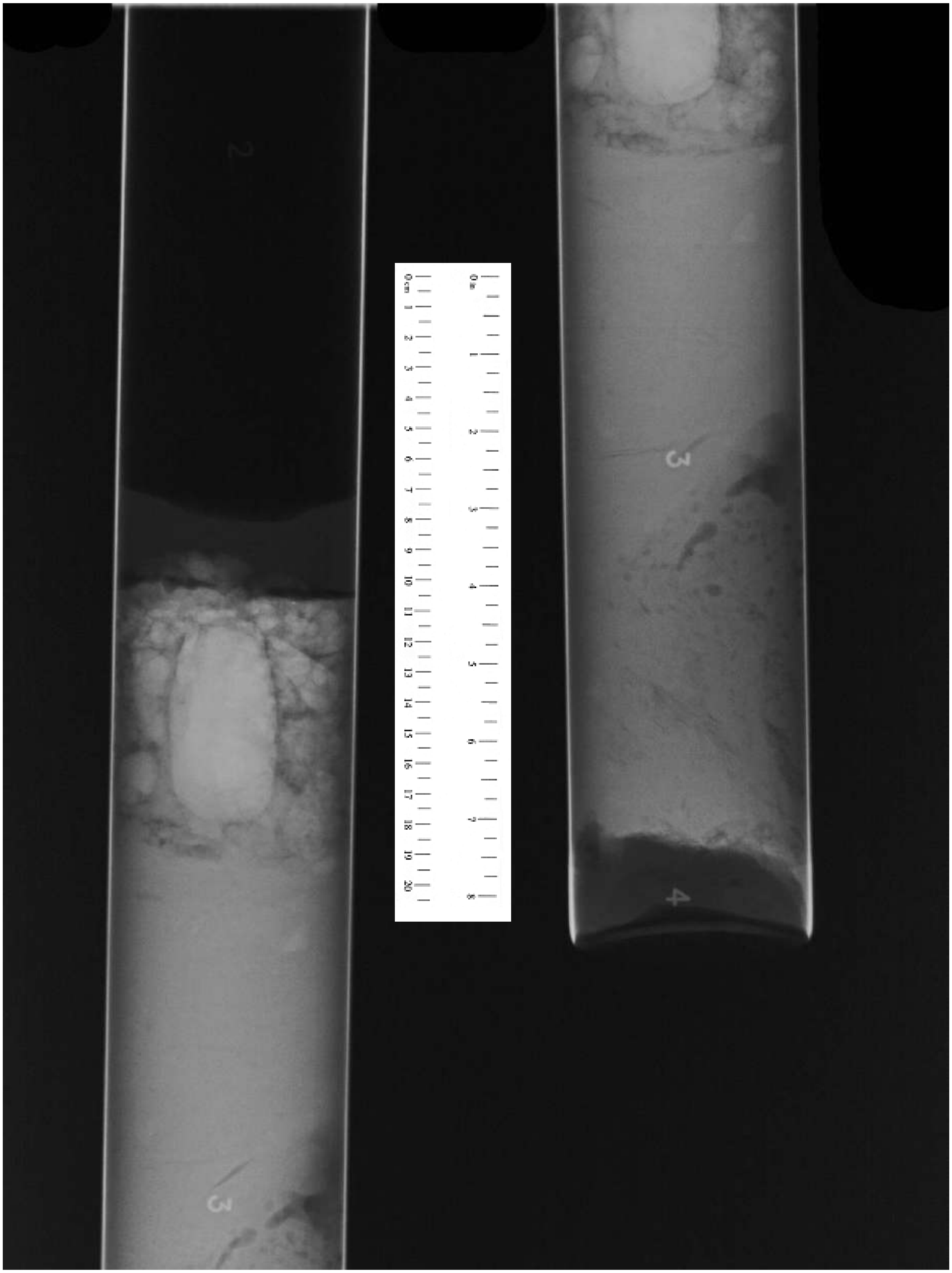
X-RAY RADIOGRAPHY IMAGES
BORING B-156, SAMPLE S-27, DEPTH 100.5 – 102.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-26b



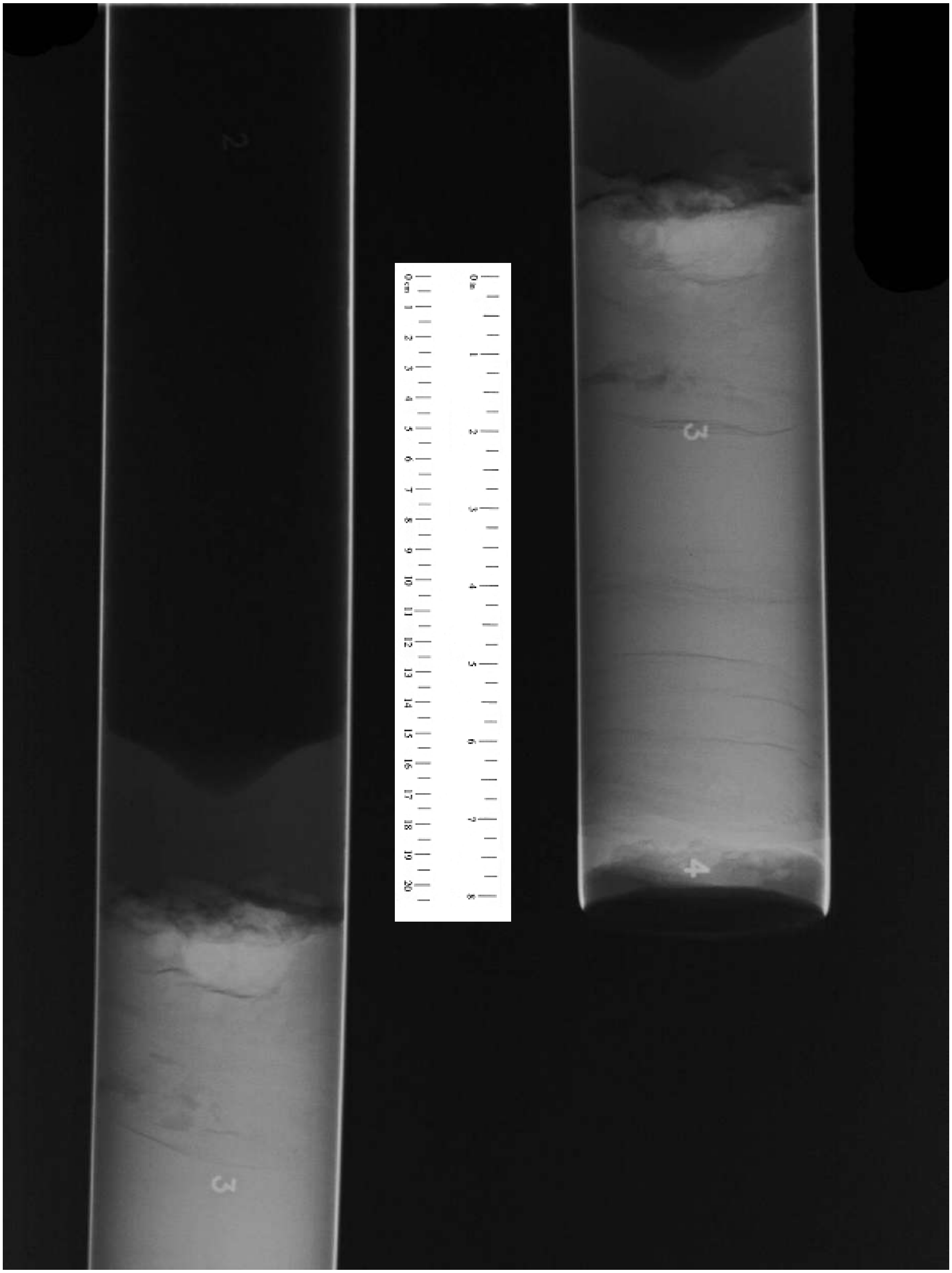
X-RAY RADIOGRAPHY IMAGES
BORING B-156, SAMPLE S-28, DEPTH 104.0 – 104.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-27



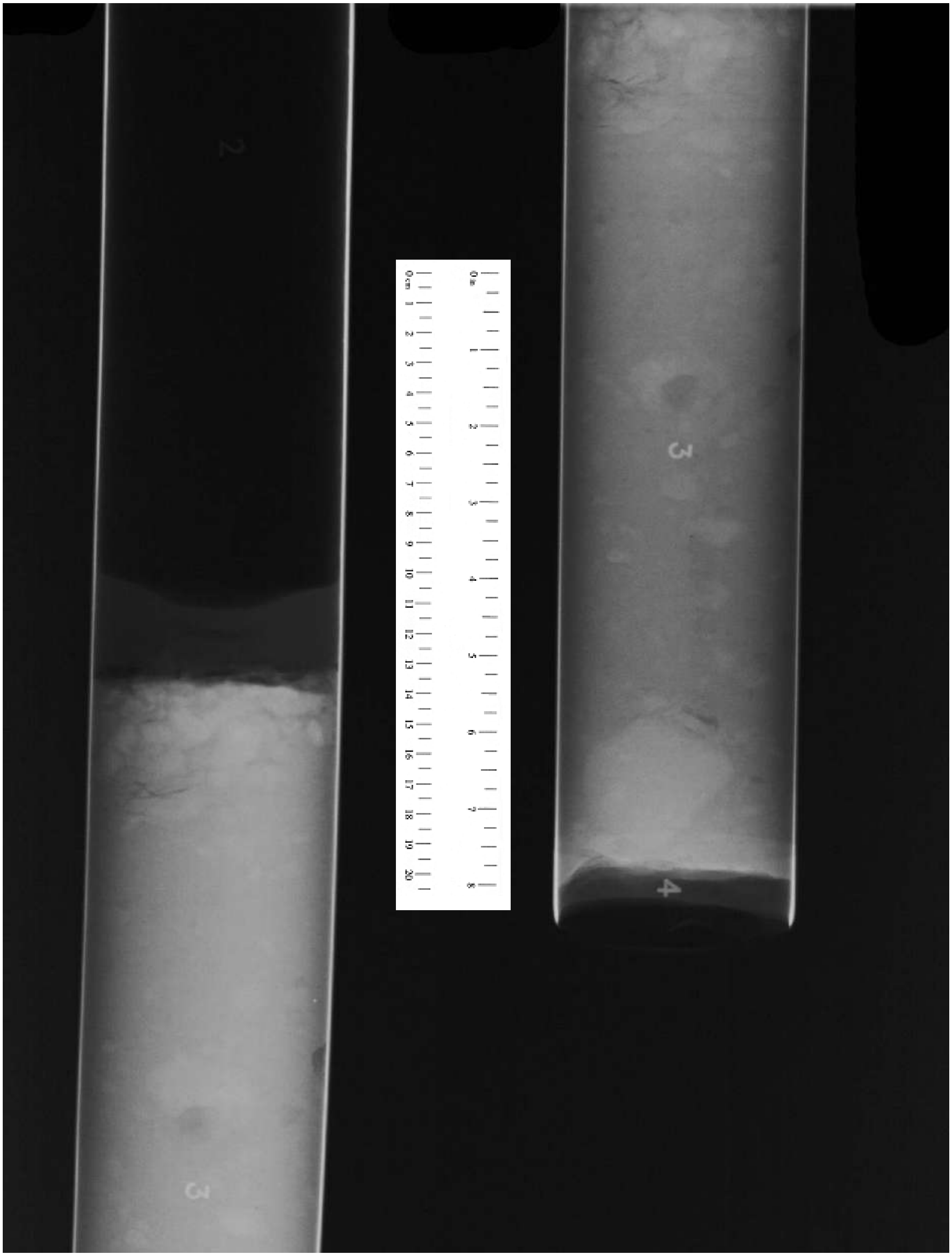
X-RAY RADIOGRAPHY IMAGES
BORING B-156, SAMPLE S-32, DEPTH 137.0 – 138.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-28

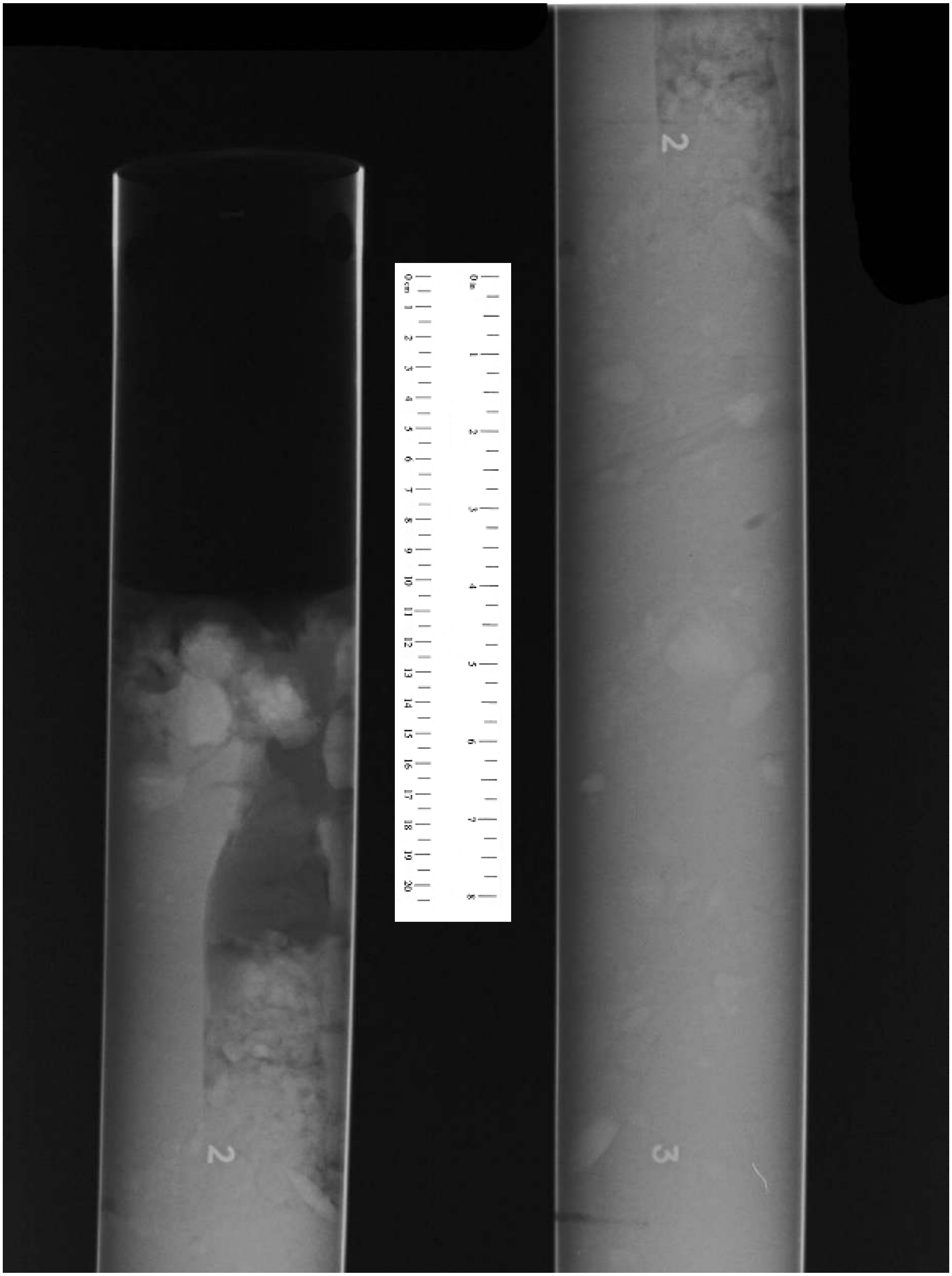


X-RAY RADIOGRAPHY IMAGES
BORING B-157, SAMPLE S-21, DEPTH 71.0 – 71.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

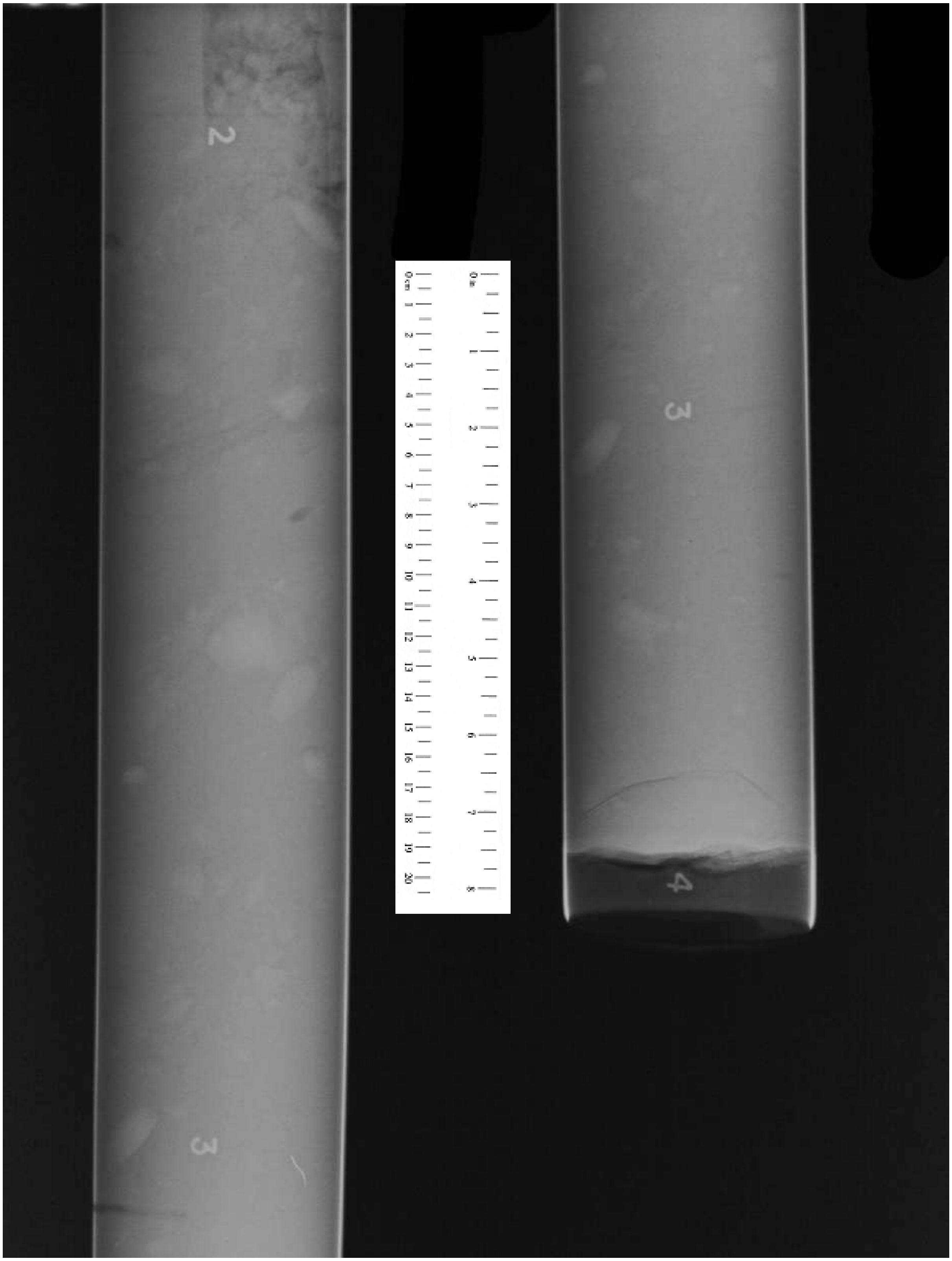
PLATE G10-29



X-RAY RADIOGRAPHY IMAGES
BORING B-157, SAMPLE S-28, DEPTH 96.0 – 97.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

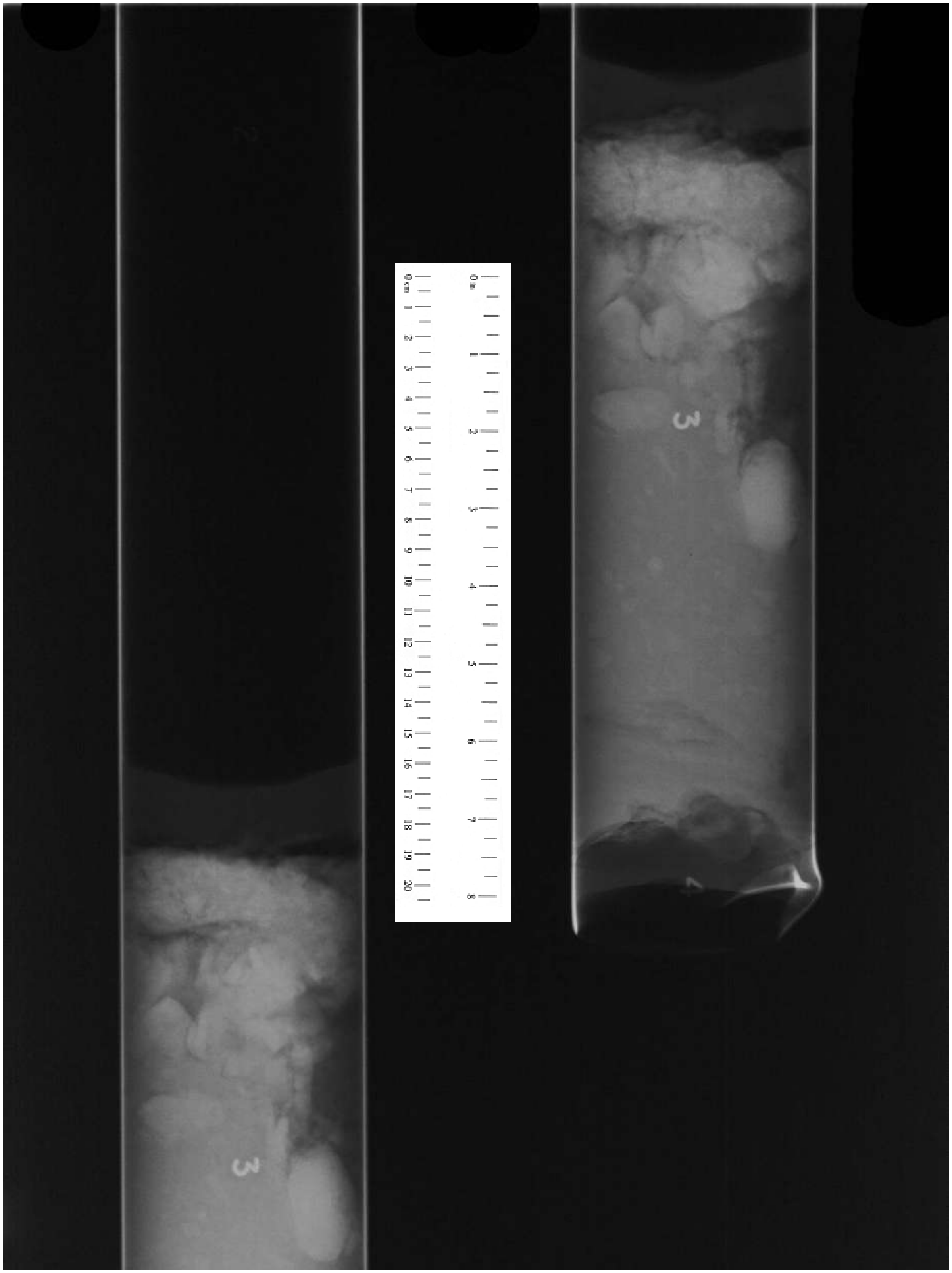


X-RAY RADIOGRAPHY IMAGES
BORING B-157, SAMPLE S-30, DEPTH 99.0 – 101.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

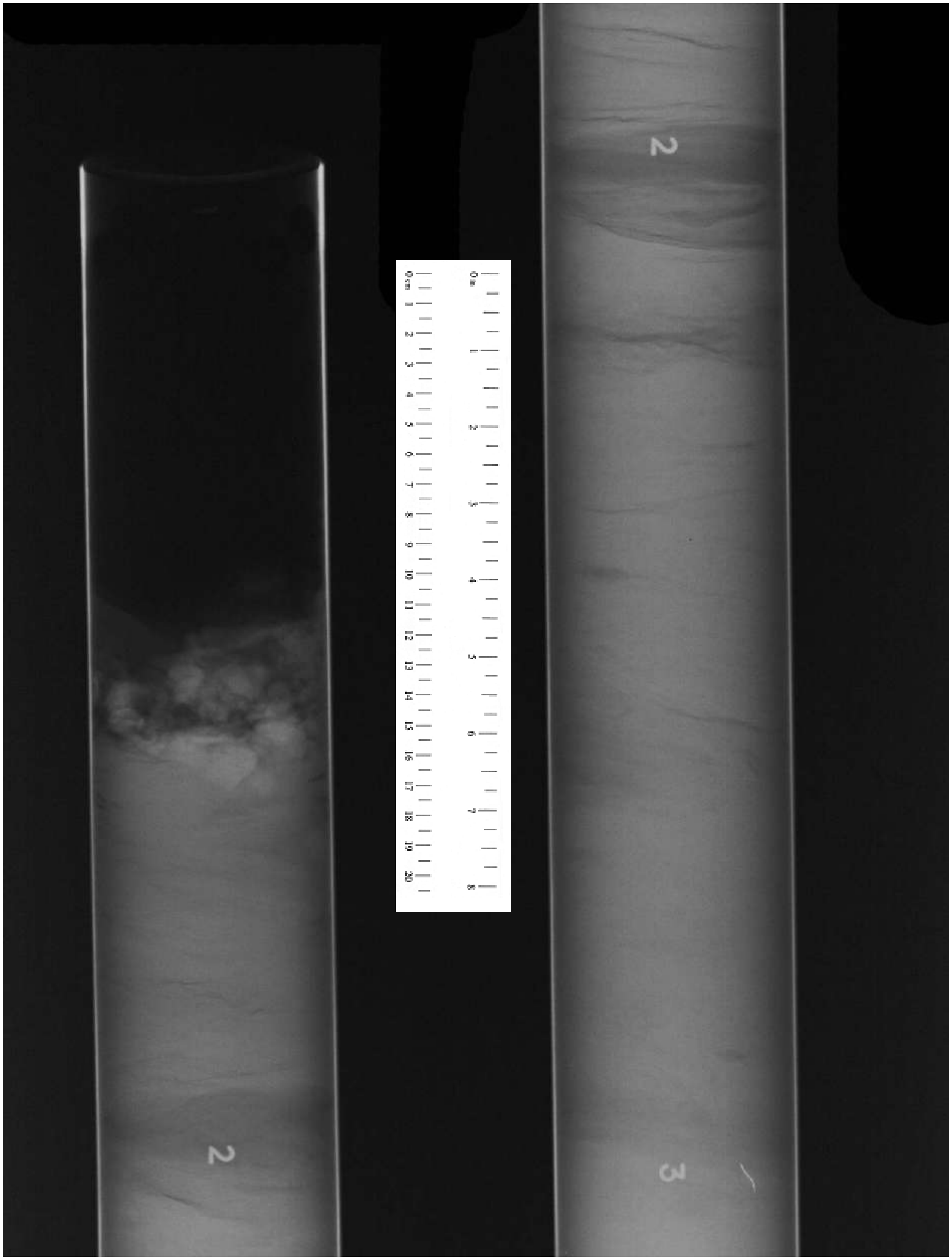


X-RAY RADIOGRAPHY IMAGES
BORING B-157, SAMPLE S-30, DEPTH 99.0 – 101.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

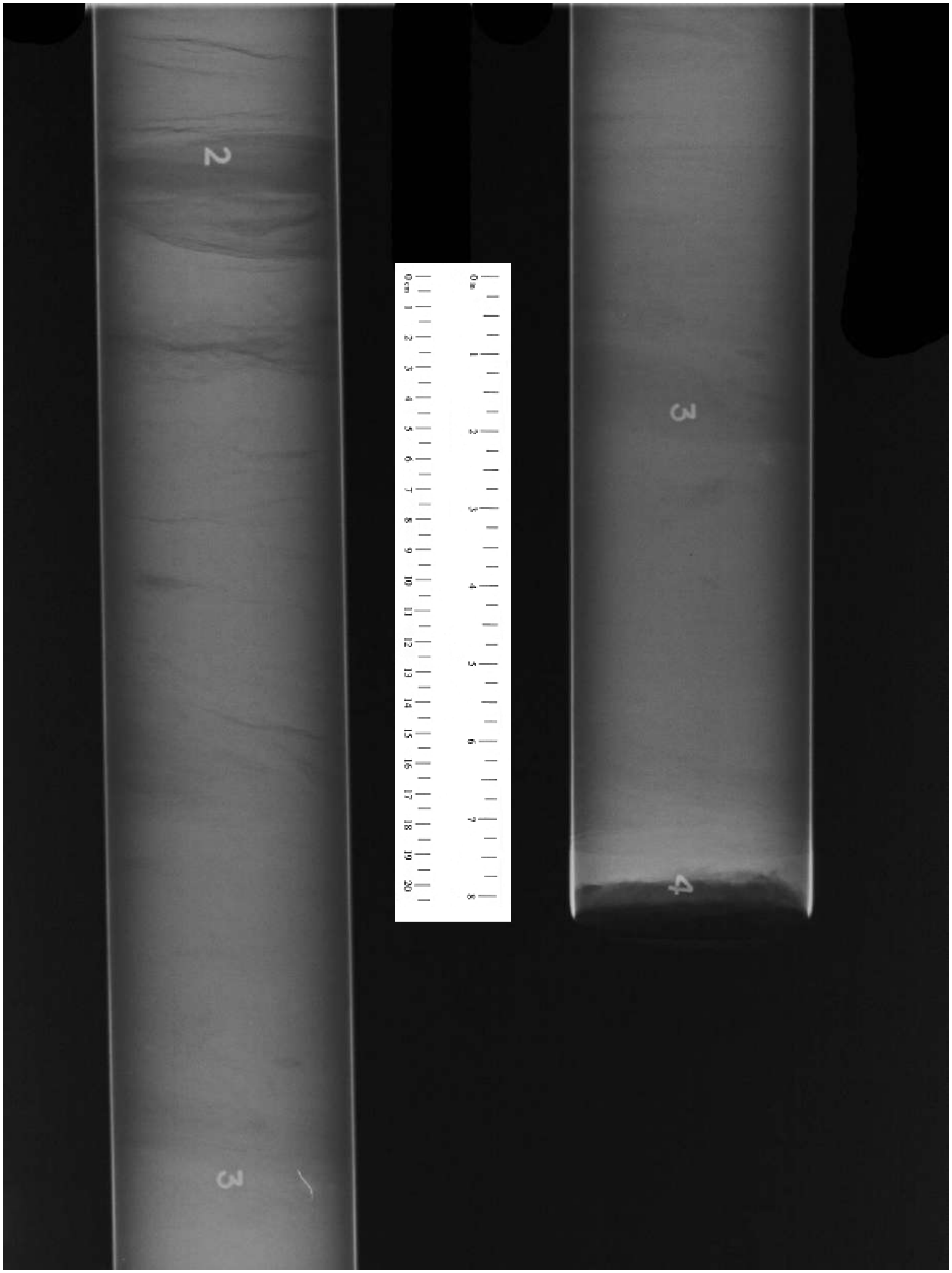
PLATE G10-31b



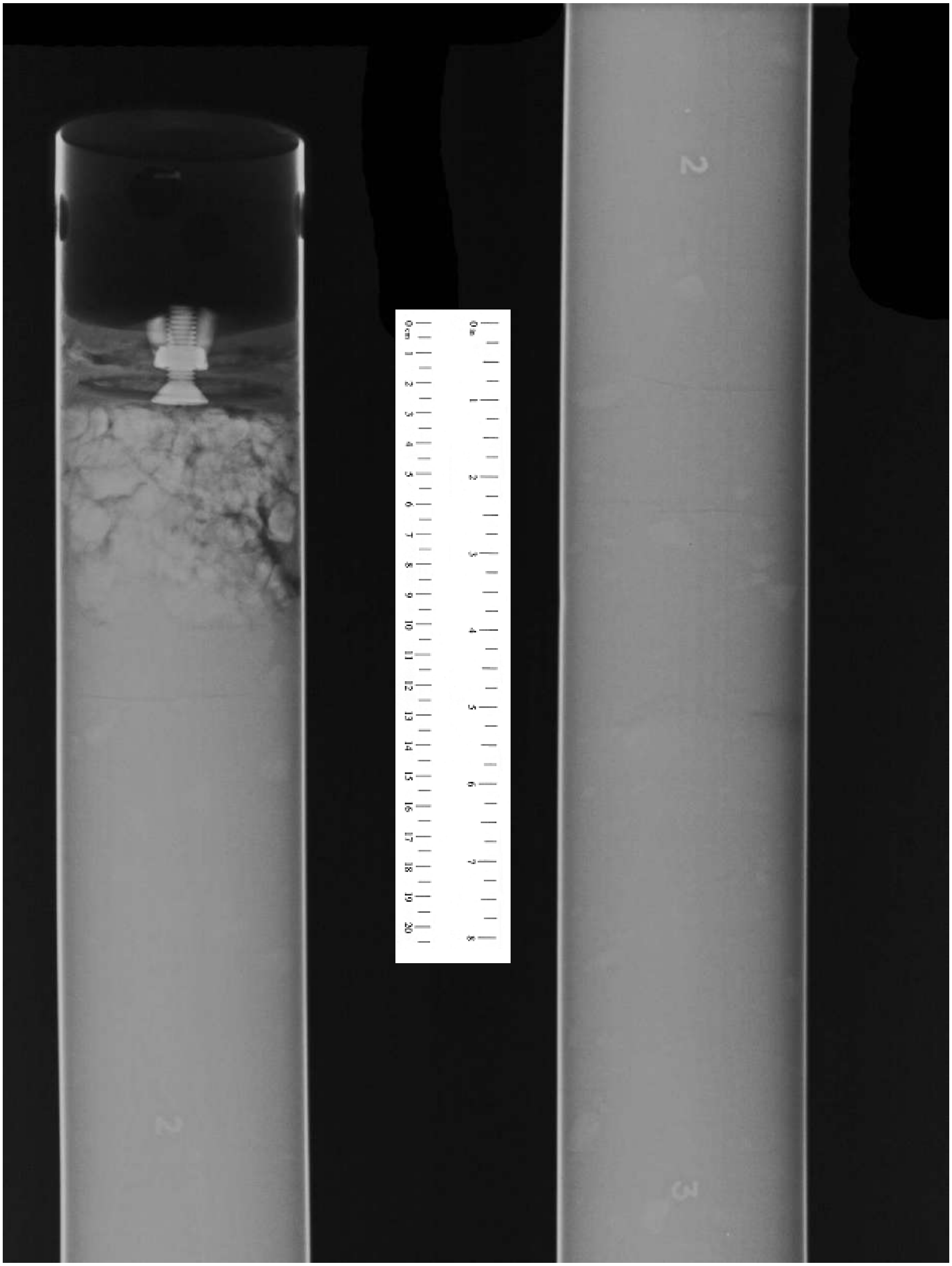
X-RAY RADIOGRAPHY IMAGES
BORING B-157, SAMPLE S-36, DEPTH 141.0 – 141.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
BORING B-159, SAMPLE S-21, DEPTH 77.5 – 78.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

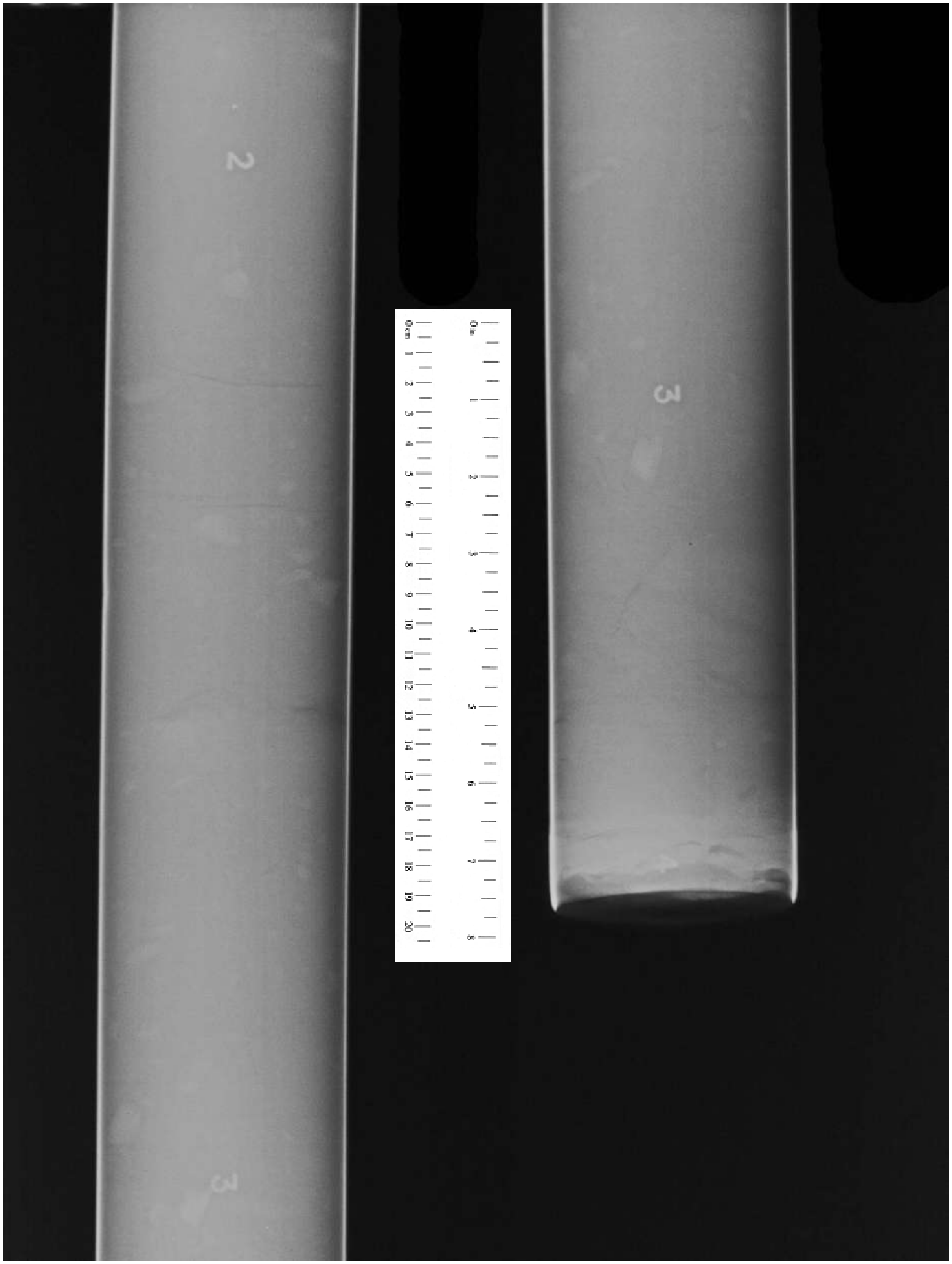


X-RAY RADIOGRAPHY IMAGES
BORING B-159, SAMPLE S-21, DEPTH 77.5 – 78.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

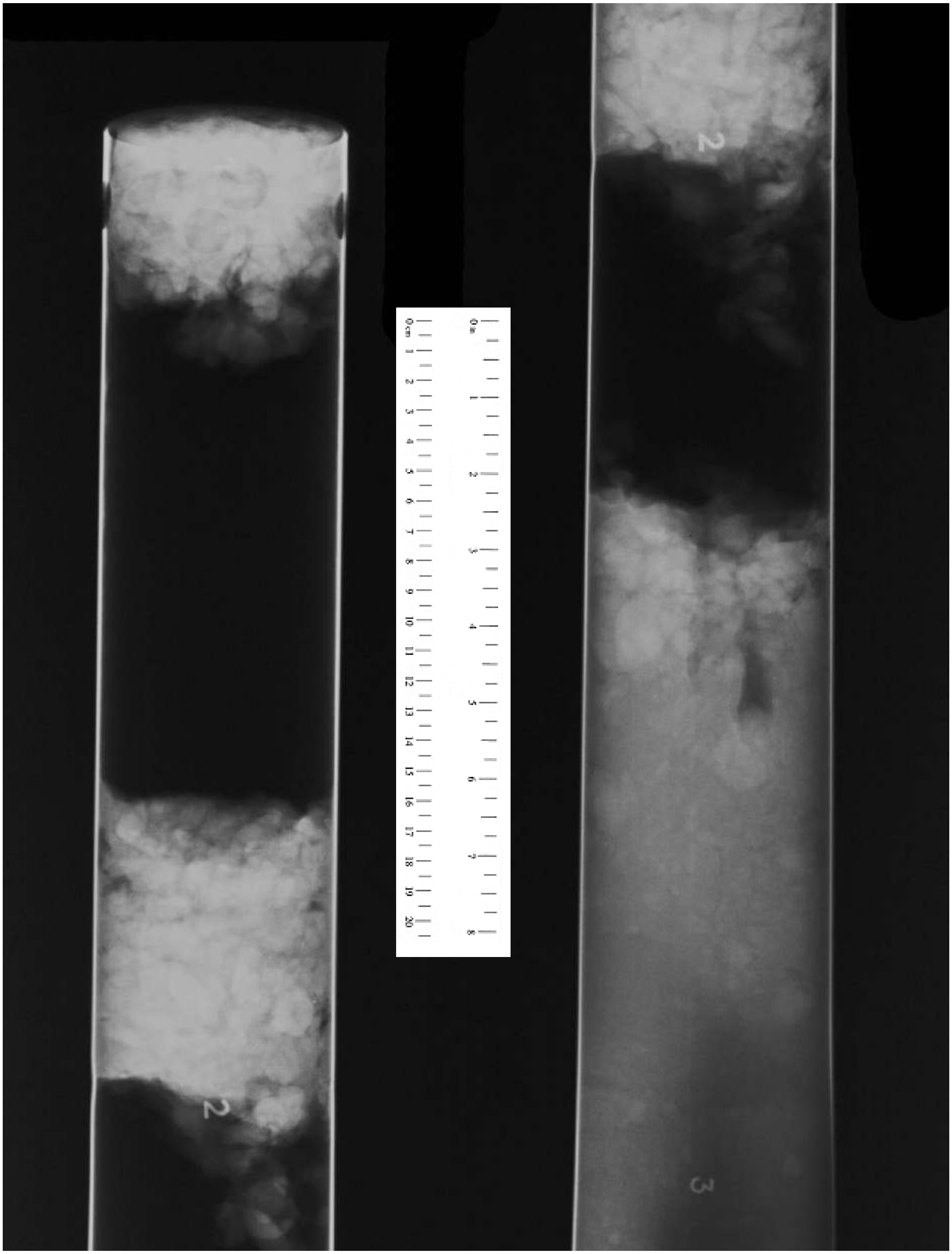


X-RAY RADIOGRAPHY IMAGES
BORING B-161, SAMPLE S-28, DEPTH 111.0 – 113.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-34a

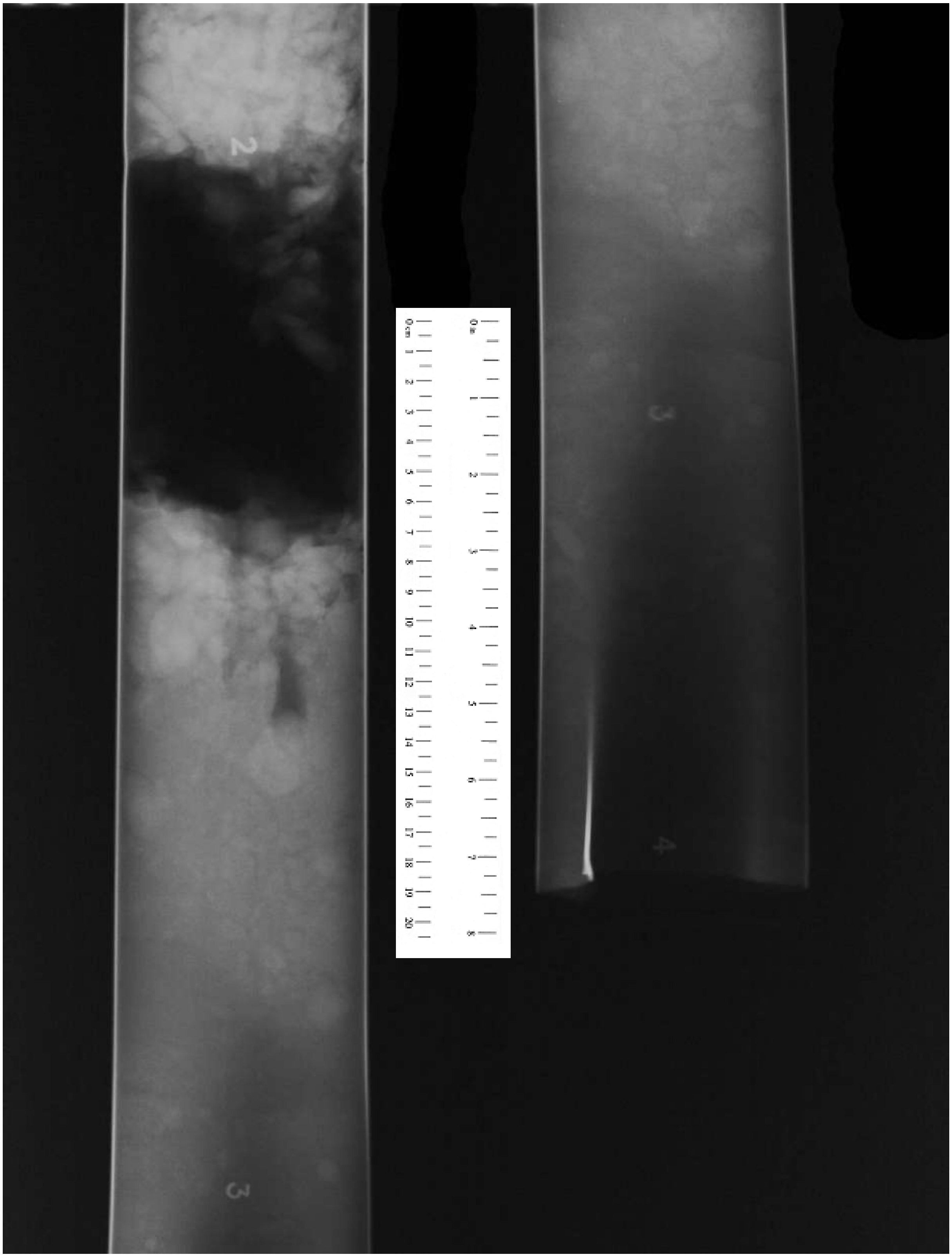


X-RAY RADIOGRAPHY IMAGES
BORING B-161, SAMPLE S-28, DEPTH 111.0 – 113.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

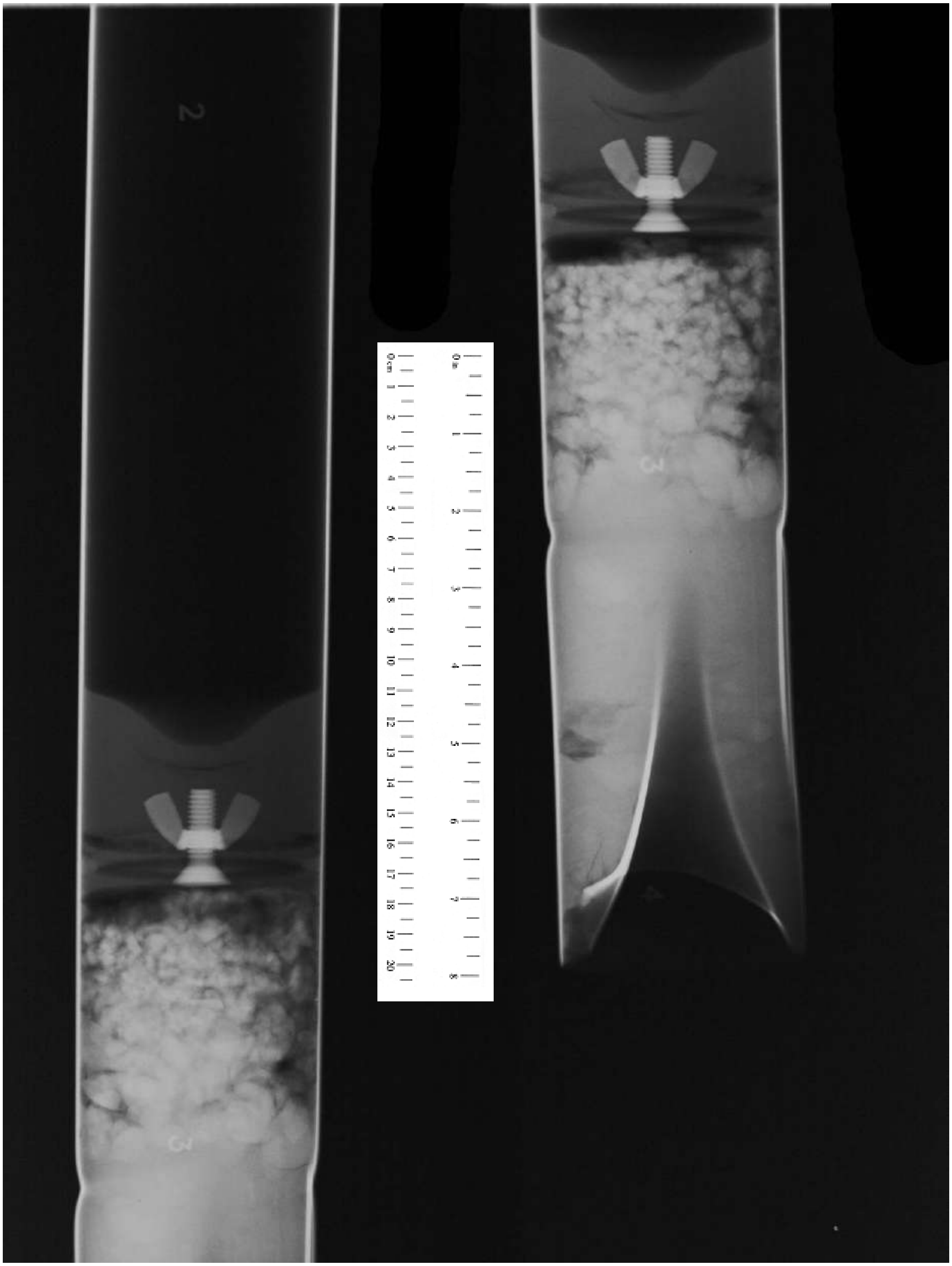


X-RAY RADIOGRAPHY IMAGES
BORING B-161, SAMPLE S-32, DEPTH 141.0 – 143.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-35a

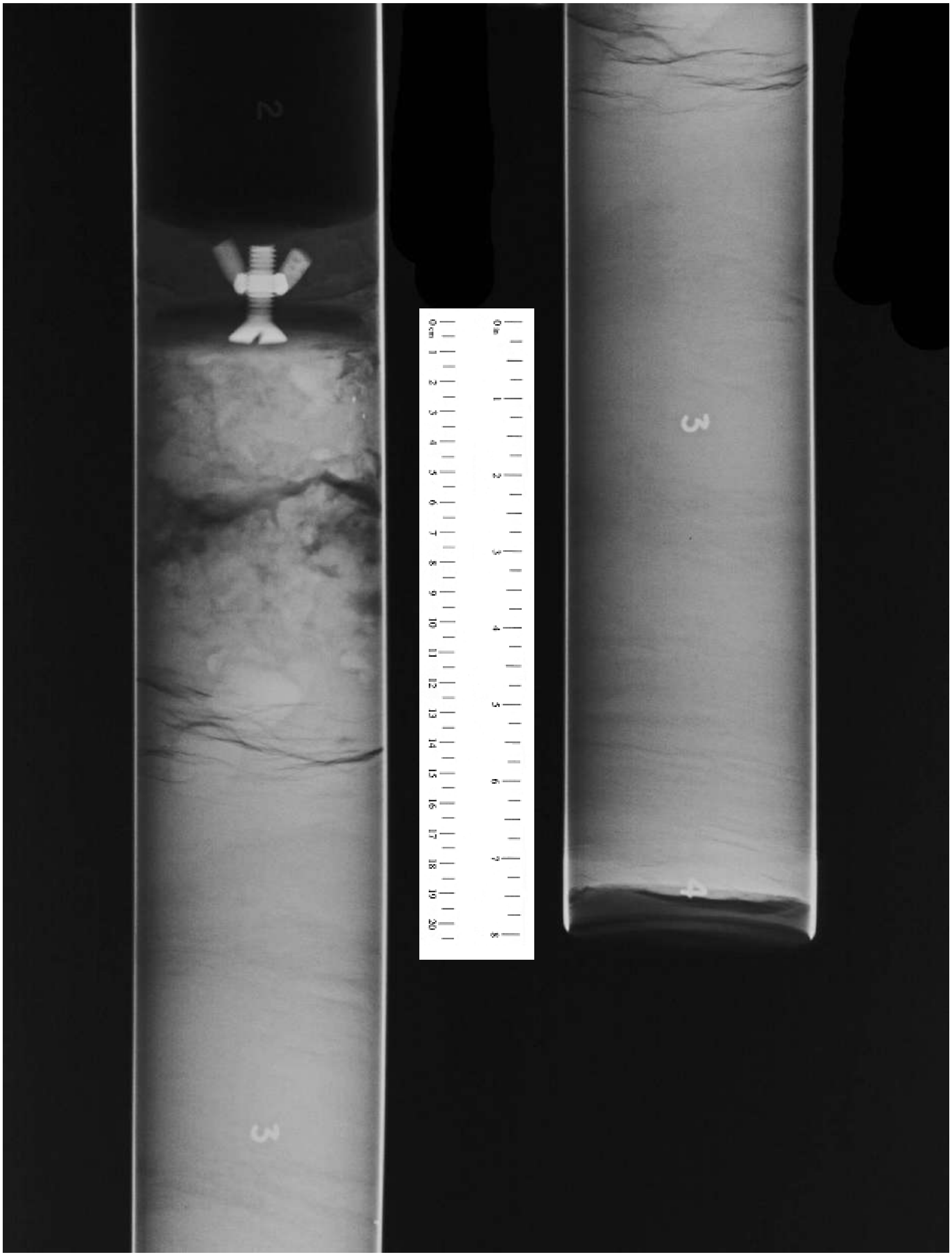


X-RAY RADIOGRAPHY IMAGES
BORING B-161, SAMPLE S-32, DEPTH 141.0 – 143.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



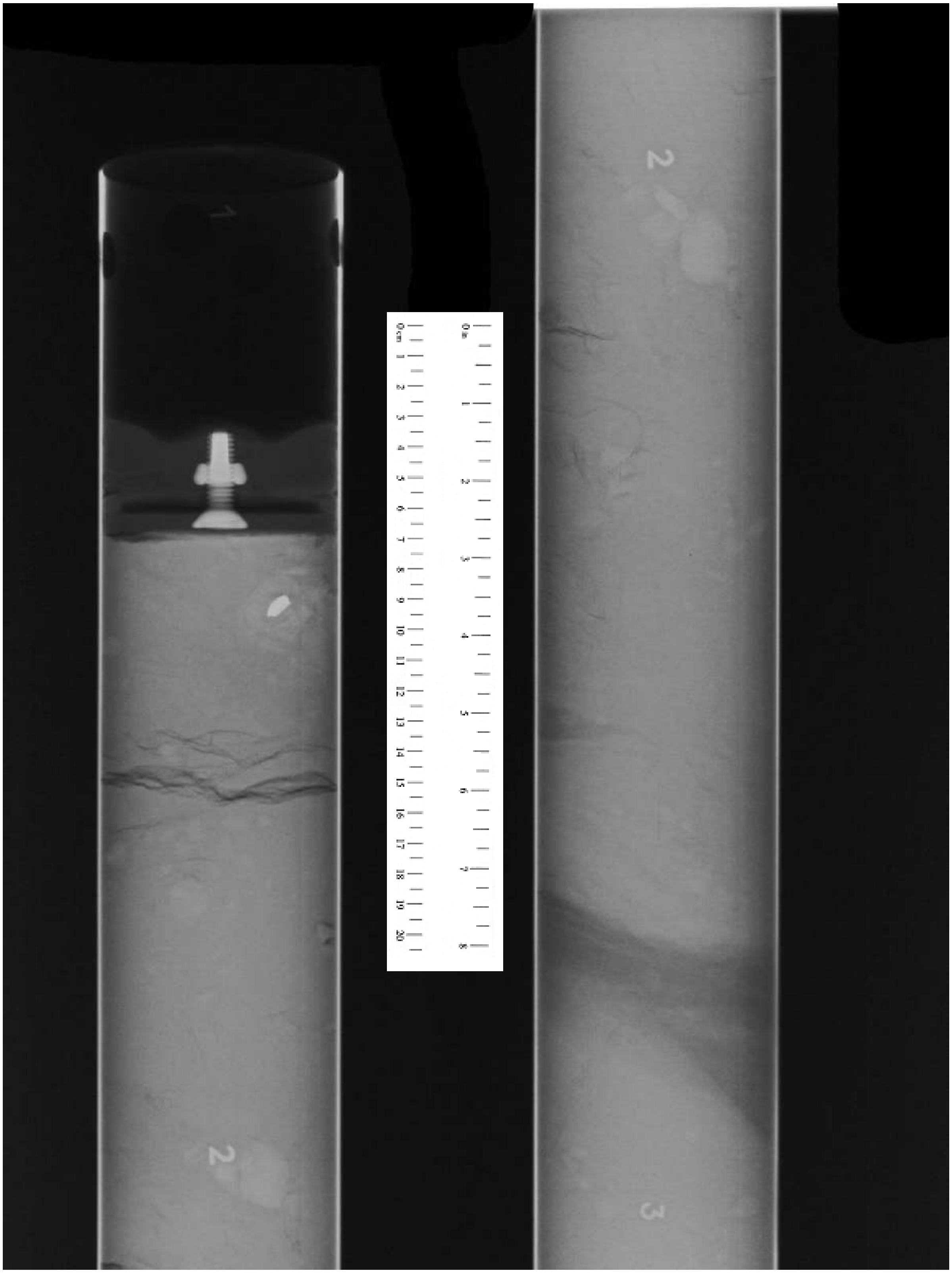
X-RAY RADIOGRAPHY IMAGES
BORING B-162, SAMPLE S-24, DEPTH 89.0 – 89.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-36

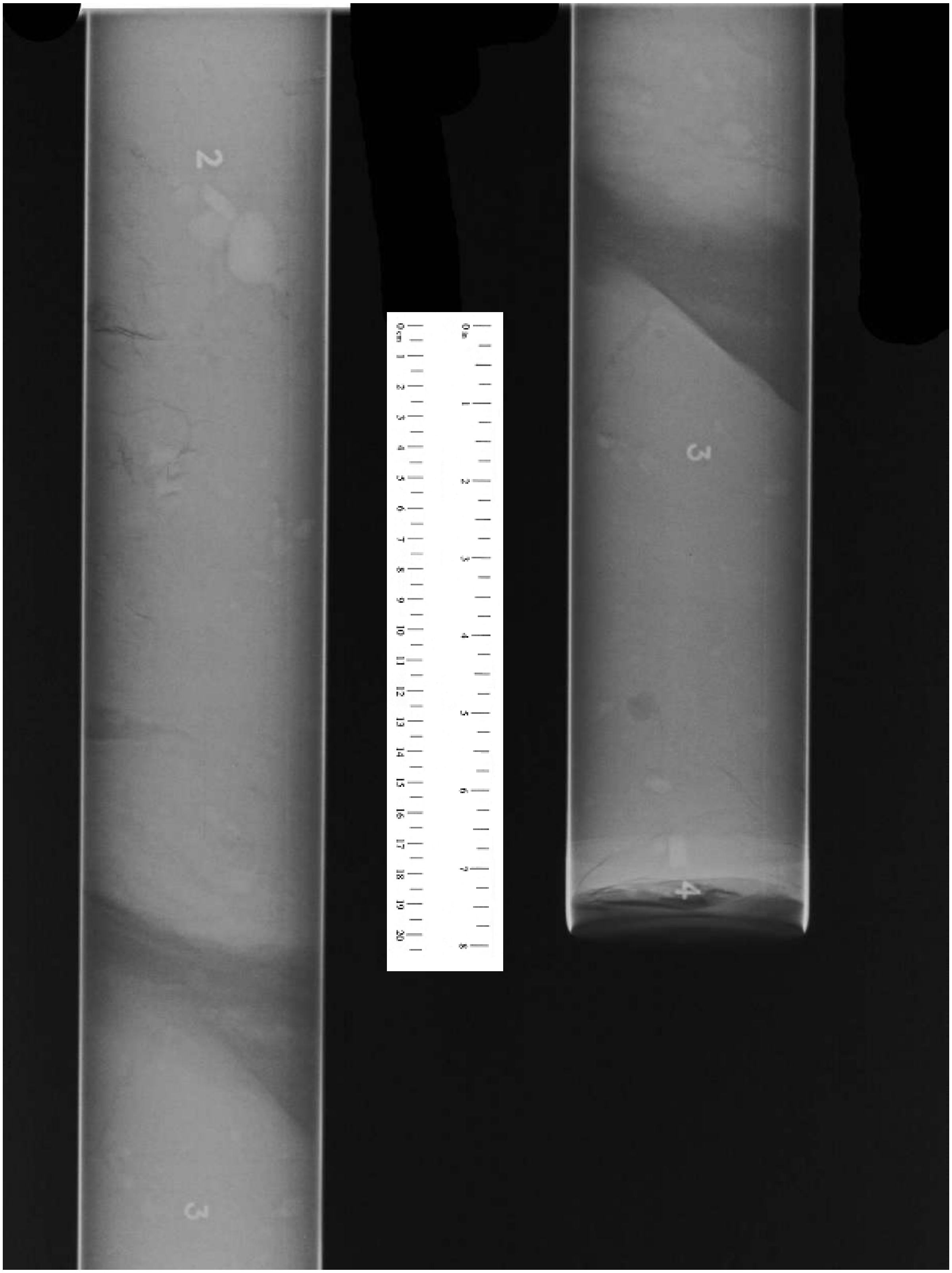


X-RAY RADIOGRAPHY IMAGES
BORING B-163, SAMPLE S-17, DEPTH 51.0 – 53.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-37

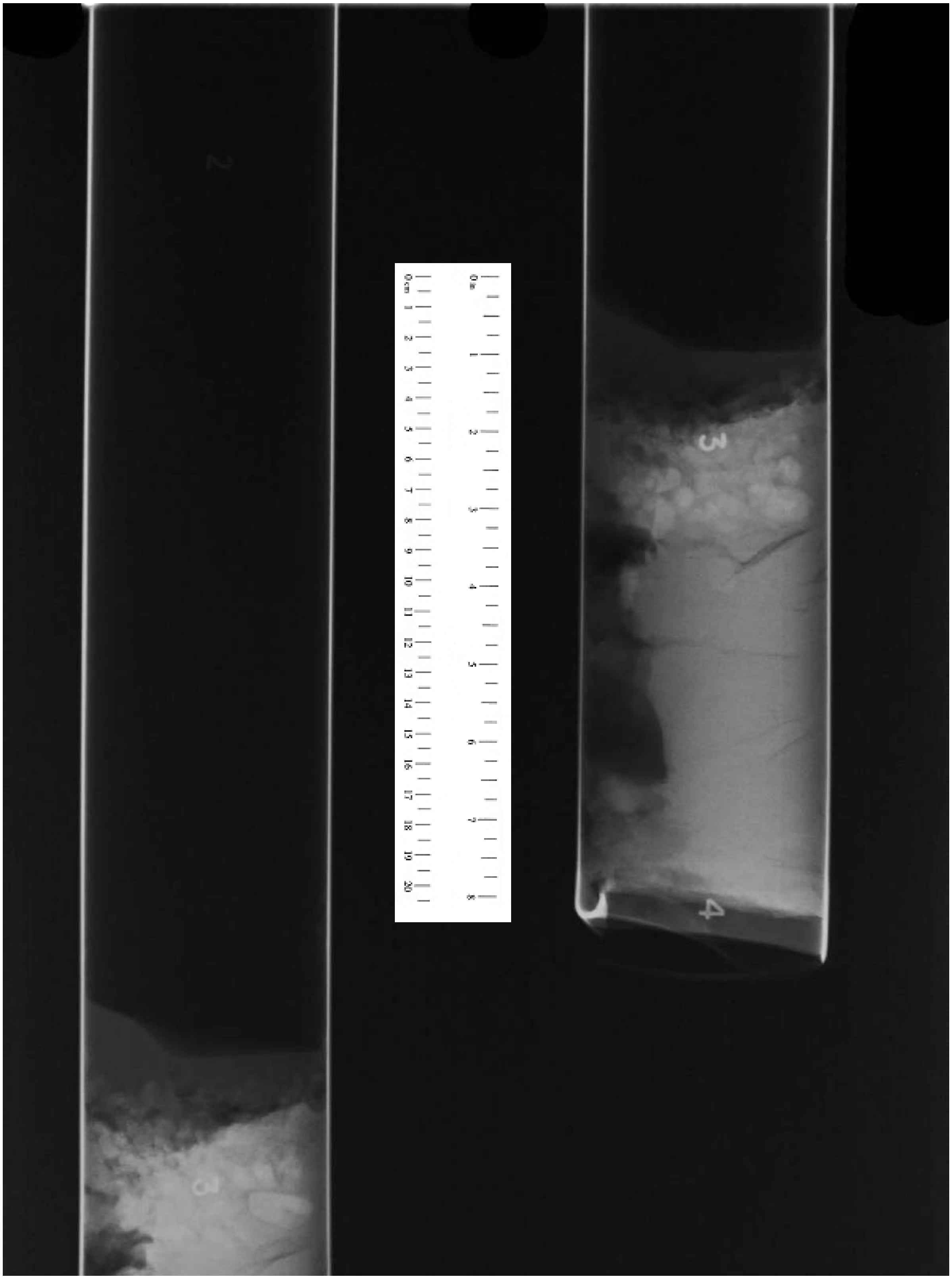


X-RAY RADIOGRAPHY IMAGES
BORING B-166, SAMPLE S-24, DEPTH 86.0 – 88.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



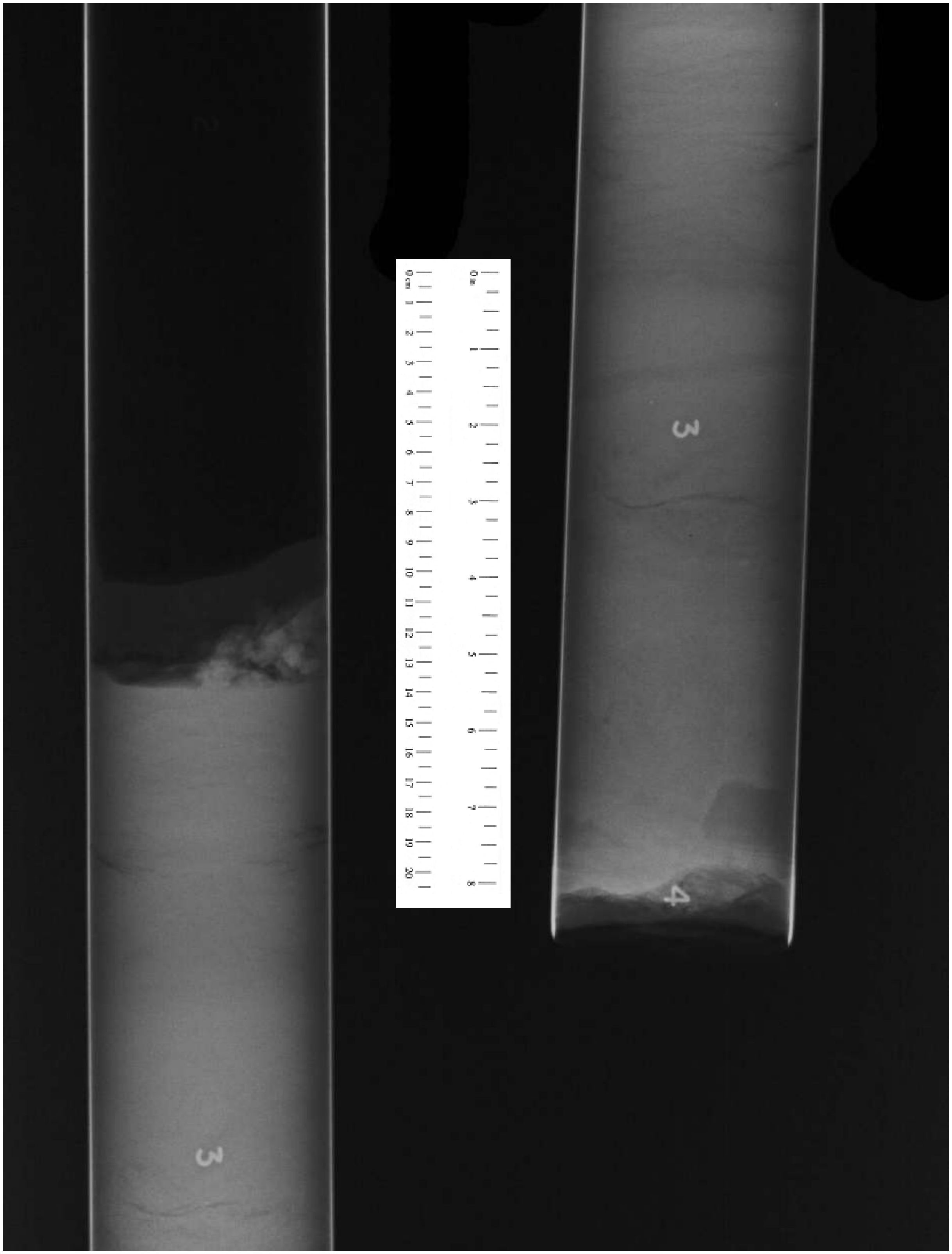
X-RAY RADIOGRAPHY IMAGES
BORING B-166, SAMPLE S-24, DEPTH 86.0 – 88.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-38b



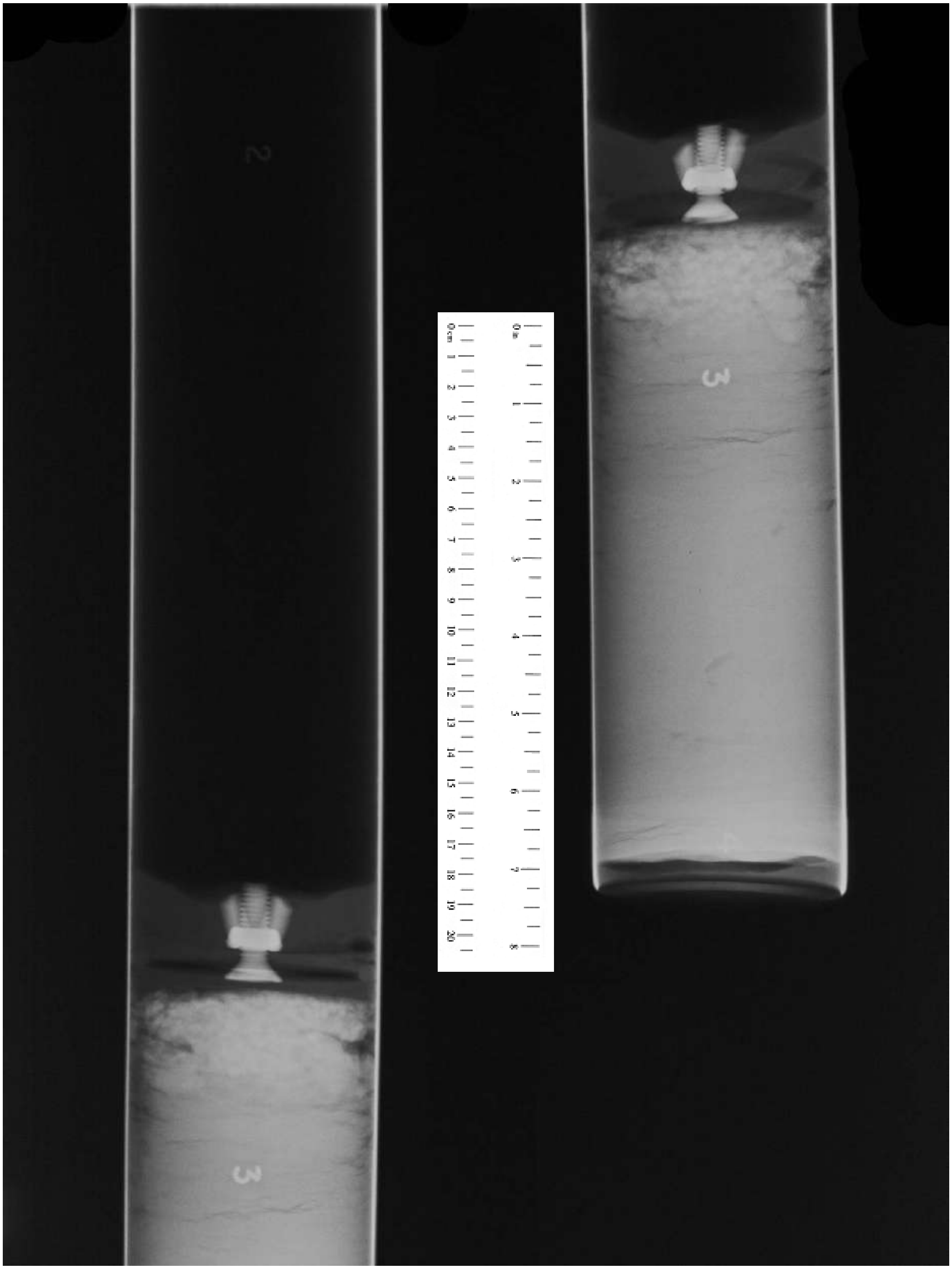
X-RAY RADIOGRAPHY IMAGES
BORING B-167, SAMPLE S-14, DEPTH 41.5 – 42.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-39

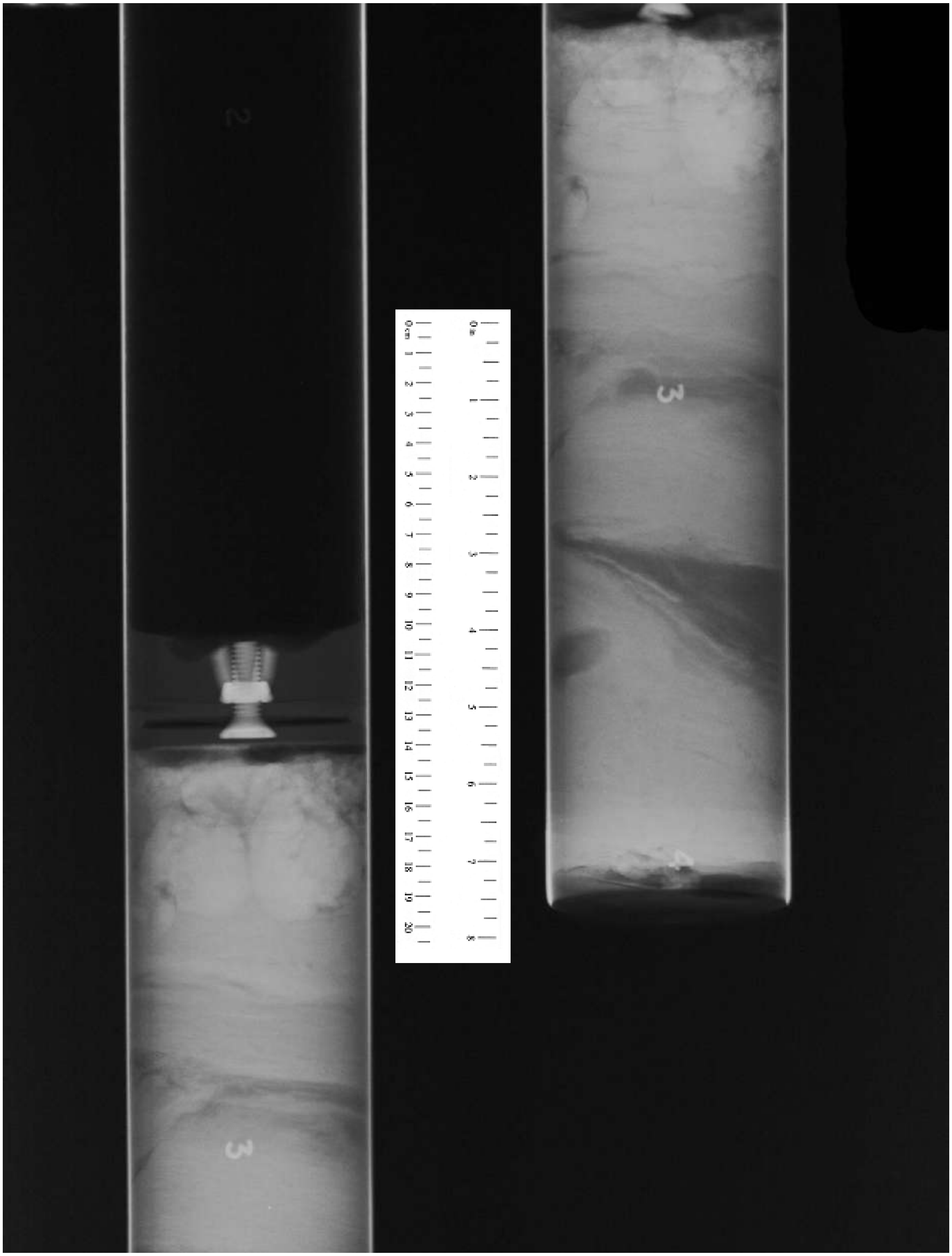


X-RAY RADIOGRAPHY IMAGES
BORING B-167, SAMPLE S-15, DEPTH 44.5 – 45.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-40

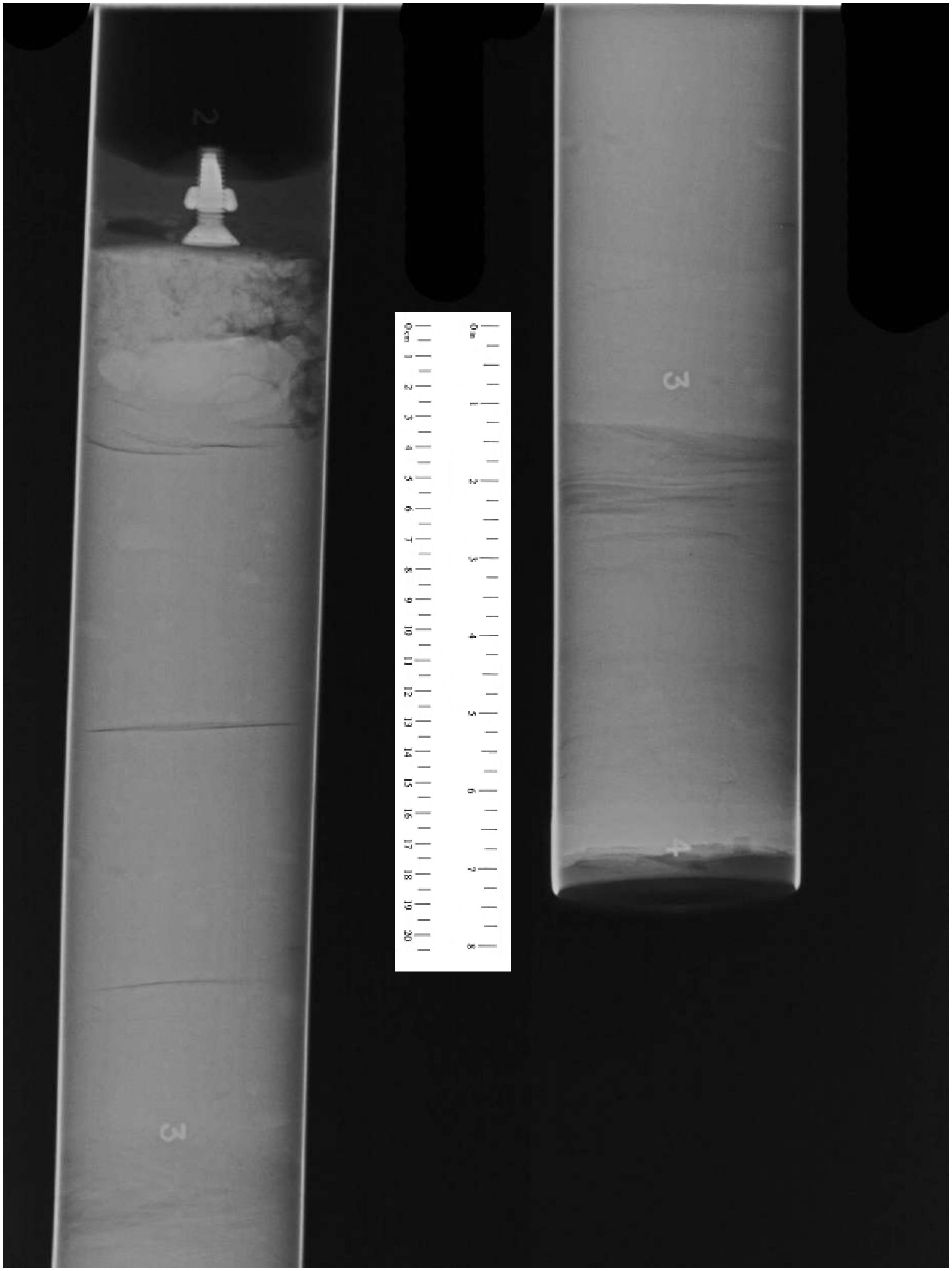


X-RAY RADIOGRAPHY IMAGES
BORING B-168, SAMPLE S-14, DEPTH 41.0 – 41.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

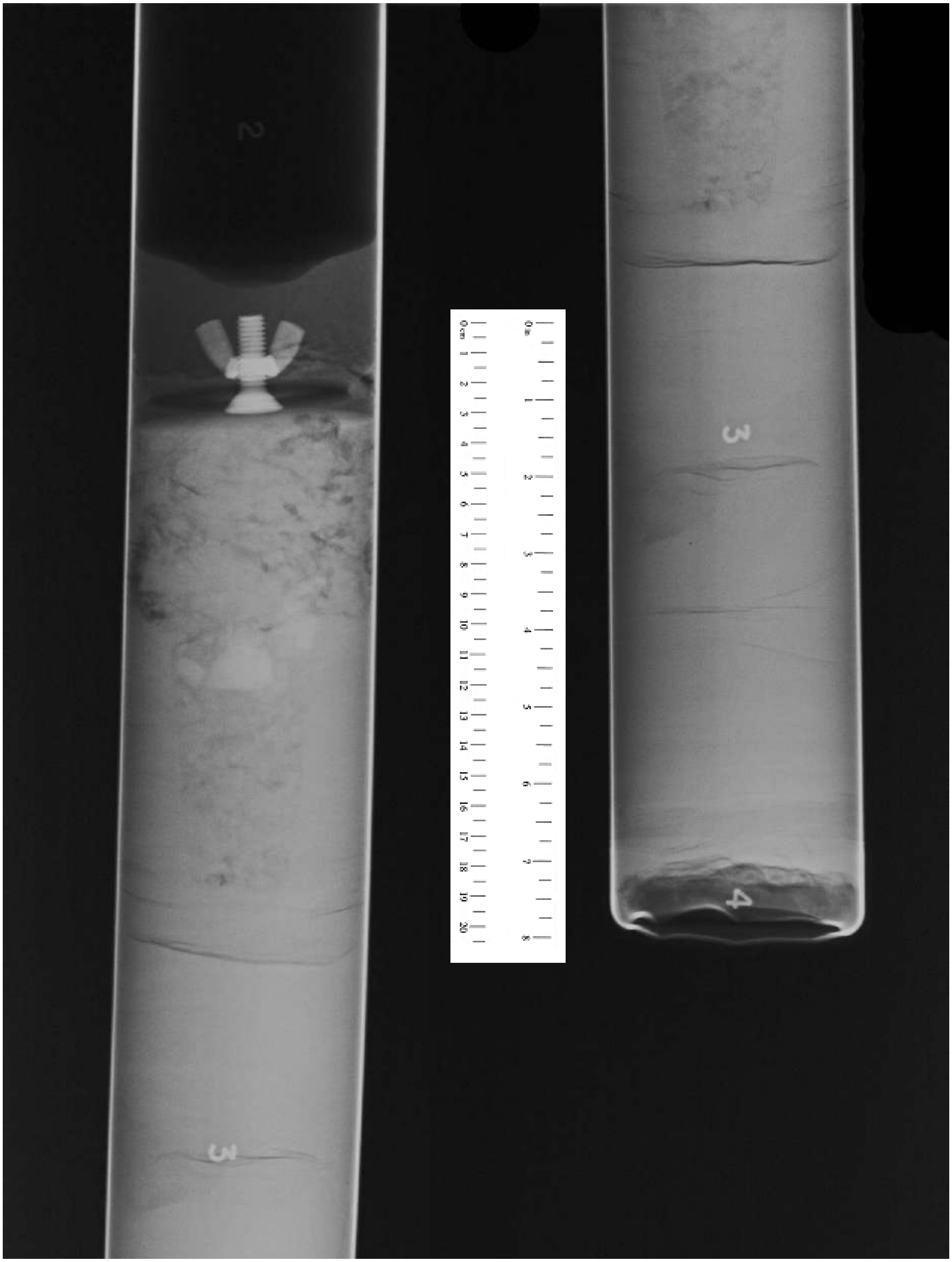


X-RAY RADIOGRAPHY IMAGES
BORING B-168, SAMPLE S-30, DEPTH 129.0 – 131.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

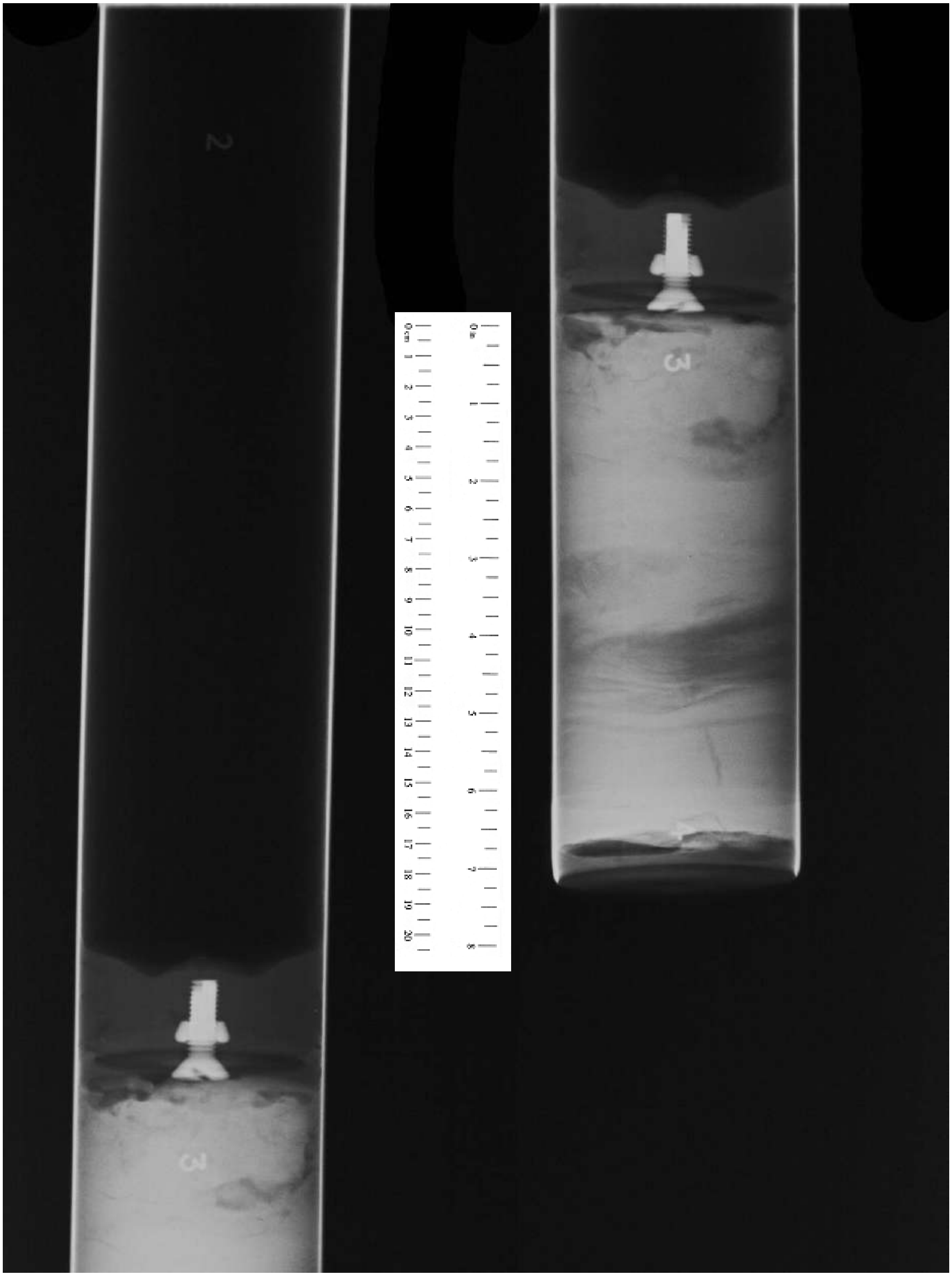
PLATE G10-42



X-RAY RADIOGRAPHY IMAGES
BORING B-168, SAMPLE S-33, DEPTH 151.0 – 152.2 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

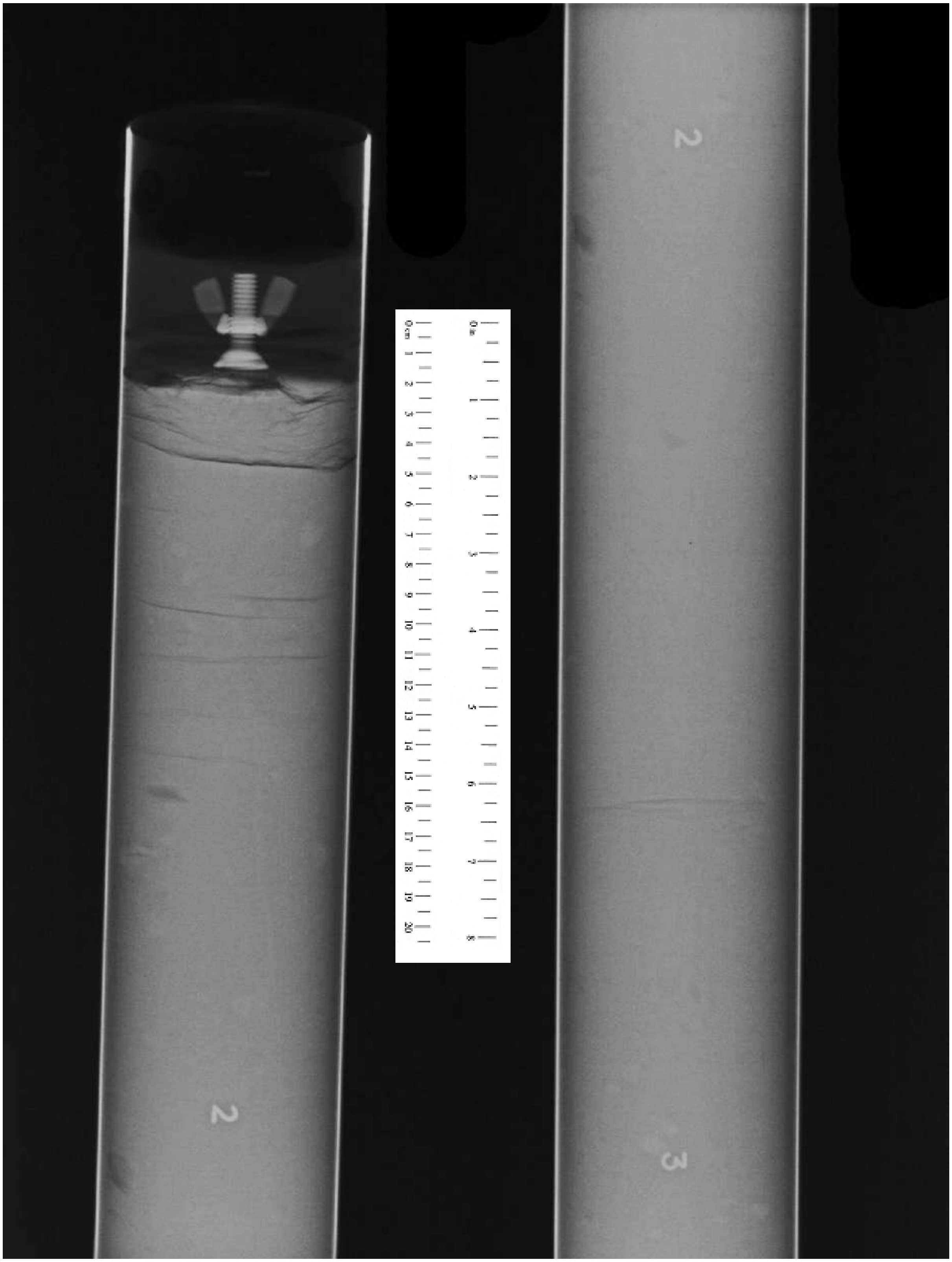


X-RAY RADIOGRAPHY IMAGES
BORING B-169, SAMPLE S-21, DEPTH 71.0 – 71.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



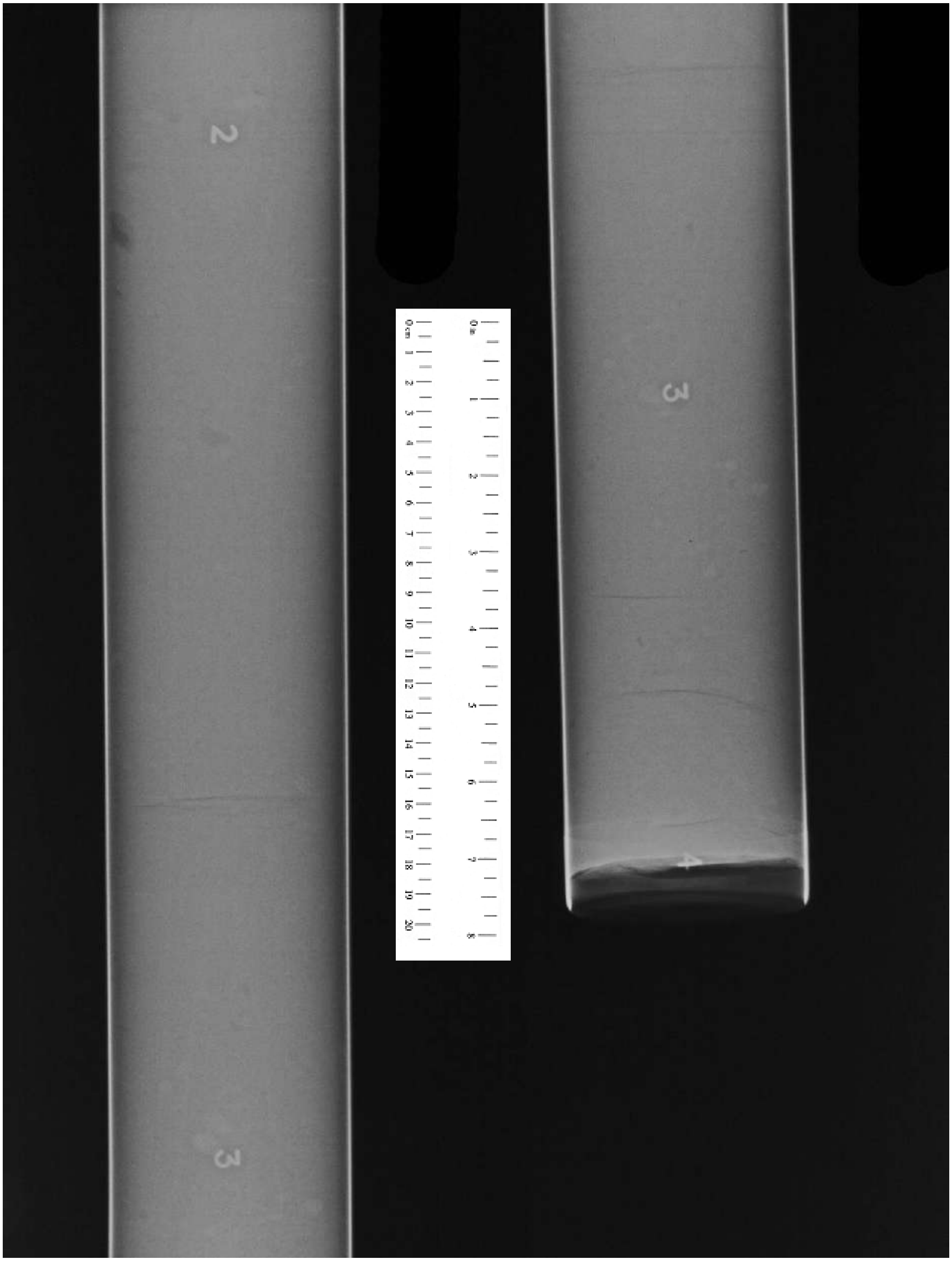
X-RAY RADIOGRAPHY IMAGES
BORING B-170, SAMPLE S-20, DEPTH 68.5 – 69.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-45



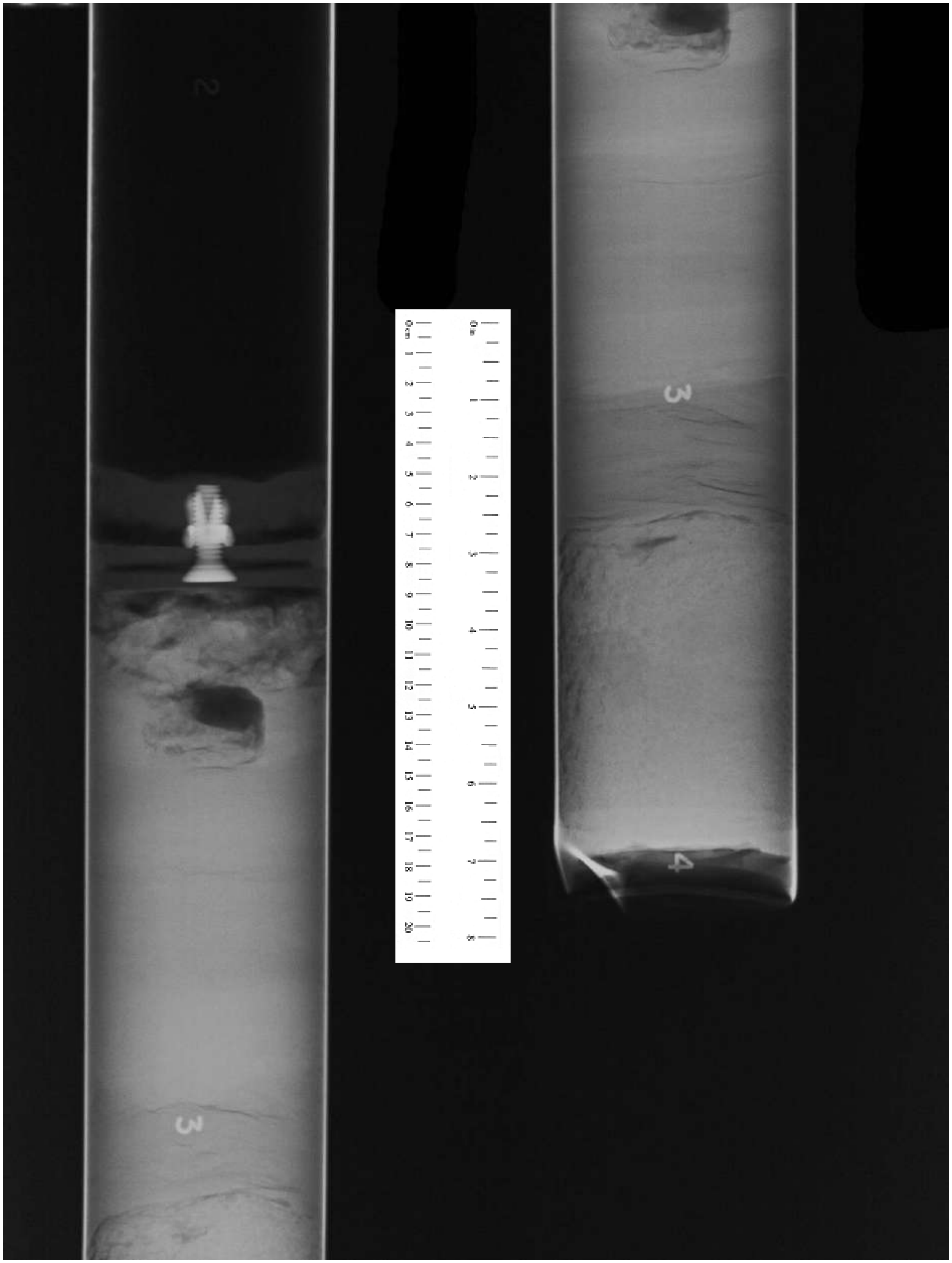
X-RAY RADIOGRAPHY IMAGES
BORING B-170, SAMPLE S-30, DEPTH 131.0 – 133.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-46a

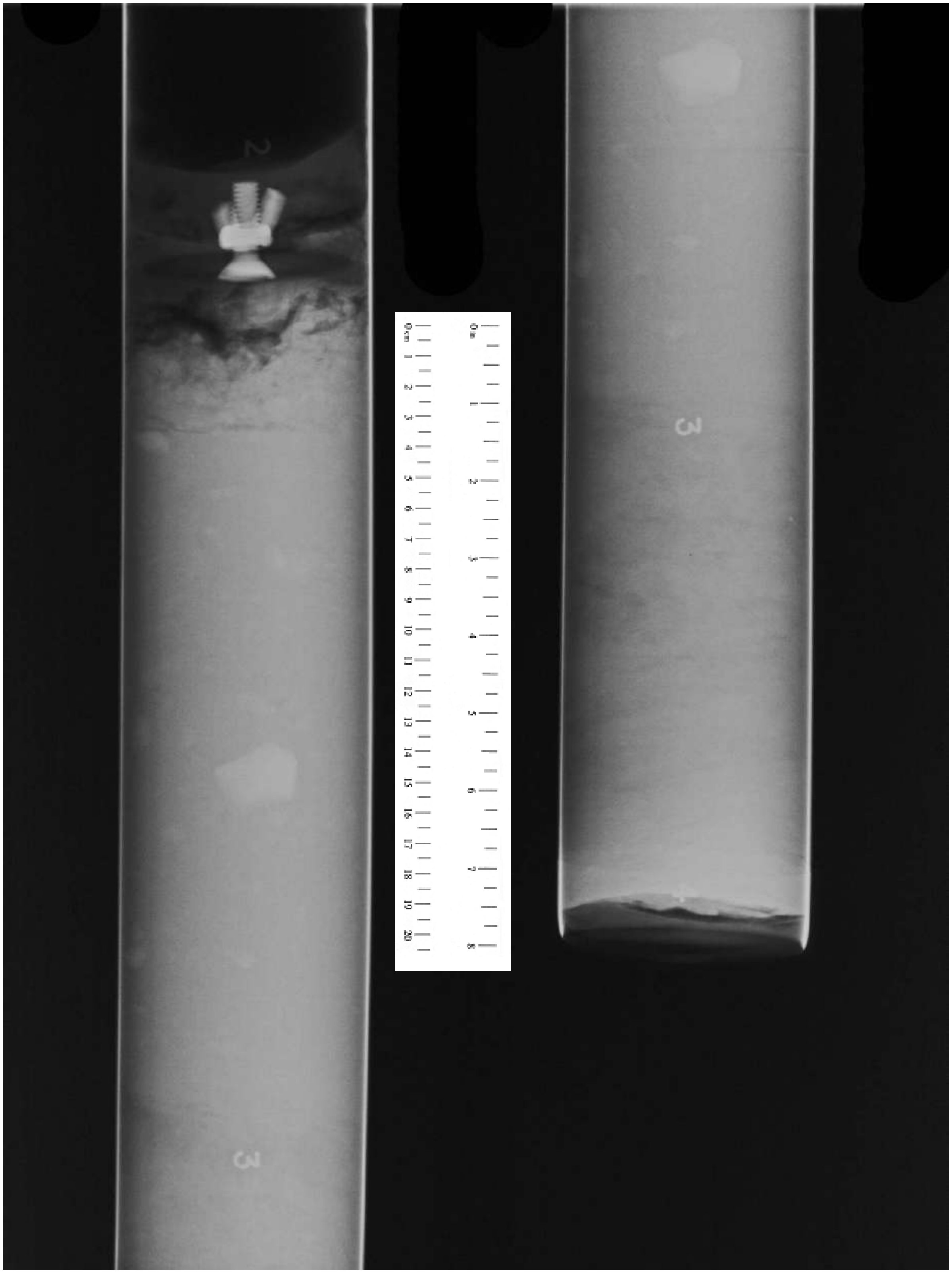


X-RAY RADIOGRAPHY IMAGES
BORING B-170, SAMPLE S-30, DEPTH 131.0 – 133.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

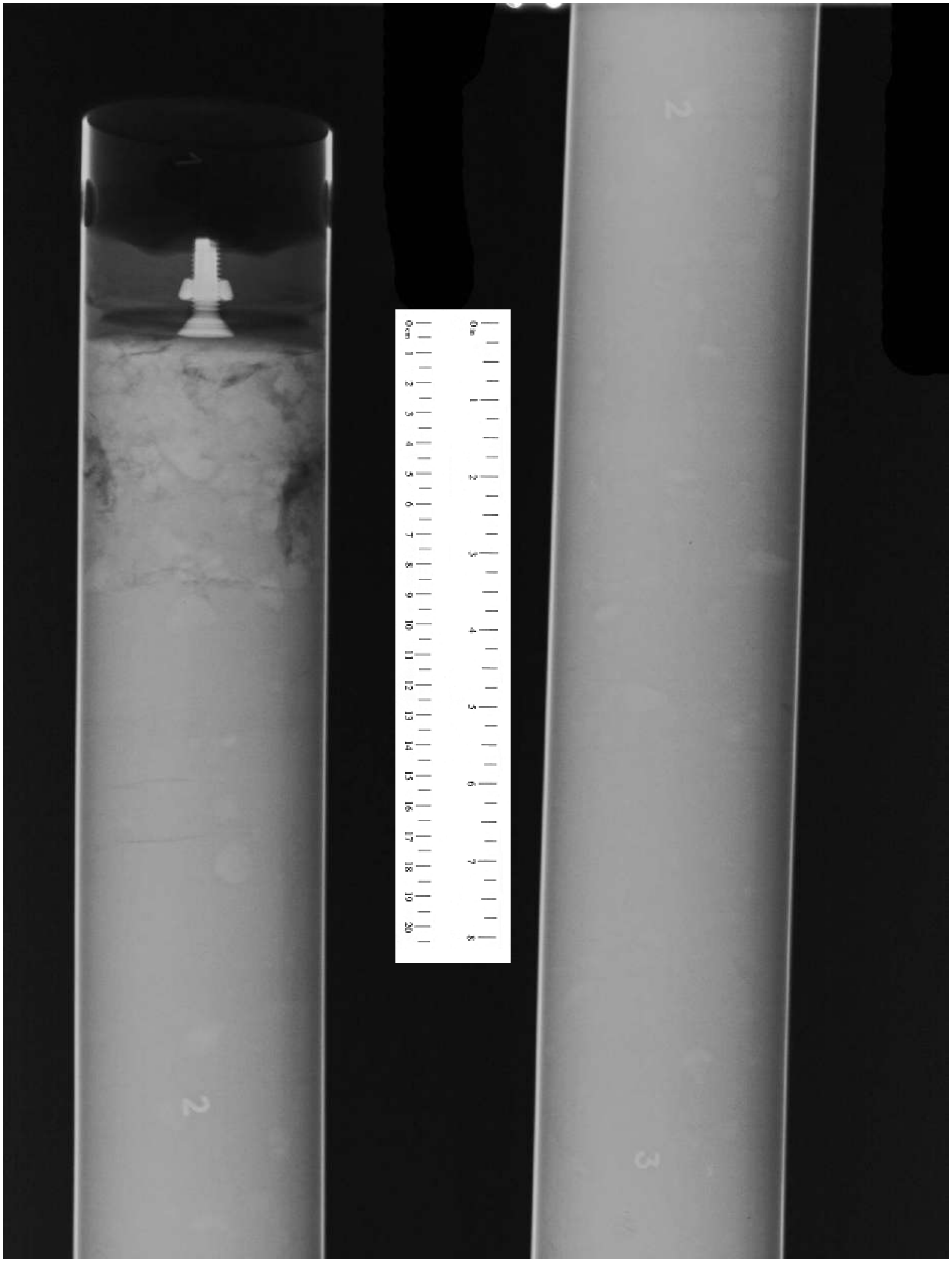
PLATE G10-46b



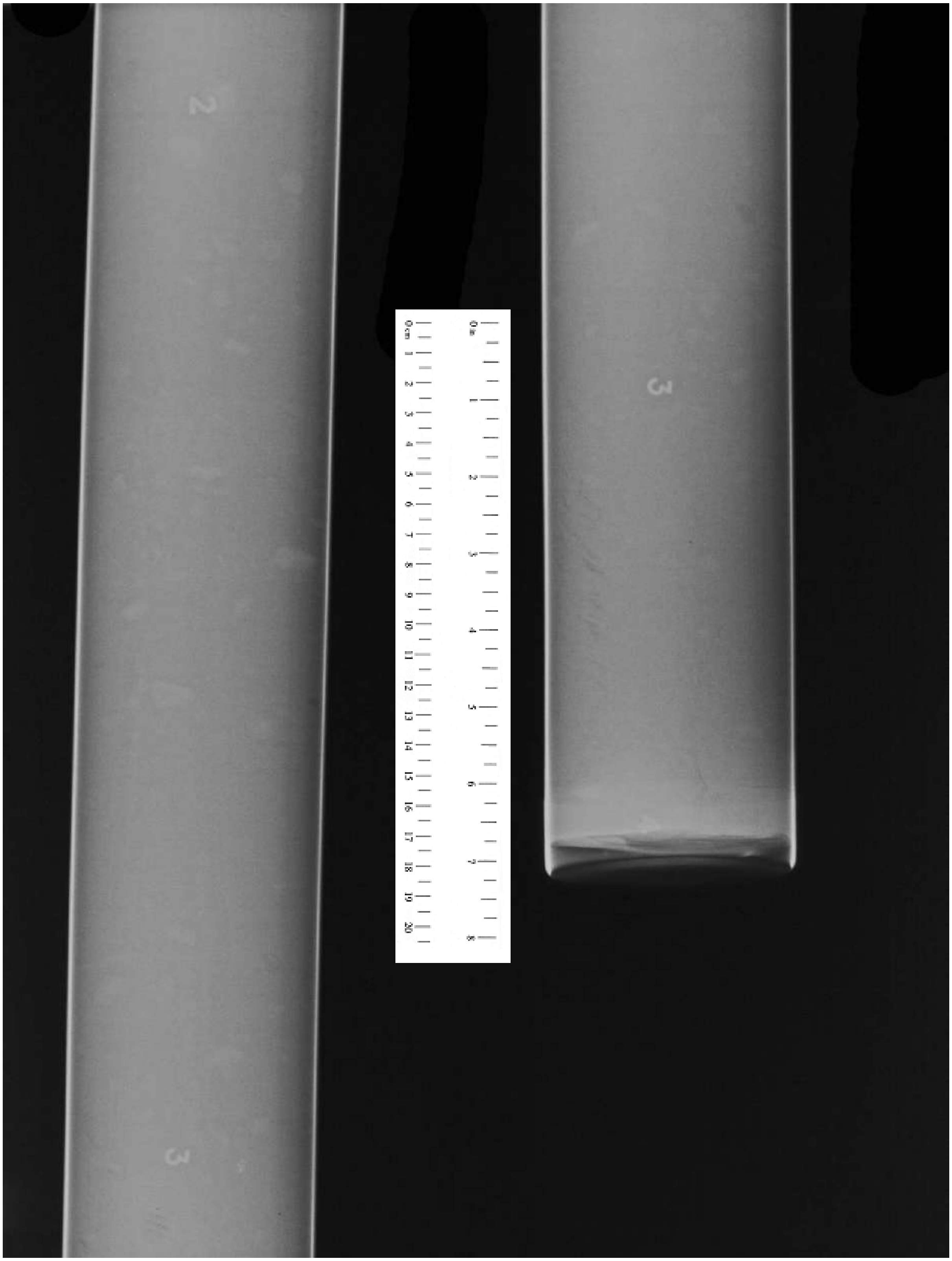
X-RAY RADIOGRAPHY IMAGES
BORING B-172, SAMPLE S-21, DEPTH 76.0 – 77.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
BORING B-172, SAMPLE S-30, DEPTH 141.0 – 143.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

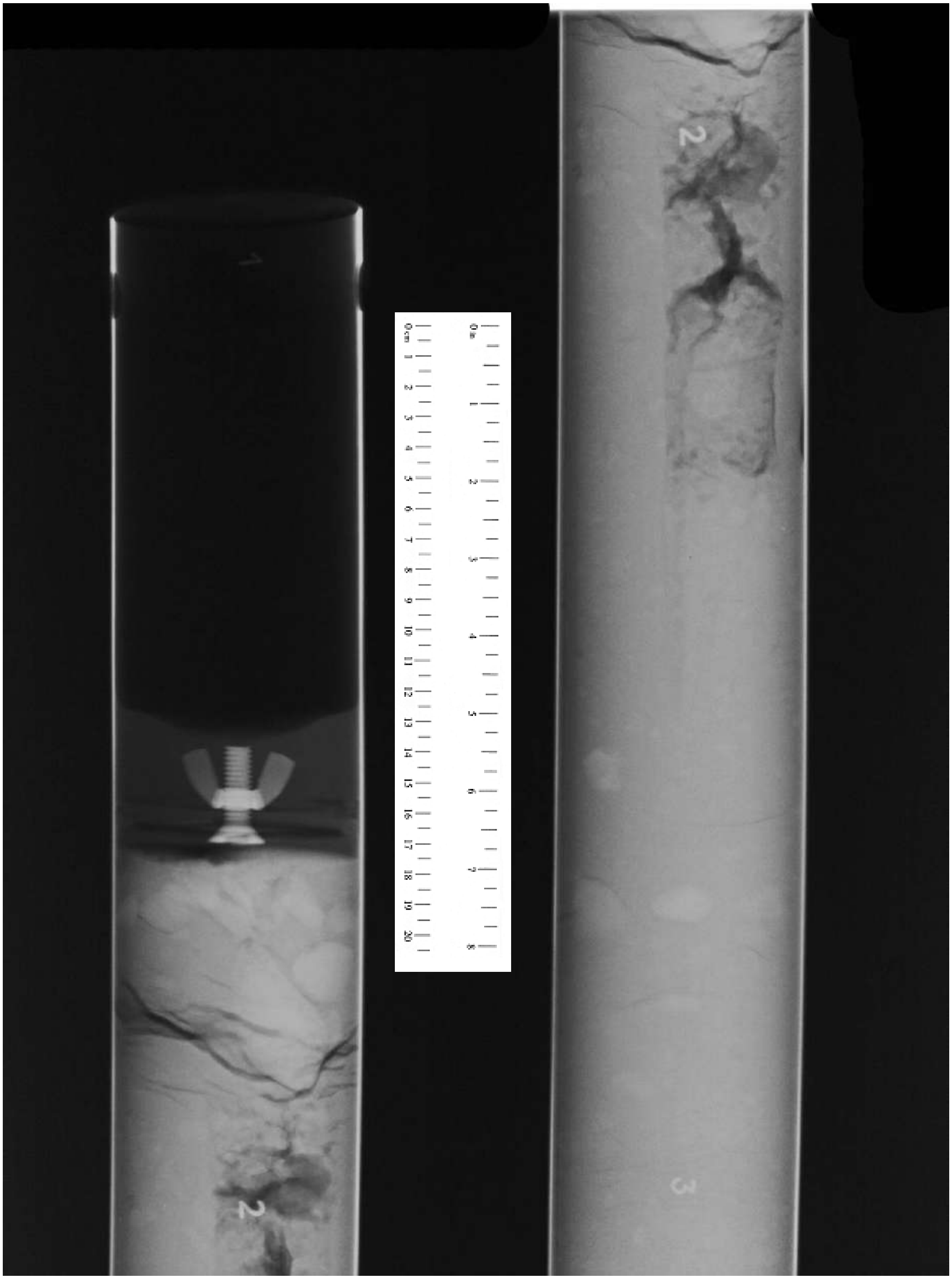


X-RAY RADIOGRAPHY IMAGES
BORING B-172, SAMPLE S-31, DEPTH 149.0 – 151.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



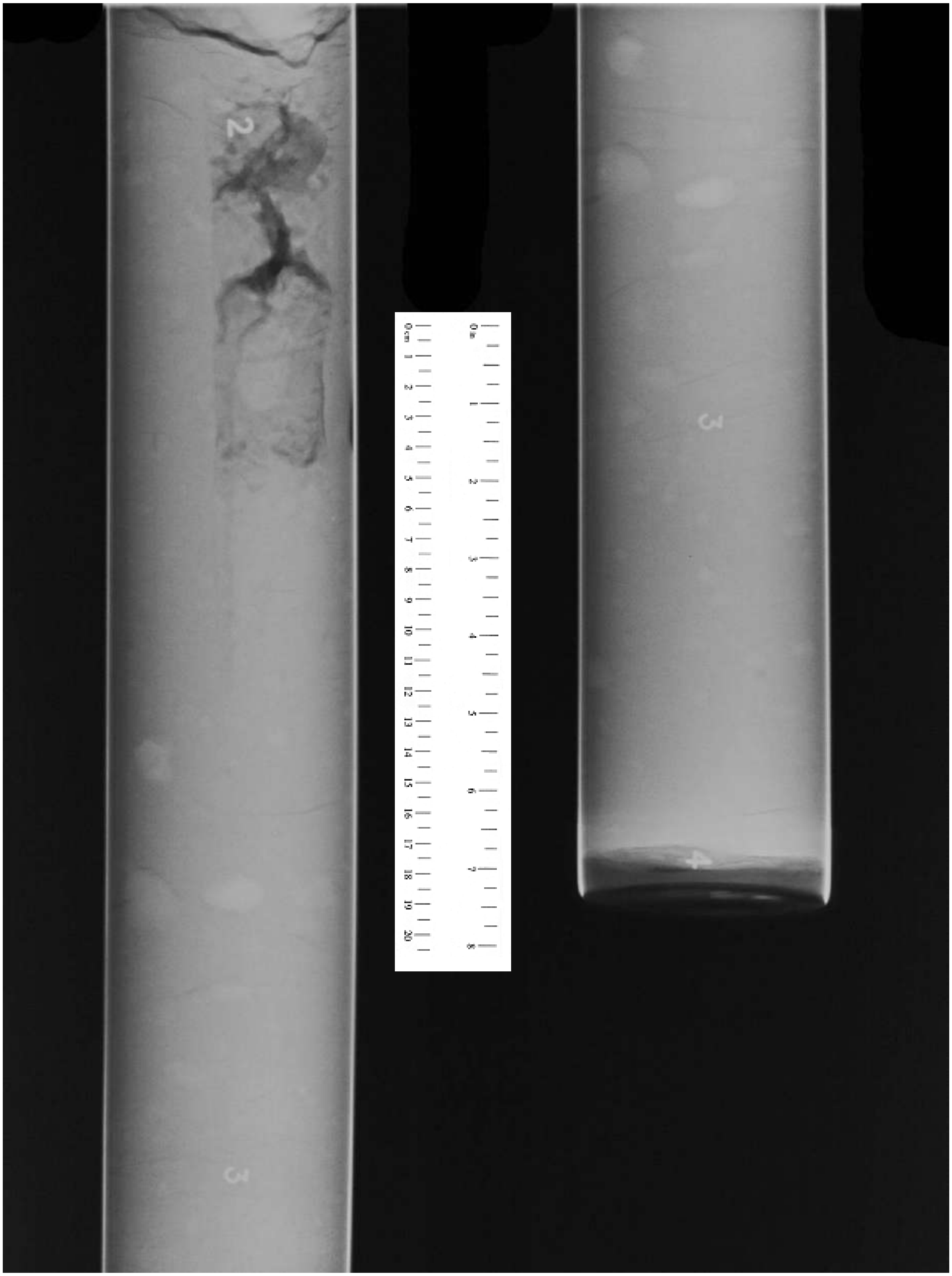
X-RAY RADIOGRAPHY IMAGES
BORING B-172, SAMPLE S-31, DEPTH 149.0 – 151.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-49b



X-RAY RADIOGRAPHY IMAGES
BORING B-172, SAMPLE S-32, DEPTH 151.0 – 152.4 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

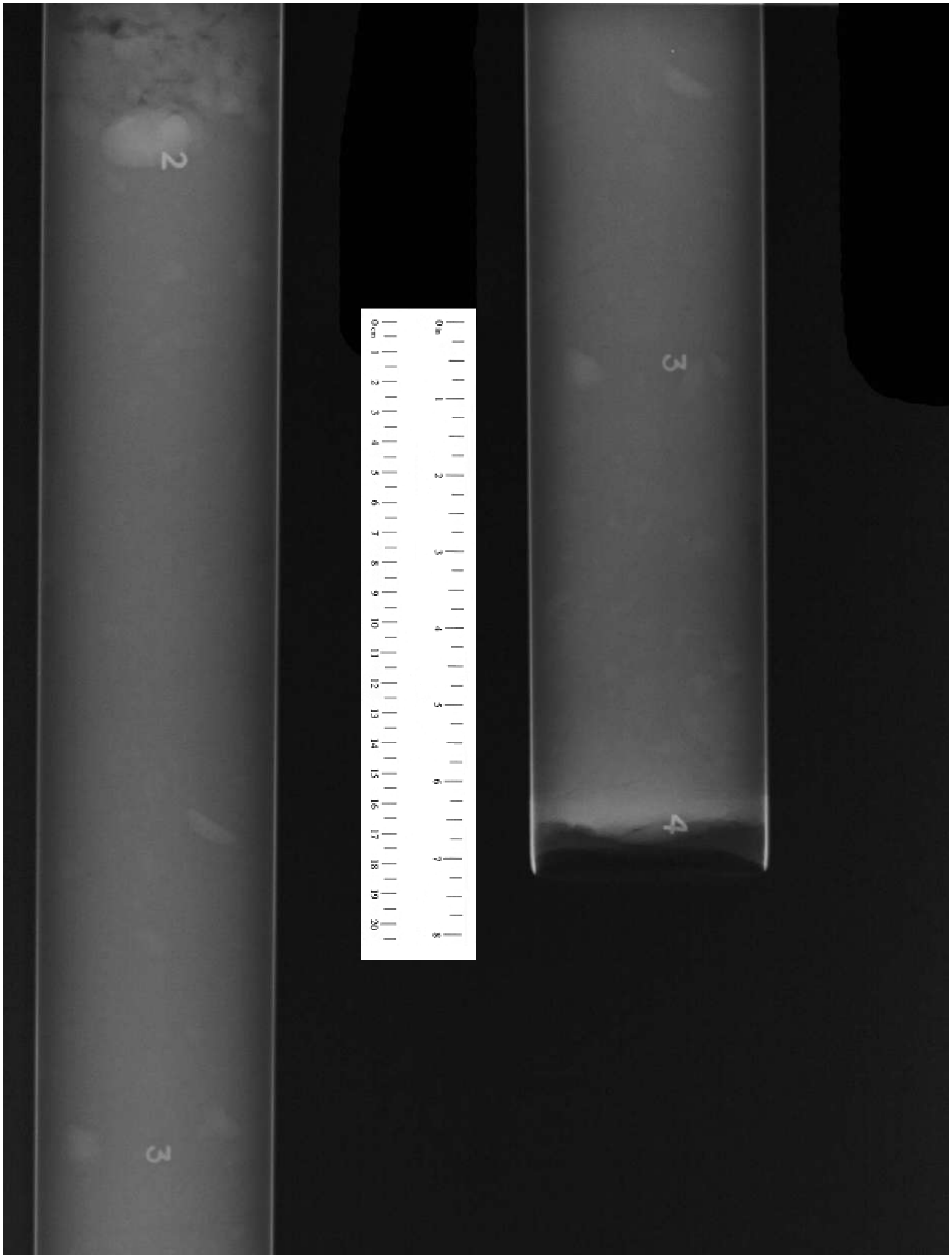
PLATE G10-50a



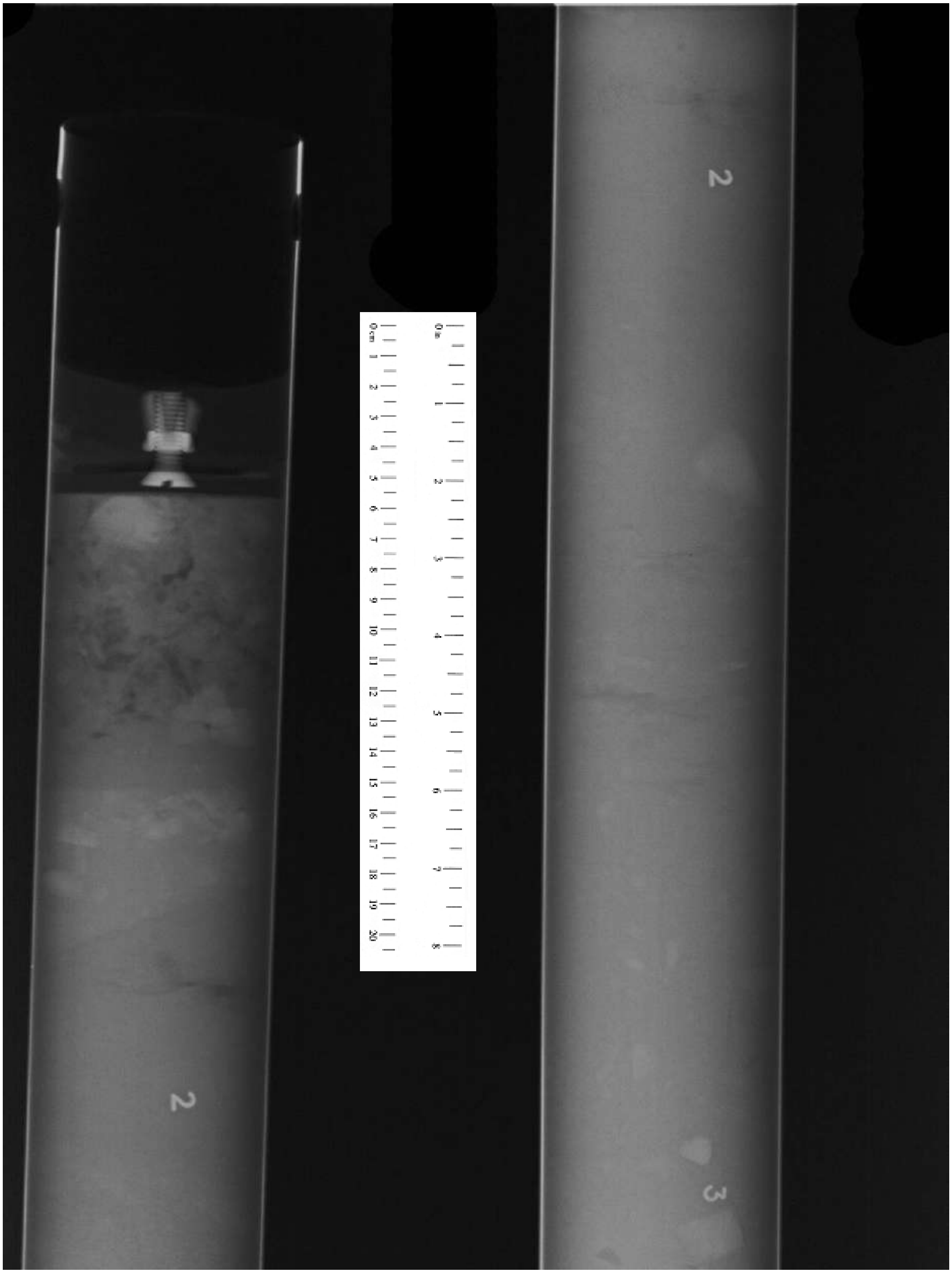
X-RAY RADIOGRAPHY IMAGES
BORING B-172, SAMPLE S-32, DEPTH 151.0 – 152.4 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-50b

X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-29, DEPTH 114.0 – 115.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

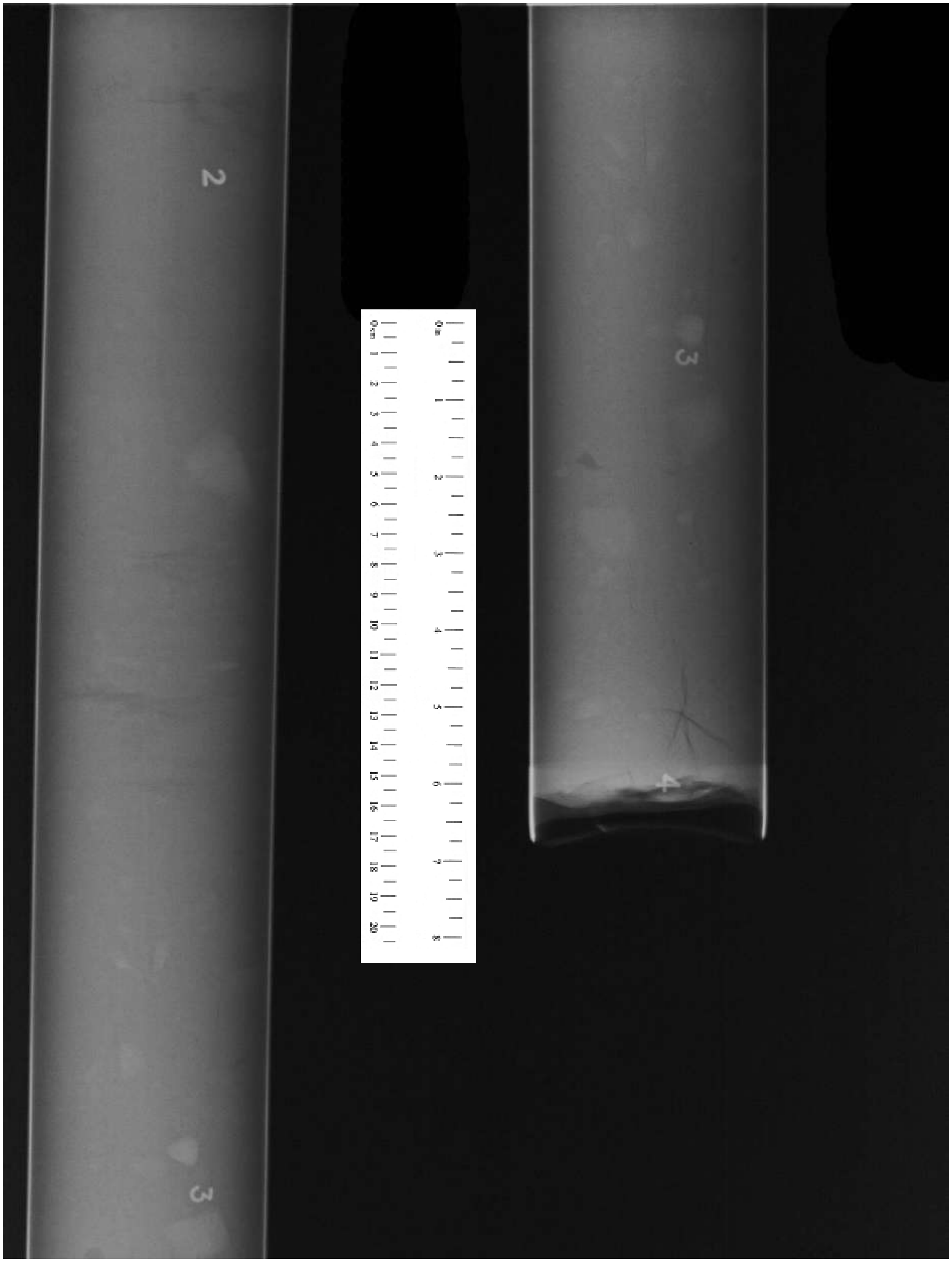


X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-29, DEPTH 114.0 – 115.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



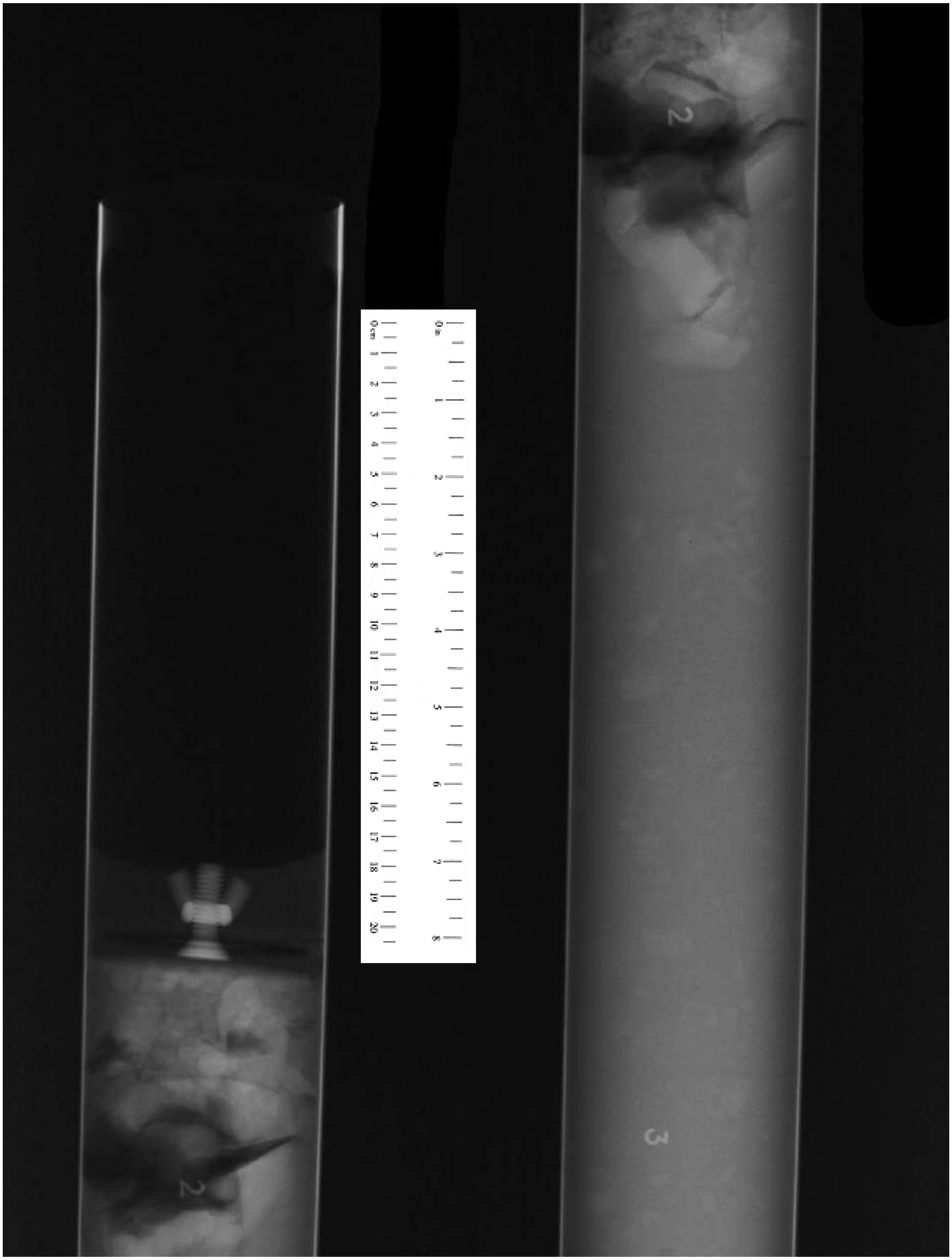
X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-30, DEPTH 119.0 – 120.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-52a

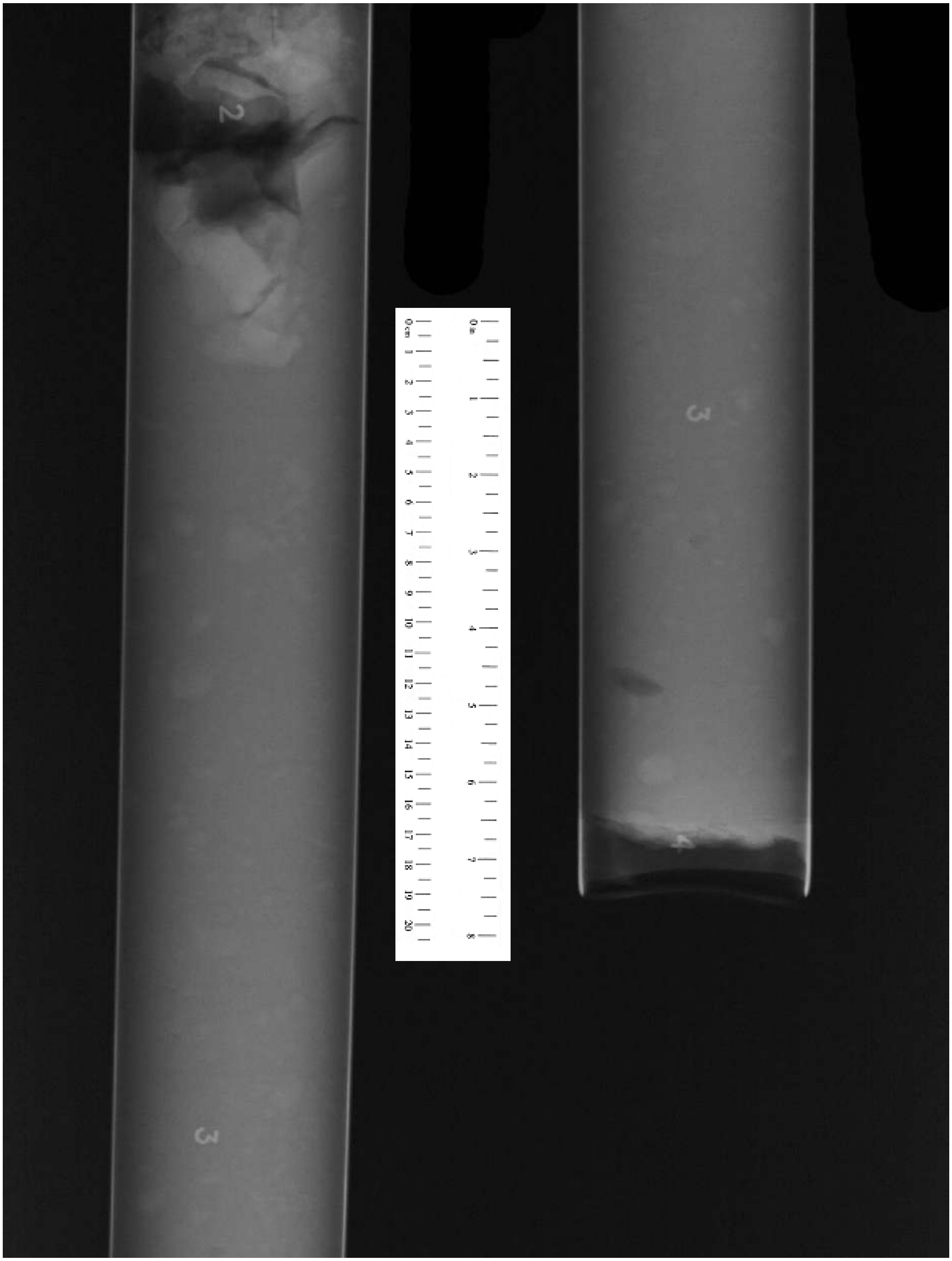


X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-30, DEPTH 119.0 – 120.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-52b

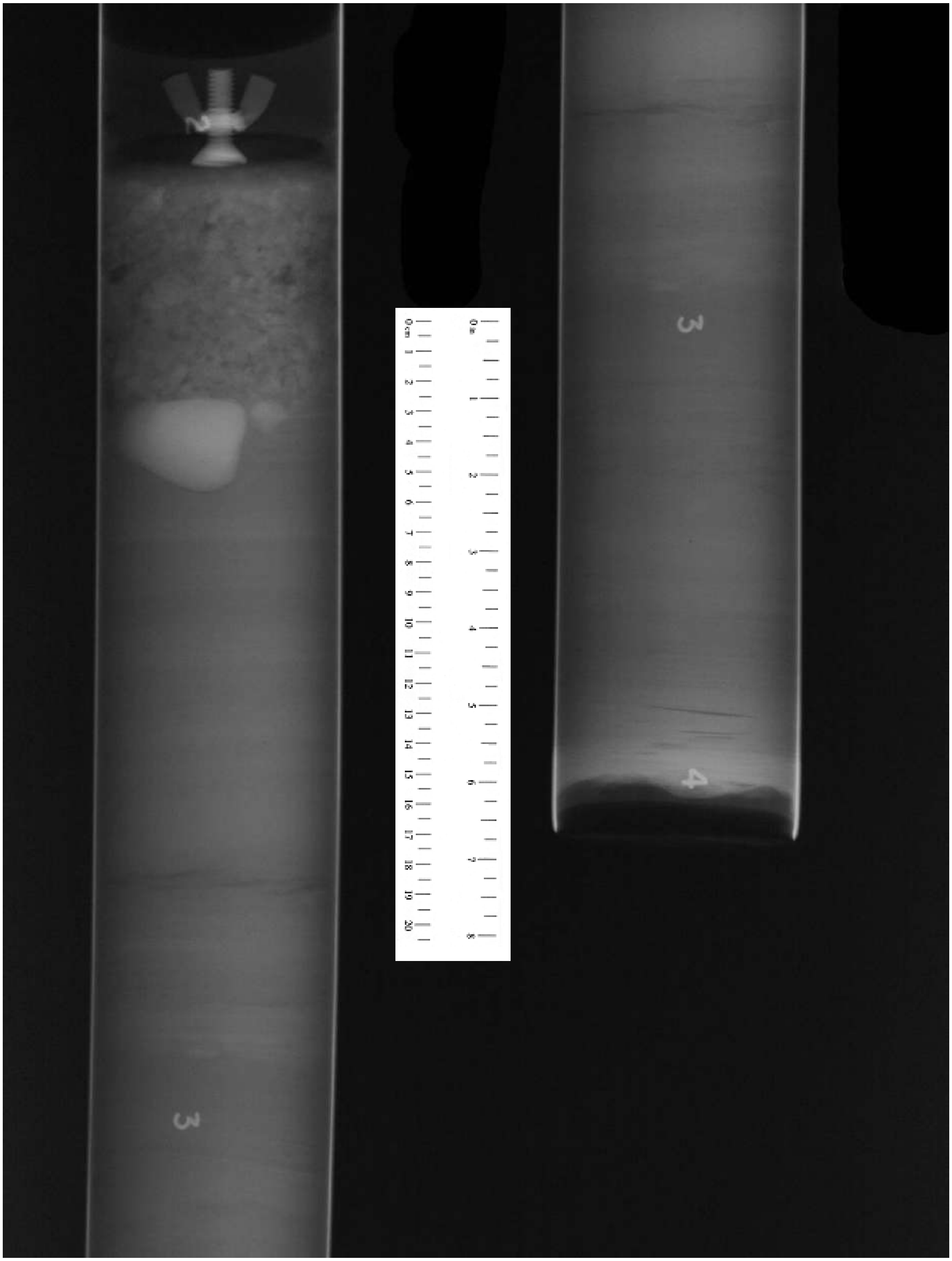


X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-33, DEPTH 126.0 – 127.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-33, DEPTH 126.0 – 127.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

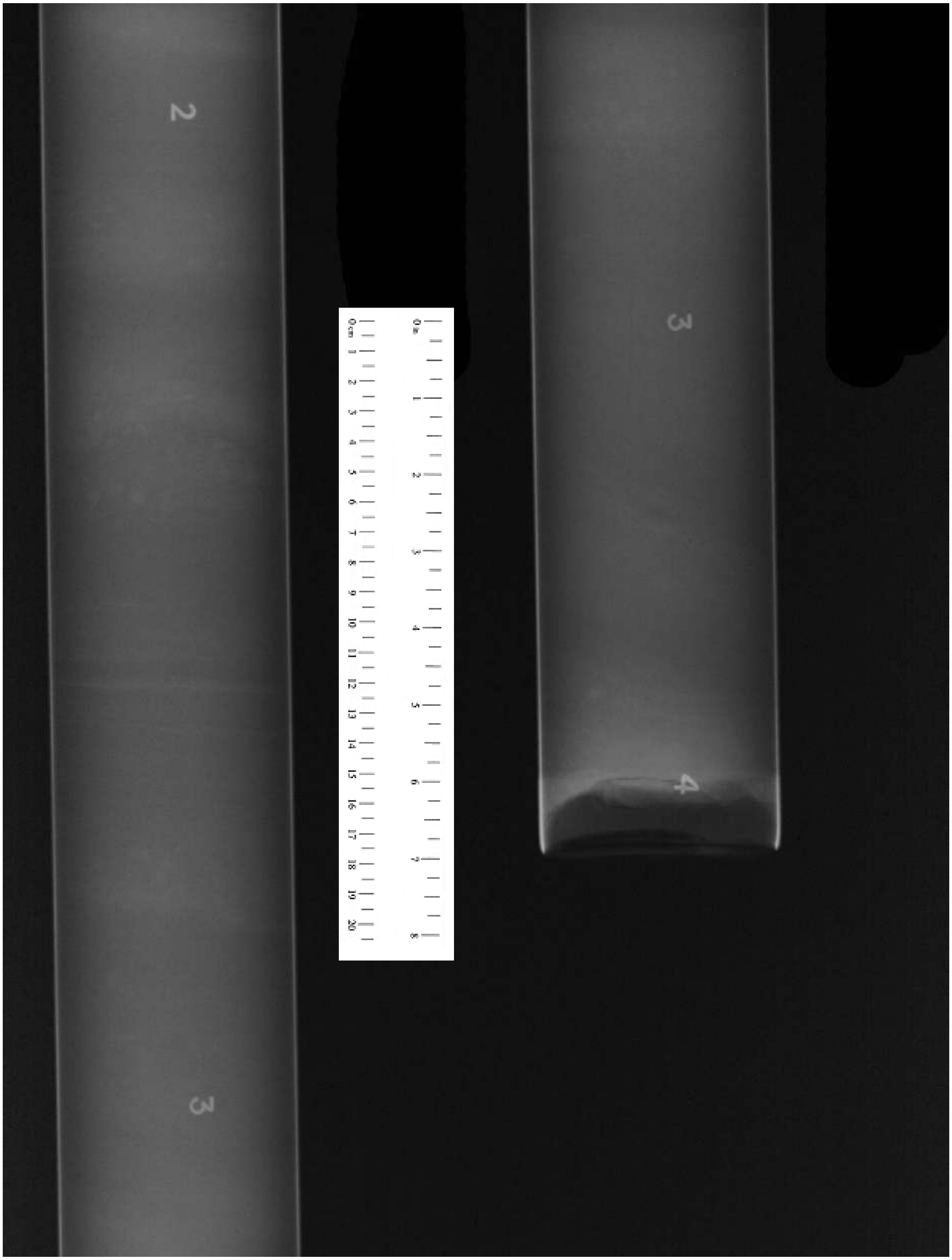
PLATE G10-53b



X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-34, DEPTH 129.0 – 130.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

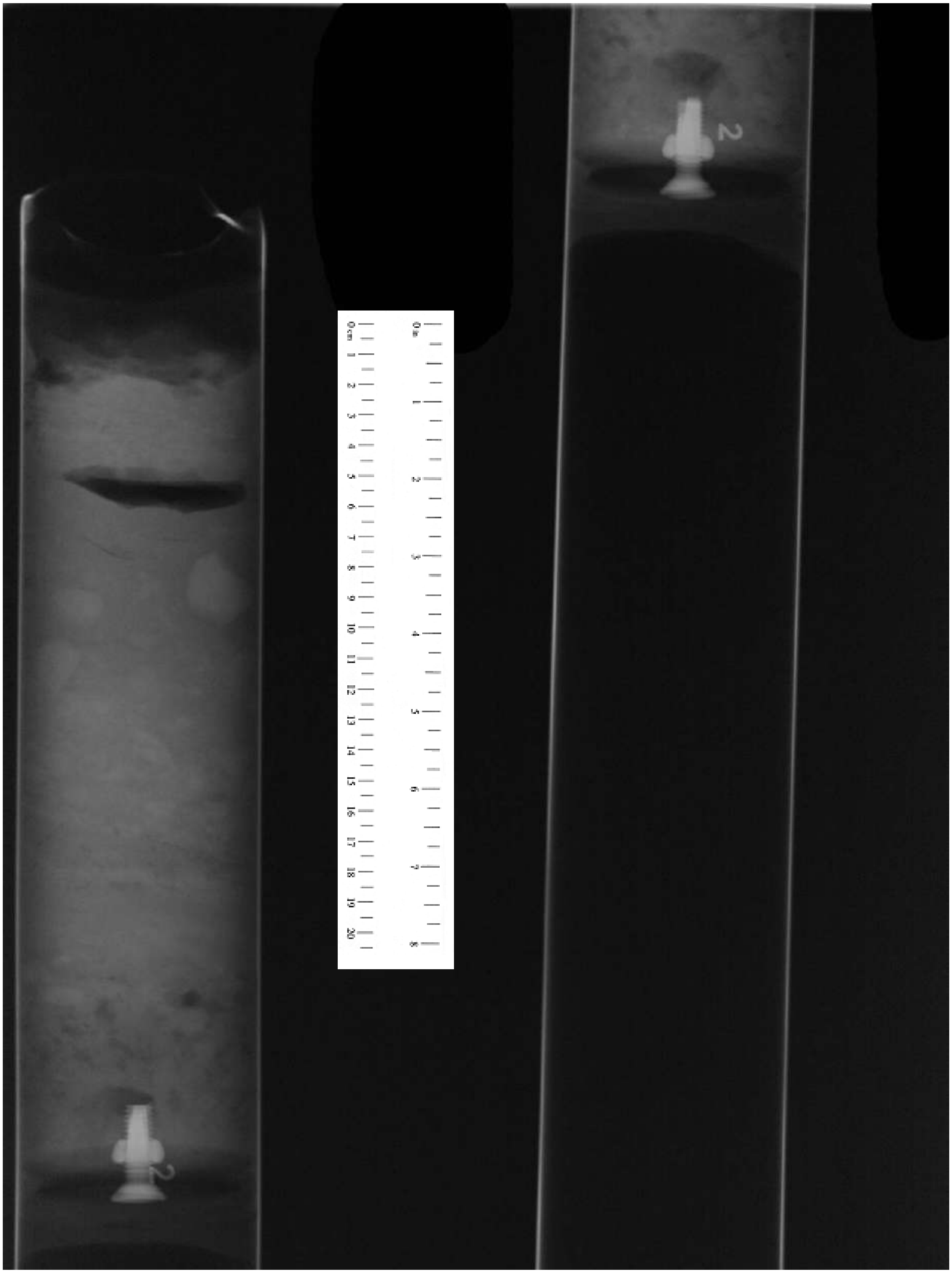
X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-45, DEPTH 176.0 – 177.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-55a

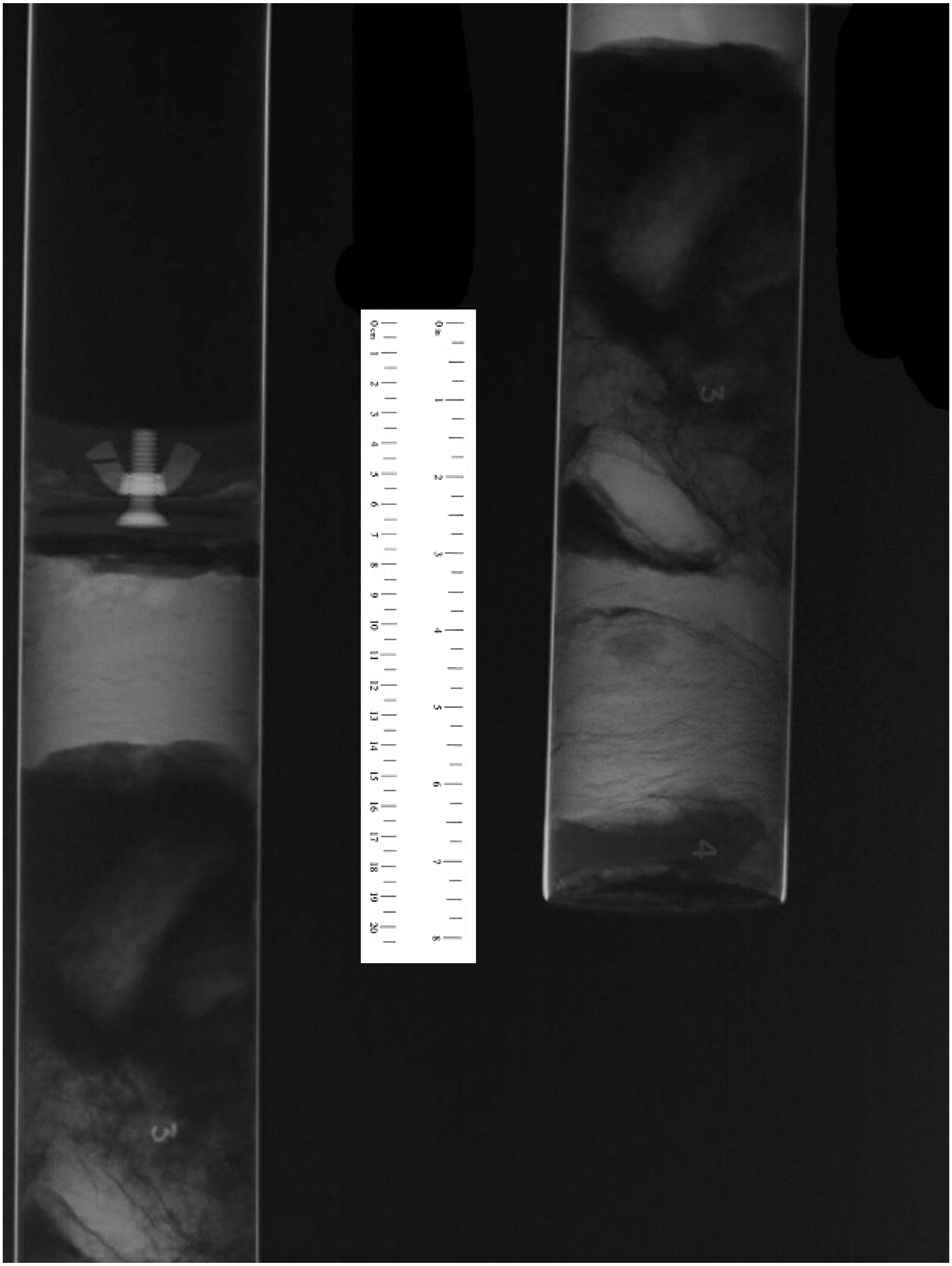


X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-45, DEPTH 176.0 – 177.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-55b

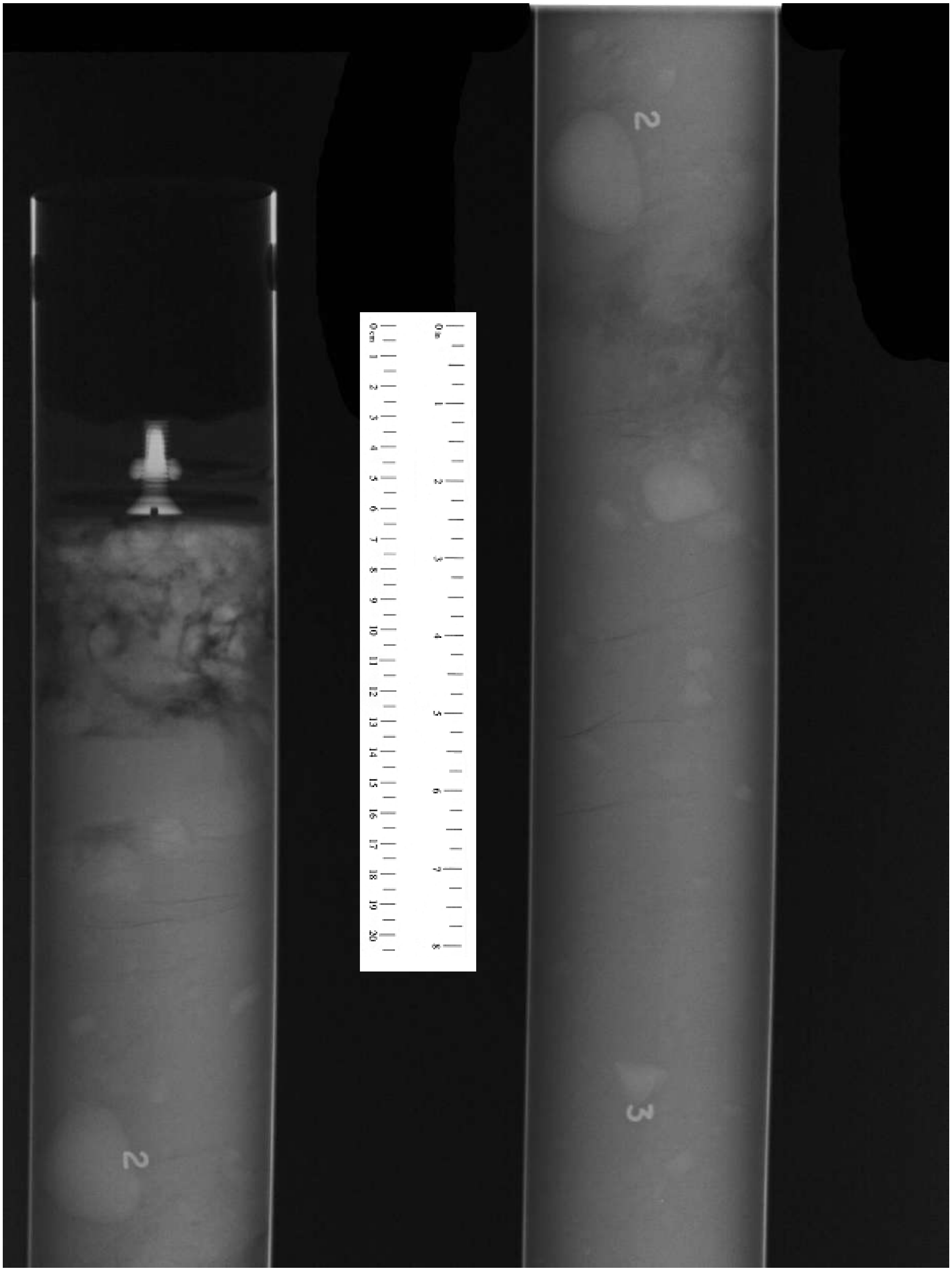


X-RAY RADIOGRAPHY IMAGES
BORING B-176, SAMPLE S-46, DEPTH 179.0 – 179.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

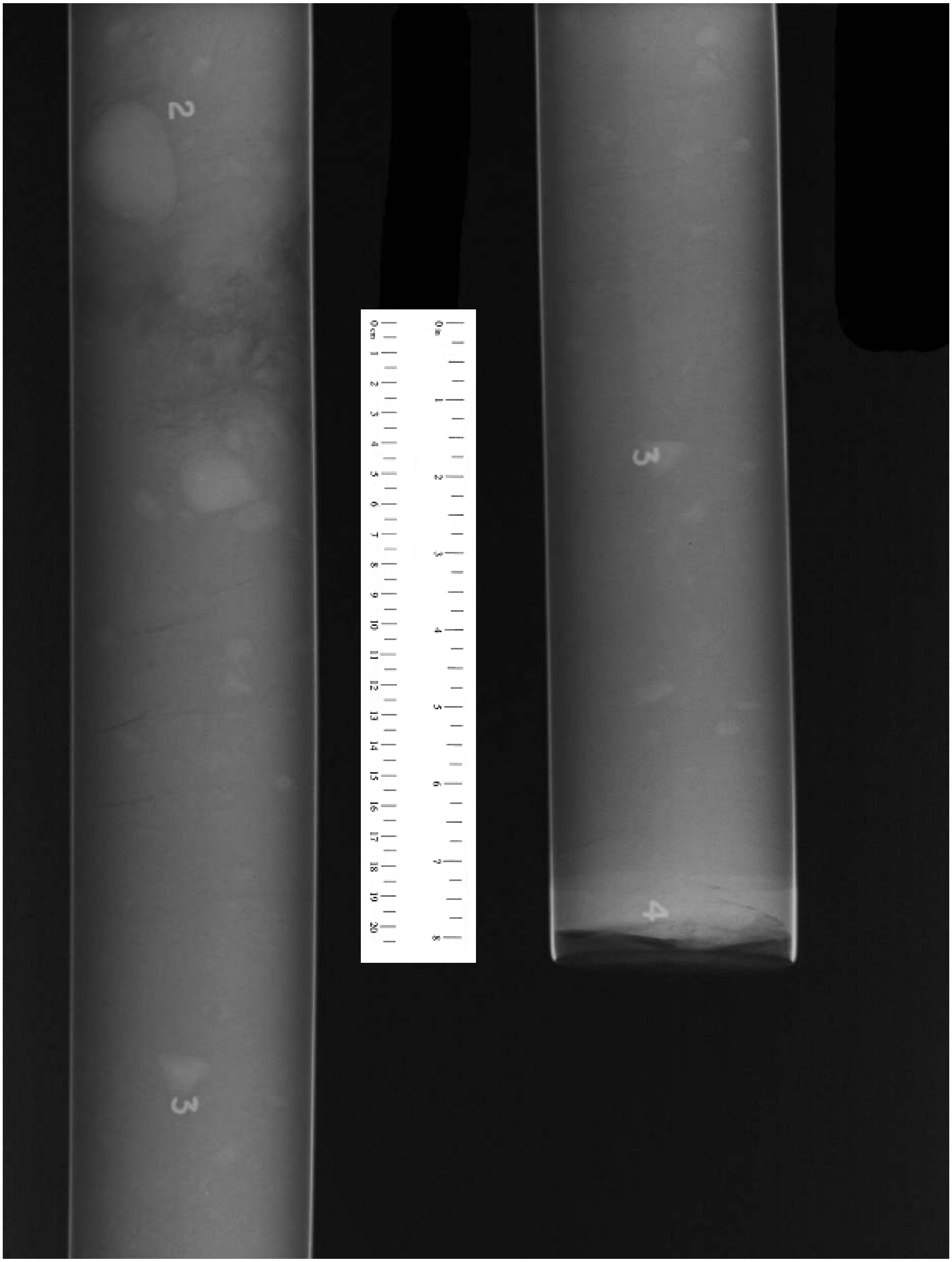


X-RAY RADIOGRAPHY IMAGES
BORING B-183, SAMPLE S-15, DEPTH 49.0 – 50.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-57

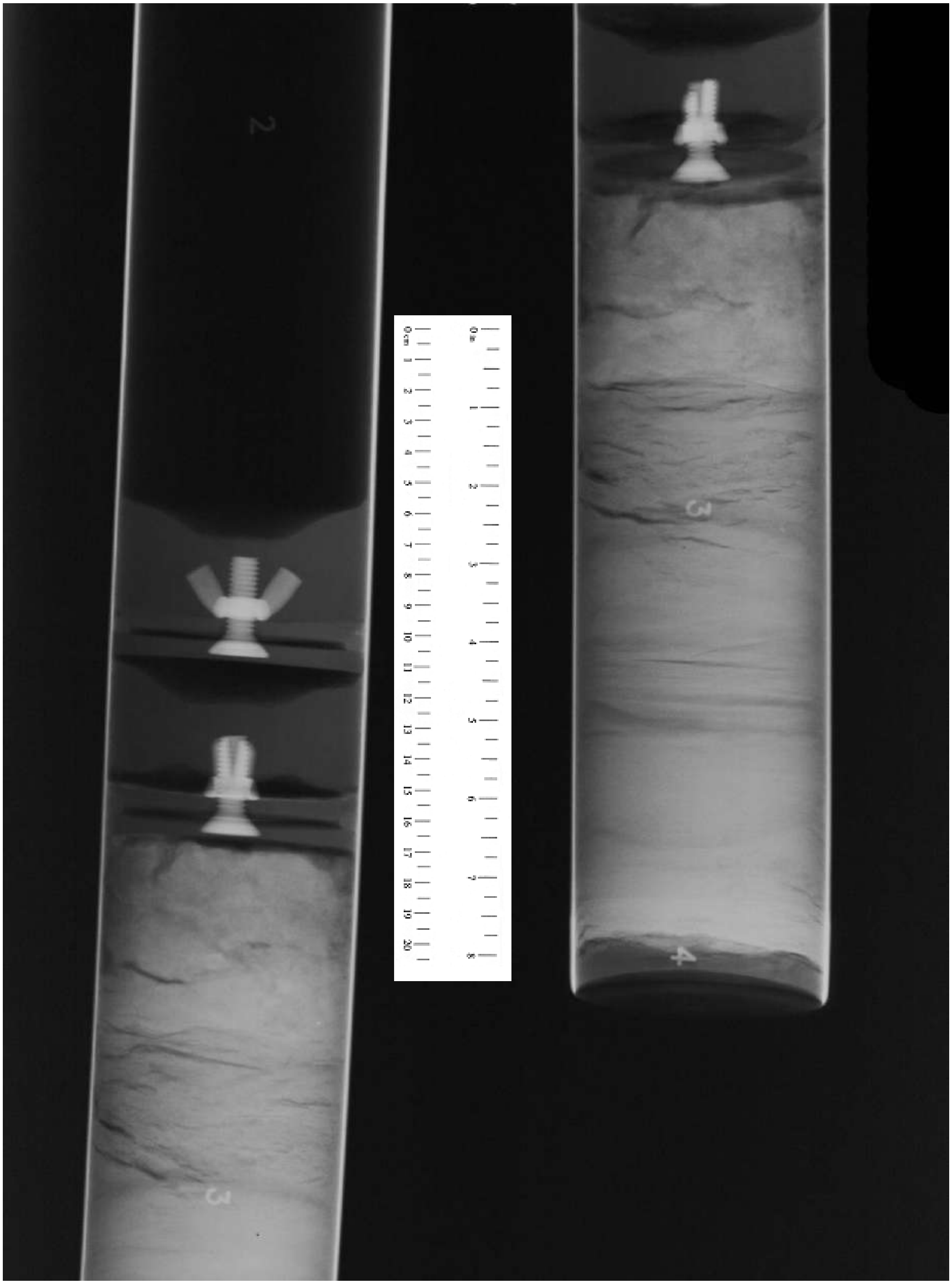


X-RAY RADIOGRAPHY IMAGES
BORING B-183, SAMPLE S-25, DEPTH 78.5 – 80.4 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

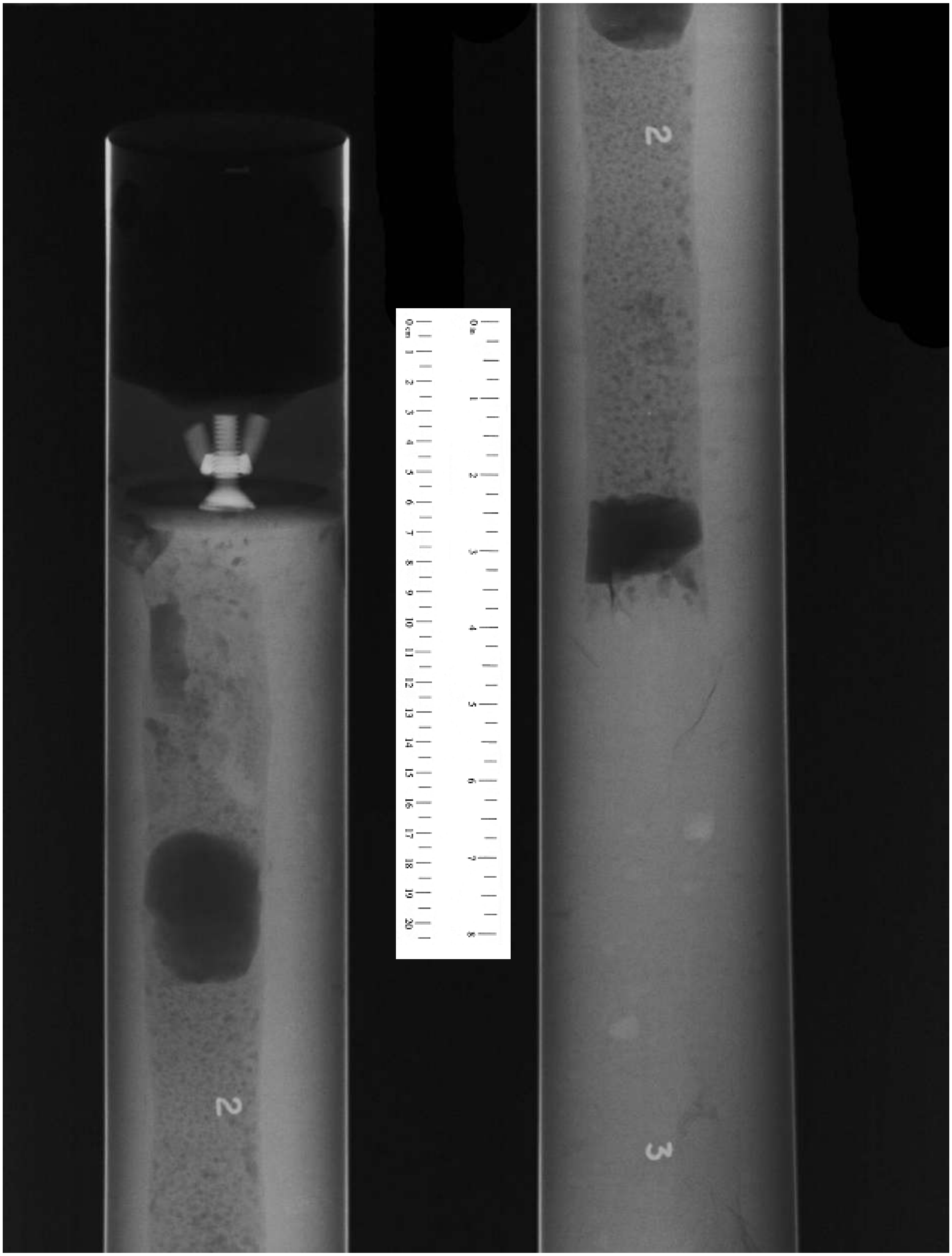


X-RAY RADIOGRAPHY IMAGES
BORING B-183, SAMPLE S-25, DEPTH 78.5 – 80.4 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-58b

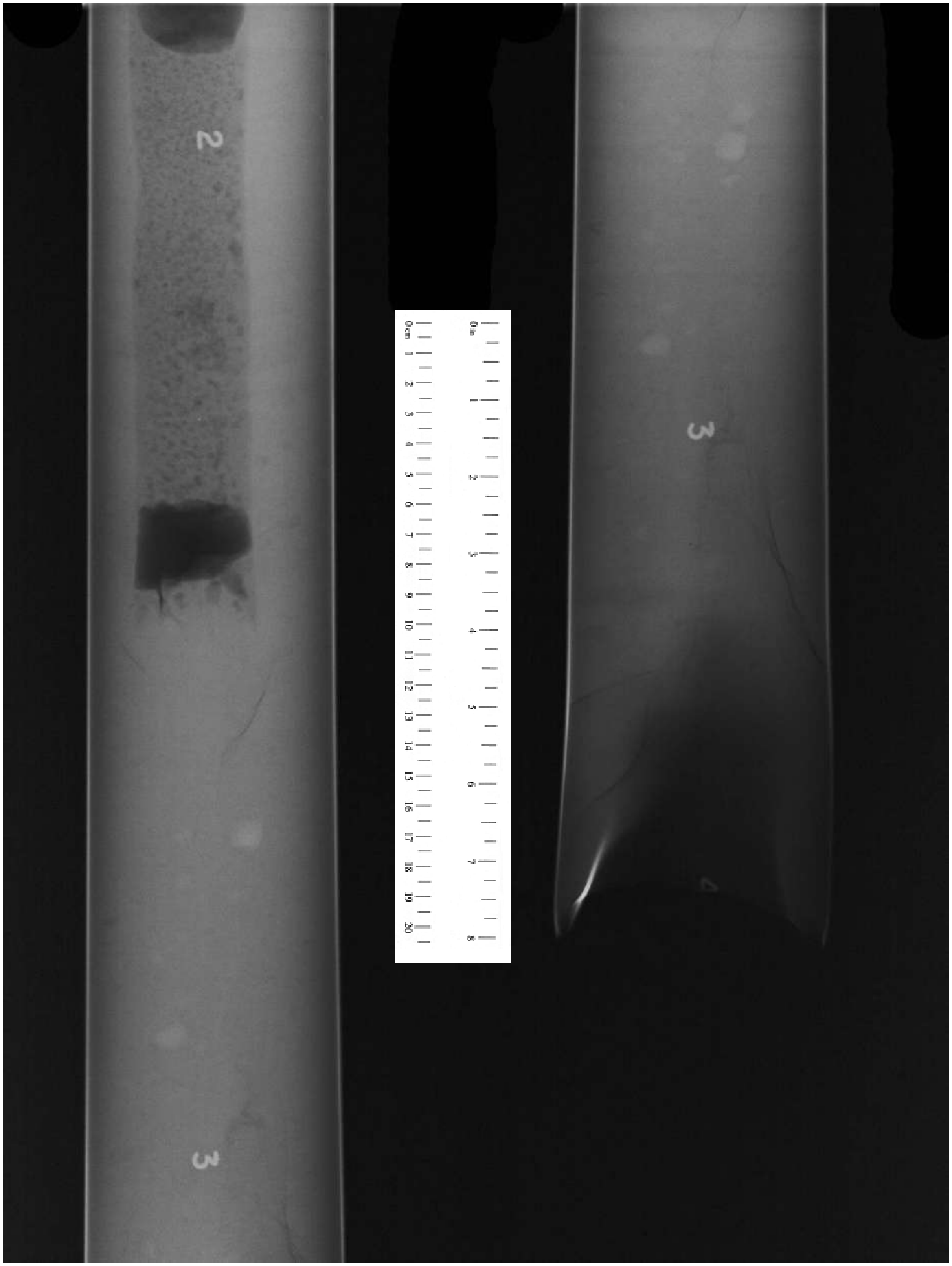


X-RAY RADIOGRAPHY IMAGES
BORING B-189, SAMPLE S-23, DEPTH 84.0 – 86.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



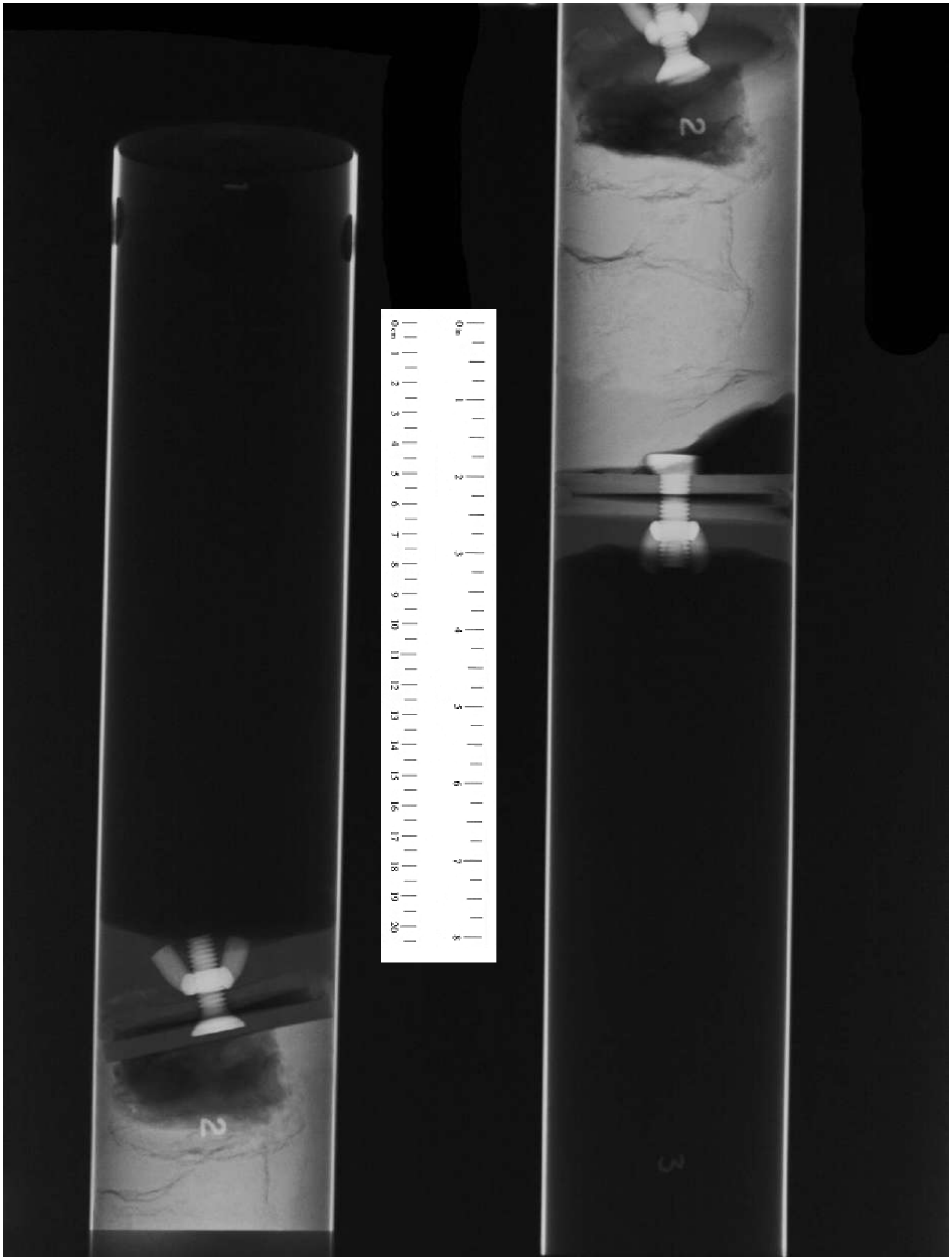
X-RAY RADIOGRAPHY IMAGES
BORING B-189, SAMPLE S-37, DEPTH 199.0 – 201.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-60b



X-RAY RADIOGRAPHY IMAGES
BORING B-189, SAMPLE S-37, DEPTH 199.0 – 201.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-60b



X-RAY RADIOGRAPHY IMAGES
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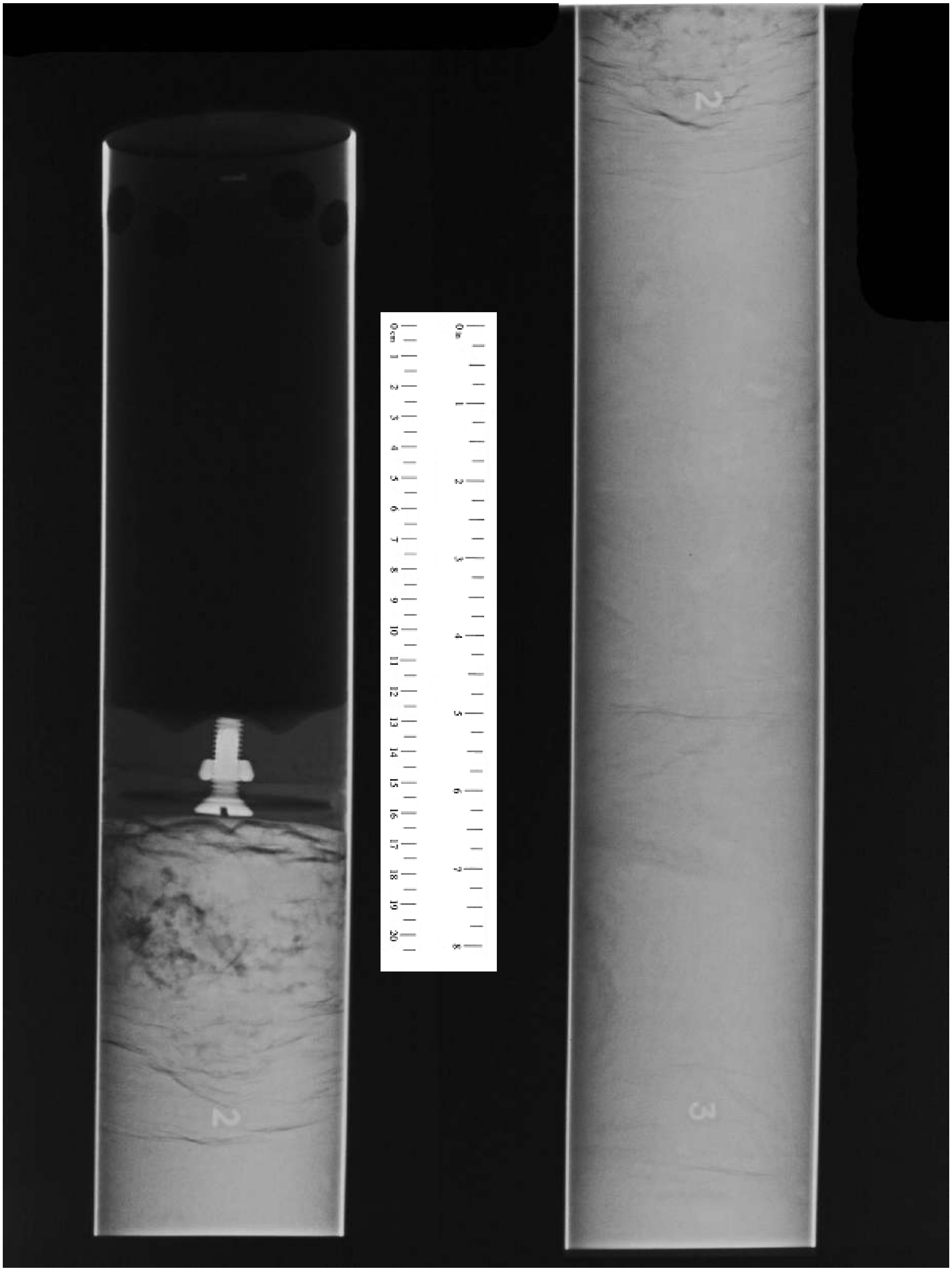
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



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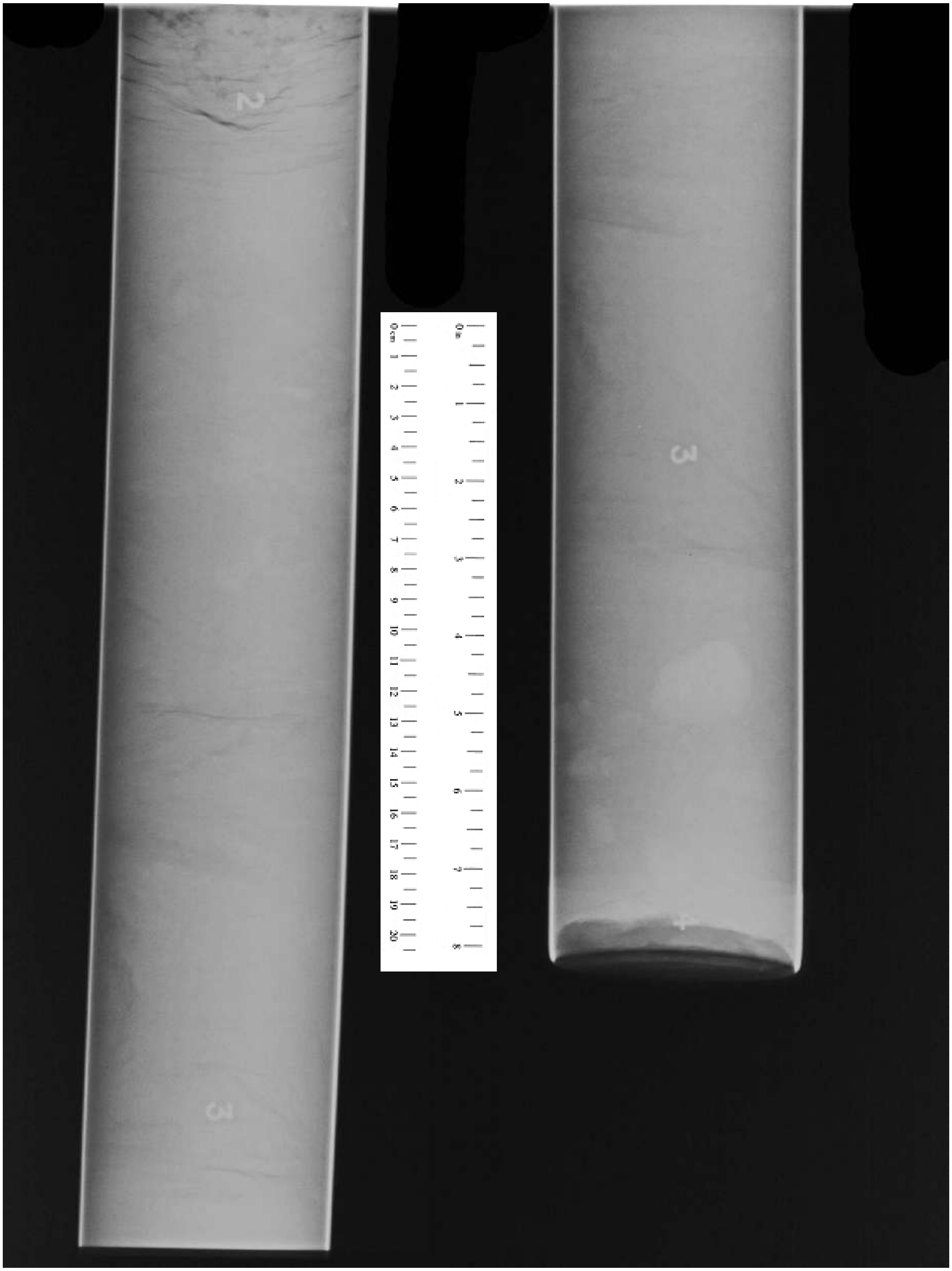
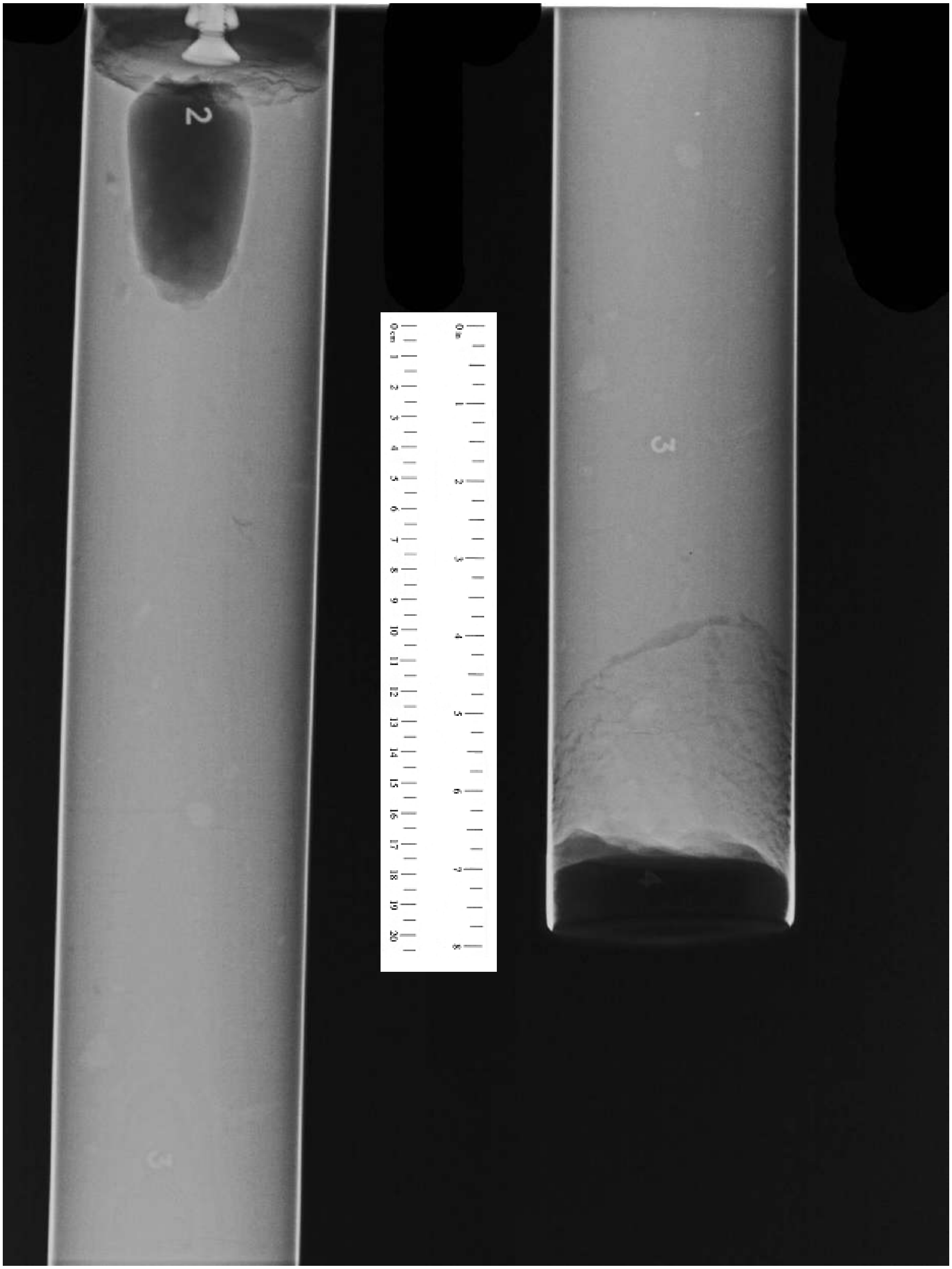
BORING B-190, SAMPLE S-16, DEPTH 46.0 – 47.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
BORING B-190, SAMPLE S-16, DEPTH 46.0 – 47.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-62b



X-RAY RADIOGRAPHY IMAGES
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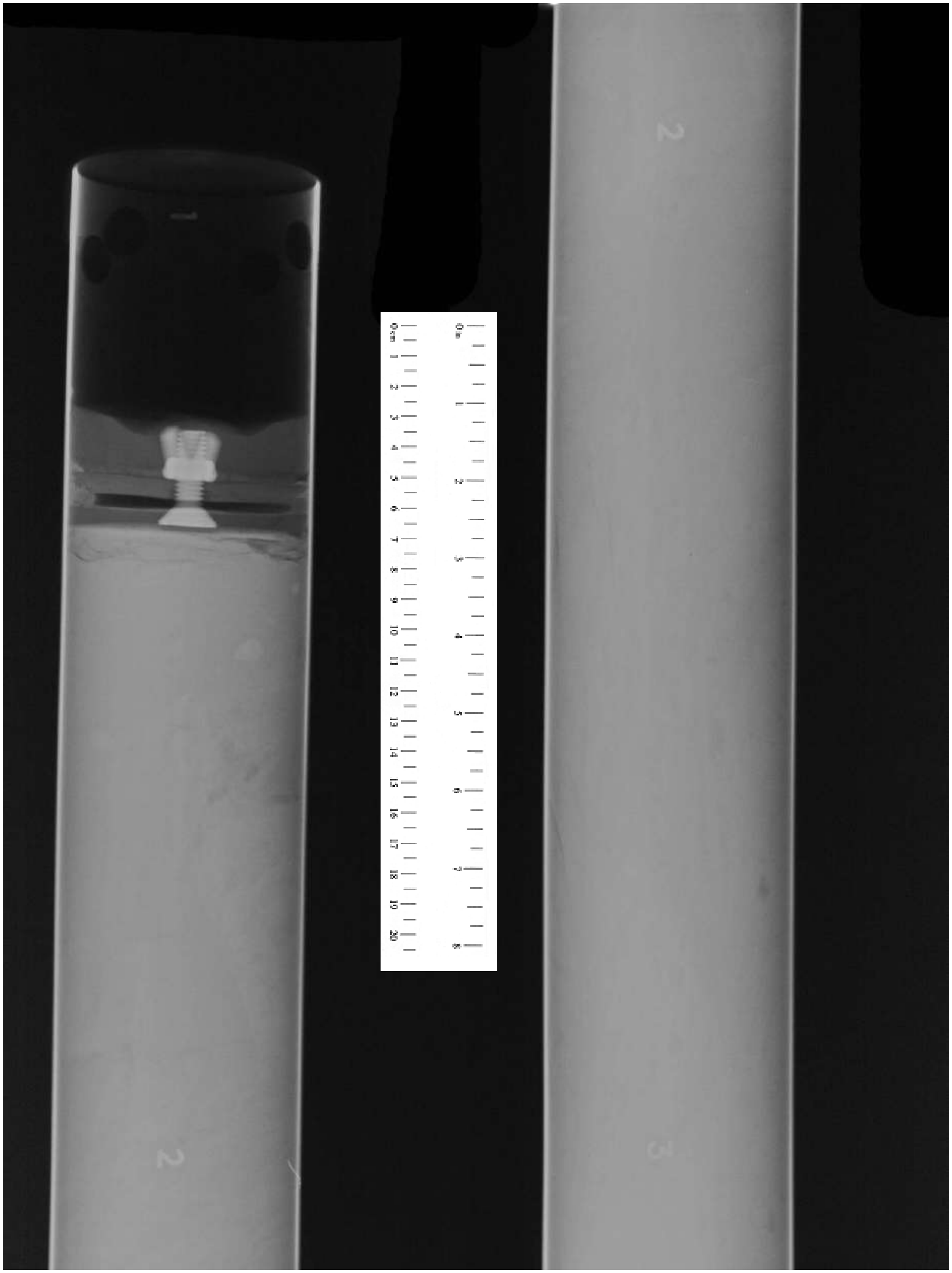
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



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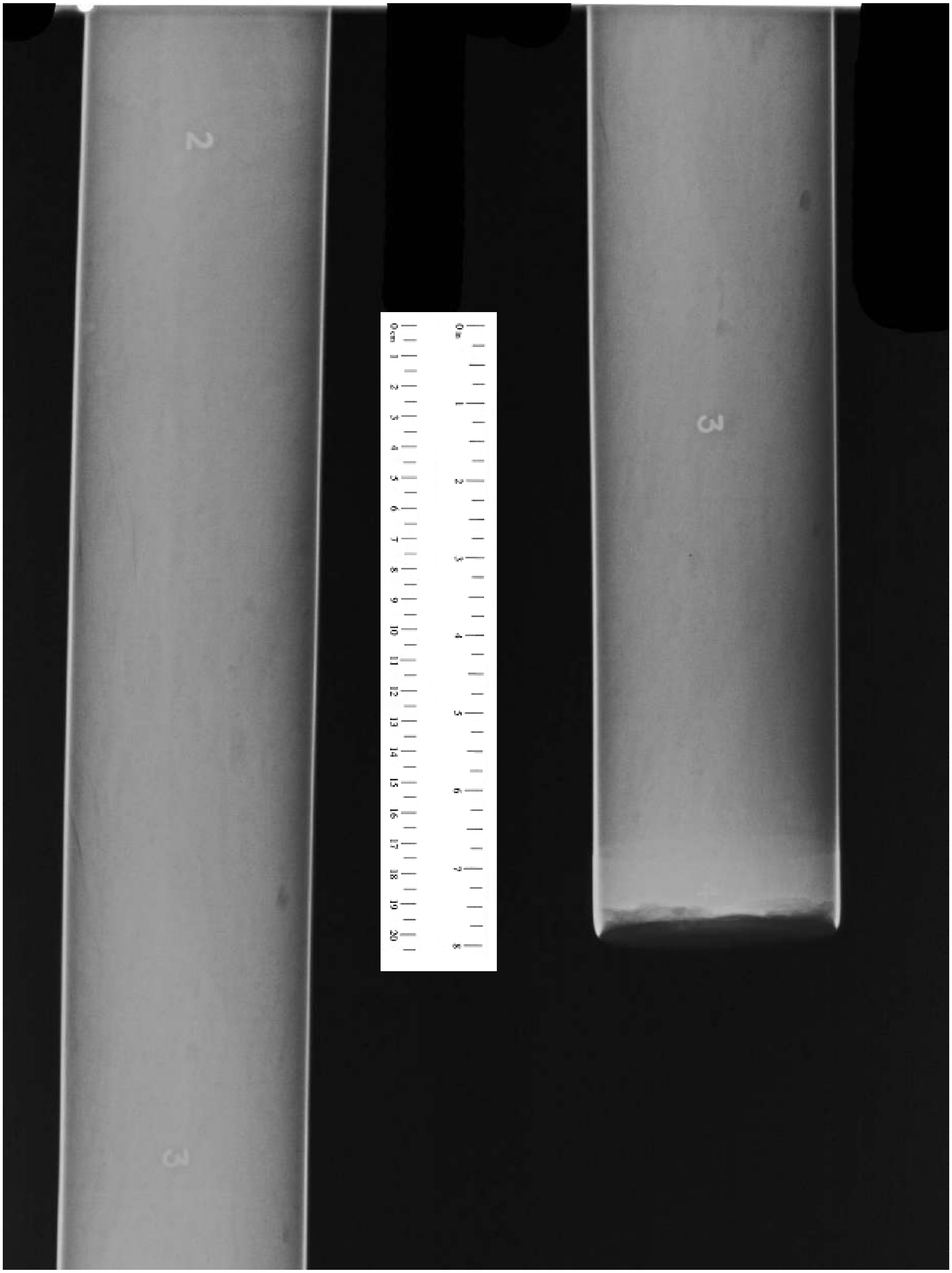
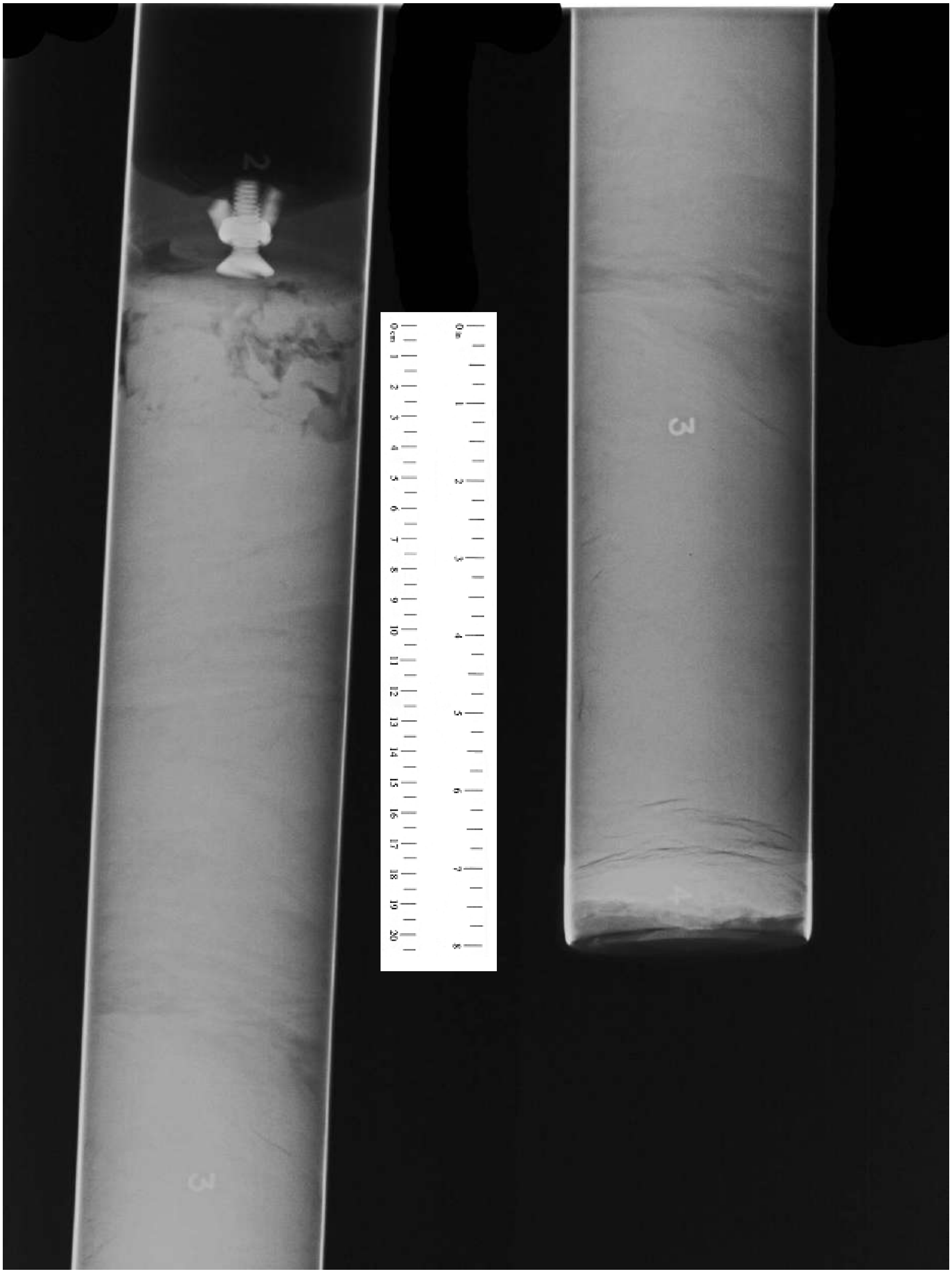
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
BORING B-190, SAMPLE S-26, DEPTH 87.3 – 89.3 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-64b



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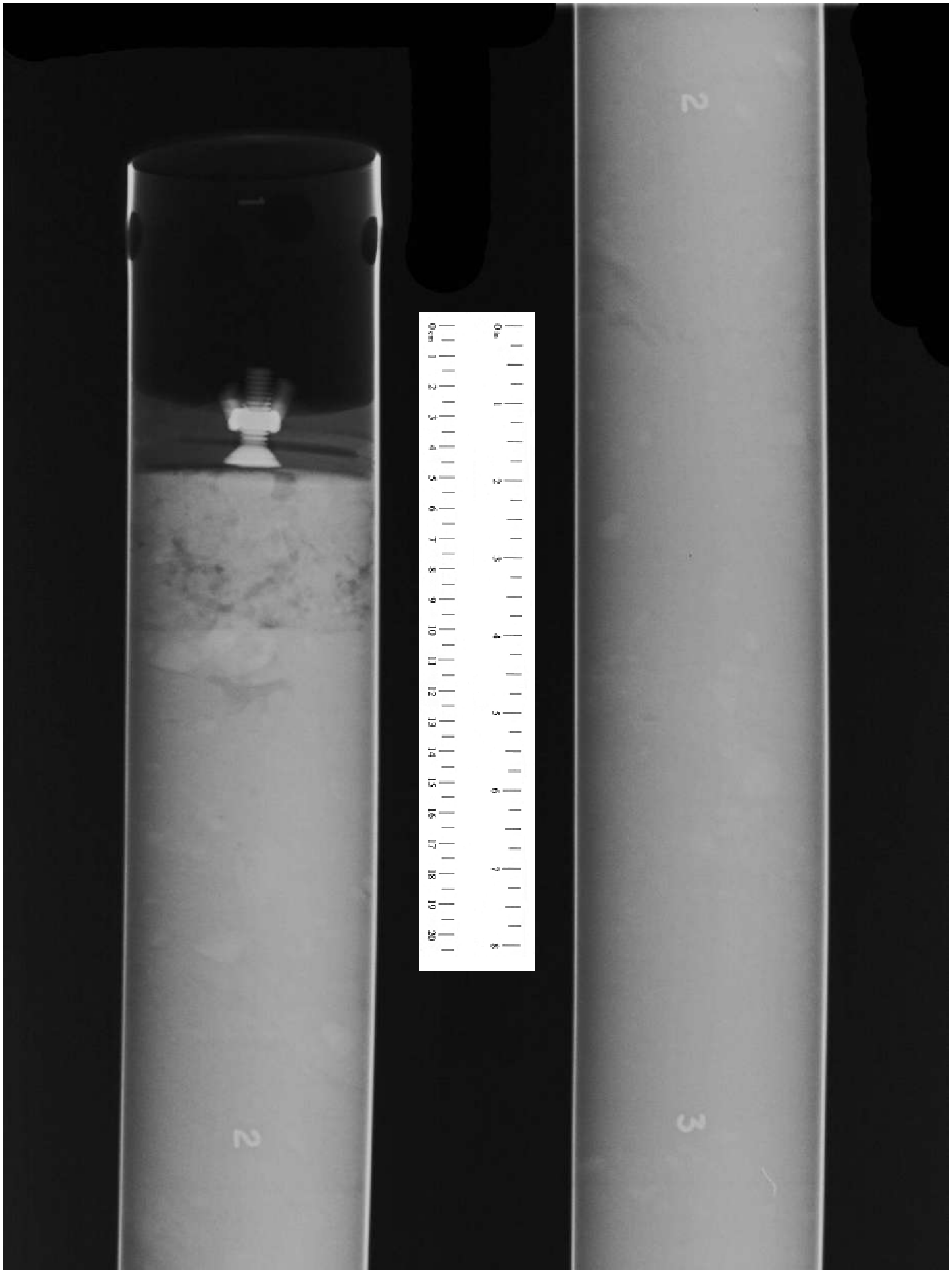
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



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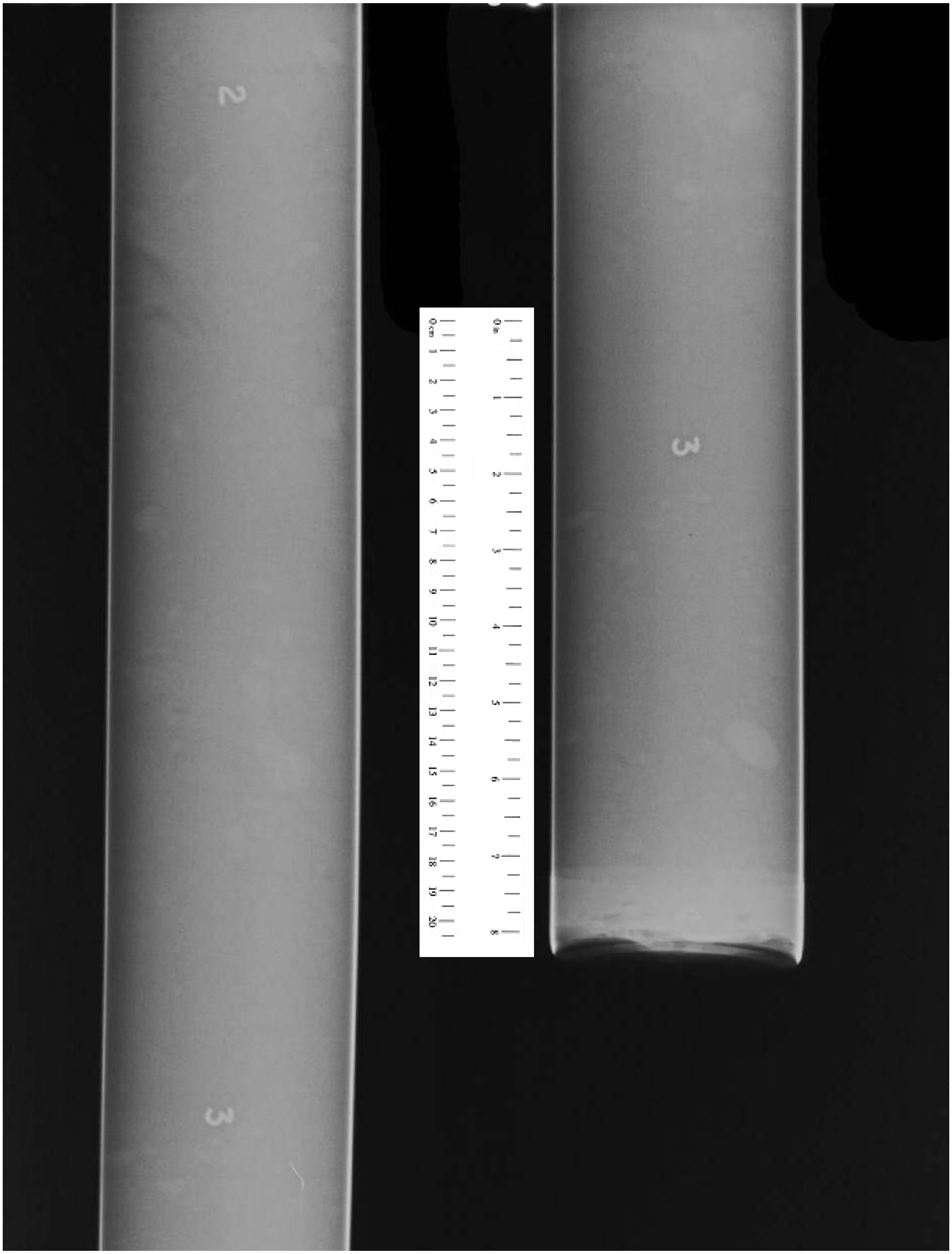
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-66a



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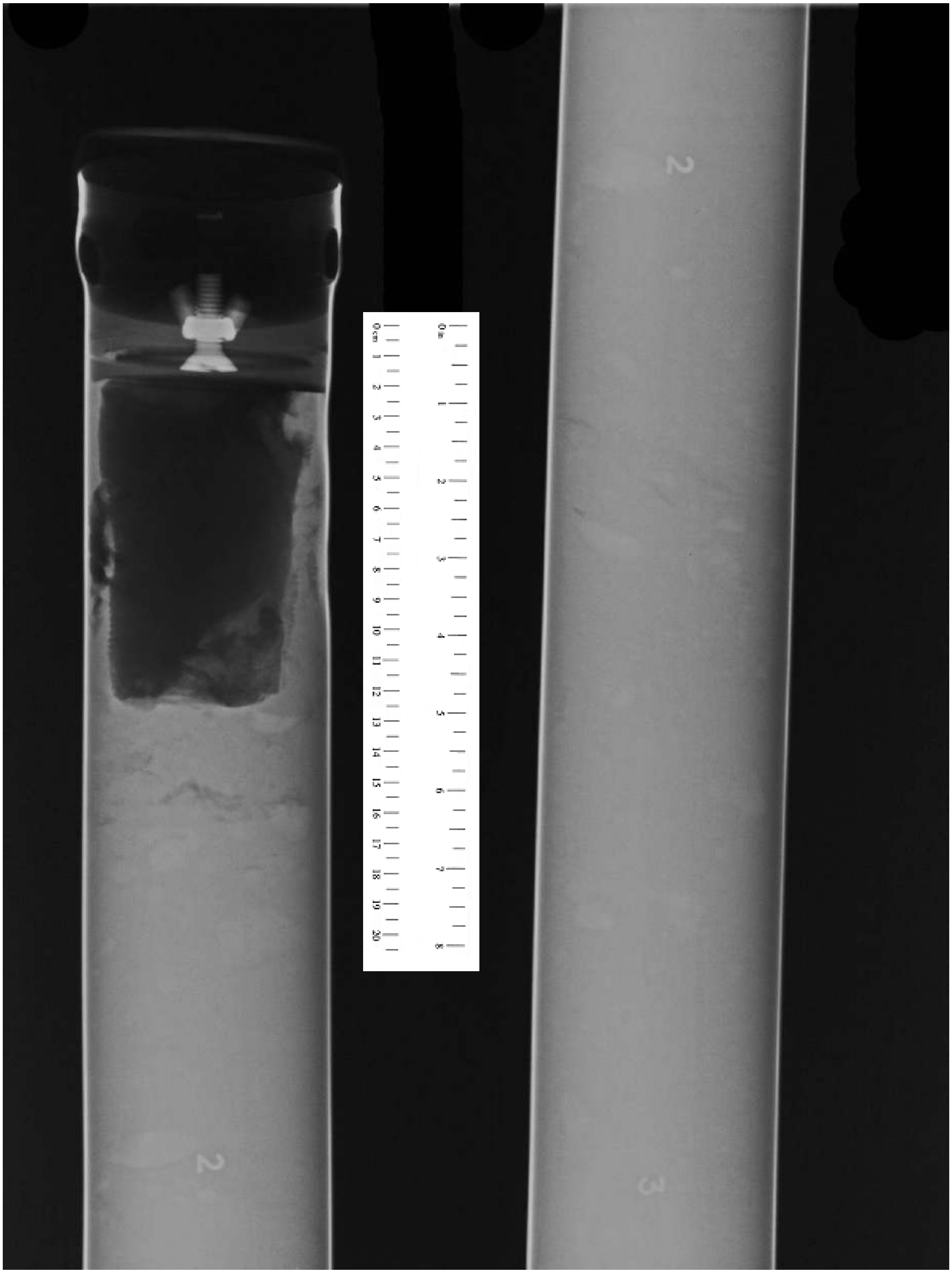
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



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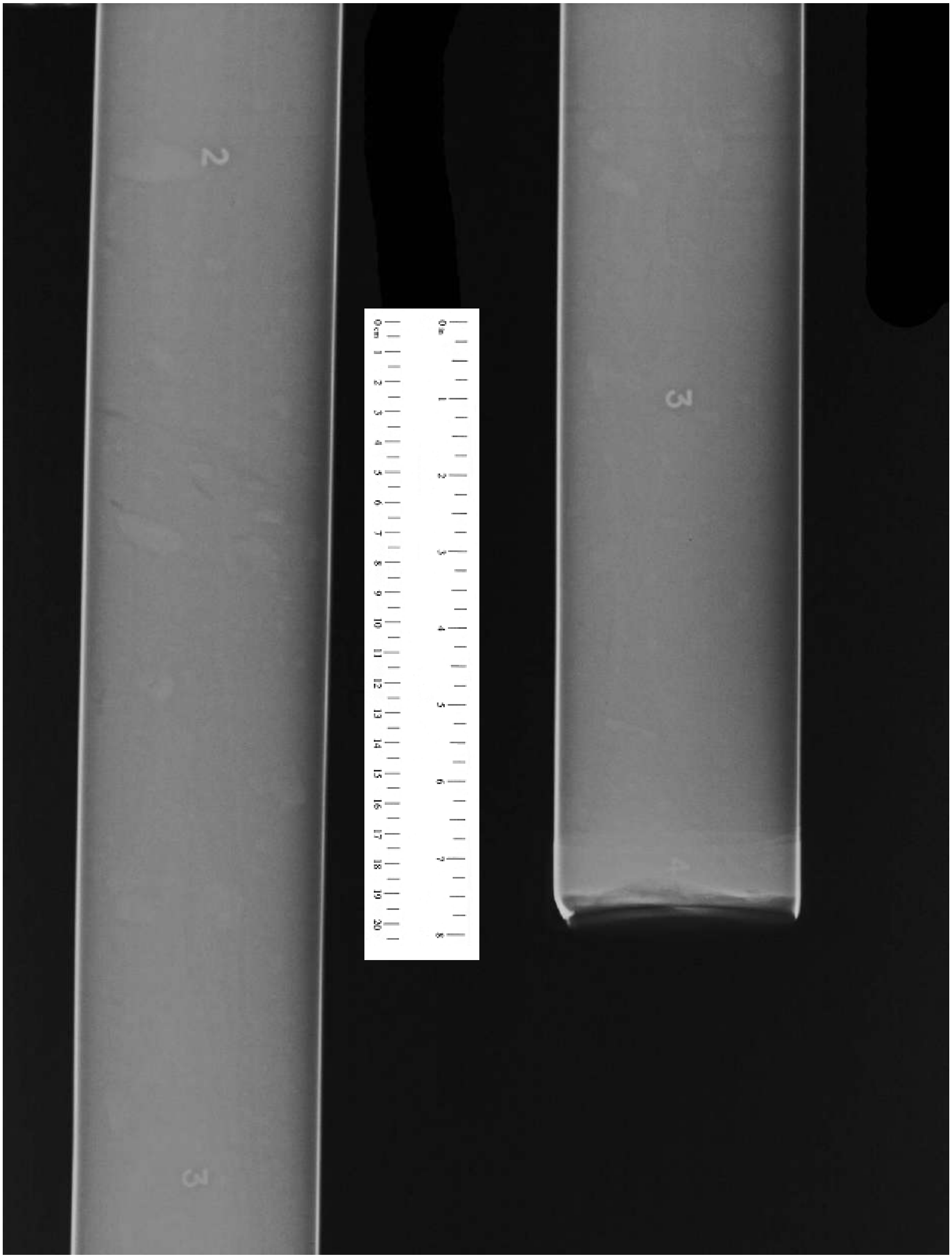
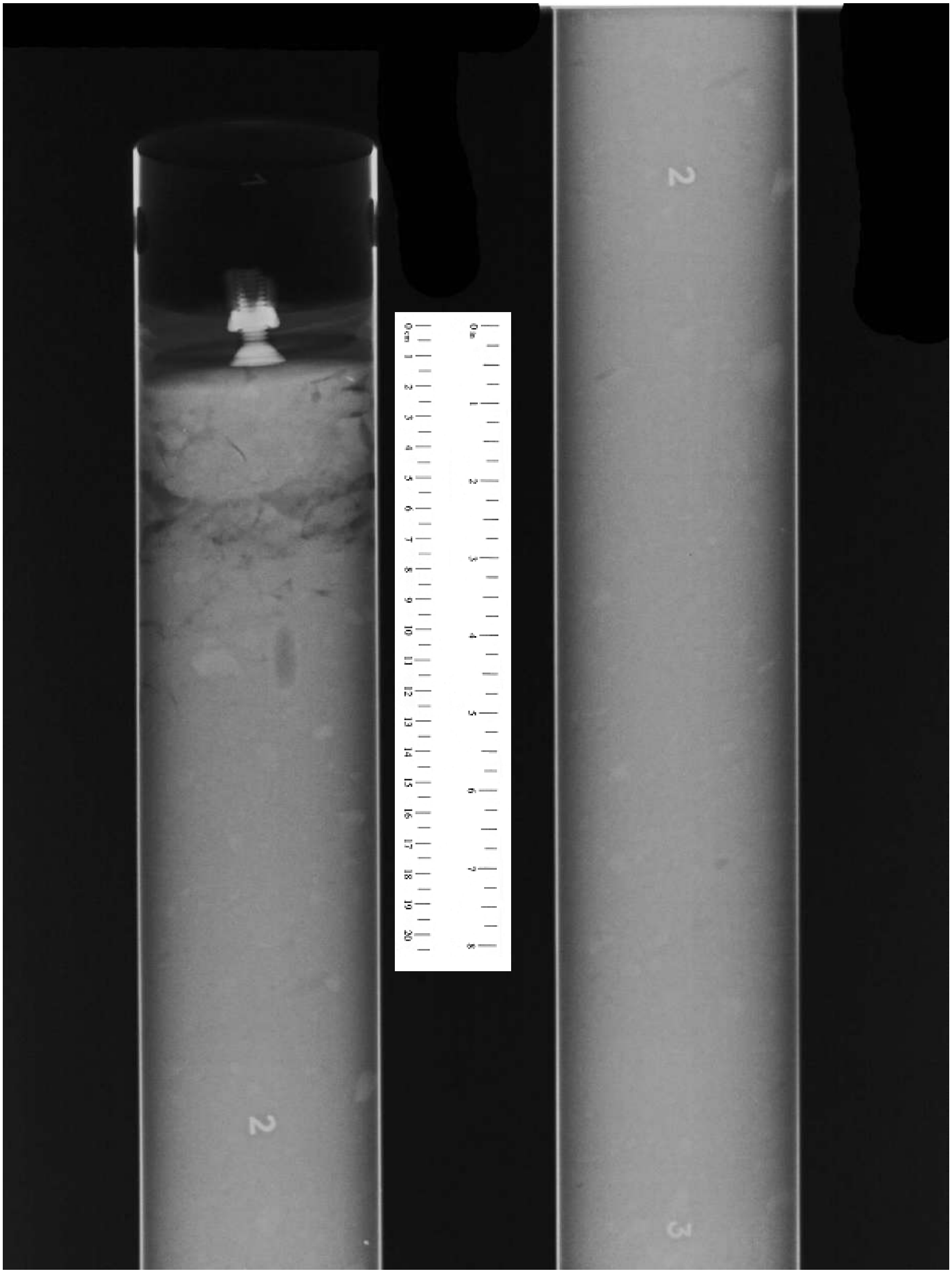
ALASKA LNG PROJECT
NIKISKI, ALASKA

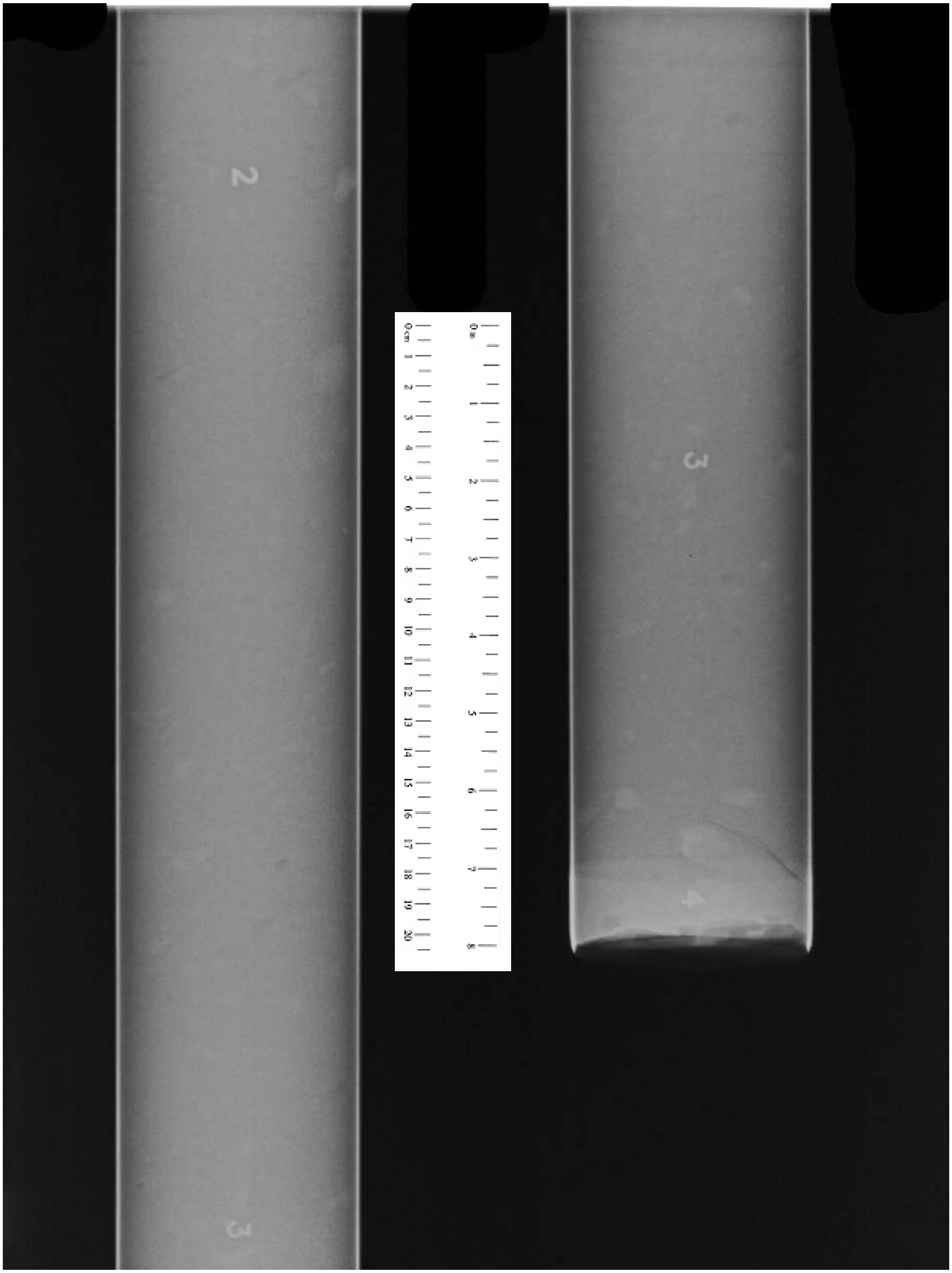


X-RAY RADIOGRAPHY IMAGES
BORING B-191, SAMPLE S-17, DEPTH 51.0 – 53.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



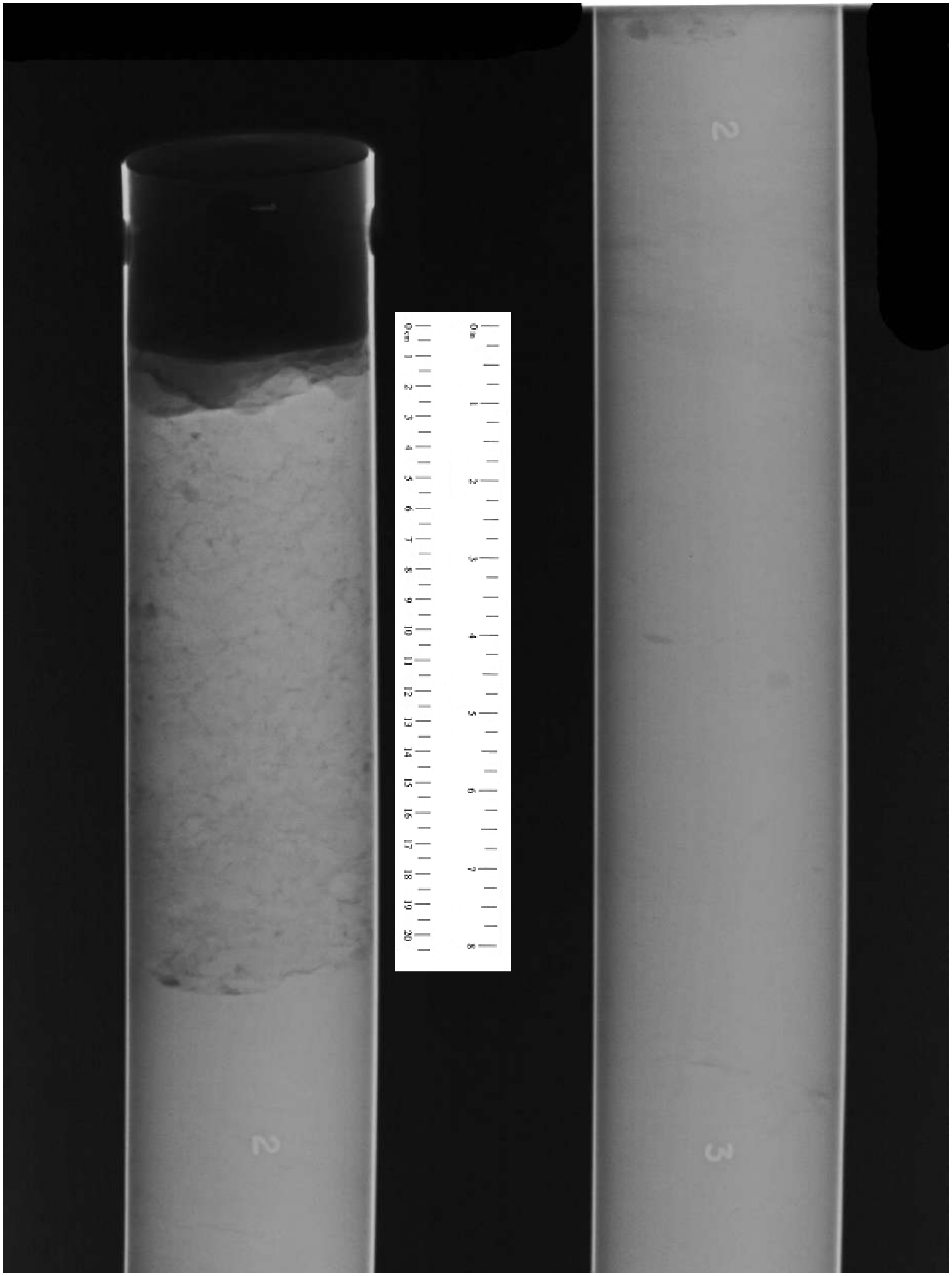
X-RAY RADIOGRAPHY IMAGES
BORING B-191, SAMPLE S-20, DEPTH 61.0 – 63.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-68a

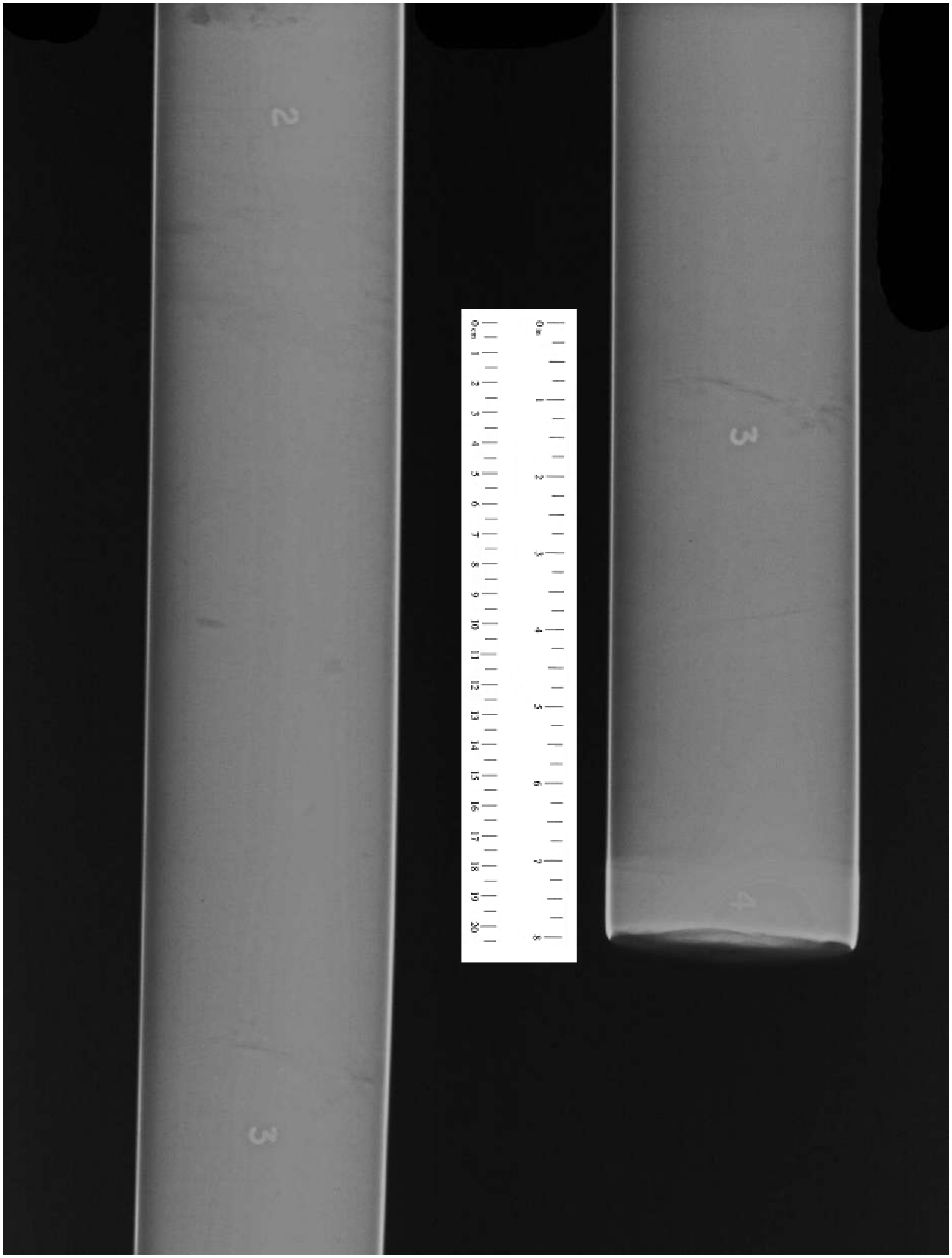


X-RAY RADIOGRAPHY IMAGES
BORING B-191, SAMPLE S-20, DEPTH 61.0 – 63.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

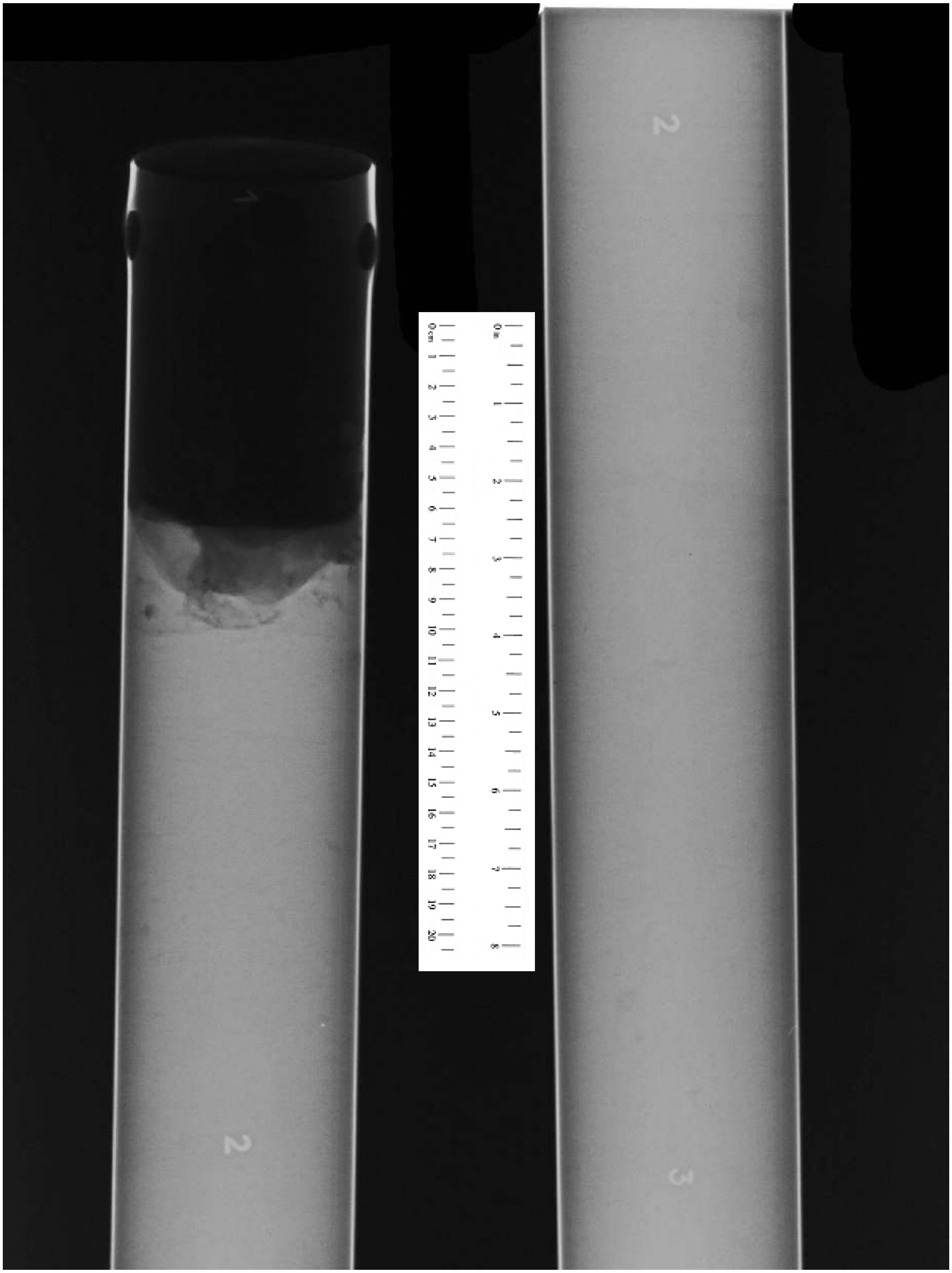
PLATE G10-68b



X-RAY RADIOGRAPHY IMAGES
BORING B-191, SAMPLE S-30, DEPTH 96.0 – 97.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

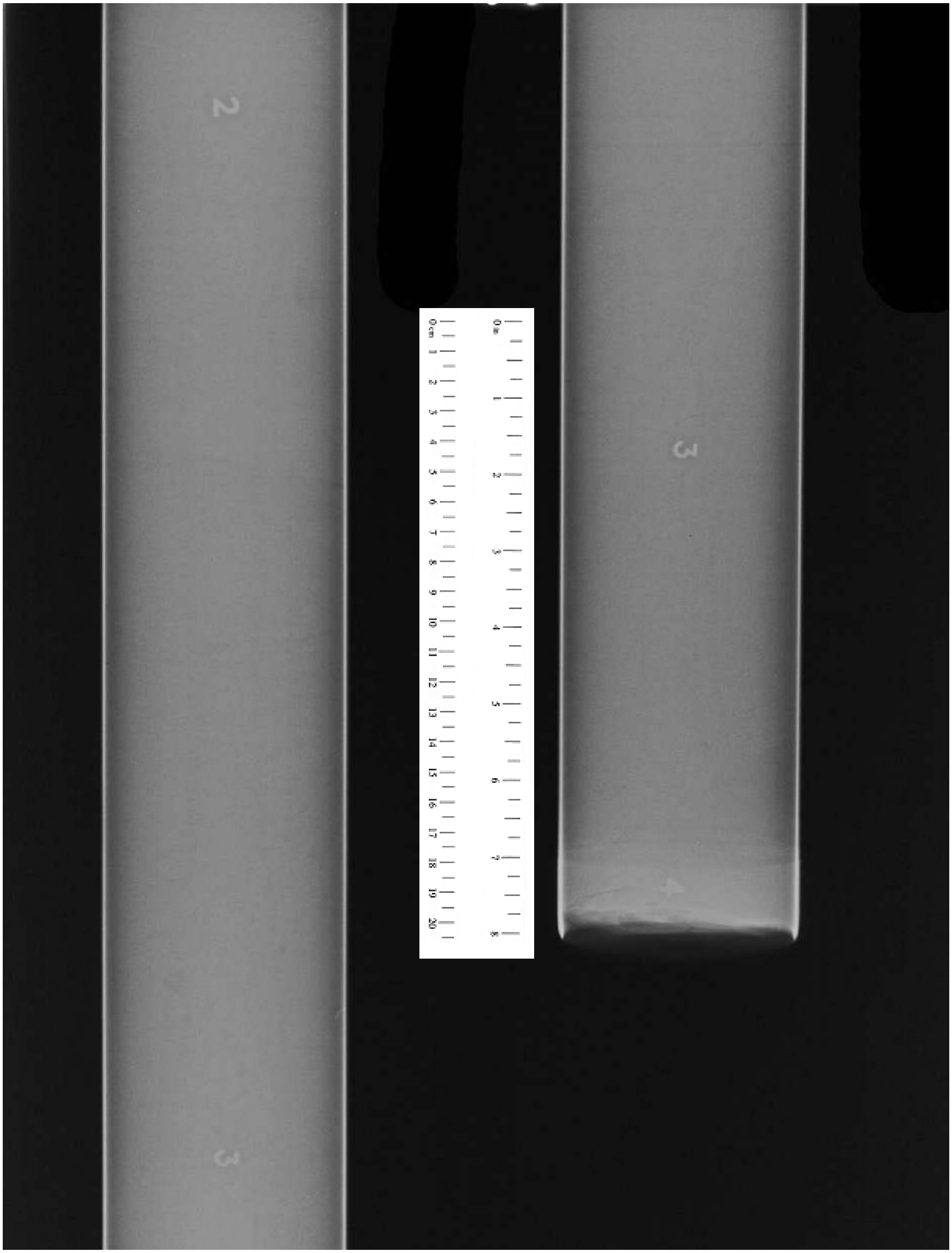


X-RAY RADIOGRAPHY IMAGES
BORING B-191, SAMPLE S-30, DEPTH 96.0 – 97.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



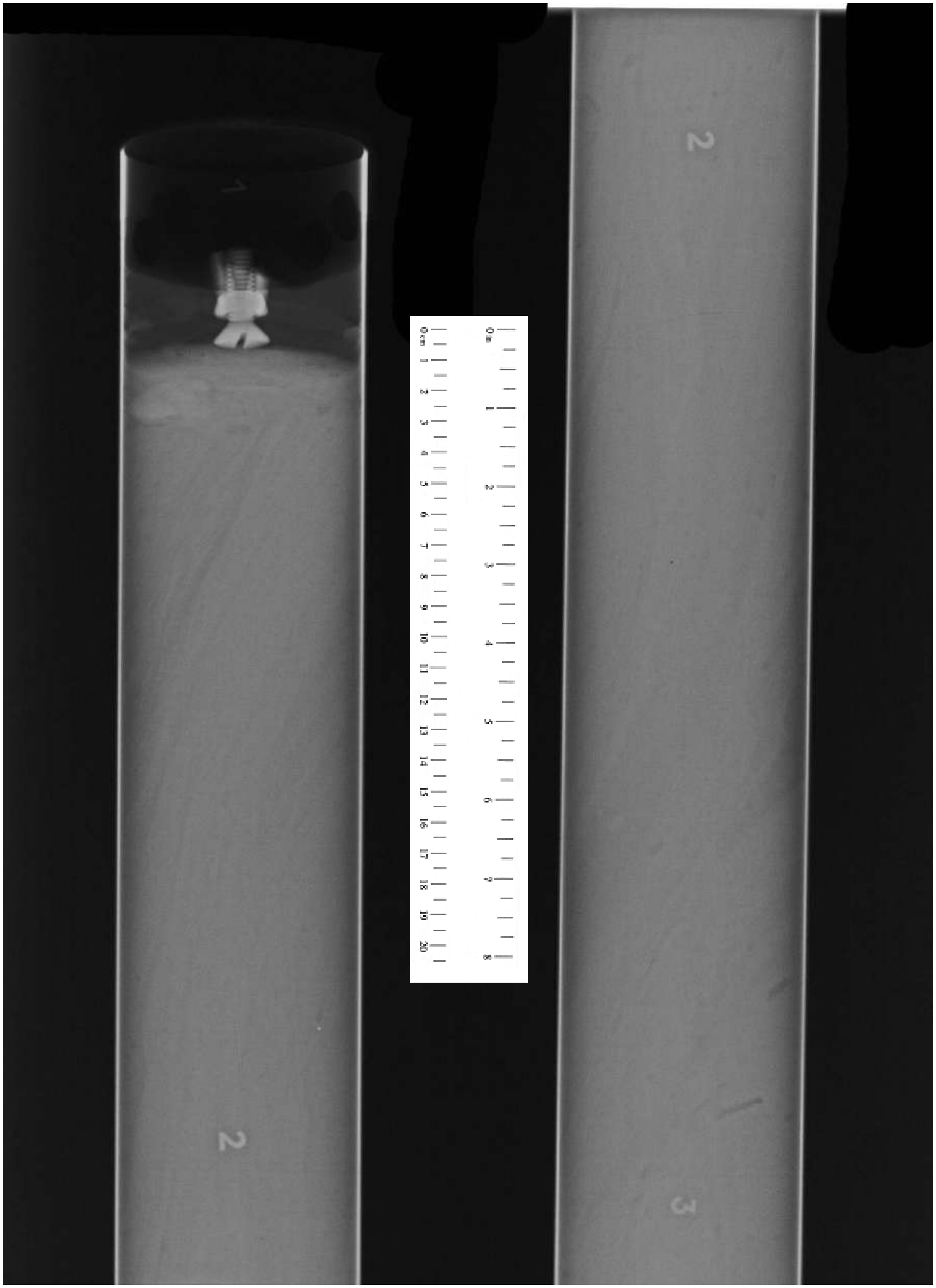
X-RAY RADIOGRAPHY IMAGES
BORING B-191, SAMPLE S-32, DEPTH 104.0 – 106.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-70a

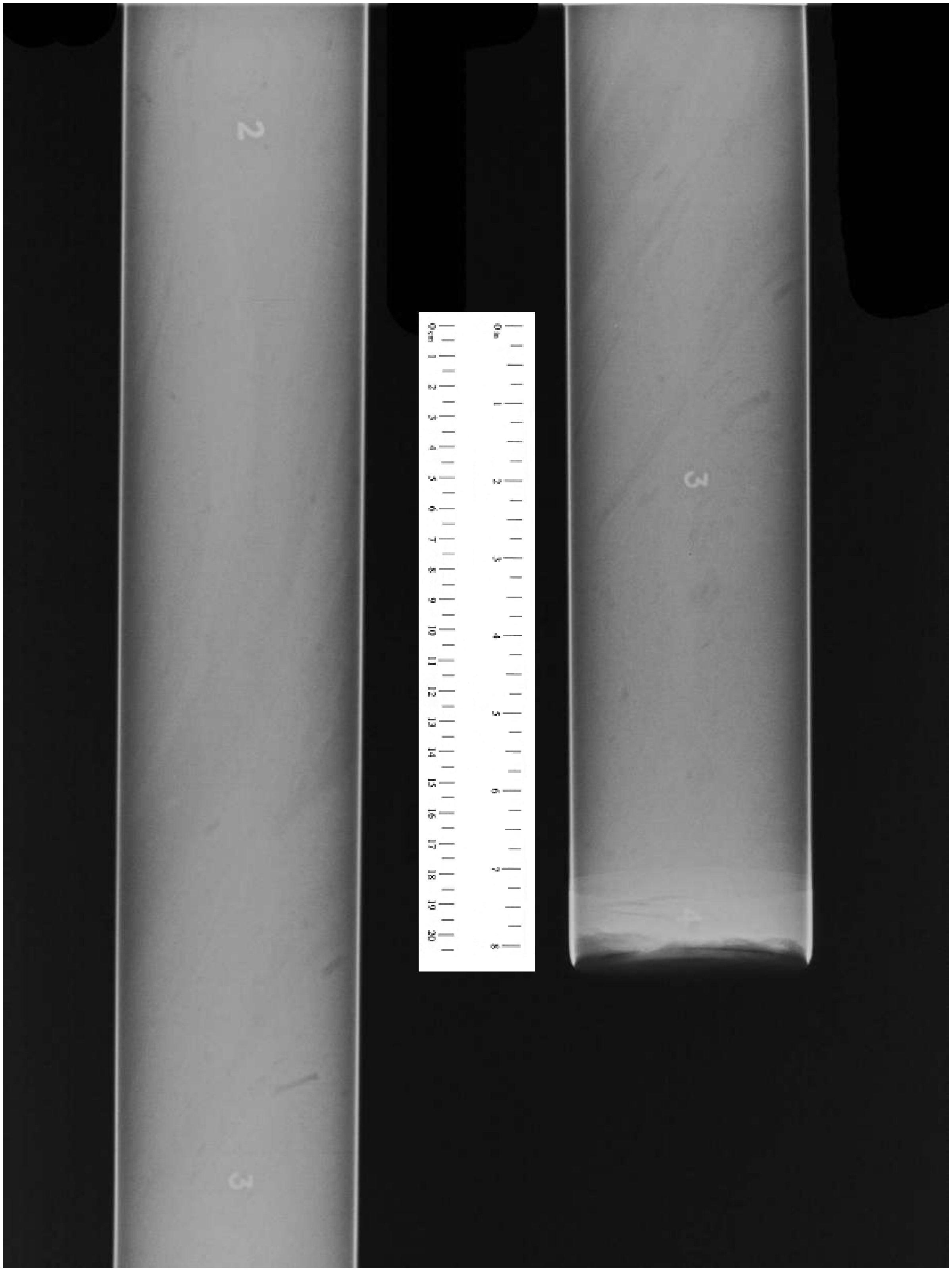


X-RAY RADIOGRAPHY IMAGES
BORING B-191, SAMPLE S-32, DEPTH 104.0 – 106.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-70b

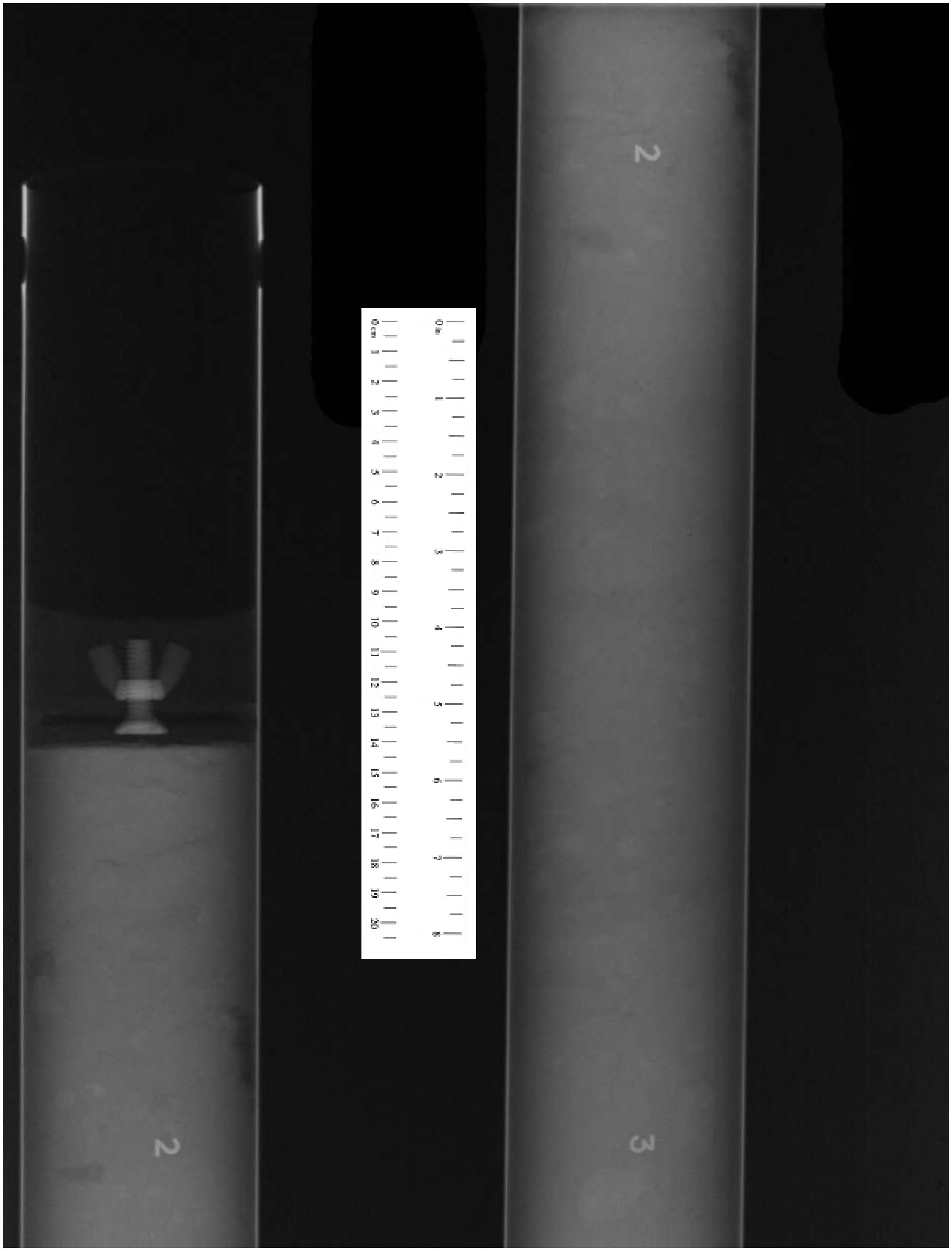


X-RAY RADIOGRAPHY IMAGES
BORING B-191, SAMPLE S-36, DEPTH 112.2 – 114.2 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



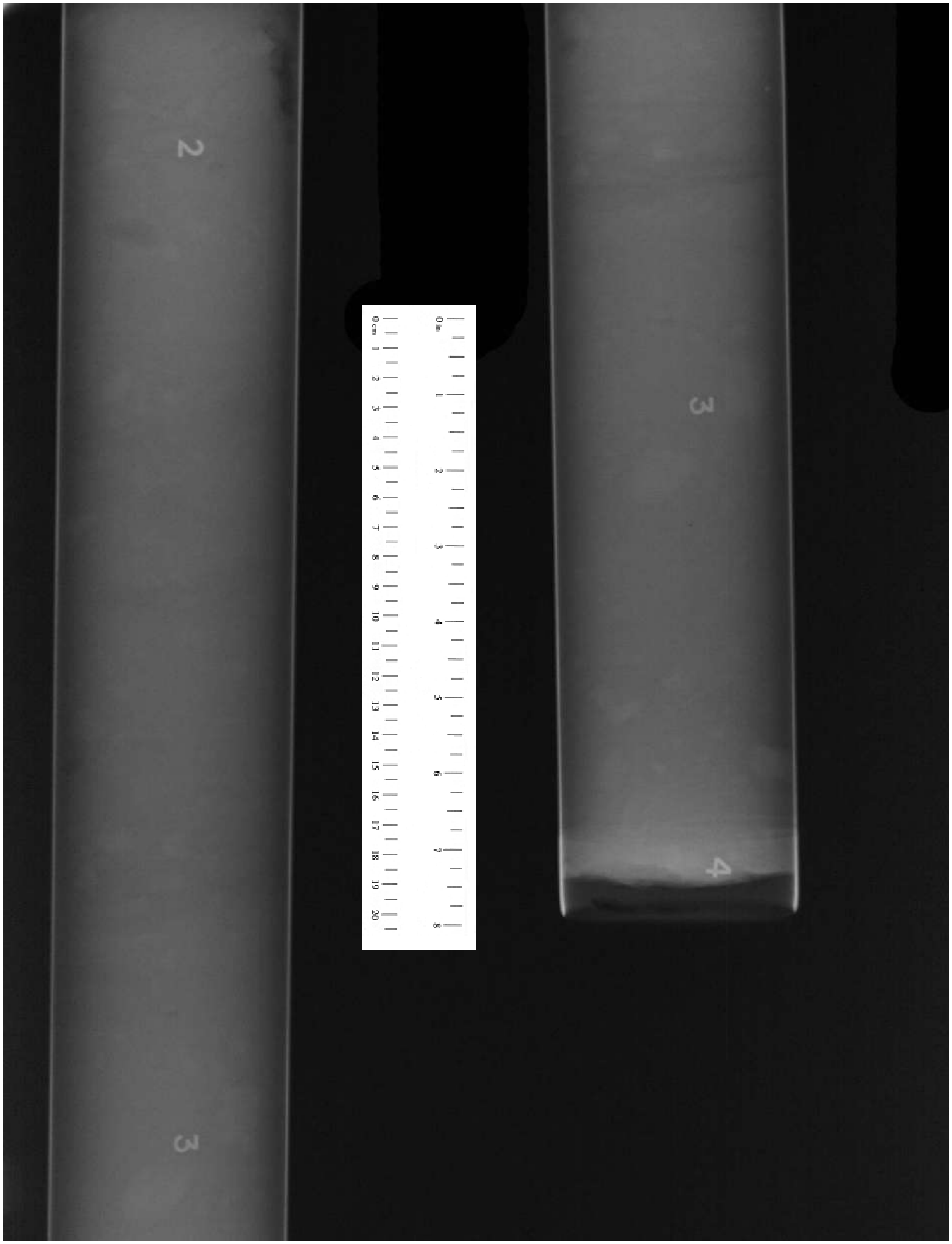
X-RAY RADIOGRAPHY IMAGES
BORING B-191, SAMPLE S-36, DEPTH 112.2 – 114.2 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-71b



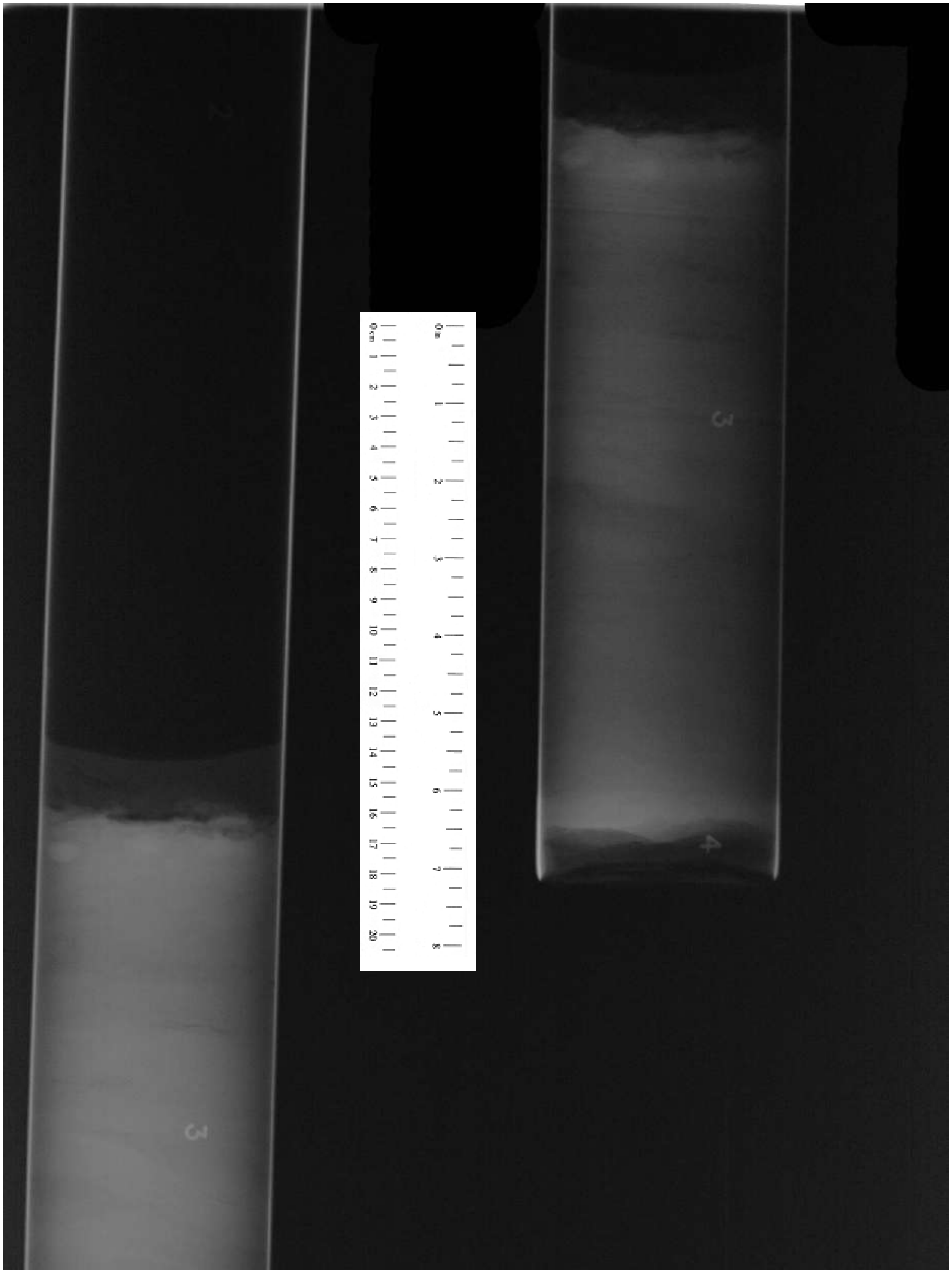
X-RAY RADIOGRAPHY IMAGES
BORING B-192, SAMPLE S-24, DEPTH 91.0 – 92.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-72a



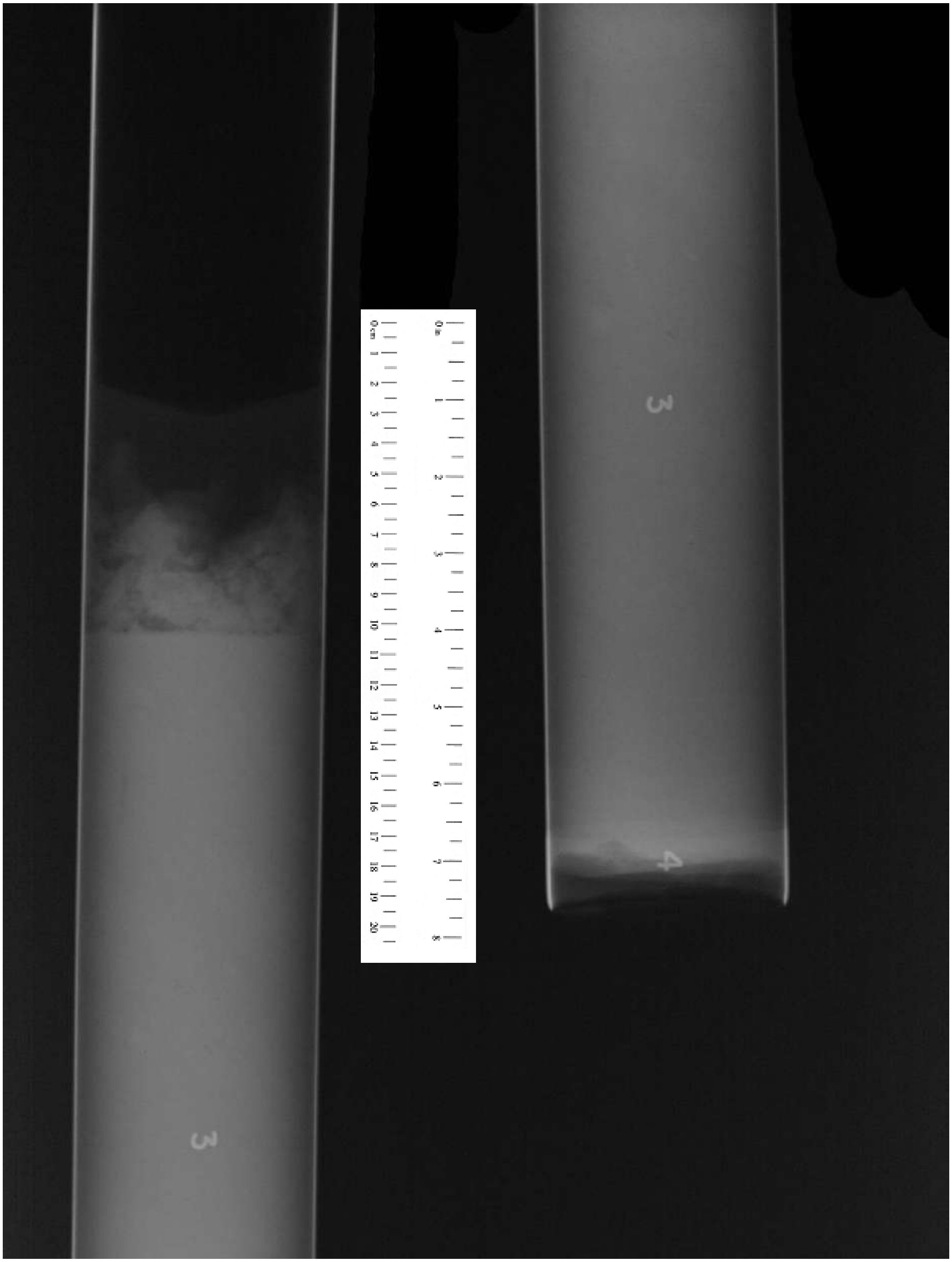
X-RAY RADIOGRAPHY IMAGES
BORING B-192, SAMPLE S-24, DEPTH 91.0 – 92.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-72b



X-RAY RADIOGRAPHY IMAGES
BORING B-192, SAMPLE S-27, DEPTH 105.0 – 105.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-73



X-RAY RADIOGRAPHY IMAGES
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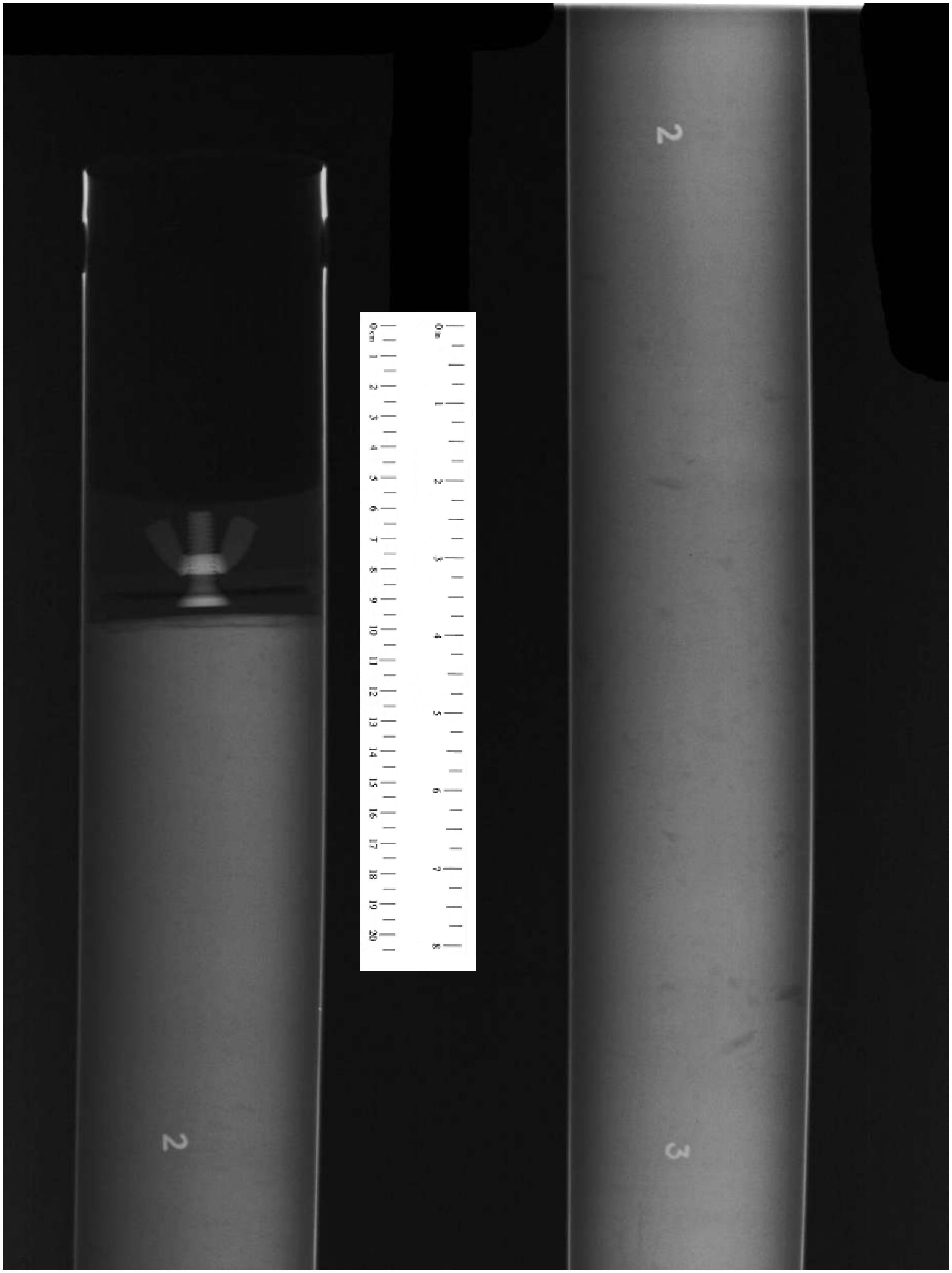
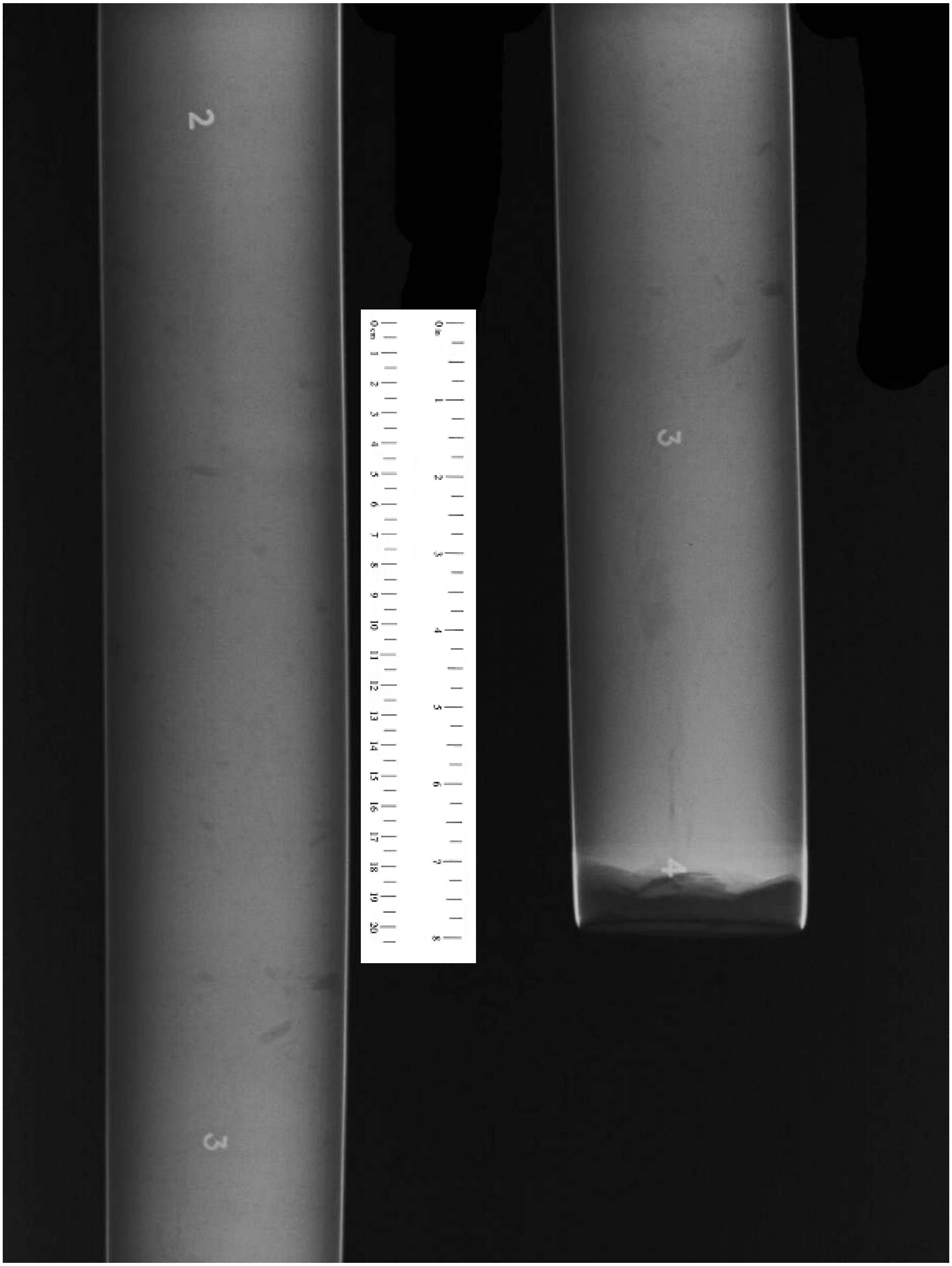
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



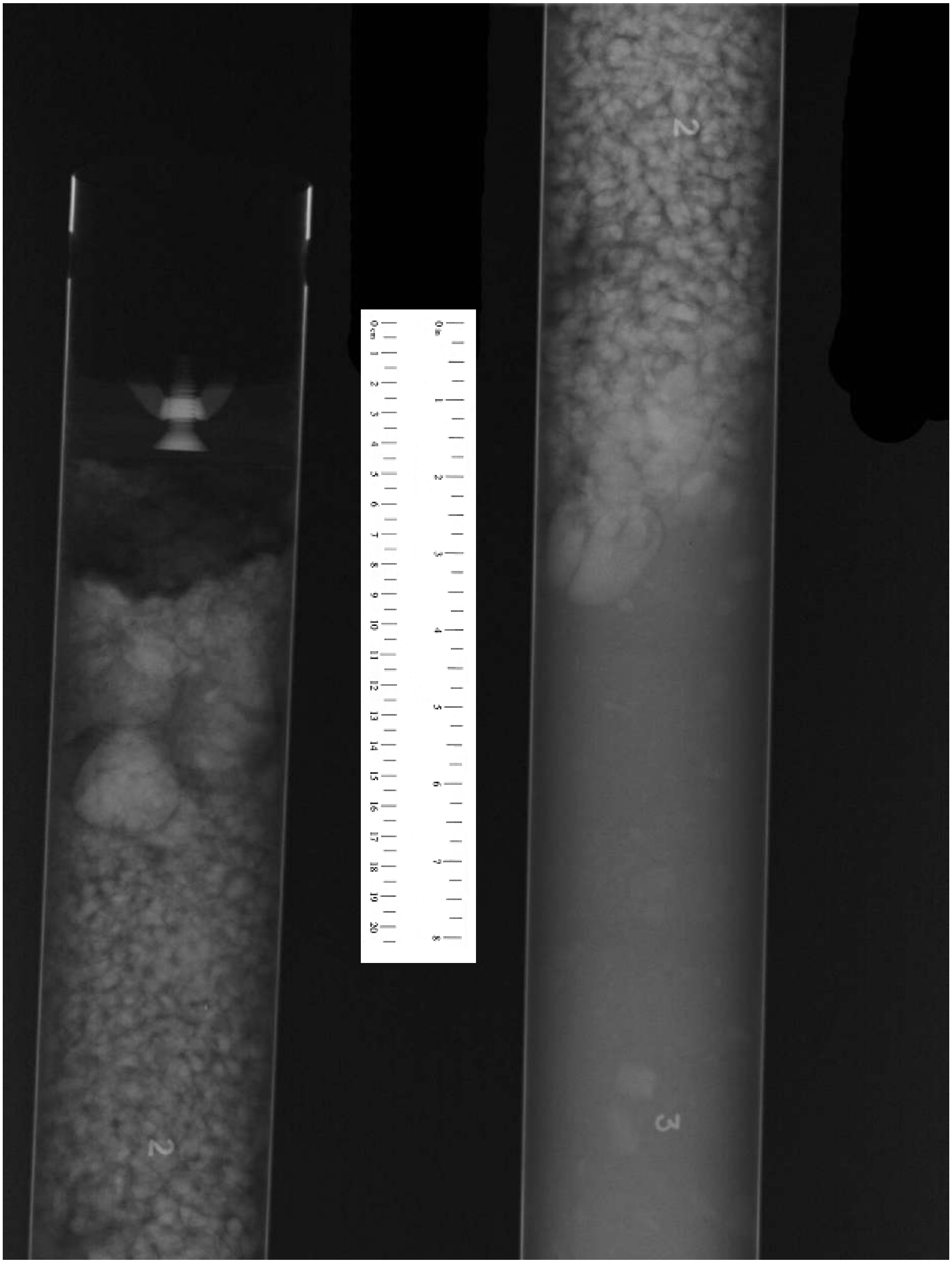
X-RAY RADIOGRAPHY IMAGES
BORING B-192, SAMPLE S-45, DEPTH 219.0 – 220.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-75a



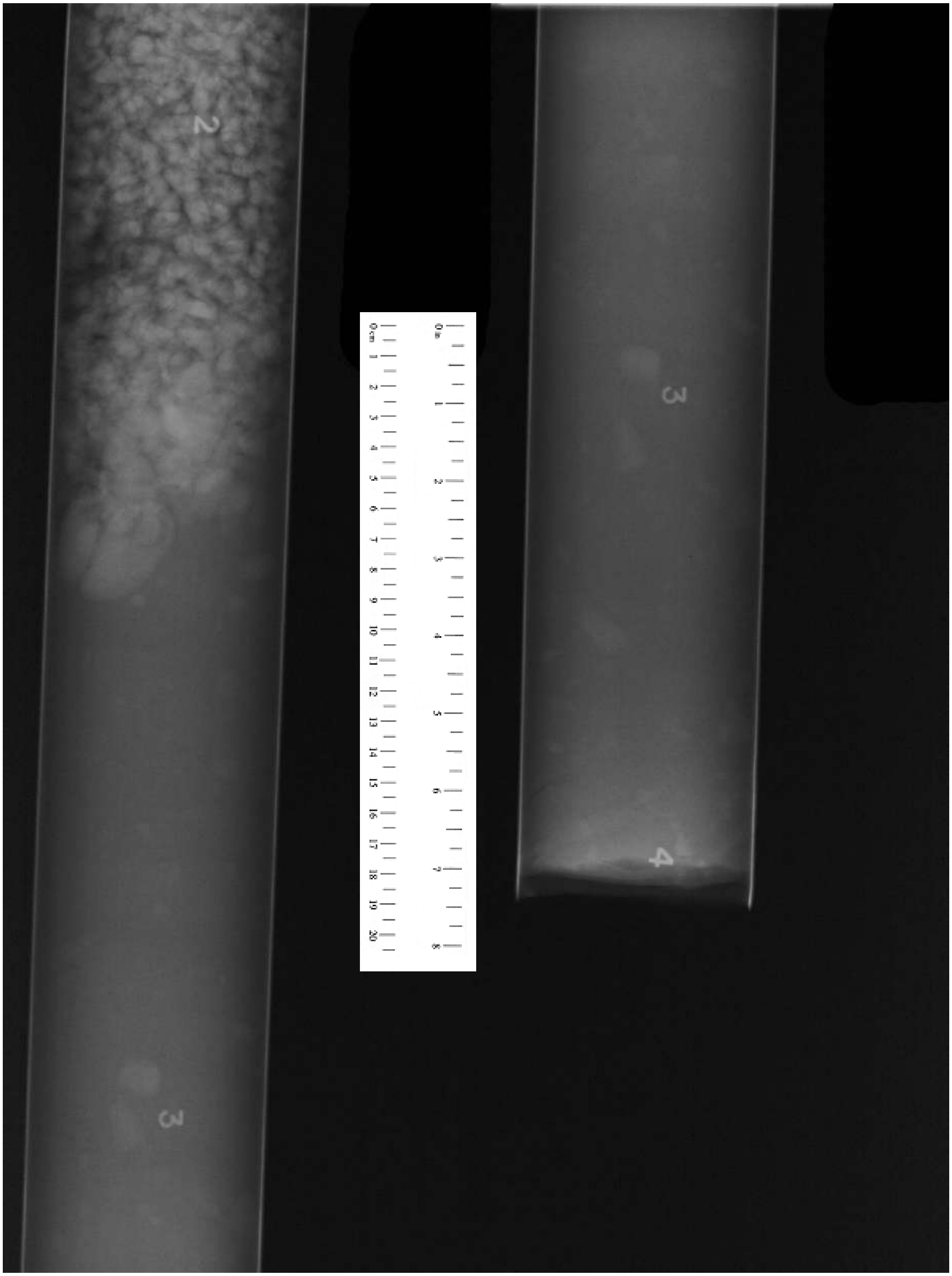
X-RAY RADIOGRAPHY IMAGES
BORING B-192, SAMPLE S-45, DEPTH 219.0 – 220.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-75b



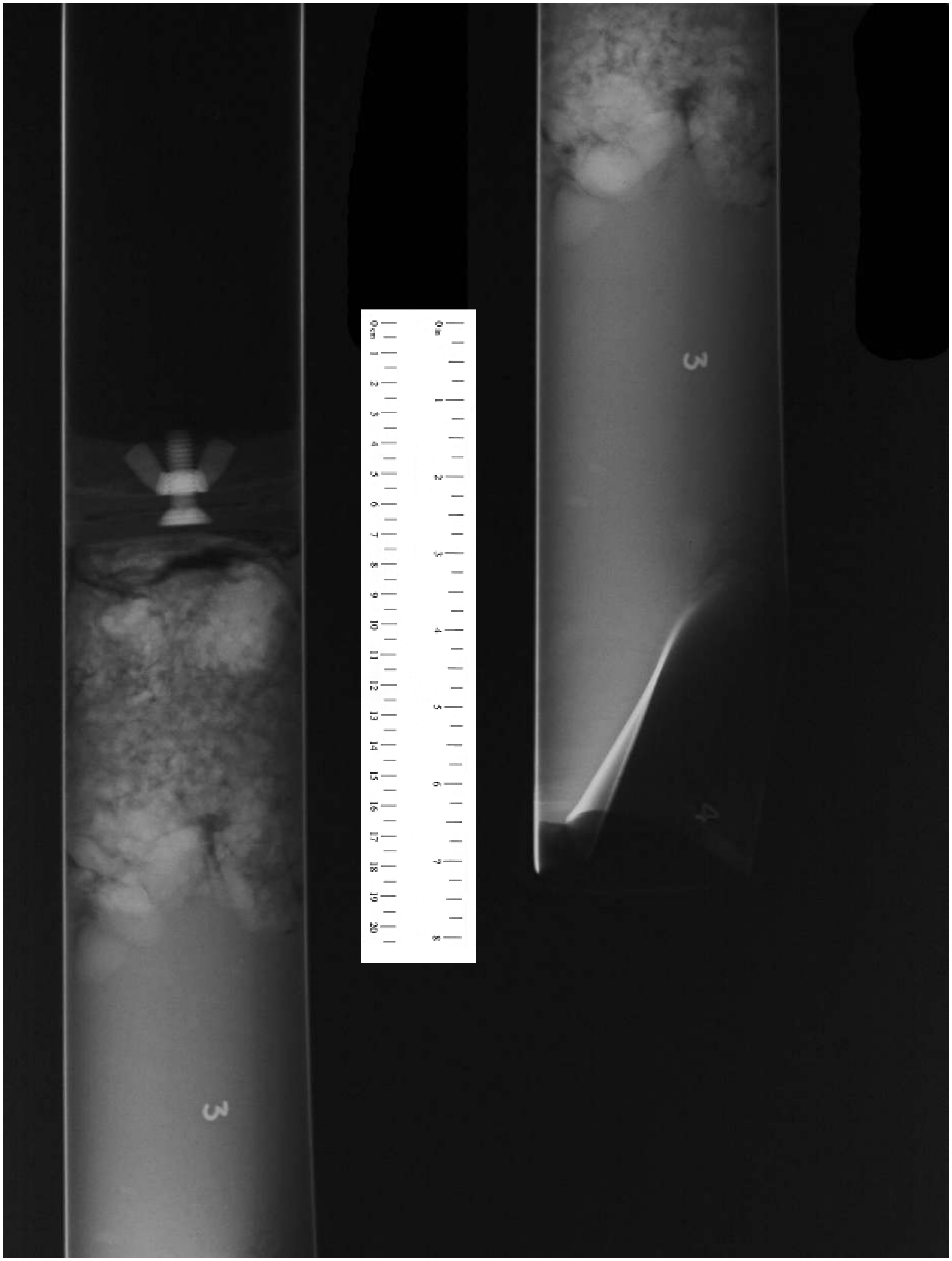
X-RAY RADIOGRAPHY IMAGES
BORING B-195, SAMPLE S-34, DEPTH 150.5 – 152.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-76a



X-RAY RADIOGRAPHY IMAGES
BORING B-195, SAMPLE S-34, DEPTH 150.5 – 152.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-76b



X-RAY RADIOGRAPHY IMAGES
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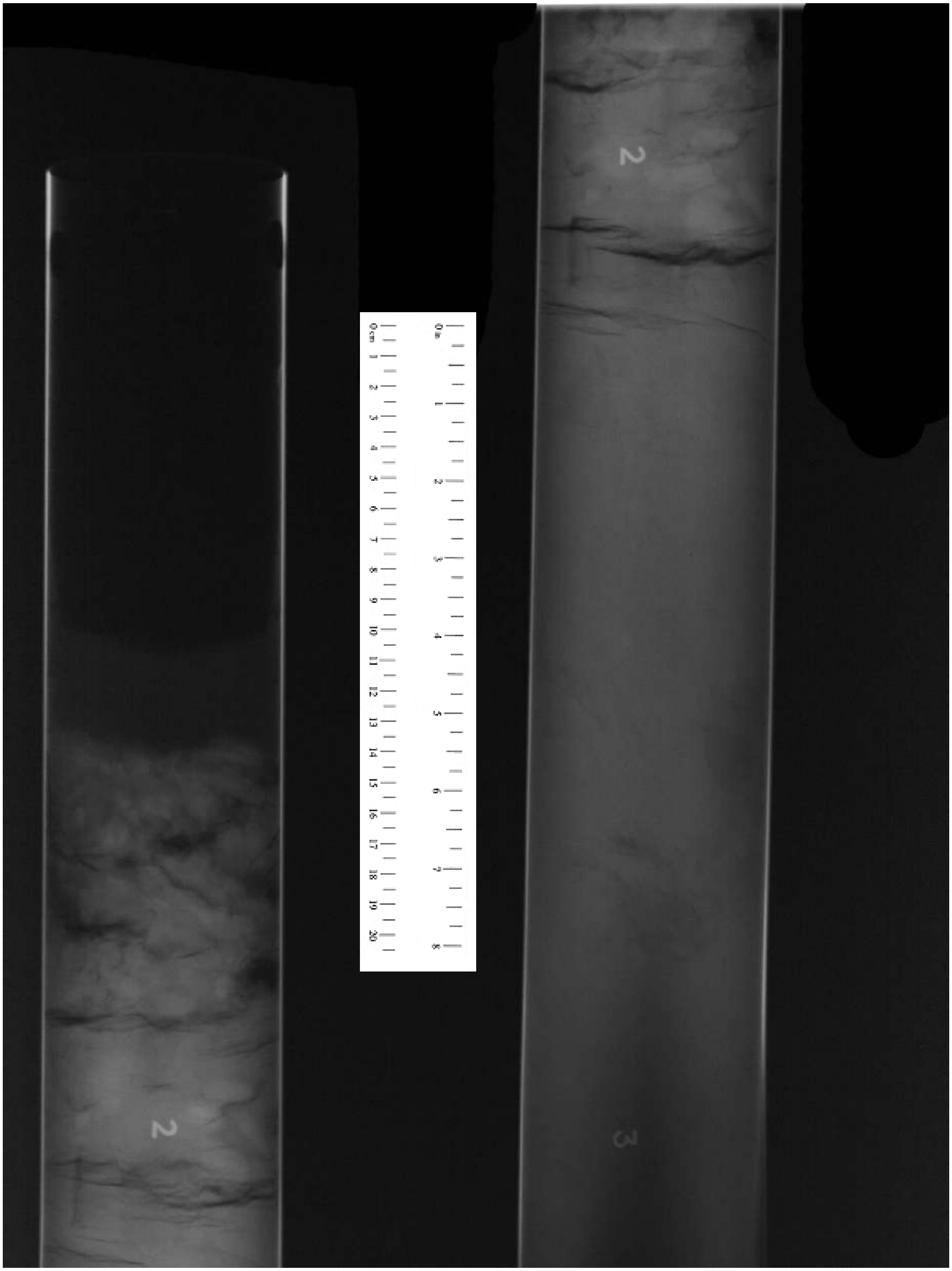
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-77



X-RAY RADIOGRAPHY IMAGES
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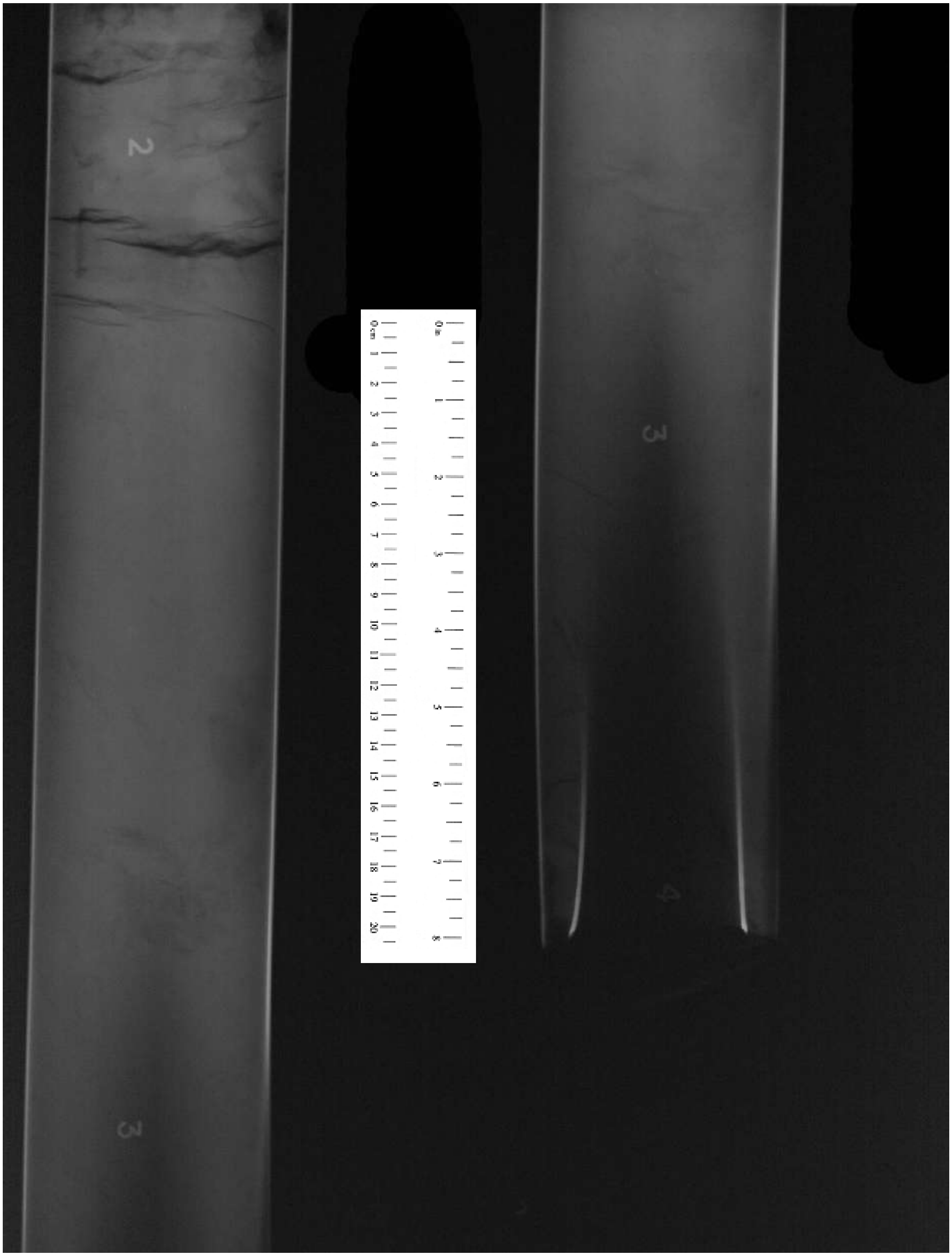
ALASKA LNG PROJECT
NIKISKI, ALASKA



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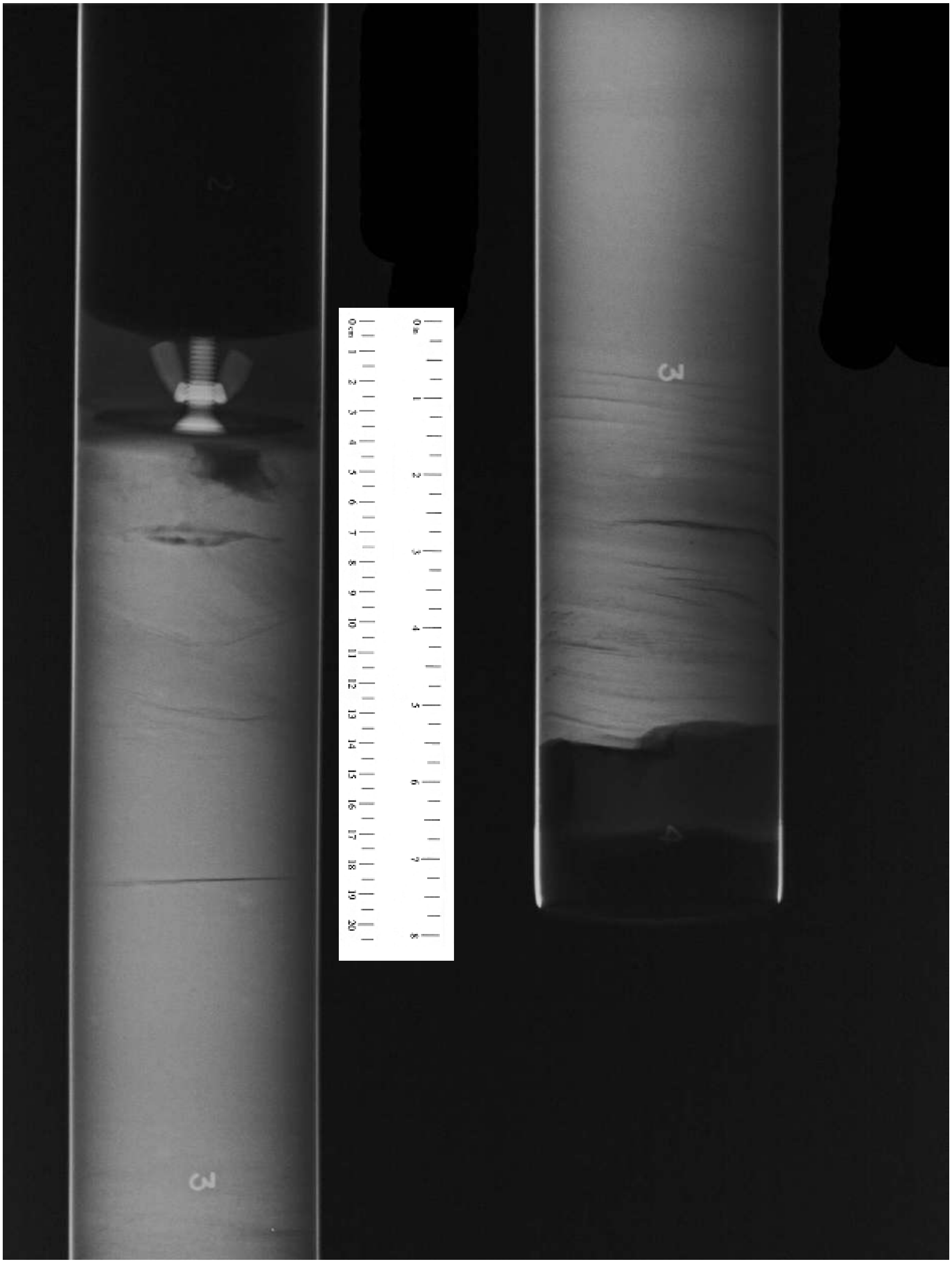
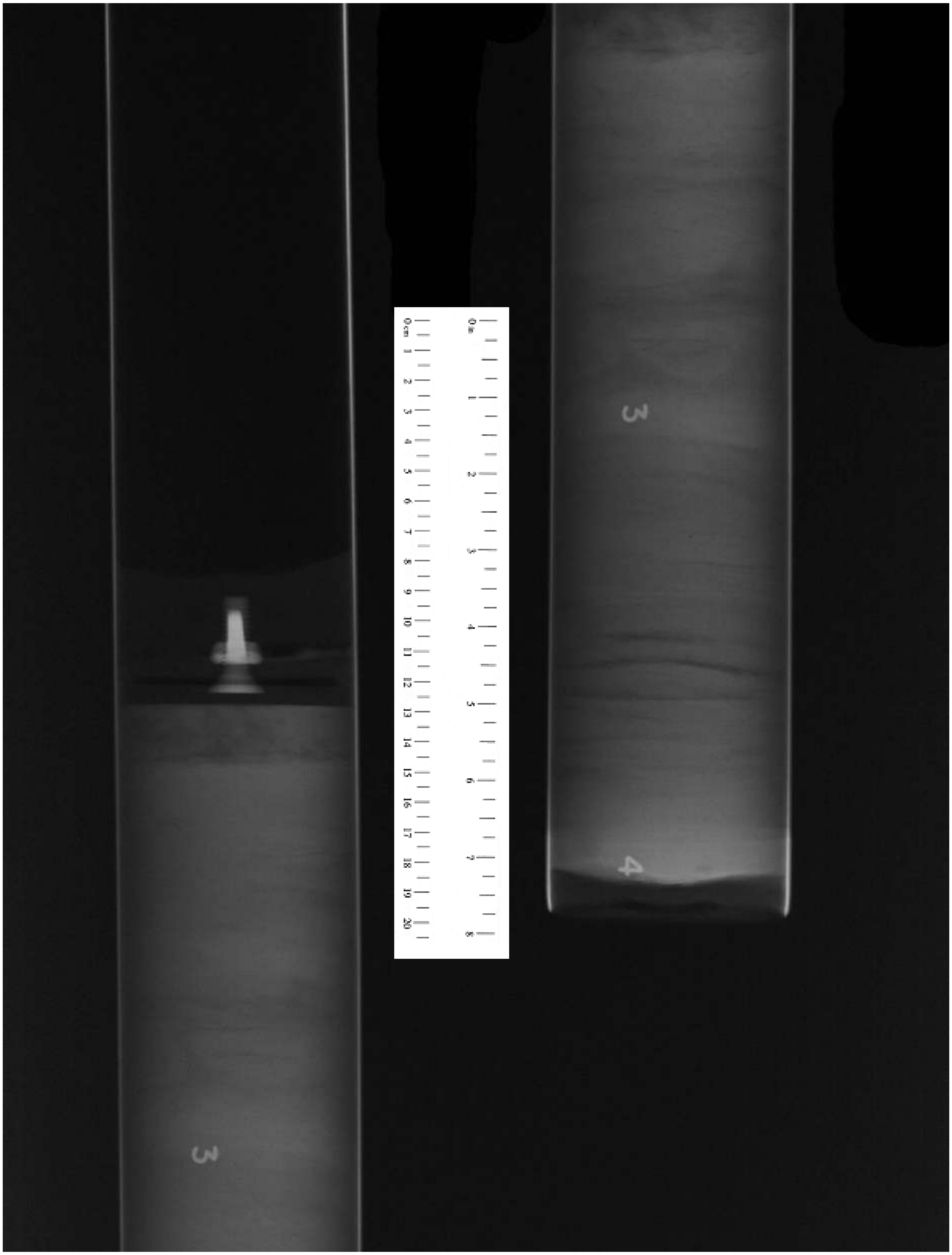
BORING B-195, SAMPLE S-44, DEPTH 200.5 – 202.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-78b



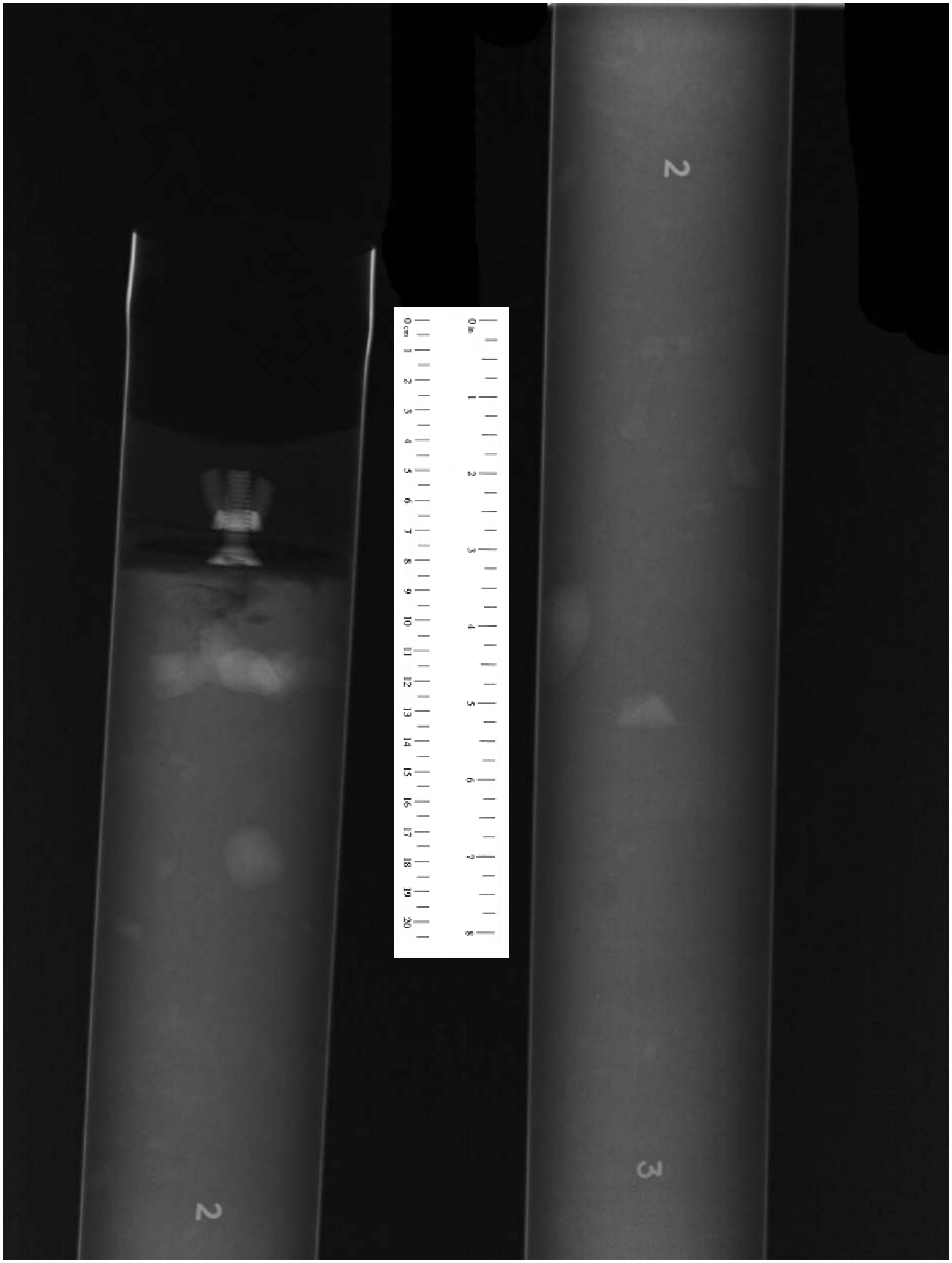
X-RAY RADIOGRAPHY IMAGES
BORING B-197, SAMPLE S-27, DEPTH 104.5 – 105.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-79



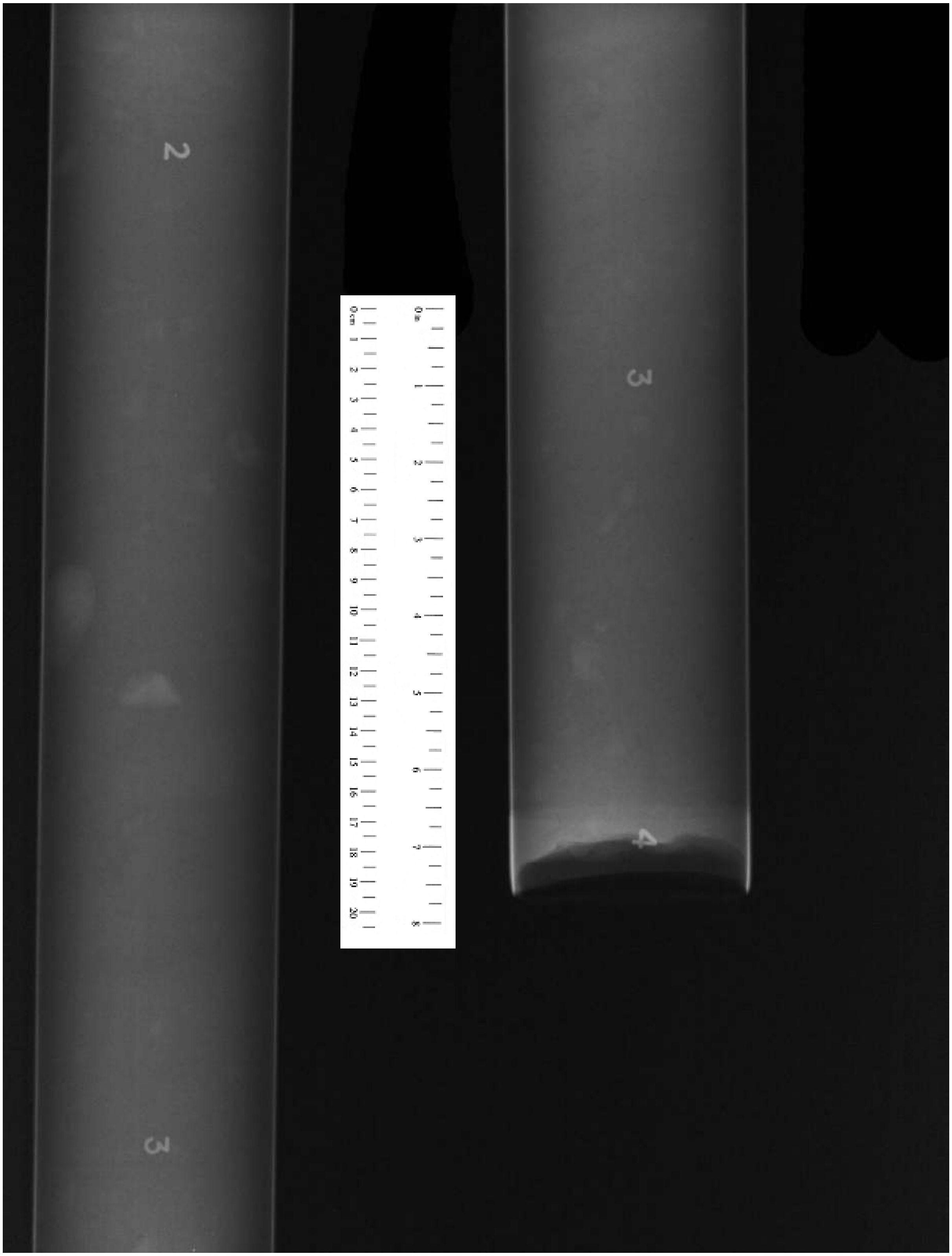
X-RAY RADIOGRAPHY IMAGES
BORING B-197, SAMPLE S-28, DEPTH 109.0 – 109.8 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-80



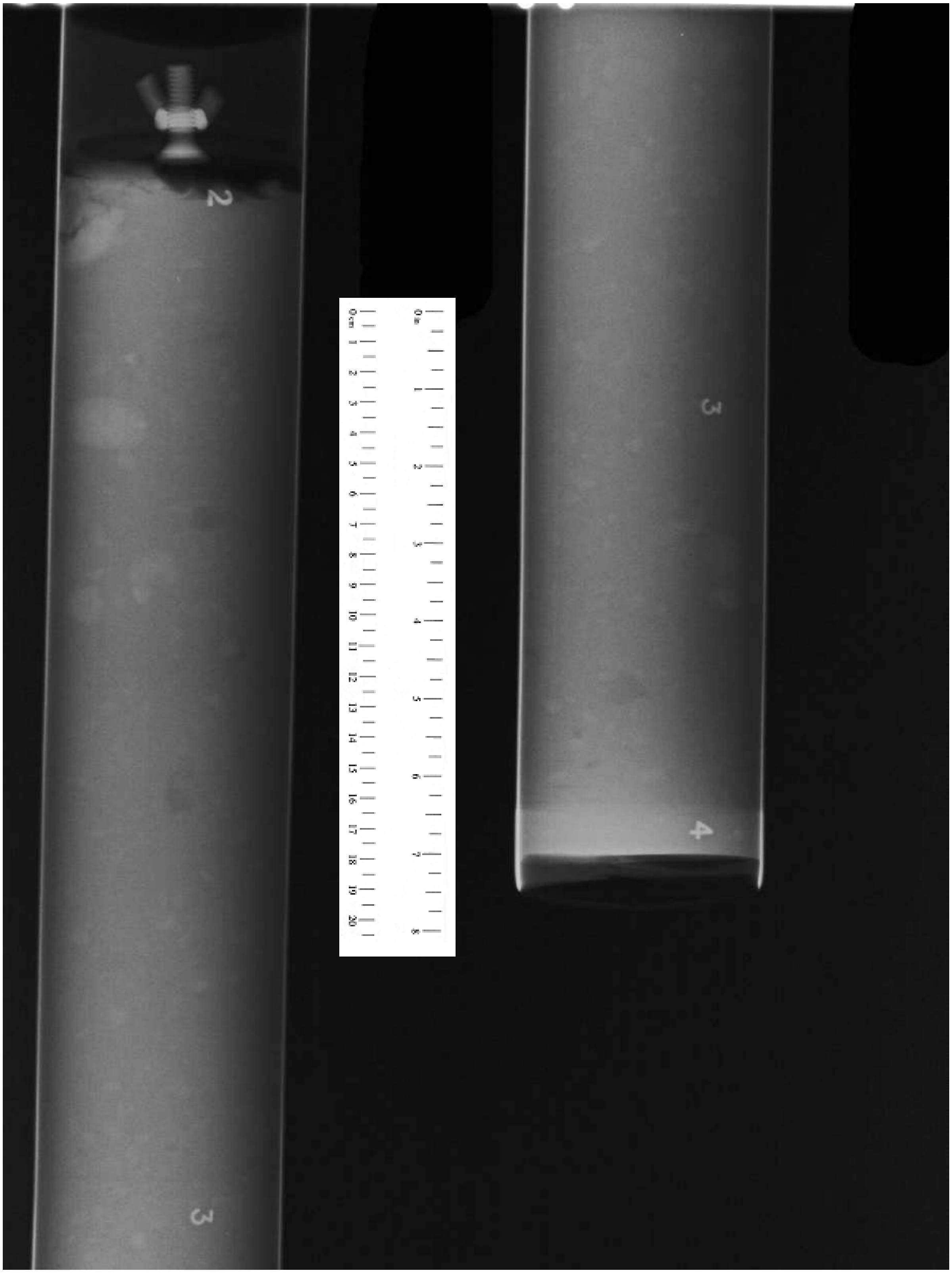
X-RAY RADIOGRAPHY IMAGES
BORING B-197, SAMPLE S-36, DEPTH 166.0 – 167.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-81a



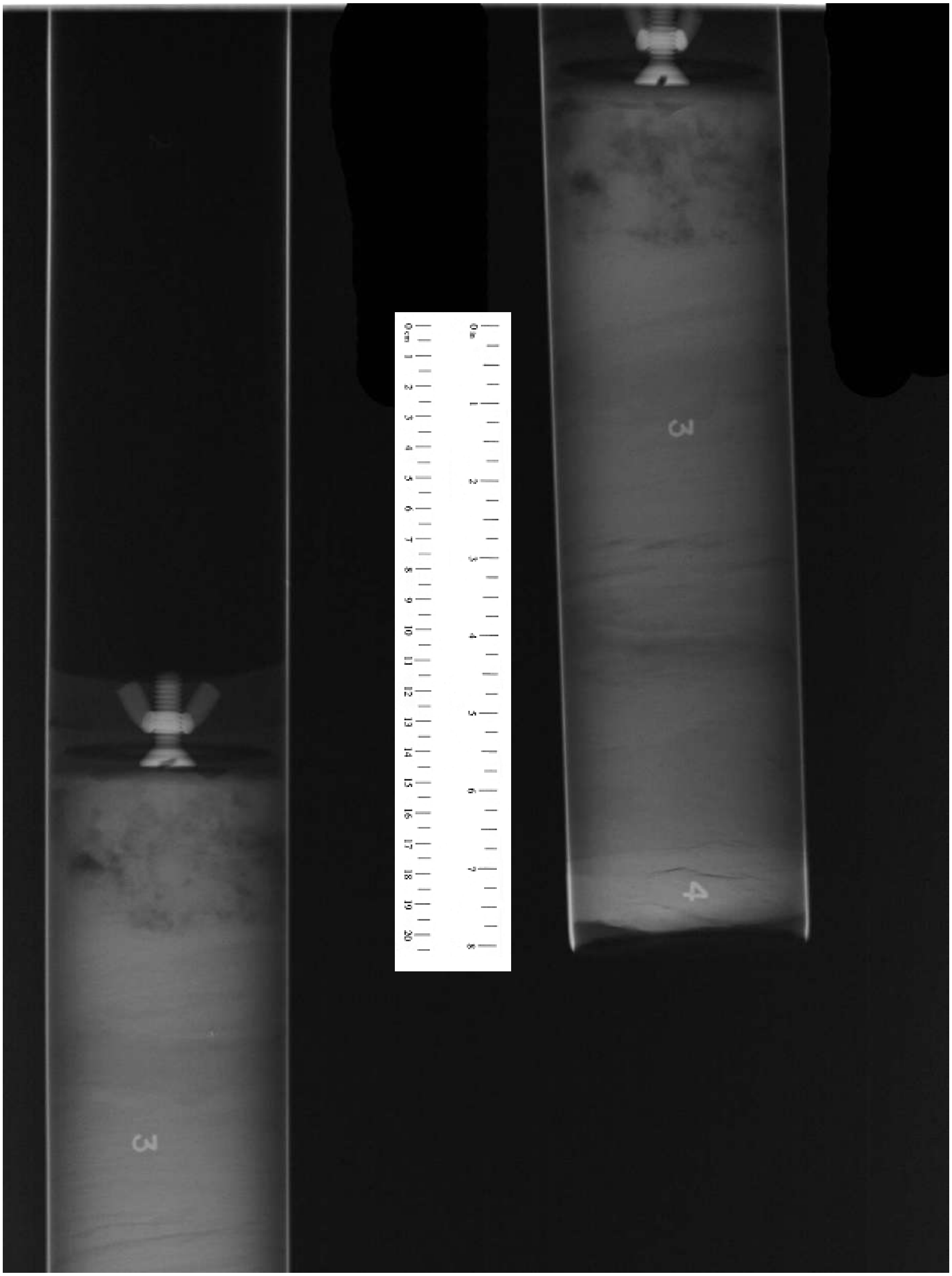
X-RAY RADIOGRAPHY IMAGES
BORING B-197, SAMPLE S-36, DEPTH 166.0 – 167.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-81b



X-RAY RADIOGRAPHY IMAGES
BORING B-197, SAMPLE S-38, DEPTH 176.0 – 177.6 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

X-RAY RADIOGRAPHY IMAGES
BORING B-197, SAMPLE S-40, DEPTH 184.0 – 185.7 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
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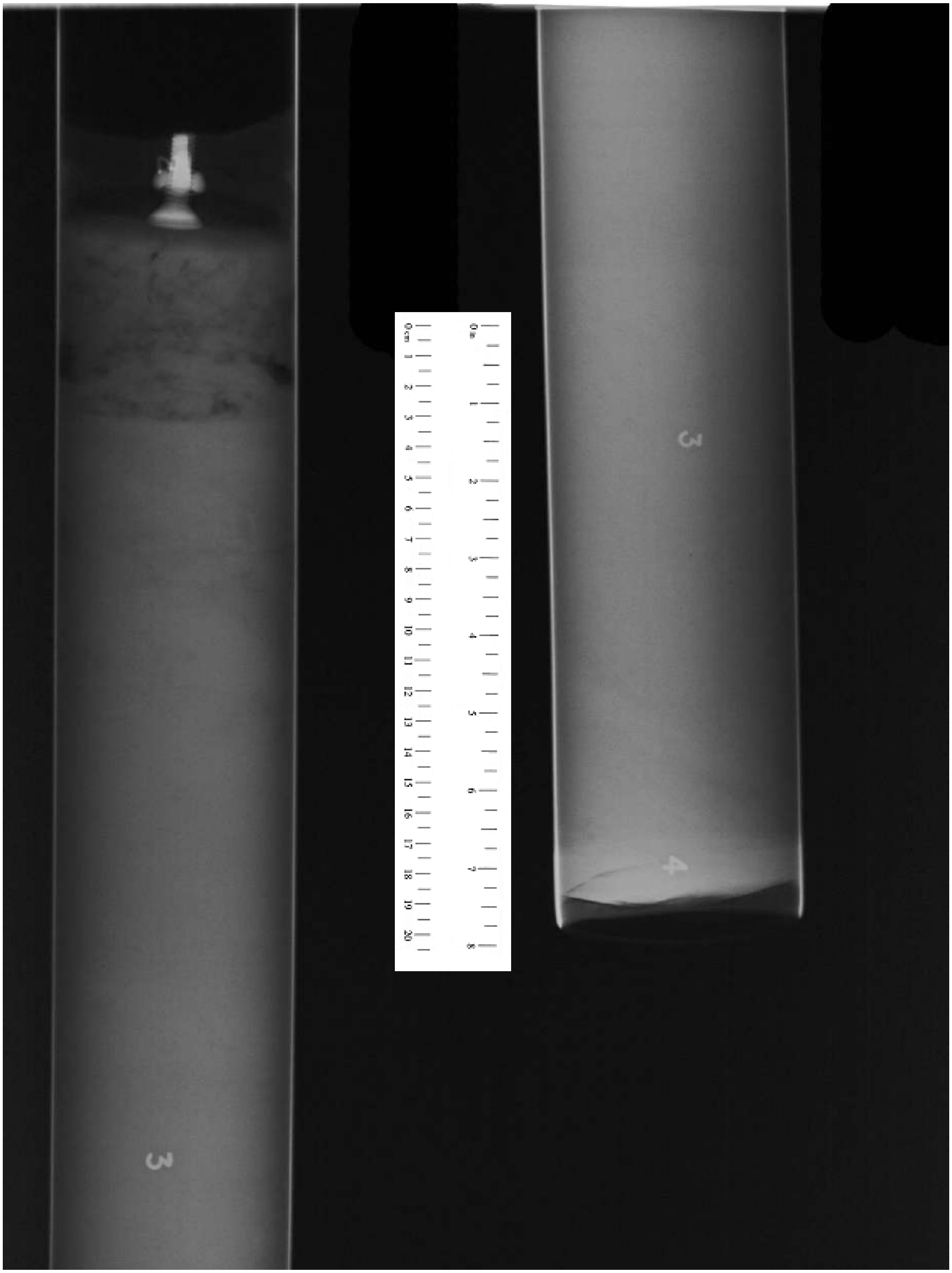
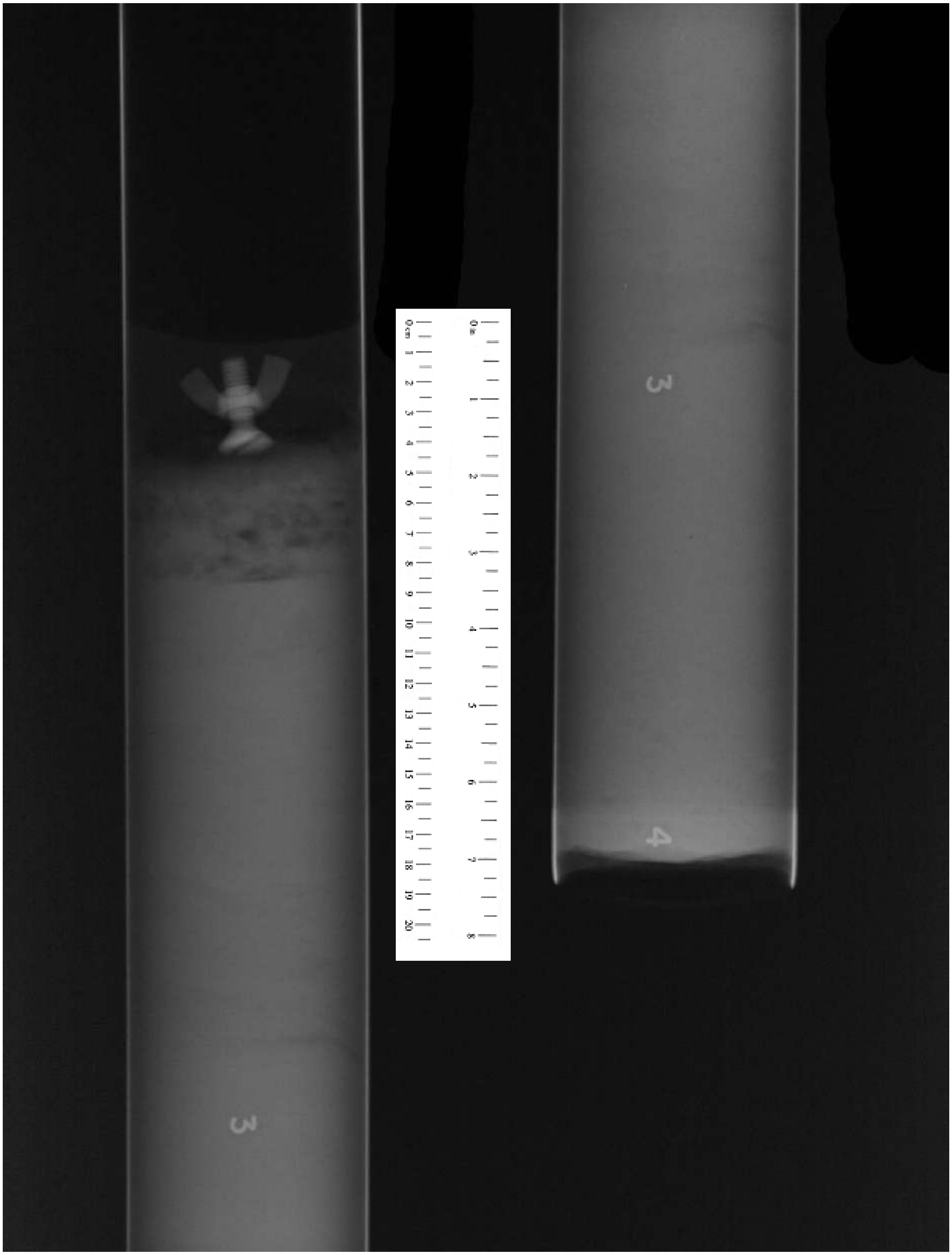
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
BORING B-197, SAMPLE S-45, DEPTH 209.0 – 210.1 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-85



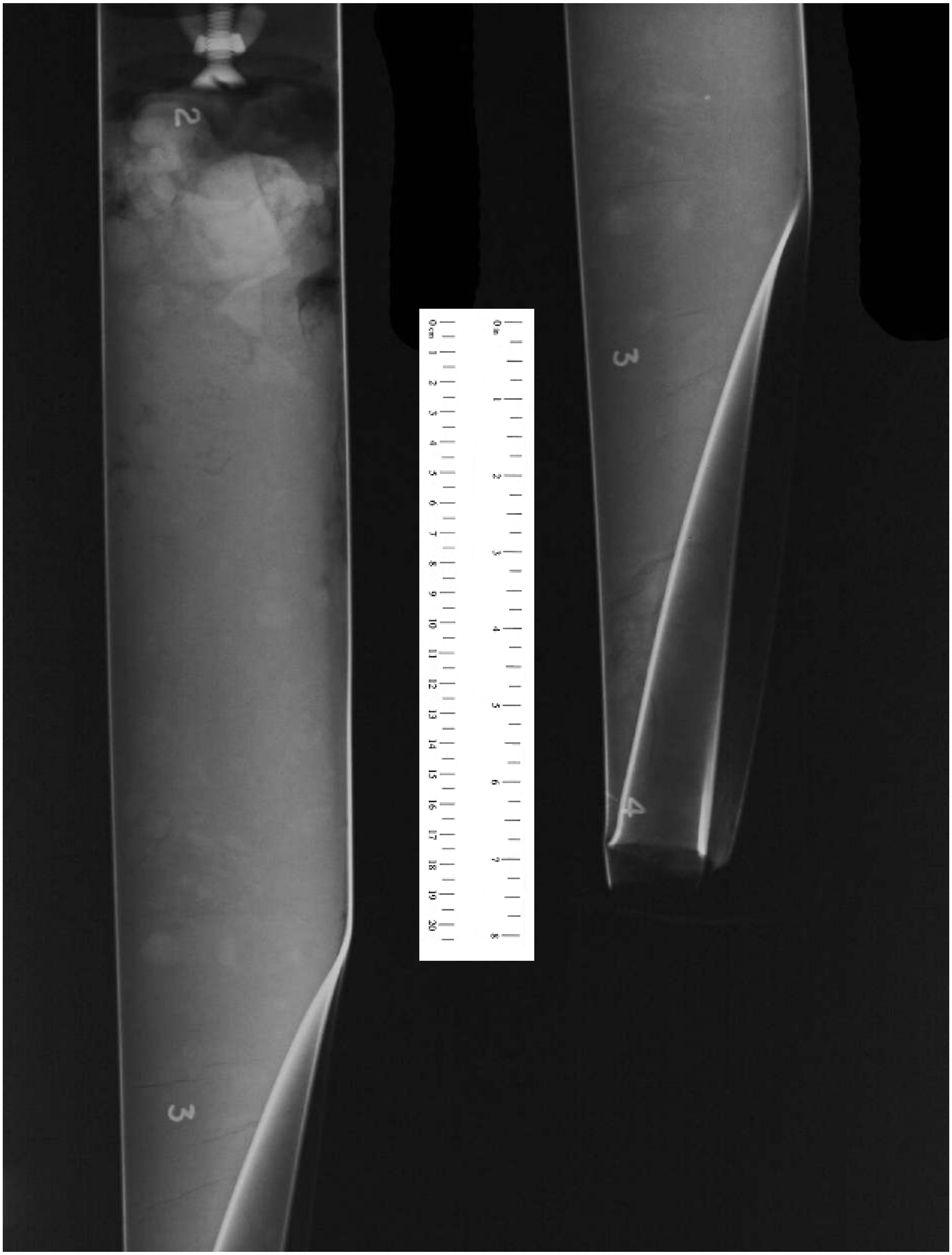
X-RAY RADIOGRAPHY IMAGES
BORING B-197, SAMPLE S-47, DEPTH 219.0 – 220.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE G10-86

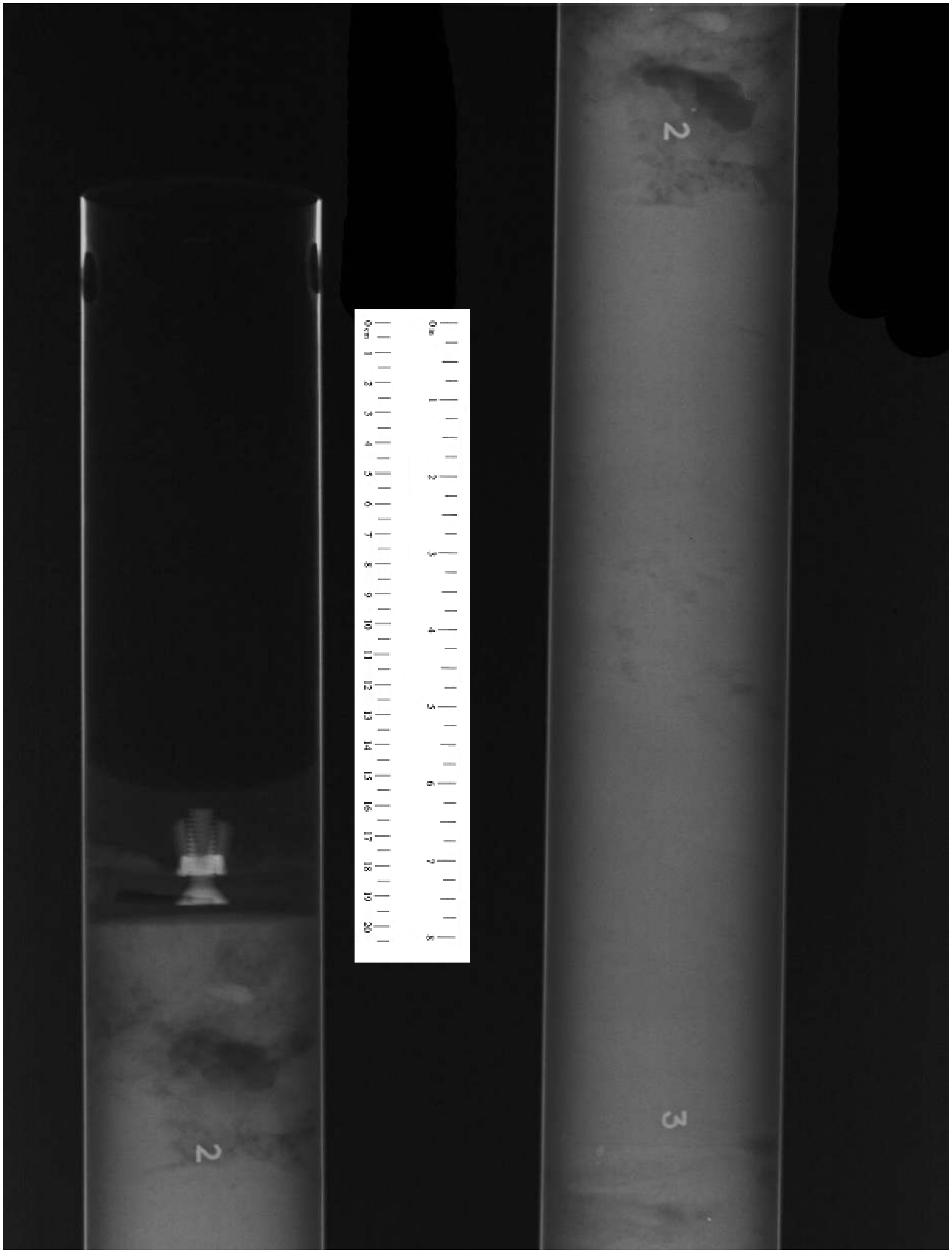
X-RAY RADIOGRAPHY IMAGES
BORING B-197, SAMPLE S-49, DEPTH 229.0 – 230.0 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

X-RAY RADIOGRAPHY IMAGES
BORING B-198, SAMPLE S-32, DEPTH 150.5 – 152.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

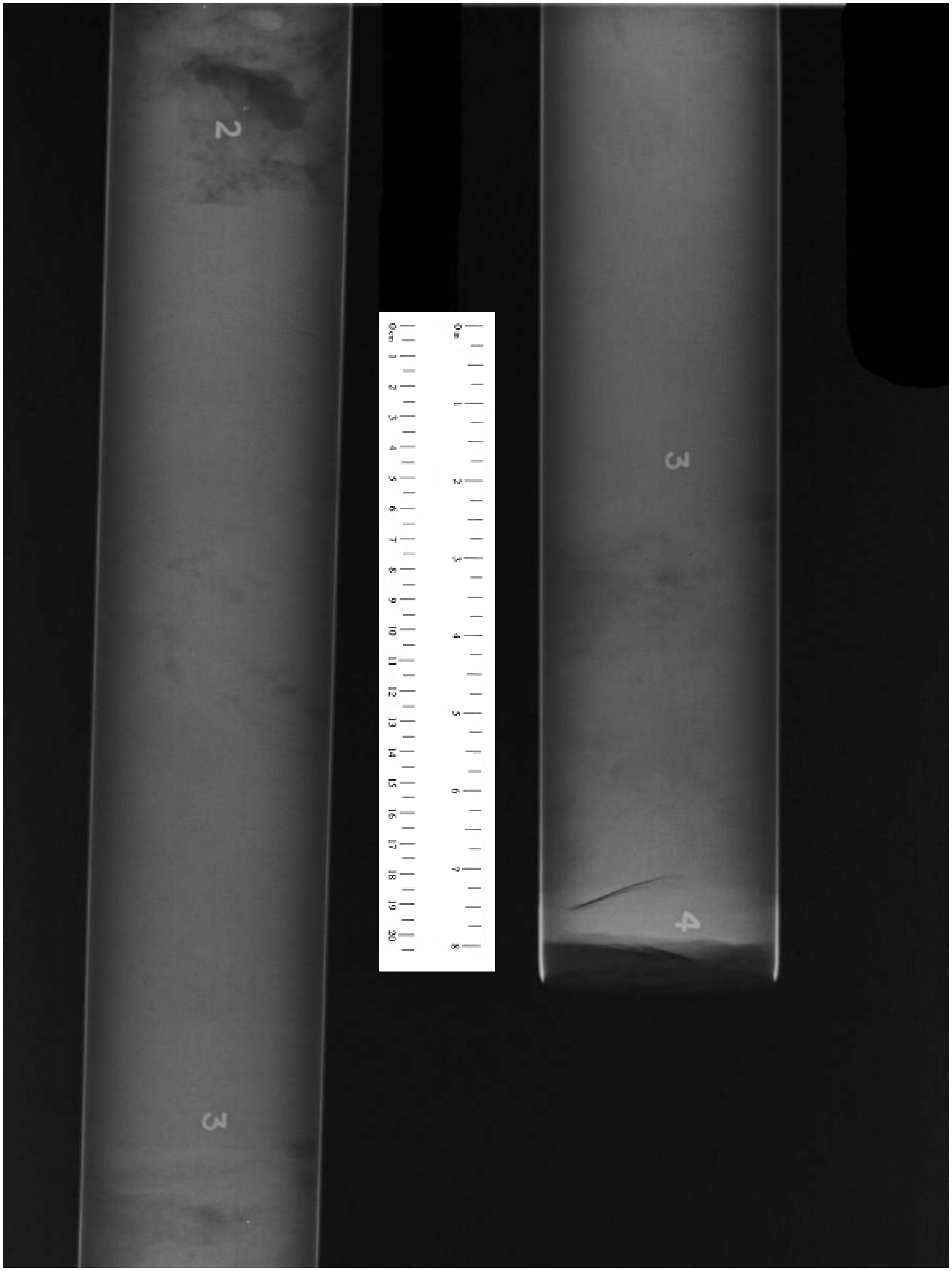
PLATE G10-88



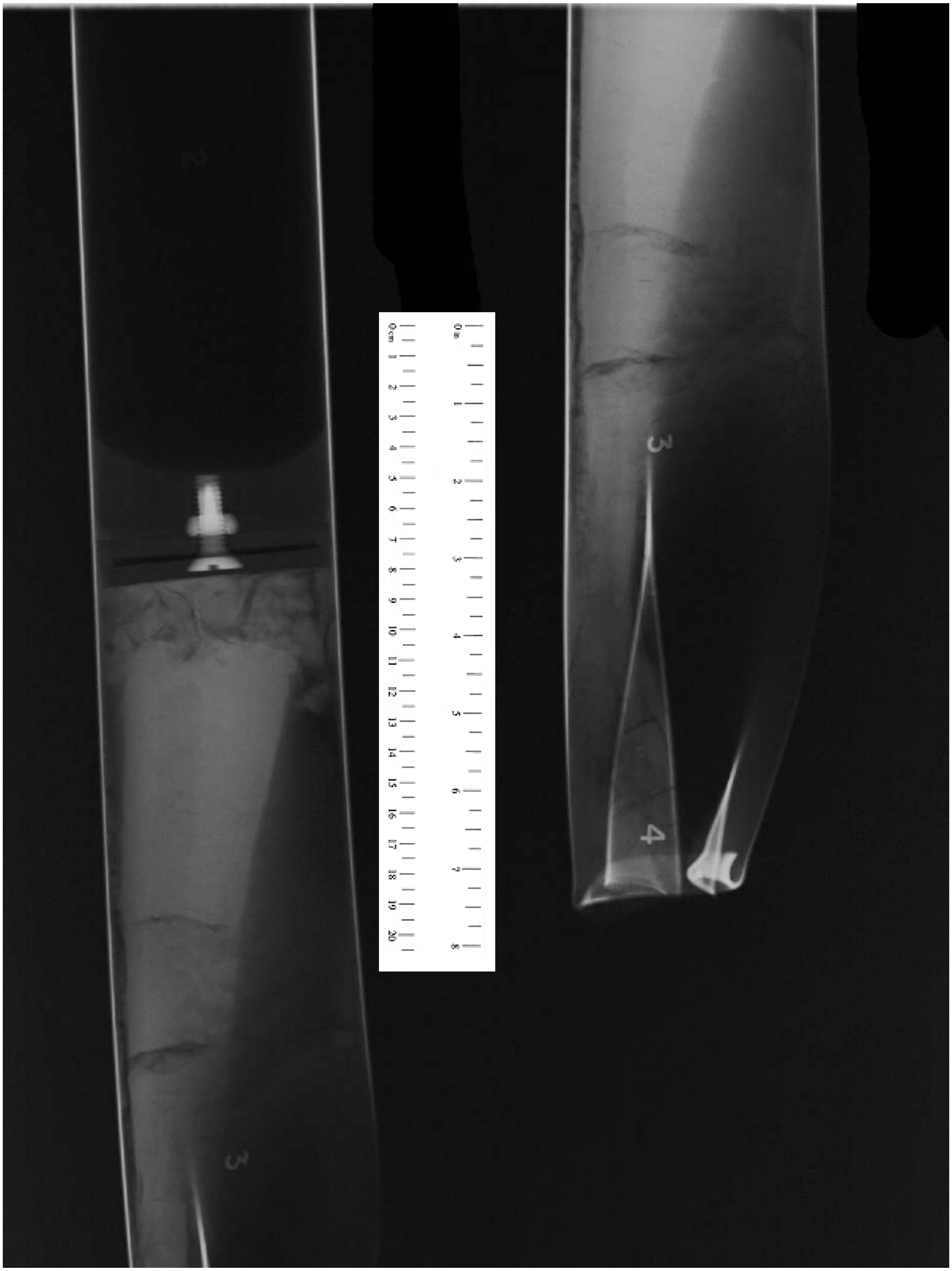
X-RAY RADIOGRAPHY IMAGES
BORING B-198, SAMPLE S-35, DEPTH 169.0 – 170.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



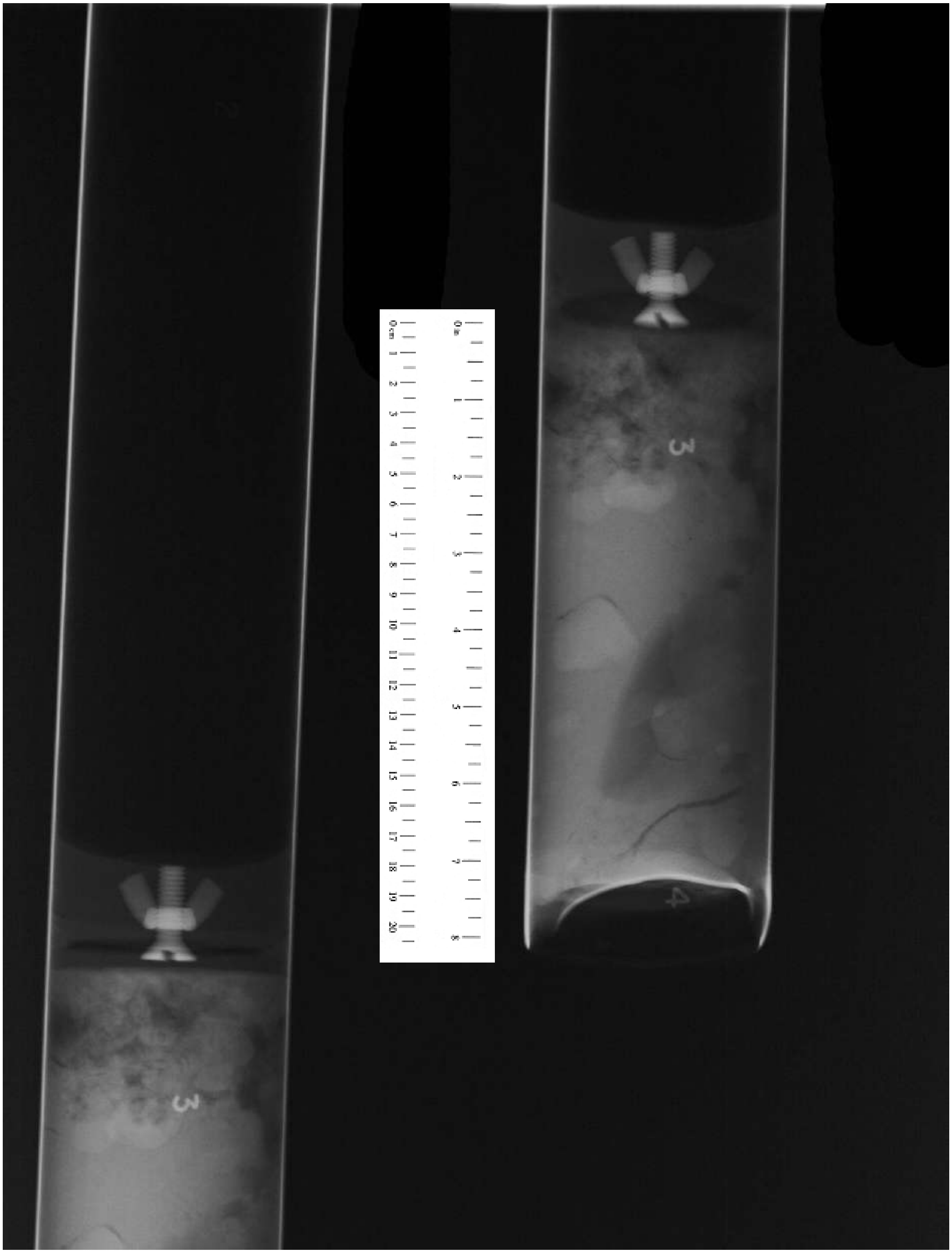
X-RAY RADIOGRAPHY IMAGES
BORING B-198, SAMPLE S-41, DEPTH 204.0 – 205.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
BORING B-198, SAMPLE S-41, DEPTH 204.0 – 205.5 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



X-RAY RADIOGRAPHY IMAGES
BORING B-198, SAMPLE S-44, DEPTH 219.0 – 219.9 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



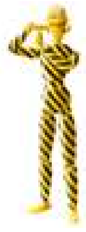
X-RAY RADIOGRAPHY IMAGES
BORING B-198, SAMPLE S-54, DEPTH 264.0 – 264.4 FT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

APPENDIX H

Method Statements

Table.H. Summary of Method Statements and Procedures

Category	MS No.	Task
General	OS-GN-MS-001	Utility Terrain Vehicle Operations
	H10-HS-R74	Waste Management
Vegetation Clearing	OS-VC-MS-001	Vegetation Clearing
Onshore Geotechnical Investigation	OS-GT-MS-001	Geotechnical Drilling
	OS-GT-MS-003	Soil Field Screening
	OS-GT-MS-004	Artesian Borehole Abandonment Procedure
	OS-GT-BRIDGE-001	Intertidal HSSE Bridging Document
Onshore Geophysical Surveys	OS-GP-MS-002	Downhole Seismic Test
	OS-GP-MS-003	Geophysical Utility Survey
	OS-GP-MS-004	Vertical Electrical Sounding Test

# METHOD STATEMENT	No: OS_GN_MS_001 Rev 1	
Utility Terrain Vehicle Operations		

CONTENTS

Developed by:	Reviewed/authorized for issue by:
Bob Mosher	Rachel Keesee 5-11-16

A METHOD STATEMENT IS ONLY EFFECTIVE IF IT IS DISCUSSED AND AGREED BEFORE WORK BEGINS AND THEN FOLLOWED BY THOSE CARRYING OUT THE WORK.

24-Hour Emergency Safety Number 1-888-333-4577 METHOD STATEMENT	No: OS_GN_MS_001 Rev 1	
Utility Terrain Vehicle Operations		

1. Introduction

This Method Statement relates to the safe operating procedures for Utility Terrain Vehicles (UTVs) used to transport personnel and material. UTVs may be electric or gas-powered type vehicles (Argo's, Polaris, Gators, Viking, etc.) used by Fugro or its subcontractor employees. In addition, supervisors and employees must review and follow the procedures described in operator's manuals supplied by the manufacture for each such UTV.

2. Main Activity / Area of Work

The activity area will be the AKLNG proposed project area in Nikiski within approximately 3-6 miles of Kenai Spur mile post 22.5.

UTV are not permitted on state roads, they may cross a state road at a 90 degree angle coming to a complete stop and before traveling across state roads, and proceeding when crossing traffic be done safely. Transportation of UTVs down state roads will be permitted by trailer only. Driving UTVs on borough roads will be evaluated on a case-by-case bases and shall be approved by the site manager in advance.

In the project area, a number of pre-established utility vehicle paths run parallel to main roads and most borehole locations will have cleared mulched paths for safe access.

3. Manpower and Supervision

The table below lists the manpower involved in the G & G field works operation and their responsibility.

Nominated Person	Responsibility
Trainers	• Possess the knowledge, training, and experience necessary to train operators and evaluate competence. • Train UTV operators and evaluate their competence. • Attend a train-the-trainer course, if required. • Document training of UTV operators.

Site Manager	• Overall responsibility for all site activities • Advise team leaders on project requirements and requirement to comply with method statement in order to enable the work to be carried out safely. • Ensure personnel and equipment are fit for task. • Designate qualified employees for training • Revoke or suspend crew operating privileges in the event of reckless behaviour (failure to comply with this document or the associated TRA). • Ensure that regular maintenance and inspections are performed on UTV. • Ensure that appropriate training / evaluation for UTV drivers is documented and recorded. • Ensure use of required personal protective equipment and safety controls. • Enforce safe operation of UTVs.

Field HSSE Personnel	• Ensure method statements and risk assessments are in place for safe UTV operations • Ensure that required appropriate training / evaluation is provided and documented prior to crew member use of UTV • Ensure that competent person(s) are identified who can provide training / evaluation for project UTV drivers. • Ensure that required training is provided and training records are maintained • Revoke or suspend crew operating privileges in the event of reckless behaviour (failure to comply with this document or the associated TRA). •
Employees Performing Task	• Complete required UTV training / evaluation prior to UTV operations. • Review operator manual prior to UTV use • Comply with this method statement and task risk assessments in addition to all Fugro Consultants (FCL) HSE requirements. • Complete inspections and ensure equipment and self are fit for task. • Follow guidelines on modification and attachments to UTVs as required

4. Associated Documents (Drawings, Manuals, Method Statements, Plans, Permits)

Document(s)	**Number(s)**
AKLNG PEP	04.10140334-1

Onshore Emergency Response Plan	04.10160001-1
Daily Inspection	UTV Daily Inspection Sheet
UTV Spare Parts List	Owner's Manual (specific to UTV)
UTV Maintenance Intervals	Owner's Manual (specific to UTV)

5. Task Risk Assessments

Task Risk Assessments (TRA) relevant to the task include:

Number	Name
ON-GN-TRA-001	Utility Terrain Vehicle Usage
ON-GN-TRA-331 /	Loading and Offloading Trailer
DO117 (Denali)	Trailer Loading and Unloading of Equipment

FUGRO 24-Hour Emergency Safety Number 1-888-333-4577 METHOD STATEMENT	No: OS_GN_MS_001 Rev 1
Utility Terrain Vehicle Operations	

6. Security - Barriers/Fences/Warning Signs

UTVs will be placed in a secure area when not in use. UTVs will not be left unattended running or with keys in unit.

7. Constraints/Restrictions/Special Conditions

Current operations are planned to take place 12 hours per day 7 days a week. Geotechnical and Geophysical schedule will be in such a way that planned operation will be during day light hours only or will require that a management of change be implemented.

UTVs are to be used for authorized work activities only.

8. Plant and Equipment

UTVs present unique hazards in the work area that must be addressed. These hazards include, but are not limited to:

- Rolling over on steep slopes or dangerous terrain
- Injury to pedestrians from UTVs or from loads falling off of UTVs
- Trapping hands or arms between roll over protection and a solid object
- Collision with another UTV, ATV, motorcycle or Vehicle
- Injury to driver or passengers from falling from the UTV
- Injury to the eyes from dust, insects, and debris falling from overhead while the UTV is in motion
- Noise

9. Safe Operations

General procedures for safe operations of UTVs are as follows:

- All UTV operators must complete UTV safety training / evaluation prior to operating a UTV. Supervisors must monitor all persons operating UTVs and ensure that such person have been instructed in the safe operation of UTVs, and are able to demonstrate the knowledge and ability to perform basic operations in a safe manner.
- A manufacture service plan / daily check and operational limitations review must be conducted as part of the training
- The speed limit for UTVs is 10 mph maximum or slower UTV operations shall have a buddy system in place to ensure no one it traveling alone.
- The UTV operator must immediately report any accidents to their supervisor, and report as per requirement in the PEP and other state or local agencies as required.
- Operators are to use extreme caution at all times. Stunt driving and horse play is prohibited.
- Operators are prohibited from operating UTVs on roadways outside of the boundaries of the jobsite and access to the job site.
- Operators are to stay on the mulched cleared paths going between sites to reduce the risk of injury and fire.

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Utility Terrain Vehicle Operations		

- Pedestrians have the right-of-way. UTVs must yield to pedestrians at all times. Speed is to be reduced to a minimum when crossing driveway access or known ATV trails to avoid accidents with other vehicles or pedestrians.
- UTVs are not to be overloaded, i.e., carrying more passengers than seating provided or overloading the vehicle's recommended cargo carrying or load capacity. Jumping off or on a UTV in motion, as well as clinging to a UTV in motion, is prohibited.
- Riding in the non-passenger cargo area of any UTV is prohibited.
- UTV operators are responsible for ignition keys for the period of time in which they are using the vehicle. Keys shall not be left in the vehicles.
- Operators must park UTVs away from heavily travelled pedestrian area or in designated parking areas. UTVs must not block access to fire extinguishers, standpipes, or emergency / fire exits. Do not park UTVs on utility vehicle routes or block building entrances.
- Operators transporting cargo must secure the load and position the load to prevent load shifting. Never load tailgates and avoid top-heavy loading.
- UTVs are to be maintained in accordance with the manufacturer's guidelines. The program is required to keep all preventative maintenance and repair records related to the UTV.
- UTV shall be equipment with a 3 BC fire extinguisher at a minimum
- UTVs shall have a functioning audible back up Alarm
- Operator shall possess a valid driver's license

10. Records

- Training Certification / Letter of qualification for onsite training
- Maintenance Records (as applicable)
- Daily Inspection Sheets
- Operator Training / Certification Records

11. Emergency Procedures

The Onshore Emergency procedure will be adhered to all times. Details of the emergency responses are incorporated in the PEP. A current list of Emergency contact numbers present on the UTV at all times.

12. Personal Protective Equipment (PPE) & Safety Equipment

The following personal protective equipment will be worn:

Hard Hat or Helmet	mandatory
Safety boots/shoes	mandatory
Safety glasses or goggles	mandatory
High visibility vest clothing or vest	mandatory
Appropriate hearing protection	mandatory – noise exceeds 85 dba at the ears

Gloves	as required per TRA

13. Photos

Anticipated types for AKLNG – Polaris Rangers 570 Crew proposed by ASRC

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Utility Terrain Vehicle Operations	

Anticipated types for AKLNG – Polaris Rangers 4 wheel and 6 wheel proposed by Denali – could not get current photos, they will not have wind shield or door, they do have seat belt and ROPS and winches

Similar to this with a winch on the front.

From Great Lands – Polaris Series 11, will have winch

14. Methodology & Sequence of Work

The planned activities for UTVs will be transiting to, from and between work site locations on identified access routes that are in alignment with the project. UTVs will be used for the following:

- Provide access between geophysical and geotechnical work sites
- Moving supplies that can be safely secured for transit
- Moving personnel between location or to welfare facilities

15. Appendices

1. **Pre-Drive Check List (guidance document)**
2. **Spare – Field Kit (guidance document)**
3. **UTV Task Risk Assessment**

DOCUMENTED PROCEDURE
HS-R74
WASTE MANAGEMENT

1.0 PURPOSE

The purpose of this documented procedure is to define the processes by which waste is managed by Fugro Consultants (FCL).

2.0 SCOPE

This documented procedure relates to the production, handling, storage, and disposal of waste generated by FCL. Wastes included in this procedure include:

- medical waste from performing First Aid
- paper
- cardboard, packaging, wood
- domestic waste
- toner cartridges and other office waste
- chemical waste
- Hazardous waste electrical equipment
    - Batteries (rechargeable, alkaline, and vehicle/equipment)
    - Lamps and Fluorescent Tubes
    - TV's, Monitors, and Computer Equipment
- Waste oils and fluids
- Mercury
- Metals

The above list is not exhaustive but covers the main types of waste produced, handled, stored, and disposed of by FCL.

3.0 RESPONSIBILITY

Waste management is a Line Manager responsibility, usually conducted with the assistance of the HSE department. It is the responsibility of employees to segregate and store waste in the appropriate containers at the designated areas.

4.0 PROCEDURES

4.1 WASTE PRODUCTION

Waste produced by routine activities should be minimized through re-use and recycle where practicable.

Waste produced from equipment should be minimized through efficient operation and maintenance in accordance with manufacturer's instructions.

4.2 WASTE HANDLING AND STORAGE

- Items classified as waste should be handled in accordance with applicable legislation.
- Chemical wastes should be handled per the applicable Material Safety Data Sheet (MSDS).
- All waste should be stored in a safe and secure manner pending collection by a licensed third party contractor for recovery, recycling, or disposal.
- Liquid wastes should be stored in containers appropriate for the properties of the waste.
- When hazardous waste is stored, the date of original accumulation should be indicated on the container. Waste should be disposed of at an interval not to exceed twelve calendar months from the date accumulation began.
- At locations where provisions have been made for the segregation of waste for recycling, the containers will be clearly and appropriately labeled.

4.3 WASTE COLLECTION AND DISPOSAL

- Waste collected by FCL should only be transported offsite by a registered waste company. A copy of the waste disposals license should be obtained.
- All waste transferred offsite should be accompanied by a waste manifest.

Rev. #	Date	DCR #	Approved By:	Description of Change:
0	8/2012	---		Initial Document Release
0	4/2014	--	Cm	“Revision 0” added to header for conformity to other procedures – no content change so no revision change.

METHOD STATEMENT	No: OS-VC-MS-001-r3
Vegetation Clearing	

CONTENTS

Developed by:	Reviewed/authorized for issue by:
David VanDehey	Bob Mosher / Rachel Keesee

A METHOD STATEMENT IS ONLY EFFECTIVE IF IT IS DISCUSSED AND AGREED BEFORE WORK BEGINS AND THEN FOLLOWED BY THOSE CARRYING OUT THE WORK.

METHOD STATEMENT	No: OS-VC-MS-001-r3
Vegetation Clearing	

1. Introduction

This Method Statement relates to the safe equipment recovery operation of mulching and mastication machines mounted on tracked carriers using a soft recovery strap between two pieces of equipment.

2. Main Activity / Area of Work

The Activity will be in the vicinity of Kenai spur mile post 22.5 on AKLNG parcel that required vegetation clearing for Geotechnical equipment access, lay down areas and drilling pads. The planned activity will take place in the summer of 2016.

3. Manpower and Supervision

Nominated Person	Responsibility
Supervisor	Review method statement and associated Task Risk Assessments (TRA) with employees performing the task. Regularly inspect activity for compliance. Ensure roles and responsibilities are clearly define Ensure equipment and personnel are fit for work Reinforce STOP work responsibilities Work with the site manager to ensure access and land availability is in place Conduct daily tool box Coach team in safety awareness program e.g. Hazard Observation Program
Operators	Daily equipment inspection Fuelling of equipment / daily maintenance requirements following TRA Ensure PPE is in place and proper working order Communication test and verification Participation in safety awareness program

Spotters	Ensure PPE is in place and in proper working order Communication test and verification Participate in safety awareness program Public awareness in activity area (point of contact, distribute AKLNG reference contact number as necessary) Ensure fit for work

4. Associated Documents (Drawings, Manuals, Method Statements, Plans, Permits)

Document(s)	**Number(s)**
Operator Manual for	Cat 299XHP
Project Onshore Emergency Response Plan	Project Work Plan Part D Appendix O-1
Safety Data Sheet	Safety Data Sheet Binder
Spares Part	List of Spares

5. Task Risk Assessments

Task Risk Assessments (TRA) relevant to the task include:

Number	**Name**
SC-E101	Transportation of Machinery on Road
SC-E102	Chain Saw Operations
SC-E103	Weed Eater
SC-E104	Equipment Fuelling
SC-E105	Loading and Unloading Rollback
SC-E106	Brush Clearing by Mechanical Equipment
SC-E201	Stuck Equipment Recovery

6. Security - Barriers/Fences/Warning Signs

Machines will be turned off and doors and access compartments locked when not in use. Due to the nature of the operations of this machine, no personal shall be within 300ft of an operating machine without direct communication with the operator of machine.

Spotter will visually verify discharge path of mower and monitor potential public interaction in the mowing area. Areas will be evaluated on a case by case for additional barrier or warning sign.

7. Constraints/Restrictions/Special Conditions

No smoking while operating equipment
No talking on Cell phones while operating or spotting equipment
Ensure spill prevention measures are in place
Ensure that a fully stocked spill kit is readily available
Ensure fire exhtinguishers are in place and inspected
First Aid kit and eyewash to be in place
Ensure guards are in place and all safety devises are functioning
Ensure sparks arrestors are in place and in working order if applicable
Fueling operation will have proper barriers in place and follow TRA SC-E104. Fuel will be properly stored and containers to be regularly inspected

All personnel will continually monitor for wild life habitat. In the event of a sighting the site manager will be contacted for further instruction to ensure permit requirement are complied with.

Weather will continually be monitored, the limiting factor will be the spotters ability to do his job effectively.

8. Plant and Equipment

- Cat 299XHP
- Chain Saws
- Weed Eaters
- Support Trucks

9. Safe Operations

Operators shall adhere to all safety procedures in operator’s manuals

10. Maintenance Procedures

General maintenance in the field will include track tension adjustments as needed, greasing of all moving components as designated by the manufacturer, cleaning of wind shields and replacement and/or tightening of teeth on mowing head. Additionally drive belts may be tensioned or replaced and fluids added to reservoirs as needed. For maintenance levels above this the machine will be removed from field or a work plan will be discussed with Greatland and Fugro supervisors.

Spare parts will be available on site. A list of spare parts for the equipment is listed in the appendices and will be maintained.

If a repair is required, to permit the equipment to be removed from site, the site manager and Greatland supervisor will develop a JHA to cover the steps and ensure applicable TRAs are reviewed. Post installation of repair a thorough check will be performed prior to start up and a ground barrier shall still be in place as a contingency to protect against environmental damage or fluid contact with the ground. Any hoses that are made for repair shall have a quality assurance from a Greatland approved vendor that explains the procedure used to ensure hoses are of the correct pressure range per the equipment manual and that hoses are properly seated on the fitting. Once equipment has been function tested and fluids up to temperature, repair area will be inspected to ensure repair is fit for use.

11. Preparation of Works/Location of Services

When Machinery is required to be refuelled in the field, the fuelling procedure SC-E104 will be observed and the following items will be on site.

- Fire extinguisher
- Spill Kit
- Duck Pond
- Spade
- Ground barrier

Fuelling person will be in direct control of fuel nozzle and not leave the nozzle locked on or unattended

12. Emergency Procedures

Please refer to the onshore emergency response plan for emergency contingencies. The following will be in place on each work site:

- Emergency contact numbers will be in each machine
- Fire extinguisher will be present on each machine
- Spill response kits will be on machine or support vehicle

13. Personal Protective Equipment (PPE) & Safety Equipment

- Machinery ROP'S and FOP'S shall be maintained and not altered or removed,
- Fire extinguisher shall be charged and in good working order
- Operator shall have a form of communication with spotter

The **following personal protective equipment will be worn:**

Hard Hat	mandatory
Safety boots/shoes	mandatory
Safety glasses or goggles	mandatory
High visibility vest, jacket or shirt	ANSI class 2
Ear Protection	mandatory - noise above – 80dB(A)
Gloves	as required per TRA
Clothing	Coveralls or Long sleeve pants and shirt at

	minimum and additional clothing as required
Face Shield	For chainsaw and weed whips
Leg Chaps	For chain saw and weed whips

14. Photos

Cat 299XHP with mowing head

Extraction Rigging

15. Methodology & Sequence of Work

- Daily JHA to be conducted
- Prior to operation machine will be inspected and the inspection will be documented
- The area to be treated will be inspected for hazards
- Operator will start machine and allow it to reach normal operating temperatures
- Operator will check communications with spotter
- Operator will then engage mowing head and start to process material in work site
- Flying debris will be discharged in a safe direction and not towards personal or structures

- If large trees are to be felled by machine the overhead will be clear of power lines and the drop zone will be sufficient size to push the tree. Then the tree will then be mulched on the ground
- Upon completion of operations the machine will be run at idle to cool down and allow rotating equipment to stop moving and enter a "zero energy state."
- The equipment will then be cleaned of loose debris and moved off site or secured in place
- Depending on distances of travel on Borough road, the equipment may be driven or loaded and hauled on support vehicle
- Loading and unloading of equipment will follow TRA SC-E105, operator and spotter will be in place for equipment loading.
- Load securement / all equipment will be secured for transit with chains and ratchet binders

16. Equipment Recovery

If equipment recovery is required for a stuck piece of equipment the following actions will take place:

- Prior to any operation A pre-job meeting will be held to determine how best to extricate stuck equipment TRA SC-E108 will be reviewed
- A typical extraction would require a second machine with attached rigging to pull out stuck machine
- A recovery kit will be in place consisting of Shackle Crosby ¾" 4.5 ton SWL and Nylon Strap 24,000 lbs SWL for straight line pull. Riggins will be stored for protection from the environment.
- Each piece of equipment has a manufactures identified recovery attachment point which will be used and inspected prior to attaching rigging

Equipment Recovery for mechanical failure will follow manufactures procedures. Recovery may require 3rd party services. If services are required Greatland will coordinate with site manager and site HSSE to develop a recovery plan and ensure all personnel involved have reviewed the plan and roles and responsibility are clearly defined.

17. Appendices

Equipment Check Sheet

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Vegetation Clearing	

ITEMS	CONDITION			REMARKS/HOUR COMPLETED
	Good	Rejected*	N/A	
1. Mowing head teeth for tight, drum spins freely				
2. Mowing head bearings greased every four hour				
3. Mowing head hydraulics connected				
4. Hydraulic hoses in good condition				
5. Hydraulic System (no leaks)				
6. Hydraulic reservoir is in correct range				
7. Pivot points on arms and tracks are greased every eight hours				
8. Tracks are tight				
9. Debris guards in place				
10. Spark arrestor				
11. Fire extinguisher (charged/mounted)				
12. Engine oil is at correct level				
13. Coolant level is correct				
14. Engine compartment guard is in place				
15. Steps free of debris, windshield is clean				
16. Radio communication functions				
17. Engine sounds normal on start up				
18. Gauges read normally				
19. In cab safety arms function properly				
20. Parking brake functions properly				
21. Hydraulics function properly				
22. Back up alarm works				

23. Mower head sounds normal on spool up				
24. Inspect mower head pump and pump connections behind inspection plate once weekly or 40 hours				
25. Clean air filter every week or 40 hours				
26. Inspect and clean underneath cab once every two weeks or 80 hours				
27. Clean hydraulic radiator as needed				

Greatland Tree Service Inventory List - FUGRO

Part Name	Equipment ID	Vendor	Quantity in Stock	Reorder Level	Reorder Time in Days
Tooth Cutting	Gyro Trac - Cat 299	King Kong Tools	25	6	4
Bolt tooth	Gyro Trac - Cat 299	Fire and Fastner	6	0	1
nut tooth	Gyro Trac - Cat 299	Fire and Fastner	6	0	1
washer tooth	Gyro Trac - Cat 299	King Kong Tools	25	6	4
Drive Belt	Gyro Trac - Cat 299	Gyro-Trac	1	0	3

METHOD STATEMENT	No: OS-GT-MS-001	
Geotechnical Drilling		

CONTENTS

Developed by:	Reviewed/authorized for issue by:

METHOD STATEMENT	No: OS-GT-MS-001
Geotechnical Drilling	

1. Introduction

This Method Statement relates to the safe operation of drilling machines mounted on truck or track carriers, for drilling and sampling geotechnical test boreholes.

2. Main Activity / Area of Work

The fieldwork consists of drilling 50 onshore geotechnical boreholes and installing PVC pipes for downhole shear wave velocity testing. Details for the field work are listed below:

- Drilling a total of 16 soil boreholes to a maximum depth of 200 feet below existing grade.
- Drilling a total of 22 soil boreholes to a maximum depth of 150 feet below existing grade.
- Drilling a total of 2 soil boreholes to a maximum depth of 100 feet below existing grade.
- Drilling a total of 10 soil boreholes to a maximum depth of 50 feet below existing grade.
- Installing PVC pipes for down-hole shear wave velocity tests in 10 boreholes to a maximum depth of 200 feet.

3. Area of Work and Access

The activity will be conducted in the vicinity of the Kenai Spur Mile Post 22.5 primarily on AKLNG parcels where geotechnical information will be obtained. Denali Drilling Inc. (DDI) crews will be housed in Nikiski where they will have a laydown area for storing equipment and materials. Safe operations and handling of materials will be mandatory at this location.

Field activities will be performed within privately owned parcels, Kenai Peninsula Borough (KPB) property, Alaska Department of Transportation (ADOT) right-of-ways (ROW), and AKLNG-owned parcels where the majority of the boreholes are located. Access to the borehole sites will be arranged by Fugro and AKLNG site management. AKLNG-owned lands will have clearly marked boundaries to aid in reducing possible trespass occurrences into private landowners from AKLNG parcels. To prevent trespassing into the private lands owned by others and on-duty land agent will be available for consultation. Open communication between drill crews, field engineer, site management and land agent will be established to prevent incidents during access and when on sites.

Non-essential/non-project related personnel and machines and equipment will be allowed access to the site/staging area to assist drill crews when necessary. They include suppliers and trucking companies that will move machines and equipment between sites and during mobilization/ demobilization, and will adhere to all required safety protocols.

4. Manpower and Supervision

Nominated Person	Responsibilities
Project Manager 10 years' experience	Review method statement and associated Task Risk Assessments (TRA) with employees performing the task. Regularly inspect activity for compliance. Ensure roles and responsibilities are clearly defined. Ensure machines and equipment and personnel are fit for work. Reinforce STOP work responsibilities. Work with the site manager to ensure access and land availability is in place. Conduct daily tool box. Coach team in safety awareness program e.g. Hazard Observation Program. Be familiar with all machines and equipment, read operation manuals, and ensure familiarization of all drillers and helpers for the equipment used for this project.
Operators/Drillers 3 years' experience	Daily machines and equipment inspection. Fuelling of machines and equipment/daily maintenance requirements following TRA. Ensure PPE is in place and proper working order. Communication test and verification. Participation in safety awareness program. Completion of 40 hr HAZWOPER training Be familiar with all machines and equipment and read operation manual for all equipment used for this project.
Driller Assistants One year experience	Ensure PPE is in place and in proper working order. Communication test and verification. Participate in safety awareness program. Public awareness in activity area (point of contact, hand out AKLNG reference contact number as necessary). Ensure fit for work. Being familiar with all machines and equipment and reading operation manual for all equipment used for this project.

Short Service Worker Less than one year experience	SSW will be briefed on responsibilities and have taken required safety courses to be working on site. Training may be OJT Will be mentored by Project Manager, Driller, and experienced Driller's Assistant.

5. Associated Documents (Drawings, Manuals, Method Statements, Plans, Permits)

Document(s)	**Number(s)**
Operator Manual and Daily Inspection Sheet	CME75
Operator Manual and Daily Inspection Sheet	CME 85 (backup)
Operator Manual and Daily Inspection Sheet	CME 850X
Operator Manual and Daily Inspection Sheet	CME 850 (backup)
Operator Manual and Daily Inspection Sheet	Polaris UTV
Operator Manual and Daily Inspection Sheet	Bobcat
Daily Equipment Inspection Sheet	Trailer
Safety Data Sheet	Safety Data Sheet Binder
Spare Parts	List of Spare Parts
Drilling Sketches	
Site Layout	Layout drawing for minimum 30' x 60' pad
Screening and Containment	ES-R10-30 Alaska Project - Field Procedures SOP
Rest Management	Rotational Schedule - Subject to change
Utility Terrain Vehicle Operations Method Statement	OS_GN_MS_001 Method Statement

METHOD STATEMENT	No: OS-GT-MS-001
Geotechnical Drilling	

6. Task Risk Assessments

Task Risk Assessments (TRA) relevant to the task includes:

Number	**Name**
DO11	Drilling Operations
DO12	Drill Rig Maintenance
DO13	Working With Contaminated Samples
DO14	PVC Pipe Installation
DO15	Decontaminating Equipment Rev 1
DO16	Grouting for regular boreholes and PVC pipe installation
DO17	Trailer Unloading and Loading of Equipment
DO18	Vehicle Usage
DO19	Casing Jacks & Cathead
DO20	Changing Hammer Weight
GP-349	Driving Off Road
AK LNG-001	Indirect Heater Operations
AK LNG-002	Skid-Steer Loader Operations
AK LNG-003	Removing PVC Casing with Skid Steer Loader
OS-GN-TRA-001	Utility Terrain Vehicle (UTV) operation
OS-GN-TRA-004	Equipment Refuelling
OS-GN-TRA-005	Equipment Recovery
OS-GN-TRA-006	Moving Drums with Drum Sling
ON-GN-TRA-311	Material Handling
ON-GN-TRA-329	Changing a Tire
ON-GN-TRA-349	Driving Off Road
SC-E201	Equipment Recovery Is this duplicate of OS-GN-TRA-005

7. Security - Barriers/Fences/Warning Signs

Machines will be turned off and doors and access compartments locked when not in use. Due to the nature of the drilling operations personnel, not associated with the project, shall stay within no less than 50 feet of an operating machine without direct communication with the operator of the machine. For field engineer, field HSSE representative and project-related personnel an exclusion zone will be set by the drilling crew around the drill pad.

8. Constraints/Restrictions/Special Conditions

- No smoking while operating equipment.
- No cell phones shall be used while operating or spotting equipment.
- Proper ingress and egress means (e.g. proper ladder) to the elevated surfaces (e.g. drilling rig deck) shall be in place.
- Standing/stepping on equipment that is not designed for the purpose is not allowed.
- If ladders are used, they must have industrial rating.
- When working at heights (drill mast) a proper safety system (safety harness) shall be used.
- Ensure spill prevention measures are in place.
- Ensure that a fully stocked spill kit is readily available.
- Ensure fire extinguishers are in place and have been inspected within the last 12 months.
- First-aid kit and eyewash to be in place.
- Ensure guards are in place and all safety devises functioning.
- Ensure spark arrestors are in place and in working order if applicable.
- Fuelling will be done at the nearest fuelling station. When machinery and equipment cannot be removed from site, fuelling will be done on site.
- A roaming wildlife safety specialist will be available on site and all personnel will continually monitor for the presence of wildlife.
- Weather will continually be monitored; the limiting factor will be the spotter’s ability to do his job effectively.
- As necessary, air horn, mosquito nets and mosquito repellent will be used during the field activities.

9. Plant and Equipment

- CME75 on truck carrier and CME850X on track carrier
- CME85 on truck carrier and CME850 on track carrier (backup)
- Support vehicles
- Polaris UTV
- Utility trailers
- Bobcats
- Honda Generators
- 200 GPM Transfer pumps
- Water totes (250-300 gallons) with lids
- Mud mixing pits/tubs
- Support stands for drilling rods
- Liner and lumbers for containment zones
- PID meters

METHOD STATEMENT	No: OS-GT-MS-001
Geotechnical Drilling	

10. Safe Operations

- Operators shall adhere to all safety procedures in operator's manuals listed in Section 4.
- Driller shall conduct daily equipment inspections and correct non-conforming components before operations.
- Driller shall review drilling pad prior to moving equipment to site, taking into consideration egress routes, walking paths, and safe working zones for all on-site personnel.
- Close attention will be paid to placement of the rig's auto hammer onto the safety pin as the hammer may become dislodged from pin.
- Employees shall complete all safety training identified in the training matrix and project induction prior to starting work.
- All employees are expected to attend weekly safety meetings, participate in daily tool-box talks / JHAs, and contribute to the Hazard observation program.
- Employees shall exercise their Stop Work Responsibility if they observe anything they feel is unsafe.
- Good housekeeping is paramount and shall be maintained at all times.
- There will be at least two identified first aid/CPR persons on-site.
- Emergency response equipment e.g. spill response and first aid kit, shall be easily accessible and locations discussed each day. Employees shall participate in Emergency readiness drills.
- Employees shall adhere to site-specific rules, including, but not limited to, smoking policy, cell phone policy when operating equipment, use of spotter when moving equipment, use of spotter if view is blocked when moving/backing up bobcat and truck & trailer, etc.
- The drilling supervisor will continually monitor the borehole sites for safety and operational compliance and work with the crews to mitigate areas that require improvement.
- Permit to Work will be utilized for any Hot Works or work near power lines.

11. Maintenance Procedure

General maintenance in the field will include track tension adjustments as needed, greasing of all moving components as designated by the manufacturer, cleaning of windshields and replacement of worn parts. Additionally drive belts may be tensioned or replaced and fluids added to reservoirs as needed. For maintenance levels above this, the machine will be removed from field or a work plan will be discussed with Fugro and Denali project manager.
Spare parts required for the project will be identified and a list will be developed & maintained. Maintenance is done every 500 hours determined by hour meter.

12. Preparation of Work / Location of Services

Drill rig mobilization to the borehole sites will be initiated once all the activities below are completed and there are no restrictions

- Ground truthing and staking/surveying by AKLNG and Fugro site representatives,
- Vegetation clearing of access routes and drilling pads,
- Alaska One-Call and geophysical utility survey,
- Power line permit to work will be in place for borehole sites that position the equipment within 33 feet of overhead power line utilities.

Once the above preparation is completed, borehole access route and drill pad will be walked by the drilling supervisor and/or operator/driller and field engineer/site manager prior to mobilizing equipment.

The following will be conducted before the start of drilling operations at a new site:

- Toolbox meeting and Job Hazard Analysis (JHA),
- Exclusion zone (barricades) around drill pad in place,
- Placement of a containment zone if site is deemed to be in a potentially contaminated area,
- Designate smoking area selected,
- Select Emergency Muster point,
- Provide comfort stations (i.e. porta-potty stations) as close in proximity as is practicable.

13. Fuelling vehicles and equipment

Personnel vehicles (truck rigs and support trucks) that can travel on road by their own carriers will be fuelled at the nearby fuelling stations. Machines that are transported by trailers and/or with track carriers and cannot be fuelled at a fuelling stations will be allowed to fuel onsite at the borehole site, staging area (gravel pit). Safety fuel cans are required to be inspected and properly secured in secondary containment during transit. Hydrocarbons will not be transported with drilling water.

The following items will be on site:

- Fire extinguisher
- Spill kit
- Duck pond
- Spade
- Ground barrier

No more than 25 gallons of fuel should be present on site (i.e. no more than five 5 gallon safety fuel cans). Fuelling person will be in direct control of 5-gallon fuel safety can nozzle and not leave the safety can nozzle unattended.

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14. Emergency Procedures

Please refer to the onshore emergency response plan for emergency contingencies. The following will be in place on each work site.

- Emergency contact numbers will be in each machine
- Fire extinguisher will be present on each machine
- Spill response kits will be on machine or support vehicle

15. Equipment Safety Components

- Safety/emergency shutdown
- Backup alarm
- ???Horns
- Fire extinguisher

16. Personal Protective Equipment (PPE) & Safety Equipment

The following personal protective equipment will be worn:

Hard Hat	Mandatory
Safety boots/shoes	Mandatory
Safety glasses/goggles	Mandatory
High visibility vest, jacket, or shirt	As required per TRA
Ear plugs	Mandatory - noise above 85dB(A)
Gloves	Leather - for working with cables, sharp objects, ropes, etc.
Gloves	Rubber - for mixing grout, working around chemicals, anything wet
Gloves	Cotton - for basic loading/unloading materials
Clothing	Coveralls or long sleeve pant and shirt at minimum and additional clothing is required.

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17. Photos

1.

18. Methodology and Sequence of Work

* Drilling activities will be performed by a 3-men drill crew and a Fugro geotechnical engineer/geologist. In addition, a Denali drilling supervisor will be present onsite to oversee

Denali's activities. Fugro engineer will be responsible for directing and overseeing the drilling and sampling activities in accordance with the sampling schedule.

* Inspections and Fuelling - Prior to arrival on site all equipment will have been steam cleaned. Prior to operation, drilling machine will be inspected and inspection documented then all fluid levels will be checked. If oil is needed to be added to an engine, it will be poured into the engine from a quart container into the oil fill cap. If fuel is needed, on the truck rig, it will be filled up at the nearest fuelling station. On the track rig, fuel will be brought to the borehole site in 5-gallon safety cans using the UTV and lifted manually and poured in the fuel tank. A duck pond will be placed below the fuel tank and an oil/fuel spill kit (oil/fuel absorbents) will be readily available during fuelling operations. Proper PPE will be worn by anyone fuelling equipment.

* Buddy System - When working on site, individuals can operate equipment or walk to a specific area (parked trailer, pickup, porta-can, etc..) by themselves, without a partner (buddy), when in view of the drill site. If out of view of the drill site, a two man (buddy) system will be used.

* Site Setup - Drilling operations begin by moving the drilling rig on site. For the track drill, if soft ground conditions exist, 4x8-ft plastic mats will be provided to travel over for accessing the site. Then, the drill crew will check for any overhead obstructions. Drill crew will then lay timber cribbing (6x6-inx3-ft wood blocking) under each hydraulic levelling jack pad and the driller will lower the levelling jacks and level the rig. Once levelled, the drill's tower will be raised and bolted into the upright drilling position. If an environmental site, heavy ground cover cloth will be laid out prior to placement of mud pits and saw horses for laying drill rod on. If not, pits and saw horses will be laid out as per DDI site setup plan, unless site topography does not allow. At this point the drill rig is ready for drilling.

* Water Delivery - DDI will then provide and deliver potable water (water will be city water or from a well offsite and tested) in 250-gallon plastic water totes with Bobcat forklift. The water totes are designed with fork pockets to be picked from or can be lifted from the top with a four way cable system, shackled to the top picking rail and lifted by the D ring on the four way cables. If out of view from the drill site, a spotter in a UTV will travel with the Bobcat to get/bring water on site. All Bobcat and UTV operators will have reviewed the operator's manuals for safe operation of the equipment and have attended DDI's and Fugro's orientations for safe operation of equipment.

* Mixing Bentonite – Drill crews will fill mud pits with potable water, the rig water pump will be primed and circulating, and then Bentonite Quik-Gel will be mixed with the water to make the drill mud for drilling. Crew members will be wearing proper PPE to perform this task which includes eye protection, particle masks and rubber gloves.

* Drilling Start – Based on the anticipated soil and depth-to-water conditions, boreholes will be performed using a combination of auger and rotary wash drilling techniques. Drilling methods will be dictated based upon field conditions encountered at each location.

Temporary casing will be required to stabilize the upper/near surface of the boreholes. At the completion of the borehole, casing will be recovered.

* AKLNG will provide information on boreholes that will require field screening and containment zone during drilling and sampling. For these locations, containment zone and field screening activities will be performed by drilling crews. A perimeter containment berm will be constructed around the drill location to aid in managing drill spoils. A heavy duty tarp will be laid on the ground and wrapped at the edges to form containment. Field screening will be performed using photo-ionization detectors (PID) to capture volatile organic compounds (VOC), hydrogene sulfide (HS2) lower explosive limit (LEL) of methane gas (CH4), oxygen (O2) and carbon monoxide (CO). Details about the standard operating procedures for containment zone and field screening are provided in Screening and Containment ES-R10-30 Alaska Project – Field Procedures SOP document.

* Sampling will be performed continuously at (2.5-ft intervals) within the upper 20 feet, at 5 feet intervals to a depth of 100 feet, and at 10 feet intervals below 100 feet of depth and at changes in soil stratification, to termination depth of each borehole.

* Disturbed soil samples will be obtained by driving a 2.0-in OD split-barrel standard penetration test (SPT) sampler in general accordance with the Standard Penetration Test (SPT) procedure described in ASTM D1586. The SPT N-values, defined as the number of blows required for a 140-lb hammer falling 30 inches to drive the split-barrel sampler the final 12 inches of the 18 inches sampling interval, will be recorded during sampling. To increase the recovery of the soils SPT samplers will be driven up to 24 inches, where N-values were still recorded at 18-in penetration in accordance with the ASTM standard.

* When onsite soils show a high gravel/cobble content, a 3-in OD oversize split-barrel should be used in addition to the 2.0-inch OD standard size split-barrel samplers where directed by the field geotechnical engineer to collect a larger sample. Blow counts will be recorded also for oversize split-barrel sampling following the same procedure described for standard penetration testing (ASTM D1586).

* A surface sample will be taken from the ground surface to a depth of 1.5 feet (18 inches). After every sample has been taken, the split spoon sampler will be handed to Fugro engineer. Sampling will continue according to the scheme indicated above. A 5-ft long 4-in diameter casing will then be driven 2.5 feet into the ground using the rigs auto hammer or safety hammer with the hydraulic cathead. A 5-ft section of drill rod and a 3.5-in tri-cone bit is threaded to the rigs rotary box connector and placed inside the 4-in casing, the pump is turned on and drill mud is circulated. The driller then engages the rotation and slowly applies hydraulic down feed pressure and advances the drill bit to the 4-in casing shoe or next sample depth. This sequence is repeated until the final depth of the borehole is reached. Once total depth has been reached and if required at a specific borehole, PVC pipe for downhole measurements will be installed inside the borehole to the boreholes maximum depth and backfilled.

* After the completion of the soil sampling, close attention / communication will be paid after the hammer has been used. The task of securing the auto hammer after its use will be verified by the drillers helper positioned on the side opposite the driller. Additionally the securing pin for the auto hammer will be maintained with a high visibility paint / coating or marking for the helper and observers to have a visual indicator when improperly stowed.

* At the completion of the borehole the 4-in casing will be removed from the borehole first by attaching the rotary head and threading it to the 4-in casing then pulling with the hydraulic feed/retract cylinders on the drill. If the cylinders stall out and the 4-in casing does not move the driller has two options to assist in the casing removal. He can add another set of casing jacks that will be set up next to the 4-in casing and will hydraulically push against a set of casing slips/ring placed on the outside of the 4-in casing, then both the drill retract hydraulic cylinders and the hydraulic casing jacks can be used to pull the casing, thus doubling the hydraulic pull out force. Or the driller can unthread the rotary head from the casing and attach the 140-lbs or 300-lbs safety hammer and backhammer the casing using the cathead and 1-in catline attached to the safety hammer, checking to be sure that there is no slack in the line and that the line is running straight from the cathead to the crown sheaves and back down to the hammer before operating the cathead/catline. Backhammer the casing with the safety hammer while also pulling with the casing jacks if needed. If added hydraulic pull back is needed, wrap a steel braided choker around the casing, below the hydraulic jack slips/ring and shackle to the rotary head and engage the retract cylinders and casing jacks simultaneously while backhammering. Whip checks will be secured to the quick disconnect of the hose on the casing jack to prevent hydraulic hose from whipping from side to side if it blows apart. It is the driller's option to use the sequence and type of tooling he feels will work the safest and fastest to accomplish the task at hand. These three options provide the most pull back force the drill can accomplish, although the jarring action of the jackhammering is most useful and can be used at any time the driller feels the casing is becoming stuck or when removing.

* Disturbed samples will be placed in plastic bags, labelled, and stored in appropriate containers for transport to ASRC by Fugro engineer.

* Undisturbed samples of cohesive soils will be obtained by hydraulically pushing a 3-in diameter, thin-walled (Shelby) tube to a distance of about 24 inches or to refusal, whichever occurs first. The field procedure for cohesive soil sampling will be conducted in general accordance with the Standard Practice for Thin-Walled Tube Sampling of Soils (ASTM D1587). The samples obtained using Shelby tubes will not be extruded in the field. When possible, pocket penetrometer and Torvane measurements will be performed from the bottom ends of the tube samples and recorded on the borehole logs. Shelby tubes will then be transported by Fugro engineer to ASRC. Both ends of the tubes will be sealed with wax.

* All disturbed samples and undisturbed Shelby tube samples will be shipped to Houston for laboratory analysis.

* Upon completion of the geotechnical drilling/sampling and in-situ testing (when assigned), each borehole will be backfilled with a mixture of bentonite-Portland cement grout up to 18-

inches below the ground level and the remaining portion of each borehole will be backfilled using the native material.

* Soil cuttings and drill mud that are considered non-hazardous (based on field screening results) will be evenly spread on the ground at the completion of each borehole where the borehole is drilled in AKLNG property. Soil cuttings and drill mud will be collected in 55-gallon drums and transported to a disposal area when the boreholes are drilled in Kenai Peninsula Borough (KPB) and Alaska Department of Transportation (ADOT). Soil cuttings and drill mud that are considered contaminated or possibly hazardous will be collected in 55-gallon drums and transported to a disposal area for further testing and disposal.

* Following completion of the drilling operations, each site will be cleared of drilling equipment, ruts will be backfilled/levelled, excess grout will be removed and the borehole sites will be left in clean condition.

* Grouting and Completion - After total depth has been sampled, Bentonite grout will be mixed in similar fashion to drill mud and pumped into the hole for abandonment. All 4-in casing is then removed and after removal hole will be topped off with Bentonite grout and left to cure. All PPE will be worn during this activity as mentioned in “Mixing Bentonite”. Mix design is a majority of bentonite with Portland cement, and water mixed to a pumpable mixture. We can use the standard mix design as shown on any bag of Quik Grout which is 50# of grout to 23 gallons of water. The amount of grout mixed is dependent on the depth of the borehole. Water will be city water or well water that has been tested and approved. This will allow for ease and success of removal of the PVC with the loader due to the softer Bentonite material being used as backfill and not adhering to the PVC riser.

* Tidal Work - DDI has 2 boreholes to accomplish along the shoreline of this project work area. The sites have been inspected and will be sampled using the track mounted drill rig. The borehole locations are above the 20-ft tide line and allow safe access during low tides and can be worked when tides are less than 20 feet high and there is no southern wind causing a high degree of wave activity. In the event of tides higher than 20 feet or southern winds/waves DDI will not be working on the beach. This will need to be closely monitored daily and decisions made on keeping equipment on the beach or removing it. Regardless, if equipment needs to be removed, the casing left in the ground will be marked well with an orange safety cone for protection, to inform 4 wheeler and auto traffic, and to keep them from running into it. There will be an ASRC loader and operator available to remove the track drill in the event of a mechanical breakdown or the equipment getting stuck in the sand. The drill rig operator will be familiar with disable the tracks in case of hydraulic failure to allow safe towing. The operator will be contacted via cell phone. We understand this ASRC loader and operator is Fugro’s responsibility. A kick-off meeting will occur prior to the start of intertidal work.

19. Equipment Recovery

If equipment recovery is required for a stuck piece of equipment the following action will take place.

- A Tool Box Talk will take place with all team members involved
- Applicable TRA will be reviewed
- A recovery kit will be in place consisting of shackle and nylon strap stored for protection from the environment
- Each piece of equipment has a manufacturers identified recovery attachment point which will be used.

Equipment recovery for mechanical failure will follow manufacturer's procedures. Recovery may require third party services. If services are required, coordinate with site manager and site HSSE to develop a recovery plan and ensure all personnel involved have reviewed the plan and roles and responsibilities are clearly defined.

20. Appendices

Equipment Check Sheet

ITEMS	CONDITION			REMARKS
	Good	Rejected	N/A	
1. Hydraulic System (no leaks)				
2. All hoses in good condition & tight				
3. Check oil, antifreeze				
4. No broken windows				
5. Tracks are tight				
6. Check rain cap on exhaust				
7. Levelling jacks stable				
8. Debris guards in place				
9. Spark arrestor				
10. Fire extinguisher (charged/mounted)				
11. Equipment fuelled				
12. No fluids spilled in area				
13. Engine compartment guard				
14. Steps clear of debris				
15. Check stabilizer attachment points				
16. Fuel containers and flammables securely stored				
17. Safety shutdown tested				
18. Check driller stand condition				
19. Auger/tooling in place & secure				
20. Back up alarm works				
21. Sampling tools cleaned and readily available				
22. Hand tools in place and secured				
23. Cables not frayed				
24. First-aid kit in place & replenished				
25. Spill kit & absorbent pads readily available				
26. Site in orderly condition with no tripping hazards				
27. Be sure duck ponds/containment devices are cleaned out and in place				
28. Have safety gear/PPE				
29. Water tank condition & connections in good condition				
30. Water/grout hose condition				
31. Secure drill at end of day				

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32. Safety tape/barricades in place if required				
Trailer Inspection Sheet				
Trailer #				
Brake Connections				
Brakes				
Coupling Devices				
Coupling (King) Pin				
Doors				
Hitch				
Landing Gear				
Lights				
Suspension System				
Tarpaulin				
Tires				
Wheels and Rims				
Other				

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Spare Parts List:
Denali Drilling, Inc.
List of Spare Parts for Fugro Project
For CME 75, 85, 850

Quantity	Description
2	Air filters
3	Fuel filters
1	Kelly bar & bearings
1	Chain box
1	Right angle drive
1	Transmission
1	Auto hammer complete
1	3L8 Moyno Rotor
1	3L8 Moyno Stator
2	3/8-in certified winch cables - 100'
1	1-in manila catline - 100'
1	Chain box chain and two master links
1	Spare 10 x 20 tire & wheel
2	24-in pipe wrenches
1	36-in pipe wrench
1	Rigid pipe stand
1	3# hammer
1	8# hammer
1	#2 shovel
1	Rigid chain vice
1	NWJ hoist plug
1	NWJ x 2 3/8-in API regular bit sub
4	3 ½-in x 2 3/8-in pin hard formation tri cone bits
1	Set clamp jaws for 4-in pipe
6	8 x 8-in x 3-ft long timber dunnage
1	3-in x 3-in pillow block bearing
1	3-in x 3-in universal u bearing drive shaft
1	2-in HEX x AWJ M side port swivel
1	Rigid chain clamp
1	Ammo box 1-in – 3-in hose kit
2	Wire brushes
1	300# hammer
4	Chains w/chain ratchets
1	2-in hex extension
1	1-in camlock m/fm manifold w/pressure gauge
1	Set NWJ slips
1	8-ft fiberglass ladder
12	6 x 6-in x 4-ft long wood dunnage
1	140# hammer anvil w/AWJ male pin

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Quantity	Description
2	Ammo boxes track 1/2" bolt/nuts/washers
1	Hand barrel pump w/20' hose
1	160/240 nodwell tire w/o wheel
250'	4-ft high orange plastic roll fence
6	36-in safety cones
20'	1 ½-in suction hose with camlocks
	Miscellaneous 1-in & 2-in hose, est. 60-ft each
2	Large rolls 6 mil plastic
4 gals	20 penny duplex nails
1	Pry bar
1	Trash pump
1	Generator
1	Box absorbents
1	4-way with shackles
1	Ape line
1	Handyman jack
1	Propane tank and torch
1	8-in pipe clamp
1	20-ft HD jumper cables
1	100-gallon horse trough
1	24-ft x 2-in suction hose
1	1.5-ton bottle jack

STANDARD OPERATING PROCEDURES (SOPs)
Alaska LNG Project

Field Screening and Containment

1.0 General

The procedures provided in this document will be applicable to all the exploration locations proposed for the Alaska LNG Project.

Active management of drilling spoils (drilling mud, cuttings, wash water) is a project requirement. Documentation of the handling, disposal and/or release of these materials is mandatory.

For each point of investigation, the drilling rig will be positioned within the cleared 40 ft x 40 ft drill pad area. Before commencing any drilling operations a perimeter containment berm will be constructed behind the drill rig and around the investigation location. The berm will be created using 4 x 4 lumber or sand bags within a minimum 10 ft x 10 ft area.. A heavy duty tarp/ground barrier will be laid within the 10 ftx10 ft area and wrapped around the berm to minimize potential runoff.

- During drilling or hole advancement:
    - The rig will be positioned such that the boring is drilled within the contained area.
    - Initially borings will be performed using hollow stem drilling techniques to a depth of about 40 ft below existing grade. Once ground water is encountered or the hole collapses, mud rotary drilling techniques will be used.
    - A hole will be cut within the tarp and a hollow-stem auger or casing will be installed through the tarp. The tarp will be secured around the casing such that there is minimal discharge of drilling mud or cuttings onto the native ground.
    - Once mud rotary drilling techniques are implemented, a mud pit will be used to mix water and bentonite to create the drilling mud to avoid caving of soil material into the boring. The mud pit will be placed over the contained area thus the tarp will be acting as a secondary containment. Care should be taken during placement of the mud pit so as to minimize tearing of the tarp.
- PID screening will be performed at soil sample depths starting at the ground surface and continuing approximately every 5 feet thereafter; and periodically over the open borings, drill pipes as per the procedures described under the following sections of the report.
- Following are the steps to contain the cuttings inside the tarp.
    - The drill crew will move the cuttings away from the borehole within the containment area using a shovel.
    - When using the mud pit, the cuttings and drill mud will be contained in the mud pit, where the tarp underneath will serve as a secondary containment.
- If PID readings do not exceed 75 ppm, the cuttings generated and accumulated in the containment area, will be periodically spread on the ground, and within the 40x40ft cleared drill pad area. Best practices for erosion and sediment control will be used when spreading cuttings. The cuttings and mud will be evenly spread within the cleared area only such that the cuttings do not completely cover any uncut vegetation. The mud pit will be slowly emptied with controlled discharge to avoid accumulation in one single area, and avoid any ponding of the mud.

- If PID readings at the open borehole and/or in the sample bags exceed 75 ppm (Section 4.5), then drilling operations will be halted and:
  - The hole will be covered;
  - The crew will be directed to move away from the back of the rig to a safe zone; and
  - PM/Site Manager/HSE Manager will be immediately contacted for further guidance.
  - Procedures discussed in the following sections will be followed.

  A log of approximate quantity of cuttings and mud generated at each location will be noted on the daily field report.

2.0 Field Screening Using PID

Field screening will be performed with BW Technologies Gas Alert Micro 5 PID detectors rented from a local supplier of gas detection devices. The detectors will be operated by the Onsite Engineer, which has been specifically trained in the operation of the detector.

Field screening will be used for the following purposes:

- Screening of the breathing zone to ensure that proper safety precautions within the work zone are followed,
- Screening open boreholes, drill pipe or well pipe atmospheres to assist in proper PPE management, and
- Screening of selected soil and groundwater samples to assist in waste management of decisions.

Given the location of this project site, we understand that the primary contaminant of concern will be petroleum hydrocarbons and possibly natural biodegradation gas (methane, H_2S). HAZWOPER trained HSE staff will be available to observe conditions encountered during the field work.

Field crews will include staff trained to observe and field screen sample locations for the presence of observable contamination. EPA Guidance for Expedited Site Assessments (1997) will be used as a guide for site screening of petroleum hydrocarbons and vapors.

3.0 PID Calibration and Functionality

Each detector is factory calibrated for detection of combustible gases based on 50% LEL of methane (25,000 ppm), methane (%), oxygen (%), hydrogen sulfide (ppm), and volatile organics (ppm) using the detector's PID sensor.

Onsite Engineer will enable and set the alarm function of the detectors using the PID threshold for Level D PPE and the gases shown in Table 1.

The functionality of the detectors will be checked before the start of each field day. The functionality will check the alarms, pump, and zeroing function of the detector. Any detector not passing the functionality check will not be used in the field; it will be immediately replaced with a functioning unit.

Malfunctioning detectors will be returned to the rental company and a calibrated replacement unit will be provided back to the field as necessary.

Calibration and functionality records will be maintained by Onsite Engineer for each detector for the duration of the project.

4.0 Procedures

Onsite Engineer will note the serial number of the detector in use on the respective boring log and/or field notes.

4.1 Breathing Zone Screening

Breathing zone atmospheres within the work zone will be frequently checked by Onsite Engineer. Initially, screening of the breathing zone will be conducted at a minimum every 30 minutes during any downhole or excavation activities.

Onsite Engineer will hold the detector at a height between 4 and 6 feet above the ground, and walk through the work zone and observe/record measurements which represent the breathing zone atmosphere.

Detector readings will be recorded on field notes, with location, date and time. Recorded readings will be compared with the thresholds presented in Table 1.

The frequency of breathing zone screenings will be increased if noted changes or elevated readings are being recorded.

Onsite Engineer along with onsite HSE staff will decide, in the field, if work zone tasks, alarms, and/or PPE need to be modified.

4.2 Open Borehole, Drill Pipe and Well Atmosphere Screening

Detector readings will be taken periodically over the open borings, drill pipes or wells. This data will be used to evaluate the requirement of any change in the PPE.

Wave the detector probe over the opening and observe and record detector measurements. If PID concentrations are above 75ppm, stop work and call the PM to review PPE, soil containment, and decontamination procedures with staff before proceeding.

4.3 Soil Sample Screening (Headspace Screening)

At selected soil sample depths starting at the ground surface and continuing every 5 feet thereafter, a headspace screening will be made for a bag sample of soil. A full 6 inch long soil sample liner will be extruded into pre-screened, sealable plastic bag (e.g. Ziploc). The samples will be agitated and squished to remove any clods. Sealed bags will be stored in a warm space (i.e. inside vehicle, on hood of truck, in sunlight) to allow the soil to off gas into the bag for about 10 to 15 min.

A measurement of gas content in the headspace atmosphere in the bags will be made by Onsite Engineer using a detector. A small opening in the ziplock will be quickly opened and the detector probe will be inserted taking care to not allow the probe to touch the soil or the bag or any condensate which may accumulate.

Detector bag screening data will be recorded on the field bore logs at the appropriate depth, or in the field notes along with field observations regarding staining, discoloration, fill matrix, moisture content, odor, etc. Bags will be labeled with boring number and depth using black marking pens (i.e. Sharpies).

Field observations will be used in conjunction with detector readings to determine the possible presence of contamination. The readings from a detector are not considered “a stand-alone” indicator of the possible presence of contamination.

When bag samples show PID concentrations above 75 ppm, work will stop and the PM will be contacted to review PPE, soil containment, and decontamination procedures with staff before proceeding.

Soil screening above 75 ppm will require that cuttings be containerized in soil drums to be managed as contaminated material.

No other borings, well bores, or test pits will be co-located at boring locations where 75 ppm in soil cuttings has been detected.

4.4 Water Sample Screening (Headspace Screening)

Detector readings will be taken periodically during well purging and sampling to check for petroleum hydrocarbons and/or vapors which may be present.

Hold the detector probe over the collected purge water or samples and observe and record the measurements. Water vapor concentrations above 75 ppm will require that work stop and the PM contacted to discuss with staff proper procedures before continuing.

4.5 Containment and Management of Investigation Derived Materials (IDW)

Investigation derived materials will be managed in accordance with the Table 2 Waste Management Guidelines provided by EMALL.

Sampler rinse water which does not pose any odor, sheen or detector readings may be discharged on site following Best Management Practices to prevent erosion. Discharge water may not be discharged into wetland areas or drainages.

Soil cuttings and test pit excavation spoils which measure PID readings less than 75 ppm, are not considered contaminated, and may be spread evenly on the work area adjacent to the boreholes as long as the boring location is are not located in wetland areas. Soil spoils from wetland area borings which are not contaminated will need to be moved to a location designated by the Client. Best Management Practices should be followed to prevent erosion and surface water ponding near the borings.

Soil spoils, drilling mud, and decon water which are contaminated (PID concentrations above 75 ppm) will be collected in 55-gallon drums. All drums will be marked and labeled in the field for clear identification.

The drums will be left near the excavation points in a safe manner, such that they will not be in pedestrian or vehicular traffic.

Emerald Alaska, Inc. will be responsible for all IDW management after the drums are sealed by Fugro. This will include all documentation needed to track the drums through the testing, profiling and disposal process including loading and transportation to a their permitted TSD facility, drum off-loading, container cleaning, treatment and disposal of petroleum hydrocarbon investigation waste collected during excavation activities. Depending on the amount of drums generated, Emerald Alaska, Inc will be picking up and transporting drums weekly or biweekly.

A chain of custody for the drums will be prepared and provided to Emerald Alaska, Inc before the drums are picked up.

4.6 Equipment Decontamination

When hydrocarbon odors or staining areas are encountered, samplers will be triple rinsed at the boring location between each use. Triple rinsing will occur in plastic buckets and water will be collected and later placed into 55 gallon DOT drums which will be moved to the decontamination area.

Equipment used in borings which have encountered petroleum hydrocarbon impacted materials will be decontaminated following drilling. The augers, samplers, and tooling used will be transported to the Staging Area (Rig Tenders Facility) where a decontamination station will be established. The decontamination station will include inflatable ponds where steam cleaning and rinsing can be completed. Once decontaminated, the augers and tools will be transported back to the new boring location.

STANDARD OPERATING PROCEDURES (SOPs)
Alaska LNG Project

Table 1 – Breathing Zone

Detector Sensor	Used to Detect	Work Zone Thresholds	Action Levels	
PID	Volatile Organic Compounds (VOCs)	0 - 5 parts per million (ppm)	PPE, Level D	Steel toed boots, safety glasses, hard hat, and latex inner gloves and nitrile or neoprene outer gloves.
		5 - 50 ppm	PPE, Level C	Level D as above plus a half face respirator with organic vapor cartridges, chemical goggle, and polycoated Tyvek. (An exclusion zone will be marked for staff having to don Level C PPE)
		50 - 250 ppm	PPE, Level C +	Level C except with a full face respirator
		>250 ppm	PPE, Level A or B	Call HSE Manager, Cease operations until vapors dissipate and readings are below 200 ppm
Gas	Methane	10%LEL=0.5%	Stop work, turn equipment off, contact HSE manager, and allow gas to dissipate within the work zone, monitor conditions frequently.	
Gas	Hydrogen Sulfide	0.03 ppm	Stop work, turn equipment off, contact HSE manager, and allow gas to dissipate within the work zone, monitor conditions frequently.	
Gas	Oxygen	<19.5% Oxygen deficient = something is displacing oxygen	Stop work, turn equipment off, contact HSE manager, and allow gas to dissipate within the work zone, monitor conditions frequently.	
Gas	Oxygen	>22% Oxygen enriched = something is causing a chemical reaction and oxygen is being generated	Stop work, turn equipment off, contact HSE manager, and allow gas to dissipate within the work zone, monitor conditions frequently.	

Artesian Borehole Abandonment Procedures

It is known that artesian groundwater conditions are found at the AKLNG site. The following procedures were developed, in consultation with the *DRAFT Alaska Best Management Practices, Maintaining or Decommissioning Water wells and Boreholes (May 11, 2016)* and are proposed if artesian conditions occur within borings, and plugging of the borings with those conditions is desired.

Plugging High Pressure Artesian Conditions

Preparations

1. Stage a appropriately sized casing cap at the borehole locations to address a flowing artesian condition.
2. Stage a appropriately sized down hole packers at the ASRC for the boring diameters planned.
3. Stage sufficient dry bentonite powder, chips and pellets to meet sealing/grouting requirements (as described below) at the ASRC.
4. Stage sufficient water at the borehole locations, or identify a means to transport sufficient water to the borehole locations, for the mixing of bentonite grout.
5. Stage a downhole videotaping device at the ASRC.
6. Stage clean gravel or stones (to be used to weigh the packer down) at the ASRC.
7. Stage disinfectant (1-gallon household bleach) and barrel for gravel/stone pre-processing before down hole-use at the ASRC. To achieve a 50 parts per million chlorine disinfection, add 6 ounces household bleach to 50 gallons of clean water.

Procedures

8. Secure a casing cap to the top of the casing pending procurement and delivery of a packer to the well location.
9. Pull drill casing back within the aquitard an equivalent length of the packer to be set. Utilize drilling rods to push the packer into the casing, and advance the packer to the bottom of the breached aquitard.
    a. After the packer is installed to desired depth, the drill rod will be raised about 3 feet, to allow observing the stability of the packer.
    b. After 30 minutes elapses to allow time for sediments in the casing to settle, place the videotaping device into the casing and lower it to just above the top of the packer. Visually observe packer and water conditions to evaluate aquitard sealing conditions.
    c. If the packer is judged to be stable, the drill rods will be retrieved and sealing/grouting operations will start as described in item #10 below.
    d. If the packer appears to have shifted or if water flow has not been stopped, drill rods will be lowered to reset the packer and the packer will be weighted down with clean and disinfected gravel or stone.
10. Bentonite chips or pellets will then be slowly poured in a bridge-free manner, as determined by periodically monitoring the fill level while pouring into the borehole, while the casing is incrementally raised and removed from the ground, to the ground surface. Open depth to the

top of the bentonite materials will be checked every 10 feet with a weighted tape to confirm that the material is not bridged.

11. Bentonite chips and pellets will be added to the top of the boring to mound and seal the opening.

Plugging Low Pressure Artesian Conditions

Preparations

1. Stage sufficient dry bentonite powder, chips or pellets to meet sealing/grouting requirements (as described below) at the ASRC.

Procedures

2. Bentonite chips or pellets will be slowly poured in a bridge-free manner, as determined by periodically monitoring the fill level while pouring into the borehole, while the casing is incrementally raised and removed from the ground, to the ground surface.
3. Bentonite chips and pellets will be added to the top of the boring to mound and seal the opening.

INTERTIDAL ZONE GEOTECHNICAL INVESTIGATION

Bridging Document

AKLNG

Prepared by:

FUGRO CONSULTANTS, INC.

Project No. 04.10160001

Rev	Date	Revision Description	Originator	Reviewer
0	9-June-16	Intertidal Drilling Campaign #1	B.Mosher/ I. Jaramillo	R. Lukasik

June 9, 2016

Reviewed By: ______________________ Date: ____________________

Randy Lukasik
Site Manager

Reviewed By: ______________________ Date: ______________________

Bob Mosher
HSSE Manager

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APPENDICES

1. INTRODUCTION

This scope of work includes performing 2 borings to a maximum depth of 200 feet below existing grade to support the ongoing 2016 G&G study. The collection of subsurface data using onshore drilling techniques and equipment is challenging in an intertidal zone such as the Cook Inlet AKLNG site. It is essential that a secure and competent plan is in place, not only to maximize the chances of success, but to also acknowledge potential problems that may occur during the work and identify a solution that can be put into place immediately. Therefore, this document intends to set out an agreed scope of work and describe the equipment and processes that will be used to successfully complete that scope of work. Specifically, the document interfaces between the HSSE Management Systems of Fugro and its Subcontractors at the project specific level, demonstrates that all parties have the necessary procedures and controls in place to achieve the work program without compromising HSSE performance, and documents any project specific hazards that are not covered in the overall Project HSSE Plan, as well as the Project Emergency Response Plan.

The experience and lessons learned from previous intertidal work have been incorporated into the current bridging document. Measures to prevent vehicle and equipment leaks and/or spills, drilling fluid overflow from the mud pit, high tides entering the mud pit, disposing of remaining drilling fluid and artesian flow are explained in more detail in the corresponding sections. In summary, these measures include placing duck ponds under engines, covering the drill pit to protect it from the elements and high tides, and storing the drill cuttings and remaining water-bentonite mix in storage tanks. Special attention will be paid to the risk of drilling into a confined aquifer and the mitigation procedure that includes capping the borehole where artesian conditions may develop.

It should be noted that the Project Execution Plan (PEP) (AKLNG Fugro Document No. USAL-FG-GPZZZ-00-002016-001) dated March 28, 2016 developed for the proposed Alaska LNG Project (AKLNG) is the principle guiding document for the project and provides our approach from execution of the 2016 site investigation program to completing the various reporting deliverables as a part of the proposed study. This document was developed to discuss the borings located on the beach within the proposed project area.

2. SCOPE OF WORK

Details of the proposed AKLNG project and scope of work related to 2016 G&G was provided under Document No. USAL-FG-GPZZZ-00-002016-001 dated March 28, 2016. Based on the original scope of work the fieldwork consists of drilling two soil borings to a maximum depth of 200 feet below existing grade.

Plate 1 of this document shows the locations of all beach borings included in the original scope of work. Due to the land access restrictions, the following 2 borings (B-190 and B-191) will be attempted within the upcoming favorable tidal window.

A tentative tidal window between 10 and 17 of June has been identified based on the available forecasted tide charts. This window is marked on the NOAA Tide Predictions table presented in Appendix 1.

The intertidal work will be performed by a 3-man crew from Denali Drilling and a Fugro engineer with the Track Rig Nodwell (ND-56) to be used to perform the work. Additionally Denali will have a Drilling Supervisor onsite overseeing the drilling operations and logistics.

Movement plans for each tidal window will be generated based on following boring priority list that has been developed by Fugro and AKLNG technical teams.

1) B-190

2) B-191

3. BEACH FIELD LOGISTICS

The following section outlines onshore field logistics for the beach drilling activities:

- Depending on the instructions from site management and safety personnel, the onshore field personnel (i.e. Fugro and subcontractors) will drive to the ASRC's Rig Tenders (ARSC Site Office) facility in Nikiski for a toolbox meeting. Ingress/egress routes are illustrated on Plate 2.
- Tides and weather will be checked daily before accessing the beach, paying close attention to wind direction. Southwest to west winds will cause high waves along the beach, which will delay access until the tide recedes or requires early departure from a borehole to allow time to get off the beach. It should be noted the Agrium seawall boundary elevation is less than the boring pads in general and it is a controlling factor for ingress/egress logistics (Plate 2).
- The track drilling rig will access the beach through the ASRC Site Office facility or previously identified public access point. Access will be timed after the high tide cycle and suggested travel speed will be about 8-10 mph. Travel speed may vary relative to the beach/tide conditions. Borehole locations are presented in Plate 2.
- All support vehicles and the track rig will access the beach only when the tide is below tide mark of 14.5 feet and receding. The limiting factor for the mobilization/demobilization at the site is the Agrium seawall zone which has the lowest elevation (Plate 3).
- To limit potential problems with vehicles getting stuck on the beach and to prevent the area around the drill pad to be altered by vehicular transit, the number of vehicles accessing the beach will be limited to the essential. These are support vehicles bringing supplies (55-gallon barrels, water, bentonite, cement, etc.). Safety and supervising personnel shall carpool to the sites when practical.
- Based on the tide charts, working hours will be adjusted. Approximate workable hours are shown in Appendix 2a & b.
- The drill rig will be set-up above the high tide water line identified from the tidal charts (See Plate 4 and 5) on a level location if possible. If no level location is available, a leveled drill pad will be built up approximately 2 to 3 feet above grade on the sloping beach. A before and after elevation measurement will be taken to record actual sample depth.
- Drill fluid (water-bentonite mix) and cuttings will be contained in 55-gallon open top drums with lids. A tracked Skyjack VR-843D fork lift (Zoom Boom) will bring 55-gallon barrels to the work site. The barrels will be mounted on a pallet and transported to the site before the start of drilling operations. Potential water-bentonite mix spills will be collected and contained in these drums. At the completion of a boring, the drums will be transported back to ASRC by the Skyjack VR-843D fork lift, or a by a Caterpillar 980G Loader.
- A Komatsu 61P dozer will be used for equipment towing and to build up the drill pad. For the track mounted rig the dozer will be an emergency vehicle if the rig can't move under its own power.
- The crews will break for lunch every day for approximately 30 minutes.

- Cellular phones will be used to establish long distance communication between crew members and the management for the beach borings.
- Coastal bluffs are actively eroding. Care will be taken, especially below bare slopes or any non-vegetated slope, to avoid encountering debris that may fall, cascade, or ravel from the bluff face above. To minimize risk, each site will be evaluated and a safe distance to be maintained from the toe of the bluff will be established and documented in the daily JHA.
- At the end of each day the drilling rig will be left overnight at the drilling location or at an area above the anticipated high tide in that area. If a storm or unfavorable drilling conditions are anticipated overnight the drilling rig will be moved to a higher location or back to the ASRC site office.
- The drill rig will set up in a position to easily move off on its own, or to be extracted if required.
- In the case that artesian conditions are encountered while drilling the boreholes, procedure OS-GT-MS-003 will be use which was developed in collaboration of the Fugro Hydrogeology team and lesson learned and procures used in 2015. The procedure is in the next section.

3.1. PREVENTION OF GROUND CONTAMINATION BY SPILLS AND CONTROLLING ARTESIAN CONDITIONS

Several measures have been implemented for the intertidal zone drilling and sampling work of the 2016 AKLNG G&G program to prevent and/or mitigate potential incidents due to unfavorable weather conditions.

These measures are described in the following sections.

3.1.1. Prevention of Ground Contamination due to Drill Mud Pit Overruns and Spills During Drilling

To prevent ground contamination due to mud pit overruns and/or bentonite mud spills from the mud pit, the following measure will be in place:

- An impermeable tarp/ liner will be placed on the ground covering an area behind the drill rig to prevent spills from the mud pit to fall onto the ground. This tarp will be essential for containing bentonite mud and cutting spilling over the mud pit during drilling.
- Drilling fluid (primarily bentonite mud) remaining on the mud pit after the day's work, will be pumped onto the 55-gallon barrels for overnight storage. Drill cuttings will be periodically removed from the mud pit and stored in the 55-gallon drums. All barrels with cuttings and drilling mud will be removed from site at the end of the work.
- A mud pit cover will be placed over the mud pit when the drilling equipment is left at the site overnight. The mud pit cover will be secured with a ratchet strap so that it cannot be lifted and/or taken away by people or tides.
- At the end of the day, the borehole casing will be capped with the screw-on casing

weight used when driving it into the ground. The drill pipe will be lowered onto the casing weight to hold it down to prevent it from being unscrewed.

3.1.2. Controlling Artesian Conditions

During the intertidal zone work of the 2015 G&G program artesian conditions were encounter primarily at boreholes B-117 and B-136. Borehole B-136 produced a ground water flow that prevented the continuation of the drilling and sampling activities. Once artesian conditions were identified at both boreholes, drilling activities stopped and groundwater flow was controlled by injecting a dense mix of cement and bentonite. A metal cap was installed on the casing pipe at B-136. A heavy cement-bentonite mix was injected into borehole B-117.

Detailed procedures to be used for when artesian conditions develop at intertidal zone boreholes of the 2016 Geotechnical campaign are presented in Appendix 9 (Artesian Boring Abandonment Procedures OS-GT-MS-003). An operational summary of the actions to be taken when artesian conditions are presented in the following paragraphs.

- The drill crew and field engineer will monitor water pressure for noticeable changes during the drilling process, especially at depths similar to those where groundwater was encountered during the 2015 program.
- One screw-on metal cap (Plate 6a) will be staged at each borehole site in the event artesian conditions are encountered during the drilling process at either borehole location.
- An attempt will be made to recover as many 5-ft long casing sections below grade, before the flow control cap is installed onto the casing.
- Bags of cement and bentonite will be available at the borehole site in case they are needed.
- If artesian conditions develop during the drilling process, drilling will stop and procedures for plugging artesian conditions presented in Appendix 9 will be implemented.

3.2. DRILLING EQUIPMENT

For the intertidal drilling work phase Fugro and Denali are proposing to use a track-mounted CME-850X drilling rig designated as ND-56.

The ND-56 does not require mechanical modifications to able mast down and free the tracks. It would require modification to retract the leveling jacks. In order to avoid the modification to the leveling jack timers will be used at a height to minimize the amount of ram that is extended out. This will facilitate digging the material out from under the timbers to remove and allow the ram to be at height free to facilitate being towed to safe ground or off site.

The procedure for masting down and disengagement of the tracks is detailed in the next section as well as (Appendix 4).

3.2.1. Procedure for Removing Track Rig ND-56 “Nodwell” from the Intertidal

Zone

This section addresses primarily the emergency procedure for lifting hydraulic leveling jacks and removing the Nodwell from the intertidal zone. Procedures for removal of the drill rig is presented in Appendix 4.

4. HSSE MANAGEMENT SYSTEM INTERFACES FOR INTERTIDAL ZONE WORK

4.1. PROJECT OBJECTIVES AND TARGETS

It is the objective and target of Fugro to provide a safe and healthy place of work as well as to promote health, safety, and environmental protection for all personnel during this project. It is Fugro's belief that all accidents are preventable. For this project, the objectives and targets are to have zero time loss accidents and to promote positive HSSE culture at all times and at all levels.

4.2. BRIDGING PROJECT HSSE PLAN

This section has been developed to bridge the Project Safety Management Plan Part D of AKLNG Project Execution Plan, and ensure that the specified scope of work is executed in the same manner and in accordance with Client requirements.

5. HAZARD MITIGATION

5.1. UTILITY AND DEBRIS SURVEY

A shallow geophysical survey has been conducted to evaluate the presence of subsurface utilities or debris at the proposed boring locations. A combination of utility surveys (Ground Penetrating Radar (GPR), Electromagnetic Mapping (EM), and Radio detection techniques) has been performed.

5.2. WEATHER MONITORING

It is anticipated that sustained winds in excess of 15-20 mph coming out of the southwest/west could cause higher wave action and be a factor for the access to and from the borings. Weather will be assessed for the current work day along with a three-day project planning look ahead.

5.3. TIDE WINDOWS

Based on the previous experience (2015 geotechnical campaign), beach operations are anticipated to be conducted between June 10 and June 17, assuming a 19-feet high tide mark for safe work conditions. It should be noted that the final ground truthing for these two location was completed on May 23, 2016 and surveyed by Mclane Consulting and found favorable for the above tide window. The tide window will allow for at least a 3-ft safety margin between the highest tide expected during the selected window and the borehole pad elevation.

5.4. PERSONNEL EVACUATION

The area around the borehole location is, for the most part, high bluff to the north and Inlet water to the south. East and west access in a few areas could be restricted due to wave action or high tides above 17 feet.

A secondary foot route through private property has been identified between boreholes B-118 and B-119 of the 2015 Onshore Geotechnical Campaign (Plate 2). It is planned that this route would only be used if the safety of personnel is at risk. Notification to the land owner, although not required under this circumstance, is being done as a courtesy.

5.5. WELLFARE FACILITIES

Proper welfare facilities (drinking water, toilet, shelter) will be available in close proximity to the borehole sites. A comfort station / porta potty with hand cleaning station secured to a trailer that has been fitted with wide tires to accommodate the soft gravel and clay conditions. The comfort station will be towed the work location and place above high tide or it will be moved off location each evening by towing it by a support vehicle.

This comfort station will also be secured to prevent from accidentally being blown over by a gust of wind. Drinking water will be onsite and rain / sun shelter will be available and easily setup and anchored if required.

5.6. ADDITIONAL SUPPORT EQUIPMENT FOR BEACH ACTIVITIES

Additional support equipment that will be used during the beach drilling activities is listed below:

- 5.6.1. Skyjack VR-843D fork lift (Zoom Boom): Transport material and/or towing rig ancillary equipment.
- 5.6.2. Komatsu 61P dozer: Towing track-mounted drill rig, Caterpillar wide track dozer.

Specifications of the above listed equipment are presented in Appendix 3.

5.7. EQUIPMENT MITIGATION

As described above, this additional bridging document has been prepared to deal with the specific HSSE risks inherently associated with performing geotechnical drilling operations in an intertidal environment. There is potential for the drill rig or support equipment to become stuck, damaged, or lost and/or pollute the Cook Inlet with hydrocarbons. These risks have been identified, assessed, and mitigation measures will be in place to protect personnel and the environment prior to start the activities. The identified risks and mitigation measures are summarized below.

5.7.1. Vehicles Becoming Immobilized due to Soft Ground Conditions

Should the equipment become immobilized due to soft ground conditions, ASRC supplied equipment and operators will be standing by with their Komatsu 61P wide tracked dozer or Caterpillar D980G Wheeled Loader. As part of the preplanning the ASRC equipment operators will evaluate the site conditions and proper towing equipment will be available at ASRC Terminal. All towing configurations will be of proper rating and go through an inspection prior to use before they need to be used. Factory attachment points on equipment have been identified and visually inspected for fitness.

5.7.2. Mechanical Failure that Can Be Repaired on Location

In case of a mechanical breakdown, the field crew will immediately assess the gravity of the failure and communicate it to the site manager and drilling supervisor. Prior to performing any repair, the situation will require a close evaluation by the site manager and drilling supervisor of the tide and the type of repair and whether it is safe to perform a repair or to extract the equipment above the tidal zone.

As part of the contingency, essential spares will be addressed based on the past working history of each rig, and staged at ASRC facility.

5.7.3. Mechanical Failure that Can Not Be Repaired on Location

In case a mechanical failure occurs while the rig is over a borehole with the mast up and on the leveling jack the situation will be evaluated by the site manager and the drilling supervisor. If the mechanical breakdown cannot be repaired on location or if the allotted time does not permit a safe repair, the following procedures will be implemented.

- *Track-Mounted Rig (ND-56):*

a. If the breakdown does not affect the driving system, the track rig will demobilize from site and return to a repair location.

b. If the breakdown affects the driving system and/or the hydraulic system fails, it will be necessary to use an emergency procedure (Appendix 4)

When the driving tracks are successfully disengaged, mast is down and the block removed from beneath the leveling jacks the rig will be towed from its location with the aid of ASRC's equipment.

5.8. EQUIPMENT LEFT OVERNIGHT

It is anticipated that based on predicted tides and weather-permitting, the drill rig will be left on location for any borehole that is not completed. In the event that the drill rig must be moved off location and there is casing above ground, high visibility markers will be installed as an added precaution.

5.9. DRILLING FLUID AND SOIL CUTTINGS

During drilling operations, the drilling fluid (bentonite and potable water mix) will be circulated within the borehole and into a metal mud-pit. Soil cuttings are separated from the drilling fluid through a baffled system within the mud-pit. At the end of each drilling day the mud-pit will be covered. As a precautionary measure the amount of material in the mud-pit will be evaluated, and cuttings may be removed and drilling fluid may be reduced based on the weather conditions.

The drilling fluid and cuttings remaining after the drilling operations will be containerized in 55-gallon drums at the end of each borehole. Each drum will be labeled with their contents and hauled back to ASRC using a Skyjack VR-843D fork lift (Zoom Boom), or similar equipment.

Drums will be supplied by NRC Alaska LLC., and will be manifested and hauled away for proper processing and disposal.

5.10. REFUELING EQUIPMENT

When necessary, refueling will be performed at the Tesoro gas station for the rubber wheeled vehicles. We anticipate the track-mounted rig will conclude both boreholes within one favorable tide window. However, fuel levels will be checked periodically throughout the program and if necessary track-mounted rig will be refueled between two boreholes at the ASRC Facilities in alignment with Section 7.2.3 of this document.

5.11. ENVIRONMENTAL INCIDENT

Fugro will work with its contractors to set forth all necessary precautions to prevent and contain leaks or spills from equipment, and/or equipment failure. Inspections of all equipment will be performed as part of the preventive maintenance program, and to minimize the potential for spills.

The risk of an environmental incident(s) has been closely evaluated by the team and control measures have been put in place that include daily equipment inspections, proper material handling, and storage.

Additional safeguards will be in place to minimize the environmental impact from unforeseen incidents:

o The drilling crew will have spill prevention equipment (duck ponds, dippers, impermeable tarps etc) onsite to contain a spill from the rig.

o ASRC will have the frontend loader onsite at ASRC and within 20 minutes response to assist in preventing hydrocarbons from reaching the water.

o Duck ponds will be placed beneath vehicles' engines as a containment barrier. Ground barriers will be available to safely facilitate a minor repair if required.

o A marine spill response kit will be staged onsite. A list of items included in the spill response kit are listed in Appendix 5.

All Fugro personnel shall wear appropriate personal protective equipment (PPE). It is the responsibility of each individual to bring and to wear PPE as required by the specific task being performed, the potential hazards that a person will be exposed to, and the specifics of the jobsite. Personnel must adhere to the PPE requirements recommended on the SDS/MSDSs for material handling and required on the TRAs produced to assess the risk of that task.

The use of PPE shall comply with federal, state, and local regulations and shall be routinely inspected for defect that would compromise the intended use. All PPE shall meet ANSI or equivalent international standard.

5.12. PERMIT-TO-WORK CHECKLIST

Fugro has developed a permit-to-work checklist that will be reviewed before and after daily drilling operations. This document is presented in Appendix 6.

6. COMMUNITY INTERACTION

A portion of the land on the public beach area is private and owned by others. AKLNG land agents are involved and working with the project team to ensure that proper communication and notification are in place if required. In addition if there are any boundary issues they will be clearly marked to aid in reducing possible trespass occurrences with private land owners and communicated to the onsite team.

AKLNG land agents will be onsite and available to provide any needed information interface that cannot be addressed with the AKLNG information cards. In addition, an AKLNG community relations representative will be on call and available to come to site to assist if needed.

The Site Manager will ensure the crews all have the AKLNG cards with information and phone numbers that will connect the public with a single point of contact at AKLNG. A land agent will be available to answer question from the community or land owners for any situation related to lands. Fugro will report public interactions (e.g. location, date, time, names, claims/complaints, etc.) on a daily basis and document on the daily JHA.

7. PROJECT ORGANIZATION

The below organization chart refers to the Fugro and contractor leadership that will be in place to ensure the proper supervision and experience to execute this scope of work safely and without incident.

7.1. ORGANIZATION, RESOURCES, AND DOCUMENTATION

7.1.1. Project Organization Chart

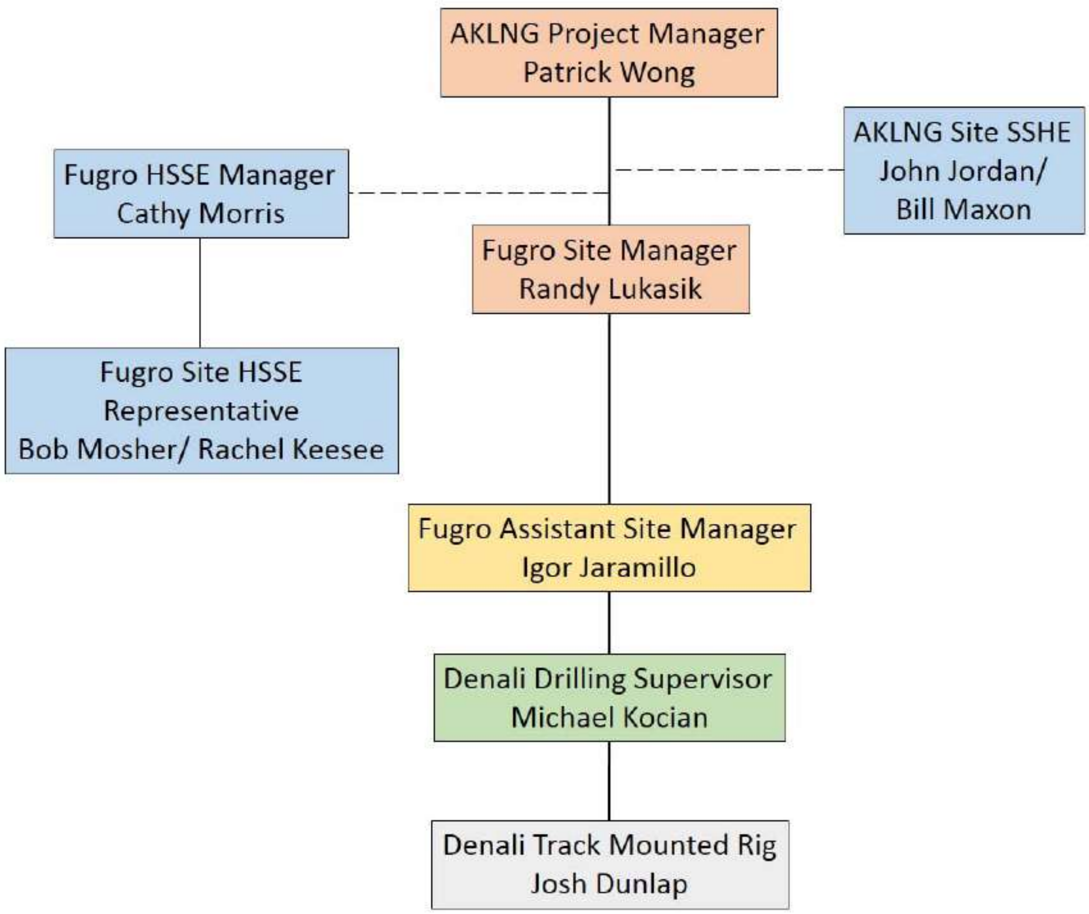


Figure 1 - Project Organization Chart

7.1.2. HSSE Meeting Structure

It is recognized that a safe-work culture is essential knowledge for all participants and the review by the Crew of the Project HSSE Plans and pre-job orientation alone are insufficient. In an effort to disseminate and reiterate safe-work policies, a pre-work scope safety meeting for the intertidal work along with daily tools box meeting will be implemented and also held on a task-related basis or when any of the crew feels it is appropriate. The morning meetings will be documented on the JHA along with an end of the day close out:

- Date, time and environmental conditions (weather forecast, wind strength and direction);
- Environmental concerns and/or hazards
- PPE Required
- Expected activities
- Review of applicable Task Risk Assessment (TRA's)
- Observation
- Land Agent and Contact number

It is important to note that safety considerations are not generated solely from previously occurring accidents. Near-miss incidents and accident prevention measures contribute significantly to a successful safety program. Accordingly, active crew member involvement, such as reporting near- miss incidents and adopting an outspoken attitude toward safety, is a crucial element in the achievement of our project HSSE goals. Hazard observation reporting will be encouraged and appropriate actions will be taken towards any hazards reported. For reporting of hazards, the Hazard Observation Card will be used.

7.1.3. Method of Statement (MS) and Task Risk Assessments (TRAs)

Onshore geotechnical drilling method of statements is presented in Appendix 7. A Task Risk Assessment will be prepared prior to start of any activity requiring hazard management. These documents will be reviewed with all applicable personnel prior to start of activity.

If there is any management of change (MOC) issues encountered during the project, applicable TRAs will be re-visited to assure that any new or elevated risks are assessed and addressed. Below listed TRAs will be in place for this scope of work (see Appendix 8).

- Drilling Operations Denali - DO11
- Fueling Operation – Denali - OS-GN-TRA-003
- Drill Rig Maintenance – Denali – D012
- Retrieval and Towing Off Highway – ASRC

7.1.4. Hazard Observation Cards (HOCs)

The Fugro "Hazard Observation Card (HOC)" program will be utilized throughout the project.

This card is used by any employee of Fugro Consultants, Inc., any Fugro subcontractors, client or visitor to report the following:

- **Safe Act or Suggestion**

Any exceptional safe act or suggestion that promotes safe working practice and demonstrates good safety awareness.

- **Unsafe Act or Condition**

An unsafe act is a specific action or lack of action by an individual e.g. removal of safety guards, standing under a suspended load, not following a procedure or, An unsafe condition is a situation or event which may result in an accident e.g. poor housekeeping, blocked escape routes, unguarded or defective machinery, lack of edge protection, etc. All completed cards must be reviewed by the Site Supervisor and where appropriate the necessary remedial action(s) taken.

As part of Fugro's Corporate HOC tracking system, HOC cards must be entered into the IMPACT data base or submitted to the HSSE department for entry.

7.1.5. Management of Change

Prior to the acceptance of any significant change to equipment, personnel, or safety procedures a management of change (MOC) form must be completed and approved by qualified personnel. The project manager in conjunction with HSSE Manager or Operations Manager can approve MOC. All completed MOC forms should be submitted to the FCL HSSE Manager within 24 hours.

7.1.6. Environmental Considerations

7.1.6.1. Weather Constraints

Heat illness awareness and prevention should be reviewed with all personnel if conditions change. At a minimum, an area to get out of the sun and plenty of drinking water must be available to all personnel.

Lightning Storms are not common in the region. If encountered all work activity will stop during lightning storms and all personnel will either assemble in a safe location or evaluate the weather conditions if leaving the site is required.

7.1.6.2. Rest Management

Rest / Fatigue can be a factor in incidents or risk to workers. A rest management program is built into the project along with a standard work day consisting of 12-14 hours which includes to and from travel accommodations. Workers should be aware that when they feel fatigued, they should rest. Supervisors should monitor workers activities and behavior to determine if a worker should be removed from the work site in order to rest. Additionally the project has built in rest weekend. A management of change will be implemented to have two rest days prior to commencement of this work since the start of the optimum tides is going into a rest weekend.

7.1.6.3. First Aid

A first aid kit and spill response kit must be available and in an easily accessible area. The first aid kit and spill kit will need to be removed from the vehicle and placed in an area where all crew member. The location of these items should be discussed in the daily safety meeting.

8. HSSE RESPONSIBILITIES

All project personnel have Stop Work Authority, giving them the right to stop work on the project at any time they believe an unsafe condition exists. All project personnel have the RESPONSIBILITY to stop the job if they believe that the work environment or procedures could jeopardize their personal health or safety, the health and safety of other personnel, or the environment. All personnel are required to report any unsafe working conditions to their immediate onsite supervisor.

Work will not resume until the site management has had an opportunity to investigate the concerns and ensure that work can resume safely.

8.1. EMERGENCY RESPONSE FLOW CHART

In the event of an emergency, use the following chart to determine points of contact.

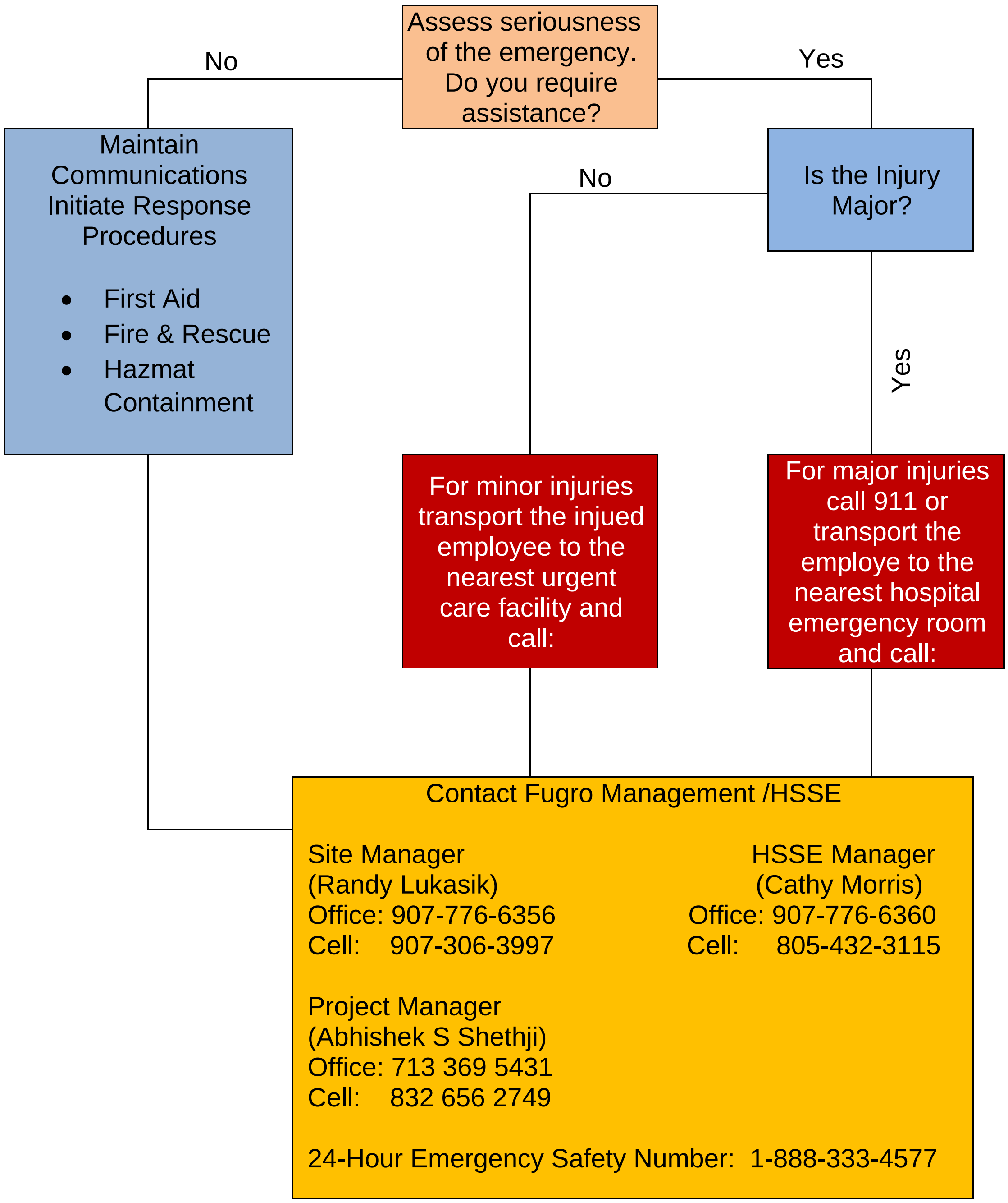
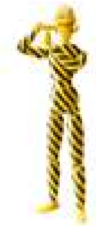


Figure 1 - Emergency Response Chart

ILLUSTRATIONS

24-Hour Emergency Safety Number 1-888-333-4577	METHOD STATEMENT	No: OS-GP-MS-002	
DOWNHOLE SEISMIC TESTS GEOMETRICS GEODE & GEOSTUFF BHG-2			

CONTENTS

Developed by:	Reviewed/authorized for issue by:
David Valintine – Geophysical Services Manager Alex Olive – Field Geophysicist	

A METHOD STATEMENT IS ONLY EFFECTIVE IF IT IS DISCUSSED AND AGREED BEFORE WORK BEGINS AND THEN FOLLOWED BY THOSE CARRYING OUT THE WORK.

FUGRO 24-Hour Emergency Safety Number 1-888-333-4577	METHOD STATEMENT	No: OS-GP-MS-002
DOWNHOLE SEISMIC TESTS GEOMETRICS GEODE & GEOSTUFF BHG-2		

1. Introduction

This document outlines the general procedure adopted by Fugro Consultants, Inc. (Fugro) for onshore Downhole Seismic tests for the AKLNG project in Nikiski, Alaska.

2. Main Activity / Area of Work

Downhole Seismic tests may include, but are not limited to;

- Off-road driving vehicles to transport equipment on site
- Deployment of equipment within cased borings
- Use of a sledgehammer energy source
- Data collection with a Geometrics Geode

The Downhole Seismic Logging surveys tests will be conducted at up to 10 locations, located on a mixture of AKLNG property, private property and public right of ways on the proposed AKLNG liquefaction site in Nikiski, Alaska, approximately between mile posts 20 and 22 of the Kenai Spur Highway. Scope of Work Drawings can be found in Appendix A of the Project Execution Plan.

3. Manpower and Supervision

Nominated Person	Responsibility
Project Geophysicist	• Provide specifications for the data acquisition • Advise Field Geophysicist on the project requirements and the requirement to comply with this method statement in order to enable the work to be carried out safely and obtain the required quality.

24-Hour Emergency Safety Number 1-888-333-4577	METHOD STATEMENT	No: OS-GP-MS-002
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Nominated Person	Responsibility
Field Geophysicist	• Overall responsibility for all site activities • Review method statement and associated Task Risk Assessments (TRA) with employees performing the task • Regularly inspect activity for compliance • Communications with the project manager, site manager and project SSHE staff during the data collection operations • Take custody of electronic data files and site notes
Geophysical Technicians	• Compliance with this method statement, company HSE requirements and taking guidance from Field Geophysicist
Wildlife Safety Specialist	• Reconnaissance of Area of Work for signs of wildlife activity and advising geophysical personnel appropriately • Remaining on guard during the geophysical site work and monitoring for wildlife • Maintain visual contact with geophysical field personnel

4. Associated Documents (Drawings, Manuals, Method Statements, Plans, Permits)

Document	Reference Number
AKLNG Project Execution Plan, specifically; Field Exploration Plan (Part A, Section 3.4.2) Project Safety Management Plan (Part D) Scope of Work Drawings (Appendix A) Traffic Control Plans (Appendix G) Task Risk Assessment Register (Appendix M) Emergency Response Plan (Appendix O)	
Alaska LNG – LNG Facilities Onshore Geophysical Survey Specification	USAL-PL-GSZZZ-00-000001-001
ASTM – Standard Test Methods for Downhole Seismic Testing	D 7400 - 08

METHOD STATEMENT	No: OS-GP-MS-002
DOWNHOLE SEISMIC TESTS GEOMETRICS GEODE & GEOSTUFF BHG-2	

Document	Reference Number
Safety Data Sheet – 12v Lead Acid Batteries	-

5. Task Risk Assessments

Number	Title
ON-GP-TRA-101	Downhole Seismic Tests – Data Acquisition
ON-GN-TRA-303	Thunder and Lightning Storms
ON-GN-TRA-310	Vehicle Usage
ON-GN-TRA-311	Material Handling and Moving
ON-GN-TRA-324	Battery Charging
ON-GN-TRA-348	Driving on Jobsites
ON-GN-TRA-349	Driving Off Road

6. Security - Barriers/Fences/Warning Signs

Where the drill pad locations for the Seismic Downhole tests encroach on public roadways or right of ways, traffic control measures will be implemented. The work will be classified as shoulder work and the Traffic Control Plan for this type of work can be found in Appendix G of the Project Execution Plan. Signage and cones will be deployed by Northern Dame, a specialist traffic control subcontractor.

As the Downhole Seismic tests usually take 1½ - 2 hours to complete, it is anticipated that testing will be completed by the end of the work day and therefore no equipment will be left on site unattended. Should it be required to leave the location during testing, all equipment should be barricaded when personnel are not in attendance.

7. Constraints/Restrictions/Special Conditions

The Downhole Seismic tests will be conducted on a combination of AKLNG, state, borough and privately owned property. The AKLNG Land Agents are responsible for obtaining a right of entry permit for each property. The Site Manager will develop a 5-day look ahead schedule, who will then relay this information on to the Land Agents with a request for notification of any special

Right of Entry (RoE) restrictions for the upcoming (and adjacent) parcels. During daily logistics meetings, the Field Geophysicist and Site Manager will communicate on areas where work will be performed on subsequent days to ensure any special RoE restrictions are understood.

Raptors, migratory birds, moose, bears, wolves, nuisance plants, insects on and other local wildlife may potentially be encountered while working on the project. All personnel will receive awareness training on such wildlife during the project induction. In addition, Wildlife Safety Specialists will be available to accompany the field crew (where and when deemed appropriate by Fugro, AKLNG and local professionals) to assess and monitor for the presence of such wildlife during field activities.

Extra precautions should be implemented in inclement weather conditions such as heavy rain and thunder / lightning storms. The instrument and all cable connectors should be protected against rain and / or surface water. During thunder / lightning storms, the downhole geophone is essentially a long, grounded conduction and therefore data collection activities should cease and all cables disconnected. Further information regarding general work activities during such inclement weather can be found in Task Risk Assessment ON-GN-TRA-303 Thunder and Lightning Storms.

8. Plant and Equipment

The following equipment may be used to facilitate access to the test locations:

- Support vehicle (to transport equipment to / along survey profiles)
    - 4wd pickup is preferred where site access permits
    - 4wd Jeep with off road tires (if inaccessible with pickup)

As a pickup truck and Jeep are both considered to be standard vehicles, other than a driver's license, no special training or certification is required for operation. Guide regarding their use can be found in Task Risk Assessments ON-GN-TRA-310 Vehicle Usage, ON-GN-TRA-348 Driving on Jobsites and ON-GN-TRA-349 Driving Off-Road.

The following equipment may be used for the Downhole Seismic Logging surveys:

- Geometrics Geode seismograph;
- Geostuff BHG-2 borehole geophone with 300ft cable;
- Geostuff BGC-1 borehole geophone controller
- 12v battery (sealed AGM if available) for external power source
- Field laptop
- 16lb sledgehammer with piezo trigger, metal strike plate and shear wave beam
- Tape measures and misc. survey-related consumables, etc.

In addition to the equipment list above, the following spare parts should be available locally in the event of failure, damage or loss:

    - 2x Trigger cables

- Field Laptop
- 12v battery (sealed AGM if available)

Contact should also be made with equipment manufacturers and multiple third party equipment rental companies prior to the commencement of the project to ensure that replacement components, in addition to the spare parts list above, can be shipped to site at relatively short notice (to arrive on site within 48-36 hours).

9. Materials (handling/storage/disposal)

No investigation derived waste or contaminated materials are expected to be generated.

The Downhole Seismic equipment uses both internal, sealed batteries and external 12v batteries as power sources that should be charged prior to use. Should these batteries become exhausted during the site works, additional external 12v batteries can be used to power the equipment (laptop, geophone controller and seismograph). Under normal operating conditions, personnel will not come in contact with fluids within the batteries. In the event of unplanned events, such as the integrity of the battery housing becoming defective, refer to the appropriate Safety Data Sheets for the type of battery being used for handling and first aid response if. For further guidance on the use and charging of batteries, refer to Risk Assessment ON-GN-TRA-324 Battery Charging. In addition, disposal of spent batteries is covered under the Routine Waste section of Project Safety Management Plan (Part D of Project Execution Plan) in which segregated recycling / waste disposal receptacles have been set up at the site office for collection and transportation onto the Kenai Peninsula Borough Waster Transfer Station.

The total weight of the laptop, seismograph and borehole geophone controller required to perform Downhole Seismic tests surveys is approximately 40 lbs. Typically, the tests are conducted from the back of a pick up and good material handling skills are required for loading / unloading equipment.

The shear wave beam is approximately 8 feet in length and therefore difficult to handle alone. Where suitable, use two-man lifting techniques and correct material handling is paramount while transporting equipment across rugged terrain.

10. Preparation of Works/Location of Services

As detailed in the Project Execution Plan, preparation of the test locations will be performed by Greatlands. It is understood that site clearing will be conducted for drill pads with the dimensions of 60’ x 60’, and centered on the borehole location and therefore there should be more than sufficient access for a pick up truck. No other site preparation is anticipated.

The location of the test locations are in the Project Execution Plan. On a daily basis during tool box talks and JHA completion, the specific locations of the survey activities, along with ingress and egress routes will be discussed.

11. Emergency Procedures

The Emergency Response Plan can be found in Appendix O of the Project Execution Plan.

The field crew will include a First Aid / CPR trained person and a first aid kit with saline eye wash will be available on site. Additionally, a roaming Wildlife Safety Specialist carrying an AED will be available to crews. Each field team will carry laminated cards with contact numbers of key project personnel (site manager, SSHE contacts) and local facilities (fire / EMS departments, hospitals etc.). In addition, at least one person per team will be registered with the Kenai Borough Council, Office of Emergency Response, Rapid Response Notification System, which provides reports of local emergency / heightened awareness situations / conditions (severe weather, earthquake, tsunami, etc.).

12. Personal Protective Equipment (PPE) & Safety Equipment

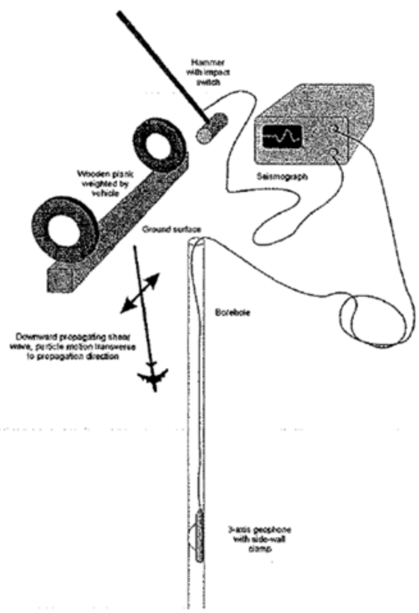
The following personal protective equipment will be worn:

Item	Detail
Safety footwear Work gloves Safety glasses Hearing protection	As per requirements of Task Risk Assessment ON-GP-TRA-101 Downhole Seismic Tests – Data Acquisition
Hard hat Reflective work vest Body protection (long sleeve shirt & pants) Sun screen Insect repellent	As per requirements of Project Safety Management Plan (Part D of Project Execution Plan)

Additional personal protective equipment to comply with the accompanying SDS guidelines and for unplanned site operations (such as vehicle maintenance or recovery) should be procured and readily available locally (i.e. at site office).

13. Photos / Images

Geometrics Geode seismograph (left) and Geostuff downhole geophones and controller (right)



Schematic showing deployment of equipment

14. Methodology & Sequence of Work

14.1 Overview

This section of the Method Statement outlines the general procedure adopted by Fugro Consultants, Inc. (Fugro) for Downhole Seismic Logging surveys.

Rather than designating a specific course of action, this document offers an organized collection of information and technical guidance. This document cannot replace the education or experience of a trained geophysicist, and should be used in conjunction with professional judgment. Not all aspects of this procedure may be applicable in all circumstances. This procedure is not intended to represent or replace the standard of care by which the adequacy of a given professional service is performed, nor should this document be applied without the consideration of a project's many unique aspects.

14.2 Referenced Documents

Fugro Consultants, Inc. – Quality Management Forms

- Quality Management Form F-305 – Field Instructions – Land Based Geophysical Projects
- Quality Management Form F- 306 – Geophysics Field Log
- Quality Management Form F-351 – Downhole Seismic Acquisition Log
- Task Risk Assessment – Downhole Seismic Tests – Data Acquisition

ASTM and Other Industry Standards

- ASTM D7400 Standard Test Methods for Downhole Seismic Testing

Other References

- Alaska LNG – LNG Facilities Onshore Geophysical Survey Specification
- Manual: Gemetrics Geode Operator's Manual
- Manual: Geostuff Wall Lock Geophone User's Manual
- Technical Paper: Shear Waves – Techniques and Systems by Doug Crice (Geostuff)

14.3 Survey Planning

Site-Specific Considerations

The field geophysicist should familiarize themselves with the objectives of the investigation as detailed in the Clients request for proposal / project specifications, Fugro's proposal and pertinent information as outlined on the Field Instructions (Quality Management Form F-305).

Prior to mobilizing to the test locations, the field geophysicist should study drillers' notes, borehole logs or geological maps to gain an understanding of the near-surface geological conditions that are likely to be encountered within the depth of the borings. The drillers' notes and installation record should also be reviewed to assess any drilling abnormalities and to check an appropriate grout mixture and volume were used during the installation of the pvc casing for the Downhole Seismic test. Further information on borehole preparation can be found in ASTM D7400.

The field geophysicist should review site-specific information pertaining to other on-site operations and any existing equipment that may be generating vibrations and influence the recorded data. Such features may include but are not limited to; heavy plant, construction activities, blasting operations, percussive drill rigs, dynamically loaded foundations including vibrating machinery such as turbines or generators.

In addition the field geophysicist should also bear in mind the requirement for good coupling between the shear beam and ground when performing a downhole test. Downhole tests are not typically conducted on concrete surface and it is usually recommended that any concrete be excavated prior to the testing to allow placement of the shear beam directly onto the underlying sub-grade / sub-base materials.

Pre-Mobilization Checks

Prior to the mobilization of the survey equipment, the Field Geophysicist shall conduct the following checks; -

- Check the date of last manufacturer service / calibration;
- Check the date of last in-house equipment checks;
- Review any Non-Conformance Reports pertaining to the survey equipment;
- Visual inspection of the equipment for any obvious signs of excessive wear and tear;
- Inventory all equipment and accessories as per Manufacturers and / or Fugro's Shipping Lists;
- Identify and itemize any additional items of equipment and / or accessories that may be needed to comply with project specific requirements.

Should any of the above checks identify any reason why the equipment may not operate as required, the Field Geophysicist shall inform the Geophysical Services Manager to develop corrective actions as necessary.

Upon completion of the above checks, all equipment should be packed into suitable shipping containers ready for mobilization to site and the Geophysical Services Manager informed of the mobilization plans.

14.4 Site Work

Equipment Set-Up

All equipment and cables should be assembled in accordance with the manufacturer's Instructions (see references above).

The center of the shear beam should be located on flat ground between 3 ft and 10 ft from the borehole. If the ground surface is undulating, attempts should be made to level the ground surface to provide secure coupling with the shear beam. Any vertical offsets in the ground surface between the shear beam and the borehole should be recorded.

Once the shear beam is situated in the required position, a load should be applied to it to reduce movement when struck. The preferred method is to park a vehicle with 2 wheels on top of the shear beam. An alternative approach is to load the shear beam with sand bags (or other similar ballast) and have the operator stand on top of the beam whilst striking it.

The plate used for the p-wave source should ideally be located at an identical offset from the borehole as the shear beam. Any vertical offsets in the ground surface between the plate and the borehole should be recorded.

The distance between the center of the borehole and the center of the shear beam and plate should be measured and recorded on the data acquisition log.

Typically, the depth of the geophone is referenced to the top of the pvc casing.. This stick up height should be recorded to allow the depths to be reduced so they are relatively to ground level.

Pre Data Acquisition Quality Control Checks

The Geophone clamping mechanisms should be tested prior to lowering the geophone(s) into the borehole(s).

The Geode Seismograph and field laptop shall be powered up and an appropriate, record length, sampling interval and delay should be set.

Prior to inserting the downhole geophone into the borehole, a background noise test should be performed in order to validate the cable connections and identify any equipment related noise within the system.

Finally, a unique the file path and unique file numbering system should be selected for the acquisition and storage of the raw seismic data files. The operator should determine the digital channel number on the seismograph for each of these component prior to deploying the geophone within the boring.

Data Acquisition

Lower the downhole geophone into the borehole. Typically, a single geophone will be deployed into the borehole, although it also acceptable to deploy a pair of geophones separated by a fixed vertical distance into a single borehole.

The depths for the project shall be at 5-foot intervals from the base of the cased borings to 25 feet depth, and then at 2½-foot intervals to the ground surface.

When the downhole geophone is at the desired test location, activate the geophone clamping mechanism until the geophone is firmly clamped to the borehole wall, allowing it to maintain its position without slipping.

The preferred data acquisition method involves recoding three data channels in each file; namely the longitudinal and transverse geophone components to capture shear wave arrivals, and the vertical component for compression wave arrivals. At each test depth, three separate files should be recorded for striking the shear beam at each end and for striking the plate. The operator should note each file number for each of source actuations.

Pull the geophone(s) up to the next test depth, controller and repeat stages 4.3.5 through 4.3.10, until measurements have been acquired at all required depth intervals.

Field Notes and Observations

The field Geophysicist should at minimum record the following data using the field acquisition logs;

- Borehole ID;
- Time & date, weather conditions;
- General site conditions including description of surficial soils and appearance of borehole collar and casing;
- File numbers and test depths;
- Channel numbers within the data files of the transverse and longitudinal geophone components for both strikes of the shear beam and the vertical component for the strike of the plate;
- Horizontal and vertical offset of the center of the shear beam and plate from the borehole collar;
- Height of casing stickup;

- Other observations that are considered relevant, such as proximity to vibrating plant or machinery.

Equipment Tear Down

The Field Geophysicist should ensure that the equipment is completely powered down and batteries disconnected (if an external battery source is used).

As equipment is packed away for transportation, an inventory should be taken to ensure all equipment has been removed from site and any possible defects / deficiencies noted for entry into Non-Conformance Reports / Observations.

Site Restoration

Under normal operating conditions, the footprint of the Downhole Seismic tests equipment is minimal and therefore other than the removal of household trash, site restoration is not anticipated to be required.

After demobilizing the equipment from the profile, the Field Geophysicist will be responsible for traversing the profile to ensure the ground surface has not been impacted. Should any disturbance be noted, the Field Geophysicist should contact the Site Manager prior to leaving the site to discuss effective site restoration strategies.

14.5 Post Site Work

At the earliest possible convenience after acquiring data, or at the end of every day or shift of acquisition, the electronic data files should be downloaded from the survey equipment and stored on a computer.

The Field Geophysicist should ensure that the data files are named or stored under directories with a logical naming convention to avoid accidental deletion or duplication and to ensure others can readily identify the nature of the contents of the files.

It is recommended that any site notes recorded in paper format be transferred to electronic files (scanning or data entry) and saved with the downloaded files.

The downloaded files should also be backed up to removable media, such as a floppy diskette, cd, or usb flash drive. The removable media should then be stored in a different location to the computer to avoid theft, loss or damage of both copies of the data.

For projects with a duration of more than three days, the data should also be transmitted (ideally) on a daily basis to Fugro's Houston office and transferred to the central server storage on a regular basis.

After demobilization, it is the Field Geophysicist responsibility to ensure that all electronic data files have been transferred to the central server, if not already done so.

The Field Geophysicist will be responsible for ensuring that all field logs, sketches and other paper records that we obtained on site are transferred to the project folder and scanned and saved on the central server.

The Field Geophysicist shall also be responsible for ensuring all equipment is demobilized, cleaned and stored. Should any faults, problems or non-conformances been observed during the site works, these will also be documented accordingly.

15. Appendices

Reference	**Title**
ON-GP-TRA-101	Downhole Seismic Tests – Data Acquisition

24-Hour Emergency Safety Number
1-888-333-4577

TASK RISK ASSESSMENT ON-GP-TRA101

DOWNHOLE SEISMIC TESTS – DATA ACQUISITION

ACTIVITY:	Downhole Seismic Tests	Date:	05/25/16
Department Involved:	Geophysics	Client:	AKLNG
Title of Person Performing Task:	Field Geophysicist, Technicians	Location of Activity:	Nikiski, AK

Please Remember: All hazards are important. Make notice of all possible hazards. Detailed safe job procedures are necessary. Awareness, teamwork, communications, and alertness apply to every situation. Use complete recommendations to eliminate or reduce hazards. This Task Risk Assessment is a compilation of potential hazards that should be expected while conducting this task. If actual work conditions or hazards require deviations from this Task Risk Assessment the employee must take the appropriate safety measures and document any changes to the Sequence of basic job steps, potential accidents or hazards, and recommendations to eliminate or reduce potential hazards listed or not listed in this Task Risk Assessment. Changes should be documented on the Jobsite Hazard Analysis (JHA) form. In addition, hazards associated with jobsite conditions should be documented on the JHA and communicated to those involved in the task.

Description of Activity / Task:

Downhole Seismic tests may include, but are not limited to;

- Off-road driving vehicles to transport equipment on site
- Deployment of equipment within cased borings
- Use of a sledgehammer energy source
- Data collection with a Geometrics Geode

PERSONAL PROTECTIVE EQUIPMENT:

	Hard Hats		Fire Extinguisher		Class 2 Reflective Work Vest
X	Safety Shoes	X	Safety Glasses w/ Side Shields		2- Life Rings w/ 90' Floating Line
X	Hearing Protection		Goggles		Tag Lines
X	Cotton Gloves		Face Shield		Work Permit Required
X	Leather Gloves		Back Belts		Lockout/Tagout
	Rubber Gloves		Safety Harness	X	Barricade (for public sites)
	Welder Gloves		Floor Mat		Snake Chaps
	Welder Helmet		Dust Mask	X	Traffic Cones

TASK RISK ASSESSMENT ON-GP-TRA-103
VERTICAL ELECTRICAL SOUNDINGS

Job Steps	Hazards	Population At Risk	Initial Risk Rating	Controls Measures	Residual Risk Rating	Risk Action
All site visits	General hazards	Employee Contractor	B3	Refer to site-specific JSA's for hazards related to the environment of the work area. Wear reflective work vest if heavy equipment is being operated in the area or testing is being performed near a roadway. Be aware of access / egress and emergency evacuation routes and procedures	B2	LOW
Mobilization of equipment to work area	Manual handling - muscular injuries	Employee	C3	Where possible, use mechanical assistance. Be aware of individual's strength limits Perform warm up and stretching exercises prior to performing lifting activities. Limit lifts to <50 lbs Lift with caution keeping your back straight and using your legs when lifting Wear appropriate PPE (leather gloves and steel toe boots) Be aware of any potential pinch-points	B2	LOW
	Traffic accidents	Employee Public Reputation	C4	Practice defensive driving. Review GP-310 Vehicle Usage. While on site particular care should be used by following the site specific speed limits and traffic signs. Obey all site posted warning and regulation signs.	B3	LOW
Set - up equipment	Trailing cables and wires - slip / trip hazard	Employee Public	C2	Restrict access to the work area Keep ingress / egress route clear Before moving equipment, walk the path of travel to remove any slip, trip, or fall hazards. If these hazards cannot be removed, select another path of travel. Use gloves and safety glasses if electrode require hammering into the ground	B1	LOW

TASK RISK ASSESSMENT ON-GP-TRA-103
VERTICAL ELECTRICAL SOUNDINGS

Job Steps	Hazards	Population At Risk	Initial Risk Rating	Controls Measures	Residual Risk Rating	Risk Action
Set - up equipment (continued)	Manual handling - muscular injuries	Employee	C3	Lift with caution keeping your back straight and using your legs when lifting Limit lifts to <50 lbs. Utilize team lifts for heavy and awkward objects	B2	LOW
	12v Battery related incidents - electrical and chemical hazards	Employee	B3	Keep battery in a dry and clean environment Use gel cell batteries where possible Safe guard against damage to or spillage from lead acid batteries Ensure battery connections are kept in good working order (no frayed wires etc)	A2	LOW
	Vehicle related incidents - positioning truck on shear wave beam	Employee Public Asset	C4	When possible, position rear wheels of vehicle on shear wave beam and if ground surface is sloping, face vehicle downhill. Reverse truck up to boring in a perpendicular manner, and then place shear wave beam behind rear wheels so truck and beam are square and aligned with each other. Use dunnage to create a ramp to allow vehicle to be driven onto shear wave beam. Use a spotter, stood on the drivers side of the vehicle to help position wheels on shear wave beam. Activate park brake and emergency break when truck is positioned on top of shear wave beam. In case of failure of vehicle brakes, use chocks to the rear of the front wheels and set out cones for 30 feet in front of vehicle. The intention here is to ensure that in the unlikely event of brake failure, the vehicle moves forward and therefore away from the work area at the rear of the vehicle.	C2	

TASK RISK ASSESSMENT ON-GP-TRA-103
VERTICAL ELECTRICAL SOUNDINGS

Job Steps	Hazards	Population At Risk	Initial Risk Rating	Controls Measures	Residual Risk Rating	Risk Action
Set - up equipment (continued)	Insects / Animals	Employee	C1	Area to be scanned by Wildlife Specialist for any animals. Keep clear of any wildlife. Keep vehicle accessible for safe harbour Wear insect repellent. Maintain a first aid kit onsite.	A1	LOW
	Nuisance/poisonous vegetation	Employee	C1	Nuisance/poisonous plants discussed in project induction. Determine what types of nuisance/poisonous vegetation might be in the area. Keep clear of suspect vegetation. Wear appropriate clothing to avoid contact with vegetation. Stay in cleared areas	A1	LOW
Operation of equipment	High noise levels near Seismic source (downhole seismic only)	Employee	C2	Use hearing protection (light ear plugs sufficient)	B2	LOW
	Crush / pinch points on seismic source	Employee	C2	Only source operator to be near source during shooting of seismic data Wear appropriate PPE (leather gloves and steel toe boots)	B2	LOW
	Instrumentation in ground - slip / trip hazards Trailing cables and wires - slip / trip hazard	Employee Public	C2	Be aware of trigger cable and geophone cable on the ground when walking around the jobsite. Keep visual surveillance of the work area.	B1	LOW
Disassemble equipment	Instrumentation in ground - slip / trip hazards Trailing cables and wires - slip / trip hazard	Employee	C2	Keep feet out of coiled cables during retrieval. When not using cables they should be coiled up and stored out of the path of travel.	B1	LOW

TASK RISK ASSESSMENT ON-GP-TRA-103
VERTICAL ELECTRICAL SOUNDINGS

Job Steps	Hazards	Population At Risk	Initial Risk Rating	Controls Measures	Residual Risk Rating	Risk Action
Demobilization	Manual handling - muscular injuries	Employee	C3	Where possible, use mechanical assistance. Be aware of individuals strength limits Perform warm up and stretching exercises prior to performing lifting activities. Limit lifts to <50 lbs Lift with caution keeping your back straight and using your legs when lifting Wear appropriate PPE (leather gloves and steel toe boots) Be aware of any potential pinch-pointsAdditional care to be taken due to fatigue	B2	LOW
	Dropping equipment on legs or feet	Employee	C3	When carrying equipment, proceed with caution holding the sample firmly. Wear appropriate gloves to help maintain grip on equipment. Wear steel toe boots or upper foot guards to protect feet	B2	LOW
	Traffic accidents	Employee Public Reputation	C4	Practice defensive driving. Additional care to be taken due to fatigue	B3	LOW

TASK RISK ASSESSMENT ON-GN-TRA-103
VERTICAL ELECTRICAL SOUNDINGS

Risk Matrix and Risk Actions

					Likelihood				
Hazard severity	**Reputation**	**Assets**	**Environment**	**People**	**A - Very unlikely** (a freak combination of factors required for incident to result)	**B - Unlikely** (a rare combination of factors would be required for an incident to result	**C - Possible** (could happen when additional factors are present but otherwise unlikely to occur)	**D - Likely** (not certain to happen but an additional factor may result in an accident)	**E - Very Likely** (almost inevitable that an incident would result)
1.Slight	Slight Impact	1- Slight damage, less than $25,000 U.S.	Little or no actual or potential for damage.	1 - Slight health effect/injury (First Aid)	A1	B1	C1	D1	E1
2.Minor	Limited Impact	2 - Minor damage, 25,000 - $100,000 U.S.	Within site boundary, short term impact recoverable by the work site	2 - Minor health effect/ injury (RWC MTO)	A2	B2	C2	D2	E2
3.Major	Considerable Impact	3 - Major damage, $100,000 - $500,000 U.S.	Beyond the site boundary unlikely to last beyond 1 month. Recovery may require external aid.	3 - Major health effect/ injury (DAWC)	A3	B3	C3	D3	E3
4.Severe	National Impact	4 - Severe damage, $500,000 - $1,000,000 U.S.	Beyond the site boundary unlikely to last beyond 12 months. Recovery requires external aid.	4 - Permanent Total Disability or single fatality	A4	B4	C4	D4	E4
5.Catastrophic	International Impact	5 - Extensive damage, greater than $1,000,000 U.S.	Massive uncontrolled release with significant impact extending well beyond the site boundary.	5 - Multiple serious injuries or fatalities	A5	B5	C5	D5	E5

Green (Low)	**Acceptable (When risk reduction / control measures have been implemented). Ensure controls are maintained and manage for continuous improvement.**
Yellow (Medium)	**Tolerable (When risk reduction / control measures have been implemented). Where possible, the work activity / task should be redefined to take account of the hazards involved or the risk should be reduced further prior to task commencement.**
Red (High)	**Intolerable (Work activity / task must not proceed). It should be redefined or further control measures put in place to reduce risk. The controls should be re-assessed for adequacy prior to task commencement.**

24-Hour Emergency Safety Number
1-888-333-4577

METHOD STATEMENT

No: OS-GP-MS-003

GEOPHYSICAL UTILITY SURVEYS

ELECTROMAGNETIC LOCATORS
GROUND PENETRATING RADAR

CONTENTS

Developed by:	Reviewed/authorized for issue by:
David Valintine – Geophysical Services Manager Alex Olive – Field Geophysicist	Rachel Keesee – HSE Specialist

A METHOD STATEMENT IS ONLY EFFECTIVE IF IT IS DISCUSSED AND AGREED BEFORE WORK BEGINS AND THEN FOLLOWED BY THOSE CARRYING OUT THE WORK.

1. Introduction

This document outlines the general procedure adopted by Fugro Consultants, Inc. (Fugro) for onshore Geophysical Utility Surveys (GUS) for the AKLNG project in Nikiski, Alaska.

2. Main Activity / Area of Work

Geophysical Utility Surveys may include, but not limiting to;

- Off-road driving vehicles to transport equipment on site
- Deployment of equipment
- Data collection with Electromagnetic Locators (Geonics EM-31 and Radiodetection RD8000)
- Data Collection with Ground Penetrating Radar (GSSI SIR3000)

The Geophysical Utility Surveys will be conducted at up to 60 locations, located on a mixture of AKLNG property, private property and public right of ways on the proposed AKLNG liquefaction site in Nikiski, Alaska, approximately between mile posts 20 and 22 of the Kenai Spur Highway. Scope of Work Drawings can be found in Appendix A of the Project Execution Plan.

3. Manpower and Supervision

Nominated Person	Responsibility
Project Geophysicist	• Provide specifications for the data acquisition • Advise Field Geophysicist on the project requirements and the requirement to comply with this method statement in order to enable the work to be carried out safely and obtain the required quality.

Nominated Person	Responsibility
Field Geophysicist	• Overall responsibility for all site activities • Review method statement and associated Task Risk Assessments (TRA) with employees performing the task • Regularly inspect activity for compliance • Communications with the project manager, site manager and project SSHE staff during the data collection operations • Take custody of electronic data files and site notes
Geophysical Technicians	• Compliance with this method statement, company HSE requirements and taking guidance from Field Geophysicist
Wildlife Safety Specialist	• Reconnaissance of Area of Work for signs of wildlife activity and advising geophysical personnel appropriately • Remaining on guard during the geophysical site work and monitoring for wildlife • Maintain visual contact with geophysical field personnel

4. Associated Documents (Drawings, Manuals, Method Statements, Plans, Permits)

Document	Reference Number
AKLNG Project Execution Plan, specifically; Field Exploration Plan (Part A, Section 3.1.5) Project Safety Management Plan (Part D) Scope of Work Drawings (Appendix A) Traffic Control Plans (Appendix G) Task Risk Assessment Register (Appendix M) Emergency Response Plan (Appendix O)	
Alaska LNG – LNG Facilities Onshore Geophysical Survey Specification	USAL-PL-GSZZZ-00-000001-001

Document	Reference Number
ASTM – Standard Guide for Using the Frequency Domain Electromagnetic Method for Subsurface Investigations	D6639-01(2008)
ASTM – Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation	D6432-11

5. Task Risk Assessments

Number	Title
ON-GP-TRA-102	Geophysical Utility Surveys
ON-GN-TRA-303	Thunder and Lightning Storms
ON-GN-TRA-310	Vehicle Usage
ON-GN-TRA-311	Material Handling and Moving
ON-GN-TRA-324	Battery Charging
ON-GN-TRA-348	Driving on Jobsites
ON-GN-TRA-349	Driving Off Road
OS-GN-TRA-002	Placing Traffic Warning Signs

6. Security - Barriers/Fences/Warning Signs

Where the Geophysical Utility Surveys encroach onto roadways or are within the public right of way, traffic control measures will be implemented and Traffic Control Plans for different scenarios can be found in Appendix G of the Project Execution Plan. Signage and cones will be deployed in accordance with the Traffic Control Plan and Task Risk Assessment OS-GN-TRA-002 Placing Traffic Warning Signs. Northern Dame, the traffic control subcontractor will be available to assist with any traffic control issue that may arise.

Unless the site is located on private property and can be secured, all equipment should be removed from site or adequately marked / barricaded when Fugro personnel are not in attendance.

7. Constraints/Restrictions/Special Conditions

The Geophysical Utility Surveys will be conducted on a combination of AKLNG, state, borough and privately owned property. The AKLNG Land Agents are responsible for obtaining a right of entry permit for each property. The Project Geophysicist will develop a 5-day look ahead schedule with the Site Manager, who will then relay this information on to the Land Agents with a request for notification of any special RoE restrictions for the upcoming (and adjacent) parcels. During daily logistics meetings, the Field Geophysicist will communicate with the Site Manager on areas where work will be performed on subsequent days to ensure any special RoE restrictions are understood.

Raptors, migratory birds, moose, bears, wolves, nuisance plants, insects on and other local wildlife may potentially be encountered while working on the project. All personnel will receive awareness training on such wildlife during the project induction. In addition, Wildlife Safety Specialists will be available to accompany the field crew (where and when deemed appropriate by Fugro, AKLNG and local professionals) to assess and monitor for the presence of such wildlife during field activities.

Extra precautions should be implemented in inclement weather conditions such as heavy rain and thunder / lightning storms. The instrument and all cable connectors should be protected against rain and / or surface water. During thunder / lightning storms, data collection activities should cease. Further information regarding general work activities during such inclement weather can be found in Task Risk Assessment ON-GN-TRA-303 Thunder and Lightning Storms.

8. Plant and Equipment

The following equipment may be used to facilitate access to the test locations:

- Support vehicle (to transport equipment to / along survey profiles)
  - 4wd pickup is preferred where site access permits
  - 4wd Jeep with off road tires (if inaccessible with pickup)

As a pickup truck and Jeep are both considered to be standard vehicles, other than a driver's license, no special training or certification is required for operation. Guidance regarding their use can be found in Task Risk Assessments ON-GN-TRA-310 Vehicle Usage, ON-GN-TRA-348 Driving on Jobsites and ON-GN-TRA-349 Driving Off Road.

The following equipment may be used for the Geophysical Utility Surveys:

- Geonics EM-31 with RS232 data cable and Juniper Archer II data logger;
- Radiodetection RD8000 cable locator system (transmitter and receiver)
- GSSI SIR 3000 including;
  - GSSI 400 MHz antenna
  - 12" GPR survey wheel
  - SIR 3000 carry harness

    - GPR data cable
- Tape measures, survey flagging / pin flags, misc. survey-related consumables, etc.

In addition to the equipment list above, the following spare parts should be available locally in the event of failure, damage or loss:

- Spare batteries for all equipment
- 2x EM31 RS232 data logging cables for Geonics EM31
- GPR data cable for GSSI SIR 3000

Contact should also be made with equipment manufacturers or multiple third party equipment rental companies prior to the commencement of the project to ensure that replacement components, in addition to the spare parts list above, can be shipped to site at relatively short notice (to arrive on site within 48-36 hours).

9. Materials (handling/storage/disposal)

No investigation derived waste or contaminated materials are expected to be generated.

The Geophysical Utility Survey equipment contains internal and disposable batteries that are charged daily. For further guidance on the use and charging of batteries, refer to Risk Assessment ON-GN-TRA-324 Battery Charging. In addition, disposal of spent batteries is covered under the Routine Waste section of Project Safety Management Plan (Part D of Project Execution Plan) in which segregated recycling / waste disposal receptacles have been set up at the site office for collection and transportation onto the Kenai Peninsula Borough Waster Transfer Station.

The equipment required to perform Geophysical Utility Surveys is relatively light with both the complete Electromagnetic Mapping and Ground Penetrating Radar systems weighing approximately 30 lbs each and therefore can be transported manually by a single person. Correct material handling is paramount while transporting equipment across rugged terrain. .

10. Preparation of Works/Location of Services

As detailed in the Project Execution Plan, preparation of the test locations will be performed by Greatlands. It is understood that site clearing will be conducted for boring pads with the dimensions of 60’ x 60’, and centered on the borehole location. No other site preparation is anticipated.

The locations of the surveys are also detailed in the Project Execution Plan. On a daily basis during tool box talks and JHA completion, the specific locations of the survey activities, along with ingress and egress routes will be discussed.

11. Emergency Procedures

The Emergency Response Plan can be found in Appendix O of the Project Execution Plan.

The field crew will include a First Aid / CPR trained person and a first aid kit with saline eye wash will be available on site. Additionally, each field team will carry laminated cards with contact numbers of key project personnel (site manager, SSHE contacts) and local facilities (fire / EMS departments, hospitals etc.). In addition, at least one person per team will be registered with the Kenai Borough Council, Office of Emergency Response, Rapid Response Notification System, which provides reports of local emergency / heightened awareness situations / conditions (severe weather, earthquake, tsunami, etc.).

12. Personal Protective Equipment (PPE) & Safety Equipment

The following personal protective equipment will be worn:

Item	Detail
Safety footwear Work gloves	As per requirements of Task Risk Assessment ON-GP-TRA-102
Hard hat Safety glasses Reflective work vest Body protection (long sleeve shirt & pants) Sun screen Insect repellent	As per requirements of Project Safety Management Plan (Part D of Project Execution Plan)

Additional personal protective equipment for unplanned site operations (such as vehicle maintenance or recovery) should procured and readily available locally (i.e. at site office).

13. Photos / Images

GSSI SIR3000 and 400MHz antenna

Geonics EM-31

Radiodetection RD8000 receiver and transmitter

14. Methodology & Sequence of Work

14.1 Overview

This section of the Method Statement outlines the general procedure adopted by Fugro Consultants, Inc. (Fugro) for Geophysical Utility Surveys using Electromagnetic Locators and Ground Penetrating Radar.

Rather than designating a specific course of action, this document offers an organized collection of information and technical guidance. This document cannot replace the education or experience of a trained geophysicist, and should be used in conjunction with professional judgment. Not all aspects of this procedure may be applicable in all circumstances. This procedure is not intended to represent or replace the standard of care by which the adequacy of a given professional service is performed, nor should this document be applied without the consideration of a project's many unique aspects.

14.2 Referenced Documents

Fugro Consultants, Inc. – Quality Management Forms

- Quality Management Form F-305 – Field Instructions – Land Based Geophysical Projects
- Quality Management Form F- 306 – Geophysics Field Log
- Task Risk Assessment – ON-GP-TRA-102 Geophysical Utility Surveys

ASTM and Other Industry Standards

- ASTM D6639 Standard Guide for Using the Frequency Domain Electromagnetic Method for Subsurface Investigations
- ASTM D6432 Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation

Other References

- Alaska LNG – LNG Facilities Onshore Geophysical Survey Specification
- Geonics Ltd. Technical Note TN-6; Electromangetic Terrain Conductivity Measurements at Low Induction Numbers
- Geonics Ltd. Technical Note TN-11; Use of EM31 In- Information
- Radiodetection Ltd.; The abc & xyz of Locating Buried Pipes and Cables
- The Survey Association; Guidance Note: Utility Surveys
- Yelf, R., 2007, Application of Ground Penetrating Radar to Civil and Geotechnical Engineering

14.3 Survey Planning

Site-Specific Considerations

The Field Geophysicist is expected to be able to demonstrate a thorough understanding of the underlying principal and theory of Electromagnetic Locator and Ground Penetrating Radar equipment. Guidance can be found in the documents under “Other References” above.

The Field Geophysicist should familiarize themselves with the objectives of the investigation (refer Fugro Quality Management Form F-305) and the site environs, with an emphasis on the nature of the target(s) being sought and the expected background conditions on site.

The Field Geophysicist should review any available site-specific information pertaining to any known or suspected subsurface features that may influence the recorded data. Such features may include but are not limited to; former foundations, subsurface utilities, areas of backfilled or contrasting ground conditions, etc.

In addition to subsurface features, the equipment operator should also bear in mind the presence of other site-specific conditions / surface features that may also influence the recorded data. Such features may include but are not limited to; overhead power lines, sources of electrical energy (i.e. aerials and antennae), cathodic protection systems etc.
After reviewing the objectives of the investigation and site environs, the Field Geophysicist should develop a conceptual understanding of the instrument readings that are expected to be recorded over both the target and background site conditions.

Pre-Mobilization Checks

Prior to the mobilization of the survey equipment, the Project Manager conduct the following;

- Check the date of last manufacturer service / calibration;
- Check the date of last in-house equipment checks;
- Review any completed Non-Conformance Reports / Observations pertaining to the survey equipment;
- Visual inspection of the equipment for any obvious signs of excessive wear and tear;
- Inventory all equipment and accessories;
- Identify and itemize any additional items of equipment and / or accessories that may be needed to comply with the project specific requirements.

Should any of the above checks identify any reason why the equipment may not operate as required, the Field Geophysicist shall consult the Senior Geophysics Manager to develop corrective actions.

Upon completion of the above checks, all equipment should be packed into suitable shipping containers ready for mobilization to site, and the Senior Geophysics Manager informed of mobilization plans.

14.4 Site Work – Survey Grid

Using tape measures and temporary flagging and / or surveyors spray paint, set-up an orthogonal survey grid. Where access permits, the grid should measure 60 x 60 feet and be centered on the proposed boring location. Along the perimeter of the survey area, additional flagging and / or spray paint should be used to denote 5 to 10-ft grid increments to provide start and end points for the survey profiles.

14.5 Site Works – Geonics EM31

Equipment Set-Up

All equipment should be assembled as per the manufacturers guidelines.

Operational tests that are to be conducted whilst assembling the equipment include;

- Checking the battery voltage (4.4 to 6) on EM31;
- Ensuring zero values are recorded when only the receiver coil is connected;
- Checking battery voltage, data and time settings on the digital data logger.

Upon completion of setting up the equipment, an area of the site with minimal cultural noise should be selected and the equipment left to stabilize for 1 - 2 minutes. The equipment operator should observe the readings during this time to ensure the equipment stabilizes.

In order to minimize any possible interference from the equipment operator, all reasonable steps should be taken eliminate metallic objects, such as removing keys, coins and cellular phone from pockets. Removal of steel toe capped safety boots is only permitted if there are not required by Clients, Landowners or Fugro Health and Safety requirements.

Pre Data Acquisition Quality Control Checks

A broad sweep of the site should be made with the equipment in a reconnaissance mode and the equipment operator should ensure the equipment readings are in-line with expectations. During this broad sweep, an area that is considered to be representative of the background conditions should be identified for functionality and latency. The Equipment Operator needs to bear in mind that this area should be away from any other site activities to ensure its environs remain constant throughout the duration of the site works.

Once a suitable area has been delimited, the equipment should be nulled using the manufacturer's instructions.

After nulling the equipment, simple functionality tests should be conducted. These may include;

- Cable shake / vibration tests to ensure good connections throughout the system
- Ensuring the readings are stable whilst the equipment is held still

- Rotating the orientation of the equipment through 360° and ensuring the readings remain relatively consistent
- Moving a conductive object close to the equipment and ensuring the readings increase

Data Acquisition

The following instrument settings shall initially be used;

- Survey mode : Auto
- Readings per second : 5
- Mode : Both (Q & IP)
- Line spacing : 5 feet

These initial instruments setting may be modified by the Field Geophysicist after an initial review of the measured data.

During data collection, boom of the EM31 should be kept parallel with the ground surface and orientated parallel to the profile direction. The operator should keep a constant walking pace to ensure accurate distance measured, and every 30 – 45 minutes check battery voltage level.

Equipment Operator will ensure that adequate spatial control is applied to the data. Typically, a tolerance of 10% of the line and station spacing will apply (i.e. when collecting data on a 10ft grid pattern, the accuracy of each location will be within 1ft).

14.6 Site Works – GSSI SIR 3000 GPR System

Equipment Set-Up

All equipment should be assembled as per the manufacturers guidelines.

Care should be taken to ensure proper attachment and orientation of survey sledge and handle to GPR antenna, along with correct mounting of the survey wheel. These connections are designed to allow some articulation to ensure the antenna can be pulled smoothly across uneven terrain.

Additional time should be taken to ensure the harness for the SIR 3000 has an ergonomic fit on the operator.

Upon completion of setting up the equipment, an area of the site with minimal cultural noise should be selected and the equipment turned on and left to stabilize for 1 - 2 minutes. The equipment operator should observe the readings during this time to ensure the equipment stabilizes.

In order to minimize any possible interference from external radiofrequency sources, the equipment operator should not carry a cellular phone.

Pre Data Acquisition Quality Control Checks

The Equipment Operator should check that the date and time settings on the SIR 3000 are set to 'local time' to assist in QC / QA on the data.

A check of the survey wheel calibration should be performed by pulling the data across a known distance and checking a data file of the correct length is recorded. If the distances do not agree within 1 – 2%, perform calibration for the survey wheel across a distance equal to at least half the length of the longest profile to be collected.

Conduct a preliminary data run to ensure the system is operating correctly, and to set data collection parameters. Adjust brightness, contrast, and gain if necessary.

A broad sweep of the site should be made with the equipment in a reconnaissance mode and the equipment operator should ensure the equipment readings are in-line with expectations. During this broad sweep, an area that is considered to be representative of the background conditions should be identified for functionality and setting of gains. The Equipment Operator needs to bear in mind that this area should be away from any other site activities to ensure its environs remain constant throughout the duration of the site works.

Once a suitable area has been delimited, the correct gain function should be set up within the operating software.

After gaining the equipment, simple functionality tests should be conducted. These may include;

- Cable shake / vibration tests to ensure good connections throughout the system
- Ensuring the readings are stable whilst the equipment is held still
- Rotating the orientation of the equipment through 360° and ensuring the readings remain relatively consistent
- Raising the antenna from the ground surface to ensure separation of the surface wave from the first reflection.

Data Acquisition

The following instrument settings shall initially be used;

- Survey mode : Wheel
- Scan per foot: 45
- Rate : 120
- Range : 60 ns
- Filters: 200 / 800 MHz

These initial instruments setting may be modified by the Field Geophysicist after an initial review of the measured data.

During data collection, antenna should be kept in contact with the ground surface. The operator should keep a constant walking pace at 2 – 2.5 ft/s to ensure proper sampling along the profiles.

For each profile, record the file name, line number, orientation, start and end coordinate along with any abnormal surface conditions that may affect the data. Care should be taken when positioning the antenna prior to each profile to ensure that center of the antenna aligns with the start coordinate (rather than the front or back of the antenna).

14.7 Site Works – Radiodetection RD8000

Equipment Set-Up

The RD8000 is shipped complete and does not require any assembly on site. The instrument should be visually checked during set up for signs of possible damage along with checking the battery voltage using the on-screen indicator.

Pre Data Acquisition Quality Control Checks

If a utility is known to be located in close proximity to the survey area, the volume / gain on the RD8000 can be set by tracing the known utility. The volume and gain should be set so that a maximum reading of 95% is obtained over the known utility. If there are no known utilities, the gain level should be set to 110.

Data Acquisition

Locator to be set in power mode and radio mode for utility location. A passive sweep is performed to search for any utilities by transecting the site at approximately 10 ft intervals in both a north-south and east-west direction. The receiver should be kept in line with the direction of the transect. When the receiver indicates the presence of a utility, the maxima and minima reading orientations should be determined by rotating the receiver through 360 degree. The orientation of the utility will be perpendicular to the orientation of the receiver when it give the maximum reading. Once this is established, the itility can then be traced out and its position noted every 5 – 10 feet across the survey areas.

14.7 Site Works – Field Notes and Observations

The Field Geophysicist shall note, at minimum, the following items on the Field Acquisition Log;

- Name of data file recorded
- Time & date, weather conditions
- General site conditions – topography, vegetation, surface conditions, preferably in sketch form

- Surface features that may affect the data
- Anecdotal evidence
- Any other immediately apparent site specific features that may affect the recorded data

14.8 Post Site Work

Equipment Tear Down

It is recommended that several repeat survey lines are acquired across each survey area to enable QC / QA of the data.

Prior to disconnecting the measurement cables and disassembling survey instruments, the Field Geophysicist should ensure that the equipment is completely powered down and batteries.

As equipment is packed away for transportation, an inventory should be taken to ensure all equipment has been removed from site and any possible defects / deficiencies noted for entry into Non-Conformance Reports / Observations.

Site Restoration

Under normal operating conditions, there is no footprint of the Geophysical Utility Surveys. Equipment is minimal and therefore other than the removal of household trash, site restoration is not anticipated to be required.

After demobilizing the equipment from the profile, the Field Geophysicist will be responsible for traversing the profile to ensure the ground surface has not been impacted. Should any disturbance be noted, the Field Geophysicist should contact the Site Manager prior to leaving the site to discuss effective site restoration strategies.

Data Files

At the earliest possible convenience after acquiring data, or at the end of every day or shift of acquisition, the electronic data files should be downloaded from the survey equipment and stored on a computer.

The Field Geophysicist should ensure that the data files are named or stored under directories with a logical naming convention to avoid accidental deletion or duplication and to ensure others can readily identify the nature of the contents of the files.

It is recommended that any site notes recorded in paper format be transferred to electronic files (scanning or data entry) and saved with the downloaded files.

The downloaded files should also be backed up to removable media, such as a floppy diskette, cd, or usb flash drive. The removable media should then be stored in a different location to the computer to avoid theft, loss or damage of both copies of the data.

For projects with a duration of more than three days, the data should also be transmitted (ideally) on a daily basis to Fugro's Houston office and transferred to the central server storage on a regular basis.

After demobilization, it is the Field Geophysicist responsibility to ensure that all electronic data files have been transferred to the central server, if not already done so.

The Field Geophysicist will be responsible for ensuring that all field logs, sketches and other paper records that we obtained on site are transferred to the project folder and scanned and saved on the central server.

The Field Geophysicist shall also be responsible for ensuring all equipment is demobilized, cleaned and stored. Should any faults, problems or non-conformances been observed during the site works, these will also be documented accordingly.

15. Appendices

Document	
ON-GP-TRA-102	Geophysical Utility Surveys
ON-GN-TRA-303	Thunder and Lightning Storms
ON-GN-TRA-310	Vehicle Usage
ON-GN-TRA-311	Material Handling and Moving
ON-GN-TRA-324	Battery Charging
ON-GN-TRA-348	Driving on Jobsites
ON-GN-TRA-349	Driving Off Road
OS-GN-TRA-002	Placing Traffic Warning Signs

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TASK RISK ASSESSMENT ON-GN-TRA-102 GEOPHYSICAL UTILITY SURVEYS

ACTIVITY:	Electromagnetic and Magnetic Methods	Date:	04/21/16
Department Involved:	Geophysics	Client:	AKLNG
Title of Person Performing Task:	Field Geophysicist, Technicians	Location of Activity:	Nikiski, AK

Please Remember: All hazards are important. Make notice of all possible hazards. Detailed safe job procedures are necessary. Awareness, teamwork, communications, and alertness apply to every situation. Use complete recommendations to eliminate or reduce hazards. This Task Risk Assessment is a compilation of potential hazards that should be expected while conducting this task. If actual work conditions or hazards require deviations from this Task Risk Assessment the employee must take the appropriate safety measures and document any changes to the Sequence of basic job steps, potential accidents or hazards, and recommendations to eliminate or reduce potential hazards listed or not listed in this Task Risk Assessment. Changes should be documented on the Jobsite Hazard Analysis (JHA) form. In addition, hazards associated with jobsite conditions should be documented on the JHA and communicated to those involved in the task.

Description of Activity / Task:

Geophysical Utility Survey, including, but not limiting to

- Off-road driving of vehicles to transport equipment on site
- Set-up, tear-down and data collection with Electromagnetic Locators and Ground Penetrating Radar equipment

PERSONAL PROTECTIVE EQUIPMENT:

	Hard Hats		Fire Extinguisher		Class 3 Reflective Work Vest
X	Safety Shoes		Safety Glasses w/ Side Shields		2- Life Rings w/ 90' Floating Line
	Hearing Protection		Goggles		Tag Lines
X	Cotton Gloves		Face Shield		Work Permit Required
X	Leather Gloves		Back Belts		Lockout/Tagout
	Rubber Gloves		Safety Harness		Barricade
	Welder Gloves		Floor Mat		Snake Chaps (Optional)
	Welder Helmet		Dust Mask		

TASK RISK ASSESSMENT ON-GN-TRA-102
UTILITY CLEARING
(Electromagnetic and Magnetic Methods)

Job Steps	Hazards	Population At Risk	Initial Risk Rating	Controls Measures	Residual Risk Rating	Risk Action
All site visits	General hazards	Employee Contractor	B3	Refer to site-specific JSA's for hazards related to the environment of the work area. Wear reflective work vest if heavy equipment is being operated in the area or testing is being performed near a roadway. Be aware of access / egress and emergency evacuation routes and procedures	B2	LOW
Mobilization of equipment to work area	Manual handling - muscular injuries	Employee	C3	Where possible, use mechanical assistance. Be aware of individual's strength limits Perform warm up and stretching exercises prior to performing lifting activities. Limit lifts to <50 lbs Lift with caution keeping your back straight and using your legs when lifting Wear appropriate PPE (work gloves and steel toe boots) Be aware of any potential pinch-points	B2	LOW
	Traffic accidents	Employee Public Reputation	C4	Practice defensive driving. Review GP-310 Vehicle Usage. While on site particular care should be used by following the site specific speed limits and traffic signs. Obey all site posted warning and regulation signs.	B3	LOW
Set - up equipment	Assembly of Equipment – manual handling and pinch points	Employee	C2	Restrict access to the work area Select an area clear of any slip, trip, or fall hazards for loading / unloading equipment and assembly. Follow manufacturer's instructions while assembling and use good hand position to avoid pinch points. Wear appropriate PPE (work gloves)	B1	LOW

TASK RISK ASSESSMENT ON-GN-TRA-102
UTILITY CLEARING
(Electromagnetic and Magnetic Methods)

Job Steps	Hazards	Population At Risk	Initial Risk Rating	Controls Measures	Residual Risk Rating	Risk Action
Set - up equipment (cont'd)	Assembly of Equipment – manual handling and pinch points (cont'd)	Employee	C2	For equipment that is carried by operator, ensure harness / straps provide an ergonomic fit.	B1	LOW
Operation of equipment	Obscured field of view due to carrying equipment - possible slip / trip hazard	Employee	B2	Plan travel path prior to personnel movement If necessary, have a second person act as look-out	A2	LOW
	Trailing cables and wires - slip / trip hazard	Employee	C2	Try to secure cables / coil excess cables prior to collecting data to mitigate trip hazards. Keep ingress / egress route clear Plan travel path prior to personnel movement	B2	LOW
	Tapes measures / pin flags on ground - slip / trip hazards	Employee Public	C2	Restrict access to the work area by setting up a soft barricade. Keep ingress / egress route clear Plan travel path prior to personnel movement	B2	LOW
Disassemble equipment	Manual handling - muscular injuries	Employee	C3	Where possible, use mechanical assistance Be aware of individuals strength limits Use correct manual handling techniques / posture Determine travel path and staging area prior to lift Wear appropriate PPE (leather gloves and steel toe boots) Be aware of any potential pinch-points	B2	LOW

TASK RISK ASSESSMENT ON-GN-TRA-102
UTILITY CLEARING
(Ground Penetrating Radar)

Risk Matrix and Risk Actions

Hazard severity	Reputation	Assets	Environment	People	Likelihood: A - Very unlikely (a freak combination of factors required for incident to result)	B - Unlikely (a rare combination of factors would be required for an incident to result	C - Possible (could happen when additional factors are present but otherwise unlikely to occur)	D - Likely (not certain to happen but an additional factor may result in an accident)	E - Very Likely (almost inevitable that an incident would result)
1.Slight	Slight Impact	1- Slight damage, less than $25,000 U.S.	Little or no actual or potential for damage.	1 - Slight health effect/injury (First Aid)	A1	B1	C1	D1	E1
2.Minor	Limited Impact	2 - Minor damage, 25,000 - $100,000 U.S.	Within site boundary, short term impact recoverable by the work site	2 - Minor health effect/ injury (RWC MTO)	A2	B2	C2	D2	E2
3.Major	Considerable Impact	3 - Major damage, $100,000 - $500,000 U.S.	Beyond the site boundary unlikely to last beyond 1 month. Recovery may require external aid.	3 - Major health effect/ injury (DAWC)	A3	B3	C3	D3	E3
4.Severe	National Impact	4 - Severe damage, $500,000 - $1,000,000 U.S.	Beyond the site boundary unlikely to last beyond 12 months. Recovery requires external aid.	4 - Permanent Total Disability or single fatality	A4	B4	C4	D4	E4
5.Catastrophic	International Impact	5 - Extensive damage, greater than $1,000,000 U.S.	Massive uncontrolled release with significant impact extending well beyond the site boundary.	5 - Multiple serious injuries or fatalities	A5	B5	C5	D5	E5

Green (Low)	**Acceptable (When risk reduction / control measures have been implemented). Ensure controls are maintained and manage for continuous improvement.**
Yellow (Medium)	**Tolerable (When risk reduction / control measures have been implemented). Where possible, the work activity / task should be redefined to take account of the hazards involved or the risk should be reduced further prior to task commencement.**
Red (High)	**Intolerable (Work activity / task must not proceed). It should be redefined or further control measures put in place to reduce risk. The controls should be re-assessed for adequacy prior to task commencement.**

24-Hour Emergency Safety Number
1-888-333-4577

METHOD STATEMENT

No: OS-GP-MS-004

VERTICAL ELECTRICAL SOUNDING TESTS
AGI MINISTING

CONTENTS

Developed by:	Reviewed/authorized for issue by:
David Valintine – Geophysical Services Manager	Rachel Keesee – HSE Specialist

A METHOD STATEMENT IS ONLY EFFECTIVE IF IT IS DISCUSSED AND AGREED BEFORE WORK BEGINS AND THEN FOLLOWED BY THOSE CARRYING OUT THE WORK.

1. Introduction

This document outlines the general procedure adopted by Fugro Consultants, Inc. (Fugro) for onshore Vertical Electrical Sounding (VES) tests for the AKLNG project in Nikiski, Alaska.

2. Main Activity / Area of Work

Vertical Electrical Sounding tests may include, but not limited to;

- Off-road driving to transport equipment on site
- Deployment of equipment / setting out electrodes on site
- Data collection with an AGI MiniSting or Sting R1 resistivity meter

The Vertical Electrical Sounding tests will be conducted at up to 10 locations, located on a mixture of AKLNG property, private property and public right of ways on the proposed AKLNG liquefaction site in Nikiski, Alaska, approximately between mile posts 20 and 22 of the Kenai Spur Highway. Scope of Work Drawings can be found in Appendix A of the Project Execution Plan.

3. Manpower and Supervision

Nominated Person	Responsibility
Project Geophysicist	• Provide specifications for the data acquisition • Advise Field Geophysicist on the project requirements and the requirement to comply with this method statement in order to enable the work to be carried out safely and obtain the required quality.

METHOD STATEMENT	No: OS-GP-MS-004
VERTICAL ELECTRICAL SOUNDING TESTS AGI MINISTING	

Nominated Person	Responsibility
Field Geophysicist	• Overall responsibility for all site activities • Review method statement and associated Task Risk Assessments (TRA) with employees performing the task • Regularly inspect activity for compliance • Communications with the project manager, site manager and project SSHE staff during the data collection operations • Take custody of electronic data files and site notes
Geophysical Technicians	• Compliance with this method statement, company HSE requirements and taking guidance from Field Geophysicist
Wildlife Safety Specialist	• Reconnaissance of Area of Work for signs of wildlife activity and advising geophysical personnel appropriately • Remaining on guard during the geophysical site work and monitoring for wildlife • Maintain visual contact with geophysical field personnel

4. Associated Documents (Drawings, Manuals, Method Statements, Plans, Permits)

Document	Reference Number
AKLNG Project Execution Plan, specifically; Field Exploration Plan (Part A, Section 3.4.2) Project Safety Management Plan (Part D) Scope of Work Drawings (Appendix A) Traffic Control Plans (Appendix G) Task Risk Assessment Register (Appendix M) Emergency Response Plan (Appendix O)	
Alaska LNG – LNG Facilities Onshore Geophysical Survey Specification	USAL-PL-GSZZZ-00-000001-001

Document	Reference Number
ASTM – Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method	G57-06(2012)
ASTM – Standard Guide for using the Direct Current Resistivity Method for Subsurface Investigation	D6431-99(2010)
Safety Data Sheet – 12v Lead Acid Batteries	-

5. Task Risk Assessments

Number	Title
ON-GP-TRA-103	Vertical Electrical Sounding (VES) Tests
ON-GN-TRA-303	Thunder and Lightning Storms
ON-GN-TRA-310	Vehicle Usage
ON-GN-TRA-311	Material Handling and Moving
ON-GN-TRA-324	Battery Charging
ON-GN-TRA-348	Driving on Jobsites
ON-GN-TRA-349	Driving Off Road
OS-GN-TRA-002	Placing Traffic Warning Signs

6. Security - Barriers/Fences/Warning Signs

The Vertical Electrical Sounding equipment includes a transmitter to inject currents up to 0.5 Amps and measures voltage up to 500 volts to acquire data. In areas trafficked by the general public, access to the test locations should be restricted through the use of cones and flagging / caution tape where appropriate. For project sites not normally accessed by the public, precautions should be taken to ensure the electrode array is clearly visible to other site users.

Where the Vertical Electrical Sounding tests encroach on public roadways, traffic control measures will be implemented. The work will be classified as shoulder work and the Traffic Control Plan for this type of work can be found in Appendix G of the Project Execution Plan. Signage and cones will be deployed in accordance with the Traffic Control Plan and Task Risk Assessment OS-GN-TRA-002 Placing Traffic Warning Signs. Northern Dame, the traffic control subcontractor will be available to assist with any traffic control issue that may arise.

Unless the site is located on private property and can be secured, all equipment should be removed from site or adequately marked / barricaded when Fugro personnel are not in attendance.

7. Constraints/Restrictions/Special Conditions

The Vertical Electrical Sounding tests will be conducted on a combination of AKLNG, state, borough and privately owned property. The AKLNG Land Agents are responsible for obtaining a right of entry permit for each property. The Project Geophysicist will develop a 5-day look ahead schedule with the Site Manager, who will then relay this information on to the Land Agents with a request for notification of any special Right of Entry (RoE) restrictions for the upcoming (and adjacent) parcels. During daily logistics meetings, the Field Geophysicist will communicate with the Site Manager on areas where work will be performed on subsequent days to ensure any special RoE restrictions are understood.

Raptors, migratory birds, moose, bears, wolves, nuisance plants, insects on and other local wildlife may potentially be encountered while working on the project. All personnel will receive awareness training on such wildlife during the project induction. In addition, Wildlife Safety Specialists will be available to accompany the field crew (where and when deemed appropriate by Fugro, AKLNG and local professionals) to assess and monitor for the presence of such wildlife during field activities.

Extra precautions should be implemented in inclement weather conditions such as heavy rain and thunder / lightning storms. The instrument and all cable connectors should be protected against rain and / or surface water. During thunder / lightning storms, as the electrode array is essentially a long conductor on the ground surface, data collection activities should cease and all cables disconnected. Further information regarding general work activities during such inclement weather can be found in Task Risk Assessment ON-GN-TRA-303 Thunder and Lightning Storms.

8. Plant and Equipment

The following equipment may be used to facilitate access to the test locations:

- Support vehicle (to transport equipment to / along survey profiles)
    - 4wd pickup is preferred where site access permits
    - 4wd Jeep with off road tires (if inaccessible with pickup)

As a pickup truck and Jeep are both considered to be standard vehicles, other than a driver's license, no special training or certification is required for operation. Guide regarding their use can be found in Task Risk Assessments ON-GN-TRA-310 Vehicle Usage, ON-GN-TRA-348 Driving on Jobsites and ON-GN-TRA-349 Driving Off-Road.

The following equipment may be used for the Vertical Electrical Sounding tests:

- AGI MiniSting or Sting R1 resistivity meter (for data collection), including;
  - 4x 18-22 awg wire on cable reel (up to 1,000 feet long and 10lbs each)
  - 4x Stainless steel electrodes (18 inches long, 0.2lbs each)
- Small hand tools – driller's hammer, screwdrivers, etc.
- Tape measures, survey flagging / pin flags, misc. survey-related consumables, etc.

In addition to the equipment list above, the following spare parts should be available locally in the event of failure, damage or loss:

- 2x 18-22 awg wire on cable reel (up to 1,000 feet long and 10lbs each)
- 2x Stainless steel electrodes (18 inches long, 0.2lbs each)
- 1x 12v battery (sealed AGM if available) for external power source.

Contact should also be made with equipment manufacturers and multiple third party equipment rental companies prior to the commencement of the project to ensure that replacement components, in addition to the spare parts list above, can be shipped to site at relatively short notice (to arrive on site within 48-36 hours).

9. Materials (handling/storage/disposal)

No investigation derived waste or contaminated materials are expected to be generated.

The Vertical Electrical Sounding equipment contains internal, sealed batteries as a power source that are charged daily. Should these batteries become exhausted during the site works an external 12v lead acid or AGM sealed battery can be used to power the equipment. Under normal operating conditions, personnel will not come in contact with battery acid. In the event of unplanned events, refer to the accompanying Safety Data Sheets for handling and first aid response if the integrity of the battery housing is suspected to be defective. For further guidance on the use and charging of batteries, refer to Risk Assessment ON-GN-TRA-324 Battery Charging. In addition, disposal of spent batteries is covered under the Routine Waste section of Project Safety Management Plan (Part D of Project Execution Plan) in which segregated recycling / waste disposal receptacles have been set up at the site office for collection and transportation onto the Kenai Peninsula Borough Waster Transfer Station.

The total weight of the equipment required to perform Vertical Electrical Sounding tests is approximately 60 lbs as is typically carried by two people (carrying 30 lbs each) to the test locations from the nearest vehicular access point. Correct material handling is paramount while transporting equipment across rugged terrain. Where possible, equipment should be transported using back packs.

10. Preparation of Works/Location of Services

As detailed in the Project Execution Plan, preparation of the test locations will be performed by Greatland. It is understood that two corridors, each 6 feet in width, 750 feet in length and centered on the test locations, will be cleared of vegetation to permit access for survey. No other site preparation is anticipated.

The location of the survey profiles are also detailed in the Project Execution Plan. On a daily basis during tool box talks and JHA completion, the specific locations of the survey activities, along with ingress and egress routes will be discussed.

11. Emergency Procedures

The Emergency Response Plan can be found in Appendix O of the Project Execution Plan.

The field crew will include a First Aid / CPR trained person and a first aid kit with saline eye wash will be available on site. Additionally, a roaming Wildlife Safety Specialist carrying an AED will be available to crews. Each field team will carry laminated cards with contact numbers of key project personnel (site manager, SSHE contacts) and local facilities (fire / EMS departments, hospitals etc.). In addition, at least one person per team will be registered with the Kenai Borough Council, Office of Emergency Response, Rapid Response Notification System, which provides reports of local emergency / heightened awareness situations / conditions (severe weather, earthquake, tsunami, etc.).

12. Personal Protective Equipment (PPE) & Safety Equipment

The following personal protective equipment will be worn:

Item	Detail
Safety footwear Work gloves Safety glasses	As per requirements of Task Risk Assessment ON-GP-TRA-103 Vertical Electrical Soundings
Hard hat Reflective work vest Body protection (long sleeve shirt & pants) Sun screen Insect repellent	As per requirements of Project Safety Management Plan (Part D of Project Execution Plan)

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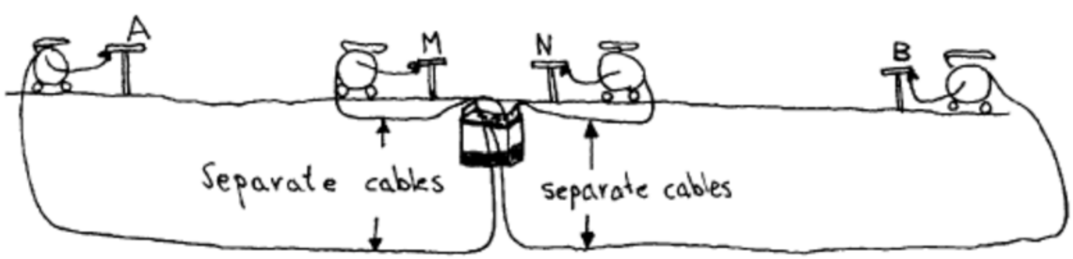
Additional personal protective equipment to comply with the accompanying SDS guidelines and for unplanned site operations (such as vehicle maintenance or recovery) should be procured and readily available locally (i.e. at site office).

13. Photos / Images


AGI MiniSting Resistivity meter (left) and sounding cables and jumpers (right)

Schematic showing connection of sounding cables, jumper and instrument



Schematic showing layout of the Wenner four-electrode method

14. Methodology & Sequence of Work

14.1 Overview

This section of the Method Statement outlines the general procedure adopted by Fugro Consultants, Inc. (Fugro) for Vertical Electrical Sounding tests.

Rather than designating a specific course of action, this document offers an organized collection of information and technical guidance. This document cannot replace the education or experience of a trained geophysicist, and should be used in conjunction with professional judgment. Not all aspects of this procedure may be applicable in all circumstances. This procedure is not intended to represent or replace the standard of care by which the adequacy of a given professional service is performed, nor should this document be applied without the consideration of a project's many unique aspects.

14.2 Referenced Documents

Fugro Consultants, Inc. – Quality Management Forms

- Quality Management Form F-305 – Field Instructions – Land Based Geophysical Projects
- Quality Management Form F- 306 – Geophysics Field Log
- Quality Management Form F-353 – Vertical Electrical Soundings - Data Acquisition Log
- Task Risk Assessment – Vertical Electrical Sounding Tests

ASTM and Other Industry Standards

- ASTM D6431 Standard Guide for Using the Direct Current Resistivity Method for Subsurface Investigation
- ASTM G57 Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method

Other References

- Alaska LNG – LNG Facilities Onshore Geophysical Survey Specification
- Loke, M.H, 2010, Tutorial : Electrical Resistivity Surveys
- Advanced Geosciences, Inc., MiniSting Instruction Manual

14.3 Survey Planning

Site-Specific Considerations

The Field Geophysicist is expected to be able to demonstrate a thorough understanding of the underlying principal and theory of the VES tests. Guidance can be found in the above referenced tutorial by M.H. Loke.

The Field Geophysicists should familiarize themselves with the objectives of the investigation (refer Fugro Quality Management Form F-303 and F-305) and the site environs, with an emphasis on the nature of the target(s) being sought and the expected background conditions on site.

The Field Geophysicist should review any available site-specific information pertaining to any known or suspected subsurface conductors that may influence the recorded data. Such features may include but are not limited to; former foundations, subsurface utilities, areas of backfilled or contrasting ground conditions, etc.

In addition to subsurface conductors, the equipment operator should also bear in mind the presence of other site-specific conditions / surface features that may also influence the recorded data. Such features may include but are not limited to; overhead power lines, sources of electrical energy (i.e. aerials and antennae), cathodic protection systems etc.
After reviewing the objectives of the investigation and site environs, the Field Geophysicist should develop a conceptual understanding of the instrument readings that are expected to be recorded over both the target and background site conditions.

Pre-Mobilization Checks

Prior to the mobilization of the survey equipment, the Project Manager will conduct the following;

- Check the date of last manufacturer service / calibration;
- Check the date of last in-house equipment checks;
- Review any completed Non-Conformance Reports / Observations pertaining to the survey equipment;
- Visual inspection of the equipment for any obvious signs of excessive wear and tear;
- Inventory all equipment and accessories as per Manufacturers Shipping Lists;
- Identify and itemize any additional items of equipment and / or accessories that may be needed to comply with the project specific requirements.

Should any of the above checks identify any reason why the equipment may not operate as required, the Field Geophysicist shall consult the Senior Geophysics Manager to develop corrective actions.

Upon completion of the above checks, all equipment should be packed into suitable shipping containers ready for mobilization to site, and the Senior Geophysics Manager informed of mobilization plans.

14.4 Site Work

Equipment Set-Up

All equipment should be assembled in accordance with the Manufacturer's Instructions (see reference above).

Depending upon the survey requirements, the four electrodes of the VES array shall be deployed along the specified alignment using pre-installed survey markers, or by determining the location from existing drawings or setting out with a differential GPS system. It is expected that the mid-point of test will be known with an accuracy of less than 1 meter.

At no point should the orientation of the VES array change by greater than 10 degrees.

The insertion depth of each electrode shall not exceed more than 10% of the unit spacing. Care should also be taken over steep or inclined topography to ensure that the electrodes are installed perpendicular to the ground surface.

Whilst connecting the electrodes to the cable reels and jumpers, it should be ensured that the connection mechanism on the electrode and cables are free of dirt, dust, and corrosion (etc) to assist in obtaining a sound electrical contact. This may require the contacts to be cleaned with a small wire brush.

Efforts should be made to ensure the connections between the cable reels and jumps area suspended out of the water for the duration of the measurements.

Whilst laying the electrode cables on the survey surface, it is recommended that efforts be made to ensure they are not excessively coiled, or contain any knots or tangles. Ideally, the electrode cables should be kept on one side of the array to enable relatively free access (ideally with a vehicle) along the other side.

Upon completion of setting up the equipment, the Field Geophysicist shall walk along the survey profile to perform a visual check of the array.

Pre Data Acquisition Quality Control Checks

Operational tests that can be conducted whilst assembling the equipment include;

- Checking the battery voltage (10 – 12v)
- Checking system against a test resistor

Upon completing the set-up of the array, the Field Geophysicist shall select the appropriate command file, measurement settings, and active electrodes on the survey instrument. Specifications for these settings would have been predetermined by the Project Geophysicist and included on the Field Instructions issued. These setting are also to be logged by the Field Geophysicist on the VES Data acquisition log.

Data Acquisition

The Field Geophysicist should ensure that the data files acquired on the survey instrument use a logical naming convention to avoid accidental deletion or duplication and to ensure others can readily identify the nature of the contents of the file.

For each electrode spacing used, multiple readings shall be taken to ensure that the measurements are stable, to reduce the likelihood of data being effected by external sources (poor wiring, subsurface conductors etc.).

The Field Geophysicist should pay attention to the climate conditions on site and take measures to ensure the survey instrument is protected from excessive heat, precipitation etc. This may involve keeping the equipment within an air- conditioned vehicle.

Measurement Settings

The following instrument settings shall initially be used for the Vertical Electrical Sounding tests;

- Max current : 500 milliAmps
- Max cycles : 5
- Max error : 0.5%
- Cycle time : 3.6 seconds
- Max voltage : 400 volts

These initial instruments setting may be modified by the Field Geophysicist after an initial review of the measured data.

Readings shall be taken using the following electrode spacing:
2, 4, 6, 10, 15, 20, 30, 40, 60, 80, 100, 150, 200 and 250 feet

Field Notes and Observations

The Field Geophysicist shall note, at minimum, the following items on the Field Acquisition Log;

- Name of data file recorded
- Time & date, weather conditions
- General site conditions – topography, vegetation, surface conditions
- Surface features that may affect the data
- Anecdotal evidence
- Any other immediately apparent site specific features that may affect the recorded data

Equipment Tear Down

Prior to disconnecting the measurement cables and electrodes, the Field Geophysicist should ensure that the equipment is completely powered down and batteries disconnected (if an external battery source is used).

As equipment is packed away for transportation, an inventory should be taken to ensure all equipment has been removed from site and any possible defects / deficiencies noted for entry into Non-Conformance Reports / Observations.

Site Restoration

Under normal operating conditions, the footprint of the Vertical Electrical Sounding equipment is minimal and therefore other than the removal of household trash, site restoration is not anticipated to be required.

After demobilizing the equipment from the profile, the Field Geophysicist will be responsible for traversing the profile to ensure the ground surface has not been impacted. Should any disturbance be noted, the Field Geophysicist should contact the Site Manager prior to leaving the site to discuss effective site restoration strategies.

14.5 Post Site Work

At the earliest possible convenience after acquiring data, or at the end of every day or shift of acquisition, the electronic data files should be downloaded from the survey equipment and stored on a computer.

The Field Geophysicist should ensure that the data files are named or stored under directories with a logical naming convention to avoid accidental deletion or duplication and to ensure others can readily identify the nature of the contents of the files.

It is recommended that any site notes recorded in paper format be transferred to electronic files (scanning or data entry) and saved with the downloaded files.

The downloaded files should also be backed up to removable media, such as a USB flash drive. The removable media should then be stored in a different location to the computer to avoid theft, loss or damage of both copies of the data.

For projects with a duration of more than three days, the data should also be transmitted (ideally) on a daily basis to Fugro’s Houston office and transferred to the central server storage on a regular basis.

After demobilization, it is the Field Geophysicist responsibility to ensure that all electronic data files have been transferred to the central server, if not already done so.

The Field Geophysicist will be responsible for ensuring that all field logs, sketches and other paper records that we obtained on site are transferred to the project folder and scanned and saved on the central server.

The Field Geophysicist shall also be responsible for ensuring all equipment is demobilized, cleaned and stored. Should any faults, problems or non-conformances been observed during the site works, these will also be documented accordingly.

15. Appendices

Reference	Title
ON-GP-TRA-103	Vertical Electrical Sounding (VES) Tests

24-Hour Emergency Safety Number
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TASK RISK ASSESSMENT ON-GP-TRA103

VERTICAL ELECTRICAL SOUNDINGS

ACTIVITY:	Vertical Electrical Soundings	Date:	04/26/16
Department Involved:	Geophysics	Client:	AKLNG
Title of Person Performing Task:	Field Geophysicist, Technicians	Location of Activity:	Nikiski, AK

Please Remember: All hazards are important. Make notice of all possible hazards. Detailed safe job procedures are necessary. Awareness, teamwork, communications, and alertness apply to every situation. Use complete recommendations to eliminate or reduce hazards. This Task Risk Assessment is a compilation of potential hazards that should be expected while conducting this task. If actual work conditions or hazards require deviations from this Task Risk Assessment the employee must take the appropriate safety measures and document any changes to the Sequence of basic job steps, potential accidents or hazards, and recommendations to eliminate or reduce potential hazards listed or not listed in this Task Risk Assessment. Changes should be documented on the Jobsite Hazard Analysis (JHA) form. In addition, hazards associated with jobsite conditions should be documented on the JHA and communicated to those involved in the task.

Description of Activity / Task:

Vertical Electrical Sounding tests, including, but not limiting to

- Off-road driving and use of utility vehicles to transport equipment on site
- Deployment of equipment / setting out electrodes on site
- Data collection with an AGI MiniSting or Sting R1 resistivity meter

PERSONAL PROTECTIVE EQUIPMENT:

	Hard Hats		Fire Extinguisher		Class 2 Reflective Work Vest
X	Safety Shoes	X	Safety Glasses w/ Side Shields		2- Life Rings w/ 90' Floating Line
	Hearing Protection		Goggles		Tag Lines
X	Cotton Gloves		Face Shield		Work Permit Required
X	Leather Gloves		Back Belts		Lockout/Tagout
	Rubber Gloves		Safety Harness	X	Barricade (for public sites)
	Welder Gloves		Floor Mat		Snake Chaps
	Welder Helmet		Dust Mask		

TASK RISK ASSESSMENT ON-GP-TRA-103
VERTICAL ELECTRICAL SOUNDINGS

Job Steps	Hazards	Population At Risk	Initial Risk Rating	Controls Measures	Residual Risk Rating	Risk Action
All site visits	General hazards	Employee Contractor	B3	Refer to site-specific JSA's for hazards related to the environment of the work area. Wear reflective work vest if heavy equipment is being operated in the area or testing is being performed near a roadway. Be aware of access / egress and emergency evacuation routes and procedures	B2	LOW
Mobilization of equipment to work area	Manual handling - muscular injuries	Employee	C3	Where possible, use mechanical assistance. Be aware of individuals strength limits Perform warm up and stretching exercises prior to performing lifting activities. Limit lifts to <50 lbs Lift with caution keeping your back straight and using your legs when lifting Wear appropriate PPE (leather gloves and steel toe boots) Be aware of any potential pinch-points	B2	LOW
	Traffic accidents	Employee Public Reputation	C4	Practice defensive driving. Review GP-310 Vehicle Usage. While on site particular care should be used by following the site specific speed limits and traffic signs. Obey all site posted warning and regulation signs.	B3	LOW
Set - up equipment	Set out electrodes - slip / trip hazards Trailing cables and wires - slip / trip hazard	Employee Public	C2	Restrict access to the work area Keep ingress / egress route clear Before moving equipment, walk the path of travel to remove any slip, trip, or fall hazards. If these hazards cannot be removed, select another path of travel. Use gloves and safety glasses if electrode require hammering into the ground	B1	LOW

TASK RISK ASSESSMENT ON-GP-TRA-103
VERTICAL ELECTRICAL SOUNDINGS

Job Steps	Hazards	Population At Risk	Initial Risk Rating	Controls Measures	Residual Risk Rating	Risk Action
Set - up equipment (continued)	Manual handling - muscular injuries	Employee	C3	Lift with caution keeping your back straight and using your legs when lifting Limit lifts to <50 lbs. Utilize team lifts for heavy and awkward objects	B2	LOW
	12v Battery related incidents - electrical and chemical hazards	Employee	B3	Keep battery in a dry and clean environment Use gel cell batteries where possible Safe guard against damage to or spillage from lead acid batteries Ensure battery connections are kept in good working order (no frayed wires etc)	A2	LOW
	Insects / Animals	Employee	C1	Area to be scanned by Wildlife Specialist for any animals. Keep clear of any wildlife. Keep vehicle accessible for safe harbour Wear insect repellent. Maintain a first aid kit onsite.	A1	LOW
	Nuisance/poisonous vegetation	Employee	C1	Nuisance/poisonous plants discussed in project induction. Determine what types of nuisance/poisonous vegetation might be in the area. Keep clear of suspect vegetation. Wear appropriate clothing to avoid contact with vegetation. Stay in cleared areas	A1	LOW
Operation of equipment	Electrocution from contact with active electrodes – similar to contact with electric fence	Employee Public	B4	If public area, restrict access to the work area using barricades, cones, flagging tape as necessary. Keep ingress / egress route clear Do not turn on equipment until electrode array is clear of personnel. Turn off equipment between individual readings.	A2	LOW

TASK RISK ASSESSMENT ON-GP-TRA-103
VERTICAL ELECTRICAL SOUNDINGS

Job Steps	Hazards	Population At Risk	Initial Risk Rating	Controls Measures	Residual Risk Rating	Risk Action
Operation of equipment (continued)	Instrumentation in ground - slip / trip hazards Trailing cables and wires - slip / trip hazard	Employee Public	C2	Be aware of electrodes and cables on the ground when walking around the jobsite. Keep visual surveillance of the work area.	B1	LOW
Disassemble equipment	Instrumentation in ground - slip / trip hazards Trailing cables and wires - slip / trip hazard	Employee	C2	Keep feet out of coiled cables during retrieval. When not using cables they should be coiled up and stored out of the path of travel.	B1	LOW
Demobilization	Manual handling - muscular injuries	Employee	C3	Where possible, use mechanical assistance. Be aware of individuals strength limits Perform warm up and stretching exercises prior to performing lifting activities. Limit lifts to <50 lbs Lift with caution keeping your back straight and using your legs when lifting Wear appropriate PPE (leather gloves and steel toe boots) Be aware of any potential pinch-pointsAdditional care to be taken due to fatigue	B2	LOW
	Dropping equipment on legs or feet	Employee	C3	When carrying equipment, proceed with caution holding the sample firmly. Wear appropriate gloves to help maintain grip on equipment. Wear steel toe boots or upper foot guards to protect feet	B2	LOW
	Traffic accidents	Employee Public Reputation	C4	Practice defensive driving. Additional care to be taken due to fatigue	B3	LOW

TASK RISK ASSESSMENT ON-GN-TRA-103
VERTICAL ELECTRICAL SOUNDINGS

Risk Matrix and Risk Actions

					Likelihood				
Hazard severity	**Reputation**	**Assets**	**Environment**	**People**	**A - Very unlikely (a freak combination of factors required for incident to result)**	**B - Unlikely (a rare combination of factors would be required for an incident to result**	**C - Possible (could happen when additional factors are present but otherwise unlikely to occur)**	**D - Likely (not certain to happen but an additional factor may result in an accident)**	**E - Very Likely (almost inevitable that an incident would result)**
1.Slight	Slight Impact	1- Slight damage, less than $25,000 U.S.	Little or no actual or potential for damage.	1 - Slight health effect/injury (First Aid)	A1	B1	C1	D1	E1
2.Minor	Limited Impact	2 - Minor damage, 25,000 - $100,000 U.S.	Within site boundary, short term impact recoverable by the work site	2 - Minor health effect/ injury (RWC MTO)	A2	B2	C2	D2	E2
3.Major	Considerable Impact	3 - Major damage, $100,000 - $500,000 U.S.	Beyond the site boundary unlikely to last beyond 1 month. Recovery may require external aid.	3 - Major health effect/ injury (DAWC)	A3	B3	C3	D3	E3
4.Severe	National Impact	4 - Severe damage, $500,000 - $1,000,000 U.S.	Beyond the site boundary unlikely to last beyond 12 months. Recovery requires external aid.	4 - Permanent Total Disability or single fatality	A4	B4	C4	D4	E4
5.Catastrophic	International Impact	5 - Extensive damage, greater than $1,000,000 U.S.	Massive uncontrolled release with significant impact extending well beyond the site boundary.	5 - Multiple serious injuries or fatalities	A5	B5	C5	D5	E5

Green (Low)	**Acceptable (When risk reduction / control measures have been implemented). Ensure controls are maintained and manage for continuous improvement.**
Yellow (Medium)	**Tolerable (When risk reduction / control measures have been implemented). Where possible, the work activity / task should be redefined to take account of the hazards involved or the risk should be reduced further prior to task commencement.**
Red (High)	**Intolerable (Work activity / task must not proceed). It should be redefined or further control measures put in place to reduce risk. The controls should be re-assessed for adequacy prior to task commencement.**

J.3 - Onshore Geophysical Survey Report

Document Number:	Description:	Revision:	Appendix:
USAL-FG-GRZZZ-00-002015-005	LNG Facilities Onshore Geophysical Survey Report	Rev 0	Public

Confidential

LNG FACILITIES ONSHORE GEOPHYSICAL SURVEY REPORT

USAL-FG-GRZZZ-00-002015-005

Rev	Date	Revision Description	Originator	Reviewer / Endorser	Response Code	Approver
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LNG FACILITIES ONSHORE GEOPHYSICAL SURVEY REPORT
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

AKLNG REPORT NO. USAL-FG-GRZZZ-00-002015-005

REPORT NO. 04.10140334-7
EXXONMOBIL ALASKA LNG LLC (EMALL)
HOUSTON, TEXAS

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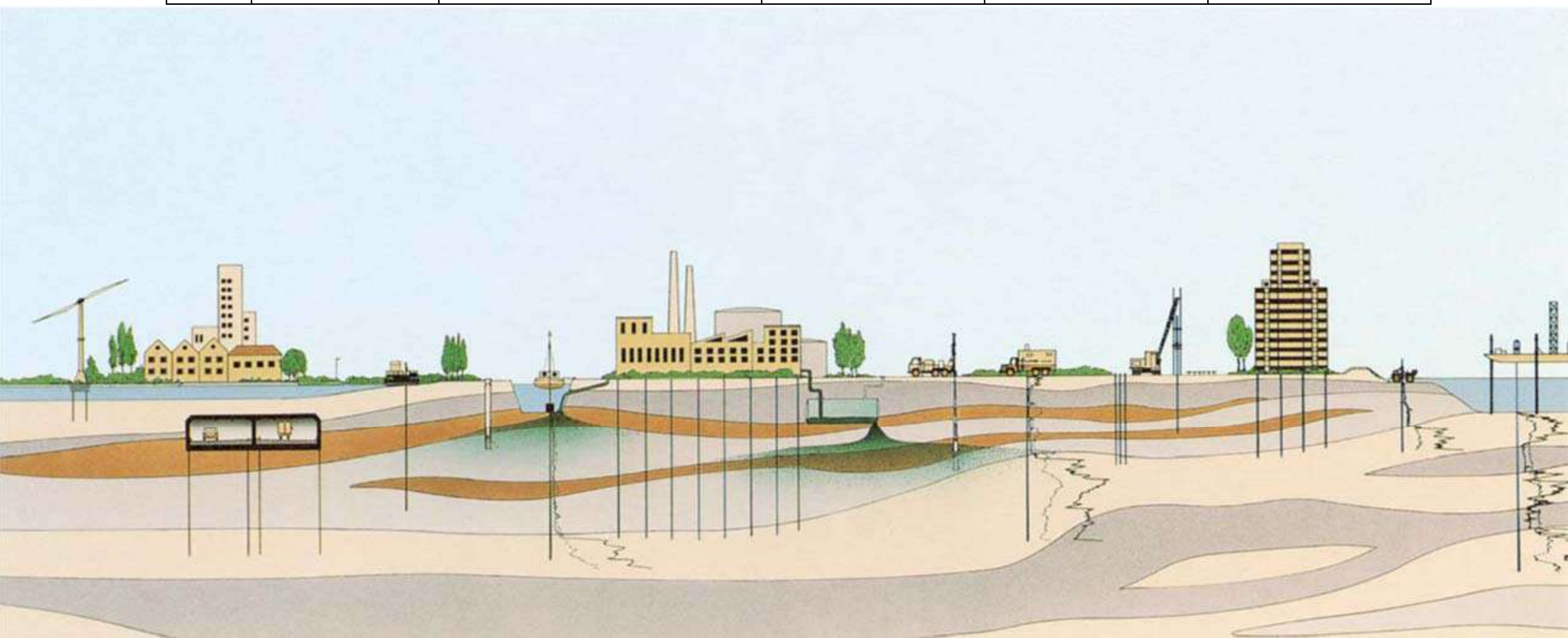

6100 Hillcroft (77081)
Houston, Texas 77274
Tel: (713) 369-5400
P.O Box 740010

Fax: (713) 369-5518

AKLNG Report No. USAL-FG-GRZZZ-00-002015-005
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June 10, 2016

ExxonMobil Alaska LNG LLC (EMALL)
10613 W. Sam Houston Pkwy N, Suite 500
Houston, TX, 77064

Attention: Patrick Wong
Geotechnical Engineer/Technical POC

LNG Facilities Onshore Geophysical Survey Report
Onshore LNG Facilities
Alaska LNG Project
Nikiski, Alaska

Fugro Consultants, Inc. (Fugro) is pleased to present this geophysical survey report for the onshore facilities of the Alaska LNG Project (AKLNG) located in Nikiski, Alaska. Our services were authorized under Service Work Order No. AKLNG-FUG-US-003 Rev 0, dated August 8, 2014 in accordance with the Service Agreement No. A2275592 between Fugro and ExxonMobil Global Services Company, dated October 29, 2012.

Fugro has been performing geophysical and geotechnical site investigation (G&G) for the proposed AKLNG Project since August 2014. This report presents the results of the onshore geophysical surveys conducted for the 2015 G&G between May and October, 2015 and also contains the results of re-processed seismic data acquired during onshore geophysical survey conducted for the 2014 G&G program.

We appreciate the opportunity to be of service to EMALL. Please call us at (713) 369-5400 if you have any questions or comments concerning this report, or when we may be of further assistance.

Sincerely,

FUGRO CONSULTANTS, INC.
TBPG Firm Registration No. 50337

David E. Valintine, P.G.
Geophysical Services Manager

Dan R.H. O'Connell, Ph.D.
Senior Principal Geophysicist

Copies Submitted: E-mail

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1. INTRODUCTION

1.1 Project Description

The Alaska Gasline Development Corporation, BP Alaska LNG LLC, ConocoPhillips Alaska LNG Company, and ExxonMobil Alaska LNG LLC (Applicants and also referred as AKLNG in this report) plan to construct one integrated liquefied natural gas (LNG) Project (Project) with interdependent facilities for the purpose of liquefying supplies of natural gas from Alaska, in particular from the Point Thomson Unit (PTU) and Prudhoe Bay Unit (PBU) production fields on the Alaska North Slope (North Slope), for export in foreign commerce and opportunities for in-state deliveries of natural gas.

The Natural Gas Act (NGA), 15 U.S.C. § 717a(11) (2006), and Federal Energy Regulatory Commission (FERC) regulations, 18 C.F.R. § 153.2(d) (2014), define “LNG terminal” to include “all natural gas facilities located onshore or in State waters that are used to receive, unload, load, store, transport, gasify, liquefy, or process natural gas that is exported to a foreign country from the United States.” With respect to this Project, the “LNG Terminal” includes the following: a liquefaction facility (Liquefaction Facility) in Southcentral Alaska; an approximately 804-mile gas pipeline (Mainline); a gas treatment plant (GTP) on the North Slope; an approximately 62-mile gas transmission line connecting the GTP to the PTU gas production facility (PTU Gas Transmission Line or PTTL); and an approximately 1-mile gas transmission line connecting the GTP to the PBU gas production facility (PBU Gas Transmission Line or PBTL). All of these facilities are essential to export natural gas in foreign commerce.

These components are shown in Resource Report No. 1, Figure 1.1 - 1, as well as the maps found in Appendices A and B of Resource Report No. 1. Their current basis for design is described as follows.

The new Liquefaction Facility would be constructed on the eastern shore of Cook Inlet just south of the existing Agrium fertilizer plant on the Kenai Peninsula, approximately 3 miles southwest of Nikiski and 8.5 miles north of Kenai (Plate 1). The Liquefaction Facility would include the structures, equipment, underlying access rights, and all other associated systems for final processing and liquefaction of natural gas, as well as storage and loading of LNG, including terminal facilities and auxiliary marine vessels used to support Marine Terminal operations (excluding LNG carriers [LNGCs]). The Liquefaction Facility would include three liquefaction trains combining to process up to approximately 20 million metric tons per annum (MMTPA) of LNG. Two 240,000-cubic-meter tanks would be constructed to store the LNG. The Liquefaction Facility would be capable of accommodating two LNG carriers. The size of LNGCs that the Liquefaction Facility would accommodate range between 125,000 – 216,000-cubic-meter vessels. In addition to the Liquefaction Facility, the LNG Terminal would include the following interdependent facilities:

- Mainline: A new 42-inch-diameter natural gas pipeline approximately 804 miles in length would extend from the Liquefaction Facility to the GTP on the North Slope, including the structures, equipment, and all other associated systems. The Mainline would include up to eight compressor stations; one standalone heater station, one heater station co-located with a compressor station, and six cooling stations associated with six of the compressor stations; four meter stations; 53 mainline block valves; one pig launcher facility at the GTP meter station, one pig receiver facility at the Nikiski meter station, and eight combined pig launcher and receiver facilities at each of the compressor stations; and associated infrastructure facilities. Associated infrastructure facilities would include additional temporary work spaces, access roads, helipads, construction camps, pipe storage areas, material extraction sites, and material disposal sites. Along the Mainline route, there would be at least five gas interconnection points to allow for future in-state deliveries of natural gas. The approximate locations of three of the gas interconnection points have been tentatively identified by the State of Alaska as follows: MP 475 to serve Fairbanks, MP 763 to serve the Matanuska-Susitna Valley and Anchorage, and MP 804 to serve the Kenai Peninsula. The size and location of the remainder of interconnection points are unknown at this time. None of the potential third-party facilities used to condition, if required, or move natural gas away from these off-take interconnection points are part of the Project. Potential third-party facilities will be addressed in the Cumulative Impacts analysis found in Appendix L of Resource Report No. 1.
- GTP: A new GTP and associated facilities in the Prudhoe Bay area would receive natural gas from the PBU Gas Transmission Line and the PTU Gas Transmission Line. The GTP would treat/process the natural gas for delivery into the Mainline. There would be custody transfer, verification, and process metering between the GTP and PBU for fuel gas, propane make-up, and byproducts. All of these would be on the GTP or PBU pads.
- PBU Gas Transmission Line: A new 60-inch natural gas transmission line would extend approximately 1 mile from the outlet flange of the PBU gas production facility to the inlet flange of the GTP. The PBU Gas Transmission Line would include one-meter station on the GTP pad.
- PTU Gas Transmission Line: A new 32-inch natural gas transmission line would extend approximately 62 miles from the outlet flange of the PTU gas production facility to the inlet flange of the GTP. The PTU Gas Transmission Line would include one-meter station on the GTP pad, four MLBVs, and two pig launcher and receiver facilities—one each at the PTU and GTP pads.

Existing State of Alaska transportation infrastructure would be used during the construction of these new facilities including ports, airports, roads, railroads, and airstrips (potentially including previously abandoned airstrips). A preliminary assessment of potential new infrastructure and modifications or additions to these existing in-state facilities will be provided in Appendix L of Resource Report No.1. The Liquefaction Facility, Mainline, and GTP would require the construction of modules that may or may not take place at existing or new manufacturing facilities in the United States. EMALL's Draft Resource Report No. 1, Appendix A, contains maps of the Project footprint. Appendices B and E of Resource Report No. 1 depict the footprint, plot plans of the aboveground facilities, and typical layout of above-ground facilities.

AKLNG contracted Fugro to investigate the site conditions of the onshore LNG facilities, marine LNG Terminal, and marine pipeline corridors. Plate 1 and Plate 2 show the overview of overall project facilities described above and the proposed location of the onshore facilities, marine terminal area, and the pipeline corridors of the proposed LNG plant. More details regarding the project can be found in document USAKE-PT-SRREG-00-0001 released by AKLNG.

The summary of the reports developed as a part of site investigation are listed in Table 1.1.

This report presents the results of the onshore geophysical surveys conducted during the 2015 G&G program between May and October, 2015 and include the results of re-processed seismic data acquired during the onshore geophysical survey conducted during the 2014 G&G program.

Table 1.1: Summary of Reports

Report Title	AKLNG Document Number	Fugro Report Number
Project Execution Plan for 2015 Onshore and Marine G&G Program	USAL-FG-GRZZZ-00-002015-002	04.10140334-1
LNG Facilities Onshore Geologic Field Mapping Report	USAL-FG-GRZZZ-00-002015-004	04.10140334-2
Pipeline Marine Geophysical Survey Report - Route 1	USAP-FG-GRZZZ-10-002015-013	04.10140334-3
Pipeline Marine Geophysical Survey Report - Route 2	USAP-FG-GRZZZ-10-002015-014	04.10140334-4
LNG Facilities Marine Geophysical Survey Report	USAL-FG-GRZZZ-90-002015-010	04.10140334-5
LNG Facilities Probabilistic Seismic Hazard Analysis (PSHA) Report	USAL-FG-GRHAZ-00-002015-001	04.10140334-6
LNG Facilities Onshore Geophysical Survey Report	USAL-FG-GRZZZ-00-002015-005	04.10140334-7
LNG Facilities Onshore Geotechnical Data Report	USAL-FG-GRZZZ-00-002015-006	04.10140334-8
LNG Facilities Marine Geotechnical Data Report	USAL-FG-GRZZZ-90-002015-011	04.10140334-9
LNG Facilities Onshore Geologic Hazard Report	USAL-FG-GRHAZ-00-002015-002	04.10140334-10
LNG Facilities Onshore Groundwater Monitoring Well Installation Report	USAL-FG-GRZZZ-00-002015-007	04.10140334-11
LNG Facilities Onshore Hydrogeologic Report	USAL-FG-GRZZZ-00-002015-008	04.10140334-12
LNG Facilities Seismic Engineering Report	USAL-FG-GRZZZ-00-002015-003	04.10140334-13
LNG Facilities Onshore Integrated Site Characterization and Geotechnical Engineering Report	USAL-FG-GRZZZ-00-002015-009	04.10140334-14
LNG Facilities Marine Integrated Site Characterization and Geotechnical Engineering Report	USAL-FG-GRZZZ-90-002015-012	04.10140334-15

1.2 Purpose and Scope

The purpose and scope of the onshore geophysical surveys are broadly defined in the AKLNG Onshore Geophysical Survey Specification (AKLNG document no. USAL-PL-GBZZZ-00-000001-001 Rev. 0, dated 7 May, 2015) and detailed in our work execution plan (Fugro Report No. 04.10140334-1, dated 28 July, 2015). As the project progressed and based on discussions with AKLNG, revisions to the scope were made during the field work. A final copy of the work execution plan was submitted on August 23, 2015 (AKLNG document no. USAL-FG-GRZZZ-00-002015-002).

In general, the purpose of the onshore geophysical surveys can be divided into shallow and deep survey objectives, detailed as follows;

- The shallow onshore geophysical surveys were designed to collect data along continuous profiles across the LNG Facilities to allow extrapolation of subsurface conditions between the geotechnical borings. The three primary objectives were to attempt to verify the shallow stratigraphy (in particular, thickness of organic topsoil), map any gravel deposits that could potentially be used for construction and to image any significant geotechnical and geologic variations or structures to assist with overall site characterization.
- The purpose of the deep onshore geophysical survey was to provide subsurface geologic data, including the general subsurface characteristics of the project area, identification of faults, folds and other geologic structures for geohazard evaluation.

To fulfill the objectives of the shallow geophysical survey, a preliminary trial shallow geophysical survey was conducted. The intent of this trial was to determine which geophysical method (or combination of methods) would provide the best data quality, resolution and value to the project with respect to the survey objectives. This method would then be used for the main shallow geophysical survey.

1.2.1 Trial Shallow Geophysical Survey

Based on the information available prior to the 2015 G&G program, the Electrical Resistivity Tomography (ERT) and shallow seismic methods (Seismic Refraction Tomography, SRT, and Interferometric Multi-channel Analysis of Surface Waves, IMASW) were selected for the trial survey. As outlined above, the intent was to determine which of these geophysical methods would provide the best data quality, resolution and value to the project with respect to the survey objectives. Additionally, the trial survey was also an opportunity to verify the acquisition and processing approaches, and to as assess the field execution methods and productivity of the geophysical methods.

Four profiles, totaling some 11,500 linear feet were selected for the trial geophysical survey. Geophysical profiles EW-4 and NS-4 (see Plate 3 and Plate 4) were selected based on considerations such as the availability of geotechnical data from existing and proposed borings, site access conditions, presence of representative geomorphic features and logistical factors. Profiles TL-2 and TL-5 (two, 500 feet long profiles, centered on boring B-131 and proposed test pit TP-5, see Plate 3 and Plate 4) were selected to provide detailed subsurface data in the vicinity of the proposed seismograph station. Information pertaining to the geophysical methods, data collection and processing approaches utilized are discussed in more detail in later sections of this report.

To assist with the evaluation of the data collected during the trial geophysical survey, the existing data from completed geotechnical borings was also complimented with 11 hand-auger borings. The locations of the hand auger borings were targeted on features identified within the geophysical data to provide additional ground-truth.

Based on data acquired during the trial geophysical survey, it was determined that the Electrical Resistivity Tomography method displayed the best sensitivity to changes in the shallow stratigraphy (in the upper 20 to 40 feet of the subsurface) across the site and potentially yielded encouraging potential for the mapping of organic topsoil thickness and potential gravel deposits.

The shallow seismic survey also yielded some useful insights. However, over most of the trial survey profiles the surface often consisted of low-velocity wood-chips mixed with soil that had lower acoustic velocities than the acoustic velocity of air. In the seismic refraction tomography data, first-arrivals corresponding to the top soil layer were absent along significant stretches of the profiles; the first-arrivals corresponded to direct air wave arrivals instead of refracted energy returned from the soil and deeper subsurface layers. Further, refractions from the water table were rarely observed since the shallow SRT acquisition was limited to 71 m maximum offset to focus on shallow structure. Consequently, shallow seismic refraction tomography method was eliminated as a viable method to achieve the project objectives.

The Interferometric Multi-channel Analysis of Surface Waves method was able to map variations in the frost depth but did not consistently map soil thickness variations. IMASW trial analyses showed that 2D IMASW processing adjusted to focus on deeper structure using larger subarrays was useful to map variations in the depth of the Killey-Moosehorn contact and related larger-scale and deeper structure for geologic mapping and site-response analyses. Consequently, 2D IMASW data acquisition and processing was adjusted to improve deeper shear-wave velocity resolution to focus on structures in the 10-120 foot depth range.

1.2.2 Main Shallow Geophysical Survey

The findings of the trial geophysical survey were informally reported to AKLNG in July, 2015 and based on subsequent discussions, the scope of the main shallow geophysics surveys for the 2015 G&G program comprised of;

- Collection of an additional 9 profiles of Electrical Resistivity Tomography data, totaling 54,620 linear-feet (see Plate 3);
- Acquisition of Shallow Seismic data along 10 additional profiles, totaling 55,600 linear-feet (see Plate 4); and
- Re-processing with the IMASW technique, 5 profiles, totaling 20,619 linear-feet, of seismic refraction data acquired during the 2014 G&G program (see Plate 4).

1.2.3 Deep Geophysical Surveys

Deep seismic field activities focused specifically on obtaining crustal-scale (100 to 20,000+ feet depth range) seismic reflection data within the 5-mile site radius to evaluate for the presence or absence of tectonic folds and faults, including “blind” faults. The survey alignments are comprised of one north-south profile along the Kenai Spur Highway (NS-2), an east-northeast profile continuing along Kenai Spur Highway and extending beyond the highway to the east (EW-8), and an east-west oriented profile (EW-3) extending east from the main LNG facilities area (see Plate 5). These three survey profiles sum to total lengths of approximately 90,240 linear feet of receivers and 8,449 seismic source points acquired over a combined seismic sourcing distance of 84,490 linear feet.

1.3 Applicability of Report

We have prepared this factual report for EMALL for use as geotechnical input for the proposed Alaska LNG project. The scope of the surveys and tests performed in this report are for the Alaska LNG Project only. The tests were selected or developed based on our understanding of the project as described in this report and our discussions with Client representatives and their Contractors. The information presented in this report is intended to be used for design of the project. Additional studies will be needed to complete the investigation for final design stages of the project once the location of the structure/equipment and detailed loading conditions are finalized.

1.4 Limitations

Fugro makes no claim or representation concerning any activity or condition falling outside the specified purposes to which this report is directed. We have conducted our work using the standard level of care and diligence normally practiced by recognized engineering firms now performing similar services under similar circumstances. We intend for this report, including all illustrations, to be used in its entirety. The information presented in this report may not apply to locations not explored by borings or areas outside the project boundaries. This information should be made available to prospective users for information only, and not as a warranty of subsurface conditions.

1.5 Unit Conversion and Datums

The recommendations presented herein are based on the Imperial Unit System. Table 1.2 provides a quick reference for conversion from Imperial Units to SI.

Table 1.2: Conversion Units

From Imperial System	To SI System	Divide by
Kips – k	Kilo Newtons – kN	0.224809
Kips – k	Mega Newtons – MN	224.809
Pounds/foot^2 - psf	Kilo Newtons/meter^2 – kN/m^2 (kPa)	20.885
Pounds/foot^3 - pcf	Kilo Newtons/meter^3 – kN/m^3	6.3659
Feet – ft	Meters – m	3.2808
Inches – in.	Millimeters – mm	0.03937

All coordinates are reported in Zones AK3 AK4 AK5 North, NAD83 (NSRS 2007), and are in feet. Topographic elevations for onshore areas are referenced to NAVD88. It should be noted that the marine geophysical survey is referenced to Mean Low Lower Water (MLLW). The following formula is used to convert the elevations from MLLW to NAVD88:

- Elevation, in feet (NAVD88) = Elevation, in ft (MLLW) – 7.32 ft

Elevations presented in this report, and the corresponding illustrations and engineering plates are all referenced to the NAVD88 datum, unless noted otherwise.

Positional control of the layout of the onshore geophysical surveys was provided as part of the topographic survey performed by McLane Consulting Inc. (as detailed in USAL-FG-GRZZZ-00-002015-006 LNG Facilities Onshore Geotechnical Data Report).

2. ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY

2.1 Survey Objectives

Based on the findings of the trial shallow geophysical survey, the Electrical Resistivity Tomography technique was selected as the most appropriate method for obtaining stratigraphic information in the shallow depth range of 0 to 40 feet. The primary objectives of the Electrical Resistivity Tomography surveys were to;

- Delineate subsurface strata along the profiles between the geotechnical boring locations;
- Evaluate the subsurface materials for potential borrow sources;
- Map the variability in the topsoil thickness; and
- Identify possible areas of adverse geotechnical conditions.

2.2 Electrical Resistivity Tomography Method

Electrical Resistivity Tomography surveys use large arrays of electrodes that are deployed in a line and connected to a measurement system via multi-core cables. The apparent electrical resistivity of the subsurface is measured by selecting four individual electrodes and injecting a direct current or very low frequency alternating current between a pair and measuring the resulting potential difference (ΔV) with a second pair. The apparent resistivity of the subsurface is then calculated using a derivation of Ohms law ($R=\Delta V/I$). As the measurement system runs a series of commands that automatically selects various different combinations of electrodes, a vertical section of apparent resistivity values is created, which can be analyzed using inversion algorithms to develop a cross-section of the inferred subsurface conditions beneath the electrode array.

The resistivity of subsurface materials is highly dependent upon the resistivity of the soil / rock matrix; the presence (or absence) of pore fluids; and dissolved salts within the pore fluids. Generally, cohesive soils display relatively lower resistivity values when compared to granular soils and rocks. Superimposed, and sometimes dominating this is the presence of pore fluids and dissolved salts, which act to reduce resistivity values. It should be appreciated that the range of resistivity values for many different materials overlap and therefore the resistivity value alone is not a unique identifier for determining the subsurface materials. Furthermore, resistivity values vary logarithmically, which can sometimes hinder the identification of different subsurface materials based on comparing relative resistivity values alone. The interpretation of Electrical Resistivity Tomography data is limited to identifying trends or layers within the data, which are then correlated with geotechnical data in order to derive a geologic interpretation. In this case, geotechnical and seismic data available from 2014 and additional geotechnical data from ongoing investigation activities in 2015 contributed to interpretation.

2.3 Field Activities

The locations of the geophysical profiles were initially flagged on site by McLane Consulting, Inc. As portions of the project site were heavily vegetated, vegetation clearing was required for some of the geophysical profiles, which was performed by Greatland Tree Services, LLC using a mechanical mulcher to clear 10 – 15 feet wide access paths. Additionally, some deadwood trees were also removed to provide safe working conditions for site personnel.

The Electrical Resistivity Tomography data was collected using an AGI SuperSting 8-channel resistivity meter with an 84-electrode switch box and cables. Data was acquired with a command file containing both dipole-dipole and inverse Schlumberger array configurations. This combined configuration was selected as it is both optimal for multi-channel resistivity meters (compared to the traditional Wenner array) and provides good lateral and vertical sensitivity (from the diploe-dipole and inverse Schlumberger arrays, respectively). During the trial survey, 10-ft unit electrode spacing was used. After processing the trial data and reviewing production rate achieved, it was decided to reduce the unit electrode spacing to 8 feet for the remaining profiles, with the intent of providing increased resolution within the very shallow subsurface.

For each of the geophysical profiles, the individual electrode locations were marked out by the geophysical survey team using tape measures and pin flagging. The electrodes were inserted approximately 4 to 6 inches into the ground by hand and connected to the multi-core cables. As-built coordinates and elevations of electrodes at 10 – 40 feet centers along the profiles and at notable break-in-slopes were recorded at the time of the survey by McLane Consulting Inc.

Prior to data collection on each profile, equipment functionality was verified using a test box provided by the manufacturer. Deployment of the individual electrodes and associated cabling was verified through a contact resistance test. During this test, the contact resistance between the ground and electrode is measured and displayed on the equipment. In general, these contact resistances should be analogous to the resistivity of the surficial materials. Where anomalously high (>5,000 Ω) or erratic values were observed, the electrodes were re-planted and / or watered with a saline solution and retested until satisfactory contact resistances were obtained.

In total, 13 profiles of Electrical Resistivity Tomography data were acquired, totaling 54,620 linear-feet (see Plate 3). During the trial survey, conducted between May 14 and 19, 2015, profiles EW-4, NS-4, TL-2 and TL-4 were acquired. The remaining profiles were acquired between July 8 and Jul 31, 2015. Table 2.1 on the following page summarizes the locations and lengths of the individual profiles. It should be noted that the profiles acquired we not straight lines between the start and end locations (listed on the following page); minor deviations, as can be observed in the profiles locations on Plate 3, were made on many of the profiles due to both logistical and land access constraints.

All of the data collection activities were conducted under the on-site supervision of Mr. David Valintine P.G. of Fugro.

Table 2.1: As-Built Coordinates of Electrical Resistivity Tomography Lines

ERT Profile	Length (feet)	Starting Location		End Location	
		Northing	Easting	Northing	Easting
EW-2	3,184	2,434,788	1,396,220	2,434,708	1,399,390
EW-3	552	2,436,160	1,394,862	2,436,164	1,395,412
	3,912	2,436,071	1,395,666	2,436,001	1,399,561
EW-4	820	2,437,534	1,394,147	2,437,530	1,394,961
	4,190	2,437,526	1,395,073	2,437,349	1,399,248
EW-5	1,088	2,438,760	1,393,299	2,438,742	1,394,383
	4,816	2,438,757	1,394,690	2,438,637	1,399,484
EW-9	2,840	2,433,968	1,396,618	2,433,954	1,399,418
EW-10	552	2,435,473	1,395,187	2,435,495	1,395,735
	3,576	2,435,443	1,395,909	2,435,357	1,399,442
EW-11	4,248	2,436,757	1,395,368	2,436,624	1,399,574
EW-12	928	2,438,104	1,393,732	2,438,113	1,394,653
	4,472	2,438,077	1,395,013	2,437,967	1,399,466
NS-1	2,344	2,437,516	1,394,456	2,439,649	1,393,551
	1,736	2,435,065	1,395,466	2,436,584	1,394,691
NS-4	5,500	2,433,679	1,396,746	2,439,154	1,396,875
NS-5	1,440	2,432,111	1,398,010	2,433,548	1,398,064
	7,392	2,433,665	1,398,071	2,441,008	1,398,237
TL-2	500	2,440,062	1,397,933	2,440,561	1,397,944
TL-5	530	2,440,306	1,398,207	2,440,317	1,397,678

2.4 Data Processing

The Electrical Resistivity Tomography data was processed using the EarthImager 2D software package from AGI. Various quality control measures were applied to remove low quality data, including; analysis of repeat readings, contact resistances values (measured between the electrodes and the ground at the time of each measurement) and comparisons of the injected currents and measured potentials. The origins of the low quality data are believed to be primarily due to the relatively high resistivity values of the subsurface materials perturbing the technique, rather than due to cultural noise sources. Although overhead power lines were noted on site, they were elevated on wooden poles thus isolating them from the ground. Furthermore, the resistivity meter features 50 – 60 Hz noise rejection filters to negate potential influence from power transmission equipment. Similarly, although gas pipeline (with cathodic protection) is known to be present along the eastern verge of the Kenai Spur Highway, the resistivity profiles all terminated before encroaching to close to the highway and therefore appear to be unaffected by the pipeline.

Elevation data was imported into the data files and a least-square inversion process was then run on the data to create pseudo-sections of the subsurface resistivity distribution. The quality control measures and iterative inversion process continued until the error between the field-measured and modeled resistivity data was within acceptable tolerance. The resulting Electrical Resistivity Tomography models were then imported as a database into the Geosoft Oasis montaj software package where geospatial data, recorded by the surveyors, was also incorporated. The data was then gridded (using a minimum curvature subroutine) and displayed as contour plots. A suitable color scale for data was selected based on the range of modeled resistivity values observed across all of the profiles.

The gridded data have been presented in the uppermost panels of the Electrical Resistivity Tomography Survey Results, presented in Appendix A, Plate A-1 through Plate A-13. Representations of geotechnical borings (from 2014 and 2015 G&G programs), test pits and hand augers, located in close proximity to the geophysical profiles, have been superimposed on the gridded data.

2.5 Vertical Electrical Soundings

The AKLNG Scope of Services for the onshore geophysical survey included a requirement for Vertical Electrical Soundings to assist with the design of corrosion protection and electrical grounding. The locations for these tests were provided to Fugro on November 12, 2015, after demobilization of the field crews from 2015 G&G program and therefore tests specifically designed to acquire this data were not performed. To overcome this, the Electrical Resistivity Tomography results have been used to generate synthetic data at select locations across the project site (Plate 3).

The process used to generate the synthetic data involved extracting a vertical profile from the 2D modeled resistivity values at discrete points on the profiles and performing forward modeling using the AGI EarthImager 1D software. The forward modeling essentially calculates the theoretical apparent resistivity values that would be measured if the subsurface displayed resistivity values identical to those of the model. In comparison to traditional 1D Vertical Electrical Soundings, extracting the data from the 2D models and generating synthetic data has several advantages. Primarily, there are many more quality control measures that can be applied to the acquired 2D data and due to the vast quantity of data points acquired, the identification of potentially erroneous data is greatly simplified. Furthermore, the 2D models account for lateral variations along the profiles, which cannot be resolved in 1D Vertical Electrical Soundings. The disadvantages of using this approach are there is no cross-line data (1D Vertical Electrical Soundings are typically acquired in two, perpendicular orientations) and the depth is limited to the depth of the 2D arrays.

For this project, theoretical apparent resistivity values were calculated for a Wenner array with electrode spacings of 0.5, 1, 2.5, 5, 7, 10, 16, 25, 50 and 75 feet. The results of the forward modeling and the synthetic Vertical Electrical Sounding data have been presented in Appendix A, on Plate A-14 through Plate A-31.

2.6 Electrical Resistivity Tomography Survey – Results and Conclusions

Through comparison with the geotechnical borings, a series of correlations between the modeled resistivity values and the shallow stratigraphy have been developed. Generally, across the majority of the site, the modeled Electrical Resistivity Tomography data displays a surface layer with variable thickness, with resistivity values in the 500 to 5,000 Ω-m range (shaded green through orange). This layer correlates well with topsoil (organic, silty, clayey sandy soils), identified as Strata I in the Generalized Subsurface Conditions presented in the Onshore Geotechnical Data Report (Fugro Report No. 04.10140334-8, AKLNG Document No. USAL-FG-GRZZZ-00-002015-006) with notable increases in its thickness being observed where appreciable silty strata were found (such as on profile EW-3 in the vicinity of boring B-92, Plate A-2). It has been noted that in most instances, the resistivity values within this layer display lateral variability across relatively short distances, which is interpreted to result from both changes in the composition of the surficial soils and changes in the surface conditions on site (such as presence or absence of vegetation and local topographic variations, which potentially result in variations in soil moisture). There are also occurrences where this surface layer is not apparent within the modeled data (i.e. the resistivity values at the surface are in excess of 5,000 Ω-m), yet the survey was conducted on natural soils (as opposed to a man-made gravel surface). An example of this can be found on profile EW-3 in the vicinity of borings B-93 and B-32 (Plate A-2). Under such conditions, it is likely that the surficial soils (topsoil with organic matter, silt and loess) are either relatively thin (less than 18 inches in thickness); or composed of a high percentage of granular materials.

Underlying the surface layer, the resistivity values display less lateral variability across short distances and are in the range of 5,000 to 20,000 Ω-m (shaded orange through red). These values tend to encompass the sandy silt, clayey sand and silty sand, identified as Strata II and Strata III in the Onshore Geotechnical Data Report.

Across significant proportions of the site, resistivity values in excess of 20,000 Ω-m (shaded pink) have also been observed. Such high values can be associated with air-filled void-spaces and hence relatively dry and granular materials and have therefore been associated with regions displaying relatively more appreciable concentrations of gravels within Strata II. An example of this can be found on profile EW-11 on the eastern boundary of an existing gravel pit, between borings B-88 and B-89 (Plate A-7). With additional exploration and geotechnical testing targeted on such anomalies, it may be possible to validate that such regions represent viable gravel resources that may be used as borrow material during construction.

In some localized areas, anomalously low resistivity values have been identified below 200 Ω-m (shaded blue through cyan), which can be correlated with either clayey soils (such as on profile EW-11 at the location of boring B-88, Plate A-7) or silts and sands containing an appreciable water content (such as on profile EW-10 between HA-110 and HA-111, Plate A-6).

Using the four distinct regimes outlined above, the Electrical Resistivity Tomography data has been interpreted into layered pseudo-section models. The delineation of these individual layers was based on a combination of logic and the following additional data sources:

- Experience gained from similar geophysical surveys conducted in the past;
- Absolute and relative changes in the modeled resistivity values;
- Pattern recognition of variations observed within the modeled resistivity values;
- Surface conditions based on site observations, site photographs and notes recorded at the time of data collection, aerial photography and topographic maps; and
- Correlation of modeled data with the geotechnical borings, test pits and hand augers; and

The resulting interpreted pseudo-section models of the subsurface conditions have been presented in the lowermost panels of the Electrical Resistivity Tomography Survey Results, presented in Appendix A, Plate A-1 through Plate A-13.

During the interpretation of the Electrical Resistivity Tomography data, several anomalous features were identified that did not conform with the above regime. Through correlation with observations made during the data acquisition, the majority of these anomalous features could be associated with cultural features or the surface conditions present on site that have perturbed the Electrical Resistivity Tomography technique. For example, on Profile EW-11 at an Easting of 1,397,000 feet (Plate A-7), extreme low resistivity values are observed at the surface; these are likely to be related to metallic structures and debris noted on site, rather than the presence of clayey soils. Similarly, on Profile EW-5 near boring B-17 (Plate A-4), a series of near-vertical anomalies are present and coincide with former driveways to properties. It has been interpreted that such anomalies are related to buried metallic utilities (pipelines or cables) rather than geologic structures within the subsurface. The presence of such cultural features has prohibited interpretation of the Electrical Resistivity Tomography data and as such have also been annotated on the interpreted pseudo-sections on Electrical Resistivity Tomography Survey Results, presented in Appendix A, Plate A-1 through Plate A-13.

Finally, it is apparent that across certain regions of the site, the Electrical Resistivity Tomography method has yield sub-par data. Examples of this can be found across the easternmost portions of profiles EW-5 and EW-12, and the northernmost portion of NS-1 (Plates A-4, A-8 and A-9, respectively), all of which were conducted across a distubred area largely free of vegetation. The surface conditions this region of the site were composed of predomninantly dry gravels, which display extreme high resistivity values, well in excess of 10,000 Ohm.m. Under such conditions, the contact resistances will also be in excess of 10,000 Ohm.m and therefore the method is unable to inject appreciable current into the subsurface, resulting in measurements that are less sensitive to deeper, subsurface variations. This is reflected in the modeled data by lower than anticipated, and sometime erratic resistivity values. As above, this essentially prohibits accurate interpretation of the data and therefore these areas have been annotated on the interpreted pseudo-sections on the Electrical Resistivity Tomography Survey Results, presented in Appendix A, Plate A-1 through Plate A-13.

3. SHALLOW SEISMIC SURVEY

Shallow seismic methods were selected to obtain geologic and geophysical information in the depth range of 10 to 1,400 feet. The objectives of the shallow seismic surveys were to:

- Delineate details of geologic structure across the LNG site, particularly the geometry of beds within the Killey and Moosehorn deposits at depths of 10 to 120 ft,
- Provide shear-wave data for site response calculations,
- Obtain high-resolution seismic reflection data in the depth range of 100 to 1,400 feet along the beach to screen for potential near-surface geologic structures,
- Collect seismic data in the immediate vicinity of the planned seismographic station to ensure that acoustic-wave and shear-wave velocities were well constrained from the surface downward into the higher-velocity Moosehorn deposits.

Shallow seismic data were collected along 14 semi-continuous lines totaling 55,600 feet of data acquisition, and resulting in 47,391 feet of processed output length (Plate 4, Table 3.1). The data were collected in two separate campaigns, a trial survey in May-June of 2015, and a production survey in July of 2015. The data collection, data processing, and results of the 2015 shallow seismic surveys are discussed in detail below. Plates illustrating field data collection and presenting results are found in Appendix B.

3.1 Survey Objectives

The objectives of the shallow seismic surveys were to identify characteristic and diagnostic shear-wave velocities for subsurface units, to delineate bedding contacts along each alignment between boreholes, and to provide seismic properties for site-response analyses. The 2D data profiles will be evaluated and used to assess geologic structure in the geologic hazards report. The geologic bedding contacts within and between the Killey and Moosehorn deposits are important markers for fault and fold screening as they form subhorizontal, partly continuous reference horizons for evaluation the presence or absence of displacement or deformation. This is an important aspect of Fugro's geologic hazards assessment of the LNG site as required by FERC regulations.

Relevant to the shallow seismic surveys, the findings of the trial survey indicated that IMASW processing would provide the best imaging of geologic structure in the 10 to 120 foot depth range, and that P-wave refraction processing would not adequately image shallow structure to meet project requirements. For this reason, data acquired during the main-phase of the shallow geophysical survey were processed using the IMASW method.

Shallow high-resolution seismic reflection data were collected along the beach adjacent to the proposed LNG facilities area. Objectives of the shallow reflection imaging were to map the base of glacial deposits in angular unconformable contact with the underlying Pliocene Sterling Formation, and to develop a datum for the assessment of tectonic activity in the vicinity of the proposed LNG footprint as part of the geologic hazards investigation. The orientation of the beach line is subparallel to large-scale structural features, but is nearly perpendicular to the traces of topographic lineaments, and shallow faults identified in coastal bluff exposures outside the LNG site. The beach seismic reflection survey also fills a gap between deep seismic reflection lines onshore and offshore.

3.2 Shallow Seismic Methods

The shallow seismic field data collected provides results for three related geophysical methods: 2D P-wave seismic refraction tomography (SRT), 2D Interferometric Multi-Channel Analysis of Surface Waves (IMASW) tomography, and 2D shallow seismic reflection imaging. All three methods share similar field data collection procedures and equipment. Seismic waves are generated at the surface using a 200 lb. AWD, and an array of geophones laid along the survey line records the signals as the waves are refracted and reflected back to the surface (Appendix B, Plate B-1). Details of the field data collection are in Section 3.3. The principles of each method are summarized below.

3.2.1 Refraction Tomography Method

The P-wave seismic refraction method assumes that acoustic seismic waves travel from the source through the subsurface along a variety of wave paths, and include refractions along interfaces (acoustic impedance boundaries) such as geologic contacts and the soil-bedrock interface. Direct and refracted sound waves (P-waves) are recorded at the ground surface over a range of distances between the sources and receivers. The sound-wave first arrivals can consist of air waves, direct arrivals corresponding to acoustic waves propagating in the subsurface near the free surface, and refracted and diffracted waves from the subsurface. Data processing techniques are used to assist in identification and filtering of various first arrival waves.

The seismic refraction method has the caveat that unless the sound velocity of the subsurface materials increases with depth, estimated sound velocities will be non-unique, resulting in blind zones where sound velocities are not resolved. In particular, when the air-wave arrival precedes the first subsurface sound-wave arrival, seismic refraction profiling is not advised because the near-surface is a blind zone. Seismic velocity calculations are made by back-projecting travel time residuals along the wavepaths from the sources to the receivers. The resulting 2D profile provides acoustic-wave velocities which usually change abruptly at the depths of the abrupt increases in P-wave velocity beneath the survey line, thus providing a 2D map of P-wave velocity variations along the survey line.

3.2.2 IMASW Seismic Method

The Interferometric Multi-Channel Analysis of Surface Waves (IMASW) method is based on the transmission of Rayleigh surface waves along the free surface that propagate with varying depths of penetrating into the subsurface as a function of frequency. IMASW is used to estimate: (1) vertical variations in shallow shear-wave velocity structure averaged across the lateral dimensions of subarrays of receivers centered on each receiver position with an individual survey line, and (2) depth-averaged shear-wave velocities along each survey alignment (O'Connell and Turner, 2011). For this investigation, depth-averaged Vs data are calculated at approximately 1.6-feet or 0.5-meter vertical bin resolution. In contrast to borehole seismic surveys, IMASW surface surveys sample a large lateral volume of the subsurface and generate a one-dimensional shear-wave velocity profile averaged over the selected number of receiver channels; in this case, a subset (19-21 receiver channels) of a towed land streamer corresponding to an eighteen to twenty meter lateral extent. The one-dimensional profile approximates the velocity-depth structure at the midpoint of the receiver array subset. The 2D shear wave profiles are calculated using weighted lateral averages of the 1-m spaced 1D Vs. The 2D Vs-depth is converted to 2D Vs-elevation using elevation survey data.

3.2.3 Reflection Seismic Method

The seismic reflection method is based on the reflections of sound waves (P-waves) from subsurface impedance contrasts that result from changes in the product of velocity and density across geologic boundaries. By using vertical-component receivers the recorded ground motions consist primarily of sound waves and surface waves. The sound waves travel from the source through the subsurface along what are commonly known as wave paths that are often approximated by infinite-frequency ray paths. Impedance contrast boundaries between different geologic units beneath the earth's surface reflect sound waves back toward the surface in proportion to the impedance contrast. The sound-wave reflections are recorded by a linear array of geophones. As more geophone and source locations are used, there is an increase in the subsurface sampling density of seismic reflections. Seismic refraction and reflection processing analyses are used to develop a sound-velocity model which is input into pre-stack time- and depth-migration to produce common-midpoint time- and depth-mapping of seismic reflectivity beneath the seismic line. The seismic reflection imaging method produces a 2D acoustic reflectivity map of the stronger impedance contrasts that can often be correlated with boundaries between different geologic units.

3.3 Field Activities

The shallow seismic surveys were acquired in accordance with our work plan presented in the Shallow Seismic Operations Method Statement (Onshore Geotechnical Data Report #USAL-FG-GRZZZ-00-002015-006, Appendix I, No. AKLNG-OS-GP-MS-006). Field procedures and operations outlined in this method statement were performed by field personnel following health and safety protocols and documentation outlined in the project Health and Safety (HSE) plan.

The 2015 shallow seismic field activities were planned and directed by Fugro geophysicist Dan O'Connell and geologist Jamey Turner. Shallow seismic data acquisition was performed by subcontractor Bird Seismic Services, Inc. (Bird Seismic) with direct field oversight by D. O'Connell. The data were collected in two phases, referred to below as the trial survey and the production survey.

The seismic trial survey data were collected May 27th to June 5th, 2015, after which the data were analyzed and the results transmitted to the client as discussed in section 3.1. The trial survey utilized a geophone land streamer and 200-lb weight drop source and included IMASW and refraction data collection and processing. Lines EW-4 and NS-4, and lines 105 and 202 near the planned seismographic station, were collected during the trial survey.

The production survey utilized the same equipment layout as the trial survey. Data acquisition for the production survey began June 23rd, 2015 and the majority was completed by July 12, 2015. In the production survey, lines EW-2, the far west portion of EW-3, EW-11, NS-1 north, NS-1 south, and NS-5 were collected. The northern portion of line NS-5 was collected in early October after the completion of the deep seismic survey. In addition, four shallow “high” resolution reflection survey lines, Lines NS-0, NS-7, 300 and 301, were collected along the beach utilizing the land streamer.

A typical seismic line data collection workflow included daily job safety meetings, driving the publicly-accessible roads to access the survey lines, flagging and GPS-recording geophone locations, deploying the land streamer cables and geophones, recording data by systematically operating the source along the line, advancing the streamer and repeating sourcing. A map of shallow seismic line locations is presented on Plate 4. Line locations depicted on Plate 4 are based on as-built recorded positions provided by McLane Consulting, Inc. A list of shallow seismic line locations and lengths is presented in Table 3.1.

Geophysical surveys were conducted along existing roadways wherever feasible. The grid-like pattern of these roadways formed the initial basis for the geophysical line layouts. Where trees and brush covered portions of the lines, vegetation clearing was required to prepare the ground surface for geophysical data collection. Greatland Tree Service, LLC, a local firm, provided clearing services for the project. Fugro’s site manager provided Greatland with GPS coordinates and guidance on line locations. An approximate 10-foot-wide swath was cleared for access of the seismic crew and equipment along the line segments that extended off existing roads.

Table 3.1 2015 Shallow Seismic Survey Line Length and Location

Line No.	Total Length[1] (ft)	Starting Coordinates[2] (ft)	Ending Coordinates[2] (ft)	Elevation (ft) Line Start/End	Processing method
105	393	X 1397756.36 Y 2440315.95	X 1398149.66 Y 2440311.43	132.48/133.63	Refraction, IMASW
202	394	X 1397933.88 Y 2440467.82	X 1397925.78 Y 2440074.22	134.93/133.07	Refraction, IMASW
300	709	X 2440010.37 Y 1392114.83	X 2439401.08 Y 1392477.39	-3.81/-3.86	Reflection
301	233	X 1392275.21 Y 2439696.29	X 1392476.05 Y 2439814.18	-5.75/20.08	Reflection
EW-2	2,917	X 1396286.24 Y 2434786.50	X 1399352.88 Y 2434710.47	118.94/124.15	IMASW
EW-4	4,958	X 1394217.09 Y 2437540.37	X 1399162.72 Y 2437342.93	124.29/121.39	Refraction, IMASW
EW-3, west	434	X 1395331.69 Y 2436166.91	X 1394897.93 Y 2436160.65	118.82/17.25	IMASW
EW-11	3,301	X 1395419.69 Y 2436760.04	X 1398738.78 Y 2436656.06	124.46/119.49	IMASW
NS-0	14,223	X 2443884.45 Y 1390577.53	X 2431116.5 Y 1396726.45	12.00/12.41	Reflection
NS-1 north	2,255	X 1393578.28 Y 2439595.95	X 1394437.59 Y 2437545.14	123.92/121.35	IMASW
NS-1 south	1,578	X 1394721.59 Y 2436530.52	X 1395451.39 Y 2435131.97	120.00/116.30	IMASW
NS-4	5,993	X 1396875.75 Y 2439074.12	X 1396834.97 Y 2433268.03	131.75/112.79	Refraction, IMASW
NS-5 north	3,979	X 1398158.87 Y 2437271.77	X 1398256.28 Y 2441226.78	123.00/135.98	IMASW
NS-5 south	5,198	X 1398017.21 Y 2432139.60	X 1398156.86 Y 2437282.80	112.12/123.23	IMASW
NS-7	826	X 2447148.82 Y 1389740.68	X 2446349.72 Y 1389944.95	10.79/11.21	Reflection

[1] Length of processed output.

[2] Coordinates are in Alaska State Plane Zone 4 feet, horizontal datum NAD83 (NSRS 2007), and vertical datum NAVD88 derived using GEOID06, provided by project surveyor McClane Consultants, Inc.

Table 3.2 2014 Shallow Seismic Survey Lines Reprocessed in 2015

Line No.	Total Length[1] (ft)	Starting Coordinates2 (ft)	Ending Coordinates[2] (ft)	Elevation (ft) Line Start/End	Processing method
EW-1	2,340	X 1396897.64 Y 2433647.82	X 1399237.26 Y 2433609.30	109.02/122.83	IMASW
EW-3	2,349	X 1395663.52 Y 2436114.43	X 1398012.21 Y 2436067.83	103.21/119.24	IMASW
EW-5	4,607	X 1399372.67 Y 2438672.14	X 1394766.22 Y 2438758.04	131.42/125.64	IMASW
EW-6	5,280	X 1394318.85 Y 2440066.59	X 1399597.25 Y 2439949.23	124.81/136.02	IMASW
EW-7	6,043	X 1393855.87 Y 2441381.58	X 1399897.44 Y 2441270.83	126.82/134.94	IMASW

[1] Length of processed output.

[2] Coordinates are in Alaska State Plane Zone 4 feet, horizontal datum NAD83 (NSRS 2007), and vertical datum NAVD88 derived using GEOID06, provided by project surveyor McClane Consultants, Inc.

For a majority of the shallow seismic data acquisition, a 72-channel receiver array with one-meter-spaced 10-Hz geophones mounted to a Teflon-coated nylon strap with weighted metal base plates (as opposed to geophone spikes) was used as an array towed behind a sport utility vehicle. This receiver system is referred to as a "land streamer," and is designed to acquire seismic data very quickly on smooth surfaces because it eliminates the need to manually plant geophones by hand, and can hook up 72 connectors for each array (Plate B-1).

The land streamer system was designed to employ a "rolling geometry," in which the 72-channel system, 71 meters long, is actively sourced every third receiver station, and subsequently advanced 36 meters. This creates 1.5-meter offset, and by the third roll the effective acquisition geometry has resulting receiver data coverage every 1 meter with an active source point about every 1 meter. Plate B-2 shows a schematic illustrating the source and receiver geometry for three 72-m land streamer positions (R1, R2, and R3) that result in a total of 1441-m receiver positions (indicated by RA in Plate B-2). There are 30 half-station source positions for each streamer position, denoted by S1, S2, and S3, that result in the source spacing indicated along the combined source positions (denoted SA in Plate B-2). Within SA there is an inner interval of 1-m source spacing, intermediate intervals towards the ends of staggered 1-m and 2-m source spacing, and an end region of 3-m source spacing indicated by the brackets and double areas between SA and the individual land streamer location source positions (S1, S2, and S3). The geometry produces consistent 1-m source spacing for many streamer positions along a long line except for the first two and last two streamer positions along the line (Plate B-2). The moveout of the land streamer was reduced by 1 m (Plate B-2) to increase data density and reduce shot spacing-regularity to improve subsurface sampling. Data were recorded with a 1-ms sample rate with 1.5-s-long records to ensure the slowest surface waves in the shallow soil were captured in the recordings.

Active seismic sourcing was provided by a skid-steer-mounted 200-lb accelerated weight drop (AWD) to ensure maximum access to line locations. The AWD is a highly repeatable source that can operate very quickly and provides good first breaks and strong signal-to-noise when used in conjunction with the 72-channel system. A Seismic Source Company DAQ3-24 seismograph system was used for recording the 72-channel land streamer data. The DAQ3 seismograph system includes three 24-channel units connected in series to the recording computer using Ethernet communication lines. For the northern extension of NS-5, collected in October, 2015, following the completion of the deep seismic reflection survey, a Seistronix EX-6 data acquisition system was used to record 200 channels of receivers in a rolling receiver configuration. The surface conditions including vegetation regrowth since line clearing, made this line portion not suitable for the land streamer use. The seismic source and array were advanced along the survey alignments determined by Fugro, and flagged and surveyed by Bird Seismic. Seismic line advancement occurred as described in the following sections.

The field crew consisted of one QA Geophysicist/supervisor, Crew Chief/recording lead, a Safety supervisor (shared between other onsite activities), Layout/Line Crewmen and Source Operators, and Surveyor/marking crew. The QA geophysicist/supervisor oversaw field operations and performed QA field checks on data as they were acquired. The Crew Chief directed field operations and managed the crewmen. The crew members were cross-trained so each member could safely rotate between equipment layout and data collection responsibilities. Some of these duties included deployment and systems testing, monitoring data acquisition systems, checking batteries, and system trouble-shooting.

Source operators worked in tandem with recording system operators and maintaining their source vehicle during sourcing, although they also aided in the initial layout and pickup of the recording array. The layout crew worked in groups of 2 to more focusing on deploying the land streamer or geophones/cables, seismograph deployment, and battery maintenance in areas the land streamer was not utilized. The survey/marking crew’s primary task was to lay out survey line locations prior to the start/mobilization of the rest of the field personnel. However, due to land access constraints, the survey/marking was performed during line layout in some instances.

The records for each hammer impact were 1.5 seconds in duration and had a 1-millisecond sampling. This record length includes a 20 millisecond pre-trigger time interval to ensure that the hammer impact was completely recorded. Records from individual hammer impacts at each shot point (SP) were summed in the field to recover a stacked record for each shot. Source locations and offsets are recorded in the Observers Logs for each line, and are provided in the onshore shallow seismic data electronic files (AKLNG #USAL-FG-GBSIT-00-000003-00).

The AWD was controlled by an operator who moved into position and stopped on the shot point and operated hydraulic controls from inside the cab to lower the strike plate to the ground. Once instructed by the manned recorder, the source operator conducted a series of impacts with the AWD. To improve the safety of operating the sources over varying terrain, a spotter familiar with the source operation was used to aid in safely lowering the pad/plate, and ensured that no obstructions or personnel were near the source during acquisition. The AWD's moving parts were enclosed to prevent workers from coming in contact with moving parts during operation.

3.4 Data Processing

Shallow seismic data collected during the field campaign were processed in one of three different ways to obtain different types of results. Processing steps are detailed below for seismic refraction tomography, IMASW shear-wave velocity, and shallow seismic reflection.

3.4.1 Refraction Tomography Processing

Seismic refraction tomography processing employed a commercial software package, Rayfract, by Intelligent Resources, Inc. (version 3.33, updated 2015). 2D tomographic processing was conducted along the length of the four trial survey lines. Processing steps included importing stacked seismic field files and applying inline geometry and elevations. Data were filtered using a consistent band-pass frequency filter and automatic gain control (AGC) set to enhance the resolution of the first-break energy. First breaks were manually picked and used by the program to perform velocity inversions and generate 2D tomographic models of Vp-elevation.

The starting model was created using Rayfract's XTV inversion to create a simple smooth model, then the Wave Equation Tomography (WET) inversion was used to create the final "smooth" models. Rayfract's processing algorithms are based on the XTV and Delta-t-V inversion methods of common mid-point (CMP) data (Diebold and Stoffa, 1981). The XTV inversion reconstructs the 1D velocity/depth function below a CMP based on XTV data triples (Winkelmann, 1998 and Gawlas, 2001). The inversion is based on a layer stripping principle and the XTV uses three separate methods for the data triple as follows: Modified Dix inversion, Intercept Time Inversion, and Gradient layer inversion (or Delta-t-V method). Since the processing is based on a layer stripping approach, the inversion starts with the first XTV triple at the smallest offset. Once the first layer has been determined by one of the three methods of the triple, the offset and time are advanced to the next layer. The triple inversion process is continued iteratively until all the XTV triples have been processed. Profiles of seismic compressional wave velocities were generated based on the first arrival times of the seismic waves. The refraction tomography processing assigns data depth positioning by means of ray tracing, so the depth is dependent on calculated preferential signal ray paths. Therefore, longer lines do not always equate to deeper resolution of acoustic-wave velocities.

3.4.2 Surface-wave (IMASW) Processing

Surface-wave phase dispersion was calculated for all receiver points at least 12 stations inside the seismic line from the ends of the continuous seismic line segments corresponding to a 1 m spacing for surface-wave dispersion measurements along the seismic lines. The active source vertical ground motion recordings were processed for phase-slowness constraints using the slowness-frequency phase-stacking approach of O'Connell and Turner (2011). The precise timing of the active seismic sources and the precise (< 0.1 m position uncertainties) surveying of the source and receiver locations provided accurate differential source-receiver distances for slowness-frequency phase stacking analyses using the sometimes curved arrays of geophones. Only group velocity constraints that are consistent in both propagation directions and correspond to fundamental mode were used in the velocity inversions. Substantial side-swipe noise from vehicle traffic adjacent to the profiles precluded deriving consistent group-velocity constraints from profile Correlated Green's Function (CGF) seismograms. Consequently, Vs-depth inversions were performed using only phase-slowness constraints with strong low-velocity-zone penalty functions to obtain the smoothest velocity shear-wave models consistent with the available phase dispersion data.

The IMASW data processing involves inversion of surface waves to model shear wave velocities with depth/elevation. A subset (19-21 stations) of receivers is first used to produce frequency/slowness plots, these dispersion curves are then picked along the center of the fundamental model maximum amplitude region of the phase dispersion images. As Kausel and Roesset (1981) showed phase-velocity (inverse of phase-slowness) constrains subsurface shear-stiffness structure as a function of depth and thus provides fundamental constraints on Vs-depth needed for geotechnical and site responses analyses. The Monte-Carlo Vs-depth inversion approach of O'Connell and Turner (2011) is used to estimate sets of Vs-depth models consistent with observed Rayleigh phase slowness-frequency.

The approach of O'Connell and Turner (2011) is similar to approaches developed during the InterPacific non-invasive shear-wave velocity estimation project (Garofalo et al., 2015) particularly the approaches of Wathelet et al. (2004) and Wathelet (2008) to evaluate large varying classes of Vs-depth structure to estimate the widest range of Vs-depth structures consistent with dispersion constraints. O'Connell and Turner (2011) save up to 63 dispersion-consistent Vs-depth models investigated during Monte-Carlo simulated annealing to characterize all the classes of Vs-depth models that are consistent with observed dispersion data. The Monte Carlo inversion process employs a modified likelihood function that penalizes low-velocity zones to ensure the simplest velocity-depth models are found that are consistent with the observed phase dispersion. To ensure robust Vs-depth estimates were obtained, three different starting models with different layer thicknesses were used to calculate three independent Monte-Carlo inversion estimates at each receiver positions. The logarithmic mean of these three Vs-depth estimates were used report Vs-depth/elevation at each receiver position.

The IMASW outputs were post-processed two ways to develop larger-scale 2D cross-sections of Vs-elevation. The 1-m spaced 1D Vs-depth profiles along each line part were smoothed with a 9-m horizontal half-width box-car function and a 1-m wide vertical boxcar function to create the 2D Vs-elevation images. This smoothing is consistent with the horizontal aperture of the 19-21-station subsets used to calculate Rayleigh-wave slowness-frequency images and invert for 1D Vs-depth structure. Higher vertical resolution is obtained at each profile location by using the layer thicknesses and Vs estimated in the Monte Carlo inversion from natural log averages of the 63 best-fitting Vs-layer-thickness models at each position.

After processing, the data were plotted as 2D IMASW vertical profiles, showing Vs tomography at depths of 0 to 200 ft.

3.4.3 Shallow Reflection Data Processing

The high-resolution reflection data processing uses state-of-the-art seismic reflection analysis techniques to create 2D depth images of acoustic structure. Seismic reflection processing was performed by Agile Seismic, LLC, with oversight by Dan O'Connell of Fugro Consultants.

The seismic reflection processing consisted of the following steps:

1. Use field survey and acquisition logs to create geometry for each line
2. Apply geometry and create SEGY shot-gather files with geometry
3. Pick first-breaks and check geometric consistency checking
4. Create final geometry for each profile
5. Pick first-breaks and 2D seismic refraction-statics tomography
6. Apply spherical divergence correction
7. Apply surface-consistent amplitude correction
8. Apply time-frequency domain denoise I
9. Apply time-frequency domain denoise II
10. Apply surface consistent deconvolution
11. Estimate and apply long-wavelength refraction statics correction
12. Conduct velocity analysis
13. Generate stacks
14. Apply residual refraction static correction
15. Create post-stack time migration (PSTM) from topography
16. Conduct PSTM velocity analyses (two passes)
17. Establish time-depth conversion with final velocity model
18. Create raw output of stacked migration amplitude depth data
19. Convert to time
20. Create raw output of stacked migration amplitude time data
21. Apply time variant filter (TVF)

22. Apply Automatic Gain Control (AGC)
23. Apply Coherency filter
24. Output depth and time data

Interactive iterative residual velocity analysis on migrated Pre-Stack Depth Migration (PSDM) gathers was used to update seismic profile velocity models. This allows for interpretive seismic velocity analysis that is needed for complex geologic structure.

3.5 Shallow Seismic Survey – Results and Conclusions

Results are summarized below for four seismic refraction tomography lines, thirteen 2D IMASW lines, three 2D seismic reflection lines, and 10 1D plots of Vp and Vs versus depth. Data plots are presented in Appendix B, along with an interpretation of each profile. The interpretations are intended to indicate the main geologic features apparent in the profiles.

3.5.1 Seismic Refraction Tomography Results

The Vp profiles of the trial survey lines show that meaningful refraction results were limited to the top 50-ft or less (Plates B-4 through B-7). The 2D Vp tomography plots show the Holocene soil as a clear low velocity layer. However, below these depths, Vp tomography does not relate well to the known geometry of beds observed in the boreholes or the coastal bluff. Lines that exhibit a velocity inversion, where an apparent lower velocity layer is found below a higher velocity layer, further weakens the depth of resolution for the refraction. Generally, the site-specific ground conditions (off road) in the project area are not well-suited to P-wave refraction tomography because the sound velocity of air consistently exceeds the sound velocity of the topsoil (overburden), which effectively makes the topsoil a low-velocity zone between the atmosphere and the underlying Killey glacial deposits. Because refraction techniques are not well-suited to resolving shallow, thin low velocity zones, the refraction processing does not effectively resolve the thin soil thickness. This method does indicate that the “hard” water table, or the 100% saturation zone where the P-wave velocity will be approximately 5,500 ft/sec (excluding local perched water bodies), is typically below the Killey-Moosehorn contact. Bedding contacts between the Killey and Moosehorn deposits do not correlate with a strong seismic refractor, so this contact is typically not constrained by P-wave refraction, although this contact is constrained by the IMASW Vs processing. The Vp data were not judged to be useful for understanding geologic structure, therefore no further refraction profile processing was conducted after the conclusion of the trial survey. No interpretations of the Vp data are provided in this report.

3.5.2 IMASW Results

Nine seismic lines collected in 2015 were processed using the IMASW method (Table 3.1). The lines were processed for 2D IMASW by estimating 1D Vs-depth at every receiver position except along the 9 receivers at each end of the line segments. The 2015 seismic lines used a 1-m (3.3-ft) receiver spacing except for the northern segment of line NS-5 which used a 4-ft receiver spacing.

In addition to the 2015 lines, five of the 2014 refraction data collection lines were reprocessed as 2D IMASW profiles (Table 3.2). The 2014 data had been collected with a 10-ft receiver spacing, approximately three times larger than the 1 m to 4 ft spacing used in 2015 (AKLNG report #USAL-FG-GRZZZ-00-000002-000_0). As a result, the 2014 data exhibit somewhat lower resolution relative to the 2015 data. To ensure the highest-possible resolution of glacial stratigraphic structure, the IMASW processing parameters were optimized to image Vs in the 10 to 120-ft. depth interval. Consequently, details of Vs variations in the top 10 feet are generally not resolved in the 2D Vs-elevation profiles. Nonetheless, an estimate of topsoil thickness was made by assigning materials having a Vs of 800 fps or less to the topsoil. These data can be compared with the results of the ERT survey, which was designed to provide highest resolution in the top 20 feet.

All IMASW data plots are presented in Appendix B, Plates B-9 through B-40. Each profile is presented twice, on sequential plates. The first plate shows the uninterpreted data and the second the same data with geologic interpretation. Discussion of the significance of the results to geologic hazard evaluation is presented in the geologic hazard report (AKLNG report #USAL-FG-GRHAZ-00-002015-002).

In general, the Killey deposits range in S-wave velocity from about 800 to 1,600 ft/sec, and the underlying Moosehorn deposits from about 1,200 to 2,500 ft/second. Local high velocity beds are present in the Killey deposits. These beds are laterally discontinuous, and are interpreted to represent either discontinuous fine-grained beds or iron-cemented zones. Good examples are seen in Plate B-20 at about 2,280 ft, and Plate B-34 at 5,100 and 5,300 ft. horizontal distance. Observed only in EW-4 and NS-4, each surveyed in the late spring, are relatively thin high-velocity layers immediately underlying the topsoil. These are interpreted to be frost zones. Plate B-16 from 2,300 to 2,900 ft shows a good example.

A general relationship applies when using seismic surface-wave methods to estimate Vs-depth. The maximum depth of significant Vs resolution is about a half wavelength at the lowest frequency that Rayleigh phase velocity could be measured. The half wavelength equals to *Vr(fmin)/fmin/2* where *fmin* is the minimum frequency of Rayleigh-wave phase velocity measurements and *Vr(fmin)* is the Rayleigh phase velocity at *fmin*. For example, typical AKLNG *fmin* is 5 Hz and typical AKLNG *Vr(fmin)* is 900 to 1,200 ft/s. Consequently, the typical maximum depth of significant Vs resolution for AKLNG sites is:

$$900\frac{ft}{s} \div 5Hz \div 2 = 90ft$$

Where Hz = 1/s, ft = feet, s = seconds

There are some areas where *Vr(fmin)* is low as 750 m/s and the lowest frequency that Vr can be measured (*fmin*) is as high as 18 Hz. In these areas the half wavelength is significantly lower:

$$750\frac{ft}{s} \div 18Hz \div 2 = 21ft$$

This demonstrates that a sufficient thickness of very low velocity materials can reduce Vs-depth resolution to 30 ft or less. These areas are generally confined to large depressions containing lakes and/or wetlands or small channels with locally thicker low-velocity material.

A good example of this effect is seen on Plate B-38 at 2,700 ft horizontal distance, where the plot shows a deep low-velocity zone beneath loose organic-rich sediments in the center of a depression. This apparent deep low-velocity zone actually represents a loss of depth-resolution. Another example can be observed on Plate B-26 from 1,800 to 2,500 feet horizontal distance where the loose gravel of the quarry floor masks the underlying structure. The slot-like appearance of the 2015 data may be a result of this effect on a smaller scale.

The 2D IMASW data shows planar features where rapid increases in Vs take place over short vertical distances, representing a planar impedance contrast. Comparison with borehole data show these features correlate reasonably well with the position of fine-grained beds. See, for example, Plate B-25. Mapping out of these impedance contrasts shows the Killey-Moosehorn contact to be characterized by one to several planar impedance contrasts, each presumed to represent a dense fine-grained bed near the top of the Moosehorn deposits or base of the Killey deposits. No single planar impedance contrast could be traced laterally for long distances. This suggests that the contact is transitional, and may be modeled as a zone of interfingering beds.

Two line types are shown on the interpreted IMASW plates (Plates B-10 through B-40, even numbers). Solid lines indicate higher confidence, and dashed lines indicate lower confidence. Solid lines delineate planar impedence contrasts that have a velocity increase of at least 200 fps over a vertical distance of less than approximately five feet and extend for a minimum of 30 linear feet. The dashed lines extend from the higher confidence solid lines to connect short line segments or to extend along planar features that do not meet the higher confidence criterion. The dashed lines extend along the planar feature until the feature is no longer traceable within approximately 50 to 75 feet, or until there is more than one planar feature that could match up with the delineated feature. It should be noted that additional planar features are recognizable in the data, but are not delineated as they do not meet the aforementioned criteria.

the delineated feature. It should be noted that additional planar features are recognizable in the data, but are not delineated as they do not meet the aforementioned criteria.

3.5.3 Shallow Seismic Reflection Results

The 2015 onshore high-resolution shallow reflection program collected three seismic survey lines along the beach NS-0, NS-7, and L300, using the towed land streamer and skid steer-mounted AWD source (Plate B-3). These lines were processed for seismic reflection. The reflection data were collected along the beach to obtain subsurface imaging of geologic structure within the deeper

Quaternary glacial sediments and the underlying Tertiary marine sediments at specific locations along strike of topographic lineaments, to assess for the presence or absence of potential faults. The 2D seismic reflection profiles show reflection at depths from 50 to 1,400 feet. The location of these lines with respect to the marine airgun seismic reflection survey lines is shown in Plate B-41.

Marine airgun Line S128 was acquired sub-parallel to onshore beach lines NS-0, NS7, and L300 (Plate B-41). Marine Line S128 is time-domain data, and is shown first as a raw uninterpreted panel (Plate B-42), and with interpretations (Plate B-43), to provide context to the adjacent onshore lines. Line S128 is a well-imaged marine line located approximately 1,400 feet west of the northern end of the onshore line NS-0 and 3,300 feet from the southern end.

Interpretations shown on (Plate B-43) include two shallow unconformities. The deeper unconformity (blue) delineates the angular unconformity between the base of the glacial deposits and the underlying south-dipping strata of the Pliocene Sterling Formation (purple). The shallower unconformities (two shades of green) are more recent and may be related to Cook Inlet erosional and depositional processes, and thus this shallowest unconformity is not observed in the onshore seismic reflection data. The unconformity at the base of the glacial deposits dips down at the southern end of the profile (arrow). We interpret this to represent a trough eroded by streams or glaciers into the top of the Tertiary deposits, which is now filled with Quaternary deposits.

Beach reflection data are provided in PSDM depth-migrated seismic profiles. The seismic reflection profiles are shown uninterpreted and interpreted in Plates B-44 through B-47. The profiles exhibit a zone in the 100 to 200 feet depth range with brighter, higher-amplitude reflectivity. This bright zone is interpreted to represent depositional layers within the glacial outwash and till deposits that are more reflective than near-surface deposits above elevation -200 feet. Interpretation of beach line NS-0 (Plate B-45) shows an angular unconformity as a red horizon, which is interpreted to be the base of the Quaternary glacial deposits in unconformable contact with the underlying Pliocene Sterling Formation. Laterally discontinuous reflectivity within the glacial deposits may be attributable to aggradational glacial processes and lateral heterogeneity in glacial deposits.

Plate B-46 shows a very short reflection panel, Line NS-7, located in an effort to obtain subsurface imaging across a NE-SW oriented linear topographic feature, referred to as the “Bernice Lake lineament,” to assess the nature and origin of this feature. Two arbitrary horizons are mapped on the reflection panel, red and green, to point out relatively horizontal reflectivity, although the flat reflectors are not clearly continuous across the entire panel. NS-7 is located approximately 1,400 feet east of the northern extent of marine survey line S128 between shot points 7600 to 7792 on Plate B-41, where no reflector truncations are observed, suggesting that the topographic lineament is not related to an underlying tectonic fault.

Plate B-47 shows another short onshore seismic panel, Line L300 Beach, located to obtain seismic imaging along a noisy portion of the beach adjacent to a sheet pile wall where the data along Line NS-0 Beach was affected. Line L300 is located parallel and adjacent to NS-0 shot points 2700 to 3100, and sub-parallel and adjacent to marine airgun line S128 shot points (approximately) 4600 to 4900. Two arbitrary form lines are interpreted on Line L300 to show hummocky non-planar, subhorizontal reflectivity in the image. The unconformity mapped in NS-0 and S128 is not clearly identifiable in L300, but the near-surface laterally heterogeneous nature of the Quaternary deposits, as postulated in the NS-0 interpretation, may also be present here in L300 and explain the hummocky non-planar reflectivity in L300.

Under the NS-0 red horizon, two arbitrary form lines (green and magenta horizons) show the approximate apparent south dip of reflector packages within the Sterling Formation; reflectors are arched and discontinuous in the upper 500 feet. Rather than very tight anticlinal folding, the arches are interpreted as data artifacts related to the narrow data migration aperture associated with the onshore landstreamer system. Marine airgun line S128 (Plate B-43) shows the south-dipping Sterling Formation reflectors to be planar and not tightly folded, so this makes tight folding in the nearby NS-0 onshore data unlikely. The higher-energy marine airgun source was energetic enough to show impedance contrasts within the underlying Tertiary sediments large enough to produce a strong and continuous reflector; however the location and nature of this contact is well established by a parallel seismic reflection profile from the 2015 marine airgun survey (Plate B-43). Gentle undulations in the shallower reflectors are reflectors within the Sterling; the lower energy AWD source on loose beach gravels was able to image semi-continuous reflectivity. Interpretations between the high-resolution beach survey and the proximal airgun marine survey are consistent. Additional marine geophysics data and interpretation are presented in AKLNG report #USAL-FG-GRZZZ-90-002015-010, Marine Geophysical Survey Report.

3.5.4 Selected 1D Vs and Vp Profiles

Utilizing the both the 2014 and 2015 data, 10 locations were selected to produce 1D Vp/Vs profiles within the current proposed plant footprint (Plate B-3). These locations were selected near proposed structures and are intended to help supplement downhole seismic test data for engineering design.

Based on the trial survey results, further refraction Vp data processing was not performed on the production 2015 seismic data. However, limited additional P-wave processing was performed to produce Vp and Vs 1D profiles at selected locations. The 1D profiles were produced from the IMASW 2D Vs profiles by extracting Vs-depth data at the selected center point and two adjacent points approximately 10 feet on either side of the point. A log normal mean of the depth values was plotted. In a similar fashion, the Vp-depth data were also extracted from the refraction tomography data. In locations where refraction data were not collected during the 2015 program, 2014 data was utilized. The Vp and Vs data plots are presented on Plates B-48 and B-49. For consistency, the existing 2D data and limited additional processing both utilized the Rayfract software and refraction tomography processing method.

The typical seismic velocities at the site below the shallow highly variable slower material, ranged between approximately 700 to 2,000 feet per second (ft/sec) S-wave, and 1,000 to 7,000 ft/sec P-wave. These ranges are similar to those obtained by downhole seismic methods (AKLNG report USAL-FG-GRZZZ-00-002015-006, Geotechnical Data Report, Plates E21a and E-21b). In general, velocities increase with depth in the profiles. S-wave velocities were plotted down to an elevation of

-30 ft., and P-wave velocities to an elevation of 80 to 50 ft. The P-wave data were limited in depth of resolution due to the shorter receiver length of the towed streamer. Very shallow P-wave velocities were not resolved due to the very slow surficial material and velocity inversions found in these surficial layers. Plots of the selected Vp depth profiles are presented on Plate B-48, and plots of the Vs depth profiles are presented on Plate B-49.

3.5.4 Conclusions for Shallow Seismic Surveys

In general, the IMASW and seismic reflection methods produced very useful results, and accomplished the goals of the shallow seismic surveys.

The IMASW profiles provide good imaging of sedimentary layering in the Killey and Moosehorn deposits within the 30 to 80 foot depth range. Planar impedance contrasts match well with the positions of fine-grained beds logged in boreholes, indicating that these beds have relatively high shear-wave velocities. Tracing planar impedance contrasts laterally may delineate the tops of these fine-grained beds. This information will be very useful for correlations of bedding between boreholes and ultimately for the understanding of geologic structure.

The depth resolution of the IMASW method is reduced where thick deposits of very slow Vs materials are present near the surface. These low-velocity materials reduce the depth penetrating of the surface waves, in areas with thick very low shear-wave velocities at the surface the 2D Vs-elevation profiles will show a low-velocity zone that extending to the bottom of the profile, giving the false appearance of a low velocity slot within higher velocity material.

Shallow seismic reflection, used solely on the beach survey lines where the lack of soft topsoil allowed greater penetration of seismic waves from the AWD source, was successful in imaging deep geologic structure to depths of 1400 feet. The resulting data matched well with the nearby marine seismic reflection data, and confirmed the presence of dipping Teriary marine beds unconformably overlain by Quaternary glacial and glacially-derived sediments.

Seismic refraction tomography proved to have limited usefulness in this geologic setting. The basic premise of the method, that the P-wave velocity of the material increases with depth, is violated by shallow velocity inversions. In these unconsolidated sediments where lower velocity beds may underlie higher velocity beds, the method was unable to resolve the geologic structure. This method was applied only in the trial survey.

Geophysical properties useful for engineering analysis were also obtained from these data. Ten profiles of Vs and Vp were generated within the LNG facilities area. These, along with downhole measurements in boreholes, provide a robust dataset for geotechnical calculations.

4. DEEP SEISMIC DATA COLLECTION

4.1 Survey Objectives

The purpose of the deep seismic reflection survey is to image the geologic structure over the widest possible depth range to include glacial structure, sedimentary basin structure, and basement structure, if possible. At a minimum, the deep seismic survey needed to resolve details of the Tertiary sedimentary basin, including any faults and folds, with the objective of imaging these structures to a depth of at least 15,000 ft. The deep imaging provides a means of identifying blind faults and to assess the relative activity of the faults and folds over geologic time. This deep structural information is necessary for adequately accessing the seismic hazard at this critical site.

The deep seismic reflection survey was conducted along three alignments using two truck-mounted synchronized swept-signal vibratory active sources with over 60,000 lbs. hold down weight each, recorded by both cable-based and autonomous nodal seismic recording systems to provide long-offset data to image to 8 seconds two-way-time. Processing of the deep seismic data includes 2D first-arrival seismic refraction tomography and pre-stack time- and depth-migrated data suitable for assessing the structural geologic setting underlying the site.

Initially, four deep seismic lines were planned. These included EW-3, EW-8, NS-2 and EW-5. Due to permitting and access issues, EW-5 was removed from the acquisition program. Plate 5 shows the line locations as acquired for this survey.

4.2 Deep Seismic Imaging Method

The deep seismic reflection survey acquisition parameters were designed to simultaneously image as shallow and deep as possible, in contrast to typical oil & gas 2-D exploration surveys that are highly optimized to image within a specific depth range, and are not designed to effectively image shallower depths. Acquisition parameter selection for the deep survey was custom-engineered based upon information provided by the site-specific 2014 shallow seismic survey and knowledge developed during the geologic mapping, regional desktop study, and evaluation of industry seismic data. Goals of the 2015 seismic reflection survey were to image to maximum depths for tectonic investigation (30,000+ feet), with near-continuous imaging to the surface to evaluate for the potential of near-surface tectonic features. This is not an objective of typical depth-targeted oil and gas industry data, but rather a focused geohazards approach to seismic reflection imaging.

Several key factors were considered in the design of the deep seismic survey. These include the P-wave and S-wave velocity structure of the near surface derived from the 2014 shallow seismic survey, the frequency response and source energy attenuation in the 2014 shallow seismic survey and the high ambient noise levels expected at the site, especially along the Kenai Spur Highway. Numerous ambient noise and interference sources are present at this site and include but are not limited to vehicle traffic, industrial plant operations, underground pipelines, and simultaneous operations (SIMOPS) such as geotechnical drilling and ongoing industry seismic airgun surveys in the Cook Inlet.

Industry-standard 66,000-lb vibrator truck sources were selected for this survey because of their ease of mobility, little to no impact on infrastructure, high energy output, output frequency control, and their ability to source-sweep over a long time window (Plate C-1). The long sweeps were critical to minimizing the impact of the high ambient noise levels at this site. Vibrator truck sources are also efficient at rapid data acquisition, which made possible the high source effort planned for this survey. A tightly-spaced receiver array with receiver groups at 20 ft intervals was also selected for this survey to obtain good imaging resolution over the entire depth range, from a few hundred feet to over 25,000-ft depth.

The deep seismic reflection survey nominal data acquisition parameters included the following:

- Primary Source: 2 x Inova AHV-IV Commander VibroSeis trucks (2 x 66,000 lbs.), synchronized, 40 ft nominal offset between VibroSeis pads (Plate C-1).
- Fill-In Source (EW-3 only): United Service Alliance, Inc. AF200 hammer (200 lb. hammer) mounted on a skid steer (Plate B-1).
- Sweep Parameters: 4 Hz to 85 Hz, linear sweep, 40 second length with 8 second listen, 1.25 second start and 1.0 second end cosine taper, 75% drive level.
- Encoder/Decoder: Seismic Source Universal Encoder II / Force 3 Decoder
- GPS for Source Timing/Positioning: Novatel Ropak V3 HP
- Source Interval/Array: 4 sweeps per 40 ft, 10 ft move up per sweep (AWD 16 stacks summed, 40 ft spacing)
- Geophone Group Interval/Array: 20 ft group spacing, 4 elements per group at ~ 5 ft spacing
- Geophones: 14 Hz x 4 elements per string Sunfull PS-14B, in-fill at road crossing and off-road sections used 14 Hz x 2 elements per string Sunfull PS-14B.
- Recording Systems: Seistronix EX-6 cable telemetry and iSeis Sigma nodal systems (Plate C-2)
- Records: Each sweep recorded as individually, 48 seconds uncorrelated, SEGY
- Sample Rate: 4 milliseconds
- Acquisition Filters: all out
- Active Array: static spread with all stations live
- Effective Nominal Fold: > 300

Along one segment of EW-3, the lack of an established paved or gravel road made it impossible to use vibrator trucks. Here, the AWD was used as the seismic source. Due to the presence of a thick organic mulch along the line, which had been recently cleared through the forest, source holes were dug with an auger through the upper soft, organic soil layers to improve source coupling. This significantly improved source energy coupling and reduced high frequency attenuation.

Plate B-1 shows the AF200 weight drop mounted on a skid steer which was used for source in-fill on Line EW-3. A steel extension was fabricated by ASRC to be attached to the strike plate on the AWD and extend approximately 3 feet below the strike plate. The downhole end of the extension also has a smaller circular plate welded to it. Source holes were drilled with a 6 inch auger mounted on the skid steer. The auger was marked at the 3 ft depth which was the required depth of the source holes. The depth to glacial gravels was fairly consistent across the 90 source holes with the top of gravel at about 2.5 ft below grade. The upper materials were very soft and the auger, under the weight of the skid steer, would push straight through. Resistance was met at the top of the gravels, which would lift up the front of the skid steer. Rotation and cycling of the auger was required after contacting the gravels to get the final source depth of 3 ft.

Two recording trucks were used for this survey (Plate C-1). The main recording truck collected the Seistronix data and controlled the source operations. A second portable remote recorder with a mounted antenna tower was used to manage the iSeis Sigma nodal array. Seismic data acquisition was performed by Fugro subcontractor Bird Seismic Services. The Inova AHV-IV VibroSeis trucks were owned and operated by SAExploration, a subcontractor to Bird Seismic Services.

4.3 Field Activities

The Fugro project geophysicist, the Fugro field geophysicist, and the seismic contractor site manager arrived onsite on August 24, 2015. August 24 to August 26 included start-up meetings, site orientation, and tours of the seismic line locations. Deep seismic data were acquired in accordance with our work plan presented in the Onshore Deep Seismic Survey Operations, Method Statement No. AKLNG-OS-GP-MS-007, issued 8/31/2015. Field proceedures and operations outlined in this Method Statement were performed by field personnel following health and safety protocols and documentation outlined in the project HSE plan.

Sigma nodal recorders along the western portion of EW-3 were deployed to record Fugro offshore airgun acquisition on August 26, 2015, for continuous recording. However, due to weather delays, the offshore airgun survey was delayed and missed the onshore recording window. Stake out and equipment deployment on Line NS-2 began on August 27, with full layout completed by September 1, 2015. The vibrator trucks (VibroSeis) arrived onsite from SAExploration on August 30, 2015 and were offloaded by the SAExploration VibroSeis operators in the AKLNG quarry property off of Robert Walker Rd. An initial inspection and startup was performed by the operators after off-loading. Beginning on August 31, 2015, Dale Neidig of Seismic Source Co. installed the Seismic Source Force 3 decoders, Novatel GPS and configured the Universal Encoder II in the main and remote recording units. Following installation of the VibroSeis electronics, Mr. Neidig performed the inspection and the hardware similarity calibration.

Vibroseis source parameter testing was conducted on September 1, 2015. Source sweeps were run in the quarry off of Robert Walker Rd and along the dirt road which intersects Robert Walker Rd and Hinerman Rd on the west side of the quarry. The source test data were recorded on the Seistronix receivers deployed on NS-2. A sample test record is shown in Plate C-2.

Utilities were marked on the ground and buffer zones uploaded into the pre-plot navigation files in the lead vibe computer. A minimum of 20-ft offset was used between the vibe pads and the marked utility locations. Additionally, a Fugro employee was present at all utility crossing during sourcing to adjust offsets as necessary. When skips were required, makeup sweeps were collected on both sides of the skip.

Traffic control was provided by Northern Dame, seismic receiver station land surveying was performed by McLane Surveyors, and brush cutting was performed by Greatlands.

Real-time vibration monitoring was performed when the primary sources approached and passed potentially sensitive surface structures within 150 ft of the source locations. Plate C-2 shows the typical vibration monitoring equipment deployment.

The action threshold for particle acceleration was 0.2 inches/second next to the structure. If particle velocity exceeded the threshold, the first response was to reduce source output using the “low force” source mode which reduced drive levels to 40 percent. If reducing the force did not bring the particle velocity below the 0.2 inch/second threshold, the sources were instructed to moved up and the source points near the sensitive structures were skipped. Public concerns were addressed in the same manner. If a home or business owner expressed concerns over perceived vibration levels, even if these levels were below the action threshold of 0.2 inch/second at the structure, sources were switched to “low force” output or source locations were skipped, if necessary.

Production seismic data were recorded for the three deep seismic lines as listed in Table 4.1. The total linear footage of the receiver lines for the three deep seismic reflection lines is approximately 90,240 ft. The line locations are shown on Plate 5. The lines start and end stations and locations are listed in Table 4.2 below.

The Fugro project geophysicist was onsite during initial setup, parameter testing and start of production data acquisition, and continued overall project management from the Lakewood, Colorado office. The field geophysicist, who reported to the project geophysicist, was responsible for oversight of the deep seismic reflection survey field operations and coordination of operations with the project geophysicist, the site manager and the HSE manager. The field geophysicist also performed in-field QC checks and vibration monitoring. The Fugro assistant site personnel, under direction from the field geophysicist, provided direct coordination with Vibroseis movement and traffic control, and assisted with vibration monitoring.

Table 4.1. Deep Seismic Reflection Data Acquisition and Line Footage

Line Number	Start Active Data Acquisition	End Active Data Acquisition	Approximate Linear Footage of Receiver Array
NS-2	2 September 2015	10 September 2015	29,960
EW-8	16 September 2015	23 September 2015	31,360
EW-3	29 September 2015	4 October 2015	28,920

Table 4.2. Deep Seismic Reflection Line Endpoint Stations and Locations

Line Number	Starting Station	Easting (usft)	Northing (usft)	Elevation (ft)	Ending Station	Easting (usft)	Northing (usft)	Elevation (ft)
NS-2	1001	1399328.52	2424237.47	107.03	2449	1393835.04	2452540.67	134.17
EW-8	2165	1392317.11	2446174.49	111.43	3733	1414503.27	2465399.67	149.62
EW-3	1001	1394884.05	2436155.16	117.3	2447	1423732.06	2435480.65	132.91

4.4 Data Processing

The raw field data were checked and pre-processed by Fugro, as described in section 4.4.1, then submitted to Agile Seismic LLC for processing. Agile's processing steps, resulting in 2D seismic reflection profiles, are described in section 4.4.2.

4.4.1 Data QC and Preprocessing

Fugro conducted initial data quality checks in the field and later in Fugro offices prior to transmitting the seismic data to Fugro subcontractor Agile Seismic LLC for processing. The Vibroseis source signature recordings of all the Vibroseis sweeps from each of the two Vibroseis trucks were scanned and plotted in GIS and compared with observer's notes and field notes to determine final source positions. Receiver locations from McLane survey files were plotted in GIS and compared to preplot locations, observer's notes, and field logs to confirm proper location and station numbering of receivers. All raw and correlated Vibroseis data were visually inspected to ensure the accuracy of record start times. A small number of records were found to have one-second GPS errors which were corrected by visual inspection. The Vibroseis uncorrelated data were correlated with Vibroseis source-signature recorder Vibroseis sweep time histories to produce correlated Vibroseis records in SEGY format. Every correlated Vibroseis record was visually inspected to detect anomalies including Vibroseis start time errors and failures of Vibroseis trucks to start sweeps from missed radio triggers.

The Vibroseis (and AWD data from deep EW-3) were output in SEGY format were output by Fugro with the verified source-receiver geometry loaded into the SEGY trace headers and transmitted to Agile Seismic for processing. Agile Seismic reviewed the SEGY for accuracy using geometry checks including offsets seismic displays as well as applying linear moveout to shot gathers to verify correct positioning of receivers and source positions. SEGY header geometries were plotted in 3D to confirm correct assignment of source-receiver geometries including elevations. Agile Seismic confirmed that the geometry loaded in the SEGY trace headers passed on quality checks. Agile Seismic transmitted a summary QC report that Fugro reviewed and accepted prior to proceeding with seismic reflection processing.

4.4.2 Agile Seismic Processing Work Flow

Details of the seismic reflection data processing steps performed by Agile Seismic, LLC are presented in Appendix D.

The goal of the processing were to :

- Produce images as deep as possible up to 8 sec two-way time correspond to depths of up to ~50,000 ft in order to detect and image any possible larger geological features such as faults, synclines and anticlines.
- Produce high resolution shallow images showing shallow structure to identify and delineate shallow faulting and glacial structure

To accomplish these goals, Agile Seismic utilized a combination of proven advanced seismic processing techniques and proprietary algorithms. The primary processing results are pre-stack time migration (PSTM) and pre-stack depth migration (PSDM) seismic reflection sections that delineate both shallow and deep geologic features. Details of Agile Seismic processing are provided in Appendix D, Agile Seismic Data Processing Report. The deep seismic reflection data were processed from a floating datum with Seismic Reference Datum (SRD) of 200 ft and replacement velocity of 2700 ft/sec.

The Vibroseis PSDM and PSTM data are of excellent quality and well suited for both shallow and deep seismic reflection interpretation. The PSDM data were output using a 10 ft horizontal spacing and 15 ft vertical spacing with good signal-to-noise to 30,000-45,000 ft depth (depending on the geology). The PSDM data can be effectively high-pass or low-pass filtered to isolate and enhance detail in the shallow (< 5000 ft) or deep (> 15,00 ft) portions of the data. The PSDM have sufficiently consistent high signal-to-noise data coverage within the regions 1000 ft inside each end of each of the three "deep" seismic reflection lines in the 5000-12,000 ft depth range to use reflector continuity to evaluate for the presence or absence of faulting.

4.5 Results and Conclusions

The onshore vibrator-sourced seismic reflection data PSDM panels are described in this section and presented in Appendix C. The data are shown both without interpretations and with interpretations. Features interpreted include angular unconformities and "arbitrary" horizons, or seismic reflectors relating to geologic bedding. The geometry (dip and undulations of the bedding shows the nature of the geologic structure.

Based on geologic structure mapping of the 2015 offshore marine survey, the strike of the underlying Pliocene Sterling Formation is approximately N10°E, gently dipping to the southeast. The orientations of the three seismic lines are somewhat oblique to the true dip direction, so dips shown in the seismic panels are "apparent" dips that can be converted to true dips. Line bends, such as the northern portion of NS-2 and the southwestern portion of EW-8 appear as apparent folds, but are related to the changing azimuth of the seismic lines across obliquely dipping strata. A detailed discussion for each line follows.

4.5.1. Line NS-2 Results

Plate C-6 presents the P-wave tomographic velocity model developed for the NS-oriented alignment NS-2 as part of the PSMD depth migration, and shows higher velocities at depth to the south end of the line. Plate C-7 shows uninterpreted PSDM depth-migrated seismic reflection data for 2015 Line NS-2. Plate C-8 shows the same data panel with preliminary interpretations. These PSDM panels extend from 0 to 24,000 depth at H:V scale 18,000:18,000 with no vertical exaggeration. North is to the left; shallow glacial strata are the flat-lying strata from the surface to 300-600 foot depth. A shallow angular unconformity is mapped as the relatively near-surface bright green horizon that clearly separates the apparent south-dipping Pliocene Sterling Formation strata from the base of the relatively flat-lying Moosehorn glacial deposits. The unconformity undulates and varies in elevation between shotpoints 1250 to 1450 and 2150 to 2450, which may be related to varying erosive glacial processes, or infilled paleochannels cut into the top Pliocene Sterling along this 2D profile. Three arbitrary form lines are also mapped on this NS-2 panel, turquoise magenta, and pink, to show the apparent south-dipping strata. The upper turquoise line, at approximately -4,400 to -4,800 feet depth, appears to be gently folded with an anticlinal axis near shotpoint (SP) 2500, and otherwise bedding is very planar and dipping slightly south.

The middle magenta form line, at approximately 8,300 to 9,300 feet depth, is also anticlinally folded at SP 2500 with more amplitude on the fold relative to the turquoise reflector, and is also gently folded with an anticlinal axis near SP 1350. This SP 1350 fold does not warp the upper turquoise reflector, indicating the growth on this anticline died prior to deposition of the turquoise seismic reflector strata.

The deepest pink horizon also indicates anticlinal folding at SP 2500 and SP 1350 with the highest fold amplitudes, indicating that fold growth continued over underlying blind faults during Tertiary time, but are not observed folding most recent Pliocene and post-Pliocene strata. No reflector truncations are directly observable shallower than approximately 16,000 feet depth in line NS-2. A synclinal basin deepens to the south end of the line, with an apparent synclinal axis at approximate SP 450, which correlates with the higher velocity portions of the Vp tomographic model presented in Plate C-6.

4.5.2 Line EW-3 Results

Plate C-3 presents the P-wave tomographic velocity model developed for the EW-oriented alignment EW-3 as part of the PSMD depth migration processing, with a higher-velocity bulge from 6,000 to 10,000 foot depth from SP 1700 to SP 2400, centered about SP 2100. Plates C-4 and C-5, respectively, present uninterpreted and interpreted seismic reflection PSDM panels from 0 to 24,000 depth at H:V scale 18,000:18,000 with no vertical exaggeration.

The interpretation shown on Plate C-5 shows six interpreted reflector horizons. The bright green shallowest horizon follows the first strong bright reflector, which undulates in elevation along the profile, and is interpreted to be the base Moosehorn – top Pliocene Sterling angular unconformity, which varies in elevation from approximately -100 feet (SP 1000) to approximately -600 feet (SP 1800), similar to NS-2. The green horizon is dashed where the unconformity cannot be mapped with certainty, and solid where certain. The red horizon follows a semi-continuous reflector, and is dashed where uncertain; this reflector apparently dips gently to the east. Combined with the apparent southern dip mapped in NS-2, indicating the regional true dip is to the southeast. The regional strike and dip direction will be constrained by interpretation of the seismic survey grid. The red horizon appears to be very gently synclinally folded between SP 1500 and SP2500, with the synclinal axis at SP 2100.

The blue (-5,000 to -5,800 ft.), orange (-8,300 to -9,400 ft.), and goldenrod (-12,900 to -14,500 ft.) reflectors show the same synclinal structure, which grows in fold amplitude with increasing depth. No reflector truncations are observed above the goldenrod horizon.

Below the goldenrod horizon, a magenta horizon is mapped that is interpreted to be the top of Mesozoic basement (Shellenbaum et al., 2010). Under the magenta horizon, a fold hinge is observed under SP 1550 to 1600, and west of the hingeline deeper reflectors appear to be truncated on either an ancestral west-dipping reverse fault or an ancestral east-dipping normal fault. The tip of this fault does not appear to be shallower than -22,500 feet, and is thus interpreted to be a Mesozoic-age reverse fault that is no longer active.

4.5.3 Line EW-8 Results

Plate C-9 provides the Vp-tomographic velocity model developed for EW-8, a northeast-southwest oriented line with a southerly line bend at the southwestern extent. Southwest is to the left on Plate C-9, which shows that the northeastern half of the line exhibits higher Vp values below approximately -17,000 feet.

Plates C-10 and C-11, respectively, show uninterpreted and interpreted PSDM seismic reflection panels scaled at H:V 18,000:18,000 with no vertical exaggeration. Plate C-11 shows four interpreted seismic horizons. The bright green horizon shows the contact where the base of the relatively flat-lying Moosehorn glacial deposits are in angularly unconformable contact with the apparently northeast-dipping (but actually dipping ~100°) underlying Pliocene Sterling Formation. Within the Tertiary strata, three arbitrary reflector horizons are mapped.

The Violet horizon shows what appears to be two fold hinges along the alignment. The southwestern-most apparent fold that appears as an asymmetric anticlinal fold at approximately SP 600 is related to a bend in the line (Plate 5), and is not interpreted to be an actual fold. Along the alignment, the violet reflector is shallowest (-4,700 ft.) at the line bend at approximately SP 600, and deepest in the synclinal axis at approximately SP 2900 (-7230 ft.).The southwestern portion of Line EW-8 strikes approximately 10°, parallel to strike, near SP600 where reflectors appear flat at the apex of the line bend, and dip away in each direct of apparent dip, which is expected where the orientation of a seismic line rounds a bend and briefly parallels bedding strike.

The magenta and blue horizons show fold growth with depth along the synclinal basin structure. The upper green horizon (Moosehorn-Sterling contact) also appears to apparently dip gently to the northeast. The reflector continuity degrades to the southwest on the blue horizon south of the line bend, so the western portion is dashed as uncertain. No reflectors appear to be vertically truncated under to a depth of -16,000, where the deepest continuous reflector is observed, precluding the presence of a tectonic fault in the upper 16,000 feet along this alignment.

The syncline in the northeastern portion of EW-8 is along a similar longitude (N-S line) to the syncline observed in EW-3, and may be a northern extension of the same structure, but no seismic data exist between these two lines to confirm this structure is continuous along strike.

4.5.4 Conclusions for 2015 Deep Seismic Surveys

The deep seismic reflection surveys were successful in their goal of imaging the deep geologic structure beneath the site. Bedding planes in the Tertiary sediments are clearly resolved to depths of more than 24,000 feet, the approximate top of the Mesozoic and base of the Cook Inlet basin. The unconformity at the top of the Tertiary sediments and base of the Quaternary is well imaged. These data fill in the gap between the industry and 2015 marine seismic reflection data on the west side of the site and industry seismic reflection data to the east of the site, and will enable the construction of a robust structural geologic model of the site area.

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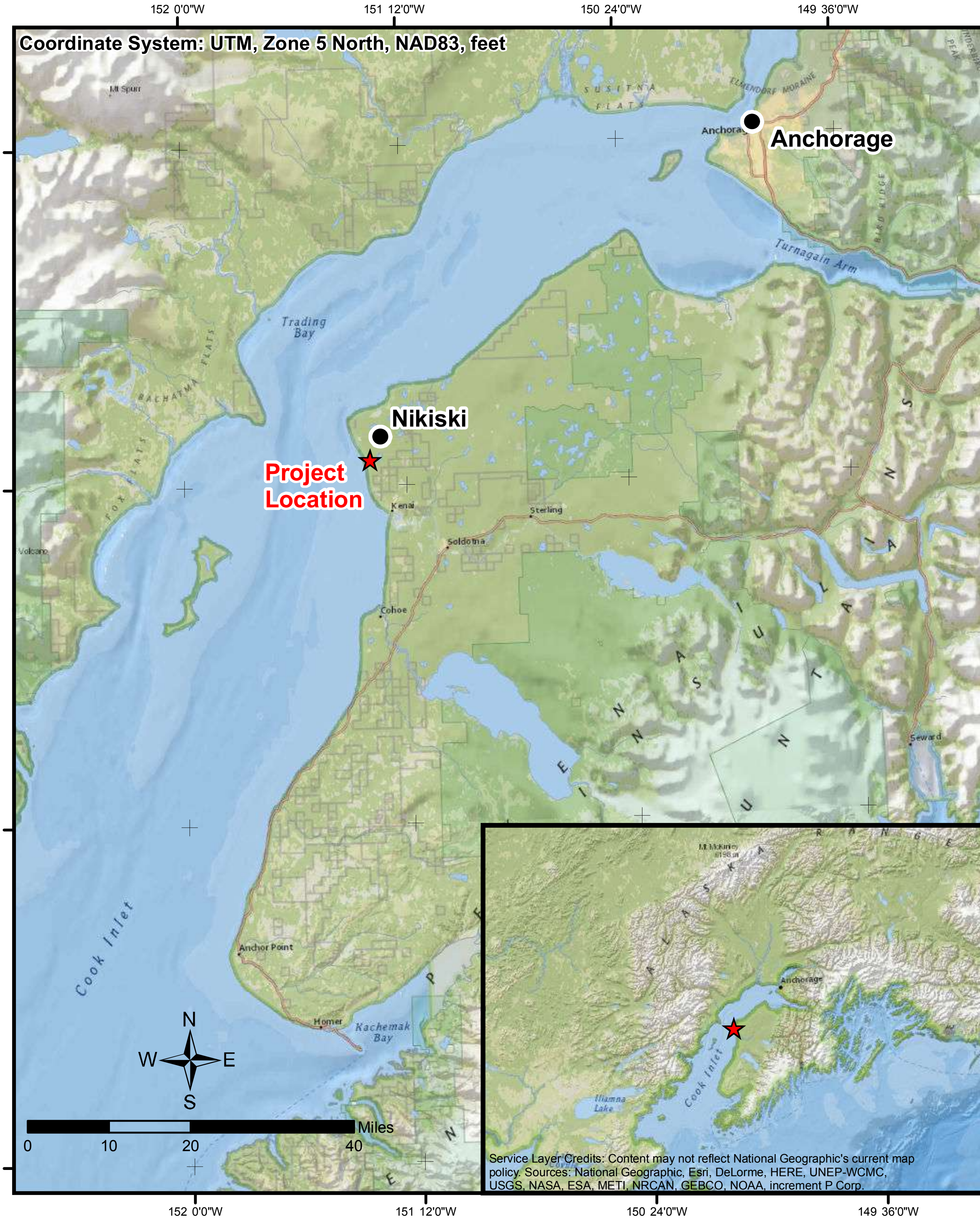
ILLUSTRATIONS



VICINITY MAP

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 1

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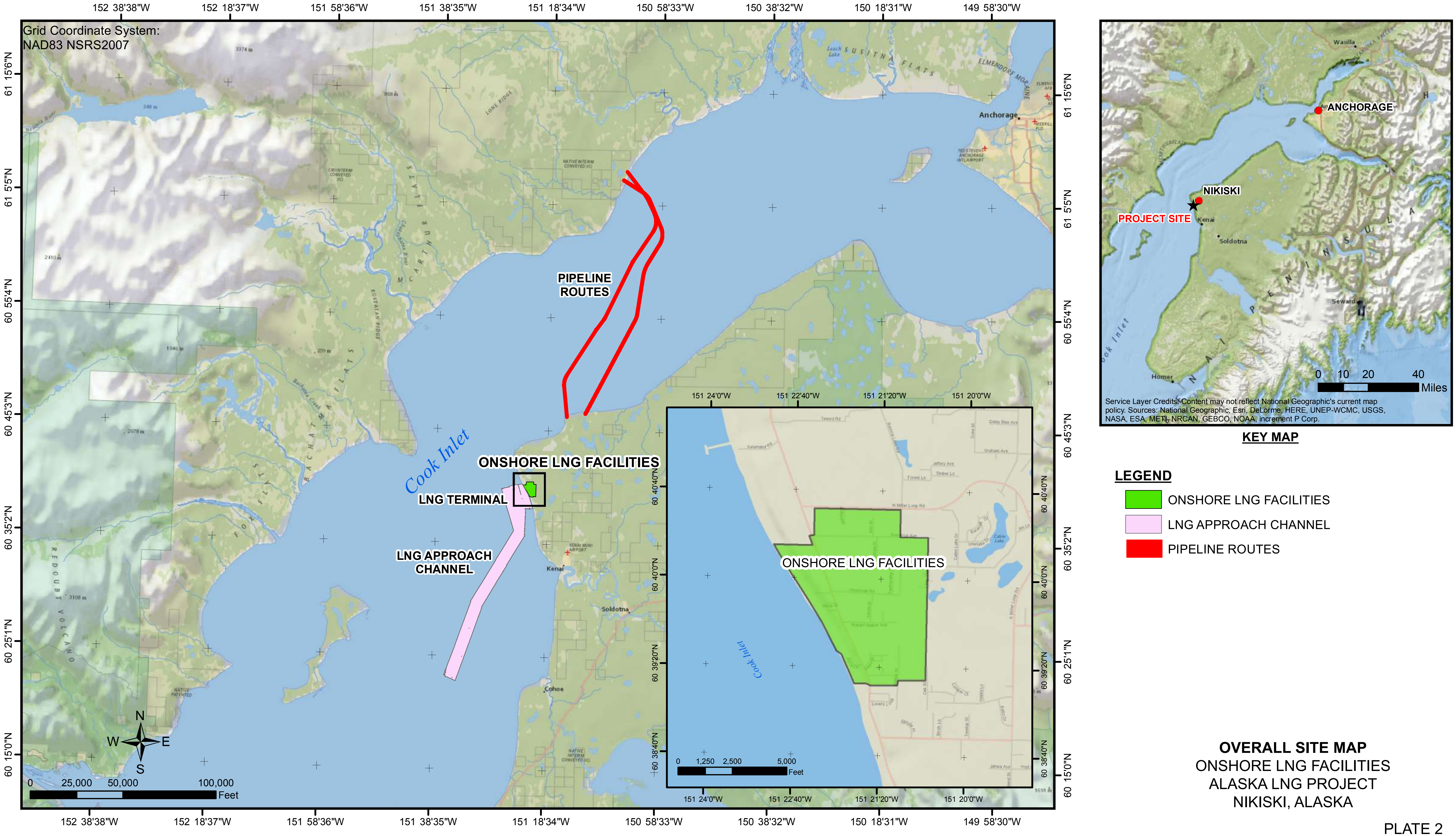

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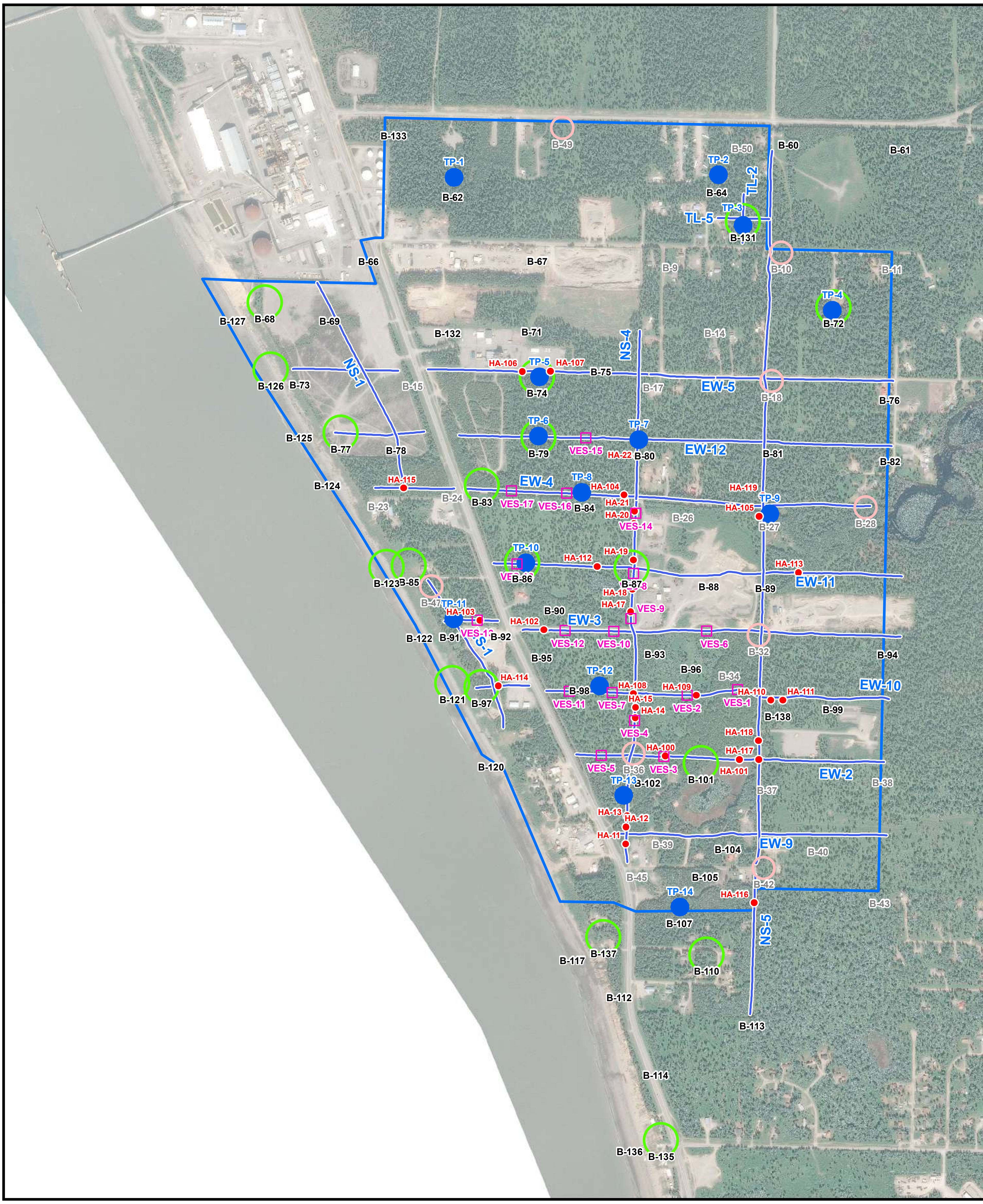
OVERALL SITE MAP
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



Legend

Borehole

- 2014 Completed
- 2015 Completed

Geophysical survey

- ERT Lines
- 1D Resistivity Test locations

Downhole seismic tests

- AKLNG2014
- AKLNG2015

- Test pits
- Hand augers
- Onshore LNG Facilities

0 500 1,000 2,000
Feet

N

GEOPHYSICAL SURVEY PLAN
ECELTRICAL RESISTIVITY
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 3

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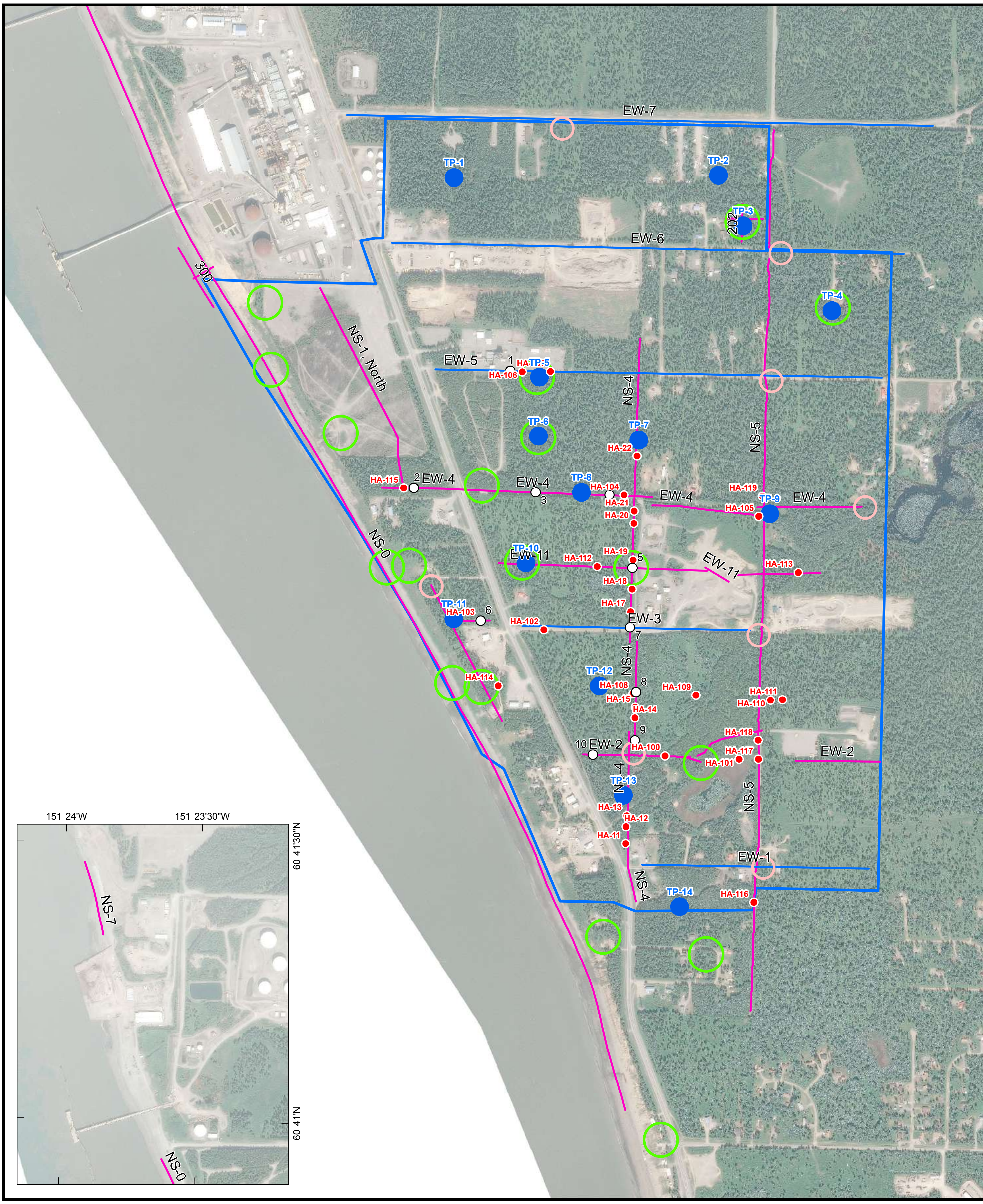

Legend

Borehole
- 2014 Completed
- 2015 Completed

Shallow survey line
- AKLNG2014
- AKLNG2015
- 1D Vp/Vs profile

Downhole seismic tests
- AKLNG2014
- AKLNG2015

- Test pits
- Hand augers
- Onshore LNG Facilities

0 500 1,000 2,000
Feet

N

GEOPHYSICAL SURVEY PLAN
SEISMIC REFRACTION & IMASW
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 4

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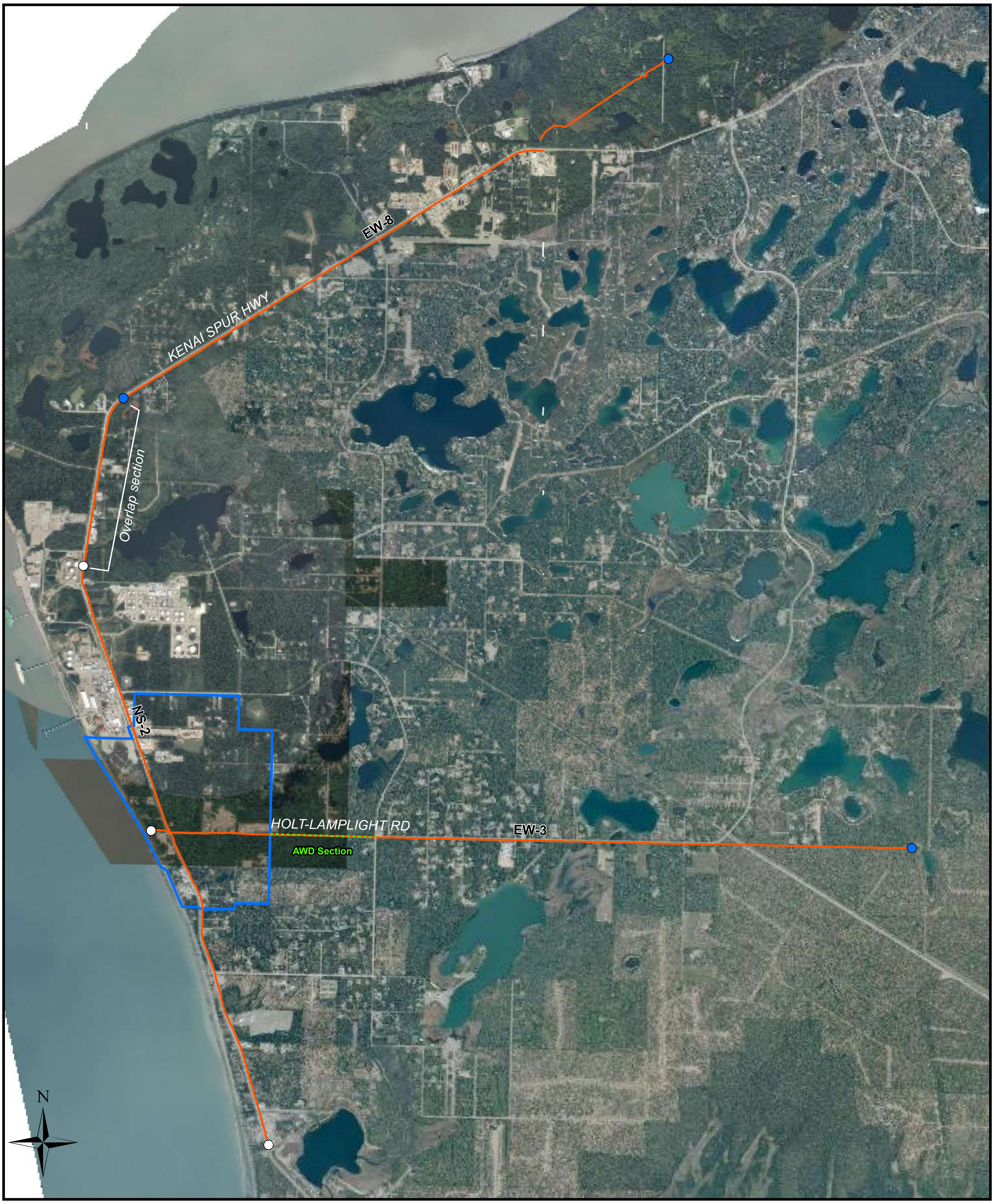

Legend

- Deep seismic surveyline
- Start station
- End station
- Onshore LNG Facilities

0 2,000 4,000 8,000
Feet

GEOPHYSICAL SURVEY PLAN
SEISMIC REFLECTION
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE 5

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APPENDIX A

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY

Plate

Scale 1" : 150'
0 100 200 300
5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - EW-2
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-1

Scale 1" : 150'
0 100 200 300
5x vertical exaggeration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117, 189, 305, 492, 1,280, 1,280, 2,065, 3,330, 5,372, 8,664, 13,974, 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - EW-3
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-2

Scale 1" : 150'

0 100 200 300

5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - EW-4
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-3

Scale 1" : 150'

0 100 200 300

5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - EW-5
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-4

Scale 1" : 150'
0 100 200 300
5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - EW-9
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-5

Scale 1" : 150'

0 100 200 300

5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - EW-10
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-6

Scale 1" : 150'
0 100 200 300
5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - EW-11
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-7

Alaska LNG

Scale 1" : 150'
0 100 200 300
5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)
117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - EW-12
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-8

Alaska LNG

Scale 1" : 150'
0 100 200 300
5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - NS-1
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-9

Scale 1" : 150'
0 100 200 300
5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - NS-4
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-10

Scale 1" : 150'
0 100 200 300
5x vertical exageration
Alaska State Plane Zone 4, NAVD88

Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

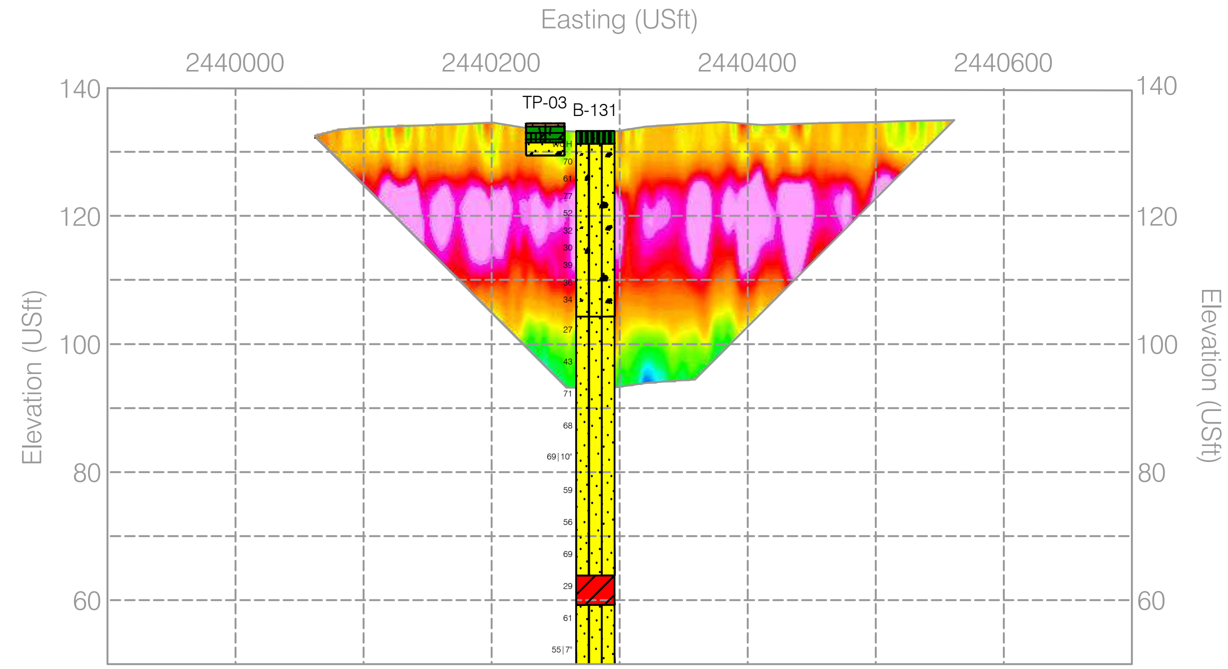
117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - NS-5
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

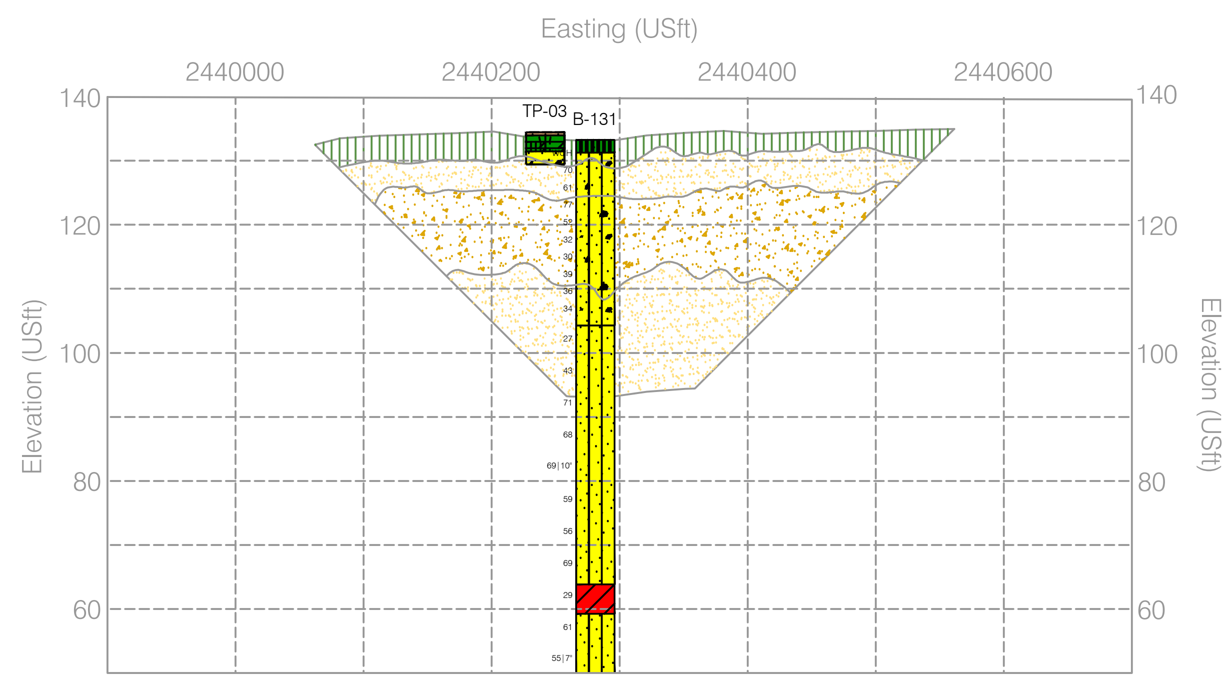
PLATE A-11



Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)

117 189 305 492 1,280 1,280 2,065 3,330 5,372 8,664 13,974 26,433



Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Interpreted Pseudo-section Legend

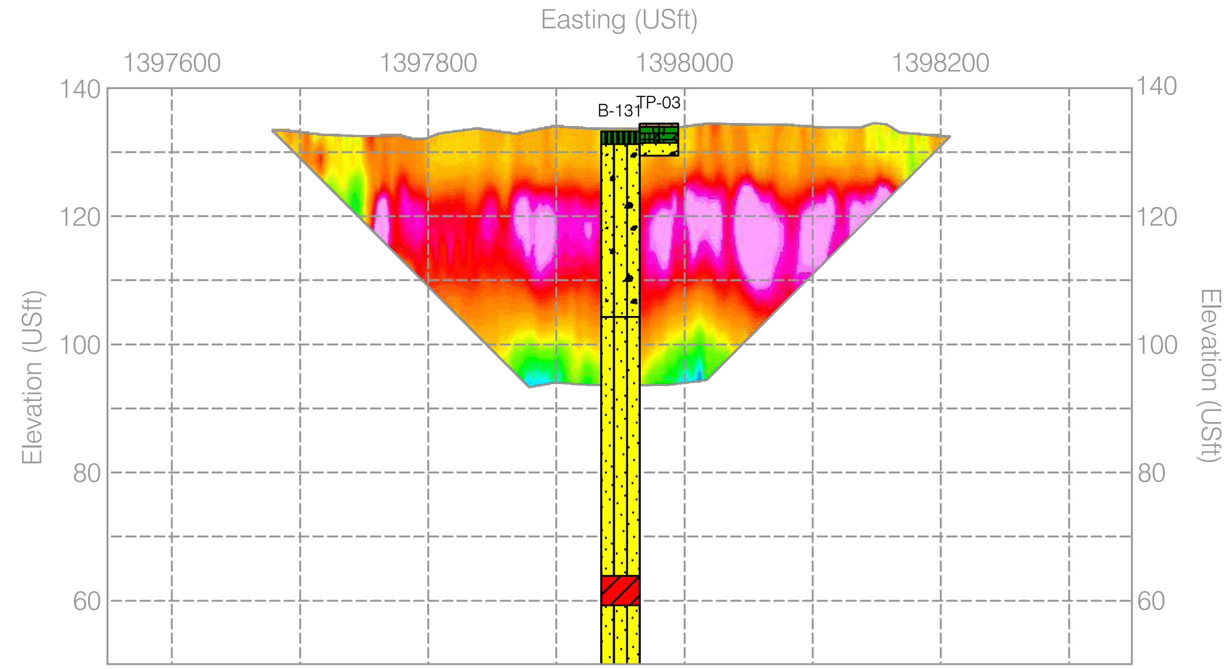
- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

Scale 1" : 150'

0 100 200 300

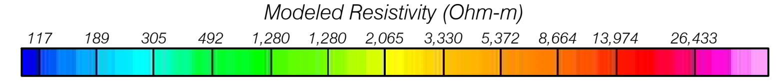
5x vertical exageration
Alaska State Plane Zone 4, NAVD88

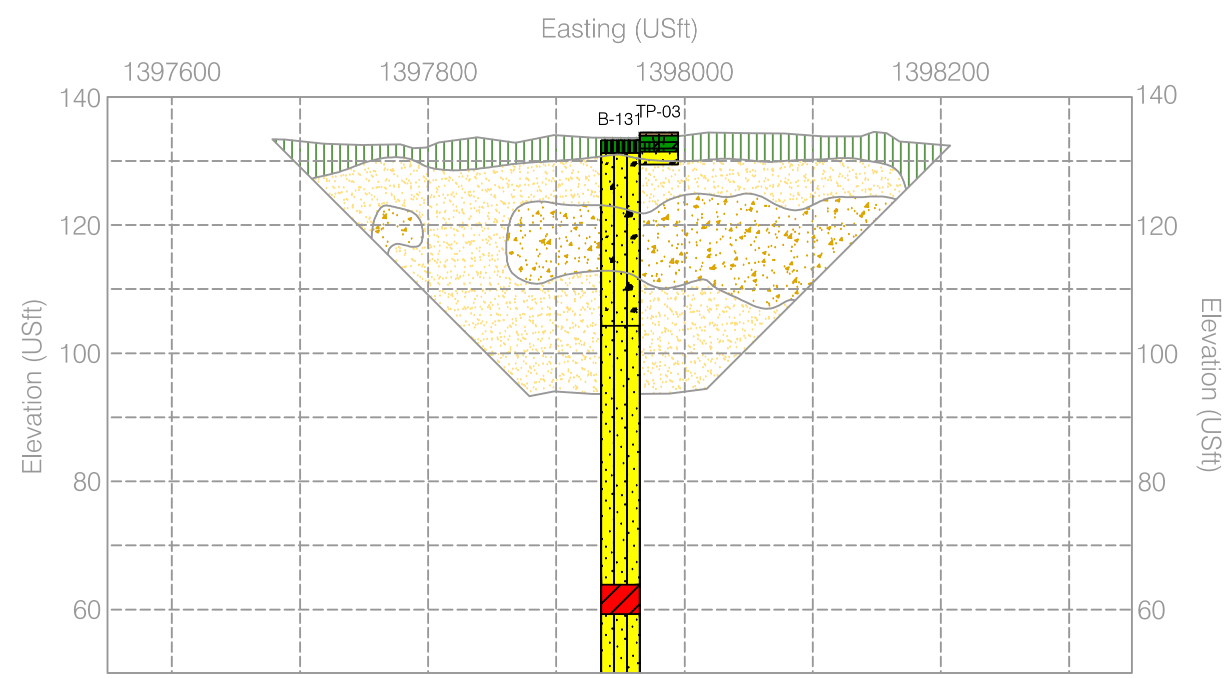
ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - TL-2
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA



Electrical Resistivity Tomography Legend

Modeled Resistivity (Ohm-m)





Boring, Test Pit and Hand Auger Legend

- TOPSOIL
- SILT with sand (ML)
- Poorly graded GRAVEL with clay and sand (GP-GC)
- GRAVEL with silt and sand (GP-GM)
- Poorly graded GRAVEL with sand (GP)
- Clayey GRAVEL with sand (GC)
- Poorly graded GRAVEL (GP)
- Lean CLAY with gravel (CL)
- Sandy lean CLAY (CL)
- Lean CLAY (CL)
- Water Level Reading (during drilling)
- Water Level Reading (from monitoring well)

Interpreted Pseudo-section Legend

- Interpreted TOPSOIL and SILT (loess deposits)
- Interpreted SAND and GRAVEL
- Interpreted regions of increased GRAVEL content
- Interpreted regions of CLAY and/or saturated SILTS & SANDS
- No interpretation

Scale 1" : 150'

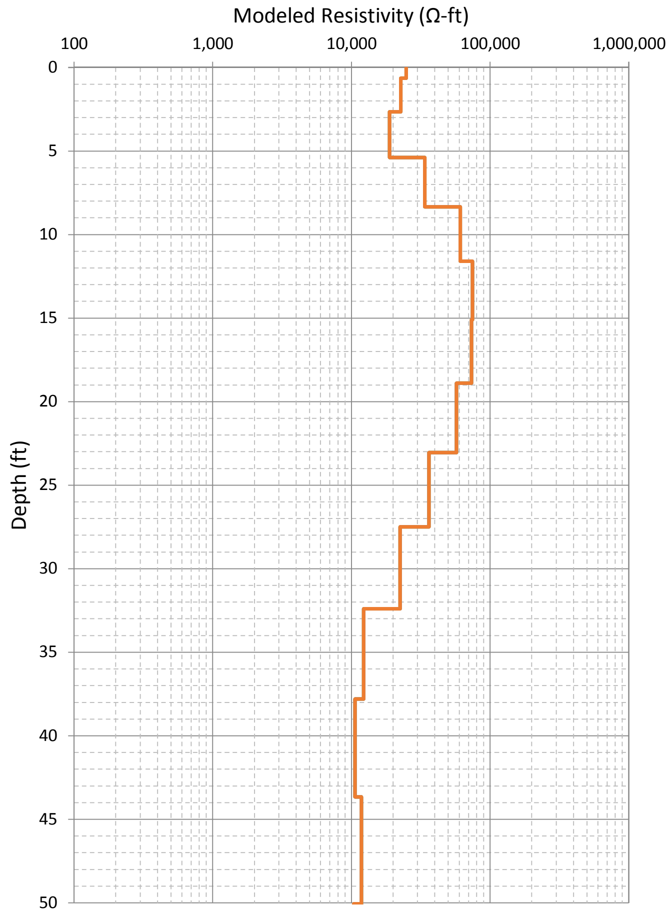
0 100 200 300

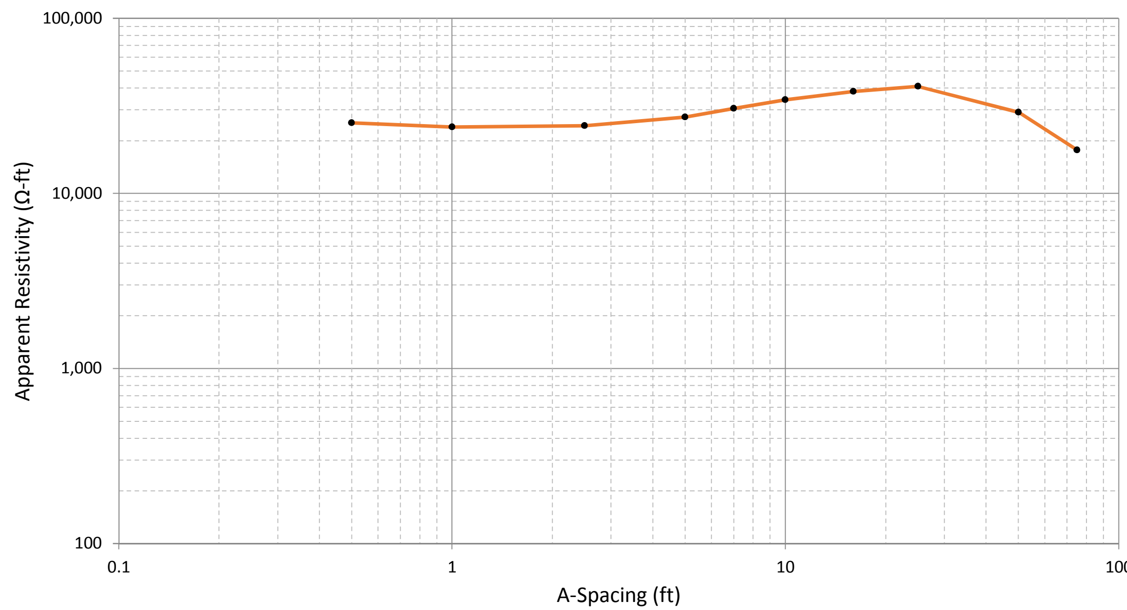
5x vertical exageration
Alaska State Plane Zone 4, NAVD88

ELECTRICAL RESISTIVITY TOMOGRAPHY SURVEY RESULTS - TL-5
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE A-13

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	25,246
1	23,978
2.5	24,309
5	27,314
7	30,559

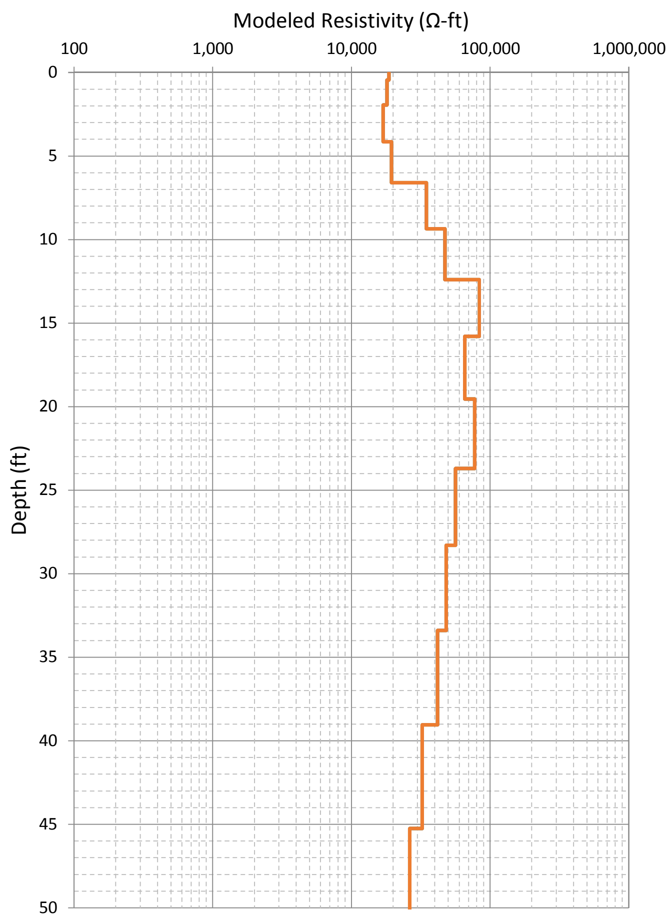
A-Spacing (ft)	App. Res. (Ω-ft)
10	34,269
16	38,206
25	40,845
50	29,088
75	17,692

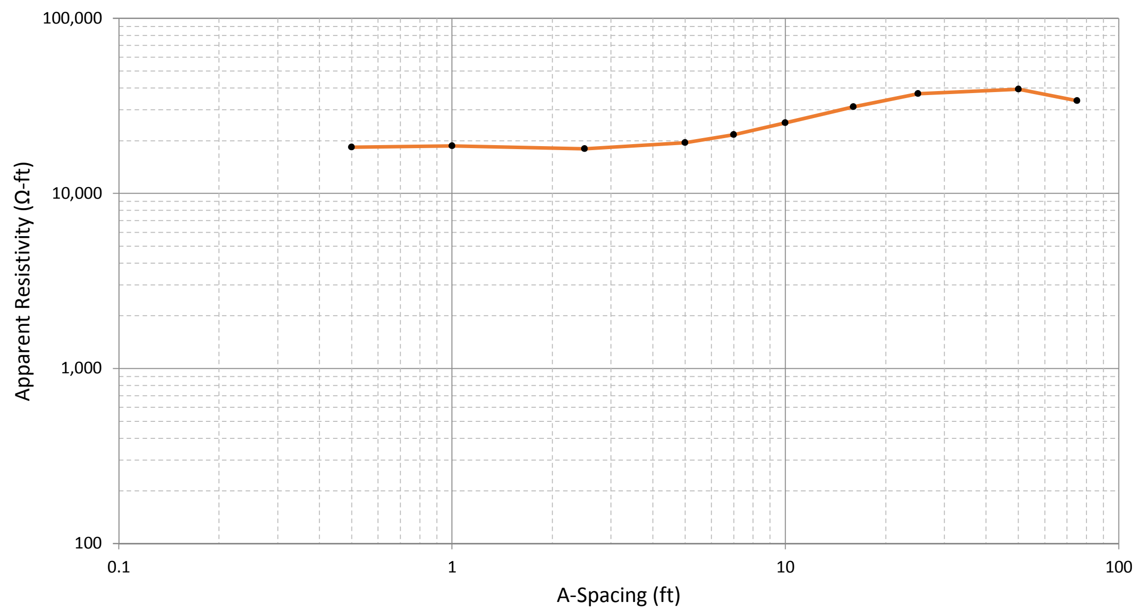
Vertical Electrical Sounding: VES-1

Northing:	2435455	US ft	Alaska State Plane Zone 4
Easting:	1397880	US ft	
Elevation:	122.5	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-1
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	18,356
1	18,678
2.5	17,965
5	19,467
7	21,643

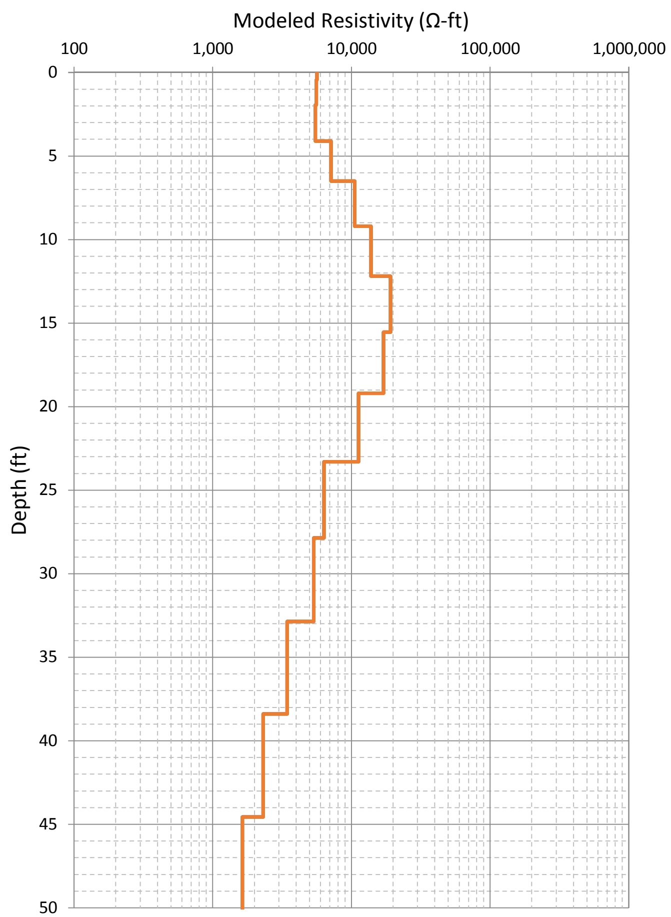
A-Spacing (ft)	App. Res. (Ω-ft)
10	25,293
16	31,192
25	37,173
50	39,324
75	33,851

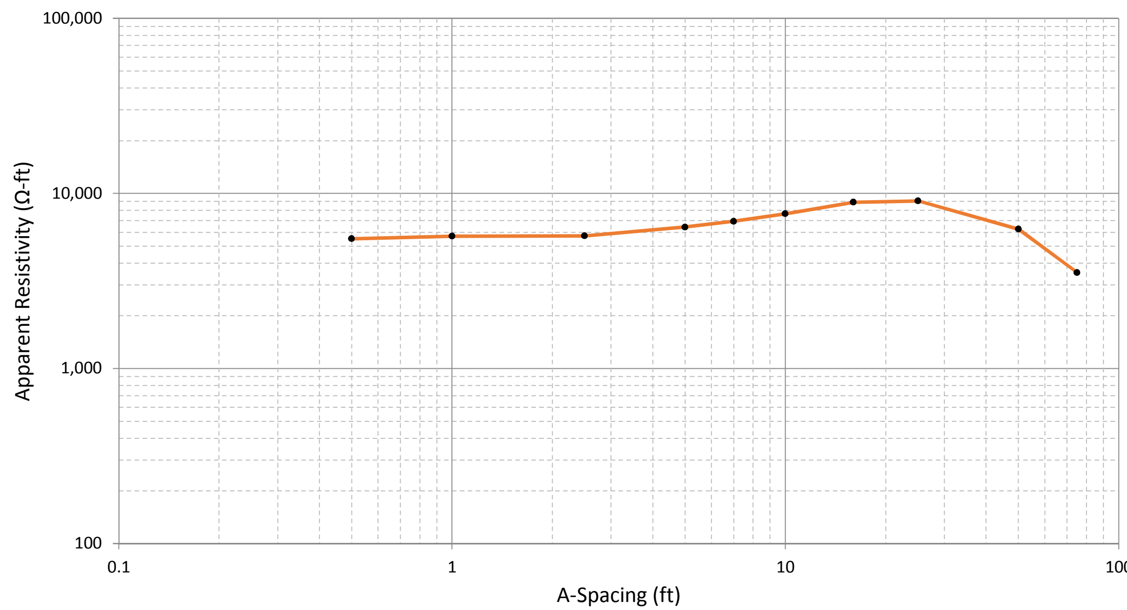
Vertical Electrical Sounding: VES-2

Northing:	2435398	US ft	Alaska State Plane Zone 4
Easting:	1397359	US ft	
Elevation:	110.6	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-2
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	5,513
1	5,686
2.5	5,712
5	6,421
7	6,927

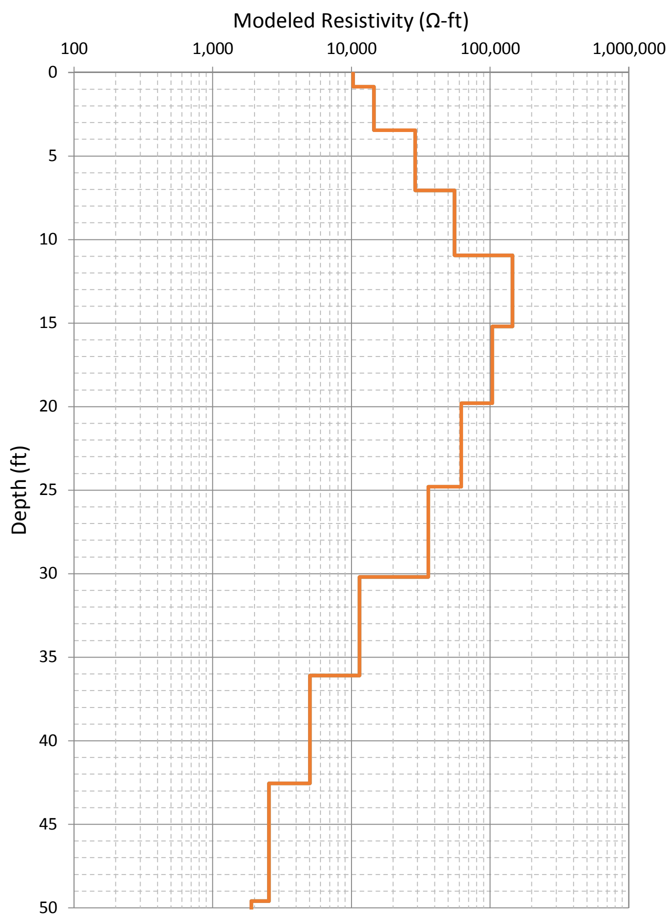
A-Spacing (ft)	App. Res. (Ω-ft)
10	7,633
16	8,899
25	9,055
50	6,236
75	3,529

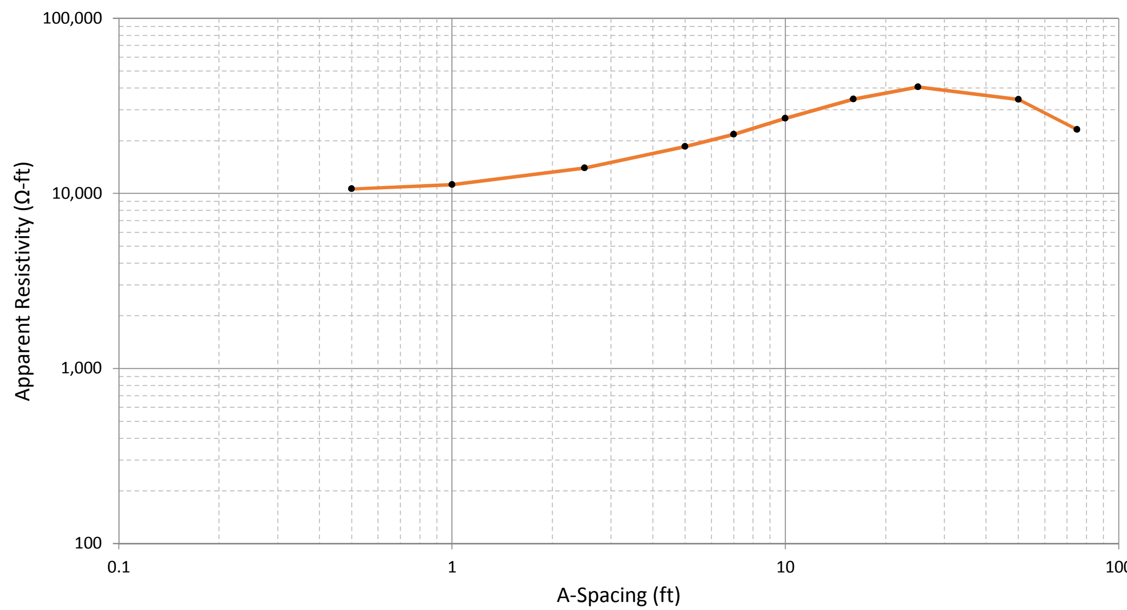
Vertical Electrical Sounding: VES-3

Northing:	2434766	US ft	Alaska State Plane Zone 4
Easting:	1397119	US ft	
Elevation:	98.9	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-3
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	10,607
1	11,241
2.5	13,953
5	18,514
7	21,733

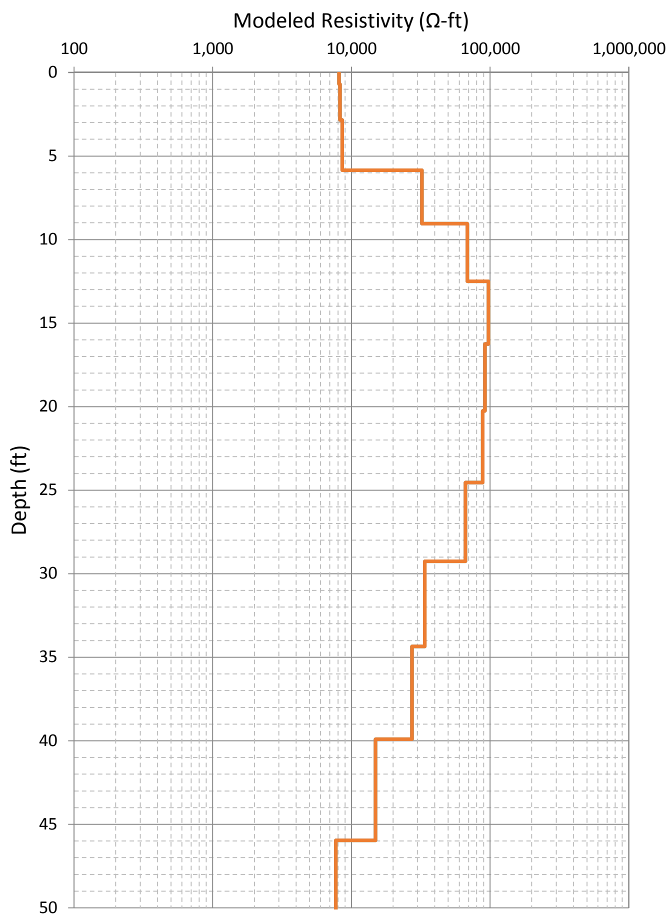
A-Spacing (ft)	App. Res. (Ω-ft)
10	26,784
16	34,526
25	40,552
50	34,377
75	23,171

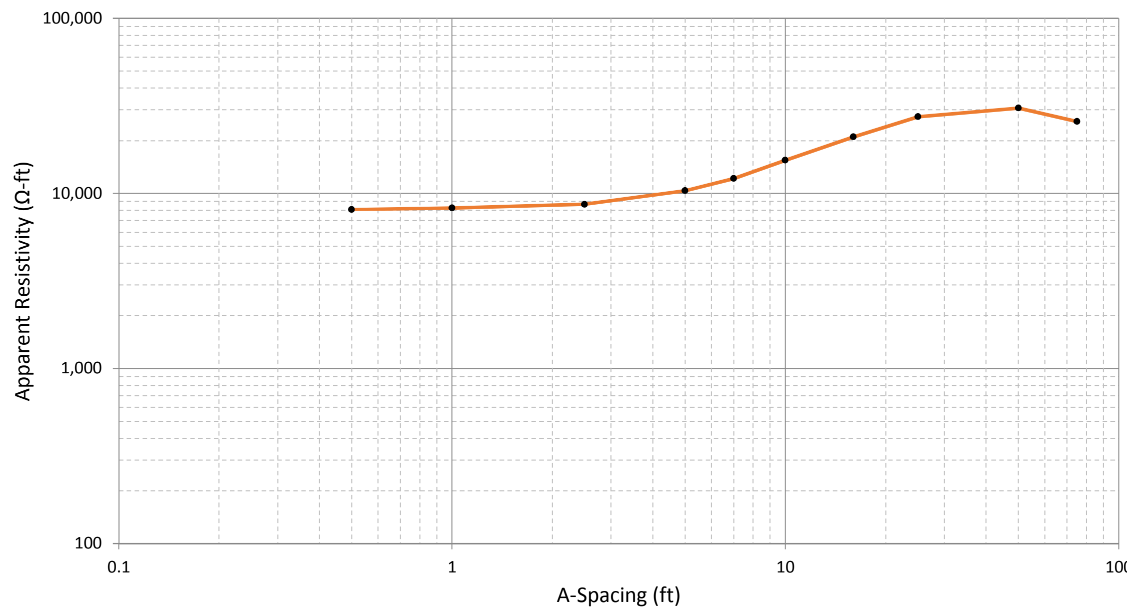
Vertical Electrical Sounding: VES-4

Northing:	2435135	US ft	Alaska State Plane Zone 4
Easting:	1396820	US ft	
Elevation:	121.6	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-4
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	8,091
1	8,254
2.5	8,660
5	10,341
7	12,153

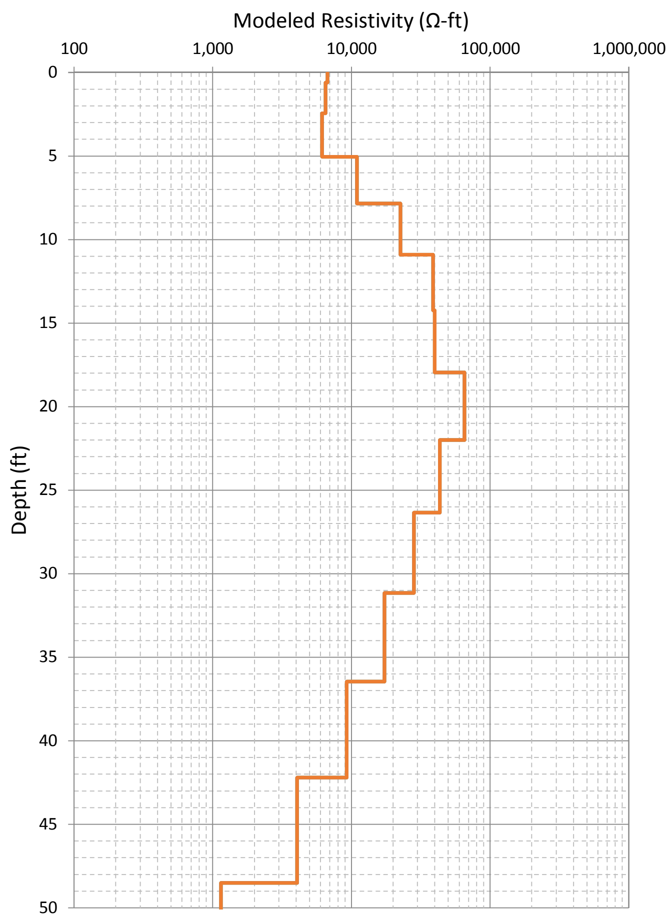
A-Spacing (ft)	App. Res. (Ω-ft)
10	15,482
16	21,041
25	27,351
50	30,703
75	25,749

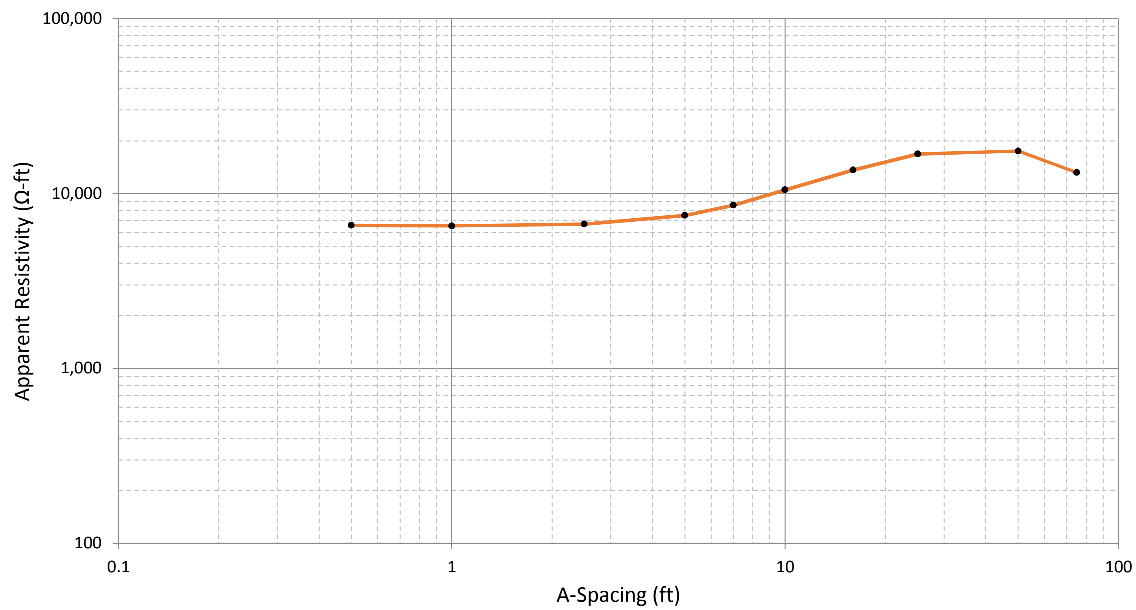
Vertical Electrical Sounding: VES-5

Northing:	2434778	US ft	Alaska State Plane Zone 4
Easting:	1396474	US ft	
Elevation:	117.1	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-5
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	6,567
1	6,529
2.5	6,685
5	7,484
7	8,556

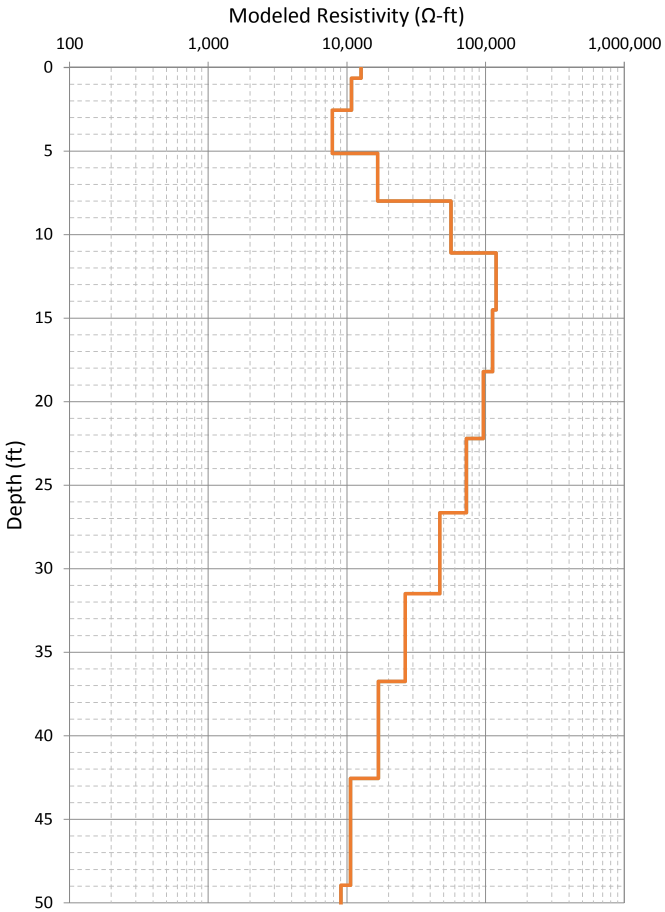
A-Spacing (ft)	App. Res. (Ω-ft)
10	10,479
16	13,623
25	16,806
50	17,485
75	13,142

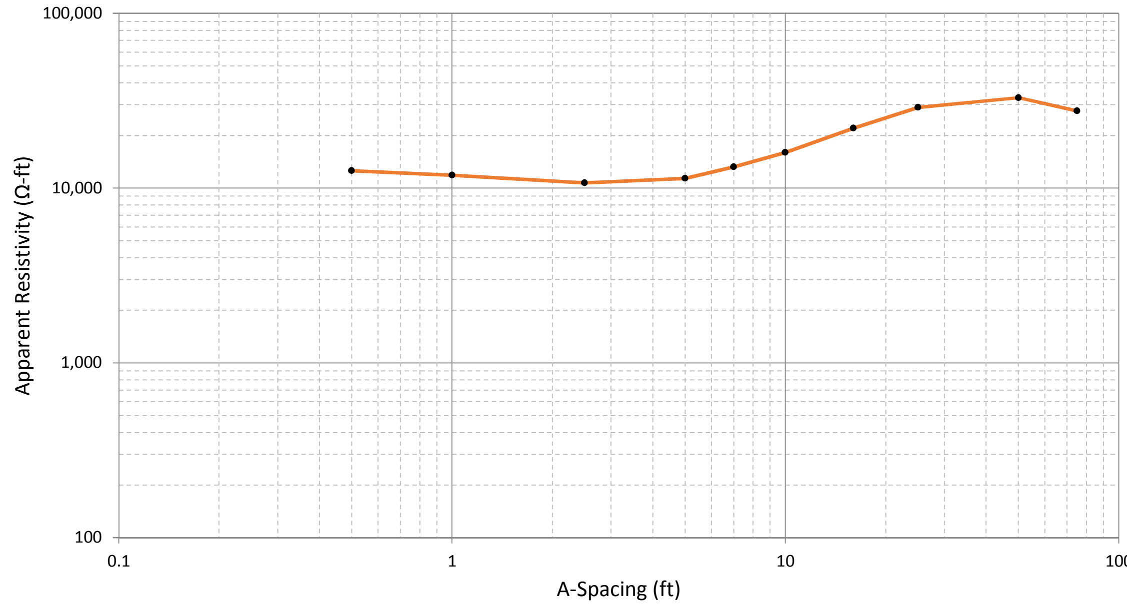
Vertical Electrical Sounding: VES-6

Northing:	2436059	US ft	Alaska State Plane Zone 4
Easting:	1397561	US ft	
Elevation:	114.7	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-6
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	12,581
1	11,838
2.5	10,701
5	11,378
7	13,239

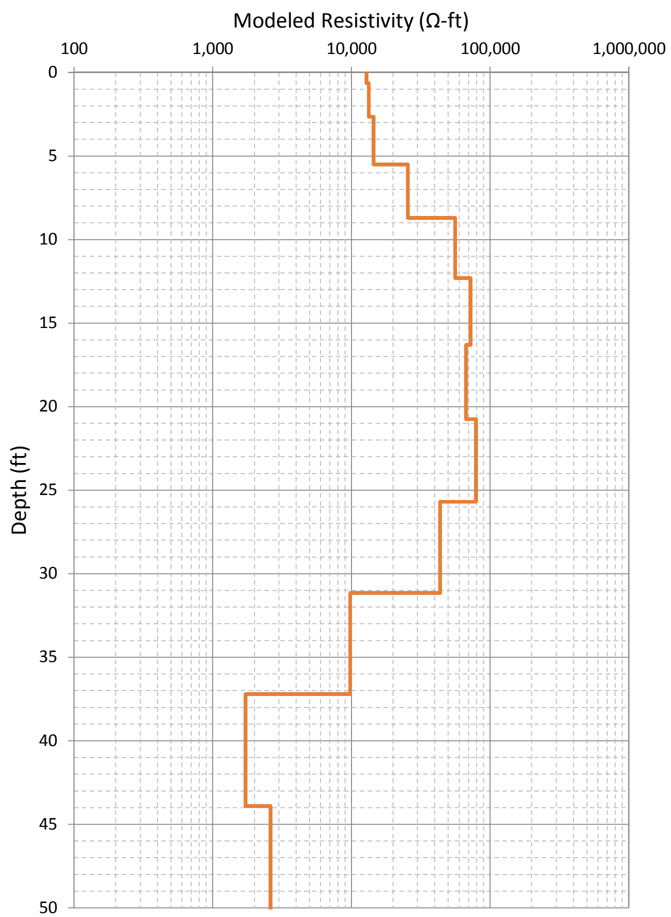
A-Spacing (ft)	App. Res. (Ω-ft)
10	15,957
16	21,971
25	28,980
50	32,882
75	27,634

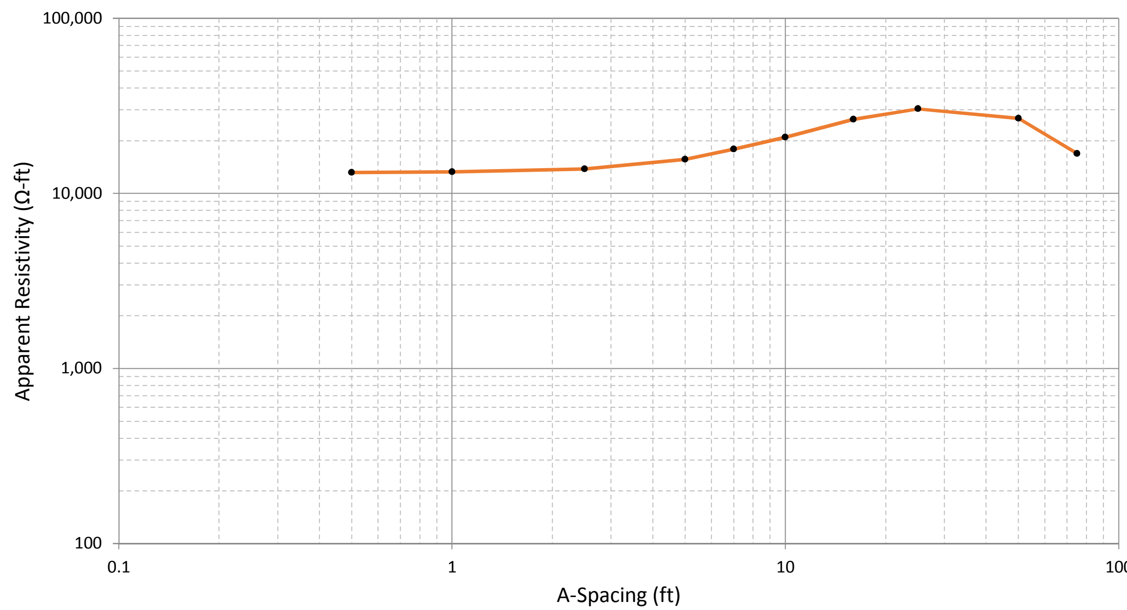
Vertical Electrical Sounding: VES-7

Northing:	2435426	US ft	Alaska State Plane Zone 4
Easting:	1396585	US ft	
Elevation:	123.3	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-7
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	13,173
1	13,296
2.5	13,815
5	15,654
7	17,884

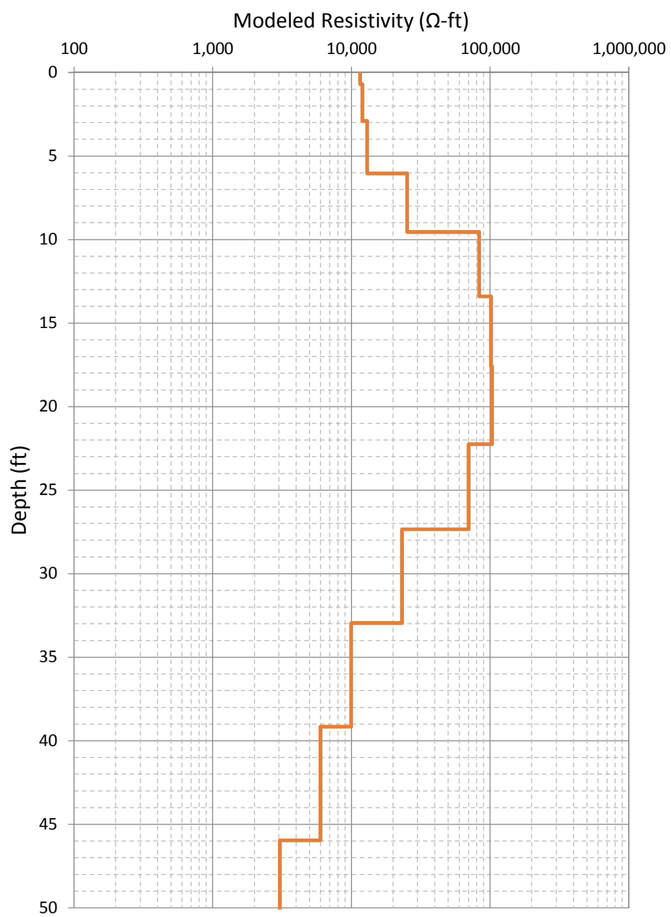
A-Spacing (ft)	App. Res. (Ω-ft)
10	20,922
16	26,502
25	30,399
50	26,824
75	16,881

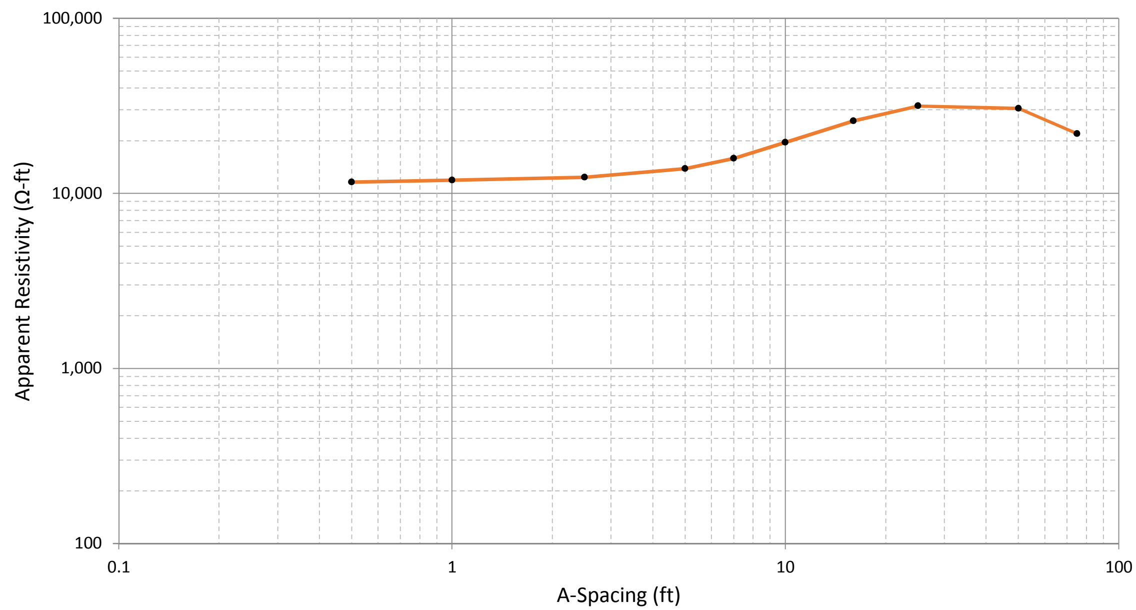
Vertical Electrical Sounding: VES-8

Northing:	2436652	US ft	Alaska State Plane Zone 4
Easting:	1396811	US ft	
Elevation:	108.6	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-8
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	11,594
1	11,900
2.5	12,355
5	13,828
7	15,833

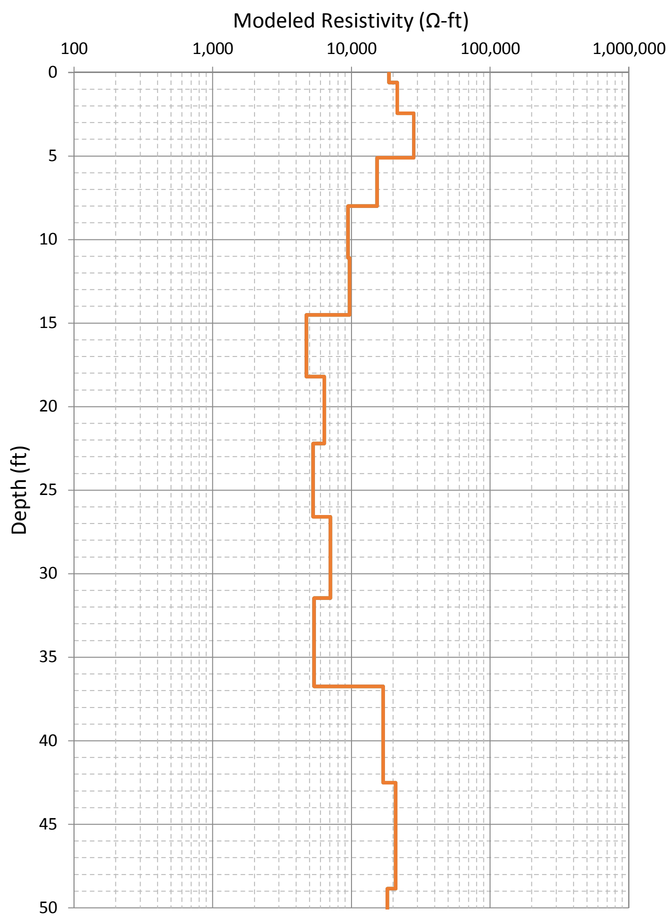
A-Spacing (ft)	App. Res. (Ω-ft)
10	19,531
16	25,947
25	31,560
50	30,544
75	21,946

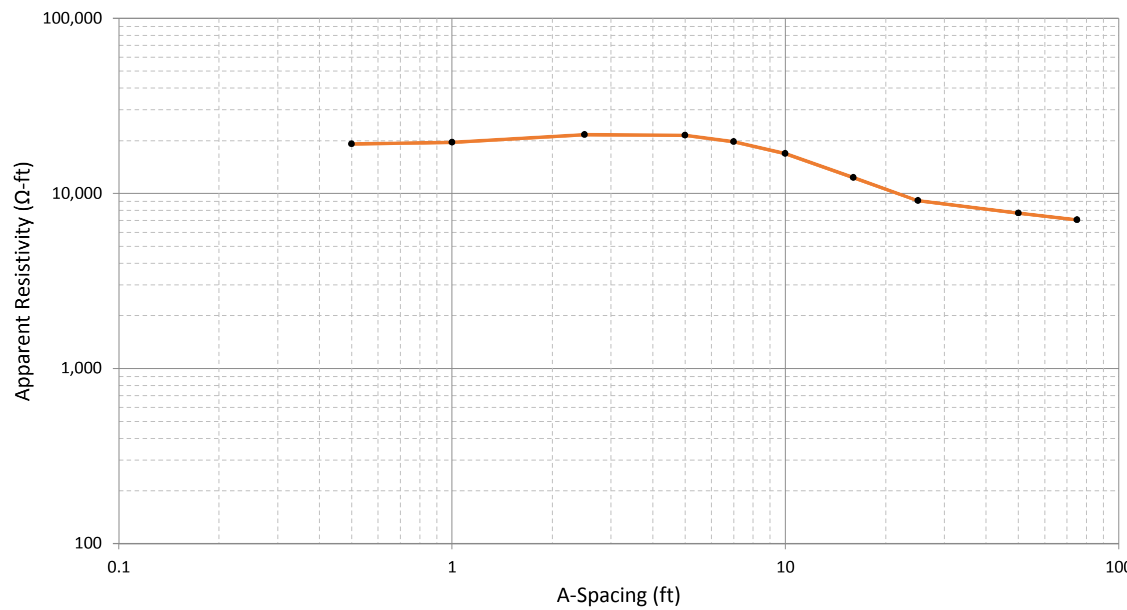
Vertical Electrical Sounding: VES-9

Northing:	2436185	US ft	Alaska State Plane Zone 4
Easting:	1396782	US ft	
Elevation:	116.6	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-9
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	19,167
1	19,548
2.5	21,618
5	21,449
7	19,763

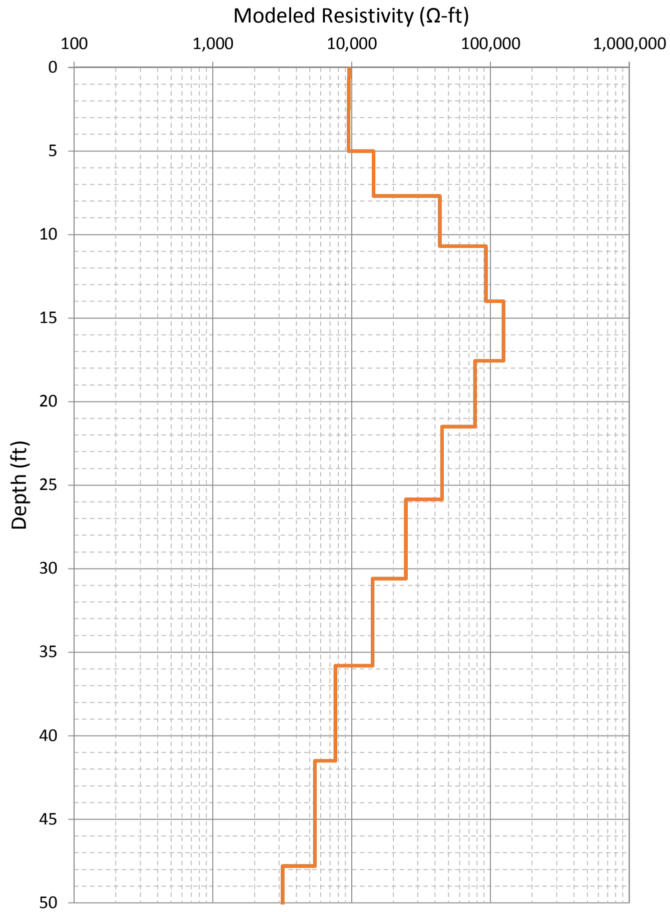
A-Spacing (ft)	App. Res. (Ω-ft)
10	16,882
16	12,298
25	9,090
50	7,711
75	7,057

Vertical Electrical Sounding: VES-10

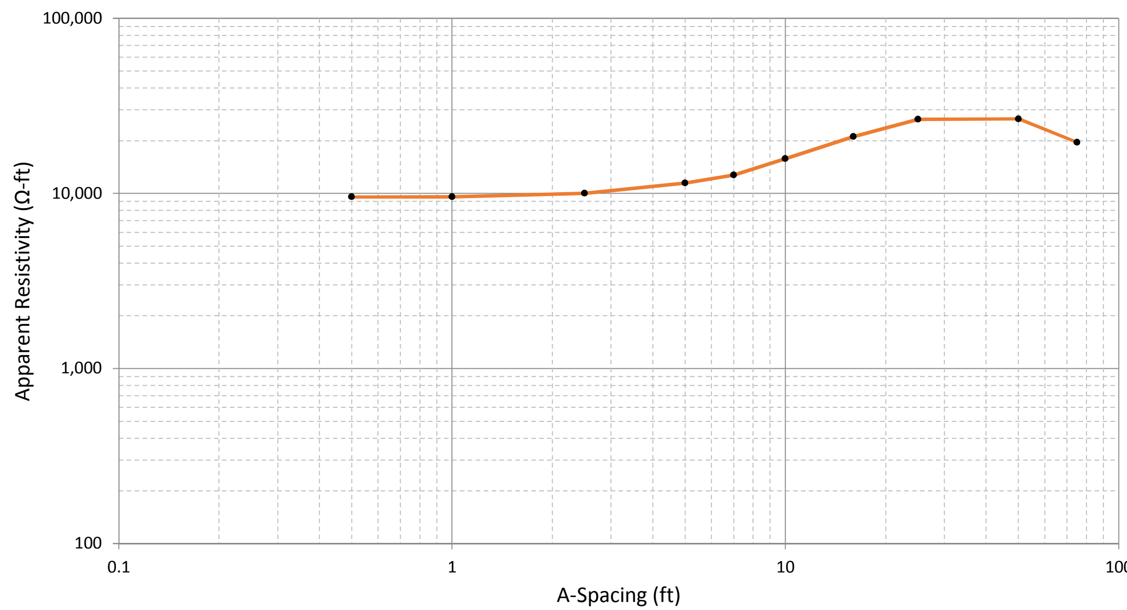
Northing:	2436058	US ft	Alaska State Plane Zone 4
Easting:	1396604	US ft	
Elevation:	115.7	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-10
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA



SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL



A-Spacing (ft)	App. Res. (Ω-ft)
0.5	9,542
1	9,571
2.5	10,030
5	11,438
7	12,727

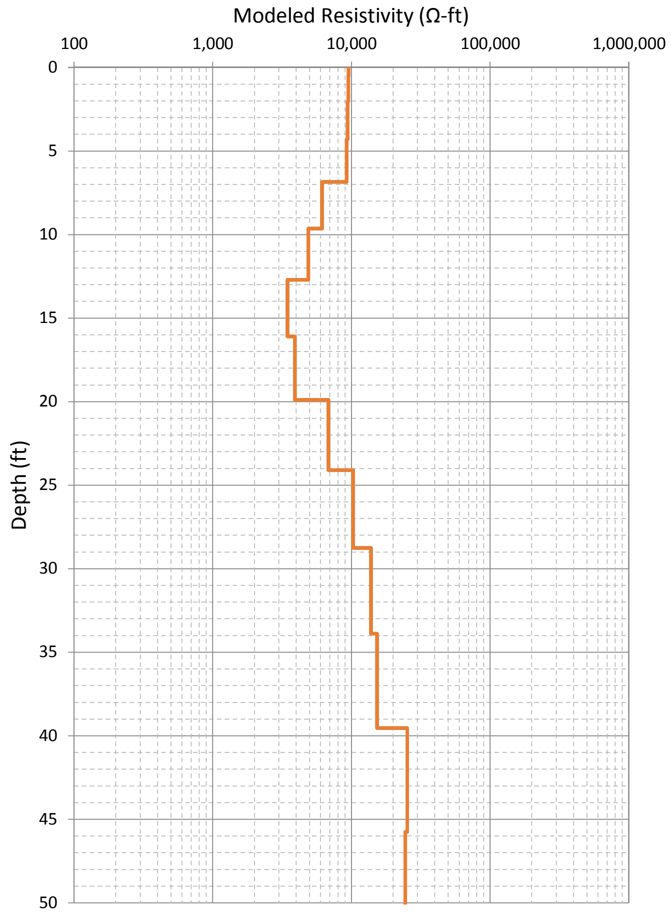
A-Spacing (ft)	App. Res. (Ω-ft)
10	15,812
16	21,142
25	26,466
50	26,651
75	19,554

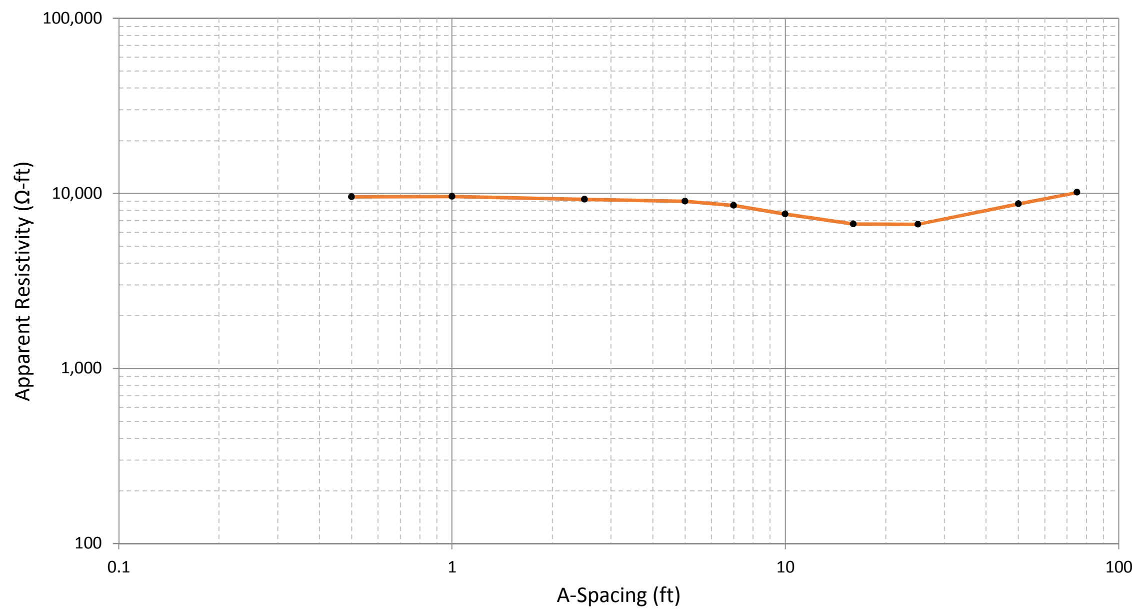
Vertical Electrical Sounding: VES-11

Northing:	2435438	US ft	Alaska State Plane Zone 4
Easting:	1396146	US ft	
Elevation:	120.4	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-11
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	9,566
1	9,608
2.5	9,249
5	9,014
7	8,527

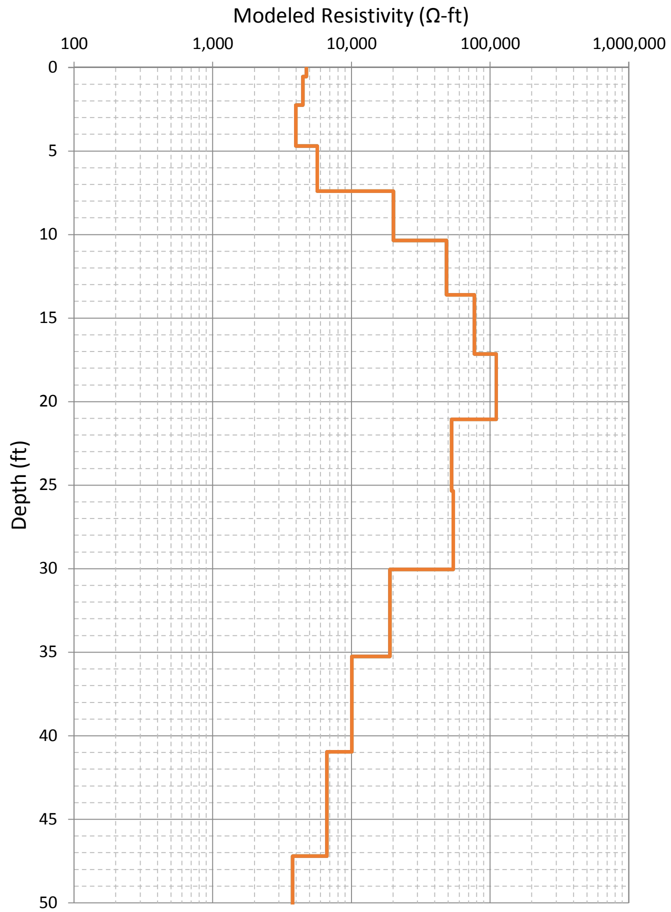
A-Spacing (ft)	App. Res. (Ω-ft)
10	7,619
16	6,696
25	6,662
50	8,708
75	10,130

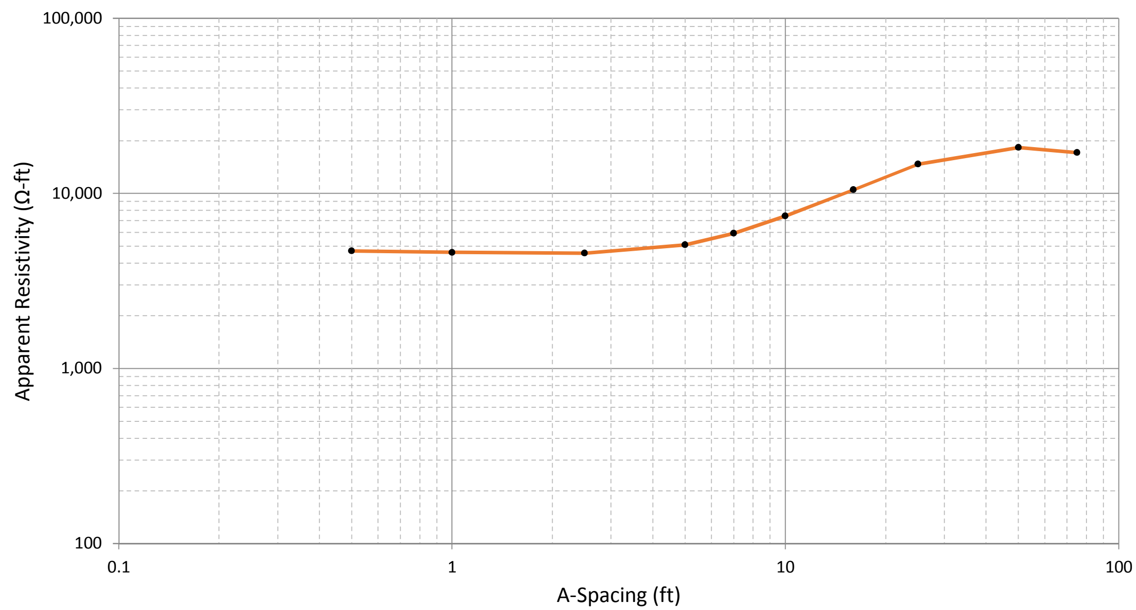
Vertical Electrical Sounding: VES-12

Northing:	2436065	US ft	Alaska State Plane Zone 4
Easting:	1396102	US ft	
Elevation:	106.9	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-12
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	4,685
1	4,604
2.5	4,561
5	5,082
7	5,924

A-Spacing (ft)	App. Res. (Ω-ft)
10	7,430
16	10,485
25	14,698
50	18,270
75	17,109

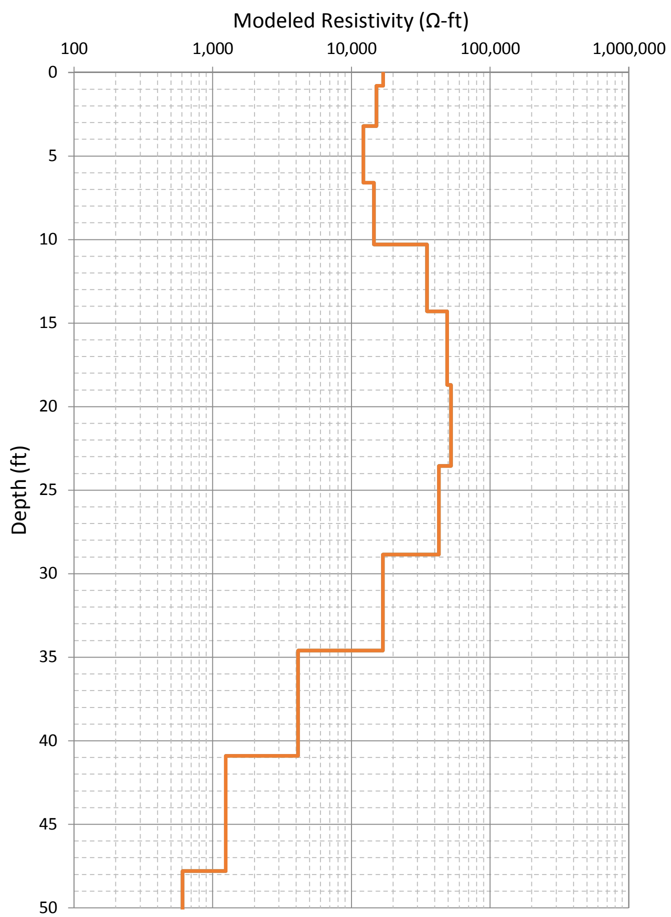
Vertical Electrical Sounding: VES-13

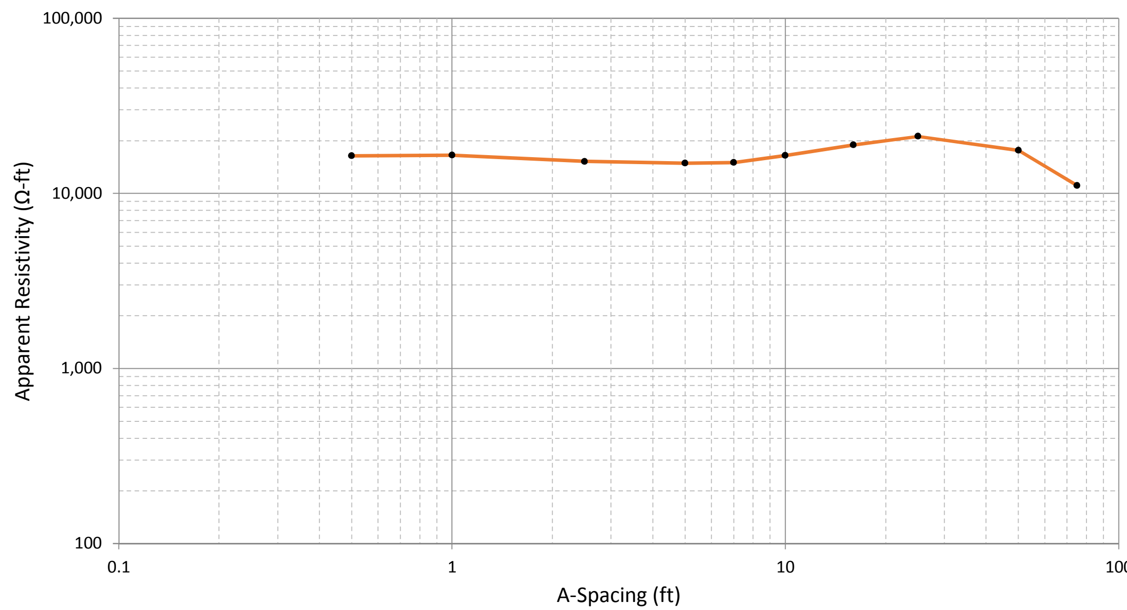
Northing:	2436171	US ft	Alaska State Plane Zone 4
Easting:	1395195	US ft	
Elevation:	117.7	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-13

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	16,421
1	16,536
2.5	15,226
5	14,862
7	15,000

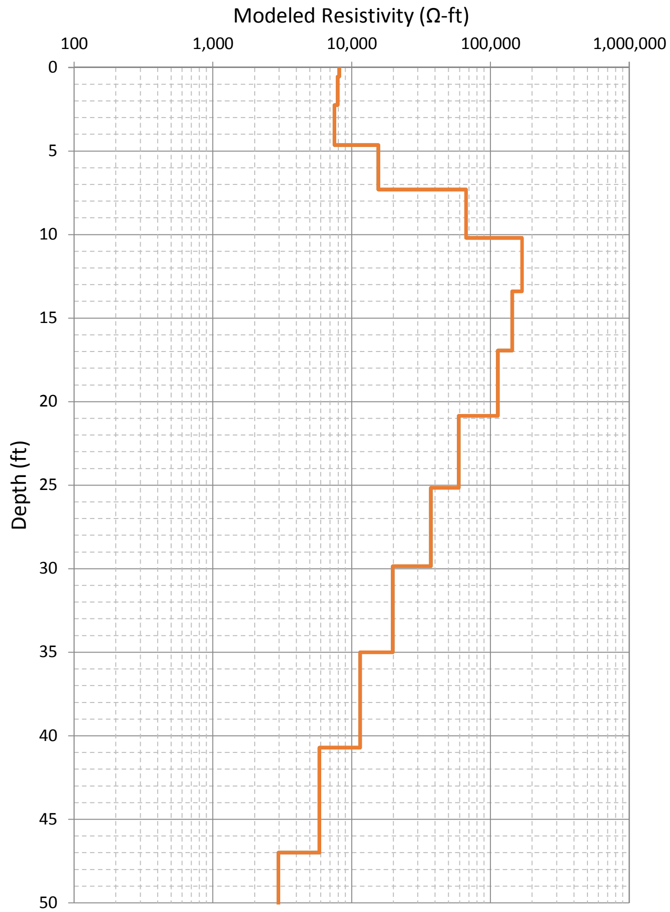
A-Spacing (ft)	App. Res. (Ω-ft)
10	16,462
16	18,945
25	21,154
50	17,614
75	11,076

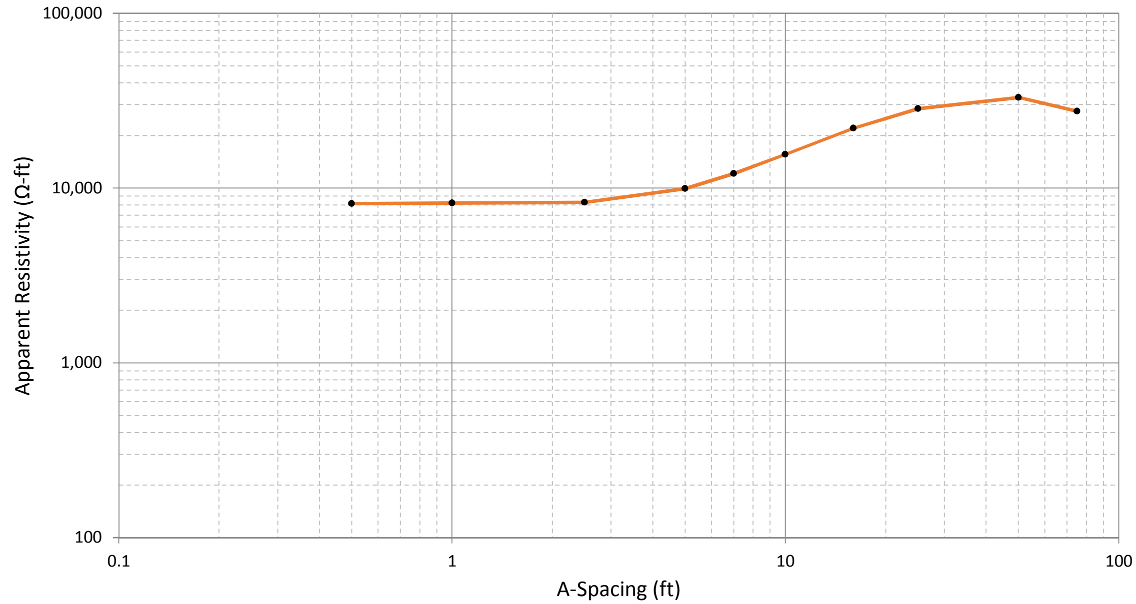
Vertical Electrical Sounding: VES-14

Northing:	2437271	US ft	Alaska State Plane Zone 4
Easting:	1396832	US ft	
Elevation:	123.4	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-14
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	8,157
1	8,229
2.5	8,281
5	9,937
7	12,110

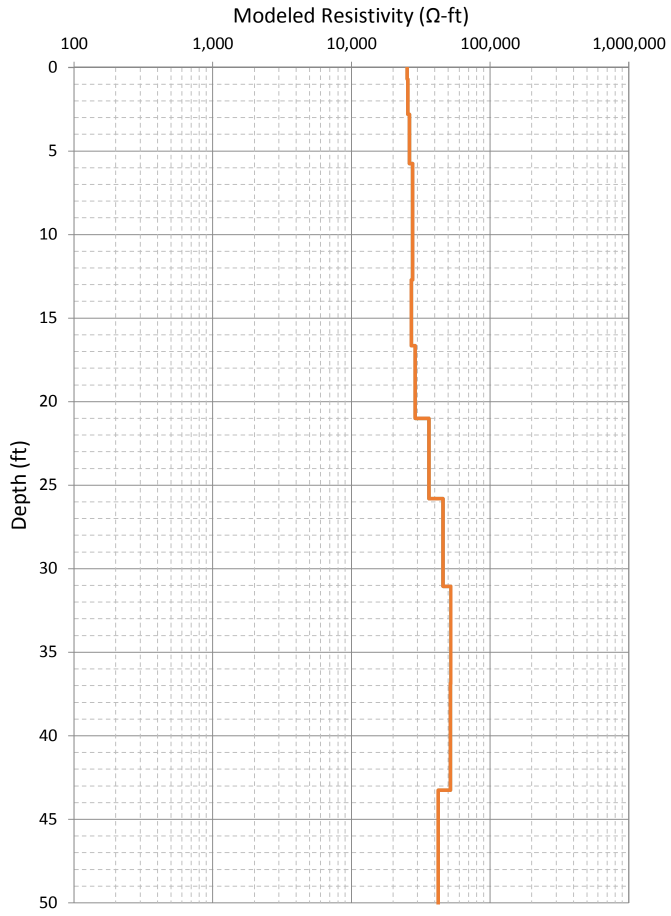
A-Spacing (ft)	App. Res. (Ω-ft)
10	15,553
16	22,012
25	28,407
50	33,006
75	27,509

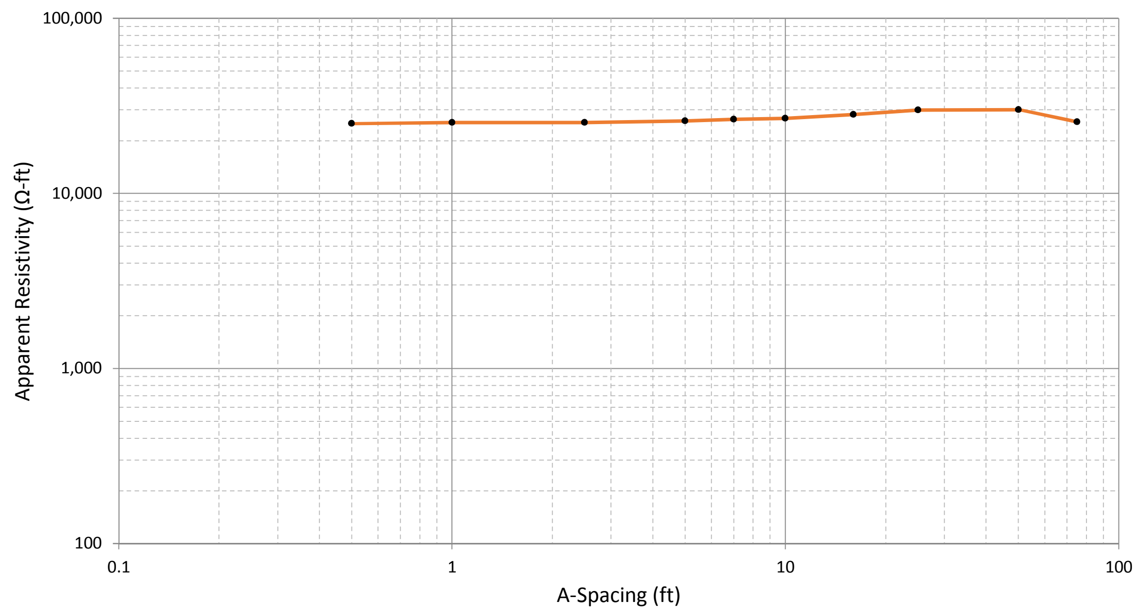
Vertical Electrical Sounding: VES-15

Northing:	2438052	US ft	Alaska State Plane Zone 4
Easting:	1396315	US ft	
Elevation:	127.4	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-15
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	25,029
1	25,430
2.5	25,417
5	25,980
7	26,520

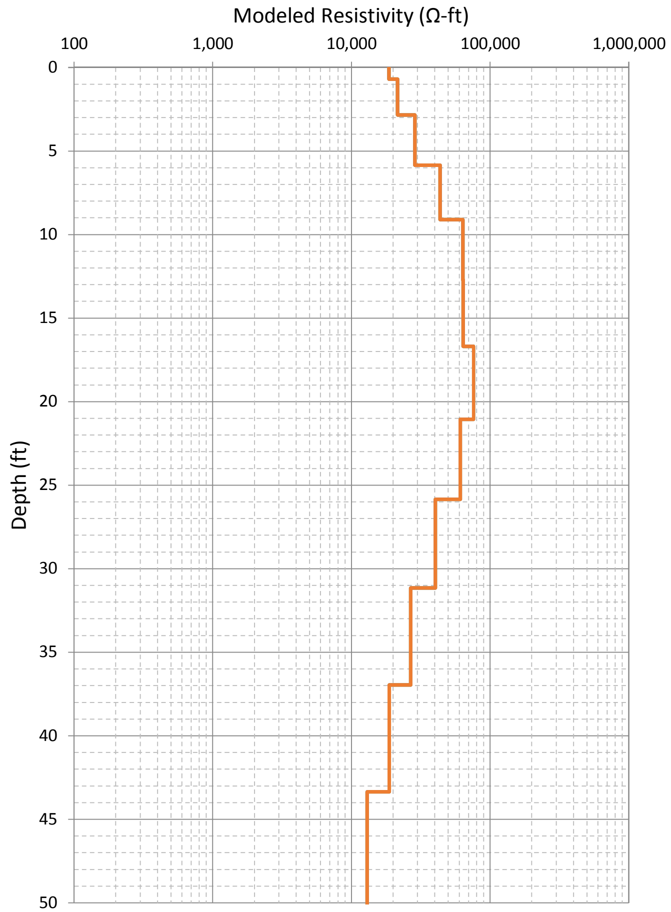
A-Spacing (ft)	App. Res. (Ω-ft)
10	26,815
16	28,241
25	29,978
50	30,089
75	25,584

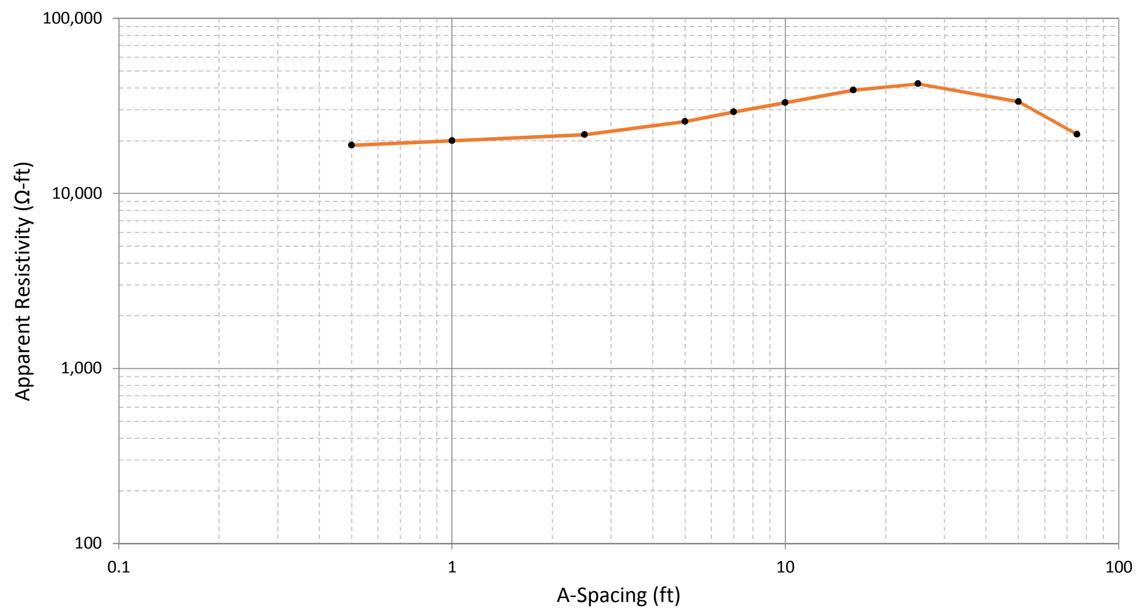
Vertical Electrical Sounding: VES-16

Northing:	2437480	US ft	Alaska State Plane Zone 4
Easting:	1396118	US ft	
Elevation:	125.8	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-16
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	18,825
1	19,956
2.5	21,649
5	25,754
7	29,168

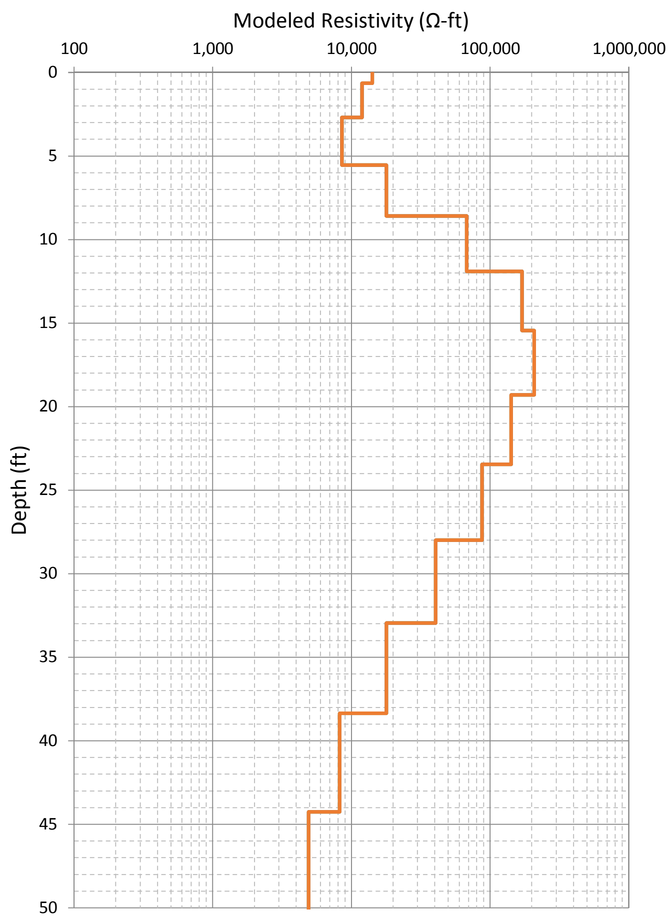
A-Spacing (ft)	App. Res. (Ω-ft)
10	33,007
16	38,926
25	42,198
50	33,461
75	21,732

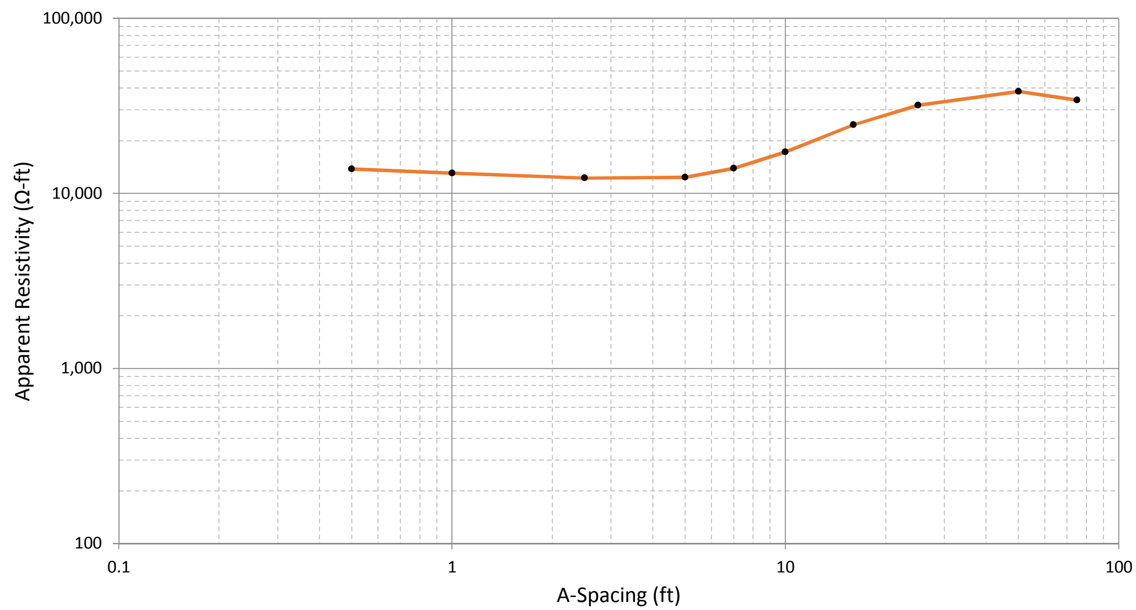
Vertical Electrical Sounding: VES-17

Northing:	2437503	US ft	Alaska State Plane Zone 4
Easting:	1395549	US ft	
Elevation:	125.8	US ft	(NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-17
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

LAYERED RESISTIVITY MODEL FROM 2D ERT DATA	SYNTHETIC 1D VERTICAL ELECTRICAL SOUNDING DATA FROM FORWARD MODEL





A-Spacing (ft)	App. Res. (Ω-ft)
0.5	13,784
1	13,054
2.5	12,233
5	12,341
7	13,923

A-Spacing (ft)	App. Res. (Ω-ft)
10	17,216
16	24,642
25	31,829
50	38,218
75	34,073

Vertical Electrical Sounding: VES-18

Northing: 2436753 US ft
Easting: 1395605 US ft
Alaska State Plane Zone 4
Elevation: 124.3 US ft (NAVD88)

SYNTHETIC VERTICAL ELECTRICAL SOUNDING DATA - VES-18
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

APPENDIX B

SHALLOW SEISMIC SURVEY

Plate

(A)

A 200-lb accelerated weight drop (AWD) mounted on skid steer, sourcing on Line EW-3.

(B)

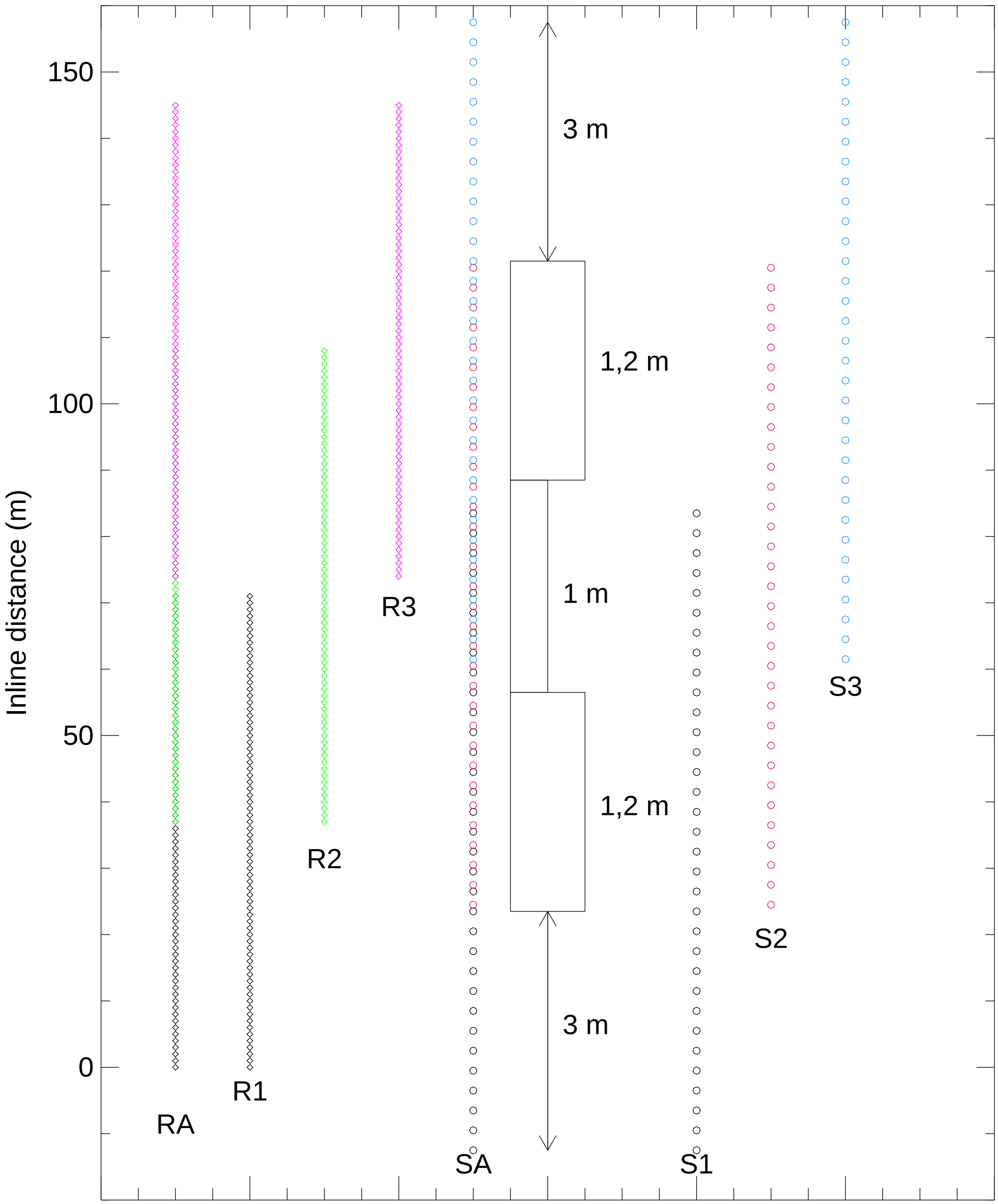
Land streamer consisting of 72 geophones spaced at 1 meter intervals along a Teflon-coated strap, is towed behind a vehicle to advance the array.

LAND STREAMER AND AWD FIELD OPERATION
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-1

fwla-wc-file1/project/Projects/10_0000/10_140334_AKLNG_PreFEED_Phase2/05_Graphics/10_140334 Geophysics

72-Channel Rolling Land Streamer Layout

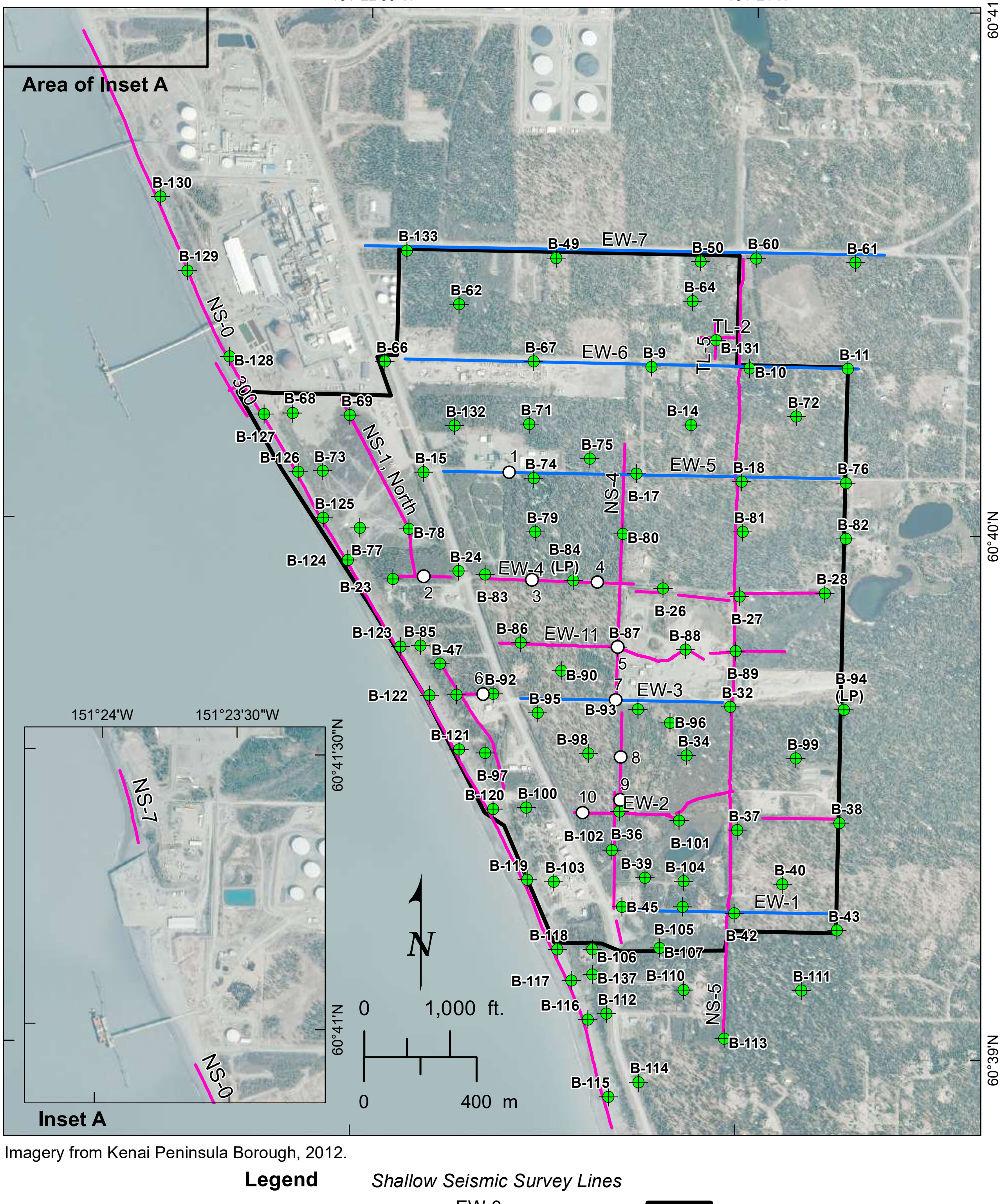


Successive streamer positions are labeled R1, R2, and R3. Each streamer position is 37 m forward of the previous one. The source positions for these streamer positions are labeled S1, S2, and S3.

SEISMIC LAND STREAMER ACQUISITION GEOMETRY
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-2

fwla-wc-file1/project/Projects/10_0000/10_140334_AKLNG_PreFEED_Phase2/05_Graphics/10_140334 Geophysics



Imagery from Kenai Peninsula Borough, 2012.

2014-2015 ONSHORE SHALLOW SEISMIC SURVEY LINES
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-3

P:\Projects\10_000010_140334_AKLNG_PreFEED_Phase2\05_Graphics\10_140334 Geophysics\B03_D_283_ShallowSeismicLinesLocation.mxd; jholmberg; 5/13/2016

Legend

Soil Descriptions

- Lean CLAY (CL)
- Lean CLAY with Sand (CL)
- Sandy Lean Clay (CL)
- Silt (ML)
- Topsoil
- Poorly-Graded SAND with Silt (SP-SM)
- Gravelly Poorly-Graded SAND (SP)
- Well-Graded SAND with Silt (SW-SM)
- Gravelly Well-Graded SAND (SW)
- Well-Graded SAND with Silt and Gravel (SW-SM)
- Clayey SAND (SC)
- Silty SAND (SM)
- Poorly-Graded SAND (SP)
- Gravel with silt and sand (GW-GM)

Vs Tomography

Vs (feet/second): 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, 1,100, 1,200, 1,300, 1,400, 1,500, 1,600, 1,700, 1,800, 1,900, 2,000, 2,100, 2,200, 2,300, 2,400

Vp Tomography

Vp (feet/second): 0, 220, 438, 656, 875, 1,094, 1,313, 1,531, 1,750, 1,969, 2,188, 2,406, 2,625, 2,844, 3,063, 3,281, 3,500, 3,719, 3,938, 4,156, 4,375, 4,594, 4,813, 5,031, 5,250, 5,469, 5,688, 5,906, 6,125, 6,344, 6,563, 6,781, 7,000

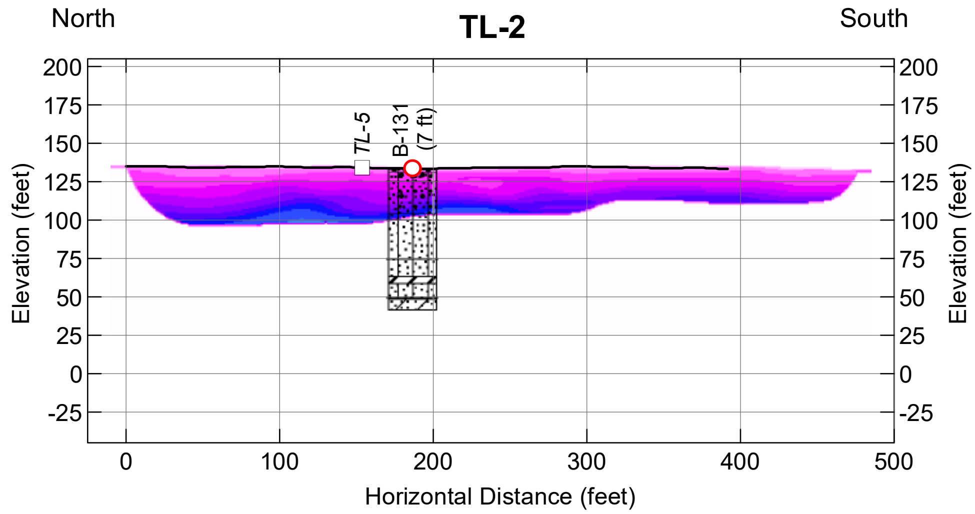
Symbols

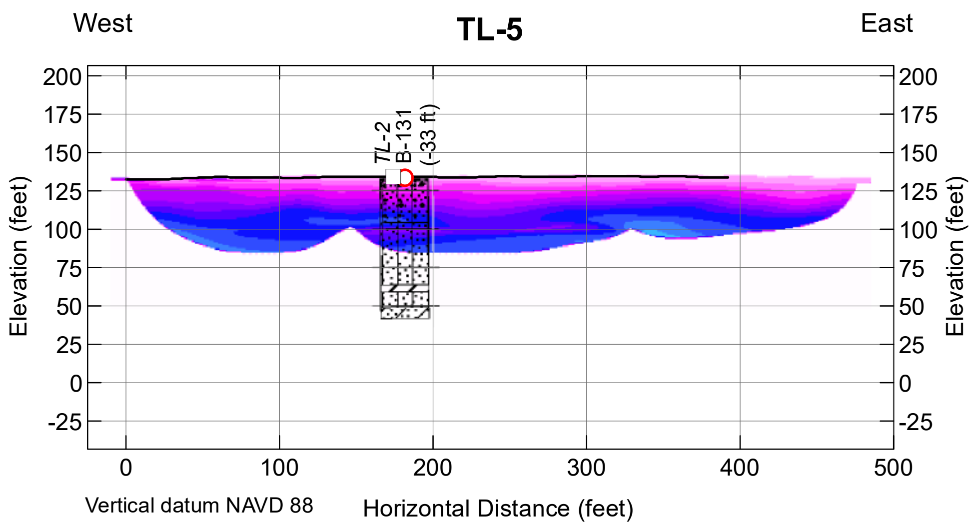
- Base of top soil and loess. (Vs ≤ ~800 fps)
- Bedding plane, well expressed change in Vs of ≥ 200 fps over ≤ 5 feet vertical distance.
- ====== Bedding plane, uncertain. Planar alignment of velocity changes, not meeting criteria for “well expressed”.
- □ Survey line intersection
- ○ Borehole location (distance in feet from the line)

EXPLANATION OF SEISMIC REFRACTION AND IMASW PROFILES

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-4





Vertical datum NAVD 88

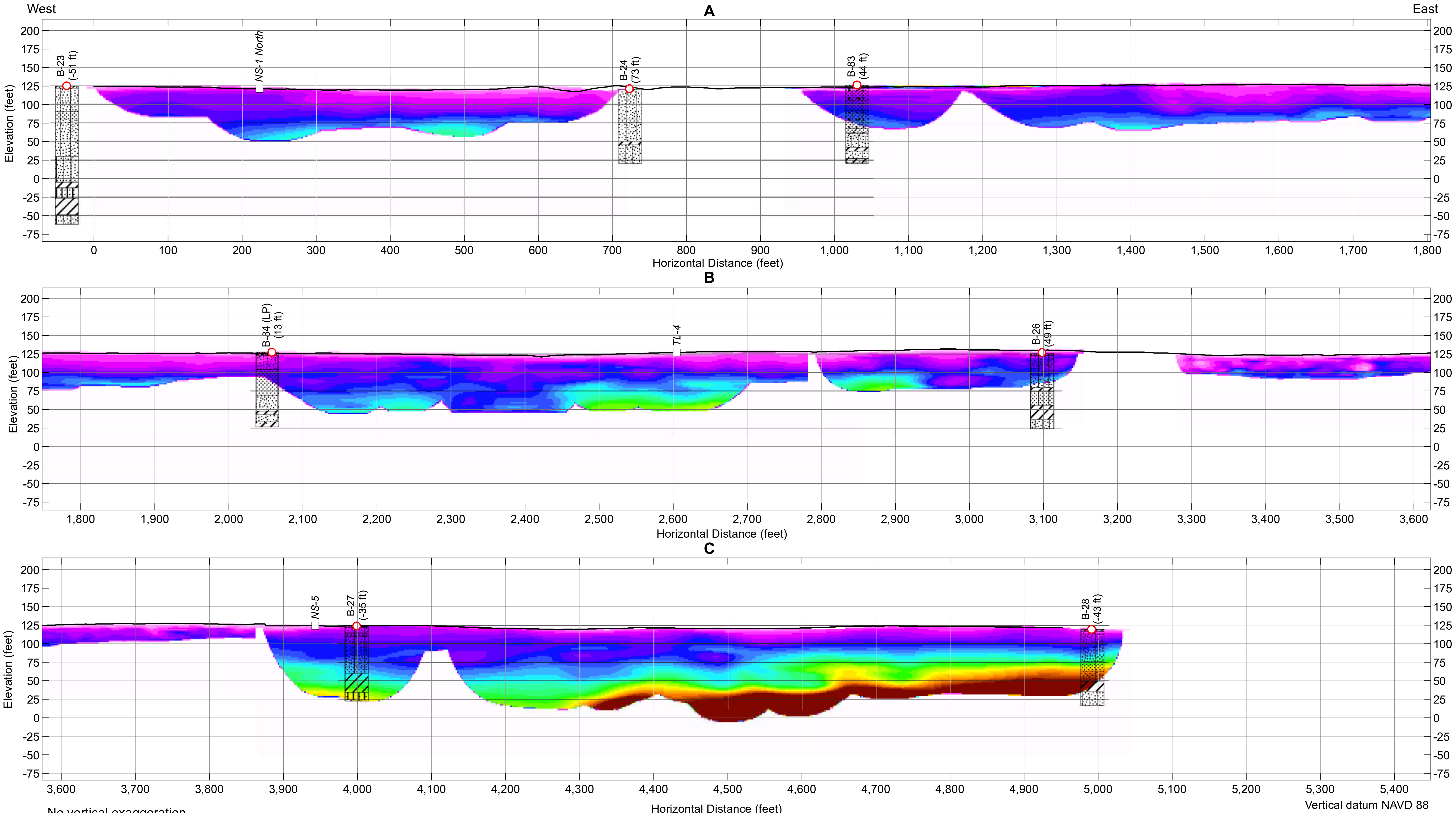
No vertical exaggeration

For legend see Plate B-4

P:\Projects\10_000010_140334_AKLNG_PreFEED_Phase205_Graphics\10_140334 Geophysics\B05_D_318_Refraction_Profile_TL2_TL5.mxd; jholmberg; 5/13/2016

SEISMIC REFRACTION VP TOMOGRAPHY PROFILE:
2015 LINE 202 (TL-2) AND LINE 105 (TL-5)
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-5



No vertical exaggeration

Vertical datum NAVD 88

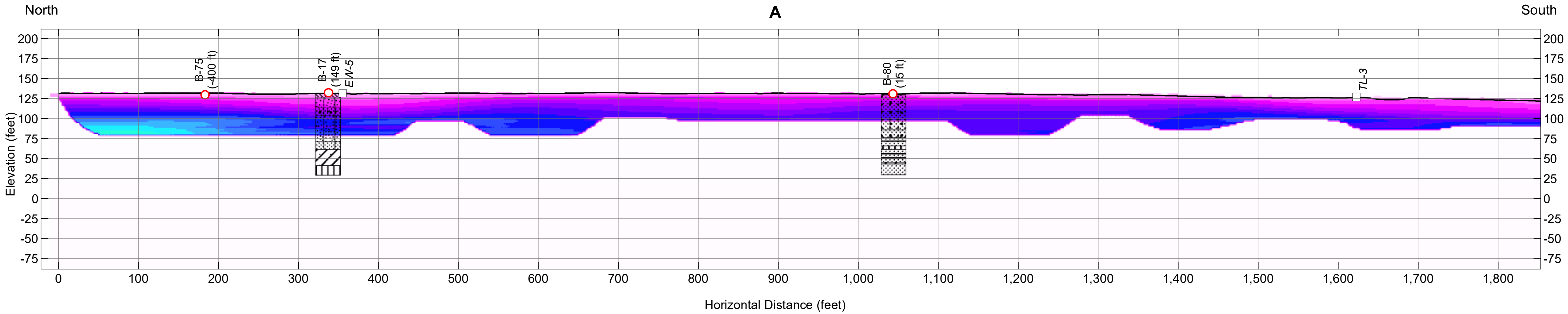
For legend see Plate B-4

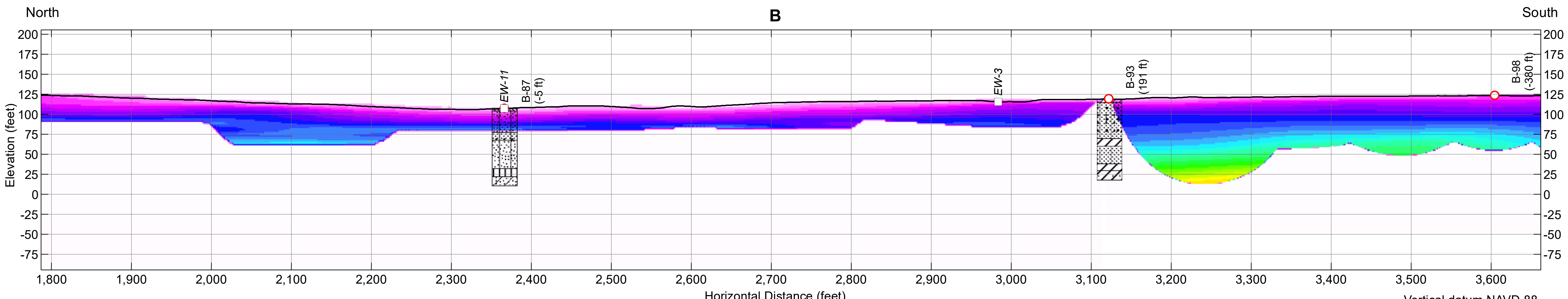
SEISMIC REFRACTION VP TOMOGRAPHY PROFILE: 2015 LINE EW-4

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-6

P:\Projects\10_0000\10_140334_AKLNG_PreFEED_Phase2\05_Graphics\10_140334 Geophysics\B06_D_319_Refraction_Profile_TL3.mxd; jholmberg; 5/13/2016





No vertical exaggeration

Vertical datum NAVD 88

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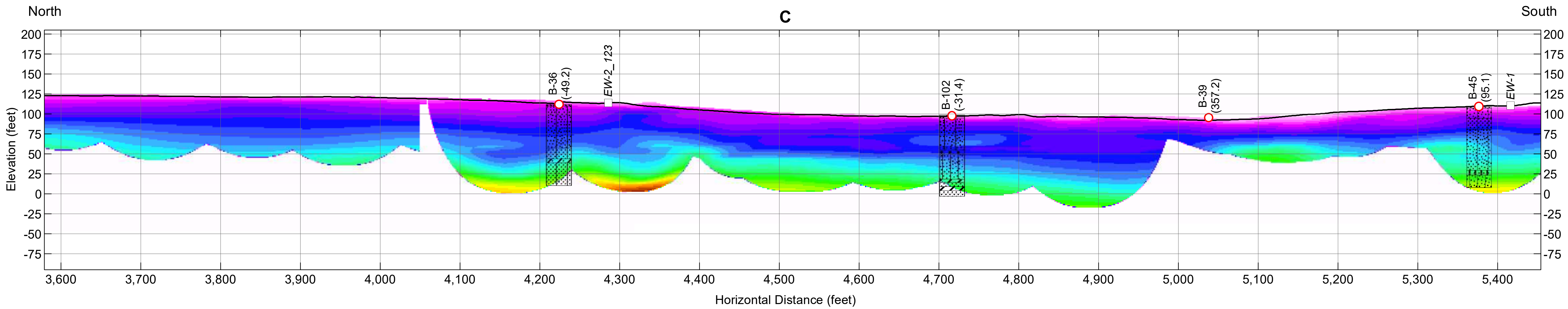
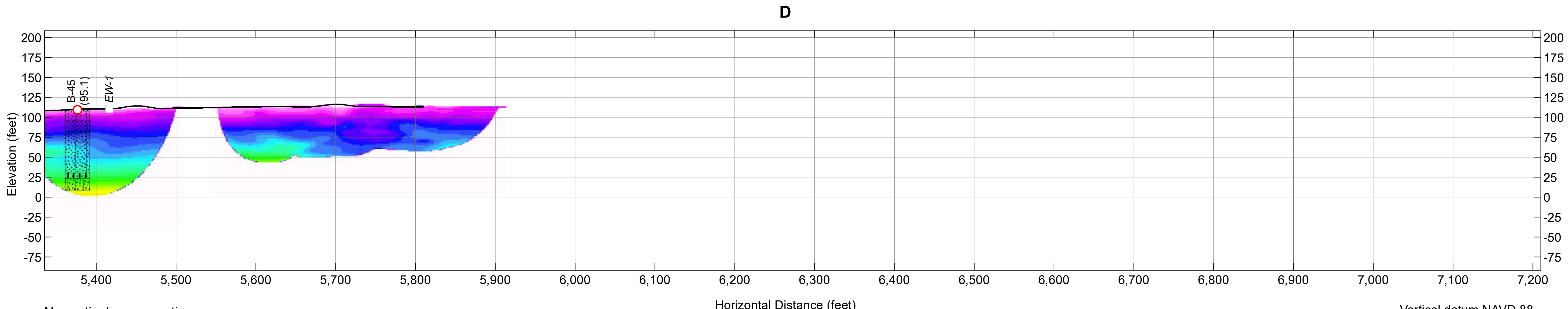
For legend see Plate B-4

SEISMIC REFRACTION VP TOMOGRAPHY PROFILE: 2015 LINE NS-4 NORTH

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-7





No vertical exaggeration

Vertical datum NAVD 88

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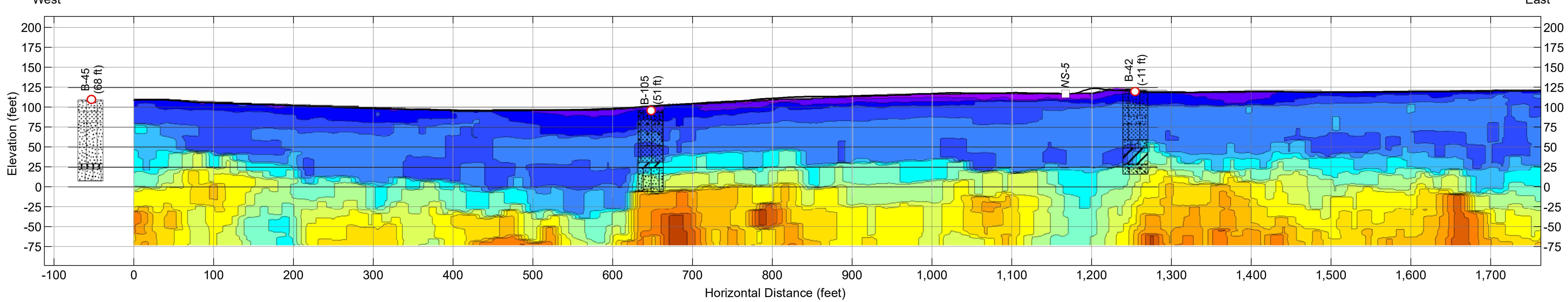
SEISMIC REFRACTION VP TOMOGRAPHY PROFILE:
2015 LINE NS-4 SOUTH

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

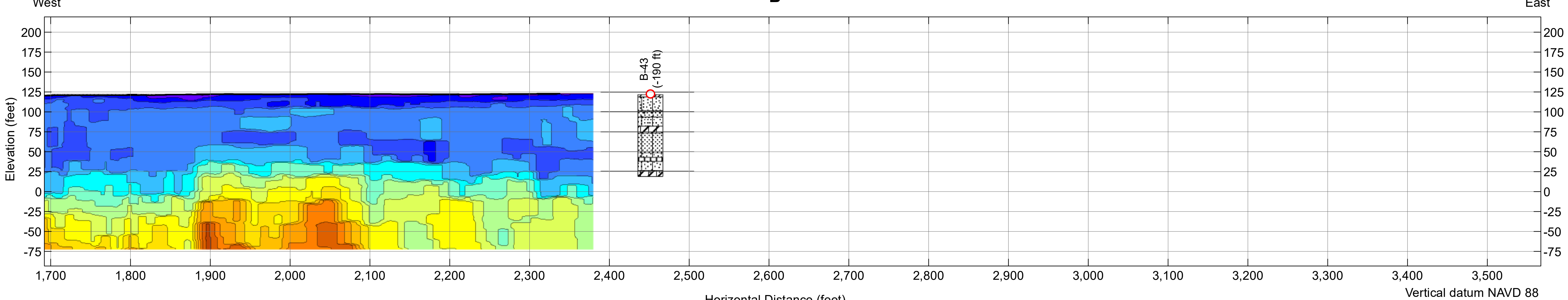
For legend see Plate B-4

PLATE B-8

A



B



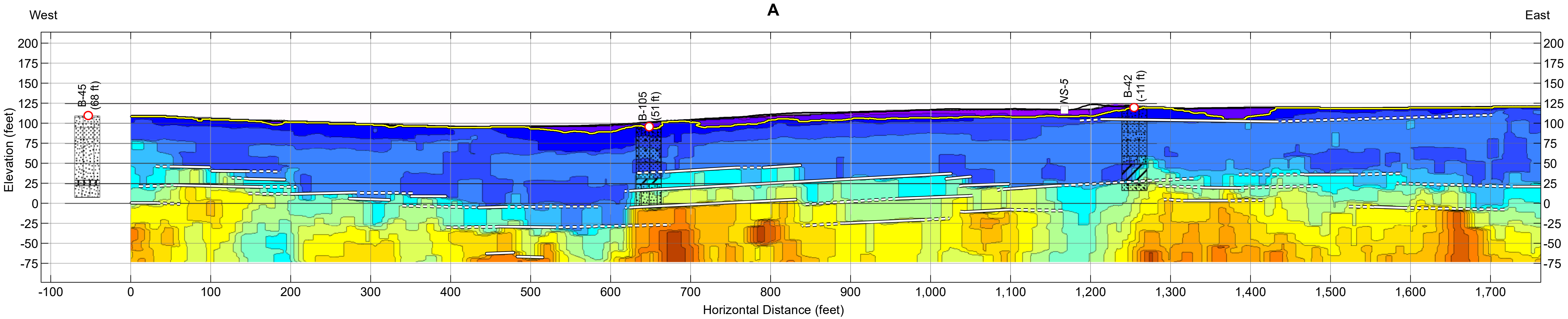
No vertical exaggeration

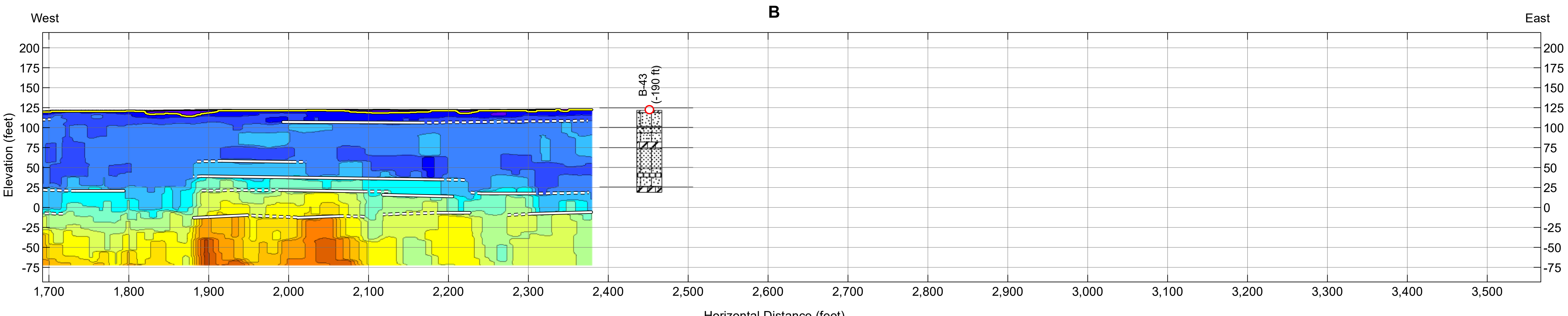
For legend see Plate B-4

IMASW VS TOMOGRAPHY PROFILE: 2014 LINE EW-1

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-9





No vertical exaggeration

Vertical datum NAVD 88

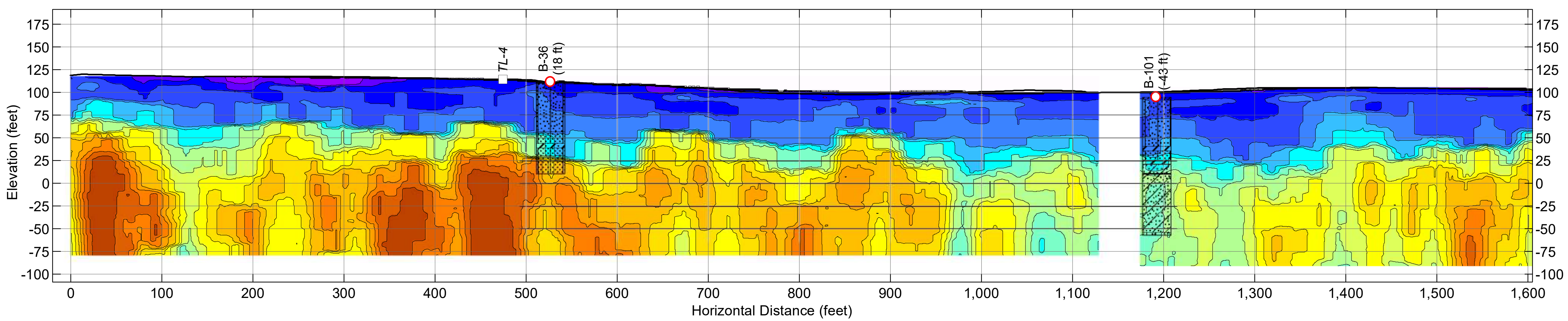
For legend see Plate B-4

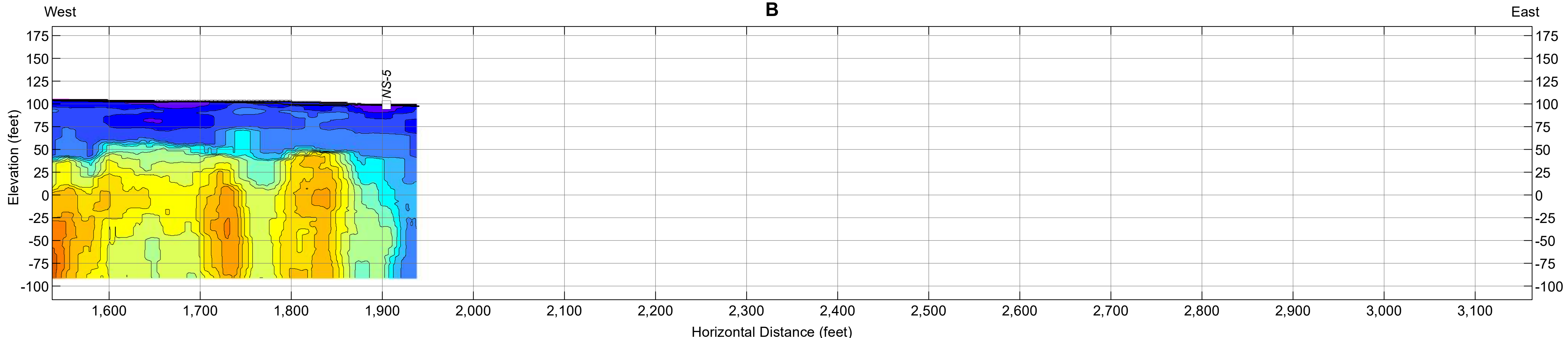
IMASW VS TOMOGRAPHY PROFILE: 2014 LINE EW-1, INTERPRETED

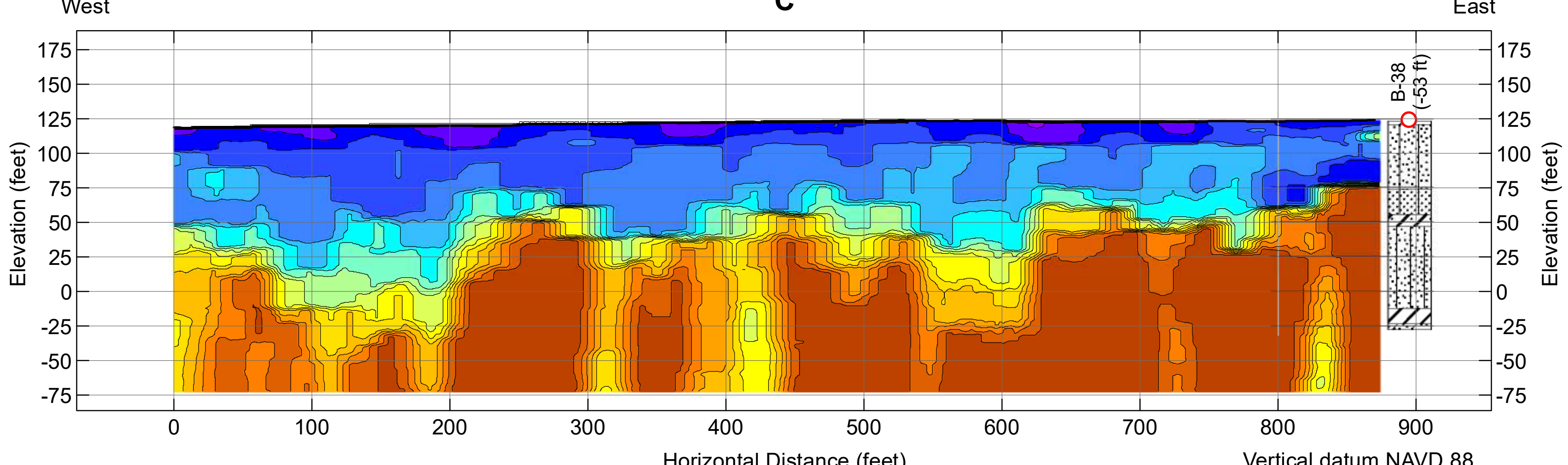
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-10

P:\Projects\10_000\10_140334_AKLNG_PreFEED_Phase2\05_Graphics\10_140334 Geophysics\B10_D_295_B_IMASW_Profile_EW1.mxd; jholmberg; 5/13/2016







No vertical exaggeration

Vertical datum NAVD 88

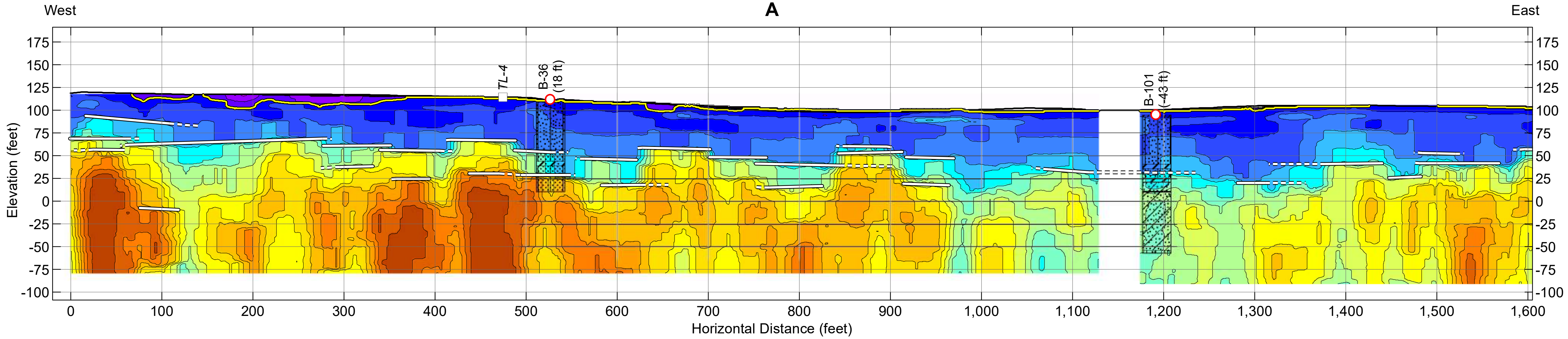
For legend see Plate B-4

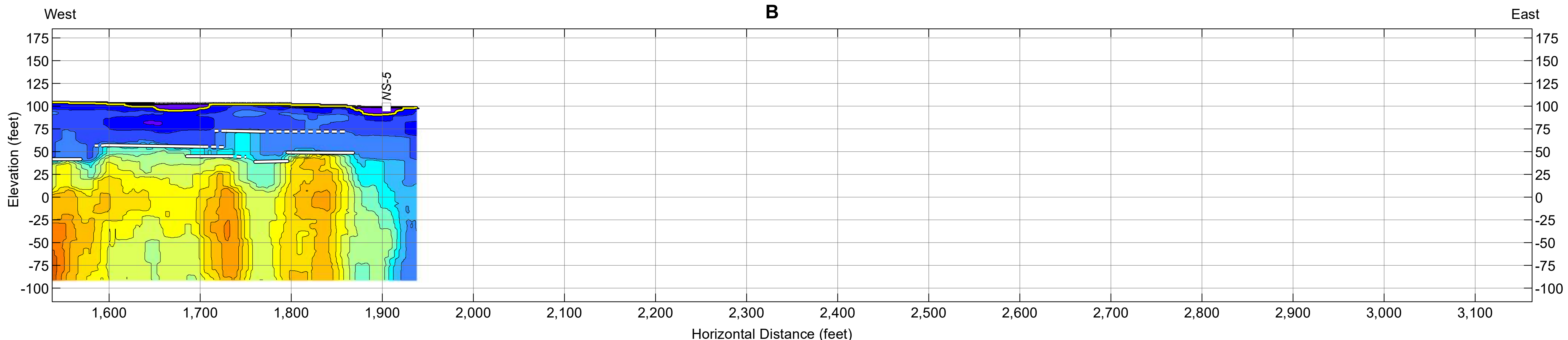
IMASW VS TOMOGRAPHY PROFILE: 2015 LINE EW-2

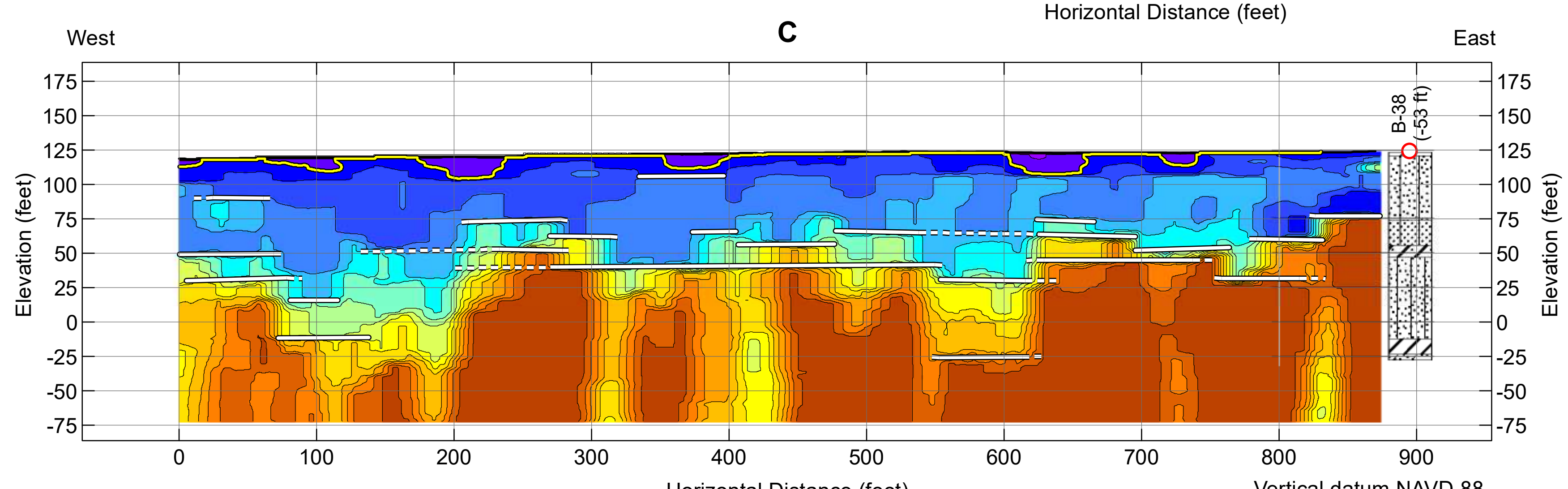
ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-11

P:\Projects\10_000010_140334_AKLNG_PreFEED_Phase2\05_Graphics\10_140334 Geophysics\B11_D_304_A_IMASW_Profile_EW2.mxd; jholmberg; 5/13/2016







No vertical exaggeration

Vertical datum NAVD 88

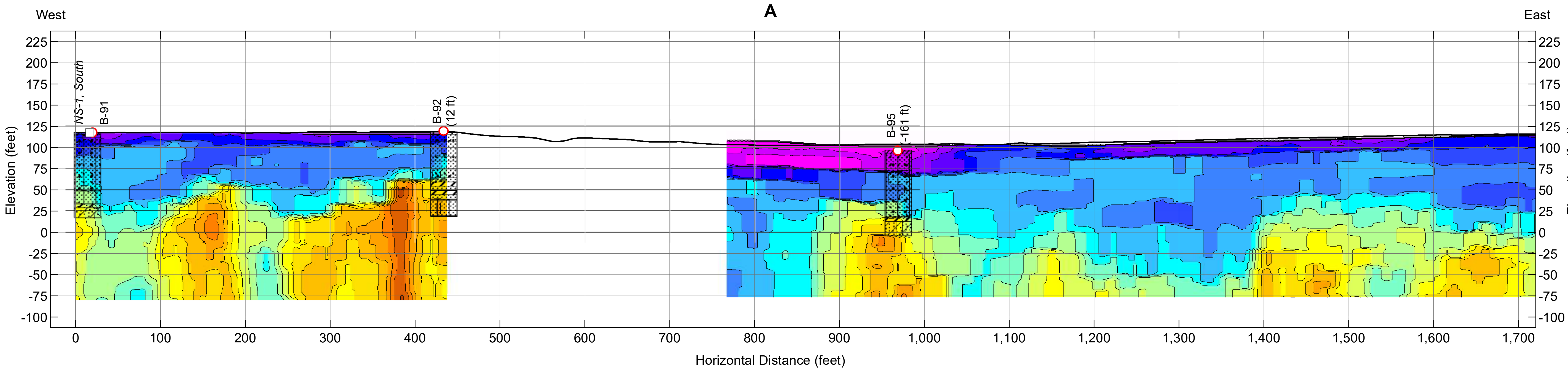
For legend see Plate B-4

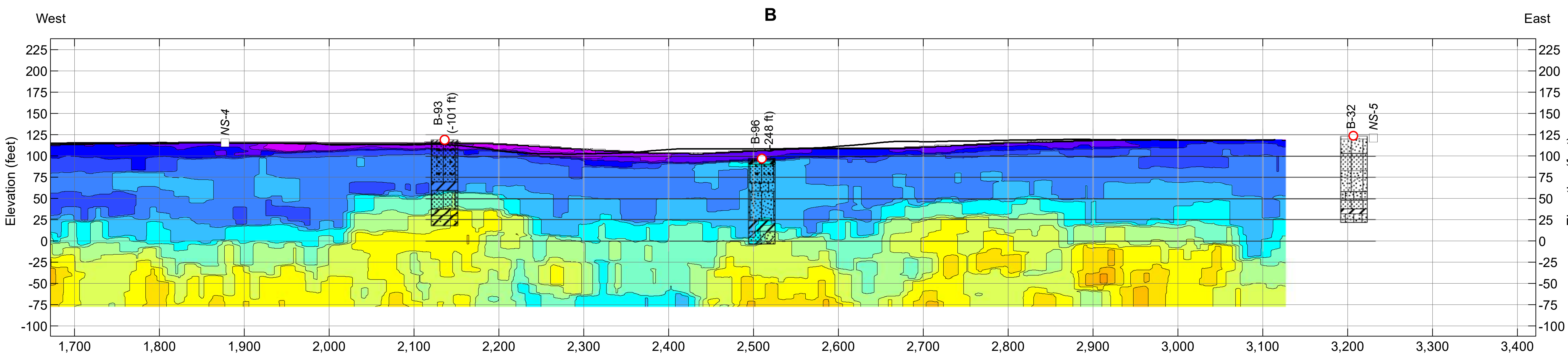
IMASW VS TOMOGRAPHY PROFILE: 2015 LINE EW-2, INTERPRETED

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-12

P:\Projects\10_000\10_140334_AKLNG_PreFEED_Phase2\05_Graphics\10_140334 Geophysics\B12_D_304_B_IMASW_Profile_EW2.mxd; jholmberg; 5/13/2016





No vertical exaggeration

Horizontal Distance (feet)

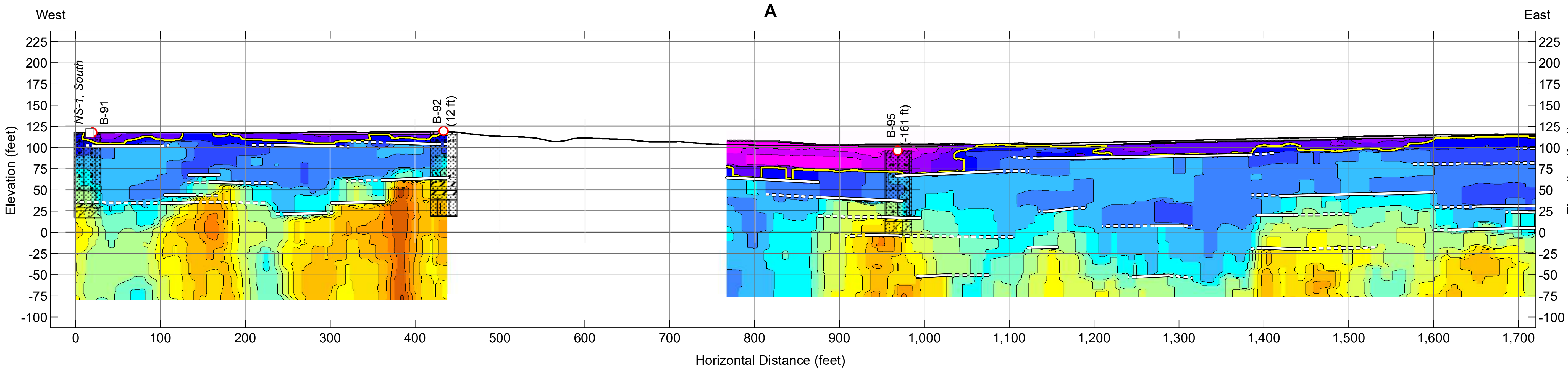
Vertical datum NAVD 88

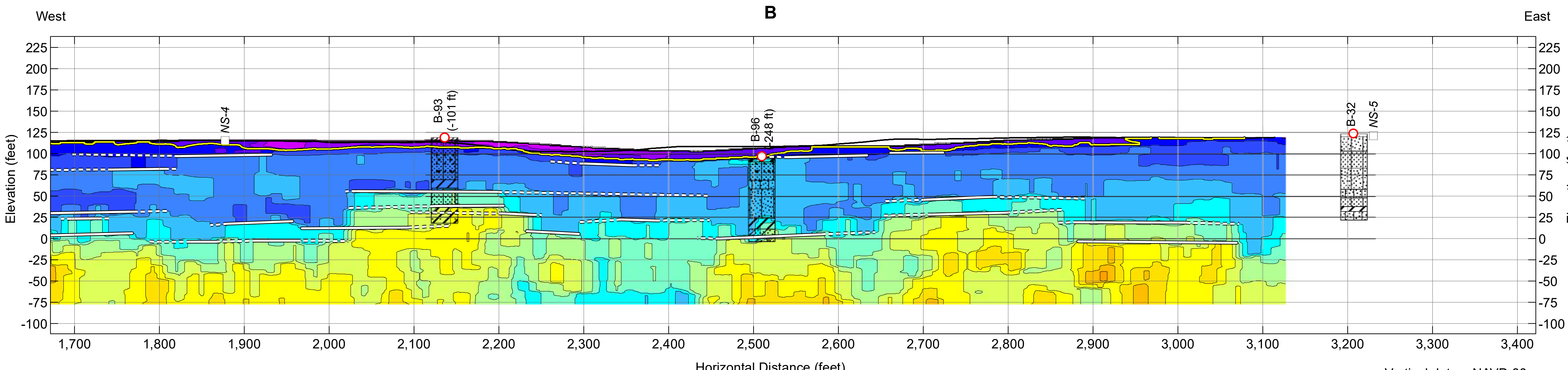
For legend see Plate B-4

IMASW VS TOMOGRAPHY PROFILE:
2014 LINE EW-3

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-13





No vertical exaggeration

Vertical datum NAVD 88

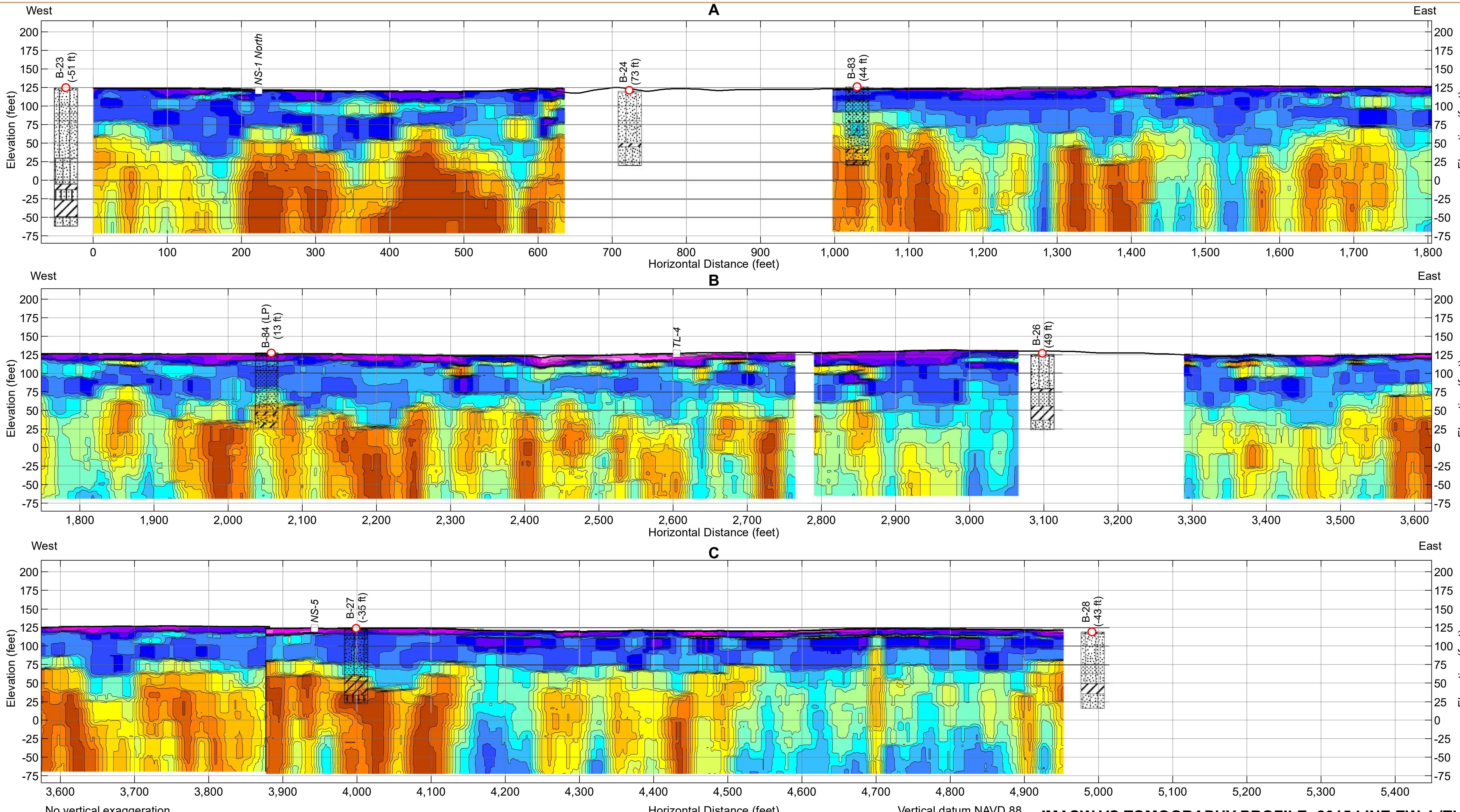
For legend see Plate B-4

IMASW VS TOMOGRAPHY PROFILE: 2014 LINE EW-3, INTERPRETED

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-14

P:\Projects\10_0000\10_140334_AKLNG_PreFEED_Phase2\05_Graphics\10_140334 Geophysics\B14_D_307_B_IMASW_Profile_EW3.mxd; jholmberg; 5/13/2016

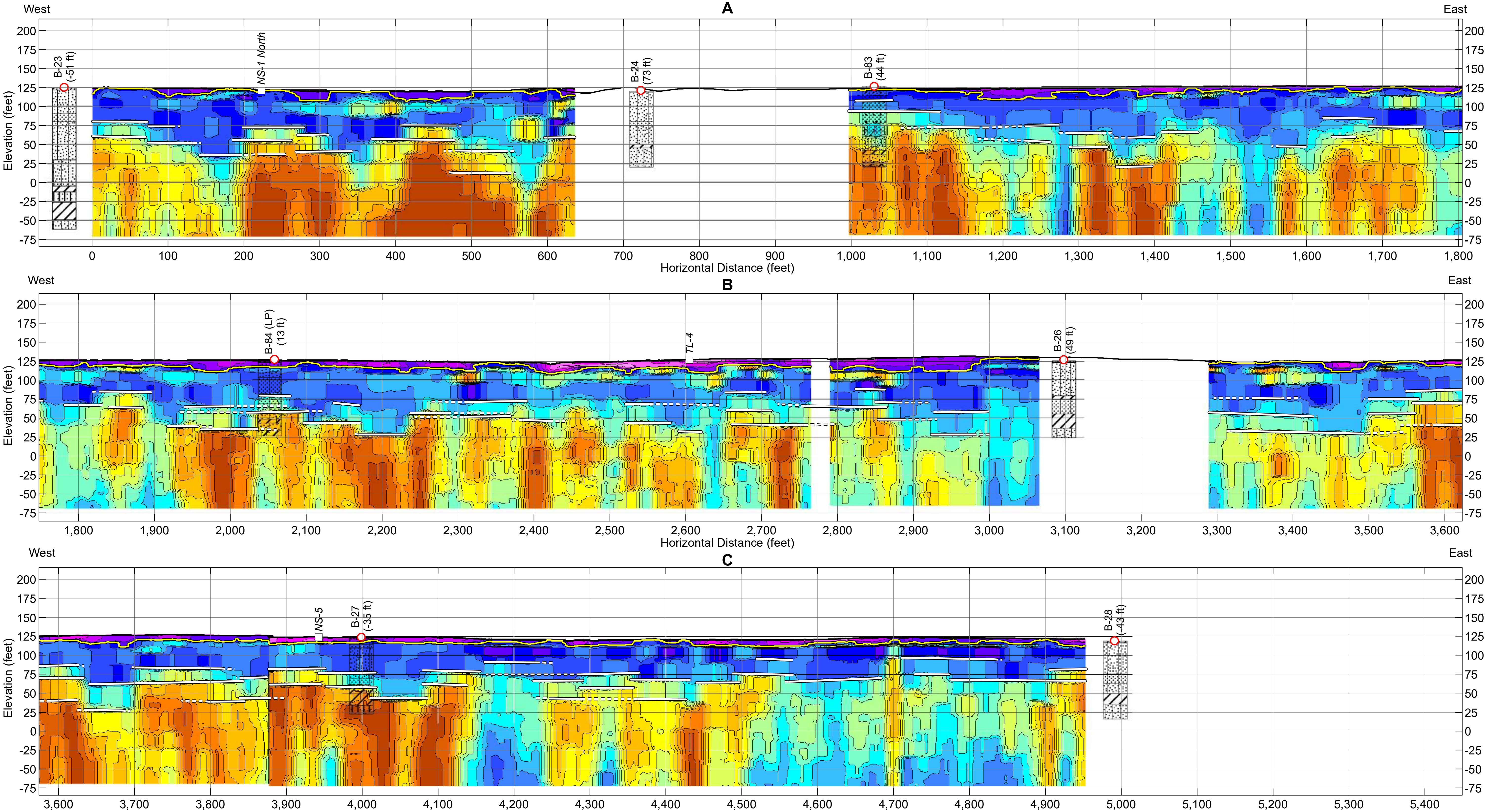


For legend see Plate B-4

IMASW VS TOMOGRAPHY PROFILE: 2015 LINE EW-4 (TL-3)

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-15



No vertical exaggeration

Horizontal Distance (feet)

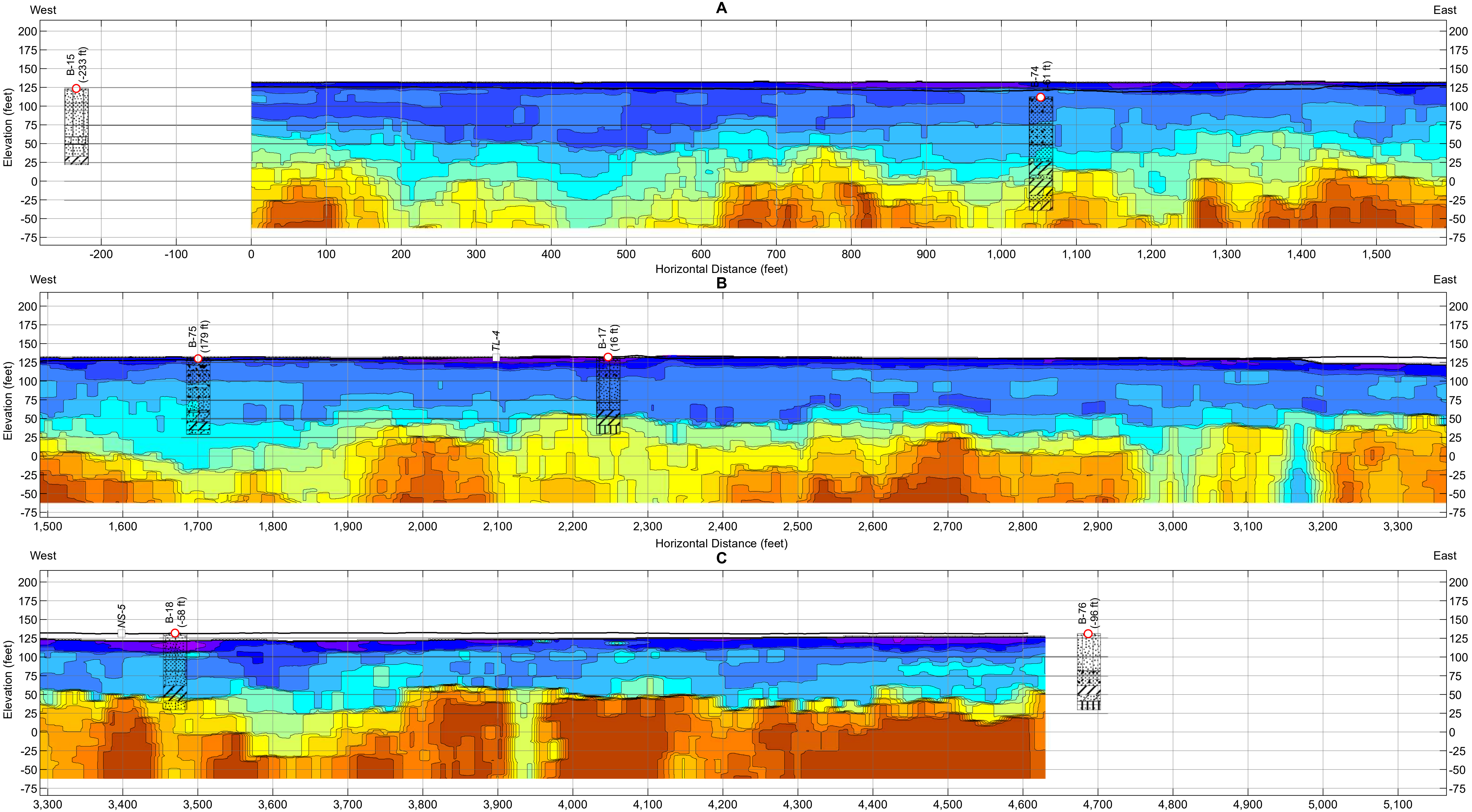
Vertical datum NAVD 88

For legend see Plate B-4

IMASW VS TOMOGRAPHY PROFILE: 2015 LINE EW-4 (TL-3), INTERPRETED

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-16



No vertical exaggeration

Horizontal Distance (feet)

For legend see Plate B-4

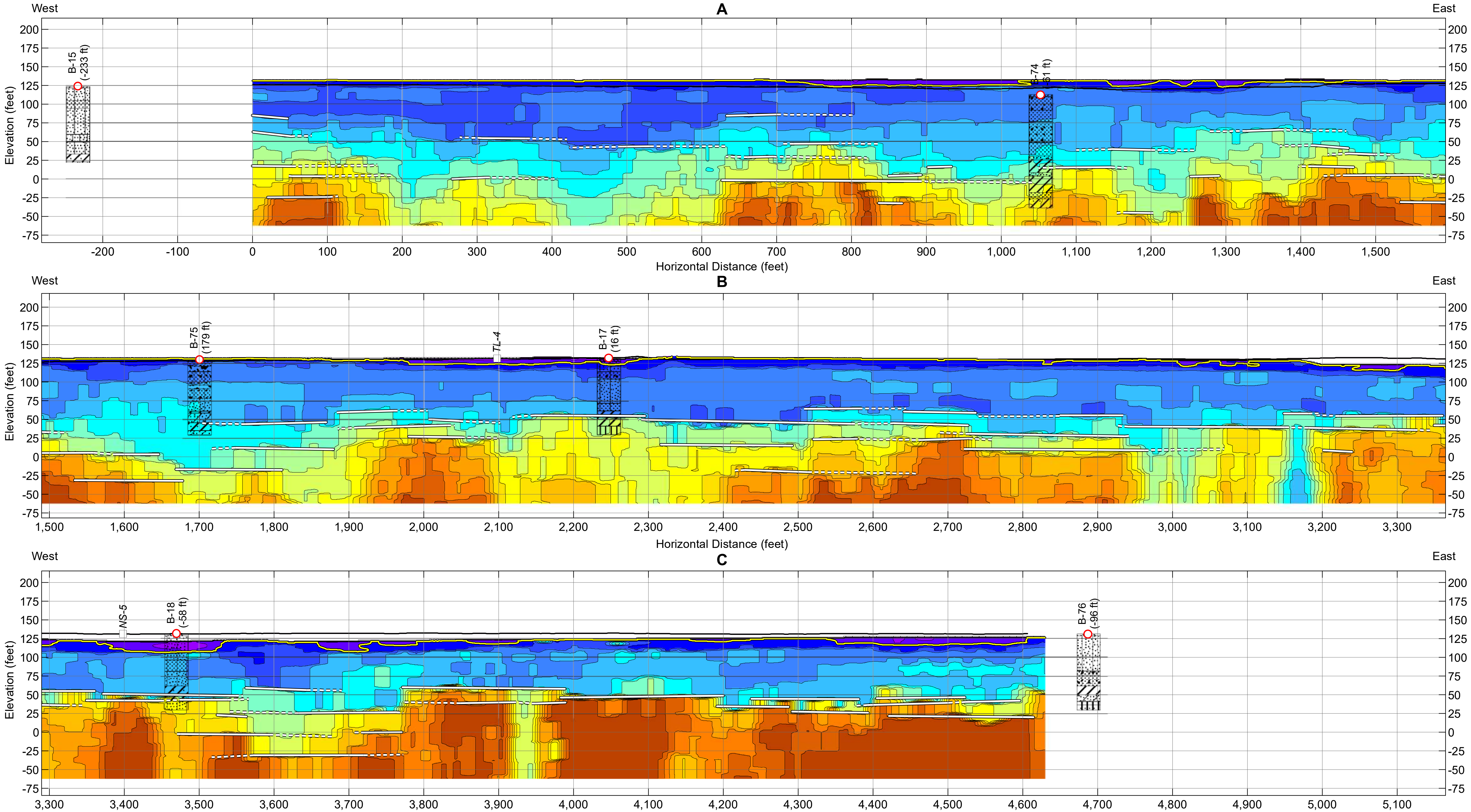
Vertical datum NAVD 88

IMASW VS TOMOGRAPHY PROFILE: 2014 LINE EW-5

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-17

P:\Projects\10_000\10_140334_AKLNG_PreFEED_Phase2\05_Graphics\10_140334 Geophysics\B17_D_296_A_IMASW_Profile_EW5.mxd; jholmberg; 5/13/2016



No vertical exaggeration

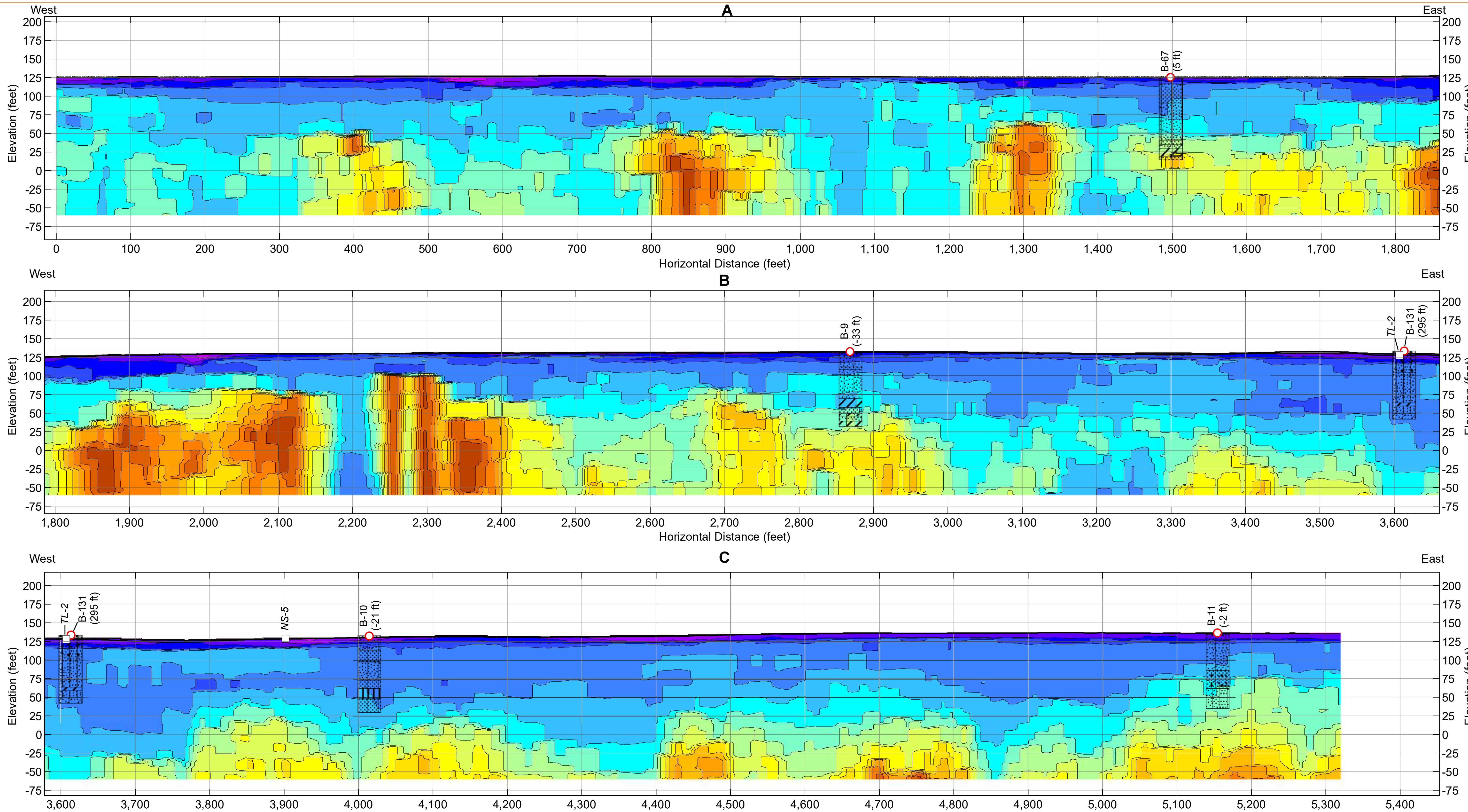
For legend see Plate B-4

Vertical datum NAVD 88

IMASW VS TOMOGRAPHY PROFILE: 2014 LINE EW-5, INTERPRETED

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-18



No vertical exaggeration

Horizontal Distance (feet)

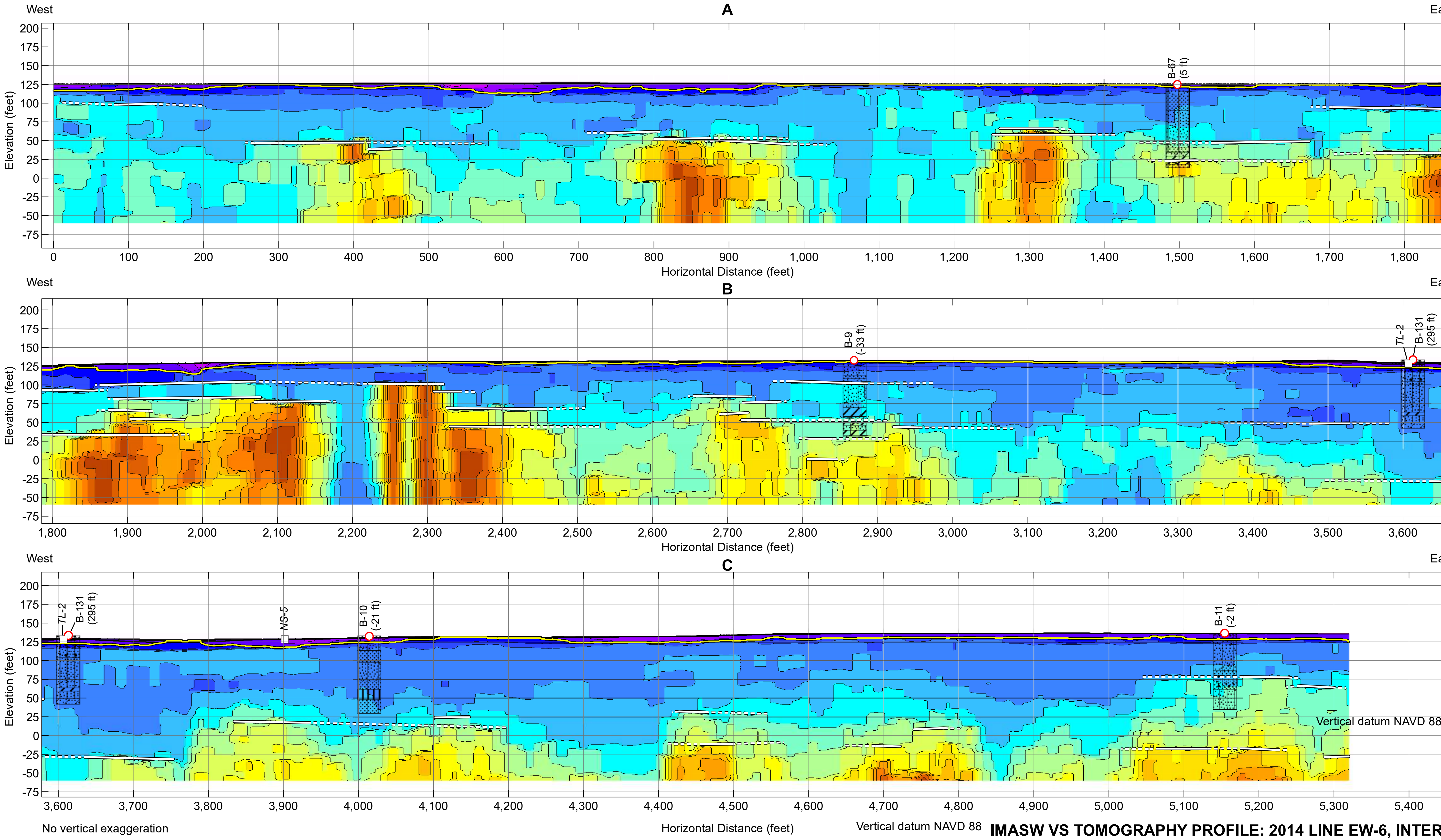
Vertical datum NAVD 88

For legend see Plate B-4

IMASW VS TOMOGRAPHY PROFILE: 2014 LINE EW-6

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-19



Vertical datum NAVD 88

For legend see Plate B-4

IMASW VS TOMOGRAPHY PROFILE: 2014 LINE EW-6, INTERPRETED

ONSHORE LNG FACILITIES
ALASKA LNG PROJECT
NIKISKI, ALASKA

PLATE B-20