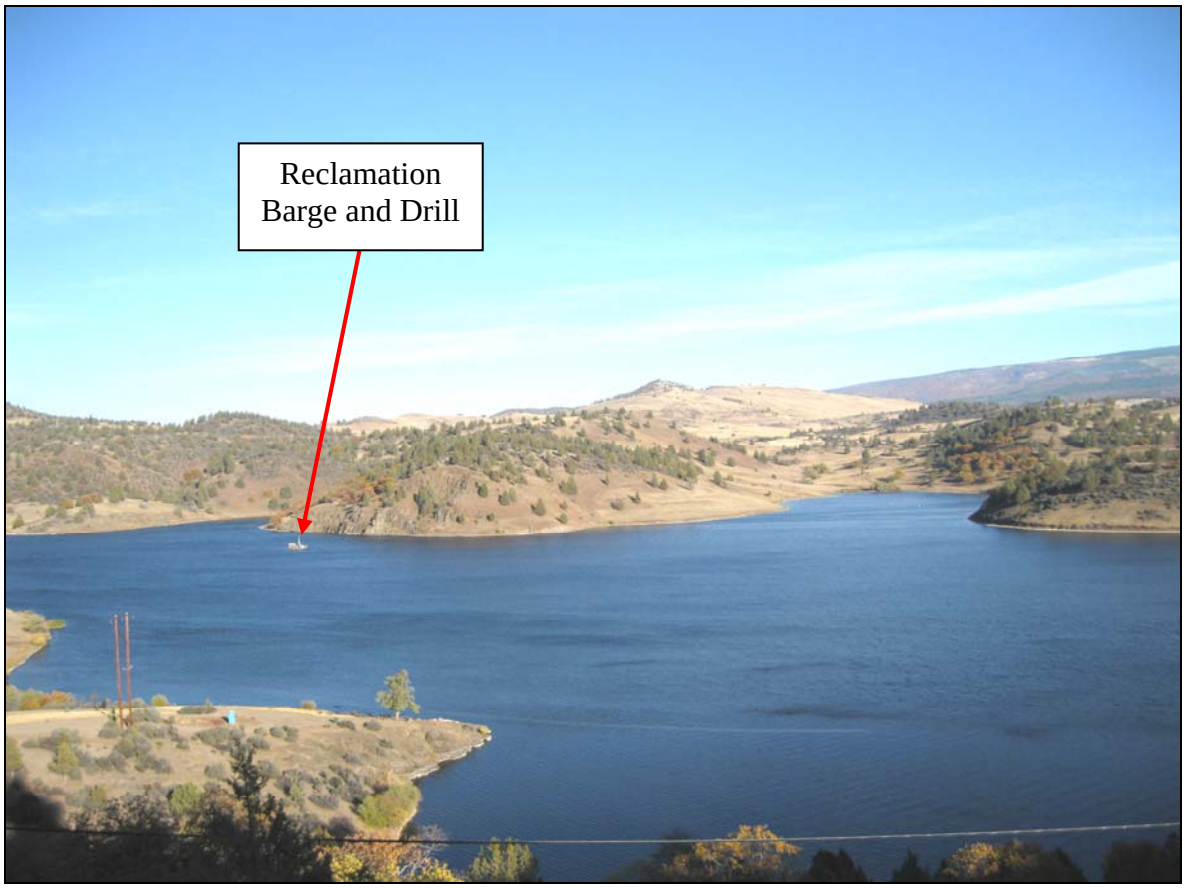
RECLAMATION

Managing Water in the West

Reclamation (2011)
Klamath River Sediment Sampling Program
Phase 1 – Geologic Investigations

Contaminant and Geotechnical Properties Sampling
J.C. Boyle, Copco-1, Copco-2, and Iron Gate Reservoirs and the Klamath River Estuary, Volume 1 of 2



Klamath Project, Oregon and California
Mid-Pacific Region, MP-230
Revision Two, September 2011

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

This report was prepared by the United States Bureau of Reclamation, Mid-Pacific Region, Geology Branch, MP-230.

Peer Review

Peer Review Certification: This document has been peer reviewed by professional geologists and is believed to in accordance with the standards of the profession. Questions concerning this report should be addressed to Greg Mongano, Regional Geologist, Reclamation, Mid-Pacific Region (MP-230) at 916-978-5331

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Table of Contents

Page

Executive Summary, Findings, and Conclusions v

Introduction

SCOPE OF WORK..... 2
Reservoir Area Geology 2
LOCATION AND ACCESS……... 2
J.C. Boyle Reservoir 3
Copco-1 Reservoir 3
Copco-2 Reservoir 3
Iron Gate Reservoir 3
Klamath River Estuary 4
PREVIOUS INVESTIGATIONS…… 4
California State Costal Conservancy (via Shannon & Wilson Inc.) . 4
PacifiCorp 4

Current Geologic Investigations

EXPLORATORY WORK COMPLETED..... 4
Drilling and Sampling Methods 5
Flight Auger Dry Core Method 5
Flight Auger Dry Core with Liner Method 5
Gravity Sampler Method 5
Direct Push/Hammer Method 6
Vibracore Method 6
Sample Processing, Storage, and Shipment 7
REGIONAL GEOLOGY…… 7
Geomorphic Provinces and Rock Types 7
Structure 8

J.C. Boyle Reservoir

GEOLOGY……..... 9
SAMPLE SITES……..... 10
RESERVOIR SEDIMENT……..... 12
Upper Reservoir 14
Transition Area 14
Middle Reservoir 15
Lower Reservoir 16
Unit Weight of Undisturbed Samples of Reservoir Sediment . . 16
GEOCHEMISTRY OF RESERVOIR SEDIMENT (ICP-MS METHOD).... 17
SUMMARY..……..... 19
FINDINGS……..... 20
CONCLUSIONS……..... 20
ADDITIONAL WORK REQUEST...……..... 21

Table of Contents
(continued)

Page

Copco-1 Reservoir

GEOLOGY……..... 22
SAMPLE SITES……..... 24
RESERVOIR SEDIMENT……..... 25
Upper Reservoir 26
Main Reservoir 26
Unit Weight of Undisturbed Samples of Reservoir Sediment . . 28
GEOCHEMISTRY OF RESERVOIR SEDIMENT (ICP-MS METHOD).... 28
SUMMARY..……..... 30
CONCLUSIONS……..... 30
ADDITIONAL WORK REQUEST...……..... 30

Copco-2 Reservoir

GEOLOGY……..... 32
SAMPLE SITES……..... 32
RESERVOIR SEDIMENT……..... 35
SUMMARY..……..... 35
CONCLUSIONS……..... 35
ADDITIONAL WORK REQUEST...……..... 36

Iron Gate Reservoir

GEOLOGY……..... 37
SAMPLE SITES……..... 38
RESERVOIR SEDIMENT……..... 38
Unit Weight of Undisturbed Samples of Reservoir Sediment . . 43
GEOCHEMISTRY OF RESERVOIR SEDIMENT (ICP-MS METHOD).... 43
SUMMARY..……..... 45
CONCLUSIONS……..... 45
ADDITIONAL WORK REQUEST...……..... 45

Lower Klamath River Estuary

CURRENT WORK……..... 47
Active River Bedload Characterization 47
SAMPLING……..... 48
Area One (Estuary). 48
Area Two (Freshwater River) 48
GEOCHEMISTRY OF THE SEDIMENT (ICP-MS METHOD)…….. 48

Table of Contents
(continued)

Page

RIVER GEOMORPHOLOGY……..... 50
Typical River Banks Upstream from Hwy. 101 Bridge . . . 51
Typical River Banks Downstream from Hwy. 101 Bridge. . . 51
River Mouth 52
CONCLUSIONS……..... 52
RIVER BANK AND BAR CHARACTERIZATION FIELD NOTES..... 53 – 55

References 69

TABLES

Table 1. J.C. Boyle Reservoir Drill Hole Summary……. 11
Table 2. J.C. Boyle Reservoir Sediment Unit Weights……. 18
Table 3. J.C. Boyle Mineral Grain Geochemistry……. 19
Table 4. Copco-1 Reservoir Drill Hole Summary……..… 24
Table 5. Copco-1 Reservoir Sediment Unit Weights…… 29
Table 6. Copco-2 Reservoir Sample Location Summary……. 34
Table 7. Iron Gate Reservoir Drill Hole Summary……..……. 40
Table 8. Iron Gate Reservoir Sediment Unit Weights……..…. 44
Table 9. Estuary and Lower Klamath River sample locations…… 49
Table 10. Estuary Mineral Grain Geochemistry…… 50

FIGURES

Figure 1. Klamath River Sediment Sampling Project Location Map map pocket
Figure 2. J.C. Boyle Reservoir Sample / Drill Hole Location Sites map pocket
Figure 3. Copco-1 Reservoir Sample / Drill Hole Location Sites map pocket
Figure 4. Copco-2 Reservoir Sample / Drill Hole Location Sites map pocket
Figure 5. Iron Gate Reservoir Sample / Drill Hole Location Sites map pocket
Figure 6. Diagrammatic Geologic Cross Section for J. C. Boyle Reservoir… 10
Figure 7. Diagrammatic Geologic Cross Section for Copco-1 Reservoir…… 23
Figure 8. Diagrammatic Geologic Cross Section for Copco-2 Reservoir…… 33
Figure 9. Diagrammatic Geologic Cross Section for Iron Gate Reservoir….. 39
Figure 10. Location map showing the Estuary and Lower Klamath River…. 57
Figure 11. Location map showing where samples were collected in the Estuary 58
Figure 12. Freshwater sample locations 2A and 2B……. 59
Figure 13. Freshwater sample location 2A and elutriate water collection…... 60
Figure 14. Freshwater sample location 2B and Field Note A……..…… 61
Figure 15. Freshwater sample location 2B and Field Note A……..…… 62
Figure 16. Map showing the location of Field Notes B, C, and D…….. 63
Figure 17. Map showing the location of Field Notes E and F……. 64

Table of Contents
(continued)

Page

Figure 18. Map showing the location of Field Note G…..…….. 65
Figure 19. Map showing the location of Field Note H…… 66
Figure 20. Map showing the location of Field Notes I and J…….. 67
Figure 21. Map showing the location of Field Notes K, L, M, N, and O…… 68

CHARTS

Chart 1. PI vs LL of J. C. Boyle Reservoir Samples 13
Chart 2. PI vs LL of Copco-1 Reservoir Samples 27
Chart 3. PI vs LL of Iron Gate Reservoir Samples 42

APPENDICIES

Appendix A. Field Exploration Request from Reclamation's Technical Service Center
Appendix B. Drill Hole Logs and Cross Sections
Appendix C. Laboratory Data (Gradations, Atterberg Limits, and Moisture Content)

VOLUME 2 OF 2

PHOTOGRAPHS

BARGE AND BOAT LAUNCHING
J.C. Boyle Reservoir 1-16
Copco-1 Reservoir 17-23
Copco-2 Reservoir 24-26
Iron Gate Reservoir 27-38

DRILLING AND SAMPLING EQUIPMENT AND PROCEDURES 39-67

GEOLOGY AND SEDIMENT SAMPLING
J.C. Boyle Reservoir Geology 68-86
J.C. Boyle Reservoir Sediment Sampling. 87-116
Copco-1 Reservoir Geology 117-127
Copco-1 Reservoir Sediment Sampling 128-163
Copco-2 Reservoir Geology 164-175
Copco-2 Reservoir Sediment Sampling 176-185
Iron Gate Reservoir Geology 186-194
Iron Gate Reservoir Sediment Sampling 195-218
Lower Klamath River and Estuary 219-259

Klamath River Sediment Sampling Program

Phase 1 – Geologic Investigations

Executive Summary, Findings, and Conclusions

Field investigations were conducted at J.C. Boyle, Copco-1, Copco-2, and Iron Gate dams/reservoirs, which are located along the Klamath River in southwestern Oregon and northwestern California. Additional field investigations were conducted in the Klamath River Estuary, and for about seven miles upstream from the mouth of the river (Figure 1).

Phase 1 of the geologic investigations comprises in-reservoir drilling to collect comprehensive suites of samples of reservoir sediment (Qr) behind each dam. There are three main purposes for this work:

1. To collect samples for screening-level analysis of organic and inorganic chemical compounds within the reservoir sediment and, where present, to determine the level and extent of contamination;
2. To collect samples of reservoir sediment to determine a standard suite of physical properties and to collect undisturbed samples for analyses of engineering properties; and,
3. To help determine the thickness of reservoir sediment throughout all major sections of each reservoir.

WORK COMPLETED

In-reservoir geologic investigations consisted of:

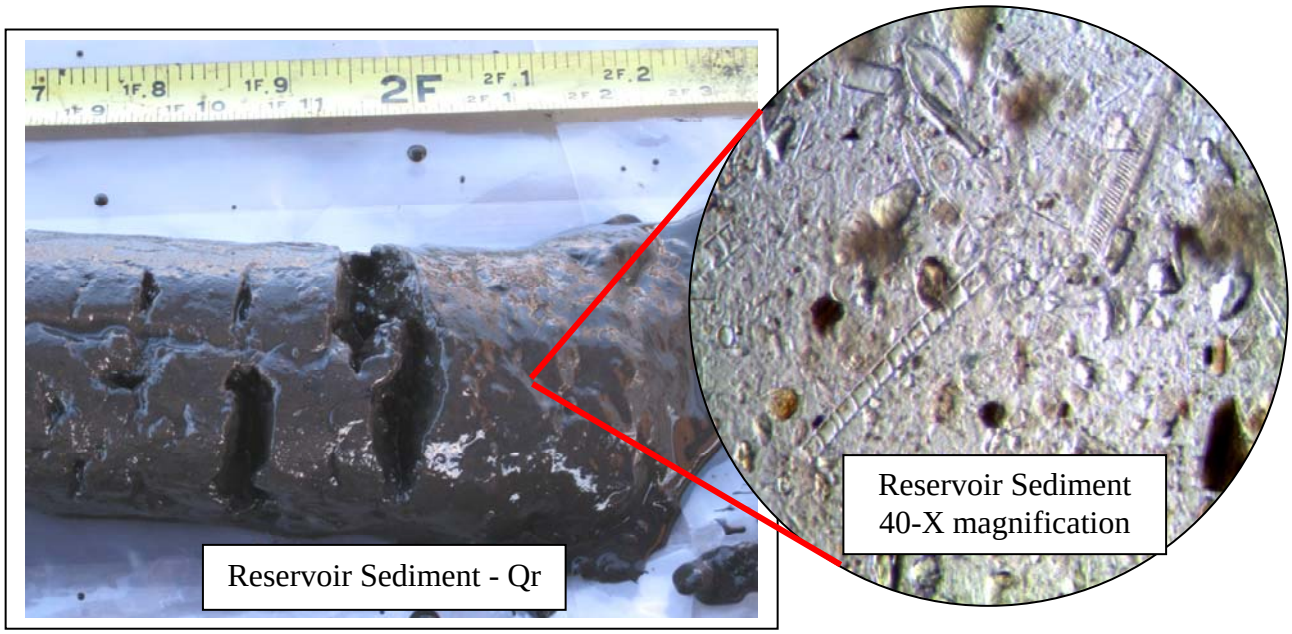
- Barge and boat platforms for Auger Drilling and Sampling;
- Barge and boat platforms for Push Tube Sampling;
- A boat platform for Vibracore Drilling and Sampling;
- A boat platform for Gravity Tube Sampling;
- Barge and boat-supported drilling/sampling took place at 55 locations in J.C. Boyle, Copco-1, and Iron Gate reservoirs (Figures 2, 3, and 5);
- Sixty-nine samples of reservoir sediment and pre-reservoir deposits were collected for gradation analysis, Atterberg limits, and field moisture content;
- Seventy-three samples of reservoir sediment were collected for chemical analysis;
- Nineteen undisturbed samples of reservoir sediment were collected in lexan liners for engineering properties testing;
- In Copco-2 Reservoir, boat-supported sampling of reservoir sediment was attempted at sixteen locations, from the dam upstream for about 1,000 feet (Figure 4); and,
- In the Klamath River Estuary and up to seven miles upstream, boat-supported sampling took place at five locations, and characterization of fluvial deposits was conducted along seven miles of the river banks.

FINDINGS

Reservoir Sediment Composition

Fine grained sediment in all of the reservoirs consisted primarily of Elastic Silt (±Organic Silt), with lesser amounts of Elastic Silt with Fine Sand; MH ±OH to (MH)s. The reservoir sediment is mostly an accumulation of silt size particles of organic material such as algae and diatoms, and silt size particles of rock (Photo A).

Reservoir sediment hosts a higher percentage of silt, sand, and gravel in the upper reaches of each reservoir. Over several thousand feet downstream this coarse sediment transitions into deposits of sandy elastic silt, then into elastic silt with trace sand.



Photograph A. View of typical reservoir sediment in J.C. Boyle, Copco-1 and Iron Gate reservoirs, and reservoir sediment from J.C. Boyle Reservoir magnified 40-times. The sediment consists primarily of algae, diatoms, and rock particles loosely arranged in an open water-filled structure.

Consistency

Fine grained reservoir sediment (Elastic Silt) throughout all reservoirs has the consistency of pudding. It is very soft and indents with very light finger pressure. Sediment firmed up a little where its thickness was in the range of 6 to 10 feet. On a microscopic scale it has an open structure that holds a very high water content. Field moisture of samples of Elastic Silt were frequently 200% to 300% of the sample's dry weight, and ranged up to 700% moisture (Photo A).

Fine grained reservoir sediment has a low cohesion, is erosive, and organic material exposed to air may decompose over time. It was noted that where river/reservoir water was flowing greater than an estimated 2 to 4 miles per hour, accumulations of reservoir sediment were generally a few inches or less. This was attributed to the sediment either remaining in suspension or eroding from the active channel, or both.

Sediment Thickness

In each reservoir, fine grained reservoir sediment was thinnest in the upstream portion of the reservoir and thickest near the dam. Reservoir sediment was also thin to nonexistent in narrow channels of the reservoirs, where water flow was greater than an estimated 2 to 4 miles per hour. Reclamation's 55 sample locations, and previous drilling, provide excellent data for modification of the geophysical sediment thickness model.

CONCLUSIONS

1. Sediment deposition throughout all four reservoirs is found to adhere to well-understood principals of geology and of fluvio-lacustrine sedimentation. Geologic investigations did not encounter any unusual characteristics of the sediment or unique depositional environments that would require special consideration or explanations.
2. Barge-supported drilling/sampling and boat-supported gravity sampling allowed for a feasibility-level determination of reservoir sediment types, and when combined with Reclamation's Technical Service Center bathymetric model, a reasonable model of sediment thicknesses throughout various reaches of the reservoirs. Adequacy of the sampling program to fulfill criteria required for a screening-level determination for various potential contaminants is to be made by MP-157 personnel in a separate report.
3. Geologic conditions vary for each reservoir, and those differences in site conditions have a strong influence on the volume of sediment contained within each reservoir, and to what degree reservoir sediment re-enters the fluvial environment following dam removal.
4. Geologic and geophysical investigations have allowed the thickness of reservoir sediment in J.C. Boyle, Copco-1, and Iron Gate reservoirs to be reasonably well-determined. Copco-2 reservoir did not contain a significant amount of fine grained sediment.
5. Most of the reservoir sediment is composed of Elastic Silt (±Organic Silt), a mix of silt-size rock particles and organic material, and will likely erode quickly where Klamath River flows are re-established to a velocity of greater than about two to four miles per hour.
6. Methane gas is currently trapped in reservoir sediment behind each dam. Dam removal will likely release a significant percentage of this greenhouse gas into the atmosphere.
7. Due to its high water content, most reservoir sediment not eroded during the initial stage of dam removal will likely take a very long time to dry out.
8. Surface geologic mapping and groundwater observation wells around each reservoir are planned for Phase-2 of the program. However observations made during the current phase of geologic investigations suggest that **when reservoirs are emptied**:
   A. Groundwater surrounding reservoirs will likely lower in elevation, and some domestic water wells may be impacted; and,
   B. Slope stability conditions around structures and private residences adjacent to the reservoirs will change.

Acknowledgements

The Klamath River Sediment Study, in support of the PacifiCorp Four-Dams Removal Project, was a large and complex undertaking that extended along more than 100 miles of the Klamath River. Geologic, geotechnical, geophysical, and contaminant investigations started at J.C. Boyle Dam in southern Oregon and extended to the Klamath River Estuary in Northwestern California.

A special acknowledgement is made to PacifiCorp employees, many of whom were instrumental in the successful outcome of the project.

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Klamath River Sediment Sampling Program
Phase 1 – Geologic Investigations

Contaminant and Geotechnical Properties Sampling
J.C. Boyle, Copco-1, Copco-2, and Iron Gate Reservoirs and the Klamath River Estuary, Volume 1 of 2

September 2011

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Introduction

In a Field Exploration Request (FER) the U.S. Bureau of Reclamation (Reclamation) tasked its Mid-Pacific Region, Division of Design and Construction's Geology Branch (MP-230) to conduct geologic and geotechnical investigations to gather feasibility level design data for use in evaluating the removal of four dams (J.C. Boyle Dam, Copco-1 Dam, Copco-2 Dam, and Iron Gate Dam) [Ref. 1] (Appendix A).

These four dams are located across the Klamath River in southwestern Oregon and the extreme northern part of California (Figure 1). In addition, field investigations were also conducted in the Klamath River estuary, and for about seven miles upstream from the mouth of the river.

Phase 1 of the work comprises on-water geologic investigations to collect comprehensive suites of samples of reservoir sediment (Qr) behind each dam. There were three main purposes for collecting samples:

- To conduct a screening-level analysis for organic and inorganic chemical contaminants within the reservoir sediment, and if present to determine the level and extent of contamination;
- To collect samples of reservoir sediment, both in-thalweg and off-thalweg and upstream to downstream, to determine a standard suite of physical properties, to collect undisturbed samples for analyses of engineering properties; and,
- To augment bathymetry in determining the thickness of reservoir sediment throughout all main sections of each reservoir.

Phase-1 field investigations were conducted between September 30, 2009 and November 17, 2009 on reservoirs behind the four dams, and on January 12th in the Klamath River Estuary and surrounding environs. Sampling was conducted by personnel from

Reclamation's Mid-Pacific Region Geology Branch and Environmental and Monitoring Branch (MP-157).

The following report summarizes previous and current geologic and geotechnical design data investigations, documents drilling procedures used on the four reservoirs and within the river estuary system to collect samples for both engineering properties and contaminant studies, presents the collected data, and provides a reasonable interpretation of findings.

Geochemical and contaminant findings are presented in a stand-alone report prepared by Reclamation's Mid-Pacific Region, Environmental Monitoring Branch (MP-157).

Scope of Work

The scope of work for the entire list of investigations required for feasibility–level design is presented in Reclamation's Technical Service Center – June 25, 2009 Field Exploration Request [Ref. 1] (Appendix A). Phase-1 of the geologic and geochemical investigations focused on the characterization of reservoir sediment behind the dams, and in the river estuary system.

Aerial photographic coverage of the project area was undertaken by Reclamation's Mid-Pacific Region, Surveys and Photogrammetry Branch (MP-220). Topographic mapping includes site coverage for dams, reservoirs, haul road alignments, waste disposal areas, tributary streams, and the main stem of the Klamath River to the estuary.

Bathymetry was obtained by Reclamation's Technical Service Center for J.C. Boyle, Copco-1, and Iron Gate reservoirs by using a boat-mounted sonar system. Bottom profiles were obtained and reservoir sediment thickness was modeled for each of these three reservoirs. Modeled bathymetry data was used to project reservoir sediment thicknesses along cross sections at each proposed drill hole location.

Geologic investigations on the water consisted of:

- Barge and boat platforms for Auger Drilling and Sampling;
- Barge and boat platforms for Push Tube Sampling;
- A boat platform for Vibracore Drilling and Sampling; and,
- Gravity tube sampling from a boat.

A total of 55 drill holes were completed on J.C. Boyle, Copco-1, and Iron Gate reservoirs with multiple samples collected in several of the holes. Additionally, gravity tube samples were also collected from the river estuary system and for about seven miles up-river from its mouth. In Copco-2 Reservoir a gravity tube sampler deployed from a boat was used to characterize reservoir material.

<u>Reservoir Area Geology</u>

As a secondary objective of this report, the geology of the area surrounding each reservoir is described in general terms and using simplified diagrams to provide a context in which to evaluate the results of the chemical analysis of sediment samples.

Descriptions of regional and reservoir area geology are based on observations of shoreline outcrops from a work-boat or drilling-barge, and information obtained from a limited review of technical articles and published geologic maps. Under terms agreed to prior to beginning the Phase 1 Geologic Investigations, Reclamation geologists conducted no geologic field mapping along the reservoir shorelines or on COPCO property at any dam or reservoir.

Location and Access

The four dams are located along a 35 mile section of the Klamath River in southwestern Oregon and northern California (Figure 1). Work in all reservoirs was with permission from, and an access agreement with the property owner (PacifiCorp).
In addition, field investigations were also conducted in the Klamath River Estuary, and for about seven miles upstream from the mouth of the river (Figure 10).

J.C. Boyle Reservoir (Figure 2; Photos 1-16)
J.C. Boyle Dam and Reservoir are located in southwestern Oregon, about 15 air-miles southwest from Klamath Falls, OR. Access to the area is via well-maintained paved state and county roads. The barge launching site was a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66). A detachable barge containing geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

Copco-1 Reservoir (Figure 3; Photos 17-23)
Copco-1 Reservoir (locally referred to as Copco Lake) is located in northern California, about 23 air-miles northeast from Yreka, CA. Access to the area is via well-maintained paved state and county roads. The boat/barge launching site was at Keaton Cove public boat launch ramp/dock, on the southern side of the lake. Equipment and samples were on/off-loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-½ miles upstream from Copco-1 Dam.

Copco-2 Reservoir (Figure 4; Photos 24-26)
Copco-2 Reservoir is a very small diversion reservoir about ¼-mile downstream from Copco-1 Dam and powerhouse, about 23 air-miles northeast from Yreka, CA. The reservoir is about 1,600 feet long and less than 200 feet wide. Access to the area is via a moderately-well maintained paved road following the northern side of Iron Gate Reservoir, with the last 3 to 4 miles on a well-maintained gravel road. About ½-mile before the dam and reservoir the road passes through a gate, with reservoir access controlled by PacifiCorp.

Iron Gate Reservoir (Figure 5; Photos 27-38)
Iron Gate Reservoir is located in northern California, about 18 air-miles northeast from Yreka, CA. Access to the area is via moderately-well maintained paved state and county

roads. The barge was launched from Long Gulch (about 4,000 feet u/s from Iron Gate Dam), along the southeastern side of the reservoir, with the final two miles of access via a well-maintained gravel road.

For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

Loading/off-loading of samples and equipment was done on a daily basis from the public access Mirror Cove boat launch on the northwestern side of the reservoir.

Klamath River Estuary (Figure 10; Photos 219-259)
The mouth of the Klamath River, and the barrier island lagoon and estuary system behind it are located in northwestern California, about 16 air-miles south-southeast from Crescent City, CA. Access to the river is from a boat launching site at Requa.

Previous Investigations

California State Costal Conservancy (via Shannon & Wilson Inc.)
Prior to the current investigations, the most significant work carried out in support of the project was carried out by the California State Coastal Conservancy and their contractor, Shannon & Wilson. Inc. Geotechnical and Environmental Consultants [Ref. 3]. Shannon & Wilson, through their subcontractor, conducted 26 over-water borings and collected 45 samples of reservoir sediment in J.C. Boyle, Copco-1, and Iron Gate reservoirs (Figures 2, 3, and 5). Sediment samples were shipped to Analytical Resources, Inc. for chemical and physical properties testing. **Results of these analyses and a wealth of additional project data and information are presented in: Sediment Sampling, Geotechnical Testing, and Data Review Report, Segment of Klamath River, Oregon and California; Shannon & Wilson Inc. Geotechnical and Environmental Consultants; November 22, 2006 [Ref. 3].**

PacifiCorp
In the Shannon & Wilson document [Ref. 3] it is stated that prior to Shannon & Wilson's investigations, PacifiCorp conducted preliminary sediment volume and size analysis in J.C. Boyle, Copco-1, and Iron Gate reservoirs; however, these analyses did not include testing of the sediment samples for grain size distribution or for chemical constituents.

Current Geologic Investigations

The current geologic investigations in J.C. Boyle, Copco-1, Copco-2, and Iron Gate reservoirs took place from October through December, 2009; and, geologic investigations in the Klamath River Estuary took place in January, 2010.

Exploratory Work Completed

- Barge and boat-supported drilling/sampling at 55 locations in J.C. Boyle, Copco-1, and Iron Gate reservoirs (Figures 2, 3, and 5). A representative e mix of thalweg (channel) and non-thalweg (off-channel) samples were collected.

- Collection of 69 samples of reservoir sediment and pre-reservoir deposits for gradation analysis and Atterberg limits.
- Collection of 78 samples of reservoir sediment for chemical analysis.
- Collection of 19 undisturbed samples of reservoir sediment in lexan liners for engineering properties testing.
- Boat-supported attempted sampling of reservoir sediment at 16 locations in Copco-2 Reservoir, from the dam upstream for about 1,000 feet (Figure 4).
- Boat-supported sampling at 5 locations in the Klamath River Estuary and up to seven miles upstream, including a characterization of deposits of fluvial sediment in bars and along banks the river.

Drilling and Sampling Methods (Photos 39-67)
All measurements are in feet. Drill hole coordinates were determined using a hand-held Garmin (Vista model) GPS. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Daily reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program. Water depth and top of reservoir sediment were measured from the barge/boat at the start of drilling.

There were five main types of drilling methods used for the collection of samples: (1) Flight Auger Dry Core (FADC) used to collect contaminant samples; (2) FADC with lexan liners used to collect undisturbed samples; (3) Gravity Sampler to collect contaminant samples; (4) Direct push/hammer of a lexan tube for contaminant samples(two tube sizes); and, (5) Vibracore using a lexan tube for collecting contaminant samples.

<u>(1) Flight Auger Dry Core method</u> (Photos 40-47)
Barge supported drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. The FADC sampler could be used with or without a metal sediment retaining basket (sand fingers). Auger sampling was the principal method used to collect contaminant samples from J.C. Boyle Reservoir.

<u>(2) Flight Auger Dry Core with Liner method</u> (Photos 48, 91, 93 & 94, and 114 & 115)
The barge supported FADC auger system fit with lexan liner inserts was used to collect undisturbed samples of reservoir sediment. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to a length of 2.5 feet.

<u>(3) Gravity Sampler method</u> (Photos 49-52)
The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length. The tube is attached to a weighted fitting that has a one-way relief valve to allow water to come out the top as sediment comes in the bottom of the tube. A sliding-weight is attached to the top of the

sample-tube fitting, and as the bottom of the sample tube rests on reservoir sediment the sliding-weight can be moved up and down (via cord to the surface) to pound the sampler into the sediment. The gravity sampler was used from both the barge and a boat to collect contaminant samples. The gravity sampler was adapted for use from the drilling barge by attaching the sample tube and fitting to a drilling winch line. This allowed a rapid turn-around time for collecting bulk samples. In shallow water, where only thin deposits of reservoir were present, the gravity sampler was fitted with a pole and used as a stab-sampler.

(4) Direct Push/Hammer method (Photos 53-59)
The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5-ft. long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an undisturbed sample for engineering properties analyses. Lexan tubes hosting engineering samples were cut to the desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

(5) Vibracore method (Photos 60-62)
Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. A lexan tube sampler was attached to the vibracore unit and suspended from a winch line. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Drilling and sampling methods used for individual drill holes are listed in the left-side column of each drill hole log [Appendix B]. In some drill holes multiple methods were used to collect the required samples. In a few drill holes reservoir sediment was not thick enough to sample at the planned location, and the drill hole had to be relocated before sampling could be completed.

Sample Processing, Storage, and Shipment
Each sample collected for the determination of physical properties including, gradations, Atterberg Limits, and field moisture content was sealed within a plastic zip-lock bag, which in-turn was enclosed within a second plastic zip-lock bag. Samples were kept out of the sun and other elements and hand-delivered to the Reclamation, Mid-Pacific Construction Office, Soil Laboratory in Willows, CA at the end of each ten-day drill shift.

Samples of in-place reservoir sediment collected in lexan liners during drilling were capped, sealed, and weighed then stored in an upright position. Lexan liner samples were hand-delivered to the Reclamation Technical Service Center Soil Laboratory in Denver, CO for processing at the end of drilling.

Contaminant samples were collected by personnel from Reclamation's Mid-Pacific Region, Branch of Environmental Monitoring, MP-157. Their procedures, including procedures for sample collection, handling, sample containers, transport, chain-of-custody, and documentation are described in the QAPP (Quality Assurance Project Plan) [Ref. 9]

Regional Geology
Regional-scale geology along the Klamath River and areas surrounding the reservoirs is present on existing geologic maps [Ref. 5, 6, 7, and 8]. Geologic mapping of the area surrounding each reservoir, and site-specific mapping of dam abutments, borrow areas, and construction haul roads was not tasked for the current phase of investigations.

A basic understanding of the geologic environment surrounding each of the reservoirs was acquired through existing geologic maps as well as observations of rock types and stratigraphic sections cropping out along the banks of each reservoir and from drilling/sampling of pre-reservoir materials.

Geomorphic Provinces and Rock Types
The Klamath River, from Klamath Falls, OR to its mouth near Klamath, CA flows through four geomorphic provinces: (1) the Basin and Range Upland; (2) the High Cascades; (3) the Western Cascades; and (4) the Klamath Mountains.

The current understanding of the tectonic relationships between the Pacific and North American plates allows for a redefinition the geomorphic province surrounding Klamath Falls, OR as the northern extension of the "Walker Lane Tectonic Province". This term is preferred to "the Basin and Range Upland" geomorphic province, as it provides a better understanding to geologists of the dominance of large scale right-lateral strike-slip faulting as the underlying cause of current geomorphic relationships throughout the region.

Rock types through which the Klamath River flows, from J.C. Boyle Reservoir to Iron Gate Reservoir are primarily volcanic in origin and relatively young (Quaternary to Tertiary age). There are lesser amounts of volcanic-related intrusive rocks along the

river, and local accumulations of pre-dam lacustrine (lakebed) sediment, fluvial deposits, talus rock fallen from steep slopes and occasional landslide/slump deposits.

A transition takes place along the Klamath River from young volcanic rocks upstream of Iron Gate Dam to older (Cretaceous to Paleozoic age) metamorphosed marine igneous and sedimentary rocks comprising most of the Klamath Mountains, starting a few miles downstream from the dam and from there extending downstream to the mouth of the Klamath River.

Because of the regional geologic setting, pre-reservoir deposits of alluvium and colluvium (slope-wash) are principally composed of young igneous (volcanic and intrusive) material beneath J.C. Boyle, Copco-1, Copco-2, and Iron Gate reservoirs. The detailed geologic setting beneath and surrounding each of the reservoirs and dams is highly complex.

Reservoir sediment within these four reservoirs is comprised of eroded particles of young volcanic and intrusive rock mixed with a large component of decaying aquatic plants such as algae, and diatomaceous material.

Structure

The Walker Lane Tectonic Province is dominated by strong regional trending north-northwest striking sub-parallel strike-slip faults and shears, many of which exhibit right lateral movement with concurrent development of local-scale normal faulting [Ref. 5, 6, 7, and 8]. This orientation of strike-slip faults and shears dominates the section of river from Klamath Falls to J.C. Boyle Dam.

Between J.C. Boyle Dam and Iron Gate Dam, the Klamath River passes through the High Cascade and Western Cascade provinces and strong north-northwest regional trending faults become fewer and fewer as the river progresses westerly, giving way to local faults and shears with a variety of orientations. A strong northeast-trending fault system is imposed on rocks surrounding Copco-1 and Iron Gate reservoirs.

Identifying local faults and shears and regional trends will help in understanding slope stability issues associated with local structures around individual reservoirs, as well as helping to understand potential changes in groundwater flows with dam removal.

As the Klamath River flows towards the Pacific Ocean, downstream from Iron Gate Dam, it passes through the Klamath Mountains geomorphic province. Rocks here are completely different from rocks upstream of Iron Gate Dam. The Klamath Mountains are mostly composed of Cretaceous to Paleozoic age metamorphosed marine igneous and sedimentary rocks.

These rocks formed as part of an ocean crust and sedimentary sequence that was thrust up onto the North American continent. Consequently numerous thrust faults and northwest-trending regional faults and antiforms are exposed along the river's path as it winds its way through the Klamath Mountains to the Pacific Ocean.

J.C. Boyle Reservoir

J.C. Boyle Dam is an embankment dam 68 feet high and 693 feet long with concrete spillway and outlet works [Ref. 2]. Completed in 1958 it is located in southwestern Oregon along the Klamath River, about 15 air-miles southwest from the city of Klamath Falls, OR (Figures 1 and 2). The reservoir is about 16,200 feet long and 350 to 2,500 feet wide, with a water depth at the sample sites of up to about 36 feet. Barge drilling did not take place in water shallower than about 6 feet.

State Highway 66 bisects the reservoir, with about 6,200 feet of reservoir downstream from the bridge to the dam, and about 10,000 feet of reservoir upstream from the bridge.

Geology (Photos 58-86)

J.C. Boyle dam and reservoir are in the Walker Lane Tectonic Province. This is an area of relatively young (Quaternary to Tertiary age) volcanic rocks and lesser amounts of volcanic-related intrusive rocks along the river. There may also be local accumulations of pre-dam lacustrine (lakebed) sediment, fluvial deposits, and talus rock fallen from steep slopes.

Bedrock surrounding and underlying the reservoir is principally composed of moderately well-bedded to massive, moderately well-consolidated volcaniclastic rocks (tuff, tuffaceous sediments, lapilli tuff, tuff breccia, and local block and ash deposits). Surficial exposures of the volcaniclastic rocks commonly weather to Silty Gravel with Sand (GM)s to Clayey Gravel with Sand (GC)s plus or minus cobbles. The Klamath River has cut its way into volcaniclastic bedrock.

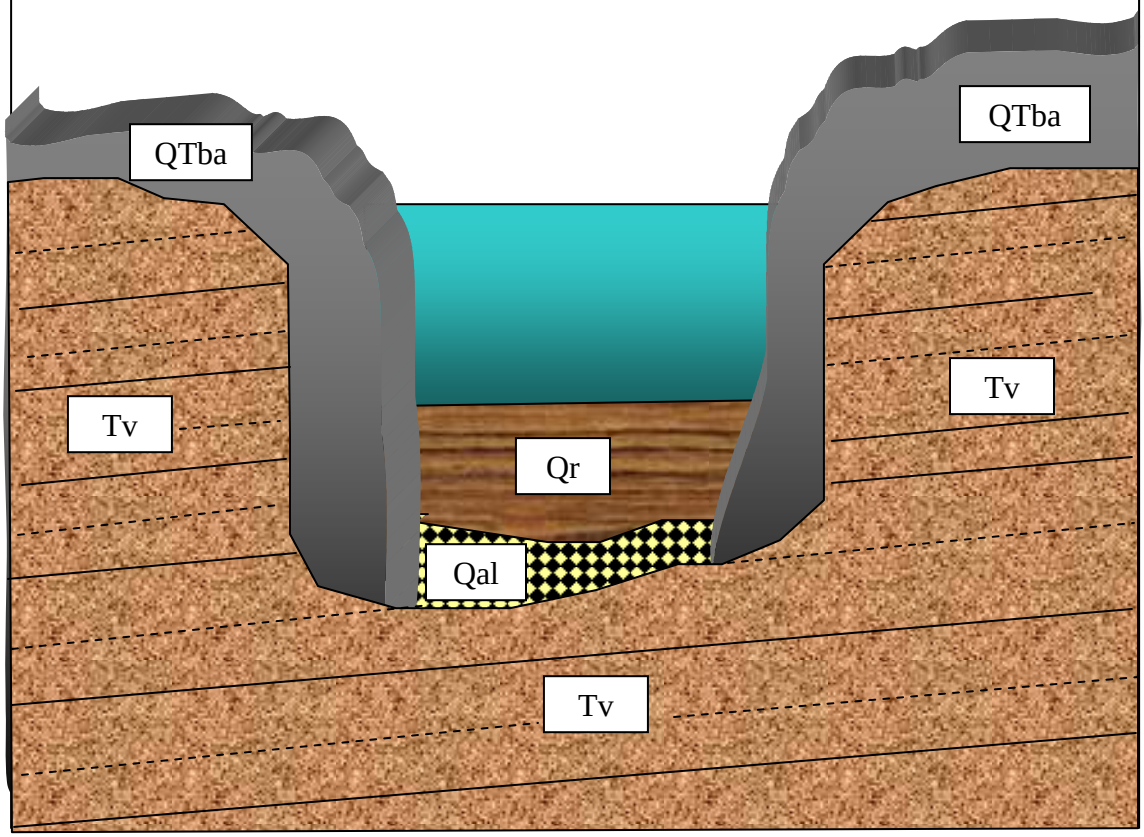
Basaltic and andesitic lava flows overlie volcaniclastic rocks and form many of the ridges above the reservoir. Downstream from the Hwy 66 bridge young lava flows line the sides of the reservoir (Figure 6).

The general sequence of local events forming rocks surrounding and underlying J.C. Boyle reservoir is likely to have been:

1. Eruption of large quantities of Tertiary to Quaternary age volcaniclastic rocks, which currently form bedrock around the reservoir.
2. Down cutting into the volcaniclastic rocks by the ancestral Klamath River.
3. Multiple periods of eruption of basaltic to andesitic lavas from several volcanic centers. Some of these flows deposited on top of the volcaniclastic rocks and others flowed down local drainages and along the Klamath River topographic low.
4. Offset of local rocks by prominent northwest trending strike-slip and normal faults.
5. Formation of local lakes and lacustrine deposits during Holocene age glacial events.
6. Continued downcutting of the Klamath River and deposition of Recent Alluvium (Qal). Much of the alluvium was deposited in a high energy environment and is composed of Silty Gravel with Sand and Cobbles (GM)sc, or other variations of coarse sediment.
7. Construction of J.C. Boyle Dam, filling of the reservoir, and deposition of reservoir sediment (Qr).

Figure 6. Diagrammatic cross section of J.C. Boyle Reservoir:

Qr – Reservoir Sediment
Qal – Pre-Reservoir Alluvium
QTba – Quaternary and Tertiary lava flows
Tv – Tertiary Volcaniclastic Rock (tuff, lapilli-tuff, tuff breccia, and volcanic breccia)



Sample Sites

Reclamation attempted contaminant sampling investigations at sixteen sites, nine of which had minor to significant thicknesses of reservoir sediment where samples could be collected. Reclamation also attempted engineering properties sampling at five sites, four of which had sufficient thicknesses of reservoir sediment to allow collection of six undisturbed samples (Table 1). Shannon and Wilson [Ref. 3] attempted contaminant sampling investigations at five sites in J.C. Boyle Reservoir.

Reclamation's sample sites were distributed throughout about 11,400 feet of the main reservoir, with the upstream 5,000 feet of the reservoir too shallow for barge access (Figure 2). Reclamation's MP-157 contaminant sampling team used a gravity sampler and a small boat to collect one additional contaminant sample about 1,200 feet further upstream from the uppermost barge location.

Shannon and Wilson [Ref. 3] attempted collecting contaminant sample material from two additional sites upstream from Reclamation's upstream-most barge drilling site.

Approximately 2,500 feet of the upper part of the reservoir, where rapids along the Klamath River transition into active reservoir storage, was not sampled either by Reclamation or by Shannon and Wilson. However, gravel, sand, and cobbles comprise several bars in the river throughout this upper section of the reservoir, and push-tube and gravity sampling attempts RECOVERED only coarse material along this section of the reservoir bottom.

Table 1. Data collected at contaminant sample drill holes (CDH) and engineering properties drill holes (EDH) in **JC Boyle Reservoir**.

J.C. Boyle Reservoir ***** Reservoir elevations provided by PacifiCorp, datum undetermined.					
Drill Hole Number	**Coordinates**	**Reservoir Elevation** (feet)	**Water Depth** (feet)	**Reservoir Sediment Thickness** (feet)	**Pre-reservoir** Qal, Qcl, and in-place Tv (feet)
CDH-09-1	The water at this location was too shallow to allow barge access. A small boat with MP-157 personnel investigated the sites upstream of CDH-09-2 and found an abundance of coarse sand and gravel bars throughout area, and a lack of fine grain-size reservoir sediment. Barge sampling was not carried out upstream of CDH-09-2.				
CDH-09-2	N 42° 08' 49.6" W 122° 02' 10.8"	3,790.8	11.8	5.0 SM	5.0 to 6.2 Qal (GM)s
CDH-09-3	N 42° 08' 33.7" W 122° 02' 07.5"	3,791.3	11.4	6.0 (MH)s	6.0 to 6.3 Qal (GM)s
CDH-09-4	N 42° 08' 34.2" W 122° 02' 03.3"	3,792.4	6.3	9.1 MH	9.1 to 9.5 Qal (MH)sg 9.5 to 10.8 Tv CL
CDH-09-4A	N 42° 08' 34.2" W 122° 02' 03.4"	3,792.4	6.8	9.2 MH	9.2 to 9.5 Qal (MH)sg 9.5 to 11.0 Tv CL
CDH-09-5	N 42° 08' 20.6" W 122° 02' 01.6"	3,792.5	15.3	0.3 MH	0.3 to 0.9 Qal (GM)s 0.9 to 2.0 Tv CL
CDH-09-5A	N 42° 08' 02.1"	3,792.5	15.0	0.3	0.3+ Qal

J.C. Boyle Reservoir * Reservoir elevations provided by PacifiCorp, datum undetermined.					
Drill Hole Number	**Coordinates**	**Reservoir Elevation** (feet)	**Water Depth** (feet)	**Reservoir Sediment Thickness** (feet)	**Pre-reservoir** Qal, Qcl, and in-place Tv (feet)
Ekman Sampler	W 122° 01' 51.8"			MH	(GP-GM)s
CDH-09-6	N 42° 08' 01.8" W 122° 01' 51.6"	3,792.5	15.0	0.0 (none)	0.0 to 1.4 Qal (GM)s
CDH-09-6A Ekman Sampler	N 42° 08' 02.2" W 122° 01' 51.4"	3,792.5	15.0	0.0 (none)	0.0 to 1.4 Qal (GM)s
CDH-09-7	N 42° 07' 23.0" W 122° 02' 46.0"	3,792.1	28.8	18.7 MH	18.7 Qal 1.5" piece of gravel in shoe
CDH-09-7A	N 42°07' 22.9" W 122°02' 46.0"	3,792.1	30.1	21.7 MH	21.7+
CDH-09-8	N 42°07' 22.4" W 122°02' 36.8"	3,792.8	18.3	1.7 MH	1.7 to 5.0 s(ML)
EDH-09-1 2.75-in id liner **2.37 – 3.20 ft**	N 42° 08' 49.5" W 122° 02' 11.0"	3,792.5	13.4	3.2 MH SP-SM	3.2 to 3.4 Qal (GM)s
EDH-09-1A No Sample	N 42° 08' 49.0" W 122° 02' 10.4"	3,792.4	13.3	3.4+ MH SM	unknown >3.4 ft. refusal on wood
EDH-09-2 2.75-in id liner **5.06 – 5.80 ft**	N 42° 08' 35.0" W 122° 02' 08.5"	3,791.7	6.1	9.0+ refusal s(ML)	unknown >9.0 feet
EDH-09-2A 2.75-in id liner **7.25 – 9.00 ft**	N 42° 08' 34.1" W 122° 02' 09.3"	3,793.2	7.4	9.0 MH s(MH)	9.0 to 9.2 Qal (GM)s max. 30mm.
EDH-09-3 2.75-in id liner **5.20 – 7.30 ft** **7.50 – 10.00 ft** **11.40 – 13.90 ft**	N 42° 07' 26.2" W 122° 02' 41.0"	3,792.8	36.5	14.0 MH MH MH	14.0 to 15.5 (SM)g

Reservoir Sediment (Photos 87-116)

Twenty-four samples were collected for gradations, Atterberg Limits (consistency), and field moisture content. Fourteen of these lab analyses were from material collected for contaminant samples, and ten analyses were from material collected as engineering properties samples. All twenty four samples were sent to Reclamation's Mid-Pacific Construction Office Laboratory (Willows, CA) for analysis, and results are presented on Chart 1 and in Appendix C. Sediment grain size and plasticity changed with distance downstream from the upstream end of the reservoir.

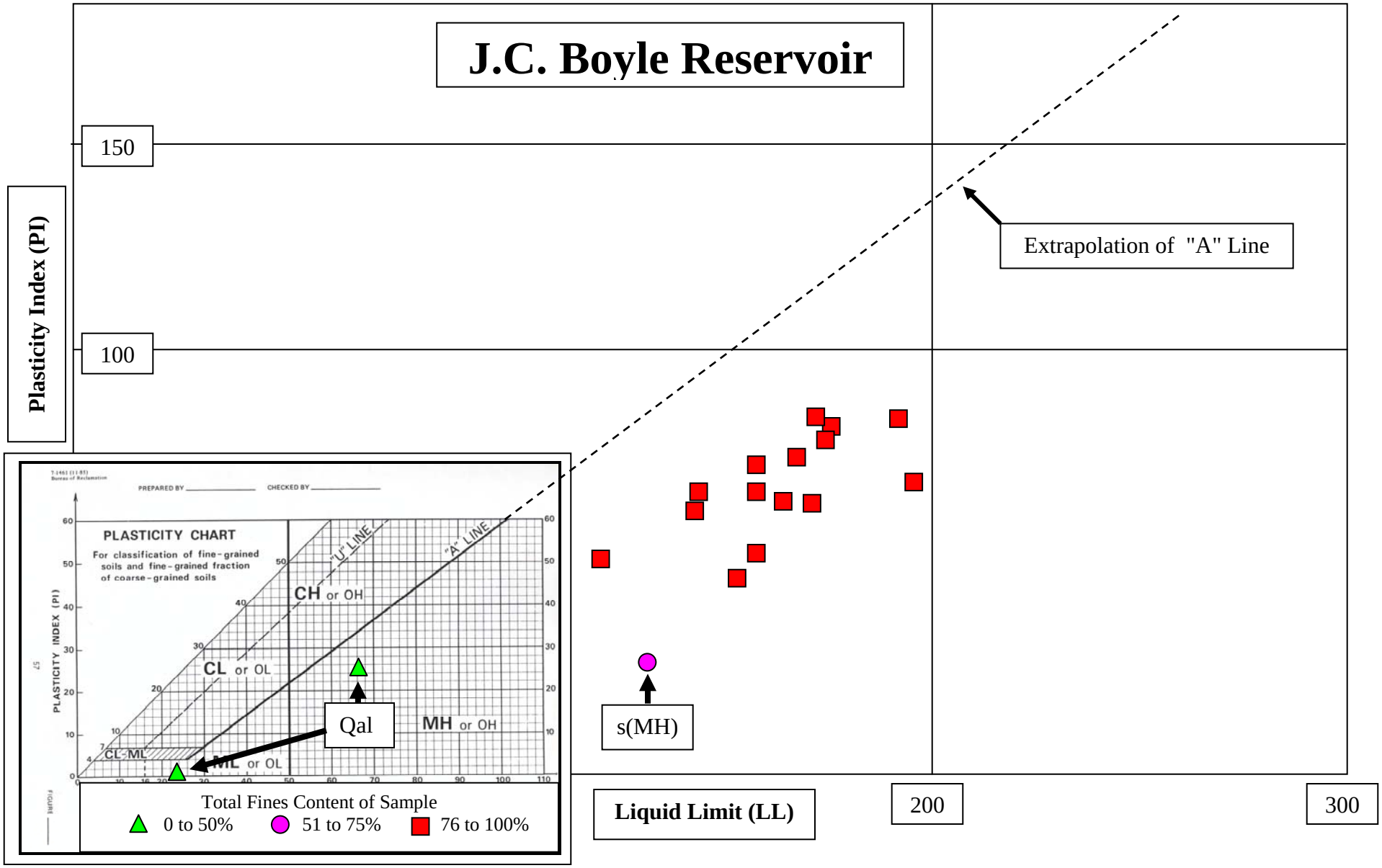


Chart 1. A plot of sixteen samples of reservoir sediment, fifteen of which were composed of Elastic Silt – MH (±Organic Silt) and one Sandy Elastic Silt s(MH). Two samples of pre-reservoir alluvium (Qal) composed of Well Graded Gravel with Silt and Sand (GW-GM)s and Silty Gravel with Sand (GW)s are also plotted. Six samples of reservoir sediment (SM, SM, SM, sML, SP-SM, and sML) contained non-plastic fines and could not be plotted.

Upper Reservoir

Due to shallow water, the farthest upstream in the reservoir that Reclamation could maneuver its drilling barge was about 11,400 feet upstream from J.C. Boyle Dam.

The thickness of reservoir sediment encountered in drilling here was between three and five feet. In this area Reclamation collected two samples of reservoir sediment from contaminant sample hole CDH-09-2 for gradation analysis. **These samples represented the full thickness of reservoir sediment at this location (5.0 feet) and were composed of Silty Sand – SM with 84.5% to 85.3% sand and the remainder nonplastic silt**.

Adjacent to drill hole CDH-09-2 two holes were drilled to collect undisturbed samples in lexan liners for engineering properties, EDH-09-1 and EDH-09-1A. **Gradation samples collected from these holes were composed of Poorly Graded Sand with Silt (SP-SM) and Silty Sand – SM with 85.2% to 89.3% sand and the remainder nonplastic fines**. Pre-reservoir alluvium (Qal) at CDH-09-2 and EDH-09-1 consisted of Silty Gravel with Sand (GM)s.

Summary of the Upper Reservoir

The upper 5,000 feet of J.C. Boyle Reservoir primarily hosts coarse grained sediment, both as pre-reservoir alluvium (Qal) overlain by Reservoir Sediment (Qr). There are an abundance of gravel/sand bars ± cobbles exposed above the reservoir water surface, with sub-surface sand and gravel found by stab-sampling. The reservoir sediment becomes finer grained with distance downstream. At barge drill holes CDH-09-2 and EDH-09-1 & 1A, about 5,000 feet downstream, reservoir sediment was three to five feet thick and was composed of Silty Sand – SM to Poorly Graded Sand with Silt (SP-SM) with less than about 15% fines.

There are likely small, local accumulations of fine grained reservoir sediment within the upper 5,000 feet of the reservoir, but most of the reservoir sediment in this section is coarse grained.

Transition Area

About 1,600 feet downstream from the Upper Reservoir, Reclamation drilled two contaminant sample holes (CDH-09-3 & -4) and two undisturbed engineering properties drill holes (EDH-09-2 & -2A). **In the center of the channel reservoir sediment ranged from Sandy Silt s(ML) to Sandy Elastic Silt s(MH) (±Organic Silt) containing 32.9% to 49.8% sand and the remainder fines**.

Away from the center of the channel, closer to the shore, reservoir sediment in drill hole CDH-09-4A was Elastic Silt - MH (±Organic Silt) with 3.7% sand.

Reservoir sediment thickness encountered in the drill holes was between six and nine feet. The depth of water and thickness of reservoir sediment in the central channel varied dramatically even within a few tens of feet. This is interpreted as being caused by a buildup of reservoir sediment where water velocity is slow and erosion of previously deposited reservoir sediment (or non-deposition) where water velocity is higher.

Based on the estimated velocities of surface water observed while the barge was anchored, it appears that non-deposition or erosion of reservoir sediment takes place when water velocity is about 2 to 4 miles/hour. Shannon and Wilson drilled one thalweg contaminant sample site in this reach of the reservoir.

Summary of the Transition Area
This portion of the reservoir exhibits a transition from coarse grained to finer grained reservoir sediment. Here, Silty Sand - SM transitions to Sandy Silt – s(ML), and fines transition from being nonplastic to having Atterberg Limits consistent with Elastic Silt. Organic material becomes much more abundant and methane gas bubbles can be found throughout the finer grained reservoir sediment.

Middle Reservoir
This section of the reservoir did not contain large amounts of reservoir sediment. Drill hole CDH-09-5, about 1,500 feet upstream from the Hwy 66 bridge and in the center of the reservoir channel, had only 0.3-ft. of reservoir sediment (Elastic Silt – MH ±Organic Silt). The drill hole penetrated reservoir sediment, 0.6 feet of pre-reservoir alluvium composed of Silty Gravel with Sand, (GM)s), and stopped in thin-bedded deposits of pre-reservoir volcaniclastic tuff (Lean Clay – CL).

The lack of reservoir sediment at this location is interpreted as being a result of relatively high water velocity (greater than about 2-4 feet/sec.). Thicker accumulations of fine grained reservoir sediment are likely to be present closer to the reservoir banks where water velocity is decreased.

A cluster of three sample sites were attempted about 400 feet downstream from the Hwy 66 bridge. One of the three sites (CDH-09-5A) contained a thin layer of reservoir sediment (0.3 feet), while pre-reservoir alluvium (Qal) was exposed on the reservoir bottom in the other two holes (CDH-09-6 and 6A). Reservoir sediment was composed of Elastic Silt – MH, and pre-reservoir alluvium was composed of Silty Gravel with Sand (GM)s, Poorly Graded Gravel with Silt and Sand (GP-GM)s, and Well Graded Gravel with Silt and Sand (GW-GM)s. Freshwater mussels were numerous in coarse grained alluvium (Photos 107 and 108).

This cluster of three sample sites is on the outside bend of a narrow section of the reservoir and flow velocity in the reservoir is estimated to be greater than about 2-4 feet/second, where reservoir sediment is likely to remain in suspension and not be deposited. A stab-sampler was used to probe the bottom of the reservoir out into the central part of the channel and the bottom appears to be composed of coarse pre-reservoir alluvium. Shannon and Wilson drilled one thalweg contaminant sample site in this reach of the reservoir.

Summary of the Middle Reservoir
Only thin deposits of reservoir sediment were present at the sample sites in this section of the reservoir. The reservoir sediment was fine grained Elastic Silt – MH with significant

accumulations of organic material. Pre-reservoir material consisted of coarse grained alluvium (silty gravel and sand), and bedrock consisted of volcaniclastic rock intensely weathered/decomposed to Lean Clay – CL.

Lower Reservoir

In the section of the reservoir for about 2,500 feet upstream from the dam, Reclamation drilled and collected samples at three contaminant sample sites (CDH-09-7, 7A, and 8) and one undisturbed sample site (EDH-09-3). Reclamation's contaminant sampling team used a gravity sampler in a small boat to collect reservoir sediment from one additional location in this reach of the reservoir. Shannon and Wilson also had one contaminant sample drill hole in this reach of the reservoir.

At drilling sites, water in this part of the reservoir was about 17 to 36 feet deep. Reservoir sediment in the drill holes was about 14 to 22 feet thick.

For gradation analyses and Atterberg limits a total of 14 samples were collected of reservoir sediment in this section of the reservoir, eight samples from contaminant sample holes and five from undisturbed engineering properties sample holes. One additional sample was collected of alluvium beneath the reservoir sediment.

All fourteen of the reservoir sediment samples were composed of Elastic Silt – MH (±Organic Silt) containing 90.4% to 98.3% fines and the remainder sand, and having a strong organic odor. The one sample of alluvium contained Silty Gravel with Sand (GM)s with about 50% gravel, 30% sand, and 20% fines. The reservoir sediment had the consistency of pudding and contained an abundance of methane gas bubbles distributed throughout. Additionally, methane gas frequently bubbled up around the drill stem and barge as drilling progressed.

Summary of the Lower Reservoir Section

Reservoir sediment in this section was the thickest found anywhere throughout the reservoir. It is uniformly Elastic Silt – MH with greater than 90% fines and overlies coarse grained pre-reservoir alluvium consisting mostly of Silty Gravel with Sand (GM)s.

Unit Weight of Undisturbed Samples of Reservoir Sediment

Six undisturbed samples of in-place reservoir sediment were collected in lexan liners and transported to Reclamation's Technical Service Center materials laboratory.

Unit weights of samples are listed in Table 2. Sample EDH-09-1 was a thalweg sample and came from the upper section of the reservoir and was composed of reservoir sediment containing Poorly Graded Sand with Silt (SP-SM). This sample had the highest unit weight of all the reservoir samples (95.9 lbs/ft^3).

Two undisturbed samples were collected from the transition area of the reservoir. EDH-09-2 was a thalweg (channel) sample of reservoir sediment containing Sandy Silt s(ML) with 46.0% sand, and a unit weight of 64.9 lbs/ft^3. EDH-09-2A was of reservoir

sediment collected closer to the reservoir bank and was composed of Sandy Elastic Silt s(MH) with 32.9% sand, and a unit weight of 66.1 lbs/ft^3.

Three samples were taken from hole EDH-09-3 in the lower part of the reservoir (near the dam). The three samples of reservoir sediment were collected of sediment relatively high up in the section, near the middle of the section, and near the bottom of the section. All three were composed of Elastic Silt – MH containing about 2% to 9% sand, with unit weights of 65.2 lbs/ft^3, 67.8 lbs/ft^3, and 67.8 lbs/ft^3.

Geochemistry of Reservoir Sediment (ICP-MS Method)

Samples collected from reservoirs along the Klamath River were submitted by Reclamation's MP-157 team for a variety of geochemical and contaminant tests. One of the laboratory methods used to determine the bulk geochemistry of samples was the ICP-MS method. The results of these analyses are presented in a stand-alone report prepared by Reclamation's Mid-Pacific Region, Environmental Monitoring Branch (MP-157).

Caution should be taken when reviewing geochemical data generated by a variety of different analytical methods. In some instances analytical results are not directly comparable, and such is certainly the case between samples that have undergone elutriate testing and samples that have been analyzed using the Induced Couple Plasma Mass Spectrometry ICP-MS method.

During the (ICP-MS) method of analysis a sample undergoes total digestion by acids. The acid digestion puts all elements comprising the sample into solution and a mass spectrometer is used to determine the elements present and their quantity.

Volcanic and intrusive rocks comprising the three geomorphic provinces upstream from Iron Gate Dam will have a different geochemical signature than metamorphic rocks comprising the Klamath Mountains downstream from Iron Gate Dam.

Photomicrographs show that sediment deposited within J.C. Boyle Reservoir is composed mostly of minus 200-sieve fines rich in siliceous diatom tests, organic material, and lesser amounts of silt and clay particles (Photos 87, 88, 89, and 90). In the upstream portion of the reservoir there is an influx of coarser sediment eroding from the upstream volcanic terrain. ICP-MS analyses of the fine grain size reservoir sediment will likely show relatively high concentrations of silica and aluminum, and lesser to trace amounts of other elements common to volcanic environments.

As the percentage of sand and gravel increases within samples of reservoir sediment, such is the case near the upstream ends of all three reservoirs, ICP-MS analyses should show an increasing amount of Si, Al, Ca, Na, K, Mg, Mn, and other rock forming elements common to volcanic rocks.

Table 2. Unit weights of reservoir sediment in samples collected for Engineering Properties (EDH) in JC Boyle Reservoir.

Drill Hole Sample Interval Liner i.d.	Liner plus Sediment Weight (lbs)	Liner Length (ft)	*Liner Weight (lbs/ft) **Cut wt. (lbs)**	Caps + Tape (4') Weight (lbs)	Sediment Weight (pounds)	Liner Volume (cubic feet) =0.0408 ft^3/ft.	**In-Place Sediment Unit Weight (lbs/ft^3)**
EDH-09-1 2.37 to 3.20-ft. 2.750-in.	3.85	0.83	0.612 (lbs/ft) 0.508 lbs	0.09	**3.25**	0.83-ft X 0.0408 ft^3/ft = **Sample Volume = 0.0339 ft^3**	3.25-lbs/0.0339 ft^3 = Qr SP-SM **95.9-lbs/ft^3**
EDH-09-2 5.06 to 5.80-ft. 2.750-in.	2.50	0.74	0.612 (lbs/ft) 0.453 lbs	0.09	**1.96**	0.74-ft X 0.0408 ft^3/ft = **Sample Volume = 0.0302 ft^3**	1.96-lbs/0.0302 = Qr s(ML) / MH **64.9-lbs/ft^3**
EDH-09-2A 7.25 to 9.0-ft. 2.750-in.	5.88	1.75	0.612 (lbs/ft) 1.071 lbs	0.09	**4.72**	1.75-ft X 0.0408 ft^3/ft = **Sample Volume = 0.0714 ft^3**	4.72-lbs/0.0714 ft^3 = Qr MH / s(MH) **66.1-lbs/ft^3**
EDH-09-3 5.2 to 7.3-ft. 2.750-in.	6.96	2.10	0.612 (lbs/ft) 1.285 lbs	0.09	**5.59**	2.1-ft X 0.0408 ft^3/ft = **Sample Volume = 0.0857 ft^3**	5.59-lbs/0.0857 ft^3 = Qr MH **65.2-lbs/ft^3**
EDH-09-3 7.5 to 10.0-ft. 2.750-in.	8.55	2.50	0.612 (lbs/ft) 1.530 lbs	0.09	**6.92**	2.5-ft X 0.0408 ft^3/ft = **Sample Volume = 0.1021 ft^3**	6.92-lbs/0.1021 ft^3 = Qr MH **67.8-lbs/ft^3**
EDH-09-3 11.4 to 13.9-ft. 2.750-in.	8.54	2.50	0.612 (lbs/ft) 1.530 lbs	0.09	**6.92**	2.5-ft X 0.0408 ft^3/ft = **Sample Volume = 0.1021 ft^3**	6.92-lbs/0.1021 ft^3 = Qr MH **67.8-lbs/ft^3**

- **Qr = Reservoir Sediment**
- Volume of the 2.75-inch i.d. lexan liners was determined by filling a liner with water, determining the weight of the water in the liner, and dividing that by the weight of one cubic foot of water (62.4-lbs/ft^3) **= 0.0408 ft^3/ft.**
- Volume of the 2.75-inch i.d. lexan liners calculated using the liner i.d. determined with a micrometer = 0.0412 ft^3/ft.
- Lexan liner weight = 0.612-lbs/ft. Two lexan liner caps plus 4-ft. of tape = 0.09-lbs.

Because of the total acid digestion of samples analyzed using the ICP-MS method, concentrations of rock-forming elements will likely be significantly higher in ICP-MS than samples submitted for elutriate testing, and these differences should increase as the percentage of larger particle sizes of the reservoir sediment increases. Results of these two analytical methods are not directly comparable because elutriate testing does not use total acid digestion of mineral grains.

Within the transition area of J.C. Boyle reservoir sand-size grains identified with a 10-power hand lens include: cristobalite or quartz, feldspar, pyroxene, magnetite, and organic matter (Table 3). The elemental chemistry comprising these and other unidentified mineral/rock grains will be reflected in the ICP-MS results.

Table 3. Mineral grains comprising visible sand-size particles in the upper reaches of J.C. Boyle Reservoir.

Mineral Grain	**Major Composition**	Minor and Trace Elements
Cristobalite / Quartz	Si	
Feldspar	Al, Si, Ca, Na, and K	B, Ba and Rb
Pyroxene	Al, Si, Mg, Fe, and Ca	Mn, Li, and Ti
Hornblende	Ca, Na, Mg, Fe, Al, and Si	F and Ti
Accessory/Trace Minerals and Organics		
Magnetite	Fe	
Vegetation/Wood Fibers	C	

Elements commonly found in sand samples eroded from volcanic a terrain that have undergone total acid digestion Induced Couple Plasma Mass Spectrometry analysis (ICP-MS) include, but are not limited to:

Al Aluminum
B Boron
Ba Barium
C Carbon
Ca Calcium
F Fluorine
Fe/Ti Iron, both Fe^3 and Fe^4 and Titanium
Li Lithium
Mg Magnesium
Mn Manganese
Rb Rubidium
Si Silica

Summary

- The geologic setting is one of Tertiary to Quaternary age volcanism locally cut by Pleistocene to Holocene faulting.
- Eight contaminant sample drill hole locations were planned for the reservoir. Reclamation attempted drilling and contaminant sampling at 16 sites, 9 of which contained enough reservoir sediment for sampling. Contaminant samples were collected at these locations and 6 additional sample locations by MP-157 personnel using a gravity sampler from a small boat.

- The primary difficulty in collection of reservoir sediment at pre-determined locations was the general lack of a significant thickness of sediment in the main channel of the reservoir (thalweg samples), except within a few thousand feet upstream from the dam.
- A total of 24 samples of reservoir sediment were collected for gradations, Atterberg limits, and moisture content. Additional samples were collected of pre-reservoir coarse grained alluvium.

Findings

- Reservoir sediment was deposited in a pre-existing river channel cut into surrounding volcanic rocks, and pre-existing alluvial terraces or lakebed sediments. Some of the reservoir sediment was deposited directly on volcanic rocks, and at other locations reservoir sediment was deposited on pre-reservoir coarse grained alluvium.
- Reservoir sediment is unevenly distributed throughout the reservoir.
  - The upper 5,000 feet of the reservoir contains reservoir sediment that is primarily an influx of coarse grained silty gravel and sand ±cobbles.
  - A transition section of the reservoir hosts reservoir sediment that is primarily composed of Poorly Graded Sand with Silt (SP-SM) to Silty Sand (SM) in the channel and Elastic Silt (MH) ±organics between the channel and the shore.
  - Where reservoir water was flowing greater than an estimated 2-4 miles/hour fine grained reservoir sediment appears to have remained in suspension, or was actively eroding.
  - In the middle section of the reservoir, upstream and downstream from the Hwy. 66 bridge, there is very little reservoir sediment. Reservoir sediment encountered is composed of Elastic Silt – MH ±organics. Several attempts to collect reservoir sediment in this section of the reservoir found the bottom to be covered in pre-reservoir coarse grained alluvium, commonly Silty Gravel with Sand (GM)s.
  - In the lower section of the reservoir, within a few thousand feet of J.C. Boyle Dam, deposits of fine grained reservoir sediment are relatively thick (in drill holes about 14 to 22 feet).
  - Twenty-four samples of fine grained reservoir sediment were collected in J.C. Boyle Reservoir and submitted for gradations and Atterberg limits. All samples were composed of Elastic Silt – MH (±Organic Silt) with very high plasticity indices and liquid limits (Chart 1). These samples also commonly held field moistures of 200% to 300%, with a two over 400%.
  - Fine grained reservoir sediment is primarily composed of loosely arranged deposits of siliceous diatoms, algae and other fine grained organics, with silt and clay size volcanic particles (Photos 87, 88, 89, and 90). Fine grained reservoir sediment has a uniform consistency of pudding and often contains an estimated 2% to 15% (by volume) bubbles of methane gas distributed throughout.

Conclusions

Barge-supported drilling/sampling and boat-supported gravity sampling allowed for a feasibility-level determination of reservoir sediment types and thicknesses throughout the various reaches of the reservoir.

Adequacy of the sampling program to fulfill criteria required for a screening-level determination for various potential contaminants will be made by MP-157 personnel in a separate report.

Additional Work Requests

The Field Exploration Request by Reclamation's Technical Service Center to MP-230 requested the collection of additional geologic data, including:

- Geologic mapping, as it relates to structures around the reservoir and potential slope instability following dam removal;
- Identification and geologic mapping of potential borrow sites;
- Geologic mapping along potential haul-road alignments;
- Geotechnical drilling investigations along potential haul-road alignments and within proposed borrow sites.
- Drilling/installing groundwater observation wells;
- River bed-load sediment sampling and characterization along the reach downstream from J.C. Boyle Dam to the start of Copco-1 Reservoir, downstream from Copco-2 Dam to the start of Iron Gate Reservoir, and downstream from Iron Gate Dam. Characterization will rely heavily on river bed-load sampling using a shovel to collect 60-lb sack samples and less on pebble-counts.
- Complete a comprehensive evaluation of soil, rock, and mineral deposits of potential commercial value located adjacent to and in areas surrounding reservoirs, and the likely impact of dam removal and reservoir unwatering on these deposits.

Copco-1 Reservoir

Copco-1 Dam is a concrete dam 126 feet high and 145 feet long with a gated concrete spillway, powerhouse, and outlet works [Ref. 2]. Completed in 1918 it is located along the Klamath River in northwestern California, about 23 air-miles northeast from the city of Yreka, CA (Figure 1). The reservoir is about 22,000 feet long and ranges between 700 to 1,500 feet wide in the upper 6,200 feet of reservoir, and 1,500 to 3,300 feet wide in the main 16,000 feet of reservoir (Figure 3). Water depth at the sample sites ranged from 7.9 feet to about 84 feet. Access to the reservoir was from Keaton Cove, a boat launching site on the southern side of the reservoir.

Geology (Photos 117-127)

Copco-1 Dam and reservoir are in the Cascade Range geomorphic province, at the very northern end of the Siskiyou Mountains. This is an area of young (Quaternary to Tertiary age) volcanic rocks including large volumes of pyroclastic flows, tuff, and other volcaniclastic rocks. The volcaniclastic rocks are locally overlain by thick lava flows, and are crosscut by young volcanic-eruptive centers. There may also be local accumulations of pre-dam fluviolacustrine deposits including diatomite, colluvium, and to a lesser extent talus rock fallen from steep slopes.

Bedrock surrounding and underlying fluviolacustrine deposits and the reservoir is principally composed of moderately well-bedded to massive, moderately well-consolidated volcaniclastic rock (tuff, tuffaceous sediment, lapilli tuff, tuff breccia, and block and ash deposits). Surface exposures of the volcaniclastic rock are mostly weathered to Silty Gravel with Sand (GM)s to Clayey Gravel with Sand (GC)s $\pm$ Cobbles. The Klamath River has cut into volcaniclastic rock and lava flows of basalt or andesite overlie volcaniclastic rock and form many of the ridges above the reservoir. Intrusions of magma similar in composition to the lava flows are exposed in the foundation of Copco-1 Dam, and along both abutments (Figure 7).

The sequence of events forming rocks around Copco-1 Reservoir is likely to have been:

1. Eruption of large quantities of Tertiary to Quaternary age pyroclastic flows and other volcaniclastic rocks, which currently form bedrock around the reservoir.
2. Down cutting into the volcaniclastic rocks by the ancestral Klamath River.
3. Multiple periods of intrusion and eruption of basaltic to andesitic lavas from several volcanic centers. Some of these flows deposited on top of the volcaniclastic rocks and others flowed down local drainages and along the ancestral Klamath River.
4. Offset of local rocks by prominent faults, including northeast-trending faults between the small town of Ager, CA and Keaton Cove.
5. Continued down cutting of the Klamath River and deposition of recent alluvium (Qal) and colluvium (Qc). Upstream and downstream of the current reservoir the river canyon is narrow and coarse alluvium was deposited in a high energy environment. The current reservoir inundates a meandering river environment, where flow velocities were generally lower, and river alluvium finer than in the narrow canyons.
6. Construction of Copco-1 Dam and filling of the reservoir.
7. Deposition of Reservoir Sediment (Qr).

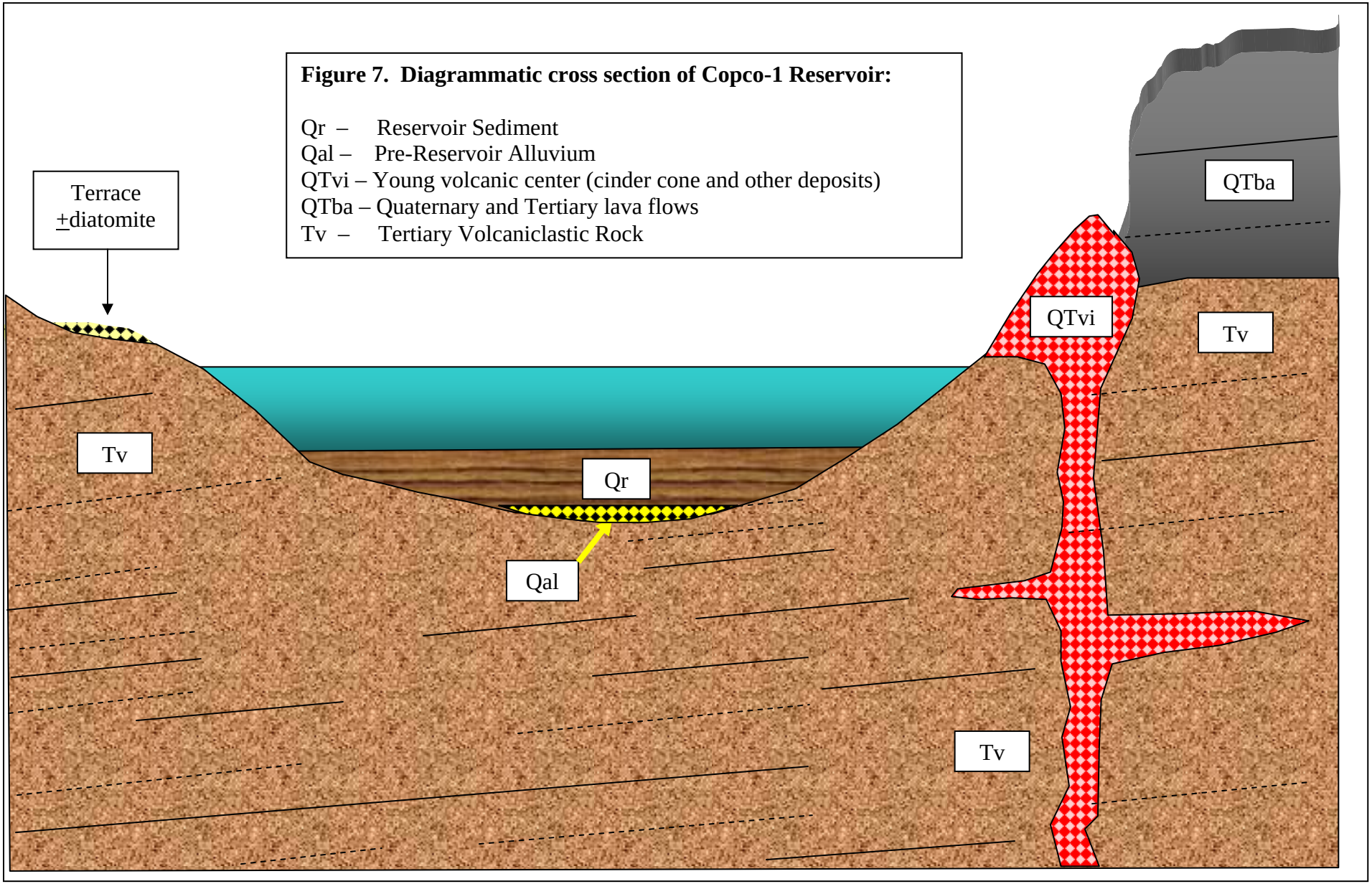


Figure 7. Diagrammatic cross section of Copco-1 Reservoir:

Qr – Reservoir Sediment
Qal – Pre-Reservoir Alluvium
QTvi – Young volcanic center (cinder cone and other deposits)
QTba – Quaternary and Tertiary lava flows
Tv – Tertiary Volcaniclastic Rock

Sample Sites

Reclamation attempted contaminant sampling investigations at fourteen sites, thirteen of which had minor to significant thicknesses of reservoir sediment where samples were be collected. Reclamation also attempted engineering properties sampling at five sites, all of which had sufficient thicknesses of reservoir sediment to allow collection of seven undisturbed samples of reservoir sediment (Table 4). Shannon and Wilson [Ref. 3] attempted contaminant sampling investigations at twelve sites in Copco-1 Reservoir (Figure 4).

Reclamation's sample sites were distributed throughout about 20,400 feet of the 22,000 foot-long reservoir. Shannon and Wilson [Ref. 3] attempted collecting contaminant sample material from two additional sites upstream from Reclamation's upstream-most boat-platform drilling site.

Table 4. Data collected at contaminant sample holes (CDH) and engineering properties holes (EDH) in **Copco-1 Reservoir**.

Copco-1 Reservoir ***** Reservoir elevations provided by PacifiCorp, datum undetermined.					
Drill Hole Number	**Coordinates**	**Reservoir Elevation** (feet)	**Water Depth** (feet)	**Reservoir Sediment Thickness** (feet)	**Pre-reservoir** Qal, Qcl, and in-place Tv. (feet)
CDH-09-9	N 41° 57' 56.7" W 122° 16' 07.4"	2591.2	12.0	> 10.0	Not Determined
CDH-09-9A	N 41° 58' 05.8" W 122° 16' 27.6"	unknown	16.0	4.6 (MH)s	4.6 to 7.0 Tv weathered tuff (CL)s
CDH-09-10	N 41° 58' 15.1" W 122° 16' 53.5"	Not Known	26.3	8.0 (MH)s MH	8.0 to 8.5 Qal SM
CDH-09-11	N 41° 58' 37.6" W 122° 17'14.5"	2,591.7	7.9	1.3 MH	1.3 to 2.5 Tv weathered tuff (CH)s
CDH-09-12	N 41° 58' 37.7" W 122° 17' 26.4"	2,591.4	31.2	5.4 MH	5.4 to 8.0 Tv tuff (?) (ML)s
CDH-09-13	N 41° 58' 53.5" W 122° 18' 01.9"	2,591.4	37.2	5.7 MH	5.7 to 6.5 Tv tuff (?) MH
CDH-09-14	N 41° 58' 53.3" W 122° 17' 52.0"	2,591.7	24.0	5.3 MH	5.3 to 6.5 Tv weathered tuff SC to SM
CDH-09-15	N 41° 59' 07.4" W 122° 18' 38.5"	2,591.4	40.0	3.0 MH	3.0 to 5.0 Qal (GM)s

CDH-09-15A	N 41° 59' 03.1" W 122° 18' 38.0"	2,592.5	69.2	9.7-ft. MH	9.7 to 10.0 Tv weathered tuff ML to CL
CDH-09-16	N 41° 58' 53.3" W 122° 19' 01.6"	2,592.8	74.0	7.5 MH	7.5 refusal on volcanic rock (?)
CDH-09-17	N 41° 59' 12.5" W 122° 19' 09.6"	2,592.3	25.0	1.2 MH	1.2 to 5.0 Tv weathered tuff SM, s(CL), SC
CDH-09-18	N 41° 59' 04.1" W 122° 19' 15.4"	2,592.8	84.0	9.2-ft. MH OL/OH	9.2 to 10.0 Tv weathered tuff (CL)s
CDH-09-19	N 41° 59' 03.2" W 122° 19' 42.2"	2,592.3	50.4	4.8 MH	4.8 to 5.5 Tv weathered tuff (CH)s
CDH-09-20	N 41° 58' 49.5" W 122° 19' 42.7"	2,592.3	80.0	7.4 MH	7.4 to 7.5 Tv weathered tuff (CL)s
EDH-09-4 3.75-in id tube **0.00 – 3.41 ft**	N 41° 58' 12.2" W 122° 16' 42.1"	2,591.7	19.8	3.5 MH	3.5 to 4.0 Tv weathered tuff CH
EDH-09-5 3.75-in id tube **0.00 – 1.85 ft**	N 41° 58' 53.4" W 122° 17' 51.8"	2,591.7	20.2	1.9 MH	1.9 to 2.5 Tv weathered tuff CH
EDH-09-5A 3.75-in id tube **0.00 – 2.14 ft**	N 41° 58' 53.4" W 122° 17' 51.9"	2,591.7	20.2	1.8 MH	1.8 to 3.0 Tv weathered tuff CH
EDH-09-6 3.75-in id tube **1.44 – 4.00 ft** **4.00 – 6.98 ft** **7.00 – 10.00 ft**	N 41° 58' 54.5" W 122° 18' 58.9"	2,591.5	77.0	10.0+ MH MH MH	>10.0
EDH-09-7 3.75-in id tube **0.00 – 3.20 ft**	N 41° 58' 48.9" W 122° 19' 36.0"	2,591.5-ft	30.5	1.8-ft. MH	1.8 to 3.2 Tv weathered tuff (CL)s
The call-in number for reservoir elevation gives a number like 191.5. For true elevation add 2,400-ft to that number (191.5 = 2,591.5-ft).					

Reservoir Sediment (Photos 128-163)

Eighteen samples were collected for gradations, Atterberg Limits (consistency), and field moisture content. Seventeen of these lab analyses were from material collected for contaminant samples, and one analysis was from material collected as an engineering properties sample. All eighteen samples were sent to Reclamation's Mid-Pacific

Construction Office Laboratory (Willows, CA) for analysis, and results are presented on Chart 2 and in Appendix C.

Copco-1 Reservoir has relatively gentile topographic side-slopes and a broad and open channel. There are only a few side drainages of significant size, and these are interpreted to contribute an extremely small amount of sediment to the reservoir.

Unlike J.C. Boyle Reservoir, Copco-1 Reservoir hosts a relatively similar depositional environment throughout its length with only the upper 6,200 feet of the reservoir having significant deposits of coarser grain size reservoir sediment.

Upper Reservoir

Reclamation's program attempted drilling at four sample locations in the upper 6,400 feet of the reservoir, at three of which reservoir sediment sampling was successful. Shannon and Wilson attempted sample collection at four sites within this section of the reservoir [Ref. 3]

The thickness of reservoir sediment encountered in drilling here was between 3.5 and 8.0 feet. In this area Reclamation collected three samples of reservoir sediment from contaminant sample holes CDH-09-9A and CDH-09-10 for gradation analysis. **These samples represented the full thickness of reservoir sediment at their respective locations (4.6-ft. and 8.0-ft.). Two were composed of Elastic Silt with Sand (MH)s containing about 20% fine sand, and the third sample was composed of Elastic Silt – MH with 3.4% fine sand. All three had Liquid Limits between 131% to 175%, Plasticity Indices between 44% to 87%, and Field Moisture between 190% and 375%.**

Main Reservoir

Of the approximately 22,000 foot-long reservoir, the 16,000 feet upstream of the dam is designated the Main Reservoir. Within this section the depositional environment for reservoir sediment is relatively uniform.

Water at drilling sites within this part of the reservoir ranged from about 8 to 84 feet deep. Reservoir sediment in the drill holes ranged from 1.3 feet to 9.7 feet thick, with the exception of one location having greater than 10 feet of sediment.

For gradation analyses and Atterberg limits a total of fourteen samples were collected of reservoir sediment in this section of the reservoir. **All fourteen of the reservoir contaminant sediment samples were composed of Elastic Silt – MH** (±Organic Silt) **containing 88.0% to 99.5% fines and the remainder sand, with three having a strong organic odor**. **Liquid Limits were between 127% and 175% with most around 150%, Plasticity Indices between 44% to 87%, and Field Moisture between 190% and 374%.**

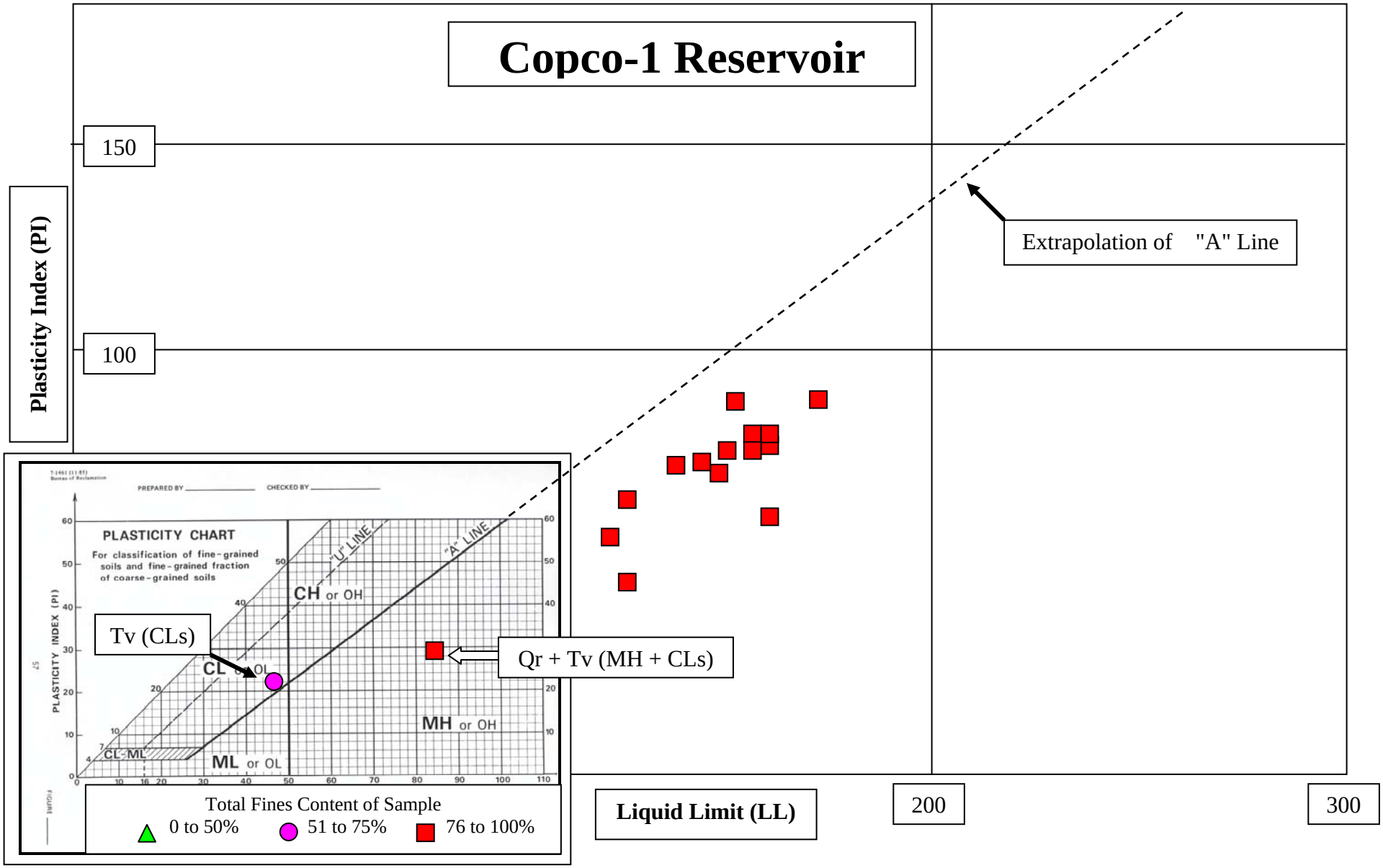


Chart 2. A plot of fourteen samples of reservoir sediment, all of which were composed of Elastic Silt – MH (±Organic Silt). One additional sample was a mix of reservoir sediment and pre-reservoir volcanics, and another sample was entirely pre-reservoir volcanics (CL)s.

One sample of Elastic Silt, from CDH-09-18 (depth from 8.9 to 10.0 feet) had significantly lower Atterberg limits and moisture content (LL 83.7%; PI 28.5%; Moisture 105.6%). It is believed that this sample is a mix of both Elastic Silt – MH reservoir sediment and underlying volcaniclastic rock decomposed to Lean Clay with Sand (CL)s.

The reservoir sediment had the consistency of pudding and contained an abundance of methane gas bubbles distributed throughout. Additionally, methane gas frequently bubbled up around the drill stem and boat as drilling progressed, forming streams of gas bubbles on the reservoir. Natural degassing of methane from reservoir sediment increased significantly when reservoir levels dropped even one to two feet.

Unit Weight of Undisturbed Samples of Reservoir Sediment

Seven undisturbed samples of in-place sediment were collected in lexan liners, and transported to Reclamation's Technical Service Center materials laboratory. Two of these samples contained both reservoir sediment and pre-reservoir volcaniclastic rock (CH to CLs). Unit weights of samples are listed in Table 4.

Four of the five undisturbed samples of reservoir sediment had a very narrow range of unit weights, 64.5 lbs/ft^3, 64.9 lbs/ft^3, 65.0 lbs/ft^3, and 66.3 lbs/ft^3. One sample from EDH-09-5A, collected from a depth of 0.46 to 2.6 feet was calculated with a unit weight of 57.76 lbs/ft^3. This sample is considered to be in error, either due to an incorrect measured length of the lexan liner, or an incorrect measured weight of the liner plus sediment.

Geochemistry of Reservoir Sediment (ICP-MS Method)

For a full discussion of this method, and how geochemical results may vary with different methods of sediment analyses, refer to the section "Geochemistry of Reservoir Sediment (ICP-MS Method)" in the section of this report covering J.C. Boyle Reservoir.

Geologic conditions in Copco-1 Reservoir are somewhat different than those in J.C. Boyle Reservoir. Even though bedrock beneath and surrounding both reservoirs are primarily volcaniclastic rocks overlain by younger lava flows, rocks underlying and surrounding Copco-1 Reservoir contain thick deposits of airfall tuff and ash-flows (Photos 121-126). Additionally there are several young volcanic eruptive centers and cinder cones around and adjacent to the reservoir.

Deposits of young volcanic tuff and ash-flows frequently host significant concentrations of metals such as mercury, antimony, bismuth, and arsenic (Hg, Sb, Bi, and As) and halogens, such as fluorine, bromine, and iodine (F, Br, and I) that are chemically loosely bound and relatively easily dispersible in a weathering or hot-spring environment.

Sediment in Copco-1 Reservoir is geologically and geochemically likely to contain higher (albeit still trace) concentrations of metals (Hg, Sb, Bi, and As $\pm$ others) and halogens (F, Br, and I) than found in J.C. Boyle and perhaps Iron Gate reservoirs.

Table 5. Unit weights of reservoir sediment in samples collected for Engineering Properties (EDH) in **Copco-1 Reservoir**.

Drill Hole Sample Footage Tube i.d.	Liner plus Sediment Weight (lbs)	Liner Length (ft)	*Liner Weight (lbs/ft) **Cut wt. (lbs)**	Caps + Tape Weight (lbs)	Sediment Weight (pounds)	Liner Volume (cubic feet) =0.0767 ft^3/ft.	**In-place sediment** **Unit Weight Calc.** **Sediment Type(s)** **Unit Weight (lbs/ft^3)**
EDH-09-4 0.59 to 4.00-ft. 3.75-in. i.d.	21.6	3.41	0.75 (lbs/ft) **2.558 lbs**	0.22	**18.82**	3.41-ft X 0.0767 ft^3/ft = **Sample Volume = 0.2615 ft^3**	18.82-lbs/0.2615 ft^3 = Qr 2.91- ft. MH Tv 0.50 - ft. CH **72.0-lbs/ft^3**
EDH-09-5 0.05 to 1.85-ft. 3.75-in. i.d.	10.83	1.85	0.75 (lbs/ft) **1.388 lbs**	0.22	**9.22**	1.85-ft X 0.0767 ft^3/ft = **Sample Volume = 0.1419 ft^3**	9.22-lbs/0.1419 ft^3 = Qr MH **65.0-lbs/ft^3**
EDH-09-5A 0.46 to 2.6-ft. 3.75-in. i.d.	11.3	2.14	0.75 (lbs/ft) **1.605 lbs**	0.22	**9.48**	2.14-ft X 0.0767 ft^3/ft = **Sample Volume = 0.1641 ft^3**	9.48-lbs/0.1641 ft^3 = Qr MH ***57.76-lbs/ft^3**
EDH-09-6 1.44 to 4.00-ft. 3.75-in. i.d.	14.88	2.56	0.75 (lbs/ft) **1.92 lbs**	0.22	**12.74**	2.56-ft X 0.0767 ft^3/ft = **Sample Volume = 0.1964 ft^3**	12.74-lbs/0.1964 ft^3 = Qr MH **64.9-lbs/ft^3**
EDH-09-6 4.00 to 6.98-ft. 3.75-in. i.d.	16.92	2.98	0.75 (lbs/ft) **2.235 lbs**	0.22	**14.47**	2.98-ft X 0.0767 ft^3/ft = **Sample Volume = 0.2286 ft^3**	14.47-lbs/0.2286 ft^3 = Qr MH **66.3-lbs/ft^3**
EDH-09-6 7.00 to 10.0ft. 3.75-in. i.d.	17.30	3.00	0.75 (lbs/ft) **2.25 lbs**	0.22	**14.83**	3.00-ft X 0.0767 ft^3/ft = **Sample Volume = 0.2301 ft^3**	14.83-lbs/0.2301 ft^3 = Qr MH **64.5-lbs/ft^3**
EDH-09-7 0.00 to 10.30ft. 3.75-in. i.d.	22.50	3.20	0.75 (lbs/ft) **2.40 lbs**	0.22	**19.88**	3.20-ft X 0.0767 ft^3/ft = **Sample Volume = 0.2454 ft^3**	19.88-lbs/0.2454 ft^3 = Qr 1.8-ft. MH Tv 1.4-ft (CL)s **81.0-lbs/ft^3**

* The computed density of reservoir sediment for drill hole EDH-09-5A is wrong. It is not known whether the error is due to an incorrect measurement of the liner length, or an incorrect total weight of the liner with sediment.

- Qr = Reservoir Sediment
- Volume of the 3.75-inch i.d. lexan tubes was determined by filling a tube with water, determining the weight of the water in the tube, and dividing that by the weight of one cubic foot of water (62.4-lbs/ft^3) = 0.0768 ft^3/ft.
- Volume of the 3.75-inch i.d. lexan tubes calculated using the tube i.d. determined with a micrometer = **0.0767 ft^3/ft.**
- Lexan tube weight = 0.750-lbs/ft. Two lexan tube caps plus 4-ft. of tape = 0.22-lbs.

Summary

- Reservoir sediment was deposited in a pre-existing river channel forming mostly a broad and open basin cut into surrounding volcaniclastic rocks. Much of the reservoir sediment was deposited directly on volcanic tuff, lapilli tuff, and tuff breccia or its nearly in-place weathered equivalent. At other locations reservoir sediment was deposited on pre-reservoir coarse grained alluvium.
- Reservoir sediment gradations are relatively homogeneous throughout Copco-1 Reservoir, with only sediment in the upper 6,200 feet of the reservoir containing significant quantities of sand ± gravel.
    - Reservoir sediment is primarily Elastic Silt – MH (±Organic Silt) with less than 10% fine sand. Samples from the upper part of the reservoir contained up to about 20% sand.
    - Copco-1 Reservoir has a much broader and open basin than J.C. Boyle or Iron Gate reservoirs. Even though Copco-1 is older than the other two reservoirs, it hosts reservoir sediment thicknesses of generally less than 10 feet thick.
    - Seventeen samples of fine grained reservoir sediment were collected in J.C. Boyle Reservoir and submitted for gradations and Atterberg limits. Fifteen samples were composed of Elastic Silt – MH (±Organic Silt) with very high plasticity indices and liquid limits (Chart 2). These samples also commonly held field moistures of 200% to 300%. The two samples of reservoir sediment collected in the upper section of the reservoir were composed of Elastic Silt with Sand (MH)s, with each hosting about 20% sand.
    - Fine grained reservoir sediment in Copco-1 Reservoir is believed to be similar to that deposited in J.C. Boyle Reservoir, which is primarily composed of loosely arranged deposits of siliceous diatoms, algae and other fine grained organics, with silt and clay size volcanic particles (Photos 87, 88, 89, and 90). Fine grained reservoir sediment has a uniform consistency of pudding and often contains an estimated 2% to 15% (by volume) bubbles of methane gas distributed throughout.

Conclusions

Barge-supported drilling/sampling and boat-supported gravity sampling allowed for a feasibility-level determination of reservoir sediment types and thicknesses throughout the various reaches of the reservoir.

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Additional Work Requests

The Field Exploration Request by Reclamation's Technical Service Center to MP-230 requested the collection of additional geologic data, including:

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- Identification and geologic mapping and of potential borrow sites;
- Geologic mapping along potential haul-road alignments;

- Geotechnical drilling investigations along potential haul-road alignments and within proposed borrow sites.
- Drilling/installing groundwater observation wells;
- River bed-load sediment sampling and characterization along the reach downstream from J.C. Boyle Dam to the start of Copco-1 Reservoir, downstream from Copco-2 Dam to the start of Iron Gate Reservoir, and downstream from Iron Gate Dam. Characterization will rely heavily on river bed-load sampling using a shovel to collect 60-lb sack samples and less on pebble-counts.
- Complete a comprehensive evaluation of soil, rock, and mineral deposits of potential commercial value located adjacent to and in areas surrounding reservoirs, and the likely impact of dam removal and reservoir unwatering on these deposits.

Copco-2 Reservoir

Copco-2 Dam is a concrete diversion dam 33 feet high and 278 feet long with a gated concrete spillway and an intake structure that leads to a powerhouse [Ref. 2]. Completed in 1925 it is located in northwestern California along the Klamath River, about ¼-mile downstream from Copco-1 Dam and about 23 air-miles northeast from the city of Yreka, CA.

Starting on the downstream side of Copco-1 Dam the reservoir is about 1,700 feet long and less than 200 feet wide. The normal water depth in the upper part of the reservoir, near Copco-1 powerhouse outlet works, is about 5 feet. The reservoir deepens as it extends downstream for about 1,700 feet to Copco-2 Dam, where normal water depth is about 20 feet. Water depth at all sixteen attempted sample sites was less than 18 feet. Access to the reservoir was from a PacifiCorp road on the northern side of the reservoir.

Geology (Photos 164-174)

Copco-2 Dam and Reservoir are in the Cascade Range geomorphic province, at the very northern end of the Siskiyou Mountains. This is an area of young (Quaternary to Tertiary age) volcanic rocks including large volumes of pyroclastic flows, tuff, and other volcaniclastic rocks. Rock at Copco-2 Dam is a combination of lava flows and shallow intrusions of similar composition. A diagrammatic cross section of the geology at Copco-2 Dam is shown in Figure 8.

Both Copco-1 and Copco-2 dams were constructed on foundations and abutments of igneous rock (basalt and or andesite). A volcanic eruptive center, with cinder cones, is present just to the north of the two dams.

Bedrock surrounding and underlying the reservoir is composed of basalt and (or) andesite. Steep talus slopes composed of angular volcanic blocks (cobbles and boulders) are along both sides of the reservoir and cobbles, boulders, and gravel $\pm$ sand form deposits in the bottom of the reservoir.

Sample Sites (Photos 174-185)

Reclamation attempted contaminant sampling investigations at sixteen sites using the gravity sampling and stick sampling methods with a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube 5 feet long (Table 6 and Figure 4).

Near the dam, three sample sites were located just upstream from gates 3, 4, and 5 (right side of the dam). For safety reasons sampling was not attempted adjacent to the diversion intake structure and gates 1 and 2 (left side of the dam). Four sample lines were set up across the reservoir channel upstream from the dam. Three sample sites were selected along each line, one on the right side of the channel, one near the center of the channel, and one on the left side of the channel (Figure 4).

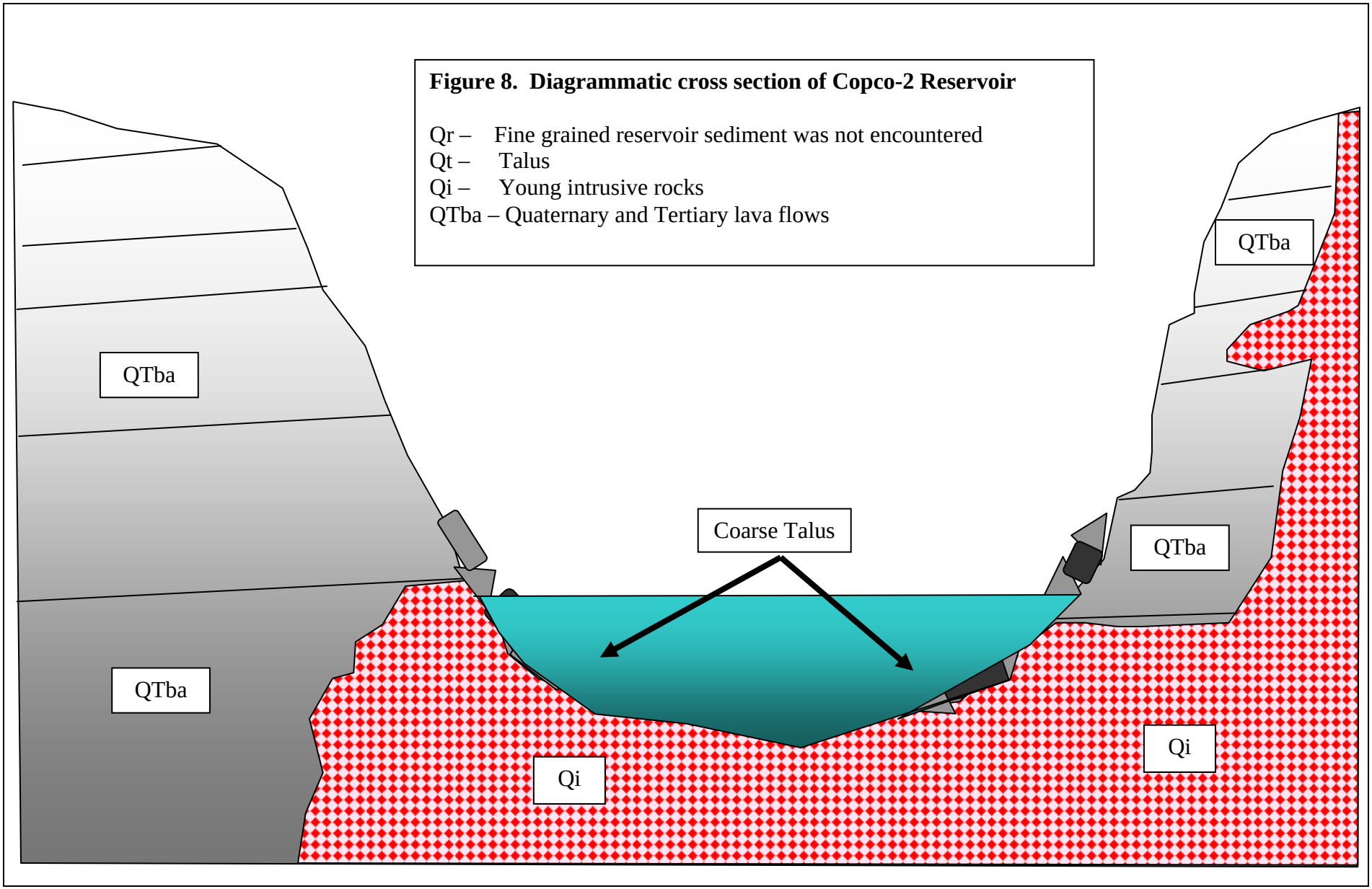

Figure 8. Diagrammatic cross section of Copco-2 Reservoir

Table 6. Location of attempted sample sites in **Copco-2 Reservoir**. None of the sites hosted fine grained sediment.

Copco-2 Reservoir Attempted Sample Locations			
***** Reservoir elevations provided by PacifiCorp, datum undetermined.			
Sample Site Number	**Coordinates**	**Water Depth (ft.)**	**Remarks**
CDH-09-33-1	41° 58' 44.20" 122° 20' 23.70"	17.2	Upstream from Gate 3. Minor gravel with sand.
CDH-09-33-2	41° 58' 44.70" 122° 20' 23.25"	17.5	Upstream from Gate 5. Sampler bounced off the bottom and it felt rocky.
CDH-09-33-3	41° 58' 44.45" 122° 20' 22.90"	16.0	Rocky with minor gravel and sand.
CDH-09-33-4	41° 58' 43.50" 122° 20' 22.50"	12.0	Near boat launch area. Rocky with minor gravel and sand.
CDH-09-33-5	41° 58' 43.10" 122° 20' 22.60"	15.5	Center of channel; rocky.
CDH-09-33-6	41° 58' 42.60" 122° 20' 23.00"	7.0	Left bank; large rocks.
CDH-09-33-6A	41° 58' 41.75" 122° 20' 21.30"	8.0	Left bank upstream from site 6; rocky.
CDH-09-33-7	41° 58' 42.30" 122° 20' 19.30"	13.5	Right side; rocky with minor gravel and sand.
CDH-09-33-8	41° 58' 41.85" 122° 20' 19.10"	14.0	Center of channel; rocky with minor gravel and sand.
CDH-09-33-9	41° 58' 41.50" 122° 20' 18.85"	14.0	Left bank; rocky, no sand or gravel.
CDH-09-33-10	41° 58' 42.20" 122° 20' 15.90"	10.0	Right side; rocky.
CDH-09-33-11	41° 58' 41.85" 122° 20' 15.85"	10.0	Center of channel; rocky with minor gravel and sand.
CDH-09-33-12	41° 58' 41.45" 122° 20' 15.70"	8.0	Left bank; rocky, minor gravel and sand.
CDH-09-33-13	41° 58' 42.10" 122° 20' 12.40"	10.0	Right side; rocky, minor gravel.
CDH-09-33-14	41° 58' 41.75" 122° 20' 12.30"	14.0	Center of channel; rocky, minor gravel.
CDH-09-33-15	41° 58' 41.45" 122° 20' 12.20"	10.0	Left bank; rocky, minor gravel.
Reservoir Elevation 2,472.6 feet (1/12/10) Gate numbers increase from left to right (looking downstream), with Gate 1 on the left and Gate 5 on the right.			

Reservoir Sediment (Photos 183-185)

Even though previous workers discounted Copco-2 Reservoir as an area where contaminant samples needed to be collected, Reclamation personnel felt it was important to make the attempt at sample collection. The principal reason for this is the reservoir's location, starting at the outlet works of Copco-1 powerhouse. Reclamation personnel believe that if any contaminants associated with the +90 years of Copco-1 powerhouse operation had gone into the Klamath River system that they might be present in fine grained sediment in Copco-2 Reservoir.

None of the sixteen sample sites in Copco-2 Reservoir hosted fine grained reservoir sediment. At one location, near gate five at the dam, a minor amount of coarse sand and gravel was recovered. However, this material was determined not to be of use since it did not contain a significant percentage of fines. At the remaining sample locations the gravity and stab sampler encountered large gravel, cobble, and boulder size talus on the bottom of the reservoir.

The channel invert appears to be covered mostly with angular gravel to boulder size talus and minor interstitial sand. This is readily apparent in photographs that PacifiCorp provided to Reclamation of the reservoir channel when it was unwatered (Photos 183, 184, and 185). These photographs show the upper 500 feet of the reservoir with channel deposits primarily composed of cobbles and boulders.

Flow velocities in the reservoir channel at the time of sampling (1/12/10) were relatively fast, and as seen in J.C. Boyle Reservoir, sediment composed of silt and clay did not deposit or was eroded when flow velocities exceeded an estimated 2 to 4 miles per hour. At Copco-2 is estimated that flow velocities exceeded 4 miles per hour.

Summary

Collection of fine grained sediment was attempted at sixteen locations throughout the downstream 970 feet of Copco-2 Reservoir. Water velocities in the reservoir channel were too high to attempt boat navigation upstream from these locations.

None of the sixteen sample sites hosted a significant percentage of fines, and no samples were collected or submitted for contaminant analysis. The reservoir sides and channel bottom are principally composed of cobble, boulder, and gravel size talus that has fallen from outcropping andesitic volcanic and intrusive rock.

Conclusions

- Previous workers were correct in discounting Copco-2 Reservoir as a place requiring contaminant sampling of reservoir sediment.
- Reclamation's program to identify and attempt to sample fine grained sediment in Copco-2 Reservoir exceeds feasibility level.
- Copco-2 Reservoir did not contain a significant amount of fine grained reservoir sediment on the date of the sampling program (1/12/10), and it is very doubtful that significant amounts of fine grained sediment accumulate in the reservoir at other times of the year.

Additional Work Requests

The Field Exploration Request by Reclamation's Technical Service Center to MP-230 requested the collection of additional geologic data, including:

- Geologic mapping, as it relates to structures around the reservoir and potential slope instability following dam removal;
- Identification and geologic mapping and of potential borrow sites;
- Geologic mapping along potential haul-roads;
- Geotechnical drilling investigations along potential haul-roads and within proposed borrow sites.
- Drilling/installing groundwater observation wells;
- River bed-load sediment sampling and characterization along the reach downstream from Copco-2 Dam to the start of Iron Gate Reservoir, and downstream from Iron Gate Dam. Characterization will rely heavily on river bed-load sampling using a shovel to collect 60-lb sack samples and less on pebble-counts.
- Complete a comprehensive evaluation of soil, rock, and mineral deposits of potential commercial value located adjacent to and in areas surrounding reservoirs, and the likely impact of dam removal and reservoir unwatering on these deposits.

Iron Gate Reservoir

Iron Gate Dam is an embankment dam 173 feet high and 740 feet long with a 680 foot-long concrete spillway [Ref. 2]. Completed in 1962 it is located in northwestern California along the Klamath River, about 17 air-miles northeast from the city of Yreka, CA. The reservoir is about 30,000 feet long and is narrow, with numerous embayments and side channels. The upstream two thirds of the reservoir ranges in width from about 400 to 1,000 feet, and the downstream third is generally 1,500 to 2,000 feet wide. Mirror Cove is a major side channel, extending northward from the main stem of the reservoir for about one mile.

Drilling took place in water as shallow as about fourteen feet near the upper end of the reservoir, and up to a depth of about 130 feet about one mile upstream from the dam.

Access to the reservoir for barge launching was from Long Gulch, a site on the southeastern side of the reservoir. Personnel, equipment, and samples were transported daily from a boat launching site in Mirror Cove, on the western side of the reservoir.

Geology (Photos 186-194)

Iron Gate Dam and Reservoir are in the Cascade Range geomorphic province, at the northern end of the Siskiyou Mountains. This is an area of young (Quaternary to Tertiary age) volcanic rocks including large volumes of pyroclastic flows, tuff, and other volcaniclastic rocks. The volcaniclastic rocks are locally interbedded with, and overlain by, thick lava flows that are crosscut by young volcanic-eruptive centers. There may also be local accumulations of pre-dam fluviolacustrine deposits, colluvium, and to a lesser extent talus rock fallen from the steep side slopes (Figure 9).

Bedrock surrounding and underlying the reservoir is principally composed of moderately well-bedded to massive, moderately well-consolidated volcaniclastic rocks (tuff, tuffaceous sediments, lapilli tuff, tuff breccia, and local block and ash deposits). Beneath the young volcanic rocks are Paleozoic to Mesozoic age oceanic crustal and sedimentary rocks, which crop out along the Klamath River a few miles downstream from Iron Gate Reservoir (Photo 188).

Surface exposures of the volcaniclastic rocks commonly weather to Silty Gravel with Sand (GM)s to Clayey Gravel with Sand (GC)s $\pm$ Cobbles. The Klamath River has cut its way into volcaniclastic bedrock. Basaltic and (or) andesitic lava flows overlie volcaniclastic rocks throughout the area and form many of the ridges above the reservoir. Along the northern reservoir rim springs are abundant along the contact between lava flows and the underlying volcaniclastic rock.

Regional scale structural orientations are evident using Google Earth satellite imagery. Orientations of northerly, northwesterly, and northeasterly are common in pre-Tertiary age rocks northwest of the reservoir, and a prominent northeasterly structural orientation is common in Tertiary age volcanic and volcaniclastic rocks surrounding the reservoir.

Pre-Cretaceous age marine sedimentary rocks to the west of Iron Gate Reservoir generally strike to the northwest.

The sequence of events forming rocks around Iron Gate Reservoir is likely to have been:

1. Eruption of large quantities of Tertiary to Quaternary age pyroclastic flows and other volcaniclastic rocks, which currently form bedrock around the reservoir.
2. Down-cutting into bedrock by the ancestral Klamath River.
3. Multiple periods of intrusion and eruption of basaltic to andesitic lavas from several volcanic centers. Some of these flows deposited on top of the volcaniclastic rocks and others flowed down local drainages and along the ancestral Klamath River.
4. Offset of rocks by local faults.
5. Continued down-cutting of the Klamath River and deposition of recent alluvium (Qal) and colluvium (Qc). Upstream and downstream of the current reservoir the river canyon is narrow, and coarse grained alluvium is deposited in a high energy environment.
6. Construction of Iron Gate Dam, filling of the reservoir, and deposition of Reservoir Sediment (Qr).

Sample Sites

Reclamation attempted contaminant sampling investigations at thirteen sites, all of which had significant thicknesses of reservoir sediment. Reclamation also attempted engineering properties sampling at seven sites, six of which had sufficient thicknesses of reservoir sediment to allow collection of seven undisturbed samples (Table 7). Shannon and Wilson [Ref. 3] attempted contaminant sampling investigations at nine sites in Iron Gate Reservoir.

Reclamation's sample sites were distributed throughout about 26,000 feet of the 30,000 foot long reservoir. Shannon and Wilson [Ref. 3] attempted collecting contaminant sample material from one site upstream from Reclamation's upstream-most barge-platform drilling site.

Reservoir Sediment (Photos 195-218)

Iron Gate Reservoir has relatively steep topographic side-slopes and a narrow channel with numerous side drainages. Three of these side drainages are large, and two (Camp Creek at Mirror Cove and Jenny Creek) likely contribute significant amounts of sediment to the reservoir.

Except for the three principal side drainages, Iron Gate Reservoir hosts a relatively similar depositional environment throughout its length. Only the upper 6,000 feet of the reservoir hosts a significant percentage of sand within the reservoir sediment.

Drilling and sampling by Reclamation took place in water ranging in depth from 14.3 feet to 129.5 feet. The thickness of reservoir sediment in drill holes ranged from 1.4 feet to 9.2 feet, mostly with a thickness of less than about five feet. At one location selected for the collection of undisturbed reservoir sediment (EDH-09-8) reservoir sediment was only 0.3 feet thick, and an alternate site (EDH-09-8A) had to be selected.

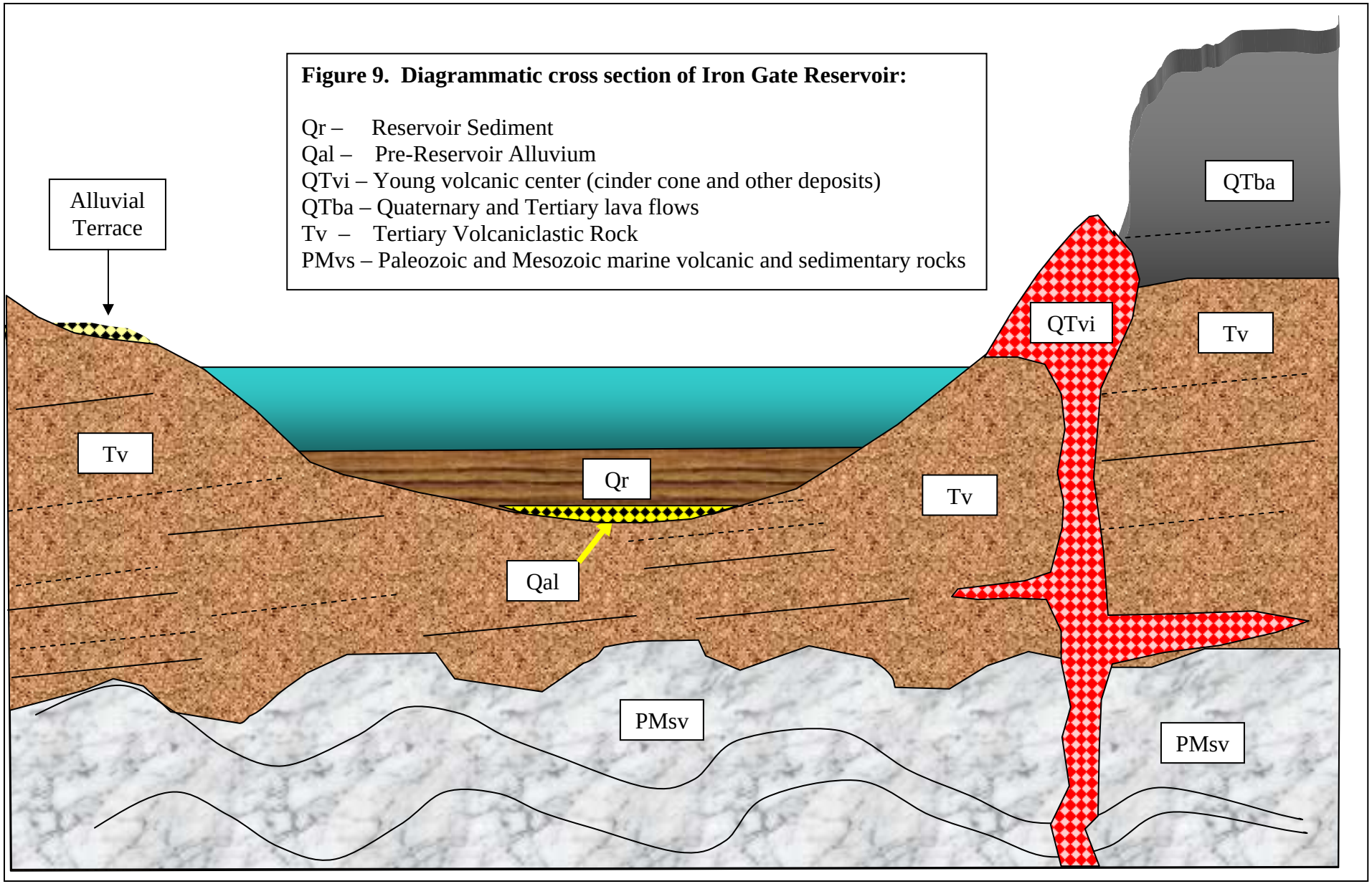

Figure 9. Diagrammatic cross section of Iron Gate Reservoir:

Qr – Reservoir Sediment
Qal – Pre-Reservoir Alluvium
QTvi – Young volcanic center (cinder cone and other deposits)
QTba – Quaternary and Tertiary lava flows
Tv – Tertiary Volcaniclastic Rock
PMvs – Paleozoic and Mesozoic marine volcanic and sedimentary rocks

Table 7. Data collected at contaminant sample holes (CDH) and engineering properties holes (EDH) from barge drilling sites in **Iron Gate Reservoir**.

Iron Gate Reservoir ***** Reservoir elevations provided by PacifiCorp, datum undetermined.					
Drill Hole Number	**Coordinates**	**Reservoir Elevation** (feet)	**Water Depth** (feet)	**Reservoir Sediment Thickness** (feet)	**Pre-reservoir** Qal, Qcl, and Tv in-place. (feet)
CDH-09-21	N 41° 58' 11.7" W 122° 22' 26.9"	2,325.1	14.3	1.5 OL/OH s(ML)	1.5 to 2.7 Tv weathered tuff (CH)gs
CDH-09-22	N 41° 58' 01.7" W 122° 23' 27.6"	2,325.2	49.8	1.4 MH	1.4 Qal (GM)s
CDH-09-23	N 41° 58' 23.3" W 122° 24' 05.5"	2,324.7	29.3	9.2 (MH)s s(ML)	9.2 to 9.7 Qal SP-SM 9.7-10.5 Tv s(Cl)g
CDH-09-24	N 41° 58' 18.6" W 122° 24' 12.7"	2,325.4	45.6	4.1 MH	4.1 to 8.5 Tv weathered tuff (CH)s
CDH-09-25	N 41° 57' 49.4" W 122° 25' 26.4"	2,324.7	99.0	5.0 MH	5.0 to 8.0 Tv weathered tuff (CL)sg
CDH-09-26	N 41° 57' 36.9" W 122° 25' 26.8"	2,325.8	29.4	2.0 MH	2.0 to 2.4 Tv weathered tuff (GC)s
CDH-09-27	N 41° 57' 55.8" W 122° 26' 06.1"	2,325.5	55.6	4.2 MH	4.2 to 4.8 Tv weathered tuff CH to (CH)s
CDH-09-28	N 41° 57' 47.4" W 122° 26' 21.2"	2,325.7	37.8	4.4 MH	4.4 to 5.3 Tv weathered tuff CH
CDH-09-29	N 41° 57' 15.7" W 122° 26' 0.4"	2,324.7	91.0	4.8 MH	4.8 to 6.9 Qal (GM)sc
CDH-09-30	N 41° 56' 50.8" W 122° 25' 54.6"	2,325.6	129.5	2.9 MH	2.9 to 3.5 Tv weathered tuff s(CH)g
CDH-09-31	N 41° 56' 39.7" W 122° 26' 12.5"	not known	50.9	4.8 (MH)s	4.8 to 5.1 Tv weathered tuff CL
CDH-09-32	N 41° 56' 23.8" W 122° 25' 52.9	2,324.7	124.0	4.3 MH	4.3 to 7.0 Qal (GC)s
CDH-09-Add #1	N 41° 57' 55.6" W 122° 26' 07.4"	2,324.6	61.2	2.4	2.4 to 4.1 Tv weathered tuff CH

Iron Gate Reservoir * Reservoir elevations provided by PacifiCorp, datum undetermined.					
Drill Hole Number	**Coordinates**	**Reservoir Elevation** (feet)	**Water Depth** (feet)	**Reservoir Sediment Thickness** (feet)	**Pre-reservoir** Qal, Qcl, and Tv in-place. (feet)
EDH-09-8 No Sample	N 41° 58' 03.4" W 122° 23' 21.1"	2,324.7	39.9	0.3 (MH)s	0.3 to 1.9 Qal (GC)s
EDH-09-8A 2.625-in id tube **0.00 – 2.13 ft**	N 41° 58' 02.6" W 122° 23' 41.3"	2,323.7	55.5	2.2 MH	2.2 to 2.3 Qal (GM)s
EDH-09-9 2.75-in id liner **1.40 – 3.00 ft**	N 41° 57' 43.0" W 122° 25' 27.0"	2,323.5	23.5	2.0 MH	2.0 to 3.3 Tv weathered tuff s(CH)
EDH-09-9A 2.75-in id liner **2.58 – 4.10 ft**	N 41° 57' 43.0" W 122° 25' 30.0"	2,323.5	37.3	3.8 MH	3.8 to 4.4 Tv weathered tuff s(CH)
EDH-09-10 2.625-in id tube **2.85 – 5.20 ft**	N 41° 57' 14.5" W 122° 25' 58.6"	2,323.8	65.4	4.5 MH	4.5 to 5.2 Tv weathered tuff (GC)s
EDH-09-11 2.625-in id tube **0.00 – 3.20 ft**	N 41° 58' 17.3" W 122° 24' 10.9"	2,325.5	46.4	3.1 MH	3.1 to 3.3 Tv weathered tuff SC
EDH-09-Add #1 2.625-in id tube **0.00 – 3.27 ft**	N 41° 57' 55.6" W 122° 26' 07.4"	2,324.2	60.4	3.0 MH	3.0 to 4.2 Tv weathered tuff (CH)s

Twenty samples were collected for gradations, Atterberg Limits (consistency), and field moisture content. Fifteen of these lab analyses were from material collected for contaminant samples and five analyses were from material collected as engineering properties samples. All twenty samples were sent to Reclamation's Mid-Pacific Construction Office Laboratory (Willows, CA) for analysis, and results are presented on Chart 3 and in Appendix C.

Seven samples were of pre-reservoir Tertiary age volcaniclastic rocks that exhibit very intense weathering. That material was mostly composed of Clayey Gravel with Sand – (GC)s, Fat Clay with Sand – (CH)s, and Fat Clay – CH.

Because of their very different physical properties, the identification of the contact between reservoir sediment and pre-reservoir weathered volcanic rock was easy to make.

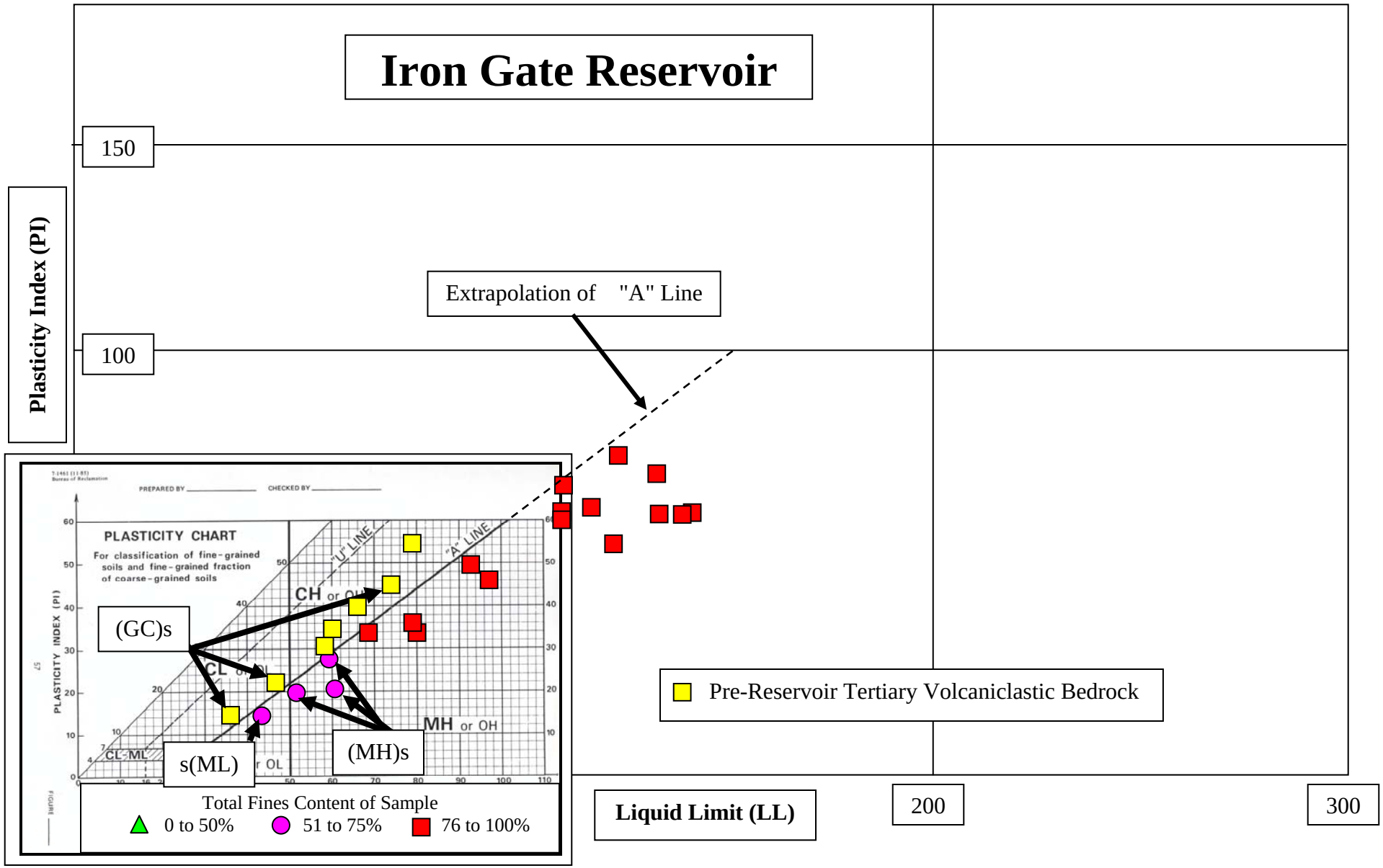

Chart 3. A plot of twenty six samples, including nineteen samples of reservoir sediment, fifteen of which were composed of Elastic Silt – MH (±Organic Silt), three with Sandy Elastic Silt s(MH), and one Sandy Silt – s(ML). One sample of reservoir sediment was composed of nonplastic Sandy Silt – s(ML) and could not be plotted. Seven samples were of pre-reservoir Tertiary age volcaniclastic rocks composed of Clayey Gravel with Sand – (GC)s, Fat Clay with Sand – (CH)s, and Fat Clay – CH.

Fif**teen of the reservoir sediment samples were composed of Elastic Silt – MH** (±Organic Silt) **containing 85.9% to 98.4% fines and the remainder sand, with five having a strong organic odor**. **These had Liquid Limits between 68% and 142%, Plasticity Indices between 33% to 68%, and Field Moisture between 97% and 355%.** One sample, from the upstream-most location in the reservoir (CDH-09-21) contained nonplastic fines with 30.9% sand (ML)s.

Reservoir sediment had the consistency of pudding and contained an abundance of methane gas bubbles distributed throughout. Additionally, methane gas frequently bubbled up around the drill stem and barge as drilling progressed. Degassing of methane from reservoir sediment increased significantly when reservoir levels dropped, even as little as one to two feet.

Unit Weight of Undisturbed Samples of Reservoir Sediment

Seven undisturbed samples of in-place sediment were collected in lexan liners, and transported to Reclamation's Technical Service Center materials laboratory. Six of these samples contained both reservoir sediment and pre-reservoir volcaniclastic rock (CH to CL ±Sand). Unit weights of samples are listed in Table 8.

Undisturbed samples had a range of unit weights from 71.0 lbs/ft^3 to 97.3 lbs/ft^3, with the densest material primarily composed of pre-reservoir volcaniclastic rock s(CH).

Geochemistry of Reservoir Sediment (ICP-MS Method)

For a full discussion of this method, and how geochemical results may vary with different methods of sediment analyses, refer to "Geochemistry of Reservoir Sediment (ICP-MS Method)" in the section of this report covering J.C. Boyle Reservoir.

Geologic conditions in Iron Gate Reservoir are relatively similar to those in J.C. Boyle Reservoir, with bedrock beneath and surrounding both reservoirs are primarily volcaniclastic rocks overlain by younger lava flows. However, terrain to the north of Iron Gate Reservoir is a complex assemblage of pre-Tertiary marine sedimentary and crustal rocks, as well as a Jurassic to Cretaceous age pluton. This diverse assemblage of rocks is drained to the south by Camp Creek, a major creek flowing directly into Mirror Cove a 5,000 foot long arm of Iron Gate Reservoir.

Sediment flowing into the reservoir from pre-Tertiary age marine sedimentary and igneous rocks to the north may add a different geochemical signature to reservoir sediment in Iron Gate than that seen in J.C. Boyle or Copco-1 reservoirs.

Table 8. Unit weights of reservoir sediment in samples collected for Engineering Properties (EDH) in Iron Gate Reservoir.

Drill Hole Sample Interval Tube/Liner i.d.	Liner plus Sediment Weight	Liner Length (ft)	*Liner Weight (lbs/ft) **Cut wt. (lbs)**	Caps + Tape Weight (lbs)	Sediment Weight (pounds)	Liner Volume (cubic feet) =0.0380 ft^3/ft.	**In-place sediment Unit Weight Calc. Sediment Type(s) Unit Weight (lbs/ft^3)**
EDH-09-8A 0.00 to 2.13-ft. 2.625-in.	6.40-lbs	2.13	0.266 (lbs/ft) **0.567**	0.08	**5.75**	2.13-ft X 0.038 ft^3/ft = **Sample Volume = 0.0809 ft^3**	5.75-lbs/0.0809 ft^3 = Qr 0.0 – 2.13-ft. = MH **71.1-lbs/ft^3**
EDH-09-9 1.4 to 3.0-ft. 2.750-in.	7.42-lbs	1.60	0.612 (lbs/ft) **0.979**	0.09	**6.35**	1.60-ft X 0.0408 ft^3/ft = **Sample Volume = 0.0653 ft^3**	6.35-lbs/0.0653 ft^3 = Qr 1.4 – 2.0-ft. = MH Tv 2.0 – 3.0-ft. = s(CH) **97.3-lbs/ft^3**
EDH-09-9A 2.58 to 4.1-ft. 2.750-in.	6.39-lbs	1.52	0.612 (lbs/ft) **0.930**	0.09	**5.37**	1.52-ft X 0.0408 ft^3/ft = **Sample Volume = 0.0620 ft^3**	5.37-lbs/0.0620 ft^3 = Qr 2.58 – 3.8-ft. = MH Tv 3.8 – 4.1-ft. = s(CH) **86.6-lbs/ft^3**
EDH-09-10 2.85 to 5.20-ft. 2.625-in.	8.20-lbs	2.35	0.266 (lbs/ft) **0.625 lbs**	0.08	**7.49**	2.35-ft X 0.038 ft^3/ft = **Sample Volume = 0.0893 ft^3**	7.49-lbs/0.0893 ft^3 = Qr 2.85 – 4.5-ft. = MH Tv 4.5 – 5.2-ft. = CH **83.9-lbs/ft^3**
EDH-09-11 0.0 to 3.2-ft. 2.625-in.	9.64-lbs	3.20	0.266 (lbs/ft) **0.851 lbs**	0.08	**8.71**	3.20-ft X 0.038 ft^3/ft = **Sample Volume = 0.1216 ft^3**	8.71-lbs/0.1216 ft^3 = Qr 0.0 – 3.1-ft. = MH Tv 3.1 – 3.2-ft. = SC **71.6-lbs/ft^3**
EDH-09-Add#1 0.00 to 3.27-ft. 2.625-in.	9.78-lbs	3.27	0.266 (lbs/ft) **0.870**	0.08	**8.83**	3.27-ft X 0.038 ft^3/ft = **Sample Volume = 0.1243 ft^3**	8.83-lbs/0.1243 ft^3 = Qr 0.0 – 3.0-ft. = MH Tv 0.0 – 3.27-ft. (CH)s **71.0-lbs/ft^3**

- Volume of the 2.75-inch i.d. lexan liners was determined by filling a liner with water, determining the weight of the water in the liner, and dividing that by the weight of one cubic foot of water (62.4-lbs/ft^3) **= 0.0408 ft^3/ft. (*volume used in the above calculations)**
- Volume of the 2.75-inch i.d. lexan liners calculated using the liner i.d. determined with a micrometer = 0.0412 ft^3/ft.
- Lexan liner weight = 0.612-lbs/ft. Two lexan liner caps plus 4-ft. of tape = 0.09-lbs.
- Volume of the 2.625-inch i.d. lexan tubes (used on the gravity sampler) was determined by filling a liner with water, determining the weight of the water in the liner, and dividing that by the weight of one cubic foot of water (62.4-lbs/ft^3) = 0.0376 ft^3/ft.
- Volume of the 2.625-inch i.d. lexan liners calculated using the liner i.d. determined with a micrometer = **0.0380 ft^3/ft.**
- Lexan liner weight = 0.266-lbs/ft. Two lexan liner caps plus 4-ft. of tape = 0.08-lbs.
- **Qr = Reservoir Sediment**

Summary

- Iron Gate Reservoir is hosted primarily within a steep walled canyon along the Klamath River. Reservoir sediment was deposited directly on Tertiary to Quaternary age volcanic rocks composed of flows, tuff, lapilli tuff, and tuff breccia and its nearly in-place weathered equivalent. At some locations reservoir sediment was deposited on pre-reservoir coarse grained alluvium.
- Reservoir sediment gradations are relatively homogeneous throughout Iron Gate reservoir, with only sediment in the upper 6,000 feet of the reservoir and a few coves or inlets containing significant quantities of sand.
    - Reservoir sediment is primarily Elastic Silt – MH (±Organic Silt) with less than 10% fine sand. (samples from the upper part of the reservoir contained up to about 20% sand).
    - Reservoir sediment thickness in Iron Gate ranged from 1.4 to 9.2 feet, but the sediment is generally less than about 5 feet thick.
    - Twenty samples of fine grained reservoir sediment were collected from Iron Gate Reservoir and submitted for gradations, Atterberg limits, and moisture content. Fifteen of the reservoir sediment samples were composed of Elastic Silt – MH (±Organic Silt) containing 88.9% to 98.4% fines with the remainder sand. Five of which had a strong organic odor. The samples had Liquid Limits between 68% and 142%, Plasticity Indices between 33% to 68%, and Field Moisture between 97% and 355% (Chart 3 and Appendix C).
    - Fine grained reservoir sediment in Iron Gate Reservoir is believed to be similar to that deposited in Copco-1 and J.C. Boyle reservoirs, which is primarily composed of loosely arranged deposits of siliceous diatoms, algae and other fine grained organics, with silt and clay size volcanic particles (Photos 87, 88, 89, and 90). Fine grained reservoir sediment has a uniform consistency of pudding and often contains an estimated 2% to 15% (by volume) bubbles of methane gas distributed throughout.

Conclusions

Barge-supported drilling/sampling and boat-supported vibracore sampling allowed for a feasibility-level determination of reservoir sediment types and thicknesses throughout the various reaches of the reservoir.

Adequacy of the sampling program to fulfill criteria required for a screening-level determination for various potential contaminants will be made by MP-157 personnel in a separate report.

Additional Work Requests

The Field Exploration Request by Reclamation's Technical Service Center to MP-230 requested the collection of additional geologic data, including:

- Geologic mapping, as it relates to structures around the reservoir and potential slope instability following dam removal;
- Identification and geologic mapping and of potential borrow sites;
- Geologic mapping along potential haul-roads;

- Geotechnical drilling investigations along potential haul-roads and within proposed borrow sites.
- Drilling/installing groundwater observation wells;
- River bed-load sediment sampling and characterization along the reach downstream from J.C. Boyle Dam to the start of Copco-1 Reservoir, downstream from Copco-2 Dam to the start of Iron Gate Reservoir, and downstream from Iron Gate Dam. Characterization will rely heavily on river bed-load sampling using a shovel to collect 60-lb sack samples and less on pebble-counts.
- Complete a comprehensive evaluation of soil, rock, and mineral deposits of potential commercial value located adjacent to and in areas surrounding reservoirs, and the likely impact of dam removal and reservoir unwatering on these deposits.

Lower Klamath River and Estuary

CURRENT WORK
Two areas of the Klamath River were sampled by boat, the saltwater estuary near the mouth of the river (Area One; Figures 10 and 11 and Table 9) and a freshwater section about five to seven miles upstream (Area Two; Figures 12, 14, and 15; Table 9).

Samples were collected at multiple locations in each area and then composited. This resulted in one composite sample for Area One (the saltwater estuary) and one composite sample for Area Two (the freshwater river). Water was collected in each area for use in elutriate testing. All sampling was completed in one day, and contaminant samples were collected, handled, and transported in accordance with the QAPP.

Samples were collected using:
- A gravity sampler with a 2-5/8-inch i.d. lexan tube collection barrel, suspended from a line on the boat in deeper water.
- The gravity sampler converted to a stab sampler, using the same a 2-5/8-inch i.d. lexan tube collection barrel for shallower water.
- A shovel was used for collecting bulk sample material in water up to a few feet deep.

Each composite sample was collected for:
- Contaminant Analysis
- Gradation Analysis
- Mineral Grain Determinations

Active Bedload Characterization
The initial request was to characterize deposits in the main channel of the river for use in constructing a sediment transport model. This was to be accomplished by anchoring the boat in the main channel and using the gravity sampler to probe the bottom.

Channel sampling was determined to be impractical with the available equipment (gravity sampler), and anchoring the boat in the swift water of the river channel was also a significant problem.

Another problem with characterization of the active bedload is that the particle size distribution is highly dependent on the velocity of the river water in the channel, and the grain size of an active bedload when the river flow is 18,000cfs is considerably different than when the flow is +30,000cfs.

It was decided that the best alternative to active bedload channel sampling was characterization of active sand/gravel bars and river bank deposits.

SAMPLING

Samples were collected at multiple locations in each area and composited. This resulted in one composite sample for Area One (the saltwater estuary) and one composite sample for Area Two (the freshwater river).

Area One (Estuary)

This area was selected as the most likely place in the lagoon and estuary where deposits of fine grain size sediment (silt and clay) would be deposited. Sediment for the composite Estuary Sample came from three locations, one along the downstream side of Safford Island and two along the southernmost bank of the Klamath River (Figures 10 and 11; and Photos 219 and 220). At Location 1A the material collected was predominantly fine grained Silty Sand (SM). At Locations 1B and 1C the material was predominantly Silty Sand (SM) to Sandy Silt s(ML), with a significant fines content (Photos 223 and 226). Combined together, material at these three locations is classified as a Silty Sand – SM with 42.7% low-plastic fines (Appendix C).

The geologic setting of samples collected from this area is a lagoon behind a barrier island. The first area to be sampled was on the lee-side of a large sand and gravel bar (Safford Island). The second area to be sampled was along the southern bank of the Klamath River, where irregularities in the river bank form small eddies that allow deposition of fines (Figures 10 and 11). One composite sample was made from material collected at these three locations.

Area Two (Freshwater River)

Sediment for the composite Freshwater River Sample came from two locations, about 4.9 miles and 7.0 miles upstream from the mouth of the river (Figures 12, 13, and 14).

The first location (2A) is on the inside bend of the river, along a prograding river bank. The river bank is currently undergoing active erosion, with new cutoff channels forming landward (Figures 13 and 18). Material sampled here was predominantly Poorly Graded Sand with Silt (SP-SM).

The second location (2B) is a sand bar next to the left (southern) bank of the river. The sand bar formed in an eddy, just downstream from a projection of bedrock into the river (Figures 12 and 14). Material sampled here was predominantly Poorly Graded Sand – SP. Combined together, material at these two locations is classified as a Poorly Graded Sand with Silt (SP-SM) with 7.8% nonplastic fines (Appendix C).

GEOCHEMISTRY OF THE SEDIMENT (ICP-MS METHOD)

Sediment sample analysis of sand size particles by "Total Digestion Induced Couple Mass Spectrometry" (ICP-MS) will break down and analyze all of the mineral grains that typically comprise sand. Mineral grains identified with a 10-power hand-lens that comprise sand size particles in samples from the Klamath River, include: feldspar, quartz, hornblende, pyroxenes, and mica plus a number of accessory minerals such as magnetite, ilmenite, chromite, sphene, and organic matter (Table 10). The elemental

chemistry comprising these and other mineral/rock grains will be reflected in the ICP-MS results.

Table 9. Location of samples collected from the Estuary and Lower Klamath River.				
Sample Number	**Type**	**Coordinates**	**Remarks**	
1A	Estuary	N 41° 32' 17.3" W 124° 04' 33.8"	Along the lagoon (downstream) side of Safford Island. Material is predominantly Silty Sand – SM.	
1B	Estuary	N 41° 32' 09.9" W 124° 04' 28.6"	Along the left (southern) bank of the river. Material is Silty Sand – SM to Sandy Silt s(ML).	
1C	Estuary	N 41° 32' 10.6" W 124° 04' 21.4"	Along the left (southern) bank of the river. Material is Silty Sand – SM to Sandy Silt s(ML).	
Composite 1A, 1B, and 1C	Percent Fines	Liquid Limit	Plasticity Index	Field Moisture
	42.7%	33.7	9.2	54.0
Sample Number	**Type**	**Coordinates**	**Remarks**	
2A	River (fresh water)	N 41° 31' 22.1" W 124° 00' 27.7"	Along the southern side of the river on the inside curve of a river bank. Material is mostly Poorly Graded Sand with Silt (SP-SM)	
2B	River (fresh water)	N 41° 30' 07.4" W 123° 59' 13.4"	Along the left (southern) side of the river in a sand bar against the river bank. Material here is predominantly Poorly Graded Sand – SP.	
Composite 2A and 2B	Percent Fines	Liquid Limit	Plasticity Index	Field Moisture
	7.8%	nonplastic	nonplastic	30.5
Elutriate Water Samples	Type	Coordinates	Remarks	
	Estuary	N 41° 32' 16.9" W 124° 04' 14.8"	About 1,400 feet upstream from sample location 1C in mid-channel	
	Fresh Water	N 41° 31' 22.1" W 124° 00' 27.7"	At sample location 2A, adjacent to the river bank.	

Table 10. Mineral grains comprising sand-size particles collected from freshwater and estuary sampling along the lower 7-miles of the Klamath River.		
Mineral Grain	Major Composition	Minor Composition and Trace Elements
Quartz	Si	Fe and Ti
Feldspar	Al, Ca, Na, and K	K, B, Ba and Rb
Pyroxenes	Al, Si, Mg, Fe, and Ca	Mn, Li, and Ti
Hornblende	Ca, Na, Mg, Fe, Al, and Si	F and Ti
Epidote	Ca, Fe, Mn, Al, and Si	
Mica (muscovite, biotite, & chlorite)	Si, Al, Mg, Fe, and K	Li, Ti and F
Accessory/Trace Minerals and Organics		
Sphene	Ca, Ti, and Si	Ba, Nb, Al, and F
Magnetite and Ilmenite	Fe and Ti	
Chromite and Rutile	Cr, Fe, and Ti	
Vegetation/Wood Fibers	C	
Common elements found in sand samples from the Lower Klamath River and Estuary expected to be released by "Total Digestion Induced Couple Plasma Mass Spectrometry" analysis include: Al Aluminum B Boron Ba Barium C Carbon Ca Calcium Cr Chromium F Fluorine Fe Iron, both Fe^3 and Fe^4 Li Lithium Mg Magnesium Mn Manganese Nb Niobium Rb Rubidium Si Silicon Ti Titanium and others (including aphanitic rock particles)		

RIVER GEOMORPHOLOGY

The lower seven miles of the Klamath River were examined during the sampling program. Following are some of the basic geomorphologic relationships that the river exhibits. Sediment load and grain size distribution are dependent on many of these relationships, and an understanding of the river geomorphology should help in modeling sediment transport.

The lower seven miles of the Klamath River is a "Confined River System" with a relatively steep gradient, and even though it is a full size river it has the morphology closest to an inter-montane stream. The Klamath River channel is largely confined by banks of hard bedrock that keep it from forming shallow braided channels. The river makes several large bends, but it has a sinuosity of less than 1.5 and is not classified as meandering. Most of the bends are controlled by local geology.

The Klamath River is relatively narrow, with a cross-channel width often between 650 to 800 feet, and locally up to 1,600 feet at large bends and where bank/bar erosion is active. The relatively narrow river banks and highly variable flow (commonly 18,000 to +30,000 cfs) make the river system "flashy", creating large variations in bedload capacity and bedload sediment gradations.

Upstream to downstream, along river banks and active in-river bars, sediments typical of "Cannes de Roche" cycles were exposed, or partly-exposed as a fining-upward sequence:

TOP	Erosional Surface
↑	Fm – massive fine sand and silt or clay.
	Sh St – cross-stratified sand overlain by horizontally stratified sand.
	Gm – horizontally stratified gravel or trough cross-stratified with horizontally stratified sand.
↓	
BOTTOM	Gt – clast supported, trough cross-stratified gravel

Typical River Banks and Bars Upstream from the Hwy 101 Bridge (freshwater)

- Gravel-dominated horizontally-bedded clast-supported locally-imbricate facies (Gm).
- Local clast-supported cobble and gravel deposits.
- River bank deposits prograde at bends in the river and are mostly composed of clast-supported gravel and cobbles with a sand matrix. This coarse material is overlain by lower-energy deposits of medium to coarse sand with very little silt and clay.
- Where gravel and cobble deposits are overlain by sand and silty sand, vegetation is abundant. Where erosion has exposed gravel and cobbles vegetation is poor.
- Every major prograding river bank in the lower seven miles of the Klamath River exhibits active cutoff channel erosion, which may reflect the large variations in river flow.
- Local deposits of sandy matrix-supported non-imbricate gravel and cobbles probably represent transport during high river-flow and flood events.

Typical River Banks and Bars Downstream from the Hwy 101 Bridge (brackish to saltwater)

- Predominantly massive to horizontally-stratified sand and silty sand, locally with matrix-supported gravel and cobbles.
- Significant areas of horizontally-stratified matrix-supported sandy gravel, locally with trace cobbles within one mile of the mouth of the river.

River Mouth

- The mouth of the Klamath River is characterized by a wave-dominated delta with a large barrier island parallel to the coast line. Behind the barrier island is a shallow lagoon about 2,500 feet long by less than 1,000 feet wide.
- The lagoon and estuary near the mouth of the river is not what many people envision as a "typical" lagoon and estuary system with broad mud flats and large highly-vegetated swampy areas in a quiescent river system. Instead, **the mouth of the Klamath River is highly dynamic, changing positions during large flood events, and transporting most of its suspended load of silt and clay out to sea**. The very limited size lagoon (locally called the South Slough) is dominated by deposits of medium grained sand and silty sand with only very local accumulations of fines.
- The Klamath River system appears to be too dynamic to have developed organic-rich sand silt and clay deposits found in "typical" lagoons.

CONCLUSIONS

- The lower seven miles of the Klamath River system is currently a dynamic medium to high energy environment. It is a confined river system capable of transporting a medium to coarse particle size bedload.

- Suspended sediment in the river, composed of silt and clay size particles, is mostly transported out to the Pacific Ocean. Where deposits of silt and clay are present in the river they are of limited size in small eddies and backwaters (micro-depositional environments) and do not form aerially extensive deposits. Additionally, the medium to high energy of the river and its "flashy nature" changes local depositional environments regularly. Deposits of fine grain size sediment present today may be washed away during the next high-flow or flood event.

- A barrier island and back-island lagoon are present at the mouth of the river. The lagoon is relatively small and does not host mud flats or other quiet-water environments typically needed for deposition of fine grained sediment (silt and clay).

- The mouth of the Klamath River is highly dynamic and can change positions during large flood events. Local residents of the town of Klamath remember the mouth of the Klamath River discharging through the southern end of the barrier island. Today it is discharging through the northern end of the island.

- Sediment sample analysis of sand size particles by "Total Digestion Induced Couple Mass Spectrometry" (ICP-MS) will break down and analyze all of the mineral grains that typically comprise sand, including: feldspar, quartz, hornblende, pyroxenes, and mica plus a number of accessory minerals such as magnetite, ilmenite, chromite, sphene, and organic matter. The elemental chemistry comprising these and other mineral/rock grains will be reflected in the ICP-MS results.

Lower Klamath River and Estuary

River Bank and Bar Characterization

*Left and right banks of the river are designated by looking downstream.

Field Note	Remarks
A	At sample Location 2B (Figure 15; Photos 232, 233, and 234). Small sand bar deposited in the downstream eddy that is created by bedrock along the southern (left) bank extending out into the river. Bedrock is also present along the left bank of the river downstream from this location. The sand bar is composed mostly of medium grain size sand with about 5% nonplastic fines. Across the river from this location the right bank of the river is composed of fine to coarse gravel with sand. Inland the gravel is overlain by 2 – 4 feet of sand (Photos 235 and 236).
B	Northern (right) side of the river (Figure 16; Photo 240). Gravel bar and river bank along the inside of a bend. The material is mostly composed of fine to mostly coarse gravel with sand. The gravel bar extends both upstream and downstream at least a few thousand feet, and appears to form the right bank of the river.
C	Southern (left) side of the river (Figure 16; Photos 237, 238, and 239). Large gravel bar formed in the Klamath River near the mouth of McGarvy Creek. The gravel bar is mostly composed of coarse gravel that was massively deposited with little layering (Photo 239). The gravel bar extends from the mouth of McGarvy Creek for several hundred feet into the main river channel. Bedrock crops out along the left bank of the river downstream from McGarvy Creek (Photo 242).
D	Northern (right) side of the river just downstream from Field Note B (Figure 16; Photo 241). This is a gravel bar and river bank along the inside of a bend. The material is composed of fine to mostly-coarse gravel with sand and trace cobbles. A small borrow area here is used by locals to obtain gravel and sand.
E	Southern (left) side of the river (Figure 17; Photos 243 and 244). View of the upstream end of a large prograding river bank cutoff channel starting to form. The river has eroded vegetation and exposed cobbles and gravel

(Photo 244). Where erosion has not taken place yet these coarse deposits are overlain by sand.

F Northern (right) side of the river at the mouth of Terwur Creek (Figure 17; Photos 245 and 246). Coarse deposits of gravel with sand and trace cobbles comprise a bar on the downstream side of the creek mouth. Deposits of sand overlie gravel along the river bank and extend landward.

Downstream from Terwur Creek to Field Note G, and extending downstream towards Hwy. 101, bedrock crops out along the northern (right) side of the river.

G Southern (left) side of the river along the prograding river bank (Figure 18; Photos 247, 248, and 249; also Photos 227 – 231). Throughout this area coarse deposits of gravel with sand and cobbles are overlain by deposits of sand (SP-SM). Where sand is present vegetation is lush, locally with trees up to 40 feet high). Gravel and cobbles are generally exposed where erosion has removed the sand. At sample location 2A there two thin (1/4-inch) layers of silt separating Poorly Graded Sand with Silt (SP-SM).

H View of a sand and gravel bar about 2,000 feet upstream from the Hwy. 101 bridge (Figure 19; Photo 250). This bar may be a recently eroded remnant of what was originally the left bank of the river. The upstream end of the bar is composed primarily of 3- to 5-inch cobbles with gravel and the downstream end is composed mostly of interbedded sand and gravel.

Estuary to Freshwater Transition about 2,000 feet Upstream from Hwy 101 Bridge
The downstream end of the gravel bar in Field Note H is a transition section of the Klamath River bedload, with predominantly coarse deposits of gravel and cobbles with sand upstream and finer deposits of sand and gravel downstream. Wildlife biologists with the Yurok Tribe denote this general location as the transition between salt/brackish water of the estuary downstream of the gravel bar and fresh water upstream.

On the southern (left) side of the river, about 2,500 feet downstream from the Hwy. 101 bridge, a recent landslide shows the continual addition of mass wasting deposits to the river (Photo 33).

I Along the northern (right) bank of the river near the town of Klamath (Figure 20; Photo 252). The river bank is composed of fine to coarse gravel and sand, overlain by finer grain size deposits of sand. Vegetation is mostly within the deposits of sand.

J	Downstream from Field Note I along the northern (right) bank of the river (Figure 20; Photo 253). Exposures along the river bank show interbedded lenses of sand and predominantly fine gravel.
K	Left bank of the Klamath River at the upstream end of Safford Island (Figure 21; Photos 254 and 255). This is a currently eroding cutoff channel exposing fine to coarse gravel with sand.
L	Right bank of the Klamath River near the town of Requa (Figure 21; Photo 256). The riverbank is comprised of fine to coarse gravel with sand and trace small cobbles, locally overlain by deposits of sand.
M	Upstream side of Safford Island (Figure 21; Photo 257). Fine to coarse gravel, predominantly fine gravel with sand.
N	Upstream side of Safford Island (Figure 21; Photo 258). Predominantly sand with local accumulations of gravel and trace cobbles.
O	Northern side of Safford Island (Figure 21; Photo 259). Predominantly sand with very minor gravel. The area is densely vegetated with few geologic exposures.

Lower Klamath River
and
Estuary

Figures 10 – 21

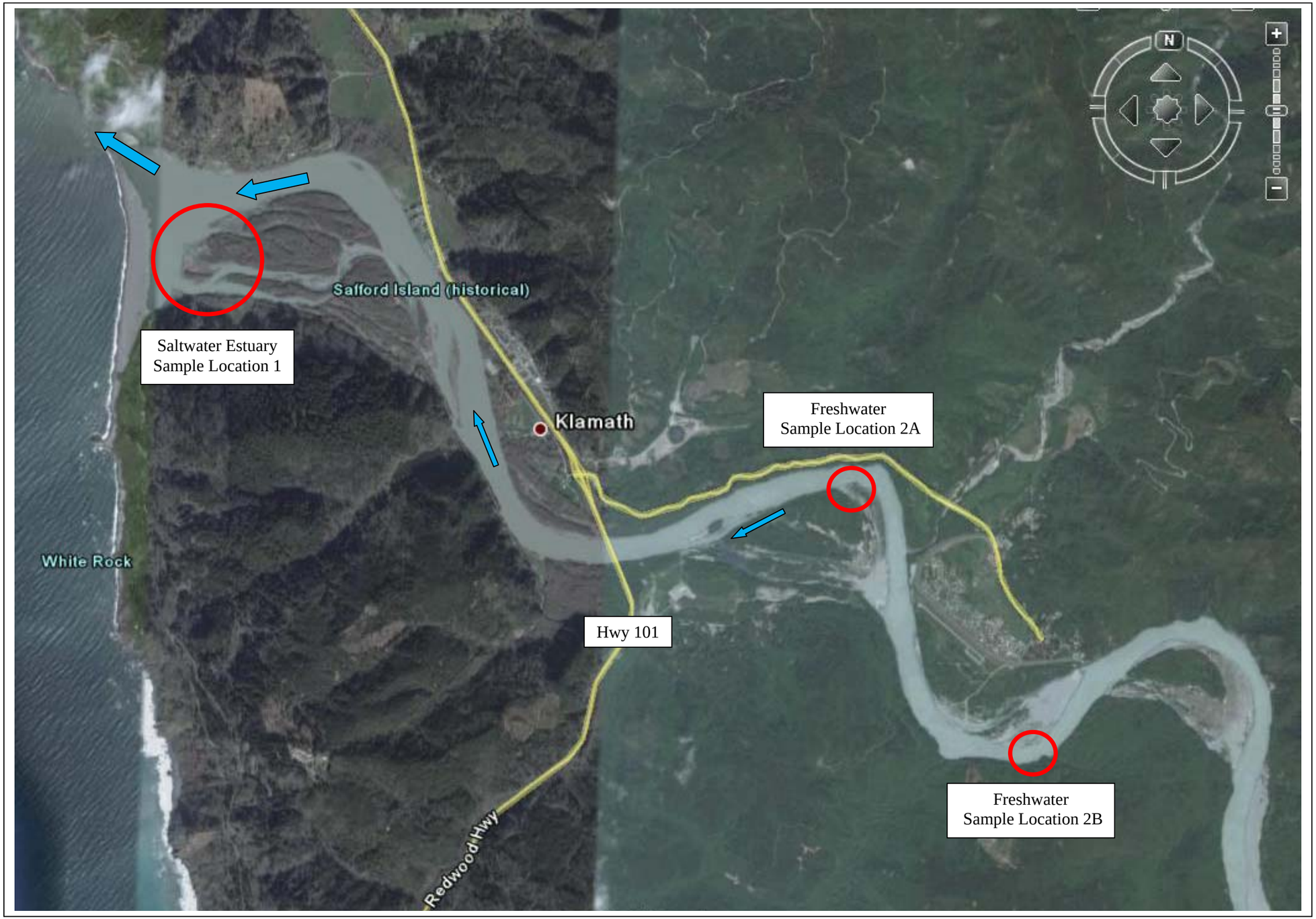

Figure 10. Location map of sample collection areas along the lower seven miles of the Klamath River. In the saltwater estuary (Area 1), samples were collected from three locations and composited into one sample (Figure 11). In the freshwater section of the river samples were collected from two locations (2A and 2B) and composited into one sample. Google Earth Image.

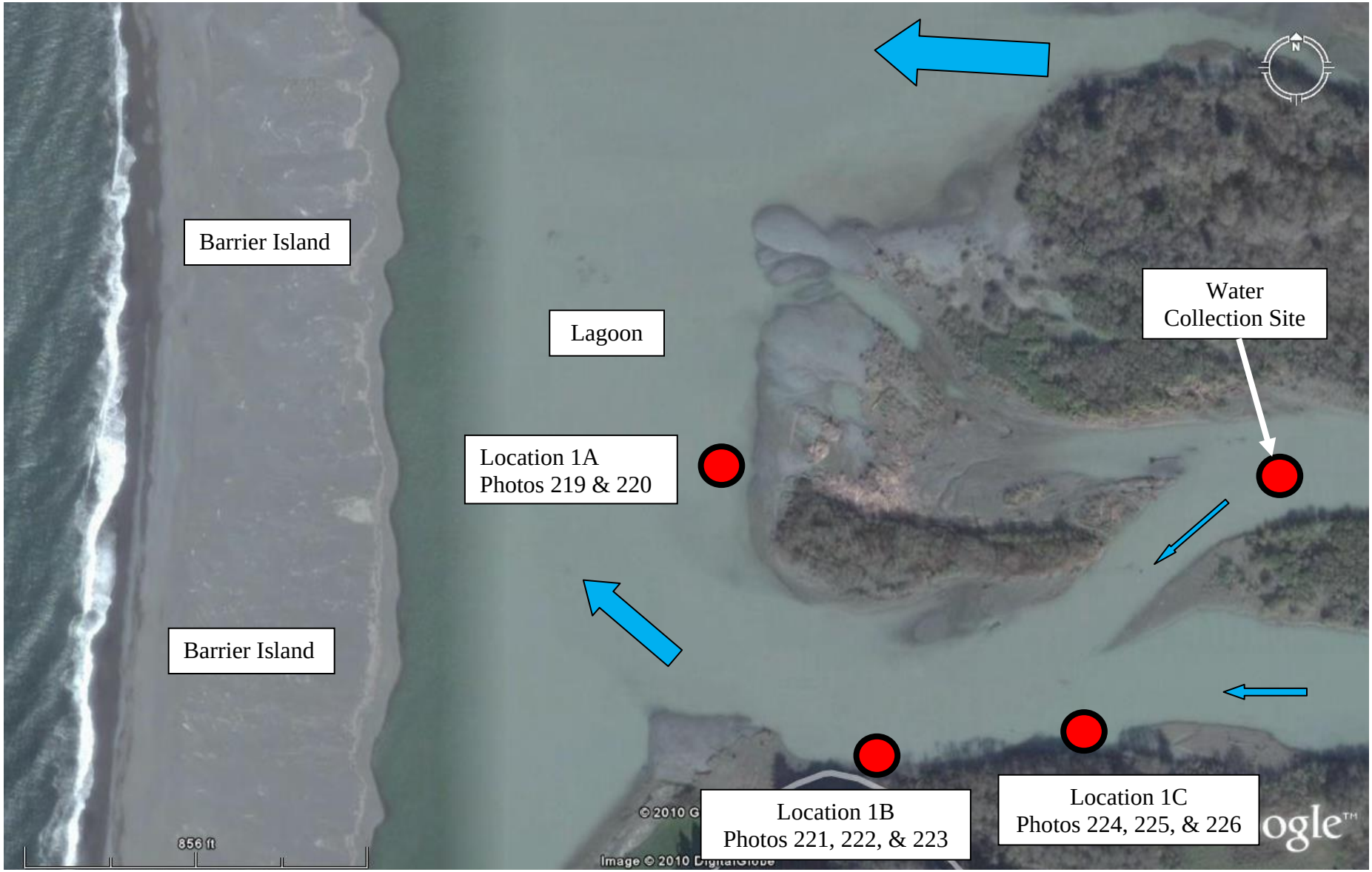

Figure 11. Location of samples collected in the saltwater estuary near the mouth of the Klamath River. A composite sample from these three locations was sent to Reclamation's Mid-Pacific Construction Office Materials Laboratory. The composite sample was Silty Sand – SM and contained 42.7% fines (including 8.7% clay size), 55.1% sand, and 2.2% gravel with a Liquid Limit of 33.7%, a Plasticity Index of 9.2%, and a Field Moisture content of 54.0%. Google Earth Image.

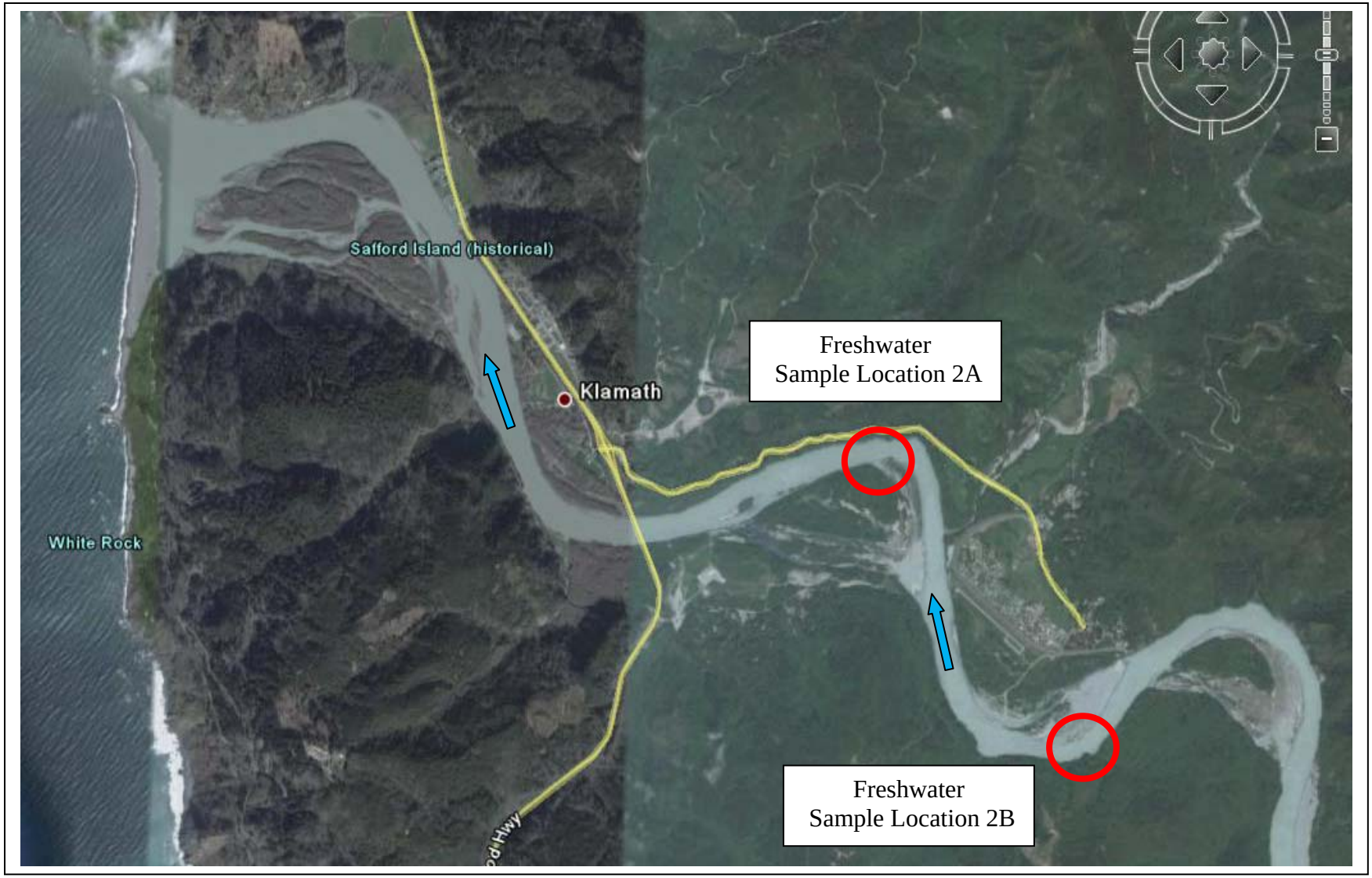

Figure 12. Location of fresh water sediment samples collected from the Klamath River. A composite sample from these two locations was sent to Reclamation's Mid-Pacific Construction Office Materials Laboratory. The composite sample is a Poorly Graded Sand with Silt (SP-SM) and contains 7.8% nonplastic fines (including 1.4% clay size) and 91.5% sand, with a Field Moisture content of 30.5%. Google Earth Image.

Figure 13. Freshwater composite sample Location 2A and elutriate water collection site on the Klamath River, about 1.25 miles upstream from the Hwy. 101 bridge crossing (Figure 10). Google Earth Image.

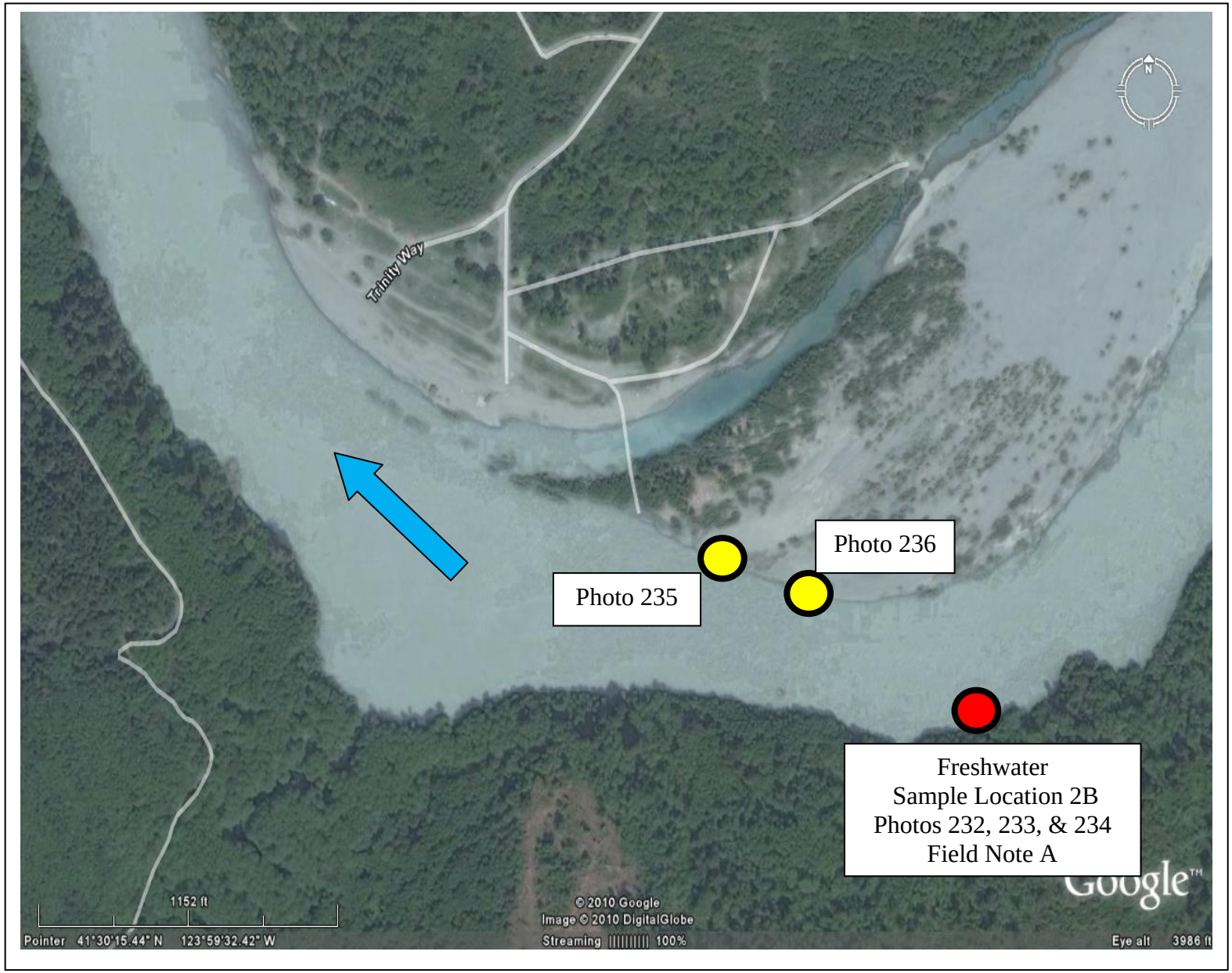

Figure 14. Location of sample 2B, field note A, and Photos 232 – 236, about 7 miles upstream from the mouth of the Klamath River. Google Earth Image.

Figure 15. Composite sample Location 2B and Field Note A along the southern side of the Klamath River (Figures 12 and 14). The material is Poorly Graded Sand with Silt (SP-SM) that formed a sand bar downstream from a bedrock point. Sampling was accomplished with both a shovel and a push-tube sampler. Photo by M. McCulla, 1-12-2010.

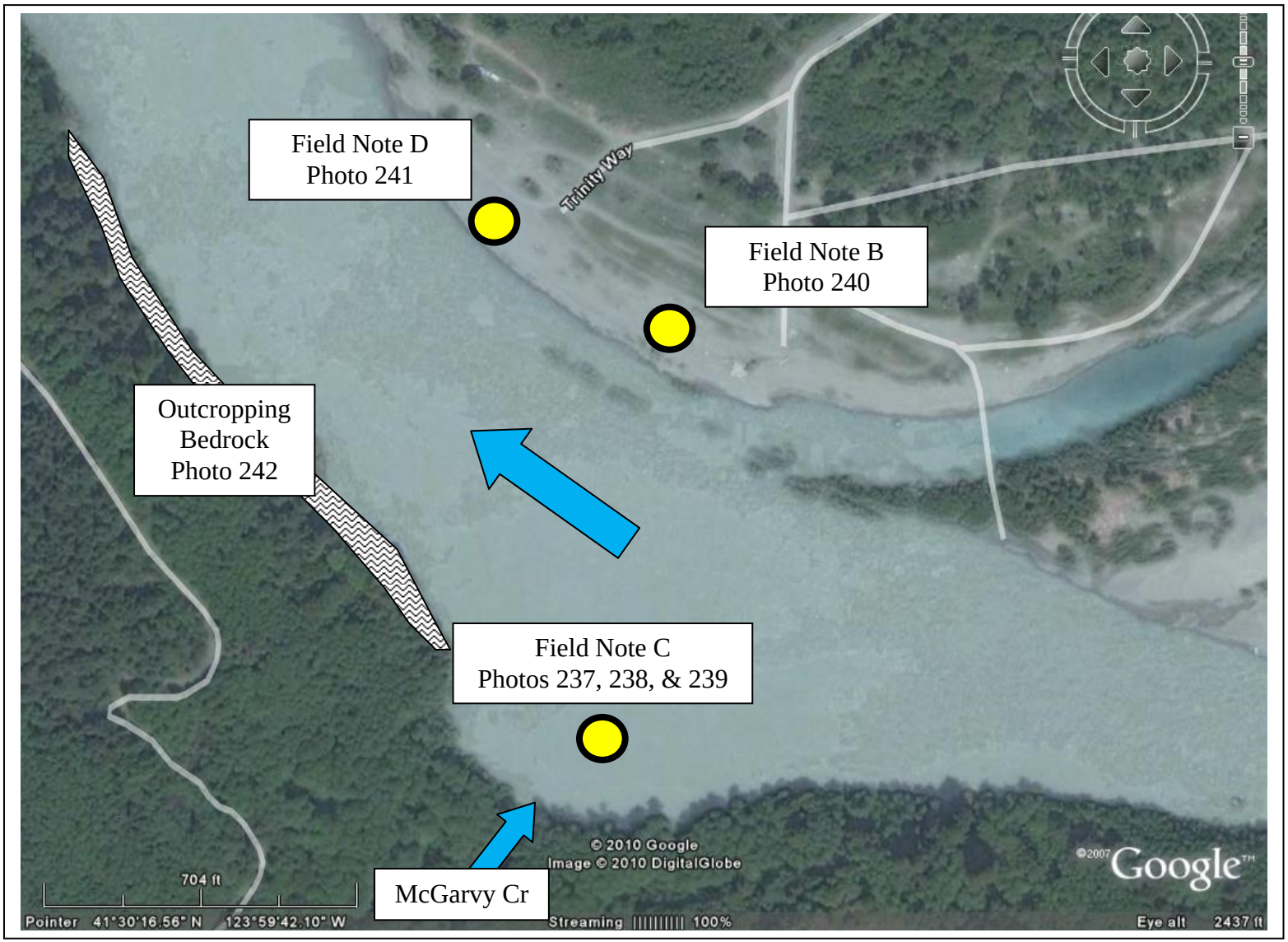

Figure 16. Location of Field Notes B, C, and D and Photos 237 through 242, along the Klamath River, about 3 miles upstream from the Hwy. 101 bridge.

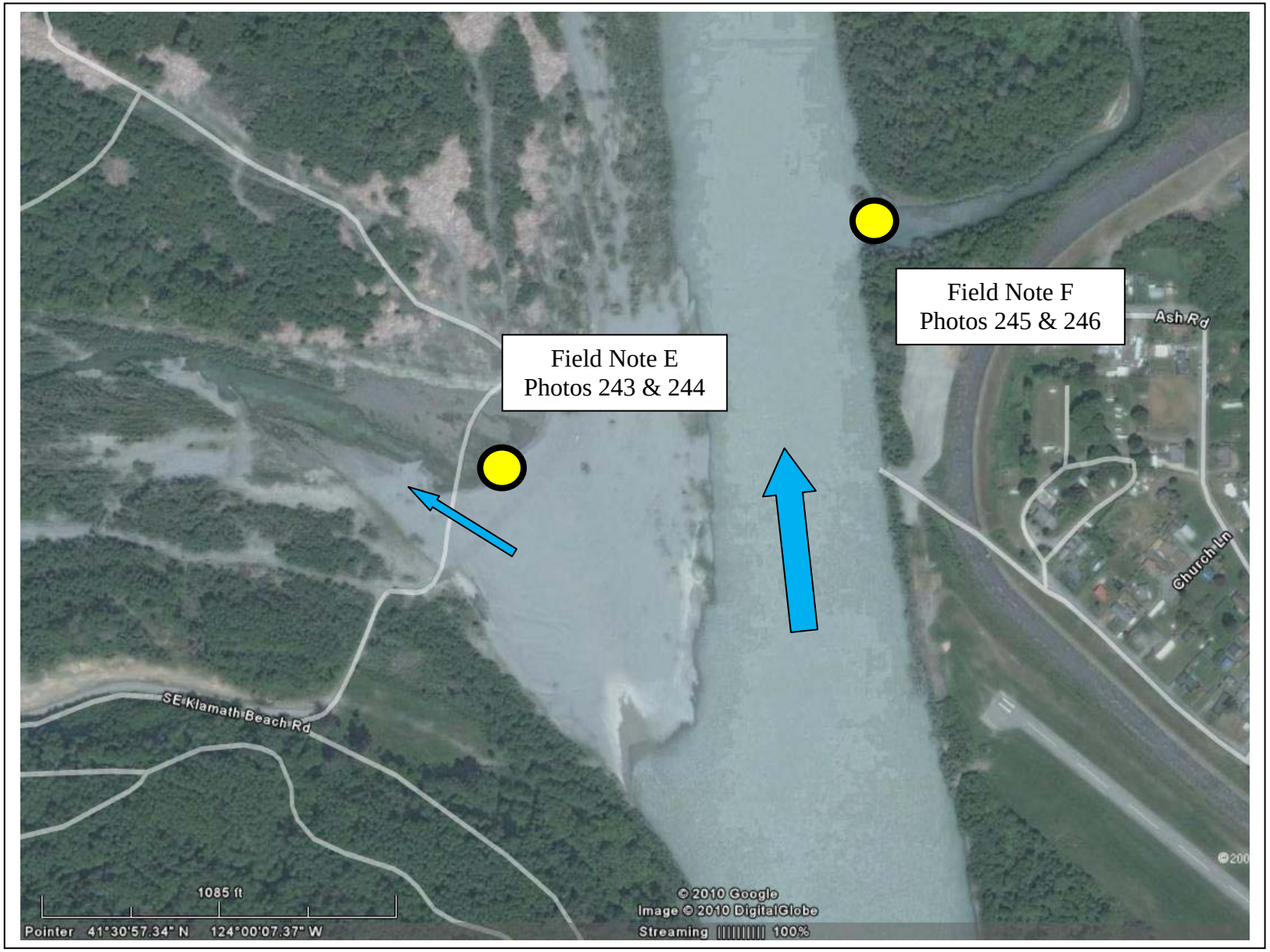

Figure 17. Location of Field Notes E and F and Photos 243 – 246, near Klamath Glen on the Klamath River. Google Earth Image.

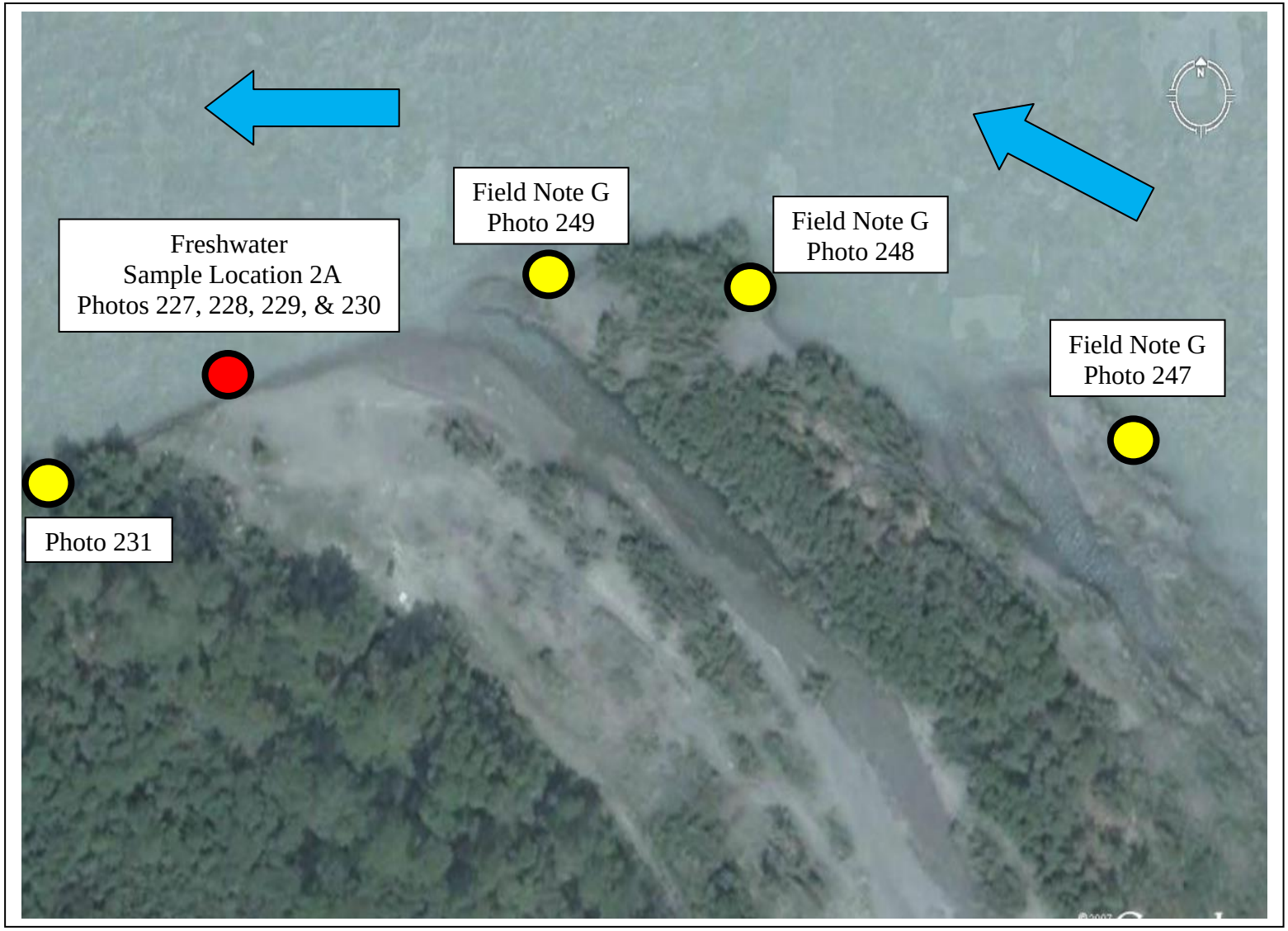

Figure 18. Location of Field Note G and Photos 227 – 231 and 247 – 249, and sample Location 2A on the southern side of the Klamath River. Vegetated areas generally indicate deposits of sand, and gray areas outside of the water generally indicate coarse deposits of gravel and cobbles. Google Earth Image.

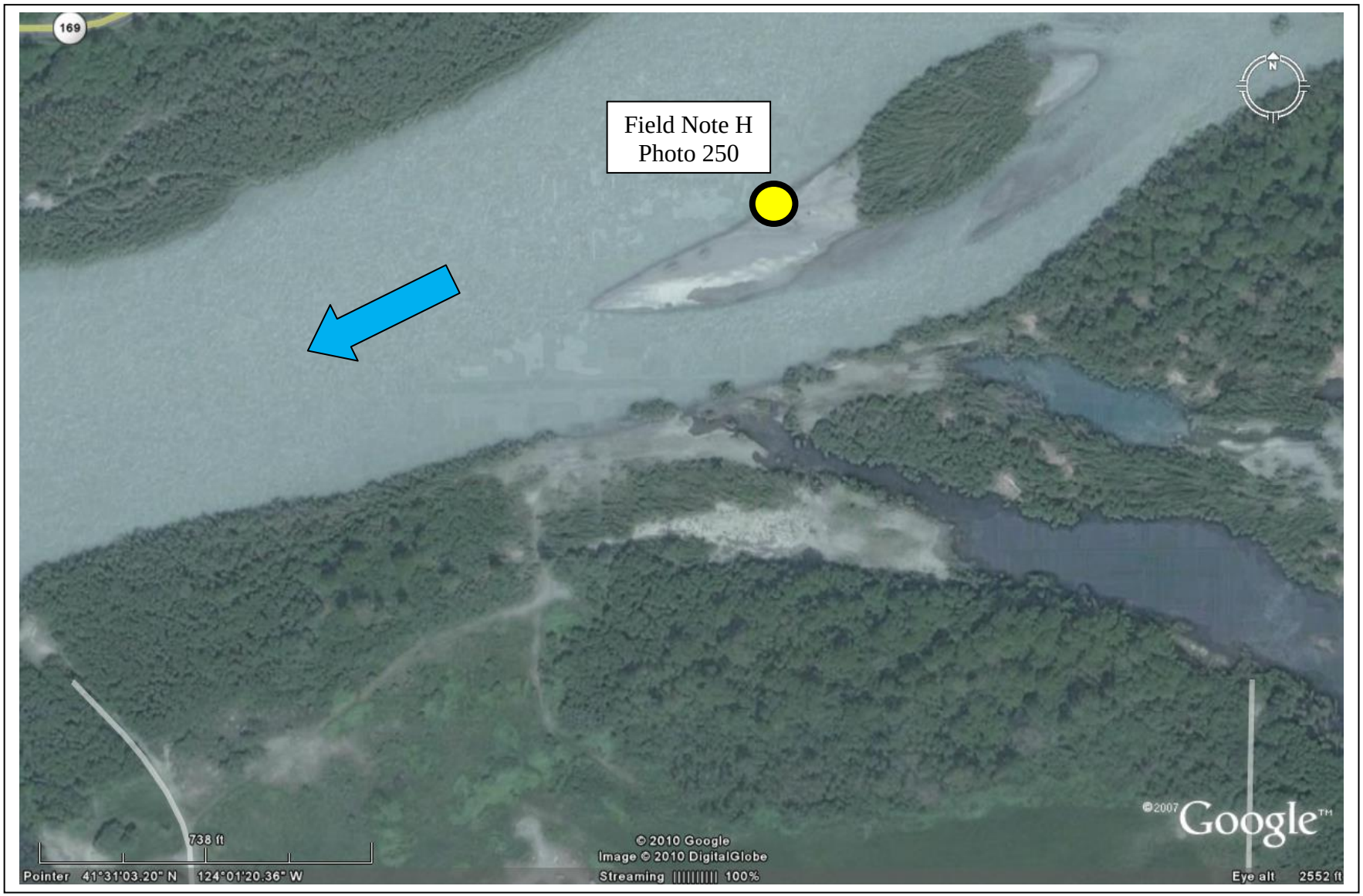

Figure 19. Location of Field Note H and Photo 250 on the Klamath River. Google Earth Image.

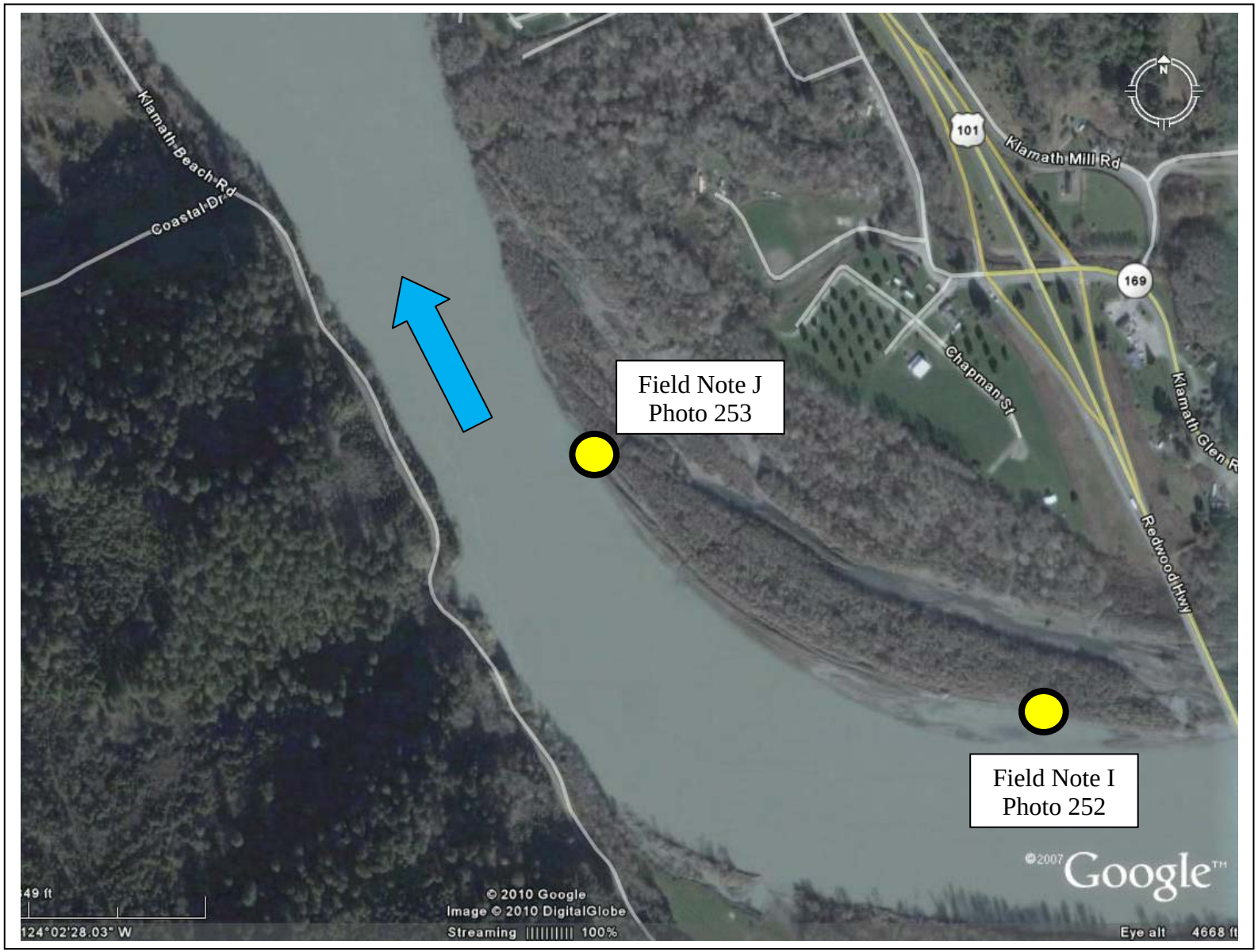

Figure 20. Location of Field Notes I and J, and Photos 252 and 253, along the northern (right) bank of the Klamath River, near the town of Klamath. Photo by M. McCulla, 1-12-2010.

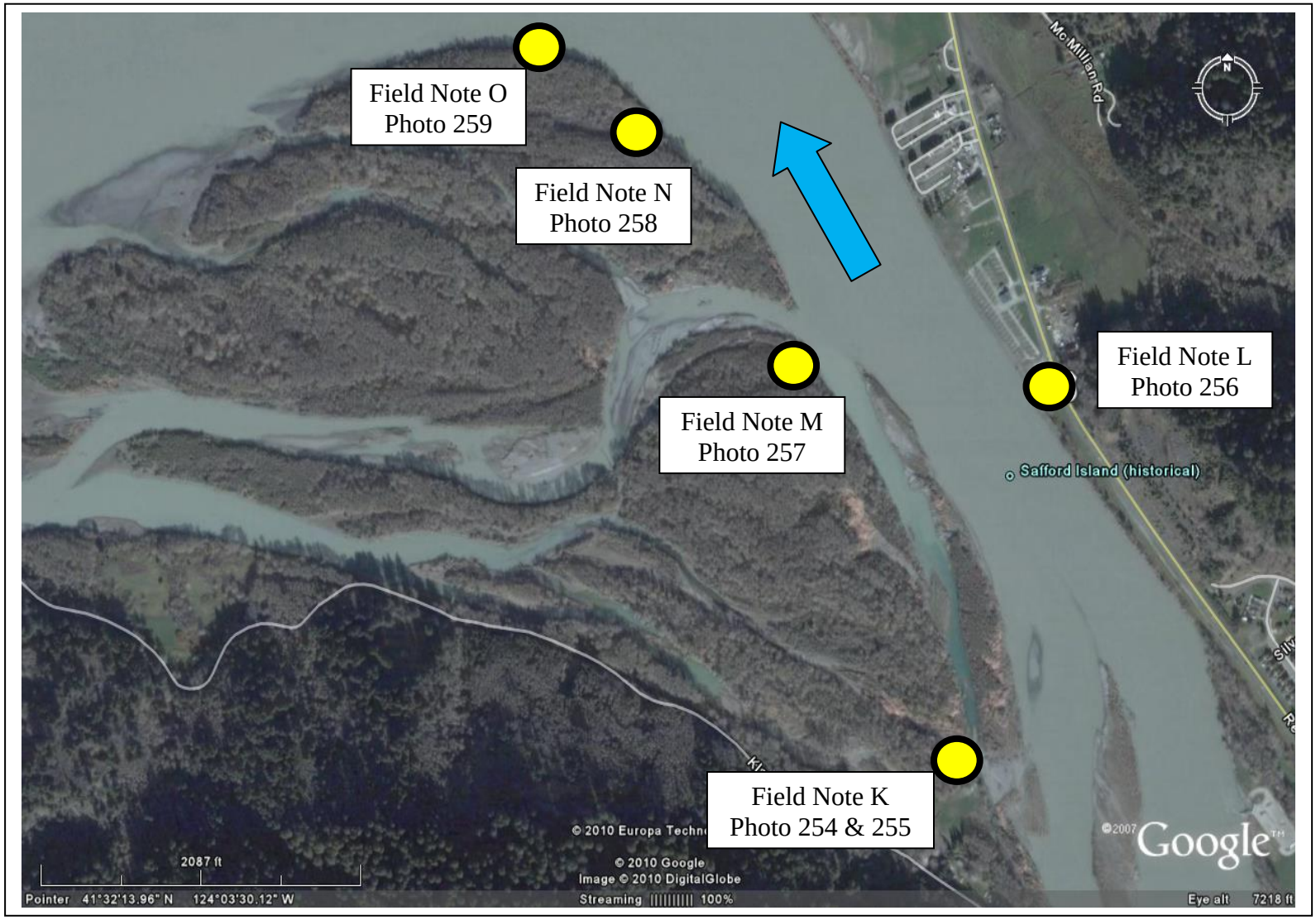

Figure 21. View of Field Note Locations K, L, M, N, and O and Photos 254 – 259, of the banks of the Klamath River near the town of Requa. Google Earth Image.

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9. August 2010 – Quality Assurance Project Plan, Sediment Contaminant Study, Klamath River Sediment Sampling Program, JC Boyle, Copco-1, Copco-1, and Iron Gate Reservoirs; Klamath River Estuary, Revision 2: August 2010 – Reclamation, Mid-Pacific Region, Branch of Environmental Monitoring, MP-157.

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Appendix A

Field Exploration Request from Reclamation's Technical Service Center

June 25, 2009 DRAFT

TSC FIELD EXPLORATION REQUEST

REGION: Mid Pacific
PROJECT: Klamath Dams Removal Study
FEATURE: Klamath River Dams
DATE: May 28, 2009

PURPOSE: Design Data Collection
TSC COORDINATOR: Tom Hepler, 303-445-3261
CONTACT: Gary Turlington, 303-445-3203
DATA SUBMITTAL DATE: See Item No. E below

TEAM MEMBERS
T. Hepler D. Gore
M. McCulla T. Strauss
B. Greimann R. Kuzniakowski
G. Turlington G. Mongano

This Field Exploration Request (FER) is to gather feasibility design data for use in evaluating removing four dams (JC Boyle Dam, Copco Dam, Copco 2 Dam, and Iron Gate Dam) on the Klamath River, and an alternative to retain those dams in place and provide fish passage structures. Objectives include obtaining geologic and geotechnical data on 1) the damsites, 2) reservoir sediment, 3) soil and rock borrow areas, 4) potential waste disposal areas, and 4) obtaining topographic data at the dams, reservoir bathymetry, and along potential haul road alignments and waste disposal sites. When data collection is complete, compile the geologic and geotechnical data in a report(s) of exploration activities with geologic and geotechnical description of engineering properties.

Item No.	Description	Location	Size	Depth	Sampling	Instrumentation or In Situ Testing	Remarks
A	Records Search						Purpose: Locate existing geologic/geotechnical data for JC Boyle, Copco, Copco 2, Iron Gate and Keno Dams for potential feasibility-level modifications designs for dam removal. Requirement: Review all available Reclamation, MP Region, Klamath Basin Area Office, PacifiCorp and its consultants, California Coastal Conservancy and its consultants, Federal Energy Regulatory Commission, and other Federal and State agencies or local sources for pertinent information concerning site design data including: • geologic and geotechnical information • potential commercial construction (borrow) materials sources; concrete aggregate and embankment (coffer) dam materials availability, haul distances, haul routes, environmental and social impacts, costs, etc. • original construction-era reports with sampling and laboratory test results on earth and concrete materials • results of exploration programs • strength, materials properties, and as-built geometry of the concrete arch dams

Item No.	Description	Location	Size	Depth	Sampling	Instrumentation or In Situ Testing	Remarks
							• potential upstream contaminant sources • existing data reports/exploration programs on contaminant investigations • pre-dam topography • listing of and information on existing water wells downstream of the dams to the coast, including water rights • any other data the field determines could be useful to analyses and design.
B	Site Topography						Obtain or generate topographic coverage and maps for the sites (dam sites, reservoirs, haul road alignments, waste disposal areas, tributary streams). Map scales should be 1”=100’ for the entire area and 1”=50’ for the immediate vicinity of the dams in AutoCAD format. Obtain or generate approximate reservoir bathymetry, including extending 200 feet up tributaries beyond the limits of each reservoir.
C	Geologic Mapping	JC Boyle Dam, Copco Dam, Copco 2 Dam, and Iron Gate Dam, Haul Roads, and Waste Disposal Areas	1 inch represents 200 feet				Purpose: The primary purpose of geologic mapping is to collect geologic and geotechnical data to enable design of fish passage structures and optimum siting of subsurface explorations based on knowledge of site geology. Requirement: Perform geologic mapping prior to initiating subsurface explorations along haul roads and in waste disposal areas. Prepare the results of geologic mapping as a plan drawing(s) and cross sections and include in the final report (Item G below).
D	34 Total Drill Holes in Reservoirs (10 to 12 additional drill holes could be added depending on results, increasing the total number of drill holes to 46):	See attached location maps Initiate drilling/sampling at Boyle Dam reservoir	Hollow stem auger/HQ; minimum size 2.5 inch diameter	25 feet	Collect continuous samples		Purpose: The primary purpose of these drill holes is to obtain engineering geologic descriptions of units/formations in the reservoirs and to collect samples for laboratory testing (engineering physical properties and contamination). The exploration and sampling program should verify results from previous explorations and obtain engineering properties of sediment within the reservoirs. Additional purposes include: • Identification of potential project sediment impacts for each alternative. • Develop cross sections for use in hydraulic model. • Calculations of sediment transport under existing conditions. • Inventory fine and coarse sediment sources to determine

Item No.	Description	Location	Size	Depth	Sampling	Instrumentation or In Situ Testing	Remarks
	- 22 drill holes to identify engineering properties and potential contaminants. - 12 drill holes to determine field and laboratory erodibility of sediment/soil						background sediment loads. • Assessment of fines within river bed material. • Compute engineering properties of reservoir sediment including erosive characteristics, how quickly the sediments drain, consolidation characteristics, ability to support vegetation, and estimate erosion rates of reservoir sediment. • Support site restoration design. • Quantify impact to infrastructure upstream of each dam due to erosion after dam removal Requirement: Determine depth to and elevation of top of bedrock. Determine engineering properties of alluvium. Collect samples suitable for laboratory testing for standard engineering properties and potential contamination. Laboratory testing of samples will be performed by the Reclamation Materials and Engineering Research Laboratory (MERL) and by the USDA under contract with the National Sedimentation Laboratory (NSL). Field explorations require NEPA compliance activities, permitting, and site access to perform drilling and sampling. Explorations require over-water (barge) access and some may require pioneering access roads. Conduct all aspects of drilling and sampling with careful attention to detail and proper procedure in accordance with the Earth Manual, Part 2, Third Edition, Bureau of Reclamation, 1990. Backfill explorations in accordance with state of Oregon and Reclamation guidelines and landowner requirements. Perform a visual classification and description of the soils obtained from the sampler. 1/, 2/, 3/, 4/
E	Observation Wells – up to 30 wells	To be determined		30 feet			Purpose: Determine impacts of lower water levels resulting from drained reservoirs on the groundwater table and private property owners water wells. Requirement: Depending on results of Item A. Records Search, drill and install observation wells to monitor relationship between river stage and shallow aquifers adjacent to reservoirs. Fewer wells are required to be installed if the Records Search and contact with private

Item No.	Description	Location	Size	Depth	Sampling	Instrumentation or In Situ Testing	Remarks
							land owners allows the government the use of private owners existing wells to monitor changes in groundwater levels.
F	River Bathymetry	Between JC Boyle and Copco I, and From Iron Gate to at least 10 miles downstream				ADCP or depth sounder mounted from boat	Purpose: River bathymetry is necessary to determine the flow hydraulics in the river reaches. The flow hydraulics are important to fish habitat, sediment transport and water quality. Requirement: An Acoustic Doppler Current Profiler or depth sounder mounted from a boat used to obtain cross sections and river profile data for at least 10 miles downstream of Iron Gate Dam. The cross sections should be placed at critical sections to be determined. Up to 100 cross sections will be obtained. A river profile will be obtained to determine the approximate thalweg elevations in the reach.
G	Reservoir Sediment Thickness	JC Boyle, Copco I, and Iron Gate Reservoir				Low frequency depth sounder mounted from boat	Purpose: Previous studies have had difficulty determining sediment thickness in the reservoir. Therefore, there is considerable uncertainty regarding the reservoir volume. This method may help quantify the amount of sediment. Requirement: A low frequency depth sounder will be used to determine the sediment thickness at JC Boyle, Copco I, and Iron Gate reservoirs. A minimum of 10 cross sections within each reservoir will be collected in addition to a profile along the deepest section of the reservoir.
H	River bed material	Downstream of JC Boyle, 0 to 10 miles Downstream of Iron Gate				Hand shovels and field sieves	Purpose: The gradation of the river bed material is important in determining sediment transport characteristics with or without dam removal. Requirement: Sample river bed material downstream of JC Boyle and Iron Gate dams to determine its gradation. Sample both fine and coarse material. The fine material will be sent to a laboratory to determine particle size distribution and organic content. The coarse material can be sieved and weighed in the field. If the material is too large to transport, a pebble count procedure should be performed.
I	Suspended Sediment concentrations	a. Downstream of Keno b. Downstream of Iron Gate c. Locations				Pump or standard USGS suspended sediment sampling equipment	Purpose: Current suspended sediment samples are necessary to determine the relative impact of the sediment loads following dam removal. Requirement: The data collection could be accomplished by USGS or other adequately trained regional personnel. Samples would be

Item No.	Description	Location	Size	Depth	Sampling	Instrumentation or In Situ Testing	Remarks
		upstream and downstream of Scott River d. Tributary sediment loads					collected primarily during high flows or a pump sampler will be used to collect more frequent information at a point in the cross section.
J	Klamath River Estuary Contaminant Sampling	Klamath River Estuary					Purpose: The primary purpose of the sampling is to obtain baseline data on existing contaminants/toxicity within the estuary prior to removing dams. Requirement: Collect sediment samples from the bottom of the Klamath River estuary in both the marine and fresh water environments. Samples will be collected using a purpose-built, push-tube type sampler operated from a small boat. Sample collection will be advanced with manual pressure to refusal.
K	Geologic Report						Prepare a geologic data package for the explorations (JC Boyle Dam, Copco Dam, Copco 2 Dam, and Iron Gate Dam, haul roads, and waste disposal areas). The data package should include a geologic map of each dam and reservoir site. The report should be a complete and concise documentation of field explorations and include exploration drill hole data, geologic descriptions, interpretations, plan drawings, cross sections, photographs, and any additional data the field determines could be useful for site selection and design. A draft report is due 11/30/09. The final report is due 1/31/10. Five copies of the draft report should be submitted to the TSC (86-68320) for use, review, and comment. Seven copies of final report should be transmitted to the TSC.

1/ All drilling, piezometer installations, and permits should comply with State and Federal regulations and Reclamation guidelines.
2/ Log drill holes in accordance with Reclamation's Engineering Geology Field Manual, 2nd Edition, 1998.
3/ At completion, survey location, ground elevation, and elevation at top of pipe at each drill hole, as appropriate. All boreholes should be backfilled or securely capped upon completion of installation.
4/ As drilling progresses, select representative samples for materials laboratory testing and ship to the Technical Service Center for laboratory testing:
US Bureau of Reclamation
Denver Federal Center
Building 56 Door S-6 for personal delivery (phone mounted on outside wall)
Building 67, Mail Room for small UPS type boxes.
Denver Colorado

Appendix B

Drill Hole Logs and Cross Sections

J.C. Boyle Reservoir

Geologic Logs and Cross Sections

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-2

FEATURE: KRSS
LOCATION: J. C. Boyle Reservoir
BEGUN: 10/15/09 FINISHED: 10/15/09
RESERVOIR WATER DEPTH: 11.8

PROJECT: Klamath
COORDINATES: N 42° 08' 49.6" W 122° 02' 10.8
TOTAL DEPTH: 6.2-ft.
RESEVOIR SEDIMENT THICKNESS: 5.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3790.8-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J.C. Boyle Reservoir. Located at the upstream-most site that the drilling-barge could access (about 4,600 feet upstream from the Hwy 66 Bridge), adjacent to drill holes EDH-09-1 and EDH-09-1A.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	5.4	**9.3**	14.7	85.3	0	NP	NP	46.2	SM	3788.2	Qr
	5.2	**10.3**	15.5	84.5	0	NP	NP	49.2	SM	3785.8	Qr
5											Qal

BOTTOM OF HOLE: T.D. 6.2-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 5.0 feet
RESERVOIR SEDIMENT - Qr

0.0 to 2.6 ft.: SILTY SAND, SM: About 85% fine to medium sand; about 15% nonplastic fines; maximum size medium sand; wet, dark gray; abundant wood chips up to 25mm; no reaction with HCl.

2.6 to 5.0 ft: SILTY SAND, SM: About 85% fine to medium, mostly medium sand; about 15% nonplastic fines; maximum size medium sand; wet, dark gray; no reaction with HCl.

5.0 to 6.2 feet
QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)

5.0 to 6.2 ft.: SILTY GRAVEL WITH SAND, (GM)s: About 45% fine to coarse, subangular to subrounded, hard gravel; about 40% medium to coarse sand; about 15% nonplastic fines; maximum size 75mm; wet, light gray; no reaction with HCl.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-2

FEATURE: KRSS
LOCATION: J. C. Boyle Reservoir
BEGUN: 10/15/09 FINISHED: 10/15/09
RESERVOIR WATER DEPTH: 11.8

PROJECT: Klamath
COORDINATES: N 42° 08' 49.6" W 122° 02' 10.8
TOTAL DEPTH: 6.2-ft.
RESEVOIR SEDIMENT THICKNESS: 5.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3790.8-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
3,790.8 feet (10/15/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
14.5 feet (water depth 11.8 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run:

Attempt 1 0.0 to 2.6 feet - auger sampling only recovered the bottom 1.3 feet of material (recovery 50%). A gravity sampler with a 2-5/8 inch i.d. lexan liner was used to collect the upper 1.3 feet of reservoir sediment.

Attempt 2 2.6 to 6.2 feet - flight augers were set to a depth of 2.6 feet and the 5 foot sample barrel on NWJ rods was hammered to a depth of 6.2 feet using a 140 pound weight; recovering 1.8 feet of material.

Contaminant Sampling was then carried out by MP-157 personnel. A gravity sampler with 2-5/8 inch i.d. lexan liner was used to collect the additional volume of reservoir sediment required for all analyses.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-2

FEATURE: KRSS
LOCATION: J. C. Boyle Reservoir
BEGUN: 10/15/09 FINISHED: 10/15/09
RESERVOIR WATER DEPTH: 11.8-ft.

PROJECT: Klamath
COORDINATES: N 42° 08' 49.6" W 122° 02' 10.8
TOTAL DEPTH: 6.2-ft.
RESEVOIR SEDIMENT THICKNESS: 5.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3790.8-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION: The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
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GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-3

FEATURE: KRSS
LOCATION: J. C. Boyle Reservoir
BEGUN: 10/15/09 FINISHED: 10/15/09
RESERVOIR WATER DEPTH: NA

PROJECT: Klamath
COORDINATES: N 42° 08' 33.7" W 122° 02' 07.5"
TOTAL DEPTH: 6.3-ft.
RESEVOIR SEDIMENT THICKNESS: 6.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3791.3-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY:

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J.C. Boyle Reservoir. Located about 3,000 feet upstream from the Hwy 66 Bridge and adjacent to drill holes EDH-09-2 and EDH-09-2A.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
5	18.1	**32.1**	50.2	49.8	0	NP	NP	229.8	s(ML)	3785.4	Qr
											Qal

BOTTOM OF HOLE: T.D. 6.3-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 6.0 feet
RESERVOIR SEDIMENT - Qr

0.0 to 6.0 ft.: SANDY SILT, s(ML) to ELASTIC SILT WITH SAND, (MH)s : Visual identification classifies the material as containing about 85% fines with medium plasticity and a high liquid limit; about 15% fine sand; maximum size fine sand; wet, dark gray, abundant plant and wood fiber; no reaction with HCl. However, the laboratory classification from a depth of 5.1 to 5.9 feet is Sandy Silt, s(ML) with 50.2% nonplastic fines and 49.8% sand; with a field moisture content of 229.8%.

Remarks: CDH-09-2 was drilled about 150 feet away from drill hole EDH-09-2, and in that hole there was a combination of both Sandy Silt s(ML) and Sandy Elastic Silt s(MH). This variation in classification is consistent with the variation in the visual classification and the laboratory classification found in drill hole CDH-09-2.

6.0 to 6.3 feet
QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)

6.0 to 6.2 ft.: SILTY GRAVEL WITH SAND, (GM)s : About 70% fine to coarse, subangular, hard gravel; about 15% medium to coarse sand; about 15% nonplastic fines; maximum size 45mm; wet, dark gray; no reaction with HCl.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-3

FEATURE: KRSS
LOCATION: J. C. Boyle Reservoir
BEGUN: 10/15/09 FINISHED: 10/15/09
RESERVOIR WATER DEPTH: NA

PROJECT: Klamath
COORDINATES: N 42° 08' 33.7" W 122° 02' 07.5"
TOTAL DEPTH: 6.3-ft.
RESEVOIR SEDIMENT THICKNESS: 6.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3791.3-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY:

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
3,791.3 ft. (10/15/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
14.1 feet (water depth 11.4 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material.

If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run:

Attempt 1 The sampler was fitted with sand fingers and a recovery sock and the augers with sampler were pushed to a depth of 6.0 feet. No sediment was recovered even though the top of the sampler had elastic silt on it.

Attempt 2 Moved the barge about 2 feet and with the same setup as used in Attempt 1 the augers with sampler were pushed to a depth of 6.5 feet (refusal). Recovered 1 foot of reservoir sediment and the sample shoe was filled with an abundance of wood fragments.

Attempt 3 Moved the barge about 2 feet and with the same setup as used in Attempts 1 & 2 the augers with sampler were pushed to a depth of 6.3 feet (refusal). Recovered 1.2 feet of material.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-3

FEATURE: KRSS
LOCATION: J. C. Boyle Reservoir
BEGUN: 10/15/09 FINISHED: 10/15/09
RESERVOIR WATER DEPTH: NA

PROJECT: Klamath
COORDINATES: N 42° 08' 33.7" W 122° 02' 07.5"
TOTAL DEPTH: 6.3-ft.
RESEVOIR SEDIMENT THICKNESS: 6.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3791.3-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY:

NOTES

Contaminant Sampling was then carried out by MP-157 personnel using a gravity sampler with 2-5/8 inch i.d. lexan liner was used to collect the additional volume of reservoir sediment required for all analyses.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-4

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/7/09 FINISHED: 10/7/09
RESERVOIR WATER DEPTH: 6.3-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 12.2" W 122° 16' 42.1"
TOTAL DEPTH: 10.8-ft.
RESEVOIR SEDIMENT THICKNESS: 9.1-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.4-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J. C Boyle Reservoir. Located about 3,000 feet upstream from the Hwy 66 Bridge, adjacent to drill hole CDH-09-3.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region
Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	41.5	**54.8**	96.3	3.7	0.0	169.7	77.1	373.7	MH		Qr
5											
										3783.2	Qal
10											Tv

BOTTOM OF HOLE: T.D. 10.8-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 9.1 ft.
RESERVOIR SEDIMENT - Qr

0.0 to 9.1 ft.: ELASTIC SILT, MH About 100 % fines with medium plasticity; wet, dark brown, organic odor; very soft, unconsolidated, trace organic material. Mussels at 9.0 feet.

9.1 to 9.5 ft.:
QUATERNARY ALLUVIUM - Qal (Pre Reservoir)

9.1 to 9.5 ft.: ELASTIC SILT WITH SAND AND GRAVEL, (MH)sg: About 75% fines with medium plasticity; about 15% fine and coarse, subrounded to rounded, hard, about 50% elongate gravel; about 10% fine to medium sand; maximum particle size, 1.5 inches; wet, dark brown, organic odor; soft, unconsolidated; gravels are basalt and pumice.

9.5 to 10.8 ft.:
TERTIARY VOLCANICS - Tv (Pre Reservoir)

9.5 to 10.8 ft.: LEAN CLAY, CL: About 100% fines with medium plasticity, slow dilatancy; trace coarse, angular to subangular, hard gravel; maximum particle size, 1.5 inches; moist, brown; massively bedded, stiff, trace roots.

Geologic Interpretation: Weathered lapill tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-4

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/7/09 FINISHED: 10/7/09
RESERVOIR WATER DEPTH: 6.3-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 12.2" W 122° 16' 42.1"
TOTAL DEPTH: 10.8-ft.
RESEVOIR SEDIMENT THICKNESS: 9.1-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.4-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
3792.4 feet (10/07/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
9.0 ft. (water depth 6.3 feet)
Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run:

Attempt 1: 0.0 to 6.0 ft - flight auger sampling only did not have any recovery.

Attempt 2: 0.0 to 6.0 ft - The barge was moved about a foot. Augers were set at the water/sediment interface, and the sampler with catcher and nylon sock was allowed to sink under its own weight to a depth of 6.0 feet. About 2.8 feet of reservoir sediment was recovered.

Attempt 3 5.8 to 10.8 ft - flight augers were set to a depth of 5.8 feet using a pilot bit, and the 5 foot sample barrel on NWJ rods was hammered to a depth of 10.8 feet using a 140 pound weight; recovering 4.8 feet of material.

A duplicate hole was drilled about 5 feet away for lab testing quality assurance.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-4

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/7/09 FINISHED: 10/7/09
RESERVOIR WATER DEPTH: 6.3-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 12.2" W 122° 16' 42.1"
TOTAL DEPTH: 10.8-ft.
RESEVOIR SEDIMENT THICKNESS: 9.1-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.4-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium and volcanic rocks.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-5

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.3-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 53.4" W 122° 17' 51.8"
TOTAL DEPTH: 2.0-ft.
RESEVOIR SEDIMENT THICKNESS: 0.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J. C Boyle Reservoir. Located about 1,500 feet upstream from the Hwy 66 bridge, adjacent to drill hole EDH-09-2

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										NR	**0.0 to 1.8 ft.: No Recovery** **0.0 to 2.0 ft.:** Drove sampler with cathead (35 Blows) - REFUSAL

BOTTOM OF HOLE: T.D. 2-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-5

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.3-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 53.4" W 122° 17' 51.8"
TOTAL DEPTH: 2.0-ft.
RESEVOIR SEDIMENT THICKNESS: 0.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
3792.52 ft. (10/06/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
18.0 feet (water depth 15.3 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

See below for detailed list of drilling activities for each run.

Attempt 1 0.0 to 1.8 ft - auger sampling did not recover any material.

Attempt 2 0.0 to 2.0 ft. - flight augers were set at the water/sediment interface and the 5 foot sample barrel on NWJ rods was hammered to a depth of 2.0 feet using a 140 pound weight; recovering 2.0 feet of material.

Contaminant Sampling was then carried out by MP-157 personnel. A gravity sampler with 2-5/8 inch i.d. lexan liner was used to collect the additional volume of reservoir sediment required for all analyses.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-5

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.3-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 53.4" W 122° 17' 51.8"
TOTAL DEPTH: 2.0-ft.
RESEVOIR SEDIMENT THICKNESS: 0.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-5A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.0-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 53.4" W 122° 17' 51.9"
TOTAL DEPTH: 2.0-ft.
RESEVOIR SEDIMENT THICKNESS: 0.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J. C Boyle Reservoir. Located about 1,500 feet upstream from the Hwy 66 bridge, adjacent to drill hole EDH-09-2

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
											Qr	***0.0 to 0.3 ft. RESERVOIR SEDIMENT - Qr*** **0.0 to 0.3 ft.: ELASTIC SILT, MH:** About 95 to 100% fines with medium plasticity; 5 % to trace very fine sand; wet, dark brown, organic odor; very soft, unconsolidated; clams present at 0.3 ft.
	55.6	***44.4***	100	0	0	123.5	49.7	244.2	MH		Qal	***0.3 to 0.9 ft.: QUATERNARY ALLUVIUM - Qal (Pre Reservoir)*** **0.3 to 0.9 ft.: SILTY GRAVEL WITH SAND, (GM)s:** About 45% fine and coarse, rounded, hard, elongate gravel; about 40% fine to coarse sand; about 15 % nonplastic fines; wet, dark brown; very firm; gravels are basalt.
										3791.2	Tv	***0.9 to 2.0 ft.: TERTIRAY VOLCANICS - Tv (Pre Reservoir)*** **0.9 to 2.0 ft.: LEAN CLAY, CL:** About 95 to 100% fines with medium plasticity; 5% to trace fine sand; moist, brown; very firm; thinly bedded with peet, vegetable matter, bark, and ash layers; high organic content; material compacted by hammer. Geologic Interpretation: Weathered lapill: tuff.

BOTTOM OF HOLE: T.D. 2-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-5A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.0-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 53.4" W 122° 17' 51.9"
TOTAL DEPTH: 2.0-ft.
RESEVOIR SEDIMENT THICKNESS: 0.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
3792.5 ft. (10/06/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
18.0 feet (water depth 15.3 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

See below for detailed list of drilling activities for each run.

Attempt 1 0.0 to 1.8 ft - auger sampling did not recover any material.

Attempt 2 0.0 to 2.0 ft. - flight augers were set at the water/sediment interface and the 5 foot sample barrel on NWJ rods was hammered to a depth of 2.0 feet using a 140 pound weight; recovering 2.0 feet of material.

Contaminant Sampling was then carried out by MP-157 personnel. A gravity sampler with 2-5/8 inch i.d. lexan liner was used to collect the additional volume of reservoir sediment required for all analyses.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-5A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.0-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 53.4" W 122° 17' 51.9"
TOTAL DEPTH: 2.0-ft.
RESEVOIR SEDIMENT THICKNESS: 0.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-6

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.0-ft.

PROJECT: Klamath
COORDINATES: N 42° 08' 01.8" W 122° 01' 51.6"
TOTAL DEPTH: 1.4-ft.
RESEVOIR SEDIMENT THICKNESS: 0.0-ft (none)

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J. C Boyle Reservoir. Located about 500 feet downstream from the Hwy 66 bridge.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region
Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	1.6	**6.6**	8.2	26.2	65.6	24.2	0.4	13.9	(GW-GM)s / 3791.1	**Qal**	***0.0 to 1.4 ft.*** ***QUATERNARY ALLUVIUM - Qal (Pre Reservoir)*** **0.0 to 1.4 ft.: SILTY GRAVEL WITH SAND, (GM)s :** About 45% fine and coarse, hard, rounded, about 60% elongate gravels; about 40 % fine to coarse, hard, rounded sand; about 15% nonplastic fines; wet, black to dark brown; very firm; gravels are predominately basalt. No reservoir sediments were recovered at this location; water current is swift.

BOTTOM OF HOLE: T.D. 1.4-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-6

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.0-ft.

PROJECT: Klamath
COORDINATES: N 42° 08' 01.8" W 122° 01' 51.6"
TOTAL DEPTH: 1.4-ft.
RESEVOIR SEDIMENT THICKNESS: 0.0-ft (none)

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
3792.52 feet (10/06/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
17.7 feet (water depth 15.0 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run.

Attempt 1 0.0 to 0.4 ft - set augers at water/sediment interface, and pushed sampler with catcher and nylon stocking with NJW rods, no material was recovered.

Attempt 2 0.0 to 1.4 ft - the barge was moved about one foot. Flight augers were set at the water/sediment interface, and the 5 foot sample barrel with catcher and nylon stockings on NWJ rods was hammered to a depth of 1.4 feet using a 140 pound weight, recovering 1.0 feet of material.

Reservoir sediment was not recovered, and an Eckman Dredge was used at an adjacent location to collect samples for contaminant testing.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-6

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.0-ft.

PROJECT: Klamath
COORDINATES: N 42° 08' 01.8" W 122° 01' 51.6"
TOTAL DEPTH: 1.4-ft.
RESEVOIR SEDIMENT THICKNESS: 0.0-ft (none)

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration into pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-6A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.0-ft.

PROJECT: Klamath
COORDINATES: N 42° 08' 02.2" W 122° 01' 51.4"
TOTAL DEPTH: 0.3-ft.
RESEVOIR SEDIMENT THICKNESS: 0.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J. C Boyle Reservoir. Located about 500 feet downstream from the Hwy 66 bridge.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										Qal	***0.0 to 0.3 ft.*** ***QUATERNARY ALLUVIUM, Qal (Pre-Reservoir)*** **0.0 to 0.3 ft.: SILTY GRAVEL WITH SAND, (GM)s:** About 60% fine, rounded gravels; about 20% fines with medium plasticity; about 20% fine sand; wet, dark brown, organic odor; very soft, unconsolidated; abundant mussels and gravels from contact of reservoir sediment and pre-reservoir alluvium.

BOTTOM OF HOLE: T.D. 0.3-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Sampled from boat with Eckman Dredge

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-6A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/6/09 FINISHED: 10/6/09
RESERVOIR WATER DEPTH: 15.0-ft.

PROJECT: Klamath
COORDINATES: N 42° 08' 02.2" W 122° 01' 51.4"
TOTAL DEPTH: 0.3-ft.
RESEVOIR SEDIMENT THICKNESS: 0.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
3792.52 feet (10/06/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
NA

Reservoir Water/Sediment Contact Depth:
15.0 feet (water depth 15.0 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run.

Attempt 1 0.0 to 0.3 ft - An Eckman Dredge was lowered from a boat and after several attempts with no recovery, about 0.3 feet of reservoir sediment mixed with pre reservoir alluvium was recovered.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon unsuccessful sampling of reservoir sediment.

HOLE COMPLETION:
Only surface sampling was attempted at this site.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Sampled from boat with Eckman Dredge

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-7

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/1/09 FINISHED: 10/2/09
RESERVOIR WATER DEPTH: 28.8-ft.

PROJECT: Klamath
COORDINATES: N 42° 07' 23.0" W 122° 02' 46.0"
TOTAL DEPTH: 18.7-ft.
RESEVOIR SEDIMENT THICKNESS: 18.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.1-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J. C Boyle Reservoir. Located about 500 feet upstream of the J.C. Boyle Dam, adjacent to drill holes EDH-09-3 and CDH-09-8.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	31.8	**62.5**	94.3	5.7	0	179.4	81.0	410.7	MH		
5										3787.1	
10											Qr
	35.4	**58.4**	93.8	6.2	0	178.2	81.9	367.6	MH		
										3780.1	
	31.6	**60.1**	91.7	8.3	0	173.2	61.3	334.8	MH		
15											
										3775.1	
	46.3	**48.1**	94.4	5.6	0	192.9	68.2	270.8	MH		
										3773.4	Qal

BOTTOM OF HOLE: T.D. 18.7-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 18.7 ft.
RESERVOIR SEDIMENT - Qr

0.0 to 18.7 ft.: ELASTIC SILT, MH: About 95 to 100% fines with high plasticity, slow to rapid dilatancy, low toughness; about 5% to trace very fine sand; wet, dark brown to black, organic hydrocarbon odor; no reaction with HCl; homogenous, unconsolidated, saturated with water, spongy texture, trace roots throughout, roots from 12.0 to 17.0 ft. Consistency thickens to soft at 12.0 ft. Lens of soft, saturated material from 17.8 to 18.1 ft. Color changes from dark brown to dark olive brown from 18.2 to 18.7 One 1.5 inch angular, elongate, hard, gravel in shoe at 18.7 ft., freshly broken vesicular basalt, marking the contact with pre-reservoir alluvium.

18.7 ft.
QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-7

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/1/09 FINISHED: 10/2/09
RESERVOIR WATER DEPTH: 28.8-ft.

PROJECT: Klamath
COORDINATES: N 42° 07' 23.0" W 122° 02' 46.0"
TOTAL DEPTH: 18.7-ft.
RESEVOIR SEDIMENT THICKNESS: 18.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.1-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
3,792.13 ft. (10/01/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.9 feet

Reservoir Water/Sediment contact Depth from Collar:
31.7 feet (water depth 28.8 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run.

Attempt 1 0.0 to 5.0 ft - Set augers at the water/sediment interface. Pushed sampler without advancing augers, recovering about 3.9 feet of reservoir sediment.

Attempt 2 0.0 to 5.0 ft - Moved the barge several feet, advanced auger and sampler, without rotating auger, to a depth of 5.0 feet with no recovery. Re-sampled same interval 2 additional times with catcher, then catcher and plastic bag, with no recovery. Re-sampled with a flapper catcher and recovered 0.9 feet of reservoir sediment.

Attempt 3 7.0 to 12.0 ft - Advanced augers and sampler with flap catcher, recovering about 1.5 feet of reservoir sediment.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-7

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/1/09 FINISHED: 10/2/09
RESERVOIR WATER DEPTH: 28.8-ft.

PROJECT: Klamath
COORDINATES: N 42° 07' 23.0" W 122° 02' 46.0"
TOTAL DEPTH: 18.7-ft.
RESEVOIR SEDIMENT THICKNESS: 18.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.1-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

Attempt 4 12.0 to 17.0 ft - Advanced augers and sampler with catcher and plastic bag, recovering about 3.2 feet of reservoir sediment.

Attempt 5 17.0 to 18.7 ft - Advanced augers and sampler with catcher and nylon stocking with the sampler set 0.3 ft ahead of auger, recovering about 3.0 feet of reservoir sediment. Refused at 18.7 ft on a gravel, which was determined to be pre reservoir alluvium.

Although the reservoir sediment/pre-reservoir alluvium contact was successfully penetrated, additional samples from intervals with poor recovery will be collected at an adjacent location.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-7A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/1/09 FINISHED: 10/2/09
RESERVOIR WATER DEPTH: 30.1-ft

PROJECT: Klamath
COORDINATES: N 42° 07' 22.9" W 122° 02' 46.0"
TOTAL DEPTH: 21.7-ft.
RESEVOIR SEDIMENT THICKNESS: 21.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.1-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J. C Boyle Reservoir. Located about 500 feet upstream of the J.C. Boyle Dam, adjacent to drill holes EDH-09-3 and CDH-09-8.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
												0.0 to 21.7 ft. ***RESERVOIR SEDIMENT, Qr***
												0.0 to 21.7 ft.: **ELASTIC SILT, MH**: About 95 to 100% fines with high plasticity, slow to rapid dilatancy, low toughness; about 5% to trace very fine sand; wet, dark brown to black, organic hydrocarbon odor; no reaction with HCl; homogenous, unconsolidated, saturated with water, spongy texture, trace roots throughout.
5	35.2	**57.3**	92.5	7.5	0	165.6	53.2	412.7	MH	3782.9		
10	31.5	**62.9**	94.4	5.6	0	154.5	68.3	297.2	MH	3780.1	Qr	
15												
20												

BOTTOM OF HOLE: T.D. 21.7-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-7A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/1/09 FINISHED: 10/2/09
RESERVOIR WATER DEPTH: 30.1-ft

PROJECT: Klamath
COORDINATES: N 42° 07' 22.9" W 122° 02' 46.0"
TOTAL DEPTH: 21.7-ft.
RESEVOIR SEDIMENT THICKNESS: 21.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.1-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
3,792.35 ft. (10/02/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.9 feet

Reservoir Water/Sediment contact Depth from Collar:
30.1 feet (water depth 27.2 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run.

Attempt 1 0.0 to 4.2 ft - Moved barge about 5 feet away from CDH-09-7. Advanced augers with sampler assembly, using catcher and nylon stocking. No recovery.

Attempt 2 4.2 to 9.2 ft - Advanced augers with sampler assembly, using catcher and nylon stocking. Recovered 1.7 feet of reservoir sediment.

Attempt 3 9.2 to 14.2 ft - Advanced augers with sampler assembly, using catcher and nylon stocking. Recovered 3.0 feet of reservoir sediment.

Attempt 4 14.2 to 21.7 ft - Drilled to refusal in two runs, did not sample. Refusal at 21.7 feet when the augers torque.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-7A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/1/09 FINISHED: 10/2/09
RESERVOIR WATER DEPTH: 30.1-ft

PROJECT: Klamath
COORDINATES: N 42° 07' 22.9" W 122° 02' 46.0"
TOTAL DEPTH: 21.7-ft.
RESEVOIR SEDIMENT THICKNESS: 21.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.1-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon refusal.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-8

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/3/09 FINISHED: 10/3/09
RESERVOIR WATER DEPTH: 18.3-ft.

PROJECT: Klamath
COORDINATES: N 42° 07' 22.4" W 122° 02' 36.8"
TOTAL DEPTH: 5.0-ft.
RESEVOIR SEDIMENT THICKNESS: 1.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.8-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
J.C. Boyle Reservoir. Located about 1000 feet upstream from the J.C. Boyle Dam, adjacent to drill holes EDH-09-3 and CDH-09-7.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	44.1	**53.0**	97.1	2.9	0	165.7	68.0	782.4	MH	3792.3	Qr
	42.3	**52.8**	95.1	4.9	0	154.3	57.4	381.9	MH	3791.1	Qr
5											Qal

BOTTOM OF HOLE: T.D. 5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 1.7 ft.
RESERVOIR SEDIMENT - Qr

0.0 to 1.7 ft.: ELASTIC SILT, MH About 95% fines with medium plasticity; 5% very fine sand; wet, dark brown, organic odor; very soft, trace roots and vegetation.

1.7 to 5.0 ft.
QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)

1.7 to 5.0 ft.: SANDY LEAN SILT, s(ML) About 60% fines with low to medium plasticity, low toughness; aobut 35% fine to coarse, soft, subangular sand; about 5% fine, soft to hard, rounded to subangular, elongate gravels; wet, dark brown, organic odor; medium soft, 1" charcoal piece at 1.8 feet.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-8

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/3/09 FINISHED: 10/3/09
RESERVOIR WATER DEPTH: 18.3-ft.

PROJECT: Klamath
COORDINATES: N 42° 07' 22.4" W 122° 02' 36.8"
TOTAL DEPTH: 5.0-ft.
RESEVOIR SEDIMENT THICKNESS: 1.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.8-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
NA

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
21.0 feet (water depth 18.3 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

See below for detailed list of drilling activities for each run.

Attempt 1 0.0 to 5.0 ft. - Advanced augers and sampler, with sample 0.4 feet ahead of augurs, to refusal on gravels at 5.0 ft. About 1.7 feet of reservoir sediment and 2.6 feet of pre reservoir alluvium were recovered.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-1

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/16/09 FINISHED: 10/16/09
RESERVOIR WATER DEPTH: 13.4-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 49.5" W 122 ° 02' 11.0"
TOTAL DEPTH: 3.6-ft.
RESEVOIR SEDIMENT THICKNESS: 3.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
J.C. Boyle Reservoir. Located about 4,600 feet upstream from the Hwy 66 Bridge; adjacent to contaminant sample drill hole CDH-09-2.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										Qr	***0.0 to 3.2 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 1.3 ft. ELASTIC SILT, MH:** About 90% elastic silt; about 10% fine sand; maximum size fine sand; wet, dark gray, pudding like consistency, moderate organic material; no reaction with HCl. **1.3 to 3.2 ft. POORLY GRADED SAND WITH SILT, SP-SM:** About 90% fine to coarse, mostly medium sand; about 10% nonplastic fines; maximum size coarse sand; wet, gray; no reaction with HCl.
	3.5	7.2	10.7	89.3	0	NP	NP	45.5	SP-SM 3789.3		***3.2 to 3.6 feet*** ***QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)*** **3.2 to 3.6 ft.: SILTY GRAVEL WITH SAND, (GM)s:** About 45% fine to coarse, subangular to subrounded, hard gravel; about 40% fine to coarse, mostly medium sand; about 15% nonplastic fines; maximum size 40mm; wet, gray; no reaction with HCl.
										Qal	

BOTTOM OF HOLE: T.D. 3.6-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample was collected with an undisturbed reservoir sediment interval of 2.37 to 3.20-feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-1

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/16/09 FINISHED: 10/16/09
RESERVOIR WATER DEPTH: 13.4-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 49.5" W 122 ° 02' 11.0"
TOTAL DEPTH: 3.6-ft.
RESEVOIR SEDIMENT THICKNESS: 3.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.5-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface Elevation:
3,792.5 ft. (10/16/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
16.1 feet (water depth 13.4 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run.
Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler, all of which was seated within the FADC system and lowered to the water/sediment interface. The whole assembly was then pushed to 2.7-feet (refusal) with no recovery.

Attempt 2 Moved the barge about 2 feet and with the same setup as used in Attempt 1, except that the sample shoe was moved out in front of the auger bit teeth 0.4-feet. The augers with sampler were allowed to sink under their own weight, stopping at 3.0 feet. Augers were then rotated went to a total depth of 3.6 feet (refusal) recovering 0.6-feet of material. Refusal may have been on a piece of wood or a stump.

Attempt 3 Moved the barge about 2 -feet and with the same setup as used in Attempt 2, but with the sampler 0.2-feet out in front of the auger bit teeth. Set the augers to the water/sediment interface and started rotating them slowly as the auger system moved down. The material firmed up at a depth of about 3.0-feet and drilling stopped at 3.4-feet in pre-reservoir alluvium recovering 0.9-ft of reservoir sediment and 0.2-ft. of pre-reservoir alluvium.
One lexan liner sample was collected with an undisturbed reservoir sediment interval of 2.37 to 3.2-feet.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium, and the collection of an undisturbed sample of reservoir sediment.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample was collected with an undisturbed reservoir sediment interval of 2.37 to 3.20-feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-1A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/16/09 FINISHED: 10/16/09
RESERVOIR WATER DEPTH: 13.3-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 49.0" W 122 ° 02' 10.4"
TOTAL DEPTH: 3.4-ft.
RESEVOIR SEDIMENT THICKNESS: Not Known (>3.4-ft.)

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.4-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
J.C. Boyle Reservoir. Located about 4,600 feet upstream from the Hwy 66 Bridge; adjacent to contaminant sample drill hole CDH-09-2.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										Qr	***0.0 to 3.4 feet*** ***RESERVOIR SEDIMENT - Qr***
5	**9.8**	14.8	85.2	0	NP	NP	59.8	SM	3789.0		

0.0 to 1.3 ft. <u>ELASTIC SILT, MH</u>: About 90% elastic silt; about 10% fine sand; maximum size fine sand; wet, dark gray, pudding-like consistency, moderate organic material; no reaction with HCl; (refusal).

1.3 to 3.4 ft. <u>SILTY SAND, SM</u>: 85.2% fine to coarse, mostly medium sand; 14.8% nonplastic fines; maximum size coarse sand; wet, gray; no reaction with HCl.

Remarks: It is not known whether refusal was on fragments of wood or coarse pre-reservoir alluvium. No coarse alluvium was present in the sample shoe.

BOTTOM OF HOLE: T.D. 3.4-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

No sample collected.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-1A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/16/09 FINISHED: 10/16/09
RESERVOIR WATER DEPTH: 13.3-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 49.0" W 122 ° 02' 10.4"
TOTAL DEPTH: 3.4-ft.
RESEVOIR SEDIMENT THICKNESS: Not Known (>3.4-ft.)

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.4-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface Elevation:
3,792.4 ft. (10/16/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
16.0 feet (water depth 13.3 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run.
Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler, all of which was seated within the FADC system and lowered to the water/sediment interface. The augers were then rotated as the assembly was lowered to 3.4 feet (refusal). Recovery was 0.7-ft. of reservoir sediment and no Qal was in the shoe. Refusal may have been on either a piece of wood, or on coarse Qal.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated upon unsuccessful penetration into pre-reservoir sediment.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

No sample collected.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-2

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/16/09 FINISHED: 10/16/09
RESERVOIR WATER DEPTH: 6.1-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 35.0" W 122 ° 02' 08.5"
TOTAL DEPTH: 9.0-ft.
RESEVOIR SEDIMENT THICKNESS: Not Known (>9.0-ft.)

STATE: Oregon and California
RESERVOIR ELEVATION: * 3791.7-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
J.C. Boyle Reservoir. Located about 3,100 feet upstream from the Hwy 66 Bridge; adjacent to contaminant sample drill hole CDH-09-4A.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
5	19.3	**34.7**	54.0	46.0	0	NP	NP	212.4	s(ML)	3785.7	Qr	***0.0 to 9.0 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 9.0 ft. SANDY SILT s(ML):** About 55% nonplastic fines; about 45% fine to medium sand; maximum size medium sand; wet, dark gray, moderate wood fragments; no reaction with HCl. Remarks: Based on the ease of pushing the sampler, reservoir sediment is believed to be present at a depth of up to 9.0 feet, although there was no recovery from 6.0 to 9.0 feet (refusal). The reservoir sediment / pre-reservoir sediment contact in drill hole EDH-09-2A (about 100 feet away from EDH-09-2) is at 9.0 feet.

BOTTOM OF HOLE: T.D. 9-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample was collected with an undisturbed reservoir sediment interval of 5.06 to 5.80-feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-2

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/16/09 FINISHED: 10/16/09
RESERVOIR WATER DEPTH: 6.1-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 35.0" W 122 ° 02' 08.5"
TOTAL DEPTH: 9.0-ft.
RESEVOIR SEDIMENT THICKNESS: Not Known (>9.0-ft.)

STATE: Oregon and California
RESERVOIR ELEVATION: * 3791.7-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface Elevation:
3,791.7 ft. (10/16/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
8.8 feet (water depth 6.1 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run.
Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler with sample fingers and a sock, all of which was seated within the FADC system and lowered to the water/sediment interface. The whole assembly was then pushed to 6.0-feet with recovery of 1.0 feet of reservoir sediment. A lexan liner sample was collected from a depth of 5.05 to 5.8 feet; a lab sample for gradations was collected from material in the sample shoe (5.8 to 6.0 feet). The second run was from 6.0 to 9.0 using two lexan liners (each 2.5-feet long) that were fitted into the split tube sampler with sample fingers but no sock. The auger assembly was pushed to refusal (9.0 feet) with no recovery.

One lexan liner sample was collected with an undisturbed reservoir sediment interval of 5.06 to 5.80-feet.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated upon unsuccessful penetration through the reservoir sediment into the underlying pre-reservoir alluvium, and the collection of an undisturbed sample of reservoir sediment.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample was collected with an undisturbed reservoir sediment interval of 5.06 to 5.80-feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-2A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/17/09 FINISHED: 10/17/09
RESERVOIR WATER DEPTH: 7.4-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 34.1" W 122 ° 02' 09.3"
TOTAL DEPTH: 9.2-ft.
RESEVOIR SEDIMENT THICKNESS: 9.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3793.2-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
J.C. Boyle Reservoir. Located about 3,000 feet upstream from the Hwy 66 Bridge; adjacent to contaminant sample drill hole CDH-09-3.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
5											Qr	***0.0 to 9.0 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 9.0 ft. ELASTIC SILT TO SANDY ELASTIC SILT MH to s(MH):** About 70% to 90% nonplastic fines; about 10% to 30% fine to medium sand; maximum size medium sand; wet, dark gray, pudding-like consistency, moderate wood chips towards the bottom; no reaction with HCl.
	30.2	**36.9**	67.1	32.9	0	129.3	26.8	236.4	s(MH)	3784.2	Qal	***9.0 to 9.2 feet*** ***QATERNARY ALLUVIUM - Qal (Pre-Reservoir)*** **9.0 to 9.2 ft SILTY GRAVEL WITH SAND (GM)s:** About 50% fine to coarse, subangular, hard gravel; about 30% fine to medium sand; about 20% medium plastic fines; maximum size 35mm; wet, dark gray, abundant wood chips at the contact; no reaction with HCl.

BOTTOM OF HOLE: T.D. 9.2-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample was collected with an undisturbed reservoir sediment interval of 7.25 to 9.00-feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-2A

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/17/09 FINISHED: 10/17/09
RESERVOIR WATER DEPTH: 7.4-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 34.1" W 122 ° 02' 09.3"
TOTAL DEPTH: 9.2-ft.
RESEVOIR SEDIMENT THICKNESS: 9.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 3793.2-ft.
HOLE LOGGED BY: M. McCulla and A. Warren
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface Elevation:
3,793.2 ft. (10/17/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
10.2 feet (water depth 7.4 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run.
Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler with a basket spring retainer (sand fingers) and a sock, all of which was seated within the FADC system and lowered to the water/sediment interface. The sample shoe was 0.2 feet in front of the drill bit teeth. The whole assembly was rotated and drilled to 9.2-feet (refusal) with recovery of 2.2 feet of reservoir sediment. A lexan liner sample was collected from a depth of 7.25 to 9.0 feet; a lab sample for gradations was collected from material in the sample shoe (9.0 to 9.2 feet). One lexan liner sample was collected with an undisturbed reservoir sediment interval of 7.25 to 9.0-feet. One lab sample of reservoir sediment was collected from 8.8 to 9.0 feet.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium, and the collection of an undisturbed sample of reservoir sediment.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample was collected with an undisturbed reservoir sediment interval of 7.25 to 9.00-feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-3

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/3/09 FINISHED: 10/5/09
RESERVOIR WATER DEPTH: 36.5-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 07' 26.2" W 122 ° 02' 41.0"
TOTAL DEPTH: 15.5-ft.
RESEVOIR SEDIMENT THICKNESS: 14.0

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.8-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
J. C Boyle Reservoir. Located about 500 feet upstream of the J.C. Boyle Dam; adjacent to contaminant sample drill holes CDH-09-7 and CDH-09-8.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from a boat ramp at the Klamath River Recreation Area, located on the Green Springs Hwy (Hwy 66), into the J.C. Boyle Reservoir. A detachable barge containing a restroom and geology and environmental sampling equipment was mobilized daily to and from the Topsy Recreation Area, located on the Topsy Grade Road, and samples were off-loaded from this location daily. For security purposes drilling and sampling equipment were stored at PacifiCorp's facility at the southern end of the reservoir, with the drilling barge anchored adjacent to the facility nightly.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	54.7	**43.6**	98.3	1.7	0.0	195.4	82.8	506.5	MH		Qr
										3787.8	
5											
											Qr
	47.1	**50.4**	97.5	2.5	0.0	167.6	61.3	224.2	MH	3785.3	

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 14.0 ft.
RESERVOIR SEDIMENT - Qr

0.0 to 14.0 ft.: ELASTIC SILT, MH: About 100% fines with medium elasticity; trace fine sand; wet, dark brown, organic odor; soft, firmness increases with depth, unconsolidated; several layers of black peat.

14.0 to 15.5 ft.:
QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)

14.0 to 15.5 ft.: SILTY SAND WITH GRAVEL, (SM)g: About 40% fine to coarse sand; about 35% fine and coarse, soft to hard, subangular to angular, elongated gravel; about 25% low-plasticity fines; moist to wet, dark gray-black, organic odor; moderately firm, gravels are volcanoclastic.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube samples:
5.20 to 7.30 feet
7.50 to 10.00 feet
11.40 to 13.90 feet

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-3

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/3/09 FINISHED: 10/5/09
RESERVOIR WATER DEPTH: 36.5-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 07' 26.2" W 122 ° 02' 41.0"
TOTAL DEPTH: 15.5-ft.
RESEVOIR SEDIMENT THICKNESS: 14.0

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.8-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface Elevation:
3,792.55 ft. (10/04/09)
3,792.78 ft. (10/05/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
39.2 feet (water depth 36.5 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run.

Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler, all of which was seated within the FADC system and lowered to the water/sediment interface. The whole assembly was then pushed to 3.1 feet with no recovery.

Attempt 2 Moved the barge several feet and used the same setup as in Attempt 1. The whole assembly was pushed to 5.0 feet with no recovery.

Attempt 3 Moved the barge several feet and used the same setup as in Attempt 1, except with catcher in sample shoe. The whole assembly was pushed to 5.0 feet with no recovery.

Attempt 4 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler, and the sampler was lowered through the augers which were set at 5.0 ft. The assembly (sampler and rods) were pushed with their own weight, without advancing augers, to 10.0 feet, recovering 3.3 feet of reservoir sediment. One lexan liner sample was collected with an undisturbed reservoir sediment interval of 7.5 to 10.0 feet. After the sampler was retrieved, the augers were advanced to a depth of 10.0 ft, with a pilot bit to clean out the hole.

Attempt 5 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler, and the sampler lowered through the augers which were set at a depth of 10.0 ft. The assembly (sampler and rods) were pushed with their own weight, without advancing augers, to 15.0 feet, with no recovery.

Attempt 6 Moved the barge several feet. Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler, with a catcher and nylon stocking. The augers were set at the water/sediment interface and the assembly was very slowly advanced to allow water to be displaced in the sampler with less pressure, to 5.0 ft, with no recovery.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
10	32.5	**58.3**	90.8	9.2	0.0	162.2	68.8	293.1	MH	3782.6		
											Qr	
	45.1	**48.5**	93.6	6.4	0.0	151.6	46.6	313.4	MH			
	~~44.5~~	~~**45.9**~~	~~90.4~~	~~9.6~~	~~0.0~~	~~175.2~~	~~75.0~~	~~214.3~~	~~MH~~	3778.8 3778.7		
	5.7	**12.4**	69.4	30.6	51.3	65.6	25.0	32.9	(GM)s		Qal	
15										3777.3		

BOTTOM OF HOLE: T.D. 15.5-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube samples:
5.20 to 7.30 feet
7.50 to 10.00 feet
11.40 to 13.90 feet

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-3

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 10/3/09 FINISHED: 10/5/09
RESERVOIR WATER DEPTH: 36.5-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 07' 26.2" W 122 ° 02' 41.0"
TOTAL DEPTH: 15.5-ft.
RESEVOIR SEDIMENT THICKNESS: 14.0

STATE: Oregon and California
RESERVOIR ELEVATION: * 3792.8-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

Attempt 7 Moved the barge one half foot and used the same setup as in Attempt 6, including catcher and nylon stocking. The augers were set at the water/sediment interface and the assembly was advanced under the weight of the sampler and rods, to 7.5 ft, recovering about 2.3 feet of reservoir sediment. One lexan liner sampler was collected with an undisturbed reservoir sediment interval of 5.2 to 7.3 feet. After the sampler assembly was removed, the augers were advanced with a pilot bit to 10 feet.

Attempt 8 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler, and the sampler was lowered through the augers which were set at a depth of 10.0 ft. The assembly (sampler and rods) were pushed with their own weight, without advancing augers, to 15.0 feet, with no recovery.

Attempt 9 Moved the barge several feet and used same setup at Attempt 8. Advanced augers with pilot bit to 8.1 feet. The assembly was pushed to a depth of 14.1 feet, recovering about 3.5 feet of reservoir sediment containing thin layers of black peat. The hole refused on pre-reservoir sediments. One lexan liner sampler was collected with an undisturbed reservoir sediment interval of 11.4 to 13.9 feet.

Attempt 10 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler, and the sampler was lowered through the augers which were set at 13.5 feet. The augers were pushed to a depth of 18.5 feet, with no recovery. A trace of sandy material containing volcanoclastics was present in the sample tubes.

Attempt 11 A smaller diameter sampler with an I.D. of 0.2 feet and a length of 2.7 feet, with catcher and nylon sock, was driven through the augers to confirm the contact between reservoir sediment and pre-reservoir alluvium. The sampler was driven to 14.4 feet with no recovery.

Attempt 12 The same set up as attempt 11 was used. The sampler was driven to 15.5 feet and recovered about 0.5 feet of reservoir sediment and 1.5 feet of pre reservoir alluvium.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
10.0 to 15.0 ft.: Difficulty removing sampler from augers.
15.0 ft.: Water surrounding barge began bubbling with methane off gassing.

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium, and the collection of undisturbed samples of reservoir sediment.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

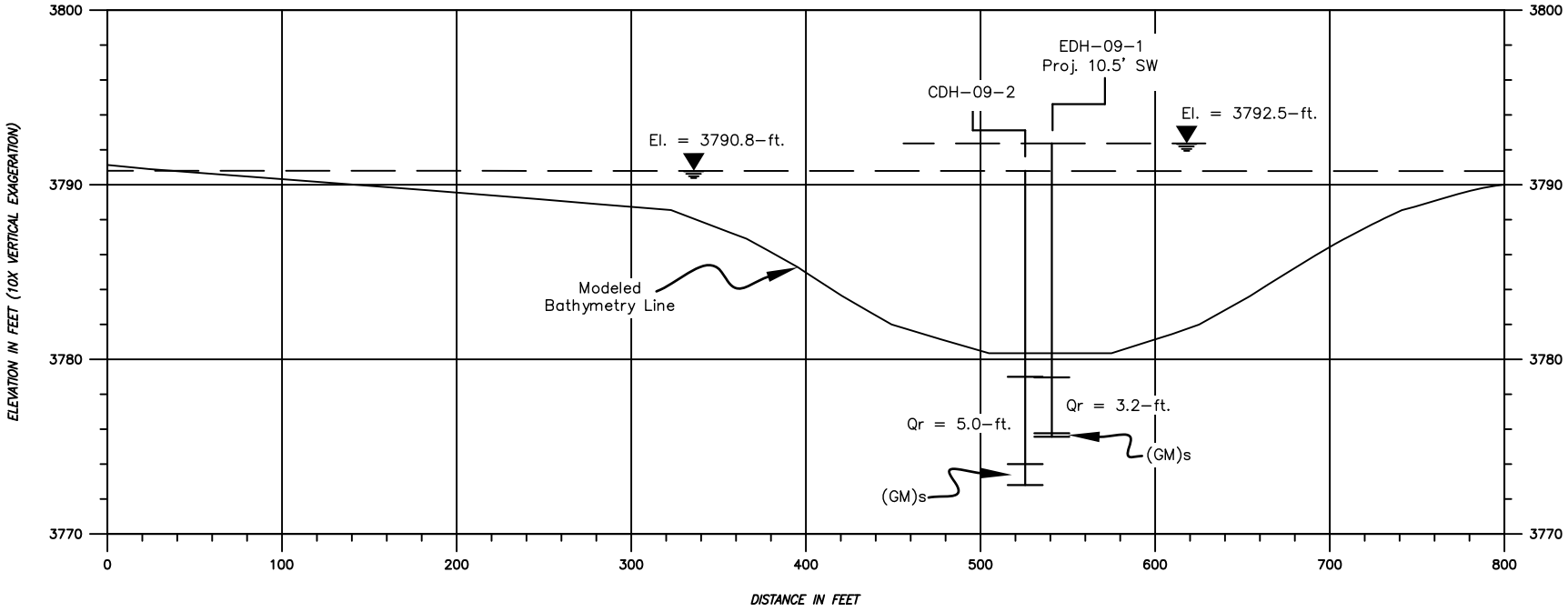
COMMENTS:

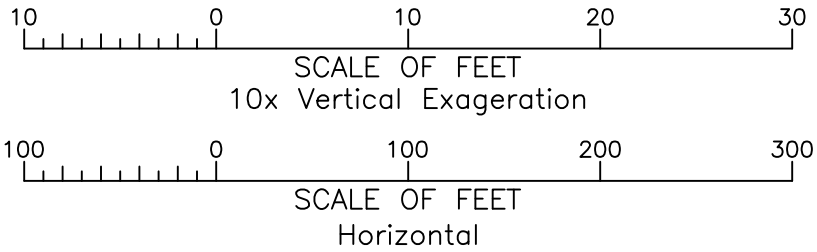
NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube samples:
5.20 to 7.30 feet
7.50 to 10.00 feet
11.40 to 13.90 feet

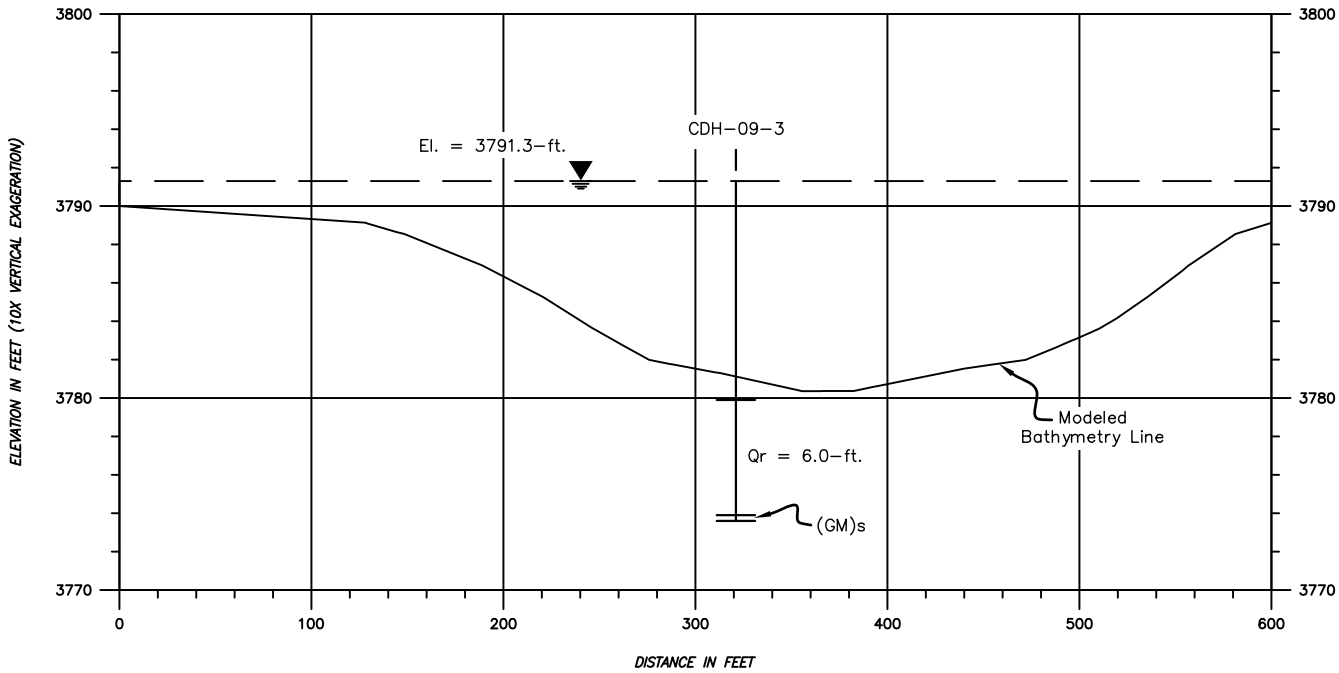
RECLAMATION
Managing Water in the West

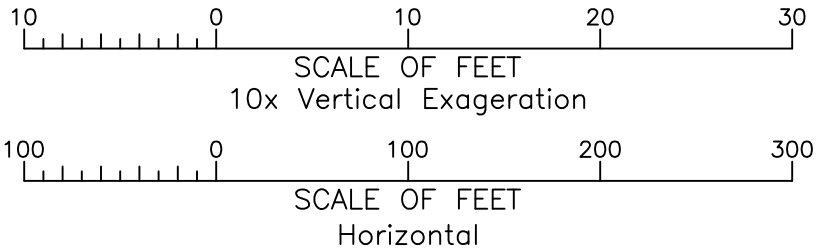
J.C. Boyle Section 1



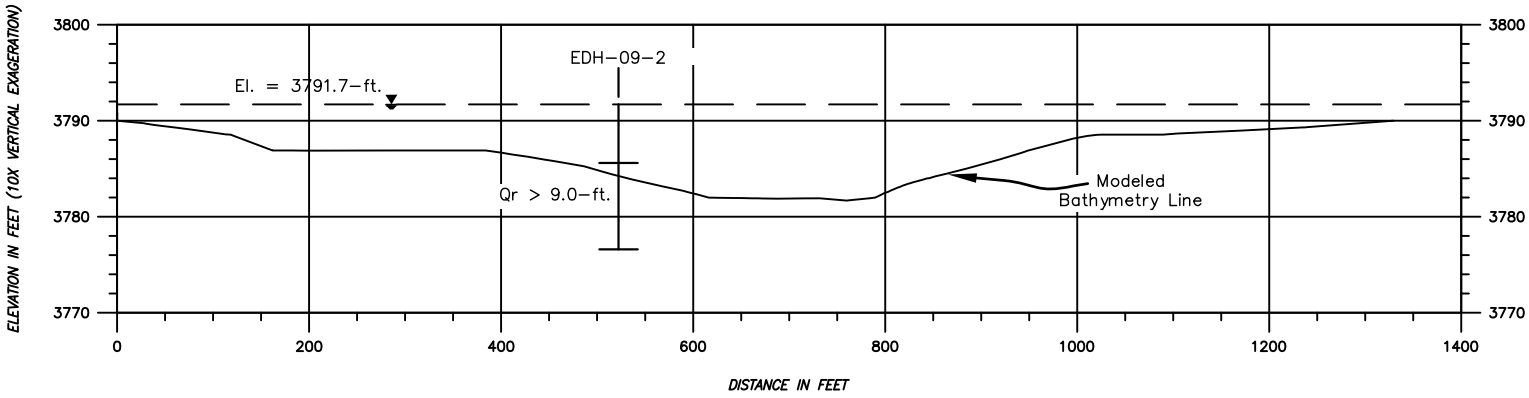


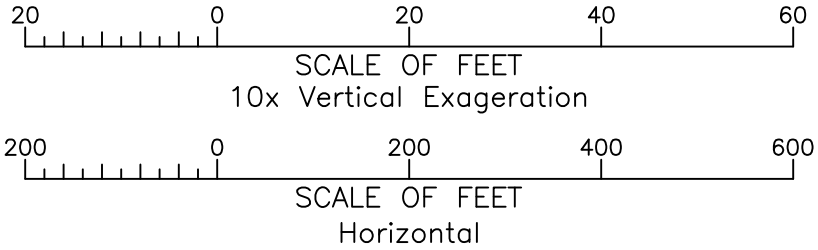
J.C. Boyle Section 2



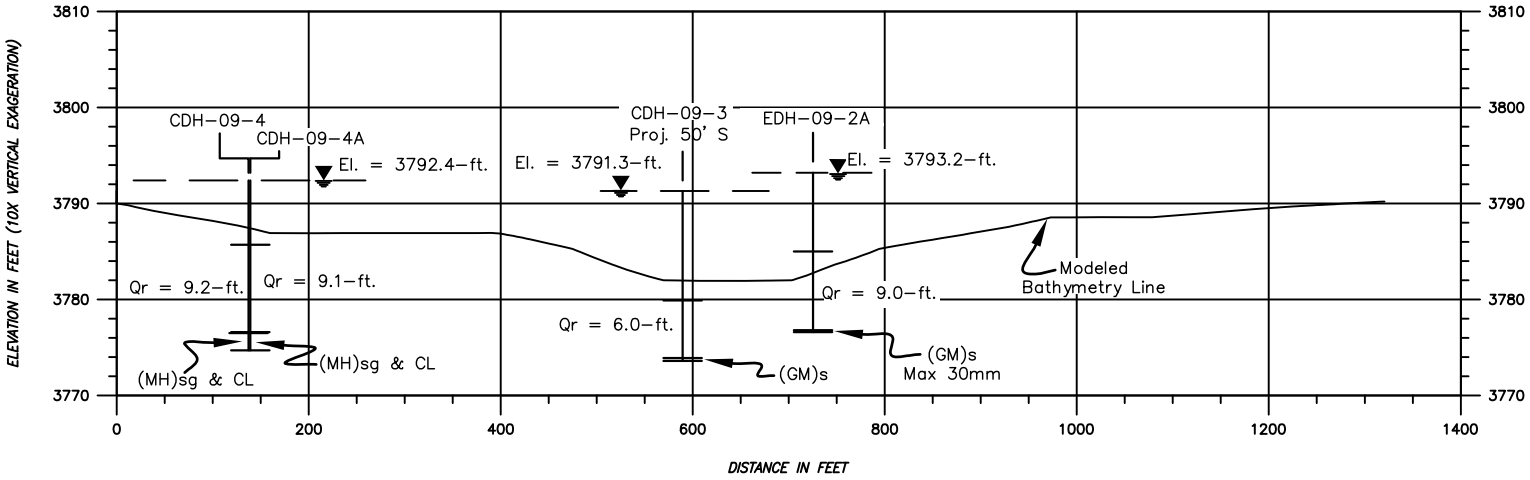


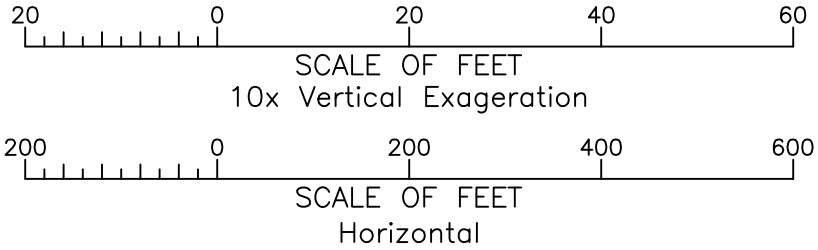
J.C. Boyle Section 3



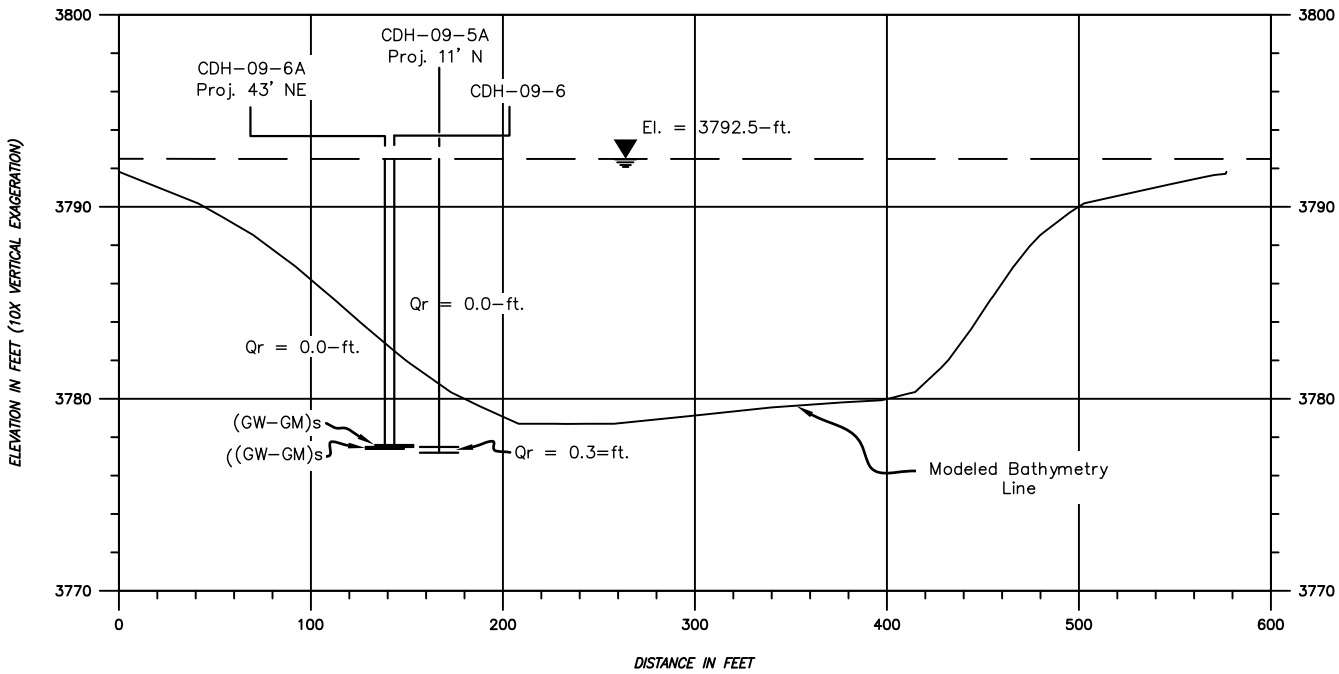


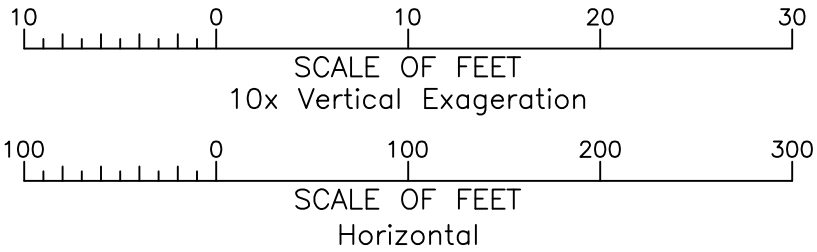
J.C. Boyle Section 4



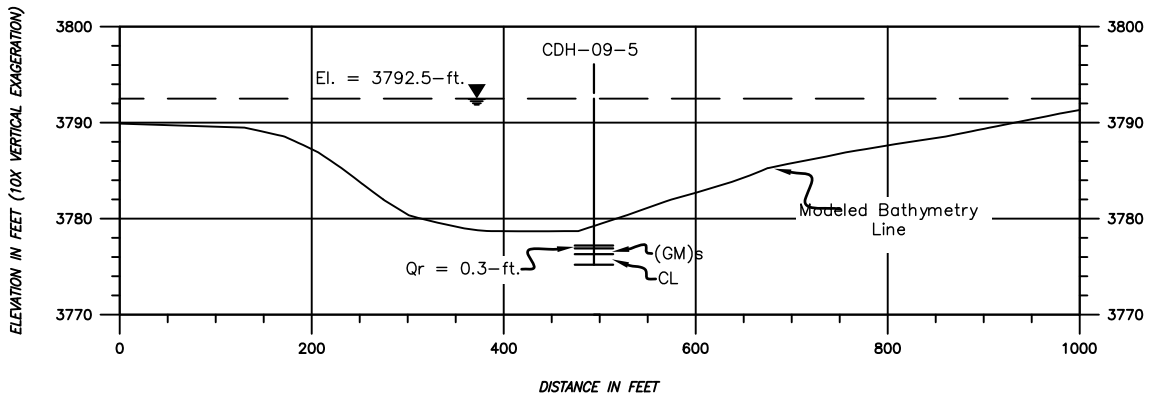


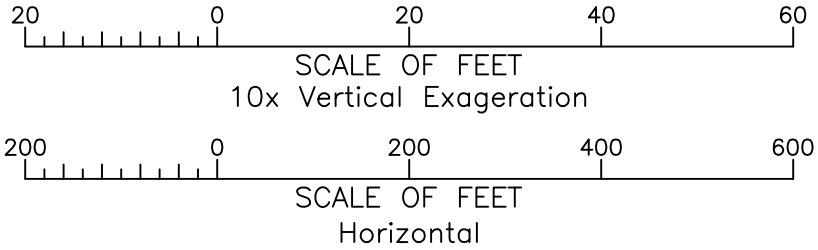
J.C. Boyle Section 6





J.C. Boyle Section 5





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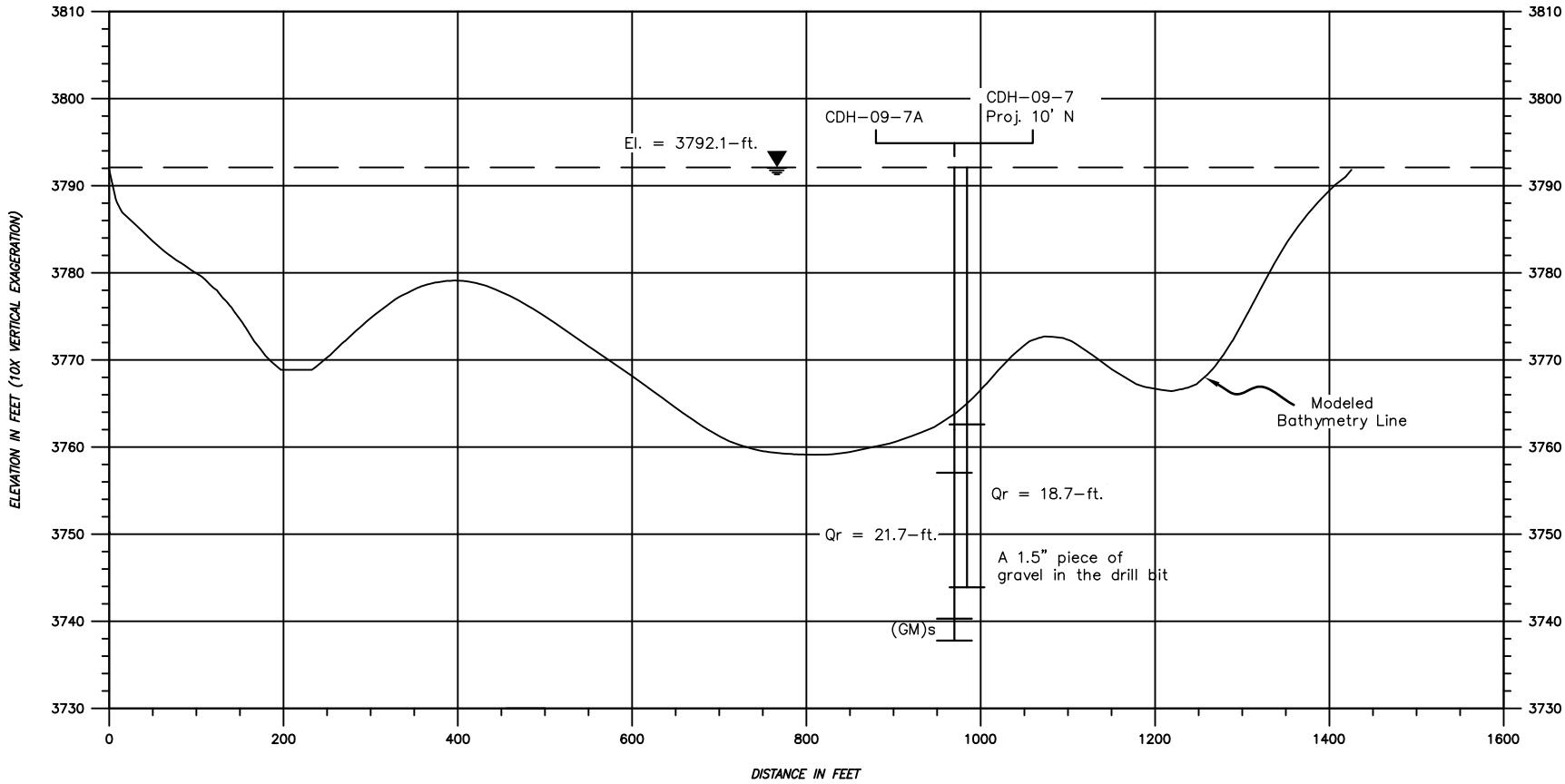
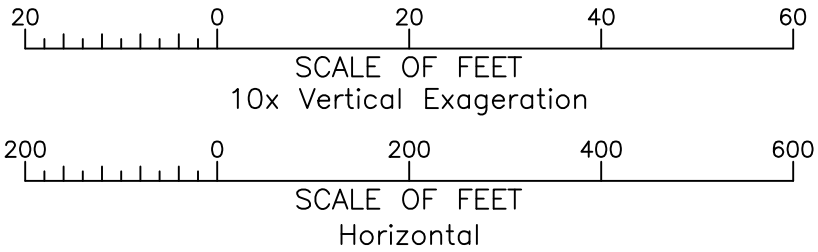
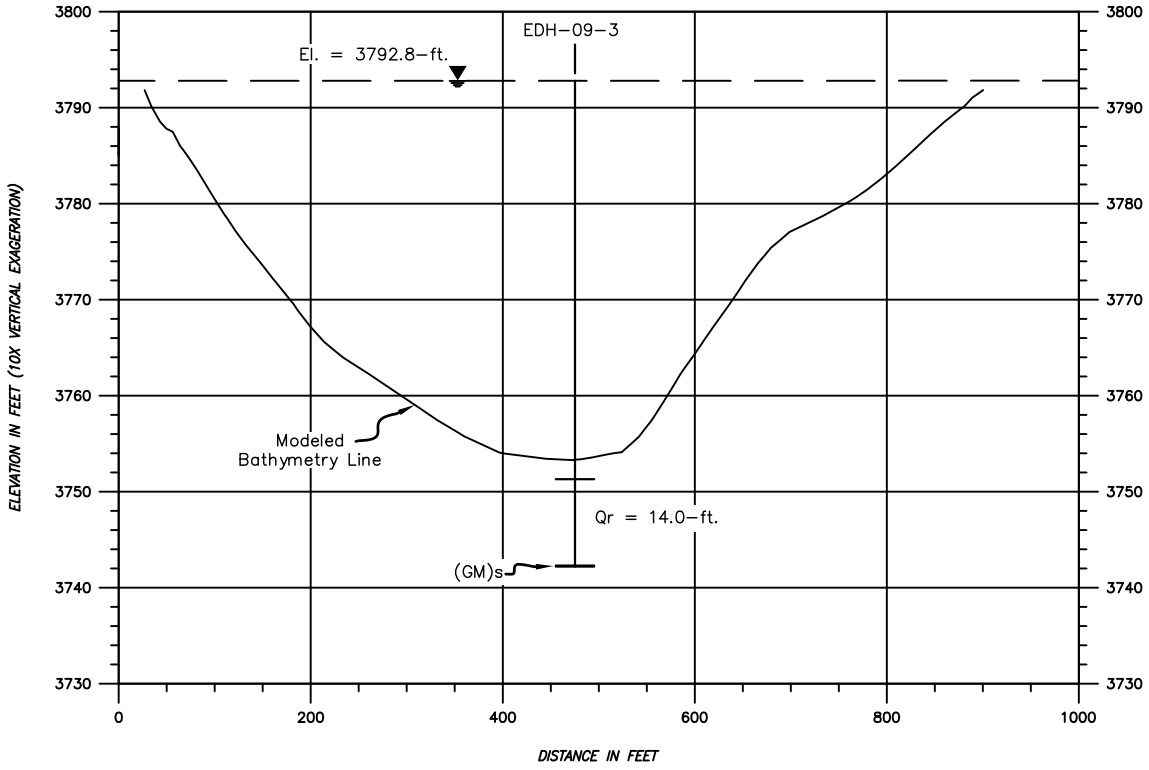
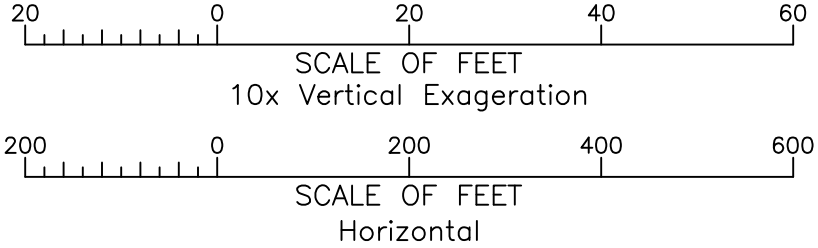


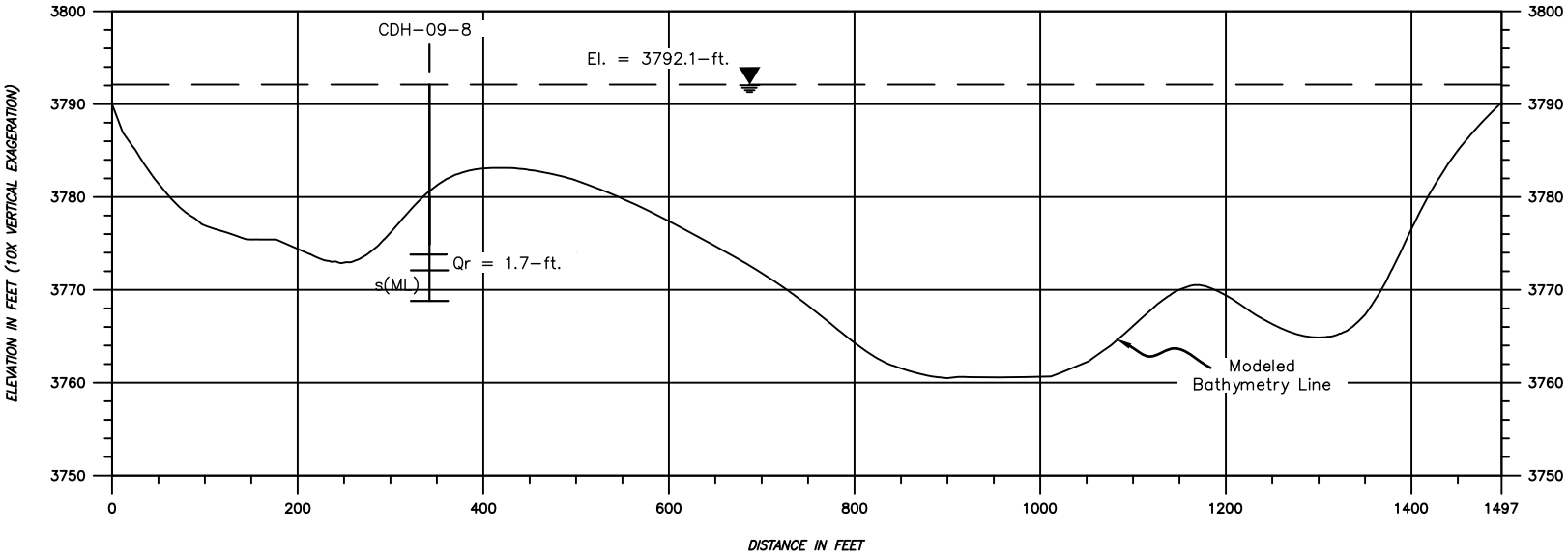


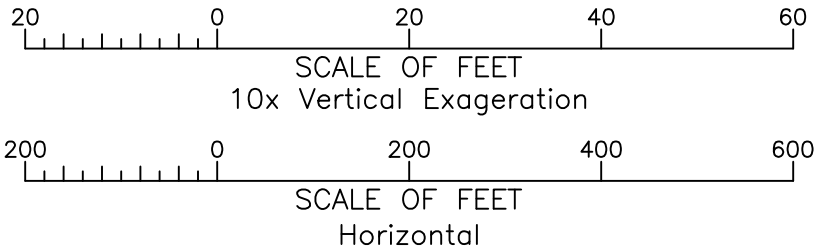
J.C. Boyle Section 7





J.C. Boyle Section 9





Copco Reservoir

Geologic Logs and Cross Sections

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-9

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/9/09 FINISHED: 11/9/09
RESERVOIR WATER DEPTH: NA

PROJECT: Klamath
COORDINATES: N 41° 57' 56.7" W 122° 16' 07.4"
TOTAL DEPTH: 10.0-ft.
RESEVOIR SEDIMENT THICKNESS: Not Determined

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,591.2-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 3.9 miles upstream from Copco-1 Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.2 ft. (11/9/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	NO RECOVERY OF RESERVOIR SEDIMENT										No recovery of reservoir sediment was made, and the drill hole location was abandoned.
5											
10											

BOTTOM OF HOLE: T.D. 10-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-9

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/9/09 FINISHED: 11/9/09
RESERVOIR WATER DEPTH: NA

PROJECT: Klamath
COORDINATES: N 41° 57' 56.7" W 122° 16' 07.4"
TOTAL DEPTH: 10.0-ft.
RESEVOIR SEDIMENT THICKNESS: Not Determined

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,591.2-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water/Sediment contact Depth:
12.0 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 7 feet and then hammered to a depth of 8.0 feet. The drive head and tube were lost during recovery. A diver retrieved the drive head assembly, but did not recover the lexan tube.

Attempt 2 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 8 feet with no recovery. The sample fell out of the tube as it was being retrieved. Reservoir sediment (mud) was present on the outside of the tube up to the first drill rod.

Attempt 3 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 10.0 feet, with recovery of 1.2 feet of wood chips and wood debris.

Attempt 4 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length. A plastic sediment retaining basket was not used. The tube was pushed to a depth of 10.0 feet, with recovery of 1.0 to 1.5 feet of wood chips and wood debris. The sample fell out of the tube as it broke the water surface, and before it could be recovered.

End of the day, will attempt collection of sediment at another location tomorrow.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-9

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/9/09 FINISHED: 11/9/09
RESERVOIR WATER DEPTH: NA

PROJECT: Klamath
COORDINATES: N 41° 57' 56.7" W 122° 16' 07.4"
TOTAL DEPTH: 10.0-ft.
RESEVOIR SEDIMENT THICKNESS: Not Determined

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,591.2-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon unsuccessful penetration through, or collection of, the reservoir sediment.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-9A

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/10/09 FINISHED: 11/10/09
RESERVOIR WATER DEPTH: 16.0-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 05.8" W 122° 16' 27.6"
TOTAL DEPTH: 7.0-ft.
RESEVOIR SEDIMENT THICKNESS: 4.6-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * Not Known-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 3.5 miles upstream from Copco-1 Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
Not Known (11/10/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	31.3	**47.4**	78.7	20.5	0.8	131.4	44.5	347.8	(MH)s	0.0	Qr
5											Tv

BOTTOM OF HOLE: T.D. 7-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 4.6 feet
RESERVOIR SEDIMENT - Qr

0.0 to 4.6 ft.: <u>ELASTIC SILT WITH SAND, (MH)s</u>: 78.7% fines with medium plasticity and rapid dilatancy; 20.5% fine sand; 0.8% fine, subrounded, hard gravel; maximum size 10mm; methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; wet, brown, massive with the consistency of pudding; no reaction with HCl.

4.6 to 7.0 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

4.6 to 7.0 ft.: <u>LEAN CLAY WITH SAND, (CL)s</u>: About 70% fines with medium to high plasticity and slow dilatancy; about 30% fine to coarse, mostly medium sand; trace fine, subangular, hard gravel; maximum size 10mm; wet, dark brown, numerous near-vertical plant roots up to 2mm in diameter; no reaction with HCl.

Geologic Interpretation: Intensely weathered volcanic tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-9A

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/10/09 FINISHED: 11/10/09
RESERVOIR WATER DEPTH: 16.0-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 05.8" W 122° 16' 27.6"
TOTAL DEPTH: 7.0-ft.
RESEVOIR SEDIMENT THICKNESS: 4.6-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * Not Known-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water/Sediment contact Depth:
16.0 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was pushed and hammered to a depth of 7 feet (refusal), with recovery of 4.8 feet of material.

Attempt 2 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 6.5 feet (refusal) with recovery of 4.8 feet of material.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanics.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-10

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/10/09 FINISHED: 11/10/09
RESERVOIR WATER DEPTH: 26.3-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 15.1" W 122° 16' 53.5"
TOTAL DEPTH: 8.5-ft.
RESEVOIR SEDIMENT THICKNESS: 8.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * Not Known
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 3.1 miles upstream from Copco-1 Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
Not Known (11/10/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL
	27.8	**53.4**	81.2	18.8	0	131.1	65.8	190.5	(MH)s	Qr
5									0.0	
	38.8	**57.8**	96.6	3.4	0	174.6	86.9	373.2	MH	
									0.0	

BOTTOM OF HOLE: T.D. 8.5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 8.0 feet
RESERVOIR SEDIMENT - Qr

0.0 to 5.0 ft.: ELASTIC SILT WITH SAND, (MH)s: 81.2% fines with medium plasticity and rapid dilatancy; 18.2% fine sand; trace to 10% organics throughout; maximum size fine sand; methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; wet, brown and dark brown with the consistency of pudding, stratified into alternating 6-8-inch layers of brown and dark brown sediment; no reaction with HCl.

5.0 to 8.0 ft.: ELASTIC SILT, MH: 96.6% fines with medium plasticity and rapid dilatancy; 3.4% fine sand; trace to 10% organics; maximum size fine sand; methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; wet, brown and dark brown with the consistency of pudding, stratified into alternating 6-8-inch layers of brown and dark brown sediment; no reaction with HCl.

<B>>8.0 to 8.5 feet
QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)

8.0 to 8.5 ft.: SILTY SAND, SM: **About 50% fines with medium to high plasticity and slow dilatancy; about 50% fine sand; maximum size fine sand; wet, dark brown; no reaction with HCl.**

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-10

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/10/09 FINISHED: 11/10/09
RESERVOIR WATER DEPTH: 26.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 15.1" W 122 ° 16' 53.5"
TOTAL DEPTH: 8.5-ft.
RESEVOIR SEDIMENT THICKNESS: 8.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * Not Known
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water/Sediment contact Depth:
26.3 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 8.0 feet (refusal), with recovery of 7.5 feet of material.

Attempt 2 Moved 2 feet over from Attempt #1. The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 8.0 feet (refusal) then hammered from 8.0 to 8.5 feet with recovery of 7.9 feet of material. There was very, very-little resistance to pushing from 0.0 to 5.0 feet, and major resistance at 8.0 feet.

Attempt 3 Moved 2 feet over from Attempt #2. The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 15.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 8.0 feet (refusal) then hammered from 8.0 to 11.5 feet with recovery of 3.9 feet of material. There was very, very-little resistance to pushing from 0.0 to 5.0 feet, and major resistance at 8.0 feet.

Attempt 4 Moved 2 feet over from Attempt #3. The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 15.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 8.0 feet (refusal) then hammered from 8.0 to 11.5 feet (refusal) with recovery of 6.5 feet of material. There was very, very-little resistance to pushing from 0.0 to 5.0 feet, and major resistance at 8.0 feet.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-10

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/10/09 FINISHED: 11/10/09
RESERVOIR WATER DEPTH: 26.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 15.1" W 122 ° 16' 53.5"
TOTAL DEPTH: 8.5-ft.
RESEVOIR SEDIMENT THICKNESS: 8.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * Not Known
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-11

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 7.9-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 37.6" W 122 ° 17' 14.5"
TOTAL DEPTH: 2.5-ft.
RESEVOIR SEDIMENT THICKNESS: 1.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: G. Mongano
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 2.6 miles upstream from Copco-1 Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.7 feet (11/15/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										Qr	***0.0 to 1.3 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 1.3 ft.: ELASTIC SILT, MH:** About 95% fines with medium plasticity and rapid dilatancy; about 5% fine sand; trace to 10% organics throughout with blades of grass and decaying organic material at 1.0 to 1.3 feet; maximum size fine sand; wet, dark grayish brown with the consistency of pudding; no reaction with HCl.
										Tv	***1.3 to 2.5 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **1.3 to 2.5 ft.: FAT CLAY WITH SAND, (CH)s:** About 85% to 90% fines with high plasticity and slow dilatancy; about 10% to 15% fine to coarse, primarily fine sand; trace fine, subangular to subrounded, hard gravel; maximum size 12mm; wet, dark brown to black; no reaction with HCl. Geologic Interpretation: Very intensely weathered tuff and lapilli tuff.

BOTTOM OF HOLE: T.D. 2.5-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-11

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 7.9-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 37.6" W 122 ° 17' 14.5"
TOTAL DEPTH: 2.5-ft.
RESEVOIR SEDIMENT THICKNESS: 1.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: G. Mongano
REVIEWED BY: M. McCulla

NOTES

Reservoir Water/Sediment contact Depth:
7.9 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 3.1 feet (refusal), with no recovery of material.

Attempt 2 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 2.5 feet (refusal), recovered 2.4 feet of material.

Attempt 3 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 2.5 feet (refusal), recovered 2.5 feet of material.

Three additional vibracore samples were collected to obtain the amount of sample required for contaminant testing.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanic rocks.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-12

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 31.2-ft.

PROJECT: Klamath
COORDINATES: N 41° 58' 37.7" W 122° 17' 26.4"
TOTAL DEPTH: 8.0-ft.
RESEVOIR SEDIMENT THICKNESS: 5.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 2.5 miles upstream from Copco-1 Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.4 ft. (11/11/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	39	**58.7**	97.7	2.3	0	153.1	75.6	342.2	MH		Qr
5										2586.0	
	37.9	**56.5**	94.4	5.6	0	215.3	87.3	369.1	MH		
										2585.4	Tv

BOTTOM OF HOLE: T.D. 8-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 5.4 feet
RESERVOIR SEDIMENT - Qr

0.0 to 5.4 ft.: ELASTIC SILT, MH: 97.7% fines with medium plasticity and rapid dilatancy; 2.3% fine sand; trace to 5% organics and roots; maximum size fine sand; wet, dark gray-brown, massive, pudding-like consistency, about 10% methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; no reaction with HCl.

Remarks: At a depth of 5.4 feet the sediment changed color, had an increasing sand content with depth, and was determined to be the pre-reservoir sediment contact. However, the lab sample (5.4 to 6.0 feet) shows this material to be Elastic Silt, MH similar to the reservoir sediment, and the true contact with pre-reservoir sediment may be slightly deeper.

5.4 to 8.0 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

5.4 to 8.0 ft.: SILT WITH SAND, (ML)s: About 60% to 80% fines with low to medium plasticity and rapid dilatancy; about 20% to 40% fine to medium sand; trace fine, subangular, hard gravel; maximum size 10mm; wet, greenish-gray, local plant roots up to 2mm in diameter, massive; no reaction with HCl.

Geologic Interpretation: Intensely weathered tuff and lapilli tuff.

Remarks: At a depth of 5.4 feet the sediment changed color, had an increasing sand content with depth, and was determined to be the pre-reservoir sediment contact. However, the lab sample (5.4 to 6.0 feet) shows this material to be Elastic Silt, MH similar to the reservoir sediment, and the true contact with pre-reservoir sediment may be slightly deeper.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-12

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 31.2-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 37.7" W 122 ° 17' 26.4"
TOTAL DEPTH: 8.0-ft.
RESEVOIR SEDIMENT THICKNESS: 5.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water/Sediment contact Depth:
31.2 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length. The tube was pushed to a depth of 7 feet and then hammered to a depth of 8.0 feet (refusal) with a recovery of 6.0 feet. Contaminant sampling was then carried out by MP-157 personnel.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanics.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-13

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 37.2-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 53.5" W 122 ° 18' 01.9"
TOTAL DEPTH: 6.5-ft.
RESEVOIR SEDIMENT THICKNESS: 5.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 1.8 miles upstream from Copco-1 Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.4 ft. (11/11/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
5	44.1	**53.9**	98.0	2.0	0	160.2	75.3	349.2	MH	2585.7	Qr
	46.7	**48.9**	95.6	4.4	0	156.2	86.2	316.4	MH	2584.9	Tv

BOTTOM OF HOLE: T.D. 6.5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 5.7 feet
RESERVOIR SEDIMENT - Qr

0.0 to 5.4 ft.: ELASTIC SILT, MH: 98.0% fines with medium plasticity and rapid dilatancy; 2.0% fine sand; trace to 5% organics and roots; maximum size fine sand; wet, dark gray-brown, massive, pudding-like consistency, about 10% methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; no reaction with HCl.

Remarks: At a depth of 5.7 feet the sediment changed color, had an increasing sand content with depth, and was determined to be the pre-reservoir sediment contact. However, the lab sample (5.7 to 6.5 feet) shows this material to be Elastic Silt, MH similar to the reservoir sediment, and the true contact with pre-reservoir sediment may be slightly deeper.

5.7 to 6.5 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

5.7 to 6.5 ft.: ELASTIC SILT, (MH): 95.6% fines with low to medium plasticity and rapid dilatancy; 4.4% fine sand; maximum size fine sand; wet, medium brown, trace plant roots up to 2mm in diameter, massive and slightly more firm than overlying reservoir sediment; no reaction with HCl.

Geologic Interpretation: Intensely weathered tuff and lapilli tuff.

Remarks: At a depth of 5.7 feet the sediment changed color from dark gray-brown to medium-brown, had an increasing sand content with depth, was firmer than the overlying reservoir sediment, does not contain any methane bubbles, and was determined to be the pre-reservoir sediment contact. However, the lab sample (5.7 to 6.5 feet) shows this material to be Elastic Silt, MH similar to the reservoir sediment, and the true contact with pre-reservoir sediment may be slightly deeper.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-13

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 37.2-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 53.5" W 122 ° 18' 01.9"
TOTAL DEPTH: 6.5-ft.
RESEVOIR SEDIMENT THICKNESS: 5.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water/Sediment contact Depth:
37.2 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 15 feet in length with a plastic sediment retaining basket (sand fingers). The tube was pushed to a depth of 5.0 feet and then hammered to a depth of 6.5 feet (refusal) with a recovery of 5.0 feet. Contaminant sampling was then carried out by MP-157 personnel.

Attempt 2 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length without a plastic sediment retaining basket (sand fingers). The tube was pushed to a depth of 5.0 feet and then hammered to a depth of 6.5 feet (refusal) with a recovery of 4.2 feet.

Attempt 3 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length without a plastic sediment retaining basket (sand fingers). The tube was pushed to a depth of 5.0 feet and then hammered to a depth of 6.5 feet (refusal) with a recovery of about 4.2 feet. However, before the sediment could be fully retrieved onto the boat it dropped out of the lexan tube and was lost.

Attempt 4 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 15 feet in length without a plastic sediment retaining basket (sand fingers). The tube was pushed to a depth of 5.0 feet and then hammered to a depth of 6.5 feet (refusal) with a recovery of 3.4 feet. Contaminant sampling was then carried out by MP-157 personnel.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-13

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 37.2-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 53.5" W 122 ° 18' 01.9"
TOTAL DEPTH: 6.5-ft.
RESEVOIR SEDIMENT THICKNESS: 5.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanics.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-14

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 24.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 53.3" W 122 ° 17' 52.0"
TOTAL DEPTH: 6.5-ft.
RESEVOIR SEDIMENT THICKNESS: 5.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: G. Mongano
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 2.0 miles upstream from Copco-1 Dam, adjacent to drill holes EDH-09-5 and EDH-09-5A.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.7 ft. (11/15/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	38.1	**59.4**	97.5	2.5	0	127.8	55.2	279.6	MH	Qr	***0.0 to 5.3 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 5.3 ft.: ELASTIC SILT, MH:** 97.5% fines with medium plasticity and rapid dilatancy; 2.5% fine sand; trace to 5% organics and roots; maximum size fine sand; wet, dark gray-brown, massive, pudding-like consistency; no reaction with HCl.
									2589.9		
5										Qr	***5.3 to 6.5 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **5.7 to 6.5 ft.: CLAYEY SAND (SC) TO SILTY SAND (SM):** About 50% fines with low plasticity and rapid dilatancy; about 50% fine to coarse sand; trace fine, subangular, hard gravel; maximum size 12mm; wet, dark gray to black, soft; no reaction with HCl. Geologic Interpretation: Intensely weathered tuff and lapilli tuff.
										Tv	

BOTTOM OF HOLE: T.D. 6.5-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-14

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 24.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 53.3" W 122 ° 17' 52.0"
TOTAL DEPTH: 6.5-ft.
RESEVOIR SEDIMENT THICKNESS: 5.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: G. Mongano
REVIEWED BY: M. McCulla

NOTES

Reservoir Water/Sediment contact Depth:
24.0 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length without a plastic sediment retaining basket (sand fingers). The tube was pushed then hammered to a depth of 4.0 feet (refusal) with a recovery of 2.6 feet of material.

Attempt 2 Moved 14 feet away from the shore. The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length without a plastic sediment retaining basket (sand fingers). The tube was pushed then hammered to a depth of 6.0 feet (refusal) with a recovery of 5.7 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

Attempt 3 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length without a plastic sediment retaining basket (sand fingers). The tube was pushed then hammered to a depth of 6.5 feet (refusal) with a recovery of 5.5 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

Attempt 4 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length without a plastic sediment retaining basket (sand fingers). The tube was pushed then hammered to a depth of 7.0 feet (refusal) with a recovery of 5.6 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-14

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 24.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 53.3" W 122 ° 17' 52.0"
TOTAL DEPTH: 6.5-ft.
RESEVOIR SEDIMENT THICKNESS: 5.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: G. Mongano

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-15

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 40.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 07.4" W 122 ° 18' 38.5"
TOTAL DEPTH: 5.0-ft.
RESEVOIR SEDIMENT THICKNESS: 3.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the main section of the reservoir; about 1.3 miles upstream from Copco-1 Dam, near drill hole CDH-09-15A.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.4 ft. (11/11/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										Qr	***0.0 to 3.0 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 3.0 ft.: ELASTIC SILT, MH:** Visual identification classifies the material as containing about 90% fines with medium plasticity and a high liquid limit; about 10% fine sand; maximum size fine sand; wet, dark gray, pudding-like consistency; no reaction with HCl. Remarks: The contact with underlying alluvium is approximate. The contact may be slightly deeper than 3.0 feet, but is definitely shallower than 4.6 feet.
										Qal	***3.0 to 5.0 feet*** ***QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)*** **3.0 to 5.0 ft.: SILTY GRAVEL WITH SAND, (GM)s:** About 60% fine to coarse, subangular to subrounded, hard gravel; about 20% medium to coarse sand; about 20% nonplastic fines; about 10% pieces of tree limbs up to a diameter of 10mm and a length of 50mm; maximum gravel size 25mm; wet, dark gray; no reaction with HCl.
5											

BOTTOM OF HOLE: T.D. 5-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-15

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 40.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 07.4" W 122 ° 18' 38.5"
TOTAL DEPTH: 5.0-ft.
RESEVOIR SEDIMENT THICKNESS: 3.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water/Sediment contact Depth:
40.0 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run.
Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 3.0 feet and then hammered to a depth of 5.0 feet, recovering 0.4 feet of material.

Attempt 2 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 1.0 foot and then hammered to a depth of 3.0 feet, recovering 1.5 feet of material.

End of the day, will attempt collection of sediment at another location tomorrow.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon unsuccessful collection of the required quantity of reservoir sediment.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-15A

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/12/09 FINISHED: 11/12/09
RESERVOIR WATER DEPTH: 69.2-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 03.1" W 122 ° 18' 38.0"
TOTAL DEPTH: 10.0-ft.
RESEVOIR SEDIMENT THICKNESS: 9.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.5-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the main section of the reservoir; about 1.3 miles upstream from Copco-1 Dam, and near drill hole CDH-09-15.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,592.9 ft. (11/12/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
69.2 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	75.1	**24.9**	100	0	0	148.3	74.0	304.8	MH		***0.0 to 9.7 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 9.7 ft.: ELASTIC SILT, MH:** 94.1% to 100.0% fines with medium plasticity and a high liquid limit; 0.0% to 5.9% fine sand; maximum size fine sand; wet, dark gray, pudding-like consistency, numerous methane bubbles throughout the sediment; no reaction with HCl. Remarks: The contact with pre-reservoir material is approximate. The contact may be slightly deeper than 9.7 feet. ***9.7 to 10.0 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **9.7 to 10.0 ft.: SILT, ML TO LEAN CLAY, CL:** About 95% fines with low plasticity and rapid dilatancy; about 5% fine sand; maximum size fine sand; wet, dark gray, trace to minor methane bubbles, soft to very soft; no reaction with HCl.
5									2587.5	Qr	
	60.8	**33.3**	94.1	5.9	0	165.3	77.9	287.3	MH		
									2582.8		
10										Tv	

BOTTOM OF HOLE: T.D. 10-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-15A

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/12/09 FINISHED: 11/12/09
RESERVOIR WATER DEPTH: 69.2-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 03.1" W 122 ° 18' 38.0"
TOTAL DEPTH: 10.0-ft.
RESEVOIR SEDIMENT THICKNESS: 9.7-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.5-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 7.0 feet, recovering 4.8 feet of material.

Attempt 2 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 10.0 feet, recovering 7.7 feet of material.

Attempt 3 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 9.0 feet, recovering 6.2 feet of material.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration of the reservoir sediment into pre-reservoir volcanic rocks, and collection of the required quantity of reservoir sediment.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-16

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/12/09 FINISHED: 11/13/09
RESERVOIR WATER DEPTH: 74.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 53.3" W 122 ° 19' 01.6"
TOTAL DEPTH: 7.5-ft.
RESEVOIR SEDIMENT THICKNESS: 7.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.8-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the main section of the reservoir; about 4,900 feet upstream from Copco-1 Dam, and near drill hole EDH-09-6.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,592.8 ft. (11/12/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
74.0 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	58.1	**31.5**	89.6	10.4	0	151.6	71.9	287.8	MH		**Qr**
5											
										2585.3	**Tv**

BOTTOM OF HOLE: T.D. 7.5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 7.5 feet
RESERVOIR SEDIMENT - Qr

0.0 to 7.5 ft.: ELASTIC SILT, MH: 89.6% fines with medium plasticity and rapid dilatancy; 10.4% fine sand; trace to 5% organics and roots; maximum size fine sand; wet, dark gray-brown, massive, pudding-like consistency, abundant methane bubbles throughout the sediment; no reaction with HCl.

Geologic Interpretation: All three attempts (push/hammer and vibracore) encountered refusal at a depth of 7.5 feet. This is believed to be the contact with pre-reservoir volcanic rock. Supporting this interpretation was the presence of a mat of decaying vegetation about 0.3 feet thick above refusal (7.2 to 7.5 feet).

7.5 to 7.5* feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

7.5 to 7.5 ft.: Refusal (no recovery) - Believed to be pre-reservoir volcanic rock.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-16

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/12/09 FINISHED: 11/13/09
RESERVOIR WATER DEPTH: 74.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 53.3" W 122 ° 19' 01.6"
TOTAL DEPTH: 7.5-ft.
RESEVOIR SEDIMENT THICKNESS: 7.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.8-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length. The tube was pushed then hammered to a depth of 7.5 feet (refusal) with a recovery of 6.5 feet of material.

11/13/09
Attempt 2 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length. The tube was pushed then hammered to a depth of 7.5 feet (refusal) with a recovery of 7.0 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

Attempt 3 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 7.5 feet (refusal), recovered 7.5 feet of material.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment in contact with the underlying pre-reservoir volcanic rocks.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-17

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 25.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 12.5" W 122 ° 19' 09.6"
TOTAL DEPTH: 5.0-ft.
RESEVOIR SEDIMENT THICKNESS: 1.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.3-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the main section of the reservoir; about 1.0 mile upstream from Copco-1 Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,592.3 ft. (11/15/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
74.0 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	62.5	**36.0**	98.5	1.5	0	142.9	72.9	344.5	MH / 2591.1	Qr	***0.0 to 1.2 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 1.2 ft.: ELASTIC SILT, MH:** 98.5% fines with medium plasticity and rapid dilatancy; 1.5% fine sand; trace to 5% organics and roots; maximum size fine sand; wet, dark gray-brown, massive, pudding-like consistency, abundant methane bubbles throughout the sediment; no reaction with HCl.
5										Tv	***1.2 to 5.0 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **1.2 to 2.0 ft.: SILTY SAND, SM:** About 65% fine to coarse sand; about 30% nonplastic fines; about 5% fine, subangular to subrounded, hard gravel; maximum size 12mm; wet, dark gray to black, strong organic order, loose but holds the shape of the lexan tube; no reaction with HCl. Geologic Interpretation: Very intensely weathered tuff and lapilli tuff. **2.0 to 5.0 ft.: SANDY LEAN CLAY, s(CL) TO CLAYEY SAND, SC:** About 65% fines with medium plasticity and slow dilatancy; about 30% fine to coarse, predominantly coarse sand; about 5% fine to coarse, subangular to subrounded, hard gravel; maximum size 25mm; wet, dark gray to black, firm; no reaction with HCl. Geologic Interpretation: Very intensely weathered tuff and lapilli tuff.

BOTTOM OF HOLE: T.D. 5-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-17

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 25.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 12.5" W 122 ° 19' 09.6"
TOTAL DEPTH: 5.0-ft.
RESEVOIR SEDIMENT THICKNESS: 1.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.3-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run.
Attempt 1 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 5.0 feet (refusal), recovered 4.6 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

Attempt 2 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 1.4 feet (refusal), recovered 1.4 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

Attempt 3 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 1.8 feet (refusal), recovered 1.8 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

Attempt 4 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 1.5 feet (refusal), recovered 1.1 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment in contact with the underlying pre-reservoir volcanic rocks.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-18

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/13/09 FINISHED: 11/13/09
RESERVOIR WATER DEPTH: 84.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 04.1" W 122 ° 19' 15.4"
TOTAL DEPTH: 10.0-ft.
RESEVOIR SEDIMENT THICKNESS: 9.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.8-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the main section of the reservoir; about 4,200 feet upstream from Copco-1 Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,592.8 ft. (11/13/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
74.0 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	82.0	**18.0**	100.0	0	0	155.5	87.0	305.2	MH	2583.9	Qr
5											
	39.4	**48.6**	88.0	12.0	0	83.7	28.5	105.6	MH	2582.8	Tv
10											

BOTTOM OF HOLE: T.D. 10-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 9.2 feet
RESERVOIR SEDIMENT - Qr

0.0 to 8.9 ft.: ELASTIC SILT, MH: 100.0% fines with medium plasticity and rapid dilatancy; trace to 5% organic material; maximum size fine sand; wet, dark gray-brown and black with multiple brown laminations (up to ½-inch thick) from 7.0 to 8.9 feet, pudding-like consistency, abundant methane bubbles throughout the sediment; no reaction with HCl.

8.9 to 9.2 ft.: ORGANIC ELASTIC SILT, OL/OH: About 50% fines with medium plasticity and rapid dilatancy; about 50% wood chips, roots, grass, and other decaying organic material; maximum size 25mm wood chips; wet, dark gray-brown and black, pudding-like consistency, abundant methane bubbles throughout the sediment; no reaction with HCl.

9.2 to 10.0 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

2.0 to 5.0 ft.: LEAN CLAY WITH SAND, (CL)s: About 80% fines with medium plasticity and slow dilatancy; about 20% fine sand; trace fine, subangular to subrounded, hard gravel; maximum size 6mm; wet, brown, soft to firm; no reaction with HCl.

Geologic Interpretation: Very intensely weathered tuff and lapilli tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-18

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/13/09 FINISHED: 11/13/09
RESERVOIR WATER DEPTH: 84.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 04.1" W 122 ° 19' 15.4"
TOTAL DEPTH: 10.0-ft.
RESEVOIR SEDIMENT THICKNESS: 9.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.8-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 7.0 feet (refusal), recovered 6.8 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

Attempt 2 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 10.0 feet (refusal), recovered 9.7 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment in contact with the underlying pre-reservoir volcanic rocks.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-19

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 50.4-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 03.2" W 122 ° 19' 42.2"
TOTAL DEPTH: 5.5-ft.
RESEVOIR SEDIMENT THICKNESS: 4.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.3-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the main section of the reservoir; about 2,900 feet upstream from Copco-1 Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,592.3 ft. (11/15/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
50.4 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	70.4	29.1	99.5	0.5	0	159.1	78.1	298.2	MH		Qr
										2587.5	
5											Tv

BOTTOM OF HOLE: T.D. 5.5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 4.8 feet
RESERVOIR SEDIMENT - Qr

0.0 to 4.8 ft.: ELASTIC SILT, MH: 99.5% fines with medium plasticity and rapid dilatancy; 0.5% fine sand; trace to 5% organic material; maximum size fine sand; wet, dark gray-brown and black with minor brown laminations (up to ½-inch thick) from 2.9 to 4.8 feet, pudding-like consistency, strong organic odor, abundant methane bubbles throughout the sediment; no reaction with HCl.

4.8 to 5.5 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

4.8 to 5.2 ft.: CLAYEY SAND, SC to SILTY SAND, SM: About 60% fine to coarse, predominantly medium sand; about 40% fines with low to medium plasticity and slow dilatancy; trace fine, subangular to subrounded, hard gravel; maximum size 12mm; wet, dark gray, soft; no reaction with HCl.

4.8 to 5.5 ft.: FAT CLAY WITH SAND, (CH)s: About 60% fines with high plasticity and no dilatancy; about 30% fine to coarse sand; about 10% fine to coarse, subangular to subrounded, hard gravel; maximum size 70mm; wet, brown, firm to very firm; no reaction with HCl.

Geologic Interpretation: Very intensely weathered tuff and lapilli tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-19

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 50.4-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 59' 03.2" W 122 ° 19' 42.2"
TOTAL DEPTH: 5.5-ft.
RESEVOIR SEDIMENT THICKNESS: 4.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2592.3-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 5.5 feet (refusal), recovered 5.4 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

Attempt 2 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 5.7 feet (refusal), recovered 3.9 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment in contact with the underlying pre-reservoir volcanic rocks.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-20

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/14/09 FINISHED: 11/14/09
RESERVOIR WATER DEPTH: 80.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 49.5" W 122 ° 19' 42.7"
TOTAL DEPTH: 7.5-ft.
RESEVOIR SEDIMENT THICKNESS: 7.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,592.3-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the main section of the reservoir; about 1,800 feet upstream from Copco-1 Dam, near drill hole EDH-09-7.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,592.3 ft. (11/14/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
80.0 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	59.7	**30.8**	90.5	9.5	0	161.6	78.9	287.3	MH		Qr
5										0.0	
	57.3	**33.9**	91.2	8.8	0	164.5	60.3	253.1	MH		
										0.0	Tv

BOTTOM OF HOLE: T.D. 7.5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 7.4 feet
RESERVOIR SEDIMENT - Qr

0.0 to 7.0 ft.: ELASTIC SILT, MH: 90.5% fines with medium plasticity and rapid dilatancy; 9.5% fine sand; trace to 5% organic material; maximum size fine sand; wet, dark gray-brown and black, pudding-like consistency, strong organic odor, abundant methane bubbles throughout the sediment; no reaction with HCl.

7.0 to 7.4 ft.: ORGANIC SOIL, OL/OH: About 50% wood debris up to 3.5-inches long; about 50% Elastic Silt (fines with medium plasticity and rapid dilatancy); maximum size 3.5-inch long wood debris; wet, dark gray-brown to black; no reaction with HCl.

7.4 to 7.5 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

7.4 to 7.5 ft.: LEAN CLAY WITH SAND, (CL)s: About 80% fines with medium to high plasticity and slow dilatancy; about 20% fine sand; trace fine, subangular to subrounded, hard gravel; maximum size 12mm; wet, dark gray, soft; no reaction with HCl.

Geologic Interpretation: Very intensely weathered tuff and lapilli tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-20

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/14/09 FINISHED: 11/14/09
RESERVOIR WATER DEPTH: 80.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 49.5" W 122 ° 19' 42.7"
TOTAL DEPTH: 7.5-ft.
RESEVOIR SEDIMENT THICKNESS: 7.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,592.3-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The vibracore method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 7.5 feet (refusal), recovered 7.4 feet of material. Contaminant sampling was then carried out by MP-157 personnel.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment in contact with the underlying pre-reservoir volcanic rocks.

HOLE COMPLETION:
Following removal of the lexan tube, the hole was allowed to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-4

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 19.8-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 34.2" W 122 ° 02' 03.3"
TOTAL DEPTH: 4.0-ft.
RESEVOIR SEDIMENT THICKNESS: 3.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan tube samples for use in determining the engineering properties of reservoir sediment.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 3.2-miles upstream from Copco-1 Dam, near drill hole CDH-09-10.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.7 ft. (11/15/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
19.8 feet

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										Qr	***0.0 to 3.5 feet*** ***RESERVOIR SEDIMENT - Qr***
											0.0 to 3.5 ft. <u>ELASTIC SILT, MH</u>: About 90% fines with medium plasticity and rapid dilatancy; about 10% fine sand; trace to 10% organics throughout; maximum size fine sand; wet, brown and dark brown with the consistency of pudding; no reaction with HCl.
											Remarks: The contact between reservoir sediment and pre-reservoir sediment could not be seen clearly through the lexan sample tube. It is believed to be at a depth of about 3.5 feet, but may be up to 0.1-ft. higher or lower.
											3.5 to 4.0 feet ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)***
											3.5 to 4.0 ft. <u>FAT CLAY, (CH)</u>: About 90% fines with high plasticity and slow to no dilatancy; about 10% fine to coarse sand; trace fine to coarse hard gravel; maximum size coarse gravel; wet, dark brown; no reaction with HCl.
											Geologic Interpretation: Very intensely weathered lapilli tuff.
										Tv	

BOTTOM OF HOLE: T.D. 4-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample from 0.0 to 4.0 feet, with the tube actually being cut to a length of 3.41 feet in length.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-4

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 19.8-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 34.2" W 122 ° 02' 03.3"
TOTAL DEPTH: 4.0-ft.
RESEVOIR SEDIMENT THICKNESS: 3.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run.
Attempt 1 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length without a plastic sediment retaining basket. The tube was pushed to a depth of 4.0 feet (refusal), with no recovery of material.

Attempt 2 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length without a plastic sediment retaining basket. The tube was pushed to a depth of 4.0 feet (refusal), with no recovery of material.

Attempt 3 The direct push method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was pushed to a depth of 4.0 feet (refusal), with recovery of 3.4 feet of material.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanic rock, and the collection of an undisturbed sample of reservoir sediment.

HOLE COMPLETION:
The lexan tube sampler was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample from 0.0 to 4.0 feet, with the tube actually being cut to a length of 3.41 feet in length.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-5

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 20.2-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 20.6" W 122 ° 02' 01.6"
TOTAL DEPTH: 2.5-ft.
RESEVOIR SEDIMENT THICKNESS: 1.9-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan tube samples for use in determining the engineering properties of reservoir sediment.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 1.9-miles upstream from Copco-1 Dam and adjacent to drill holes EDH-09-5A and CDH-09 -14.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.7 ft. (11/15/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
20.2 feet

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL
										Qr
										Tv

BOTTOM OF HOLE: T.D. 2.5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 1.9 feet
RESERVOIR SEDIMENT - Qr

0.0 to 1.9 ft. ELASTIC SILT, MH: About 90% fines with medium plasticity and rapid dilatancy; about 10% fine sand; trace to 10% organics throughout; maximum size fine sand; wet, brown and dark brown with the consistency of pudding with increasing sand content near the lower contact; no reaction with HCl.

Remarks: The contact between reservoir sediment and pre-reservoir sediment could not be seen clearly through the lexan sample tube. It is believed to be at a depth of about 1.9 feet, but may be up to 0.1-ft. higher or lower.

1.9 to 2.5 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

1.9 to 2.5 ft. FAT CLAY, (CH): About 90% fines with high plasticity and slow to no dilatancy; about 10% fine to coarse sand; trace fine to coarse hard gravel; maximum size coarse gravel; wet, dark brown; no reaction with HCl.

Geologic Interpretation: Very intensely weathered lapilli tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample from 0.0 to 1.85 feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-5

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 20.2-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 20.6" W 122 ° 02' 01.6"
TOTAL DEPTH: 2.5-ft.
RESEVOIR SEDIMENT THICKNESS: 1.9-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run.
Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length without a plastic sediment retaining basket. The tube was pushed to a depth of 2.0 feet then hammered to 2.5 feet (refusal), with recovery of 1.9 feet of material. A lexan tube sample was collected here from 0.0 to 1.85 feet for engineering properties.

Attempt 2 The boats were moved 14 feet into deeper water (with thicker sediment) and the vibracore method was used for sample collection to determine the contact depth between reservoir sediment and pre-reservoir sediment. An undisturbed sample for engineering properties was not collected with vibracore at this location. A lexan the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 6.0 feet (refusal), recovered 5.4 feet of material.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanic rock, and the collection of an undisturbed sample of reservoir sediment.

HOLE COMPLETION:
The lexan tube sampler was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample from 0.0 to 1.85 feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-5A

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 20.2-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 02.1" W 122 ° 01' 51.8"
TOTAL DEPTH: 3.0-ft.
RESEVOIR SEDIMENT THICKNESS: 1.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan tube samples for use in determining the engineering properties of reservoir sediment.

LOCATION:
Copco-1 Reservoir. Located in the eastern arm of the reservoir; about 1.9-miles upstream from Copco-1 Dam, adjacent to drill holes CDH-09 -14 and EDH-09-5.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.7 ft. (11/15/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
20.2 feet

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										Qr	***0.0 to 1.8 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 1.8 ft. ELASTIC SILT, MH:** About 90% fines with medium plasticity and rapid dilatancy; about 10% fine sand; trace to 10% organics throughout; maximum size fine sand; wet, brown and dark brown with the consistency of pudding with increasing sand content near the lower contact; no reaction with HCl.
										Tv	***1.8 to 3.0 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **1.8 to 3.0 ft. FAT CLAY, (CH):** About 90% fines with high plasticity and slow to no dilatancy; about 10% fine to coarse sand; trace fine to coarse hard gravel; maximum size coarse gravel; wet, dark brown; no reaction with HCl. Geologic Interpretation: Very intensely weathered lapilli tuff.

BOTTOM OF HOLE: T.D. 3-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample from 0.0 to 2.6 feet was cut to a final length of 2.14 feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-5A

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 20.2-ft.

PROJECT: Klamath
COORDINATES: N 42 ° 08' 02.1" W 122 ° 01' 51.8"
TOTAL DEPTH: 3.0-ft.
RESEVOIR SEDIMENT THICKNESS: 1.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.7-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run.
Attempt 1 The vibracore method was used for sample collection. A lexan the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 8.0 feet in length with a plastic sediment retaining basket. The tube was vibrated to a depth of 3.0 feet (refusal), recovered 2.6 feet of material. An undisturbed lexan tube sample was collected from 0.0 to 2.14 feet.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanic rock, and the collection of an undisturbed sample of reservoir sediment.

HOLE COMPLETION:
The lexan tube sampler was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample from 0.0 to 2.6 feet was cut to a final length of 2.14 feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-6

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/16/09 FINISHED: 11/16/09
RESERVOIR WATER DEPTH: 77.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 54.5" W 122 ° 18' 58.9"
TOTAL DEPTH: 10.0-ft.
RESEVOIR SEDIMENT THICKNESS: Not Known

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.5-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan tube samples for use in determining the engineering properties of reservoir sediment.

LOCATION:
Copco-1 Reservoir. Located in the main section of the reservoir; about 5,100 feet upstream from Copco-1 Dam, adjacent to drill hole CDH-09 -16 and close to drill hole CDH-09-15A.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.5 ft. (11/16/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
77.0 feet

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL
5										Qr
10										

BOTTOM OF HOLE: T.D. 10-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 10.0 feet
RESERVOIR SEDIMENT - Qr

0.0 to 1.5 ft. No Recovery It is believed that the upper 1.5 feet of material was missing from the 10 foot lexan tube sample.

1.5 to 10.0 ft. ELASTIC SILT, MH: About 90% fines with medium plasticity and rapid dilatancy; about 10% fine sand; trace to 10% organics throughout; maximum size fine sand; wet, brown and dark brown with the consistency of pudding, alternating bands of dark brown and dark gray layers from 8.0 to 10.0 feet, up to 10% methane bubbles throughout the sediment; no reaction with HCl.

Geologic Interpretation: The presence of alternating dark brown and dark gray layers within the bottom 2 feet of the hole, refusal of the lexan tube to further penetration by hammering, and the depth of the reservoir-sediment / pre-reservoir material contact in the closest two drill holes all indicates that either this is the full depth of reservoir sediment or that the contact with pre-reservoir material is very close (within ½-foot).

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube samples:
1.5 to 4.0 feet
4.0 to 7.0 feet
7.0 to 10.0 feet

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-6

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/16/09 FINISHED: 11/16/09
RESERVOIR WATER DEPTH: 77.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 54.5" W 122 ° 18' 58.9"
TOTAL DEPTH: 10.0-ft.
RESEVOIR SEDIMENT THICKNESS: Not Known

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.5-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run.
Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length with a plastic sediment retaining basket (sand fingers). The tube was pushed then hammered to a depth of 10.0 feet (refusal) with a recovery of 8.5 feet of material.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful collection of representative undisturbed samples of reservoir sediment to the refusal depth of 10 feet. Reservoir sediment at this location is believed to be at the refusal depth of 10 feet, or within another ½ foot. In the Adjacent drill hole (CDH-09016) reservoir sediment had a thickness of 7.5 feet, and in another close drill hole (CDH-09-15A) the reservoir sediment thickness was 9.7 feet.

HOLE COMPLETION:
The lexan tube sampler was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube samples:
1.5 to 4.0 feet
4.0 to 7.0 feet
7.0 to 10.0 feet

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-7

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/16/09
RESERVOIR WATER DEPTH: 30.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 48.9" W 122 ° 19' 36.0"
TOTAL DEPTH: 3.2-ft.
RESEVOIR SEDIMENT THICKNESS: 1.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.5-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan tube samples for use in determining the engineering properties of reservoir sediment.

LOCATION:
Copco-1 Reservoir. Located in the main section of reservoir; about 2,000 feet upstream from Copco-1 Dam, adjacent to drill hole CDH-09 -20.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Gravity Consultants LLC Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,591.5 ft. (11/16/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
30.3 feet.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
											Qr	***RESERVOIR SEDIMENT - Qr*** **0.0 to 1.8 ft. <u>ELASTIC SILT, MH</u>:** About 90% fines with medium plasticity and rapid dilatancy; about 10% fine sand; trace to 10% organics throughout; maximum size fine sand; wet, brown and dark brown with the consistency of pudding, up to 10% methane bubbles throughout the sediment; no reaction with HCl.
											Tv	***1.8 to 3.2 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **1.8 to 3.2 ft. <u>LEAN CLAY WITH SAND, (CL)s</u>:** 72.0% fines with high plasticity and slow to no dilatancy; about 28.0% fine to coarse sand; maximum size 4mm; wet, dark brown; no reaction with HCl. Geologic Interpretation: Very intensely weathered lapilli tuff.
	35.5	**34.5**	72.0	28.0	0	44.7	21.2	40.2	(CL)s	2588.6		

BOTTOM OF HOLE: T.D. 3.2-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample: 0.0 to 3.2 feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-7

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/16/09
RESERVOIR WATER DEPTH: 30.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 48.9" W 122 ° 19' 36.0"
TOTAL DEPTH: 3.2-ft.
RESEVOIR SEDIMENT THICKNESS: 1.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.5-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The direct-push and hammer methods were used exclusively at the start of the Copco-1 reservoir sediment sampling program. A lexan tube sampler was attached to the drill with 5 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of the lexan tube were 4.0 inch o.d. by 3-3/4 inch i.d., with a length up to 20 feet long that were cut to shorter lengths (as required). A lexan tube length of 8 feet was used most often. Tubes could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved, and either extracted onto an aluminum-foil lined tray for contaminant sample collection or kept in the lexan tube as an engineering sample. The lexan tube hosting engineering samples was cut to its desired length, capped and taped, weighed, and stored vertically. The hammer method used the same lexan tube and drill rod assembly as the direct push method. However, with the hammer method a SK-58 hammer head was used with a rate of 3,000 blows per minute to help penetrate sediment. Samples were recovered and processed in the same way as with the direct push method.

The third method used to obtain reservoir sediment samples was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for the final three holes at Iron Gate Reservoir. For each sample, once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push and hammer methods (above).

Listed below are details of drilling activities for each sampling run.
The first four unsuccessful attempts were on 11-15-09 at coordinates N 41o 58' 47.8" and W 122o 19' 36.5"
Attempt 1 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length without a plastic sediment retaining basket (sand fingers), but using a vacuum piston. The tube was pushed to a depth of 3.5 feet then hammered to a depth of 4.0 feet (refusal) with no recovery (clayey volcanic tuff was on the outside of the lexan tube).

Attempt 2 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length without a plastic sediment retaining basket (sand fingers), but expanding the diameter of the vacuum piston plug for a tighter seal. The tube was pushed and hammered to a depth of 1.0 feet (refusal) with recovery of 0.9 feet of material. The upper 0.5 feet was reservoir sediment (Elastic Silt, MH), and from 0.5 to 0.9 feet the material was pre-reservoir Lean Clay with Sand (CL)s containing plant roots up to 4mm in diameter.

Attempt 3 The direct push/hammer method was used with the tube 4.0 inch o.d. by 3-3/4 inch i.d. by 9 feet in length without a plastic sediment retaining basket, and without a vacuum piston. The tube was pushed and hammered to a depth of 1.5 feet (refusal) with no recovery. The outside of the tube showed 1.3 feet of Elastic Silt (reservoir sediment) and 0.2 feet of Lean Clay with Sand (pre-reservoir material).

Attempt 4 Same setup as Attempt 3, but with a longer hammering time (refusal, no recovery).

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample: 0.0 to 3.2 feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-7

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/15/09 FINISHED: 11/16/09
RESERVOIR WATER DEPTH: 30.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 48.9" W 122 ° 19' 36.0"
TOTAL DEPTH: 3.2-ft.
RESEVOIR SEDIMENT THICKNESS: 1.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2591.5-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

November 16, 2009
Attempt 5 - Coordinates and reservoir elevation shown at the top of this log.
The direct push/hammer method was used with the lexan tube 4.0 inch o.d. by 3-3/4 inch i.d. by 10 feet in length with a plastic sediment retaining basket. The tube was pushed then hammered to a depth of 3.2 feet (refusal) with recovery of 2.85 feet of material.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration of reservoir sediment into pre-reservoir material and the collection of an undisturbed lexan tube sample of reservoir sediment.

HOLE COMPLETION:
The lexan tube sampler was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample: 0.0 to 3.2 feet.

RECLAMATION
Managing Water in the West

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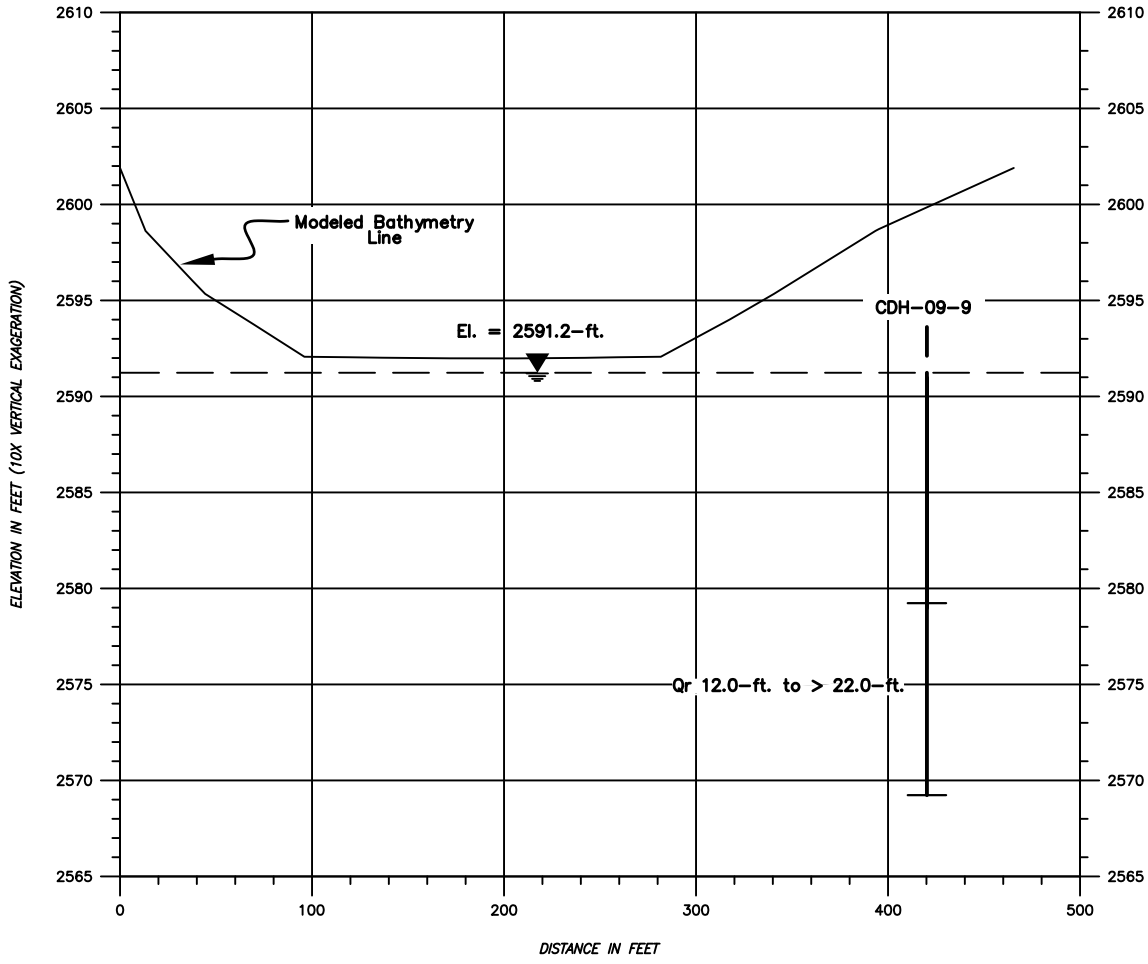

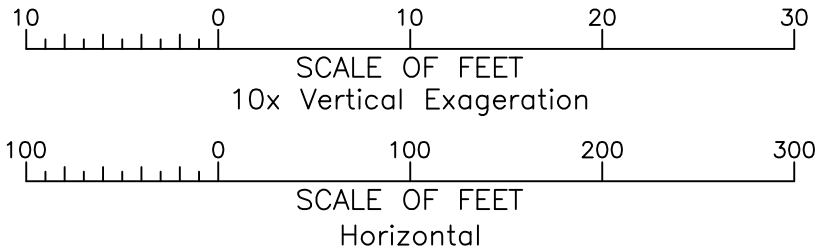

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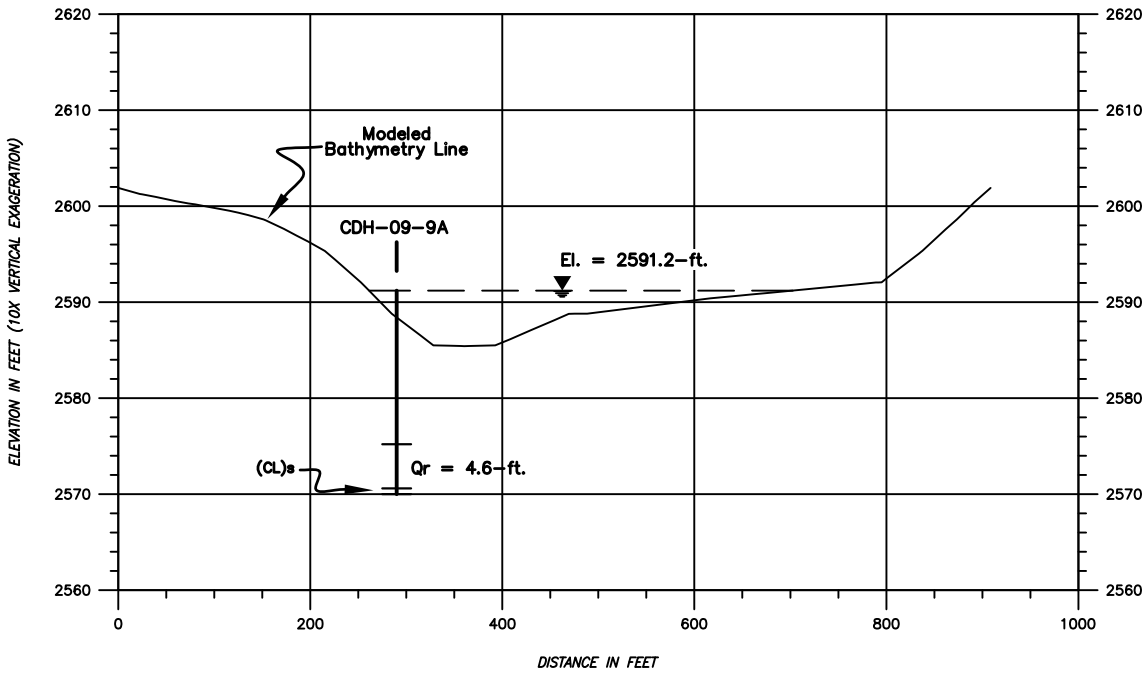

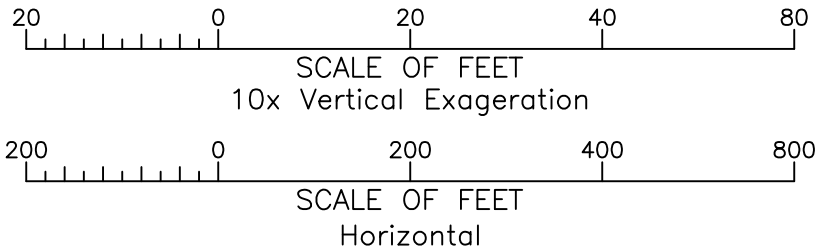

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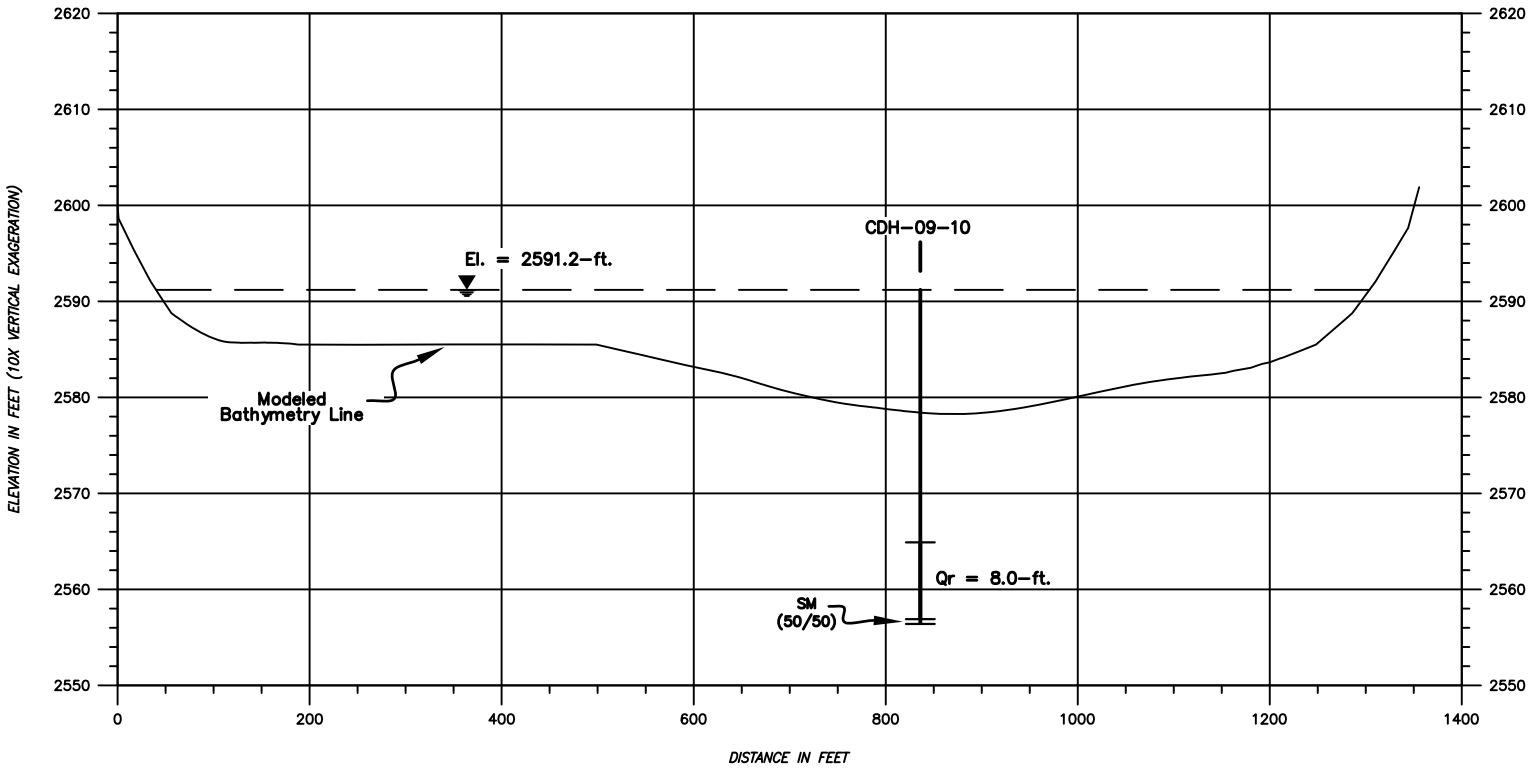

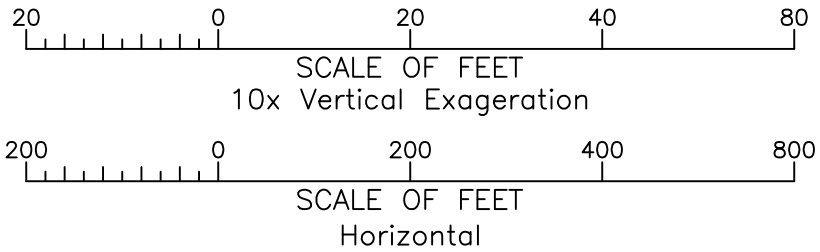

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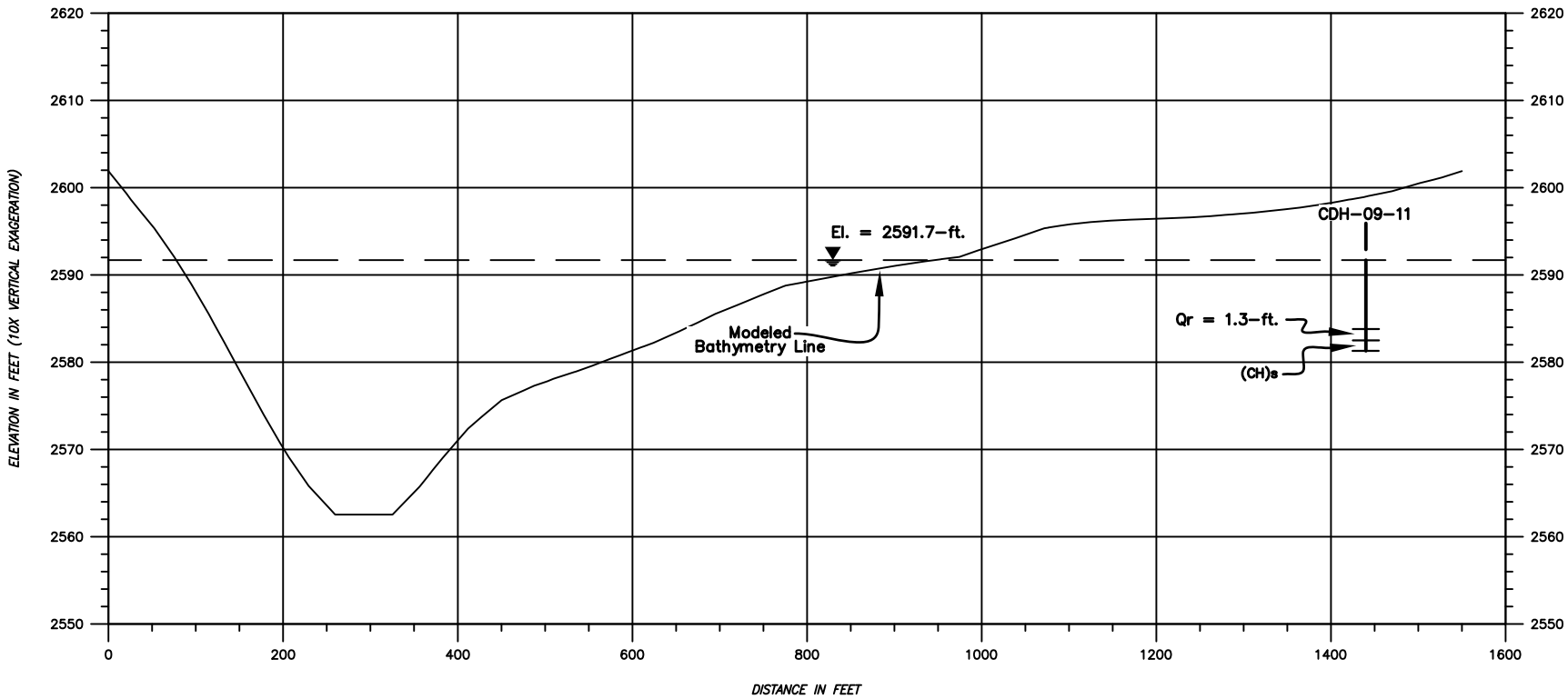

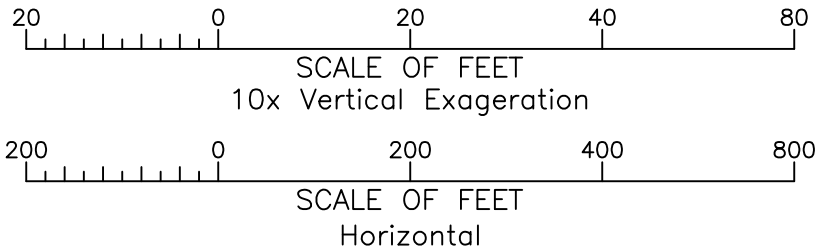

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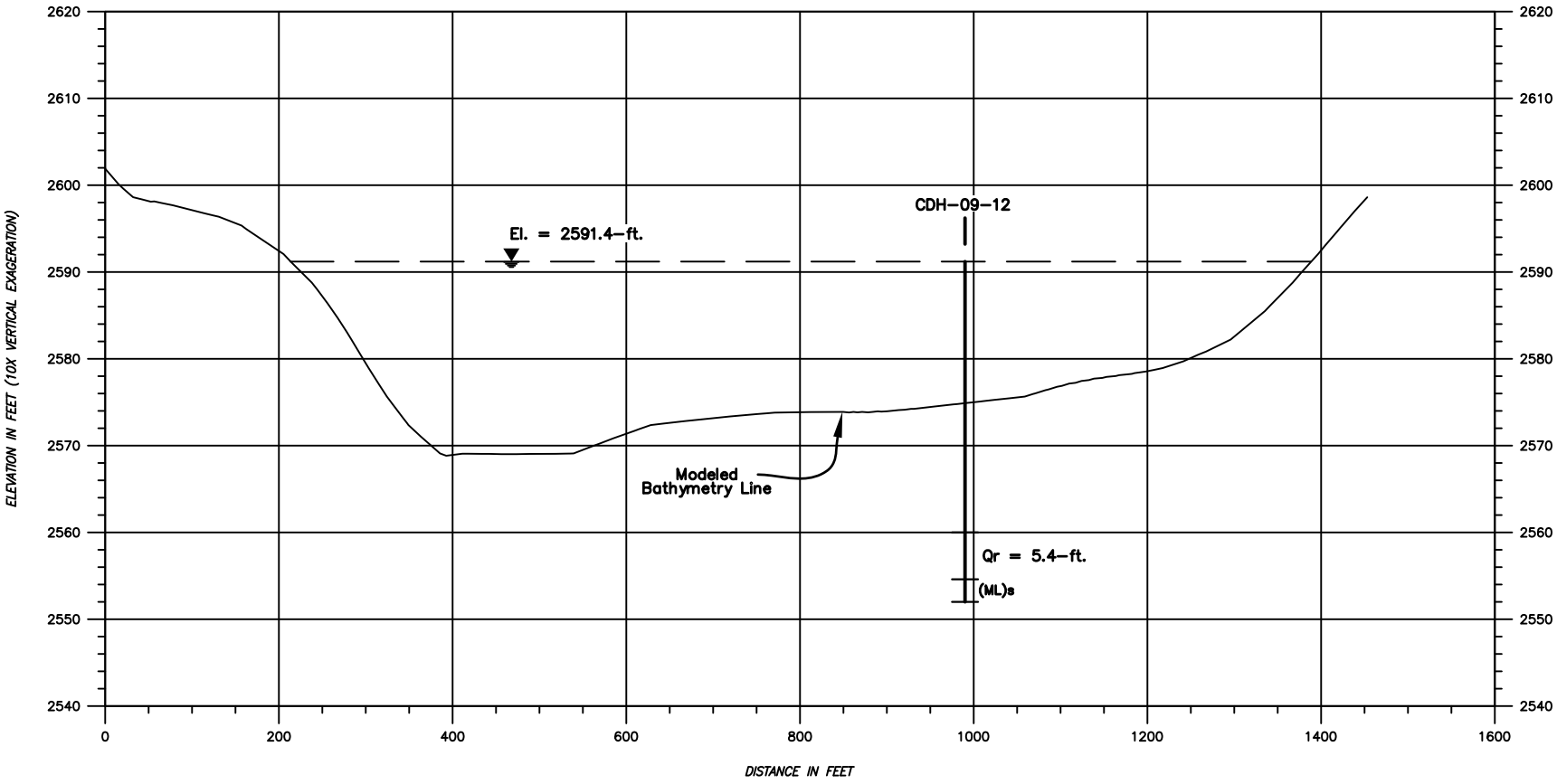

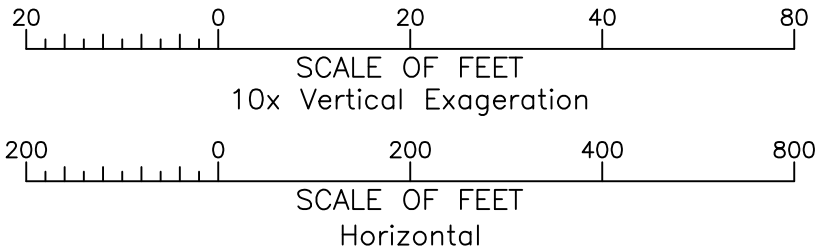

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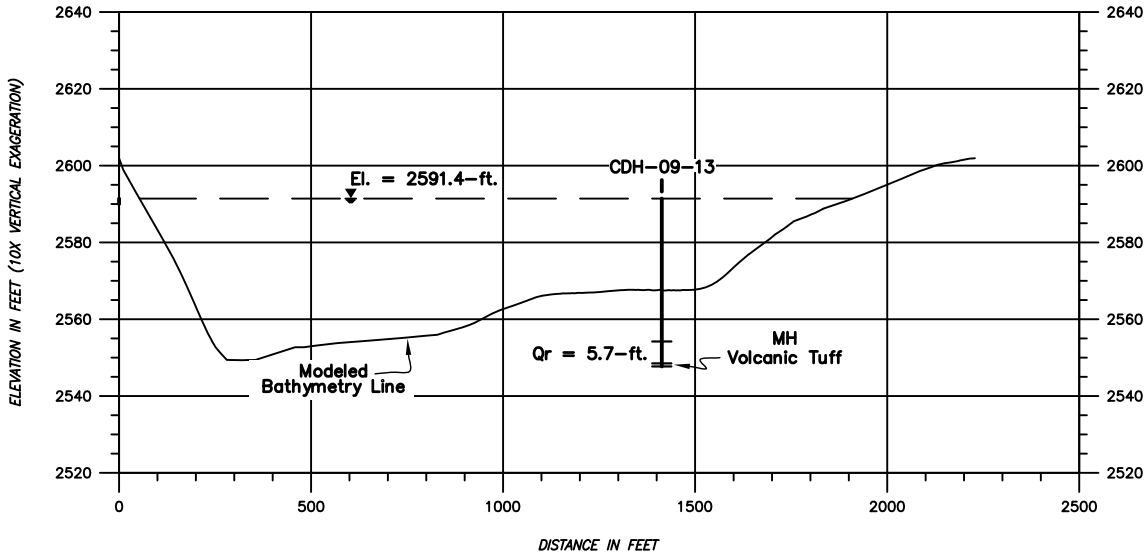

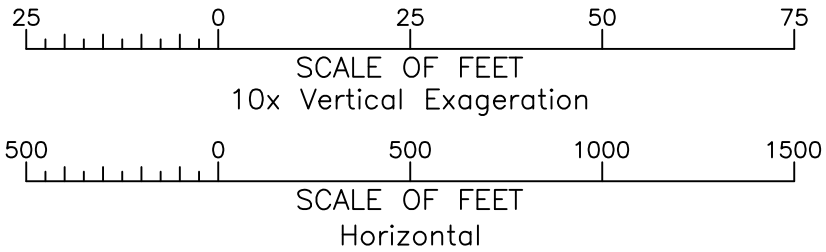

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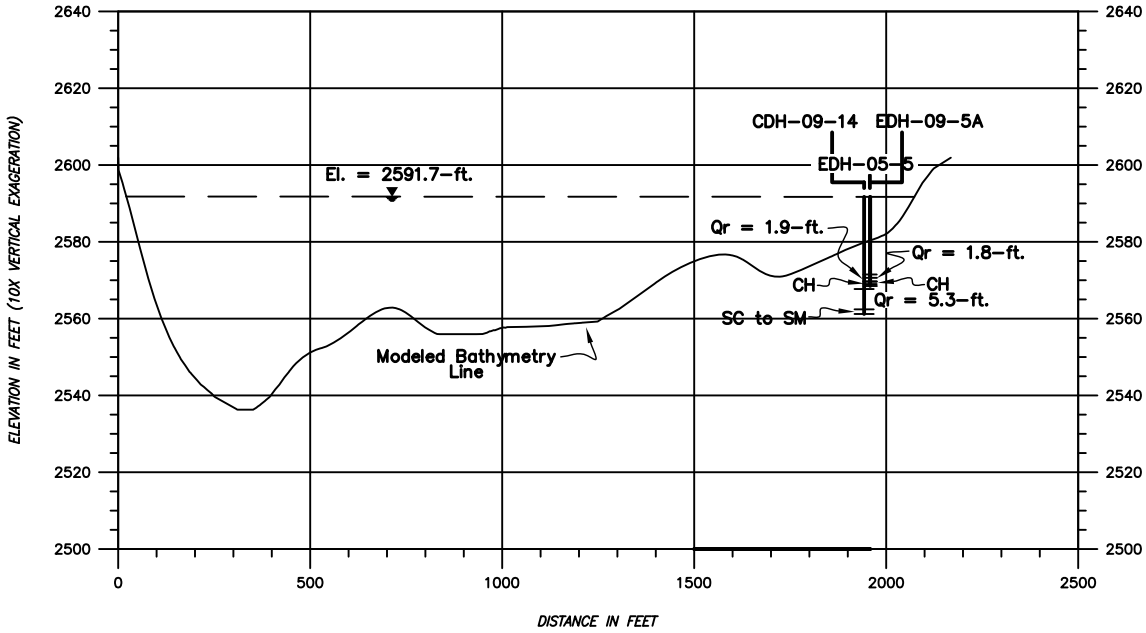

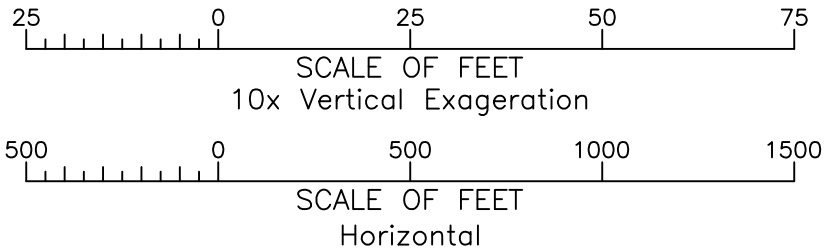

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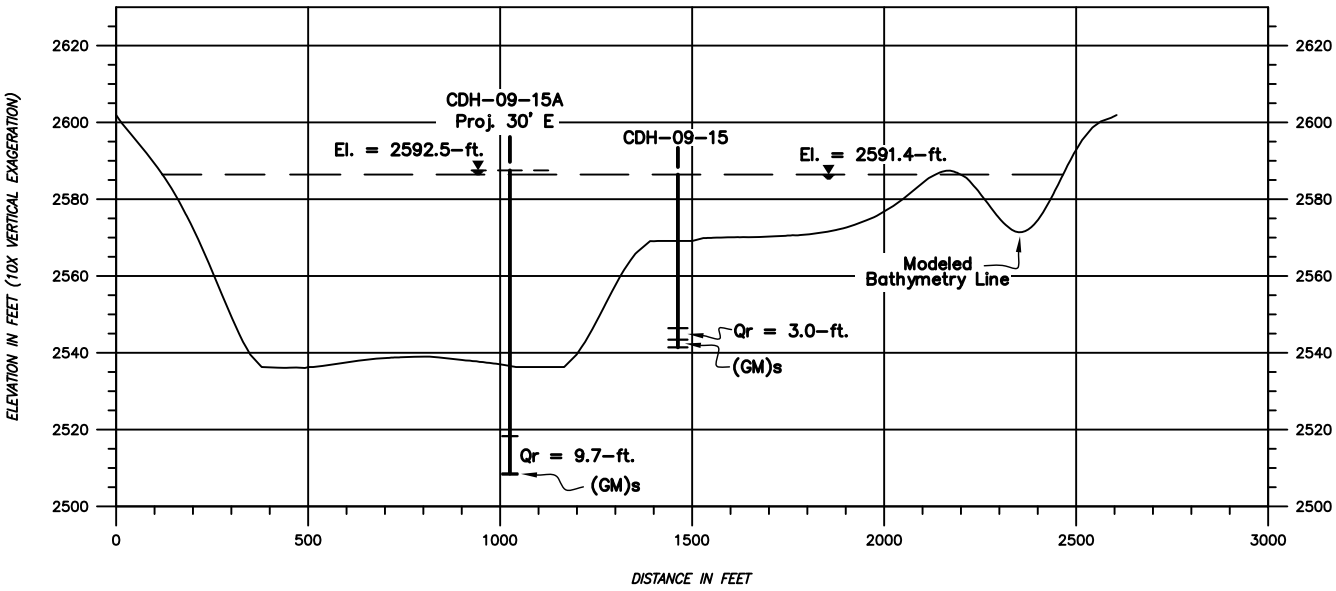

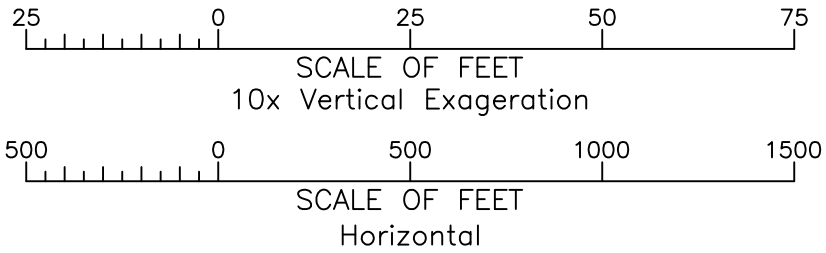

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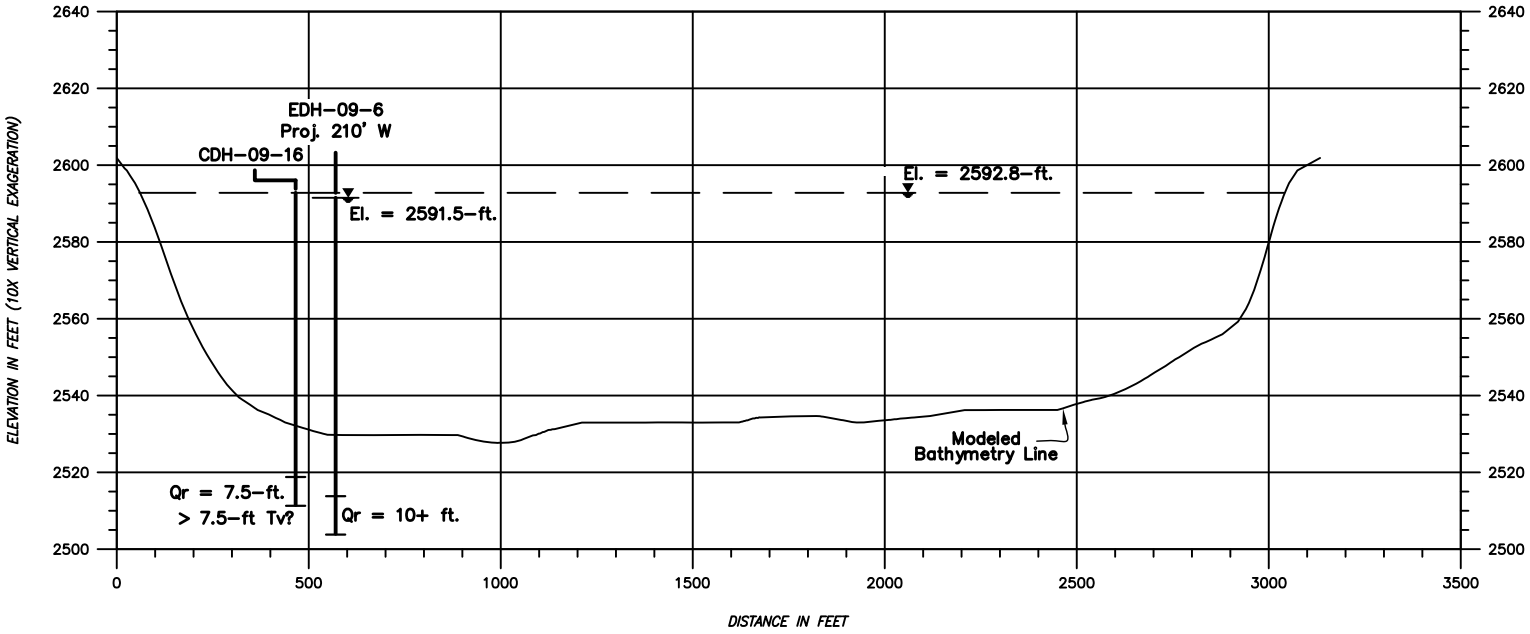

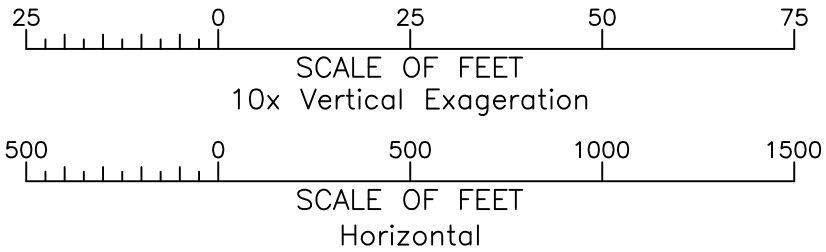

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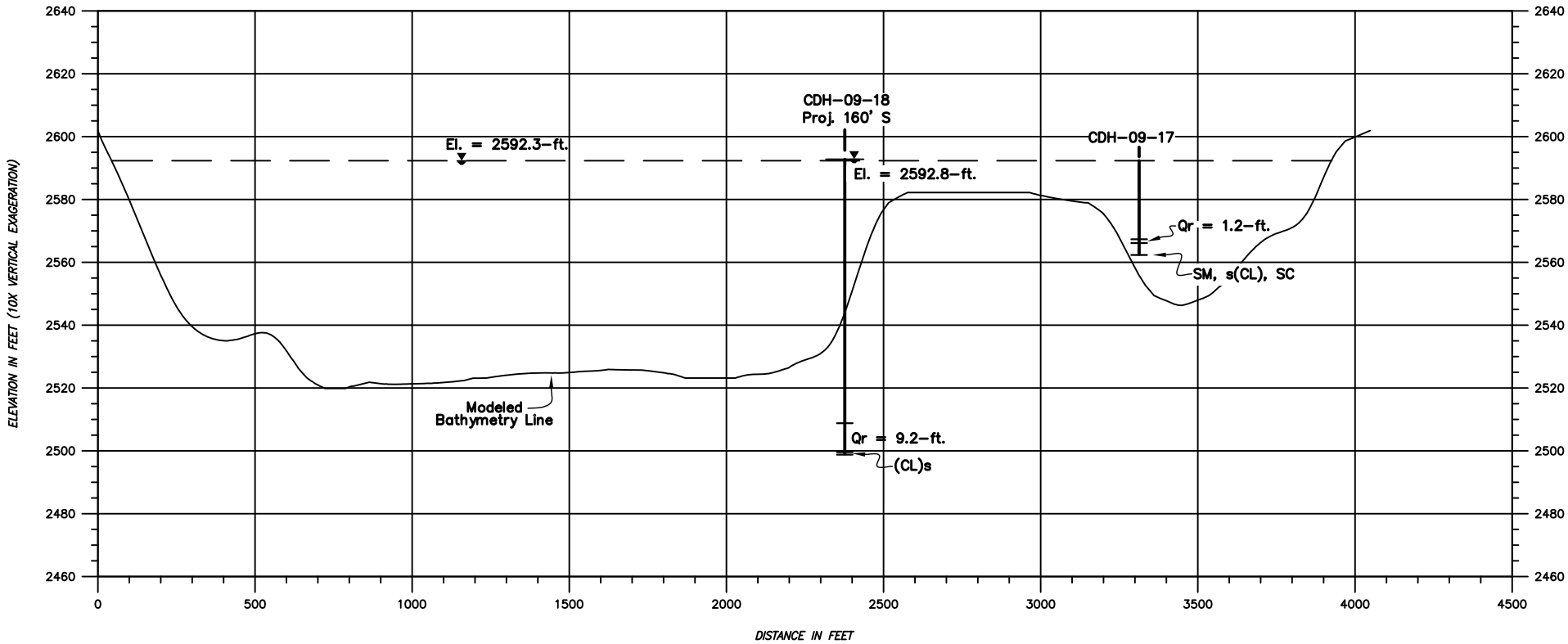

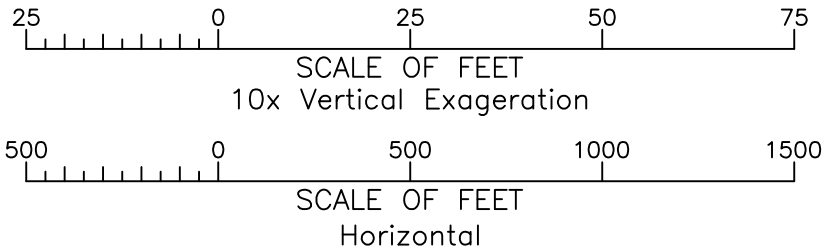

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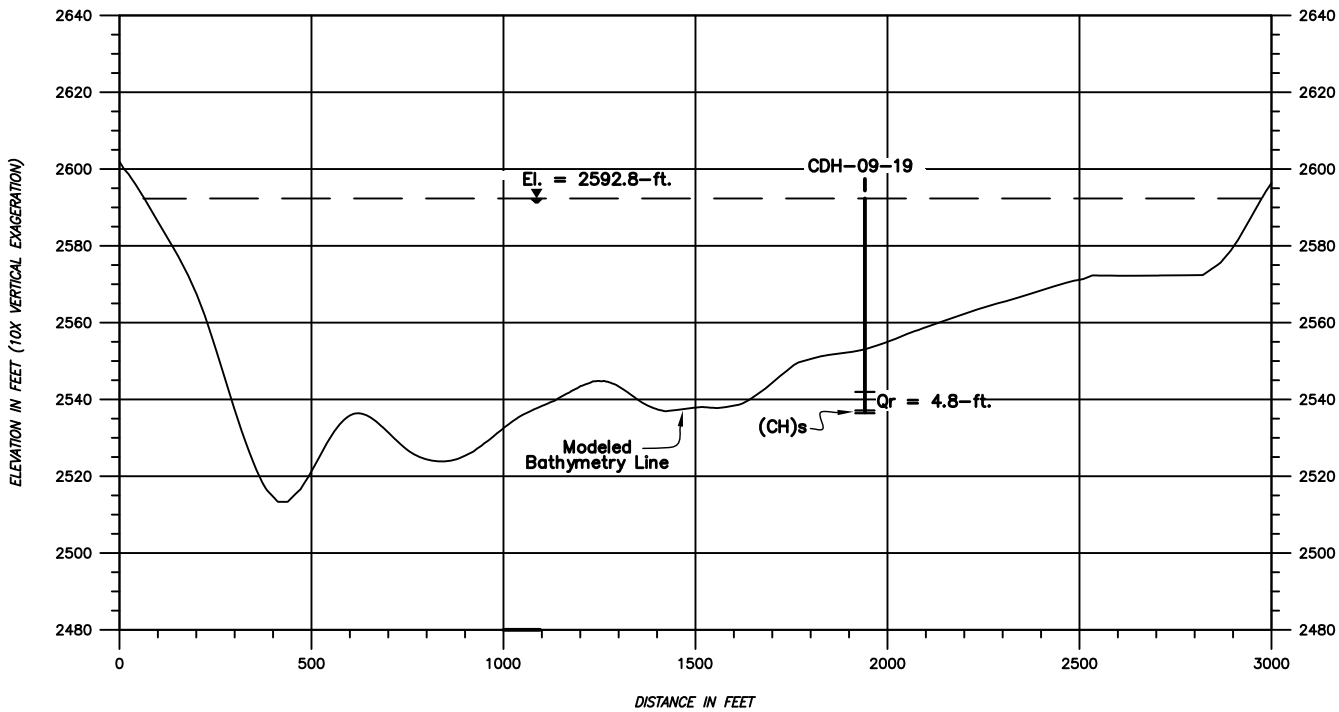

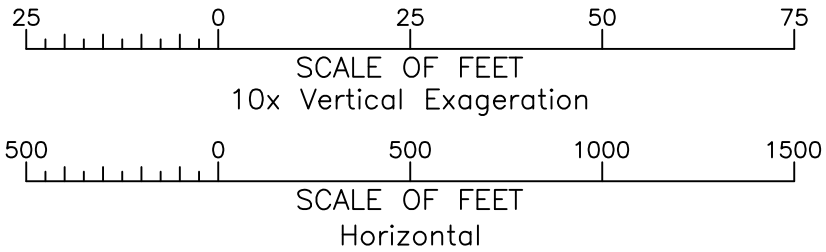

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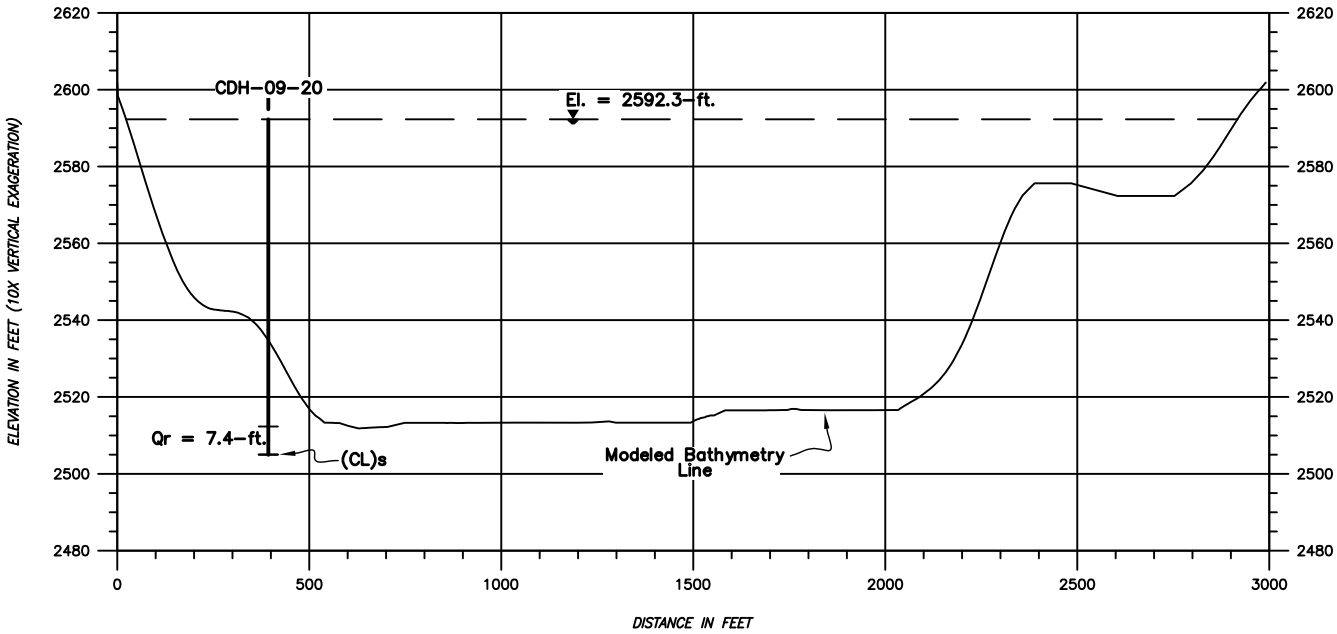

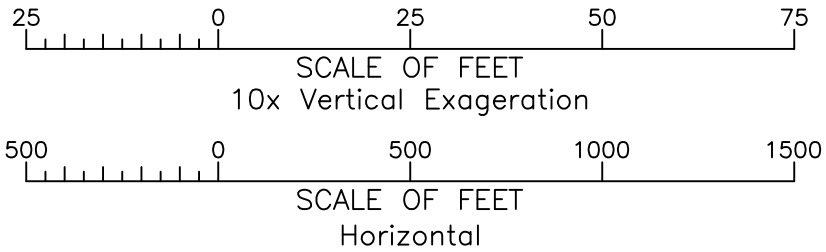

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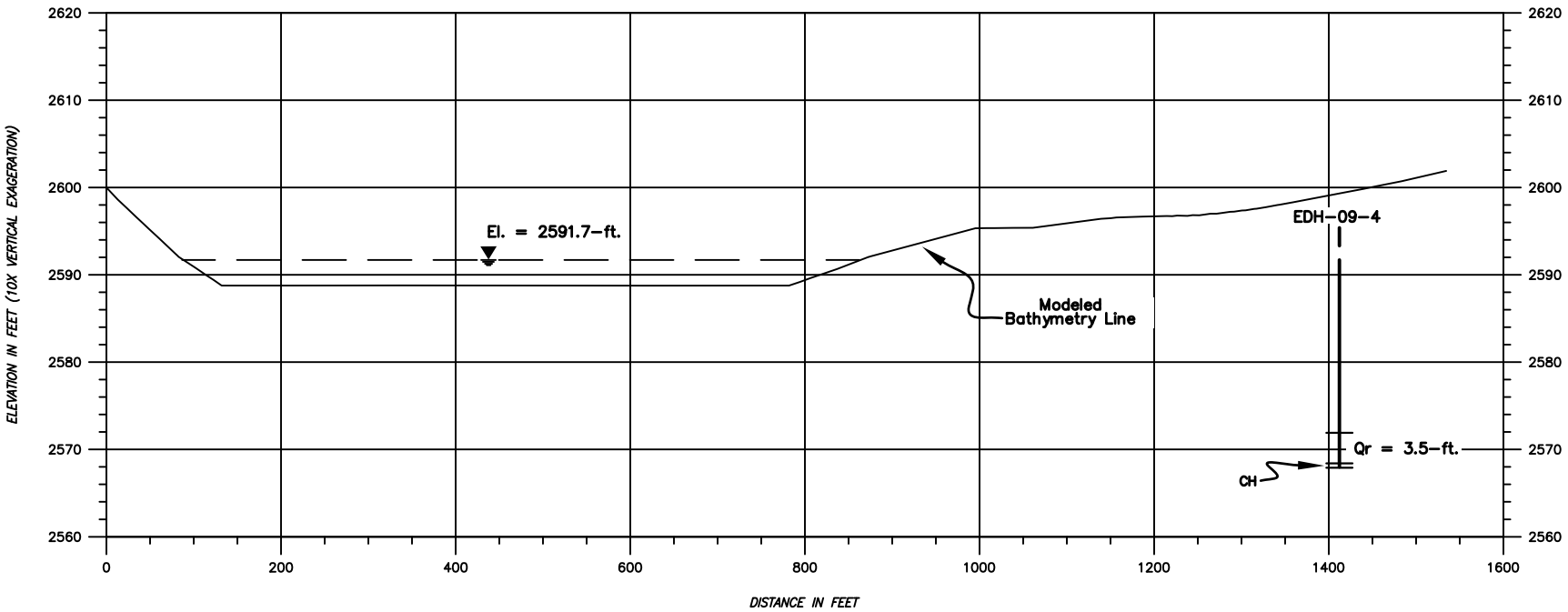

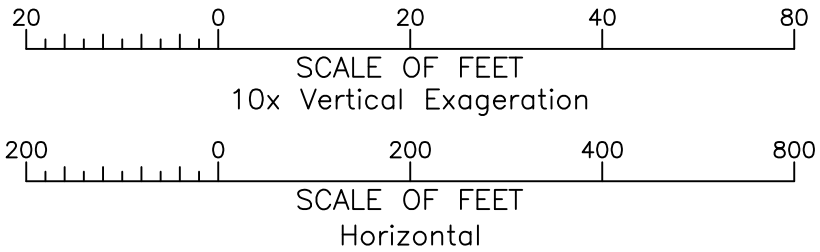

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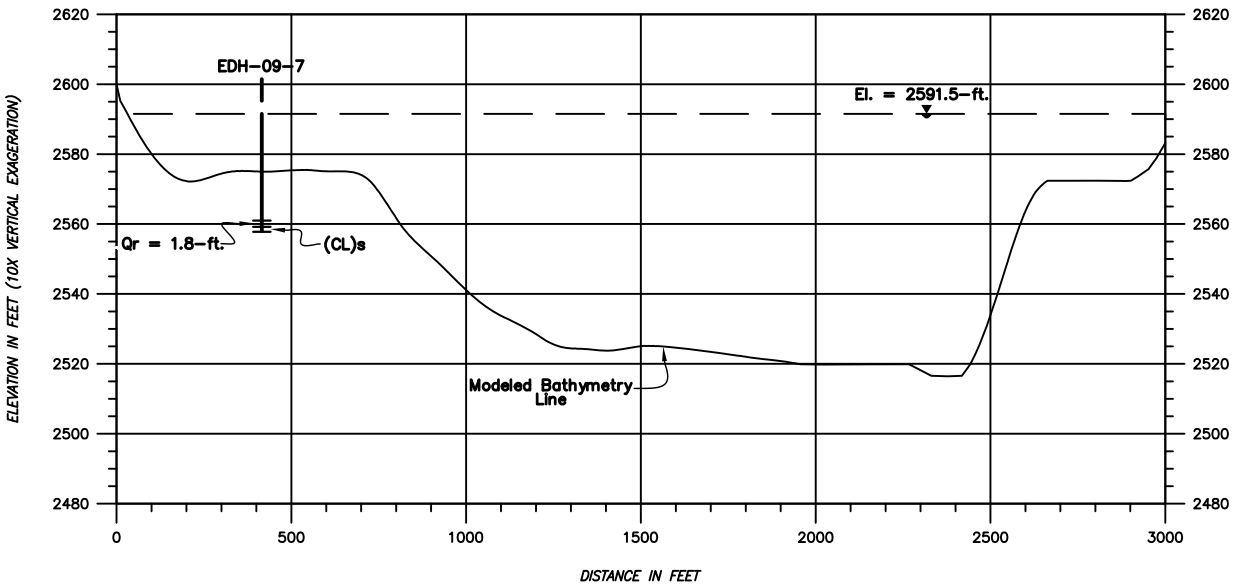
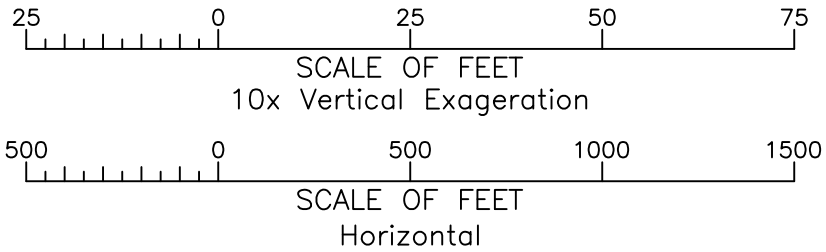




Iron Gate Reservoir

Geologic Logs and Cross Sections

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-Add 1

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 61.2-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 55.6" W 122 ° 26' 07.4"
TOTAL DEPTH: 4.1-ft.
RESEVOIR SEDIMENT THICKNESS: 2.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.6-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located in the Camp Creek (Mirror Cove) arm of the reservoir; about 2.3-miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										Qr	***0.0 to 2.4 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 2.4 ft.: ELASTIC SILT, MH:** About 90% fines with medium plasticity and rapid dilatancy; about 10% fine sand; trace to 5% organics throughout, multiple 4mm to 15mm thick layers of charcoal throughout the reservoir sediment; maximum size fine sand; wet, brown to black, massive, pudding-like consistency, methane bubbles throughout, strong organic smell; no reaction with HCl.
										Tv	***2.4 to 4.1 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **2.4 to 4.1 ft.: FAT CLAY (CH):** About 90% fines with high plasticity and slow dilatancy; about 10% fine to medium sand; maximum size medium sand; wet, reddish-brown, massive; no reaction with HCl. Geologic Interpretation: Very intensely weathered lapilli tuff. Remarks: In addition to the standard contaminant samples, MP-157 personnel filled one jar was with sediment that contained a high percentage of charcoal layers.

BOTTOM OF HOLE: T.D. 4.1-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-Add 1

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 61.2-ft.

PROJECT: Klamath
COORDINATES: N 42.1NAD 83 E 122.0NAD 83
TOTAL DEPTH: 4.1-ft.
RESEVOIR SEDIMENT THICKNESS: 2.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.6-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,324.6 ft. (11/15/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
63.9 feet (water depth 61.2 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run.

Three runs with the gravity sampler were used to collect the volume of reservoir sediment required for all analyses. All three runs penetrated the full section of reservoir sediment into pre-reservoir volcanics.

Attempt 1 The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment and into pre-reservoir volcanics to a depth of 4.1 feet, recovering 2.2 feet of material.

Attempt 2 The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment and into pre-reservoir volcanics to a depth of 4.1 feet, recovering 2.6 feet of material.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-Add 1

FEATURE: KRSS
LOCATION: J.C. Boyle Reservoir
BEGUN: 11/15/09 FINISHED: 11/15/09
RESERVOIR WATER DEPTH: 61.2-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 55.6" W 122 ° 26' 07.4"
TOTAL DEPTH: 4.1-ft.
RESEVOIR SEDIMENT THICKNESS: 2.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.6-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

Attempt 3 The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment and into pre-reservoir volcanics to a depth of 4.1 feet, recovering 2.6 feet of material. Reservoir sediment contains multiple layers of black material that looks like charcoal or burned wood (possibly runoff following a major forest fire). MP-157 personnel collected one jar sample of the layers that contained a significantly large amount of the black material (burned wood?).

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanics.

HOLE COMPLETION:
The lexan tube was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-20

FEATURE: KRSS
LOCATION: Copco-1 Reservoir
BEGUN: 11/14/09 FINISHED: 11/14/09
RESERVOIR WATER DEPTH: 80.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 49.5" W 122 ° 19' 42.7"
TOTAL DEPTH: 7.5-ft.
RESEVOIR SEDIMENT THICKNESS: 7.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,592.3-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Copco-1 Reservoir. Located in the main section of the reservoir; about 1,800 feet upstream from Copco-1 Dam, near drill hole EDH-09-7.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. Access to the reservoir was via the Keaton Cove public boat launch ramp/dock, on the southern side of Copco-1 Reservoir. Equipment and samples were on/off loaded on a daily basis and boats were tied up there nightly. The Keaton Cove boat launch is off of the Ager/Brunswick road, about 2-1/2 miles upstream from Copco-1 Dam.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,592.3 ft. (11/14/09)
* The elevation datum PacifiCorp uses at Copco-1 Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
80.0 feet

Drilling and sampling was conducted using one of three methods, direct-push, hammer, or vibracore. The

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	59.7	**30.8**	90.5	9.5	0	161.6	78.9	287.3	MH		Qr
5										0.0	
	57.3	**33.9**	91.2	8.8	0	164.5	60.3	253.1	MH		
										0.0	Tv

BOTTOM OF HOLE: T.D. 7.5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 7.4 feet
RESERVOIR SEDIMENT - Qr

0.0 to 7.0 ft.: ELASTIC SILT, MH: 90.5% fines with medium plasticity and rapid dilatancy; 9.5% fine sand; trace to 5% organic material; maximum size fine sand; wet, dark gray-brown and black, pudding-like consistency, strong organic odor, abundant methane bubbles throughout the sediment; no reaction with HCl.

7.0 to 7.4 ft.: ORGANIC SOIL, OL/OH: About 50% wood debris up to 3.5-inches long; about 50% Elastic Silt (fines with medium plasticity and rapid dilatancy); maximum size 3.5-inch long wood debris; wet, dark gray-brown to black; no reaction with HCl.

7.4 to 7.5 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

7.4 to 7.5 ft.: LEAN CLAY WITH SAND, (CL)s: About 80% fines with medium to high plasticity and slow dilatancy; about 20% fine sand; trace fine, subangular to subrounded, hard gravel; maximum size 12mm; wet, dark gray, soft; no reaction with HCl.

Geologic Interpretation: Very intensely weathered tuff and lapilli tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment. Methane gas bubbles were also present in the reservoir sediment sample.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-21

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 10/31/09 FINISHED: 10/31/09
RESERVOIR WATER DEPTH: 14.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 11.7" W 122 ° 22' 26.9"
TOTAL DEPTH: 2.7-ft.
RESEVOIR SEDIMENT THICKNESS: 1.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.1-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located in the northeastern arm of the reservoir; about 2,900 feet downstream from the Daggett Road Bridge crossing to PacifiCorp's operations facility; about 5-1/2-miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
											Qr
	29.9	**39.2**	69.1	30.9	0	NP	NP	157.9	s(ML)	2323.8	
											Tv

BOTTOM OF HOLE: T.D. 2.7-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 1.5 feet
RESERVOIR SEDIMENT - Qr

0.0 to 1.5 ft.: SANDY SILT, s(ML) visual identification classifies the material as containing: about 80% water weeds and decaying organic material. Non-organic material consists of about 70% nonplastic fines; about 30% fine sand; maximum size fine sand; wet, gray-brown, pudding-like consistency, about 10% methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; no reaction with HCl.

1.5 to 2.7 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

1.5 to 2.7 ft.: Organic Soil, OL/OH: About 70% fines with high plasticity; about 15% fine, subangular, hard gravel; about 15% fine to coarse sand; maximum size 15mm; wet, gray, massive with vertical plant roots; no reaction with HCl.

Geologic Interpretation: This is interpreted as intensely weathered tuff (Tv) with lapilli-size (gravel-size) clasts distributed throughout.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-21

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 10/31/09 FINISHED: 10/31/09
RESERVOIR WATER DEPTH: 14.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 11.7" W 122 ° 22' 26.9"
TOTAL DEPTH: 2.7-ft.
RESEVOIR SEDIMENT THICKNESS: 1.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.1-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,325.1 ft. (10/31/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
17.0 feet (water depth 14.3 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. The gravity sampling method was also used. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run:

Attempt 1 The auger sampling method was used first. The auger sampler was fitted with a basket spring retainer (sand fingers) and a recovery sock. The augers with sampler were lowered to the water/sediment interface then pushed to a depth of 1.2 feet (refusal), recovering 0.2 feet of material.

Attempt 2 Moved the barge about 5 feet and with the same setup as used in Attempt 1 the augers with sampler were lowered to the water/sediment interface then rotated to a depth of 2.7 feet (refusal). Recovered 1.4 feet of material, both reservoir sediment and pre-reservoir material.

Contaminant Sampling was then carried out by MP-157 personnel using a gravity sampler with 2-5/8-inch i.d. lexan tube to collect the additional volume of reservoir sediment required for all analyses.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-21

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 10/31/09 FINISHED: 10/31/09
RESERVOIR WATER DEPTH: 14.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 11.7" W 122 ° 22' 26.9"
TOTAL DEPTH: 2.7-ft.
RESEVOIR SEDIMENT THICKNESS: 1.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.1-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanic rock.**HOLE COMPLETION:**
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-22

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/2/09 FINISHED: 11/2/09
RESERVOIR WATER DEPTH: 49.8-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 01.7" W 122 ° 23' 27.6"
TOTAL DEPTH: 1.4-ft.
RESEVOIR SEDIMENT THICKNESS: 1.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.2-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located in the northeastern arm of the reservoir; about 1,300 feet downstream from the outcrops of columnar-jointed basalt; about 4.4-miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	42.2	**48.9**	91.1	8.9	0	97.8	46.2	276.0	MH		Qr
										2323.8	Qal

BOTTOM OF HOLE: T.D. 1.4-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 1.4 feet
RESERVOIR SEDIMENT - Qr

0.0 to 1.4 ft.: ELASTIC SILT, MH: 91.1% fines with medium plasticity and rapid dilatancy; 8.9% fine sand; trace to 5% organics; maximum size fine sand; wet, brown, pudding-like consistency, about 10% methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; no reaction with HCl.

1.4 to 1.4* feet
QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)

1.4 to 1.4* ft.: SILTY GRAVEL WITH SAND, (GM)s: In the very bottom of the gravity sampler liner there was a minor amount of alluvium consisting of: About 60% fine, subangular, hard gravel; about 20% fine to medium sand; about 20% fines with medium plasticity and rapid dilatancy; maximum size 15mm; wet, brown; no reaction with HCl.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

*At a depth of 1.4 feet sampling equipment hit refusal. A minor amount of Quaternary alluvium (Qal) was recovered in the tip of the sampler confirming the presence of alluvium, but drilling did not continue past this point.

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-22

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/2/09 FINISHED: 11/2/09
RESERVOIR WATER DEPTH: 49.8-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 01.7" W 122 ° 23' 27.6"
TOTAL DEPTH: 1.4-ft.
RESEVOIR SEDIMENT THICKNESS: 1.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.2-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,325.2 ft. (11/02/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
52.5 feet (water depth 49.8 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. A gravity sampler with a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length was used to confirm sediment contacts. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run:

Attempt 1 The sampler was fitted with a basket spring retainer (sand fingers) and a recovery sock and the sampler was out in front of the drill bit teeth 0.2 feet. The augers with sampler were lowered to the water/sediment interface and rotated to a depth of 3.3 feet, recovering 0.2 feet of reservoir sediment.

Attempt 2 The gravity sampler with 2-5/8" i.d. lexan sampling tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. It was then pounded into the material to a depth of 1.4 feet (refusal), recovering 1.4 feet.

Contaminant sampling was then carried out by MP-157 personnel using the gravity sampler system listed in Attempt 2 to collect the additional volume of reservoir sediment required for all analyses.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

*At a depth of 1.4 feet sampling equipment hit refusal. A minor amount of Quaternary alluvium (Qal) was recovered in the tip of the sampler confirming the presence of alluvium, but drilling did not continue past this point.

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-23

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/7/09 FINISHED: 11/7/09
RESERVOIR WATER DEPTH: 29.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 23.3" W 122 ° 24' 05.5"
TOTAL DEPTH: 10.5-ft.
RESEVOIR SEDIMENT THICKNESS: 9.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.7-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located in Jenny Creek Cove, in the northeastern Arm of Iron Gate Reservoir; about 3-3/4-miles upstream from Iron Gate Dam, adjacent to drill hole CDH-09-22.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL
	31.9	**39.0**	70.9	29.1	0.0	51.8	19.1	84.9	(MH)s	Qr
	26.4	**45.4**	71.8	28.2	0.0	60.9	20.4	138.4	(MH)s	Qr
5									2319.3	Qr
	27.5	**45.7**	73.2	26.8	0.0	58.5	27.8	80.7	(MH)s	Qr
									2317.6	Qr
									2317.0	Qr
	24.0	**31.2**	55.2	44.8	0.0	44.3	13.7	76.7	s(ML)	Qr
									2315.9	Qr
										Qal
10										Tv

BOTTOM OF HOLE: T.D. 10.5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 9.2 ft.
RESERVOIR SEDIMENT - Qr

0.0 to 9.2 ft.: ELASTIC SILT WITH ORGANICS, MH : About 90% fines with medium elasticity; about 10 % fine sand; wet, dark olive brown, organic odor; unconsolidated; regular fine beds of fresh organic materials consisting of flat bark, grasses, and twigs and fine beds of up to 75% fine sand.

9.2 to 9.7 ft.
QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)

9.2 to 9.7 ft.: POORLY GRADED SAND TO SILTY SAND, SP-SM: About 85 to 90% fine sand; about 15 to 10% nonplastic fines; wet, dark gray; moderately soft, fine layers of clean fine sand.

9.7 to 10.5 ft.
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

9.7 to 10.5 ft.: SANDY LEAN CLAY WITH GRAVEL, s(CL)g: About 45% fines with medium plasticity; 30% fine sand; 25% fine, hard, subrounded to rounded gravel; maximum particle size 1"; wet, dark gray, organic odor; moderately firm; abundant organics consisting of grass, twigs, and bark.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-23

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/7/09 FINISHED: 11/7/09
RESERVOIR WATER DEPTH: 29.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 23.3" W 122 ° 24' 05.5"
TOTAL DEPTH: 10.5-ft.
RESEVOIR SEDIMENT THICKNESS: 9.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.7-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
NA

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
32.0 feet (water depth 29.7 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run.

Attempt 1 0.0 to 7.1 ft - Augers and a sampler with NWJ rods were advanced to about 7.1 feet, recovering about 1.1 feet of reservoir sediment.

Attempt 2 7.1 to 8.4 ft - Augers and a sampler with NWJ rods and catcher were advanced to refusal at 8.4 feet. The cause of refusal was uncertain.

Attempt 3 The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment to collect samples at this interval. Three runs with the gravity sampler were used to collect the volume of reservoir sediment required for all analyses.

Attempt 4 8.4 to 10.5 ft - Advanced augers with pilot bit to about 10.5 feet. The last half foot was difficult to drill and the augers torqued. About 1.3 feet of pre reservoir material was recovered.

Attempt 5 The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment and into pre-reservoir alluvium. Five runs with the gravity sampler were used to collect the volume of reservoir sediment required for all analyses.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-23

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/7/09 FINISHED: 11/7/09
RESERVOIR WATER DEPTH: 29.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 23.3" W 122 ° 24' 05.5"
TOTAL DEPTH: 10.5-ft.
RESEVOIR SEDIMENT THICKNESS: 9.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.7-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-24

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/3/09 FINISHED: 11/3/09
RESERVOIR WATER DEPTH: 45.6-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 18.6" W 122 ° 24' 12.7"
TOTAL DEPTH: 8.5-ft.
RESEVOIR SEDIMENT THICKNESS: 4.1-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located at Jenny Creek Cove, in the northeastern arm of the reservoir; about 3-3/4-miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	39.5	**46.4**	85.9	14.1	0	68.8	33.6	97.3	MH		Qr	***0.0 to 4.1 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 4.1 ft.: ELASTIC SILT, MH:** 85.9% fines with medium plasticity and rapid dilatancy; 14.1% fine sand; trace to 5% organics and roots; maximum size fine sand; wet, brown, massive, pudding-like consistency, about 10% methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; no reaction with HCl. Remarks: At a depth of 4.1 feet drilling recovered a mass of decaying plant material, which is believed to mark the pre-reservoir contact.
										2321.3		
5											Tv	***4.1 to 8.5 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **4.1 to 8.5 ft.: FAT CLAY WITH SAND, (CH)s:** About 80% fines with high plasticity and slow to medium dilatancy; about 15% fine to coarse, mostly medium sand; about 5% fine to coarse, subangular, hard gravel; maximum size 60mm; moist, brown, massive; no reaction with HCl. Geologic Interpretation: Intensely weathered tuff with a minor amount of gravel-size volcanic clasts.

BOTTOM OF HOLE: T.D. 8.5-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-24

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/3/09 FINISHED: 11/3/09
RESERVOIR WATER DEPTH: 45.6-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 18.6" W 122 ° 24' 12.7"
TOTAL DEPTH: 8.5-ft.
RESEVOIR SEDIMENT THICKNESS: 4.1-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

throughout the drilling program.

Reservoir Water Surface Elevation:
2,325.4 ft. (11/03/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
48.3 feet (water depth 45.6 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. The gravity sampling method of sample collection was also used. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run:

Attempt 1 The auger sampler was fitted with a basket spring-retainer (sand fingers) and the sampler was out in front of the drill bit teeth 0.2 feet. The augers with sampler were lowered to the water/sediment interface and rotated to a depth of 6.0 feet, recovering 1.9 feet of reservoir sediment and pre-reservoir material.

Attempt 2 The same sampling setup was used as in Attempt 1. With the augers in-place to a depth of 6.0 feet, the augers and sampler were drilled from 6.0 to 8.5 feet (refusal), with recovery of 2.4 feet of pre-reservoir material.

Contaminant Sampling was then carried out by MP-157 personnel using the gravity sampler system with 2-5/8" i.d. lexan liner hooked up to a drilling winch-line to collect the additional volume of reservoir sediment required for all analyses. The gravity sampler was lowered to the water/sediment interface and pounded into the pre-reservoir sediment to obtain samples through the entire section. One 8 foot long lexan liner was stuck in the pre-reservoir Tertiary volcanic clay and could not be recovered.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-24

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/3/09 FINISHED: 11/3/09
RESERVOIR WATER DEPTH: 45.6-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 18.6" W 122 ° 24' 12.7"
TOTAL DEPTH: 8.5-ft.
RESEVOIR SEDIMENT THICKNESS: 4.1-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.4-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:
A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the barge.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-25

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/17/09 FINISHED: 11/17/09
RESERVOIR WATER DEPTH: 99.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 49.4" W 122 ° 25' 26.4"
TOTAL DEPTH: 8.0-ft.
RESEVOIR SEDIMENT THICKNESS: 5.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.7-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located in the northeastern arm of the reservoir; about 2-1/2 miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. A public boat launching ramp/dock at Mirror Cove, on the northern side of Iron Gate Reservoir, was used to launch and recover all boats.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,324.7 ft. (11/17/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
99.0 feet

Drilling and sampling was conducted using the vibracore method with a 4 inch o.d. by 3-3/4 inch i.d. lexan tube up to 20 feet in length (cut to a smaller length as required). Contaminant samples were extracted onto an aluminum-foil covered tray and

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	64.1	**26.8**	90.9	9.1	0	126.8	54.4	321.9	MH		Qr
5										2319.7	
											Tv

BOTTOM OF HOLE: T.D. 8-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 5.0 feet
RESERVOIR SEDIMENT - Qr

0.0 to 5.0 ft.: ELASTIC SILT, MH: 90.9% fines with medium plasticity and rapid dilatancy; 9.1% fine sand; trace to 5% organics; maximum size fine sand; wet, olive-gray to dark gray, massive, pudding-like consistency, strong organic smell, about 10% methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; no reaction with HCl.

5.0 to 8.0 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

5.0 to 8.0 ft.: LEAN CLAY WITH SAND AND GRAVEL, (CL)sg: About 70% fines with medium plasticity and slow to medium dilatancy; about 15% fine to coarse, mostly medium sand; about 15% fine, subangular, hard gravel; maximum size 20mm; wet, reddish gray, massive; no reaction with HCl.

Geologic Interpretation: Very intensely weathered lapilli tuff.

Remarks: At the reservoir-sediment / pre-reservoir contact there was a 0.1 foot section of decaying organic material, below which a few vertical roots were present in the volcanic rock.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-25

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/17/09 FINISHED: 11/17/09
RESERVOIR WATER DEPTH: 99.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 49.4" W 122 ° 25' 26.4"
TOTAL DEPTH: 8.0-ft.
RESEVOIR SEDIMENT THICKNESS: 5.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.7-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

processed.

Listed below are details of drilling activities for each sampling run:

Attempt 1 The vibracore method of sampling was used with a 10 foot long lexan tube. The tube penetrated to a depth of 6.5 feet, with recovery of 4.8 feet of material.

Attempt 2 The vibracore method was used with a 10 foot long lexan tube. The tube penetrated to a depth of 8.0 feet, with a recovery of 6.5 feet of material.

Contaminant sampling was carried out by MP-157 personnel.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanics.

HOLE COMPLETION:
The lexan tube was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-26

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/9/09 FINISHED: 11/9/09
RESERVOIR WATER DEPTH: 29.4-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 36.9" W 122 ° 25' 26.8"
TOTAL DEPTH: 2.4-ft.
RESEVOIR SEDIMENT THICKNESS: 2.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.8-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located about 2 1/2 miles upstream of Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	71.0	26.7	97.7	2.3	0	128.4	75.0	332.6	MH		Qr	***0.0 to 2.0 ft.*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 2.0 ft.: ELASTIC SILT, MH:** About 100% fines with medium plasticity; wet, dark brown, organic odor; very soft, unconsolidated. ***2.0 to 2.4 ft.:*** ***TERTIARY VOLCANICS - tv (Pre-Reservoir)*** **2.0 to 2.4 ft.: CLAYEY GRAVEL WITH SAND, (GC)s:** About 45% fines with high plasticity; about 35% fine, soft to hard, subangular to angular gravel; about 20% fine sand; wet, dark reddish brown; firm, gravels are andesite and basalt.
										2323.8		
											Tv	Geologic Interpretation: Weathered lapilli tuff.

BOTTOM OF HOLE: T.D. 2.4-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-26

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/9/09 FINISHED: 11/9/09
RESERVOIR WATER DEPTH: 29.4-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 36.9" W 122 ° 25' 26.8"
TOTAL DEPTH: 2.4-ft.
RESEVOIR SEDIMENT THICKNESS: 2.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.8-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet.

Reservoir Water Surface Elevation:
2,325.77 feet (11/09/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
32.1 feet (water depth 29.4 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run

Attempt 1 0.0 to 2.4 ft. - 2.4 ft.: Auger sampling recovered about 2.0 feet of reservoir sediment and 0.4 feet of pre-reservoir alluvium.

Attempt 2 The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment and into pre-reservoir alluvium. About thirty runs with the gravity sampler were used to collect the volume of reservoir sediment required for all analyses.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-27

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/4/09 FINISHED: 11/4/09
RESERVOIR WATER DEPTH: 55.6-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 55.8" W 122 ° 26' 06.1"
TOTAL DEPTH: 4.8-ft.
RESEVOIR SEDIMENT THICKNESS: 4.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.5-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located in the Camp Creek (Mirror Cove) arm of the reservoir; about 2.4-miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region
Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
											Qr
	67.5	**30.9**	98.4	1.6	0	130.8	71.3	308.7	MH	2321.3	Qr
	64.0	**21.9**	85.9	14.1	0	79.4	54.8	47.1	CH	2320.7	Tv

BOTTOM OF HOLE: T.D. 4.8-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 4.2 feet
RESERVOIR SEDIMENT - Qr

0.0 to 4.2 ft.: ELASTIC SILT, MH: 90.9% fines with medium plasticity and rapid dilatancy; 9.1% fine sand; trace to 5% organics; maximum size fine sand; wet, olive-gray to dark gray, massive, pudding-like consistency, strong organic smell, about 10% methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; no reaction with HCl.

4.2 to 4.8 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

4.2 to 4.8 ft.: FAT CLAY, CH: 85.9% fines with high plasticity and slow dilatancy, strongly cohesive; 14.9% fine sand; maximum size fine sand; wet, red-brown, massive; no reaction with HCl.

Geologic Interpretation: Very intensely weathered lapilli tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-27

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/4/09 FINISHED: 11/4/09
RESERVOIR WATER DEPTH: 55.6-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 55.8" W 122 ° 26' 06.1"
TOTAL DEPTH: 4.8-ft.
RESEVOIR SEDIMENT THICKNESS: 4.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.5-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet. throughout the drilling program.

Reservoir Water Surface Elevation:
2,325.5 ft. (11/02/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
58.3 feet (water depth 55.6 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from Iron Gate Reservoir, with contaminant sampling personnel using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run:

Attempt 1 The auger drill system was used for the first attempt. The sampler was fitted with a spring retaining basket (sand fingers) and the sampler was out in front of the drill bit teeth 0.2 feet. The augers with sampler were lowered to the water/sediment interface and rotated to a depth of 4.8 feet, recovering 1.7 feet of material.

Attempt 2 The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment and into pre-reservoir volcanics. Seven runs with the gravity sampler were used to collect the volume of reservoir sediment required for all analyses.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-27

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/4/09 FINISHED: 11/4/09
RESERVOIR WATER DEPTH: 55.6-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 55.8" W 122 ° 26' 06.1"
TOTAL DEPTH: 4.8-ft.
RESEVOIR SEDIMENT THICKNESS: 4.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.5-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanics.

HOLE COMPLETION:
The lexan liner was pulled out and the hole was left tocollapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-28

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/6/09 FINISHED: 11/6/09
RESERVOIR WATER DEPTH: 37.8-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 47.4" W 122 ° 26' 21.2"
TOTAL DEPTH: 5.3-ft.
RESEVOIR SEDIMENT THICKNESS: 4.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.7-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located adjacent to the Mirror Cove dock.

EQUIPMENT MOBILIZATION:

The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region
Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	66.8	**30.3**	97.1	2.9	0	113.0	58.6	281.2	MH	2324.7	Qr	***0.0 to 4.4 ft.*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 4.4 ft.: ELASTIC SILT, MH:** About 100% fines with medium plasticity; trace very fine sand; wet, dark olive brown, organic odor; very soft, homogenous, unconsolidated.
5											Tv	***4.4 to 5.3 ft.*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **4.4 to 5.3 ft.: FAT CLAY, CH:** About 85% fines with high plasticity, slow dilatancy, high toughness; about 10% fine sand; about 5 % fine and coarse, hard, angular gravel; wet, reddish brown; firm; trace twigs and organics, increased twigs and gravels at 4.4 ft., gravels are basalt. Geologic Interpretation: Weatered tuff.

BOTTOM OF HOLE: T.D. 5.3-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-28

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/6/09 FINISHED: 11/6/09
RESERVOIR WATER DEPTH: 37.8-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 47.4" W 122 ° 26' 21.2"
TOTAL DEPTH: 5.3-ft.
RESEVOIR SEDIMENT THICKNESS: 4.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.7-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,325.7 feet (11/06/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
40.5 feet (water depth 37.8 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8-inch o.d. by 3-3/4 inch i.d. by 5-ft. long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2-inch o.d. by 3.0-inch i.d. by 5.0-ft. long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0-inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Auger sampling was the principal tool used to collect contaminant samples from J.C. Boyle Reservoir, with contaminant sampling personnel on a separate boat using a gravity sampler to augment sample collection. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

See below for detailed list of drilling activities for each run.

Attempt 1 0.0 to 4.4 ft - RUN 1: Advance augers and sampler with flap catcher. Augers were not rotated until a depth of 2.5 feet, and then were slowly rotated to 4.4 feet. 1.0 feet of material was recovered.

Attempt 2 4.4 to 5.3 ft. - Advance augers and sampler with catcher and nylon socks. About 0.2 feet of reservoir sediment and 0.9 feet of pre-reservoir alluvium was recovered.

Attempt 3 0.0 to 1.5 ft - The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment and into pre-reservoir alluvium. Ten runs with the gravity sampler were used to collect the volume of reservoir sediment required for all analyses.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-28

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/6/09 FINISHED: 11/6/09
RESERVOIR WATER DEPTH: 37.8-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 47.4" W 122 ° 26' 21.2"
TOTAL DEPTH: 5.3-ft.
RESEVOIR SEDIMENT THICKNESS: 4.4-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.7-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-29

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/17/09 FINISHED: 11/17/09
RESERVOIR WATER DEPTH: 91.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 15.7" W 122 ° 26' 0.4"
TOTAL DEPTH: 8.2-ft.
RESEVOIR SEDIMENT THICKNESS: 4.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,324.7-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located in the main section of the reservoir; about 1-1/2 miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. A public boat launching ramp/dock at Mirror Cove, on the northern side of Iron Gate Reservoir.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,324.7 ft. (11/17/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
91.0 feet

Drilling and sampling was conducted using one of two methods, either direct-push or vibracore. Direct-push was the method used at the beginning of the Copco-1 project. A lexan tube sampler was attached to the drill with 4 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL
	75.3	**17.9**	93.2	6.8	0	141.8	61.9	355.0	MH		Qr
										0.0	
5											Qal

BOTTOM OF HOLE: T.D. 8.2-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 4.8 feet
RESERVOIR SEDIMENT - Qr

0.0 to 4.8 ft.: ELASTIC SILT, MH: 93.2% fines with medium plasticity and rapid dilatancy; 6.8% fine sand; trace to 5% organics; maximum size fine sand; wet, olive-gray to dark gray, massive, pudding-like consistency, strong organic smell, about 10% methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; no reaction with HCl.

4.8 to 8.2 feet
QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)

4.8 to 8.2 ft.: SILTY GRAVEL WITH SAND AND COBBLES, (GM)sc: About 70% fine to coarse, subangular to subrounded, hard gravel; about 15% fine to coarse sand; about 15% nonplastic fines; trace 3- to 5-inch, subangular to subrounded, hard cobbles; maximum size 4-inches; wet, light gray, massive; no reaction with HCl.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-29

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/17/09 FINISHED: 11/17/09
RESERVOIR WATER DEPTH: 91.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 15.7" W 122 ° 26' 0.4"
TOTAL DEPTH: 8.2-ft.
RESEVOIR SEDIMENT THICKNESS: 4.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,324.7-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

the lexan liner were 4.0 inch o.d. by 3-3/4 inch i.d. with a length up to 20 feet long, but could be cut to shorter lengths (as required). An 8 foot length liner was used most often. Liners could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved and either extracted onto an aluminum-foil lined tray for contaminant sample collection, or kept in the lexan liner as an engineering sample. The lexan liner hosting engineering samples was cut to its desired length, capped, taped, and stored vertically.

The second method used was to attach a lexan tube (same dimensions as above) to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for three holes at Iron Gate Reservoir. Once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push method (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The vibracore method of sampling was used with a 10 foot long lexan liner and plastic sediment-retaining basket. The liner penetrated to a depth of 5.0 feet (refusal), with recovery of 3.6 feet of material.

Attempt 2 The vibracore method of sampling was used with a 10 foot long lexan liner and plastic sediment-retaining basket. The liner penetrated to a depth of 5.0 feet (refusal), with recovery of 3.8 feet of material.

Attempt 3 The boat was moved about 25 feet to the east (towards shore) from Attempts 1 & 2. At this location the reservoir water was 91 feet deep. The vibracore method of sampling was used with a 10 foot long lexan liner and plastic sediment-retaining basket. The liner penetrated to a depth of 8.2 feet, with recovery of 6.9 feet of material.

Two additional runs were made with the vibracore sampler to collect the volume of material required to conduct all analyses. Contaminant sampling was carried out by MP-157 personnel.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
The lexan tube was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-30

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/5/09 FINISHED: 11/5/09
RESERVOIR WATER DEPTH: 129.5-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 56' 50.8" W 122 ° 25' 54.6"
TOTAL DEPTH: 3.5-ft.
RESEVOIR SEDIMENT THICKNESS: 2.9-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.6-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located about 5000 feet upstream of the Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill rig with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL
	65.8	**25.6**	91.4	8.6	0	137.1	60.6	334.2	MH	Qr
									2323.1	
										Tv

BOTTOM OF HOLE: T.D. 3.5-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 2.9 ft.
RESERVOIR SEDIMENT - Qr

0.0 to 2.9 ft.: ELASTIC SILT, MH: About 100% fines with medium plasticity, no toughness; trace very fine sand; wet, black, organic odor; unconsolidated, very soft, loose; some organic lenses.

2.9 to 3.5 ft.
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

2.9 to 3.5 ft.: SANDY FAT CLAY WITH GRAVEL, s(CH)g: About 55% fines with high plasticity; about 30% fine to coarse, subangular, hard sand; about 15% fine, subrounded to subangular, hard gravel; maximum particle size, 1 inch; wet, dark brown to black, organic odor; moderately firm; roots and organics throughout, yellow grass material present from 3.2 to 3.5 ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-30

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/5/09 FINISHED: 11/5/09
RESERVOIR WATER DEPTH: 129.5-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 56' 50.8" W 122 ° 25' 54.6"
TOTAL DEPTH: 3.5-ft.
RESEVOIR SEDIMENT THICKNESS: 2.9-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.6-ft.
HOLE LOGGED BY: A. Warren
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface Elevation:
2,325.60.8 feet (11/05/09)
* The elevation datum PacifiCorp uses at J.C. Boyle Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
132.2 feet (water depth 129.5 feet)

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

See below for detailed list of drilling activities for each run.

Attempt 1 0.0 to 3.5 ft - Auger sampling was not attempted due to the depth of the water/sediment interface. The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment and into pre-reservoir alluvium. Five runs with the gravity sampler were used to collect the volume of reservoir sediment required for all analyses.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
Drilled without fluid

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-31

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/10/09 FINISHED: 11/10/09
RESERVOIR WATER DEPTH: 50.9-ft.

PROJECT: Klamath
COORDINATES: N 41° 56' 39.7" W 122° 26' 12.5"
TOTAL DEPTH: 5.1-ft.
RESEVOIR SEDIMENT THICKNESS: 4.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * Not Known
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located in the main section of the reservoir; about 4,600-ft. upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL
	55.7	**27.4**	83.1	12.9	4.0	113.4	61.1	198.4	(MH)s	Qr
									0.0	
5										Tv

BOTTOM OF HOLE: T.D. 5.1-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 4.8 feet
RESERVOIR SEDIMENT - Qr

0.0 to 4.8 ft.: ELASTIC SILT WITH SAND, (MH)s: 83.1% fines with medium plasticity and rapid dilatancy; 12.9% fine sand; 4.0% fine, subangular to subrounded, hard gravel; maximum size fine gravel; wet, dark brown, massive, pudding-like consistency; no reaction with HCl.

4.8 to 5.1 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

4.8 to 5.1 ft.: LEAN CLAY, CL: About 90% fines with medium to high plasticity and slow to medium dilatancy; about 10% medium to coarse sand; trace fine to coarse, subangular, hard gravel; maximum size 25mm; wet, dark brown, massive; no reaction with HCl.

Geologic Interpretation: Very intensely weathered lapilli tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-31

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/10/09 FINISHED: 11/10/09
RESERVOIR WATER DEPTH: 50.9-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 56' 39.7" W 122 ° 26' 12.5"
TOTAL DEPTH: 5.1-ft.
RESEVOIR SEDIMENT THICKNESS: 4.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * Not Known
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

throughout the drilling program.

Reservoir Water Surface Elevation:
Not Known

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
53.6 feet (water depth 50.9 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Samples were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. On occasion with contaminant sampling drill holes lexan liners were used. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length.

In Iron Gate Reservoir the gravity sampler was fully integrated into the barge-supported drilling program. The gravity sampler uses a 2-3/4 inch o.d. by 2-5/8 inch i.d. lexan tube up to 12 feet long, which was often cut down to between 5 to 8 feet in length. Sample contaminant sites in Iron Gate Reservoir were first drilled with the auger drilling method (described above) to determine the thickness of reservoir sediment and the depth of contact with pre-reservoir material. If a significant amount of material was collected it could be used as part of a contaminant sample and/or a sample to be sent for physical properties testing (gradations and Atterberg limits). Following auger drilling the gravity sampler was often used to collect the large quantity of reservoir sediment required for multiple contaminant sample testing.

Listed below are details of drilling activities for each sampling run:

Attempt 1 Auger drilling was used for the first attempt. The sampler was fitted with a spring retaining basket (sand fingers) and the sampler was out in front of the drill bit teeth 0.2 feet. The augers with sampler were lowered to the water/sediment interface and rotated to a depth of 5.1 feet, recovering 1.5 feet of material.

Attempt 2 The gravity sampler with 2-5/8" i.d. lexan liner was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. The sampler was then pounded through the reservoir sediment and into pre-reservoir volcanics. Multiple runs with the gravity sampler were used to collect the volume of reservoir sediment required for all analyses.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanics.

HOLE COMPLETION:
The auger and sampler were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-32

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/17/09 FINISHED: 11/17/09
RESERVOIR WATER DEPTH: 124.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 56' 23.8" W 122 ° 25' 52.9"
TOTAL DEPTH: 7.0-ft.
RESEVOIR SEDIMENT THICKNESS: 4.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,324.7-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING THE CONTRACTOR'S BOAT-MOUNTED GPS NAVIGATION SYSTEM. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BOAT AT THE START OF DRILLING.

PURPOSE OF HOLE:
Determine the thickness of reservoir sediment (Qr) at each location; and, to collect samples for physical properties testing and chemical (environmental) testing for possible contaminants.

LOCATION:
Iron Gate Reservoir. Located in the main section of the reservoir; about 2,300 feet upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The boats, drill rig, and drilling equipment were mobilized from Gravity Consultants LLC facility in Snoqualmie Washington on trailers. A public boat launching ramp/dock at Mirror Cove, on the northern side of Iron Gate Reservoir.

BOATS:
Two main boats were used for the drilling and sampling program, the drilling boat (approximately 16 feet long) and the sample layout boat (approximately 20 feet long). The two boats fit together and served as the combined drilling/sampling platform. A small service boat was also used on occasion to ferry personnel.

DRILL RIG:
Deck-mounted Simco Combi drill with hydraulic head

DRILLED BY:
Reclamation's PN-Region Drill Crew
Shawn Hintz (Driller)
Dale Bean (Helper)
Mark Weber (Helper)
Steve Saugen (Helper)

CONTAMINANT SAMPLING BY:
A Combination of Reclamation's MP-Region Environmental Monitoring Branch (MP-157)
Stuart Angerer
Laura Benninger
Maria Del Hoyo
Harry Horner

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the reservoir surface. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,324.7 ft. (11/17/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water/Sediment contact Depth:
124.0 feet

Drilling and sampling was conducted using one of two methods, either direct-push or vibracore. Direct-push was the method used at the beginning of the Copco-1 project. A lexan liner sampler was attached to the drill with 4 foot long drill rods, with each rod being added or removed by hand with wrenches. The dimensions of

DEPTH	% CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	74.7	**22.4**	97.1	2.9	0	136.6	59.9	342.9	MH	0.0	Qr	***0.0 to 4.3 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 4.8 ft.: ELASTIC SILT, MH:** 97.1% fines with medium plasticity and rapid dilatancy; 2.9% fine sand; trace to 5% organics; maximum size fine sand; wet, olive-gray to dark gray, massive, pudding-like consistency, strong organic smell, about 10% methane bubbles, 2 to 10mm in size, are distributed throughout the reservoir sediment; no reaction with HCl.
	9.4	**10.1**	19.5	23.8	56.7	46.8	21.6	21.5	(GC)s	0.0	Qal	***4.3 to 7.0 feet*** ***QUATERNARY ALLUVIUM - Qal (Pre-Reservoir)*** **4.8 to 7.0 ft.: CLAYEY GRAVEL WITH SAND, (GC)s:** About 60% fine to coarse, angular, hard gravel; about 25% medium to coarse sand; about 15% fines with medium plasticity; maximum size 65mm; wet, red-brown, massive; no reaction with HCl.
5												

BOTTOM OF HOLE: T.D. 7-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. CDH-09-32

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/17/09 FINISHED: 11/17/09
RESERVOIR WATER DEPTH: 124.0-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 56' 23.8" W 122 ° 25' 52.9"
TOTAL DEPTH: 7.0-ft.
RESEVOIR SEDIMENT THICKNESS: 4.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2,324.7-ft.-ft.
HOLE LOGGED BY: M. McCulla
REVIEWED BY: M. McCulla

NOTES

the lexan liner were 4.0 inch o.d. by 3-3/4 inch i.d. with a length up to 20 feet long, but could be cut to shorter lengths (as required). An 8 foot length liner was used most often. Liners could be used with or without a plastic sediment retaining basket (sand fingers). When used, the retaining basket was held in place with pop-rivets. Once the sample was collected it was retrieved and either extracted onto an aluminum-foil lined tray for contaminant sample collection, or kept in the lexan liner as an engineering sample. The lexan liner hosting engineering samples was cut to its desired length, capped, taped, and stored vertically.

The second method used was to attach a lexan tube with the same dimensions as above to a vibracore unit. Vibracore sample collection was used mostly during the second half of the drilling program at Copco-1 Reservoir, and for three holes at Iron Gate Reservoir. Once the vibracore unit was retrieved to the boat, contaminant and engineering samples were processed in the same way as with the direct-push method (above).

Listed below are details of drilling activities for each sampling run:

Attempt 1 The vibracore method of sampling was used with a 10 foot long lexan tube and plastic sediment-retaining basket. The lexan tube penetrated to a depth of 7.0 feet (refusal), with recovery of 5.4 feet of material.

Attempt 2 The vibracore method of sampling was used with a 10 foot long lexan tube and plastic sediment-retaining basket. The lexan tube penetrated to a depth of 5.5 feet (refusal), with recovery of 2.6 feet of material.

Attempt 3 The vibracore method of sampling was used with a 10 foot long lexan tube and plastic sediment-retaining basket. The lexan tube penetrated to a depth of 6.5 feet (refusal), with recovery of 4.9 feet of material.

Attempt 4 The vibracore method of sampling was used with a 10 foot long lexan tube and plastic sediment-retaining basket. The lexan tube penetrated to a depth of 6.5 feet (refusal), with recovery of 5.8 feet of material.

Contaminant sampling was carried out by MP-157 personnel.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium.

HOLE COMPLETION:
The lexan tube was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

A moderate amount of methane gas was encountered during drilling of the reservoir sediment, and bubbled up around the boats.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-8

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/1/09 FINISHED: 11/1/09
RESERVOIR WATER DEPTH: 39.9-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 03.4" W 122 ° 23' 21.1"
TOTAL DEPTH: 1.9-ft.
RESEVOIR SEDIMENT THICKNESS: 0.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.7-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
Iron Gate Reservoir. Located in the northeastern arm of the reservoir; about 800 feet downstream from outcrops of columnar-jointed basalt crossing the river, and about 4-1/2-miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,324.7 ft. (11/01/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL
	32 30	**48.5** **41.4**	80.5 71.4	19.5 28.6	0	80.5 59.2	33.6 27.2	163.0 190.9	(MH)s 2324.4	Qr
	9.7	**12.9**	22.6	11.7	65.7	36.9	14.4	15.8	(GC)s 2322.8	Qal

BOTTOM OF HOLE: T.D. 1.9-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 0.3 feet
RESERVOIR SEDIMENT - Qr

0.0 to 0.3 ft. ELASTIC SILT WITH SAND, (MH)s: About 70% to 80% fines with medium plasticity and rapid dilatancy; about 20% to 30% fine to medium sand; maximum size medium sand; wet, gray-brown, pudding-like consistency, moderate decaying organics; no reaction with HCl.

0.3 to 1.9 feet
QATERNARY ALLUVIUM - Qal (Pre-Reservoir)

0.3 to 1.9 ft CLAYEY GRAVEL WITH COBBLES (GC)sc: 65.7% fine to coarse, subangular to subrounded, hard gravel; 22.6% fines with low to medium plasticity and slow dilatancy; 11.7% fine to coarse sand; trace 3- to 5-inch subangular, hard cobbles; maximum size 85mm; wet, gray; no reaction with HCl.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

There is only a very thin layer of reservoir sediment at this location (0.3 feet), and not enough to collect a sample in a lexan liner.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-8

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/1/09 FINISHED: 11/1/09
RESERVOIR WATER DEPTH: 39.9-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 03.4" W 122 ° 23' 21.1"
TOTAL DEPTH: 1.9-ft.
RESEVOIR SEDIMENT THICKNESS: 0.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.7-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
42.6 feet (water depth 39.9 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run.
Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler and seated within the FADC system and lowered to the water/sediment interface. The sample shoe was set 0.2 feet in front of the drill bit teeth. The whole assembly was pushed to 0.9-feet (refusal) with no recovery.

Attempt 2 The barge was moved about 2 feet for the second drilling attempt. Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler with sample fingers and a sock, all of which was seated within the FADC system and lowered to the water/sediment interface. The sample shoe was set 0.2 feet in front of the drill bit teeth. The whole assembly was pushed to 1.0-feet (refusal) with no recovery.

Attempt 3 The barge was moved about 5 feet for this attempt. Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler with sample fingers and a sock, all of which was seated within the FADC system and lowered to the water/sediment interface. The sample shoe was set 0.2 feet in front of the drill bit teeth. The whole assembly was rotated and drilled to 1.9-feet (refusal) with recovery of 0.9 feet of reservoir sediment. Reservoir sediment and alluvium comprised of clayey sand, gravel, and cobbles was recovered. Three samples were collected for laboratory analysis of gradations and Atterberg limits.

The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. It was then pounded into the material to a depth of 0.6 feet (refusal), recovering 0.6 feet of material. This sampler was used to better determine the contact between reservoir sediment and pre-reservoir sediment.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

There is only a very thin layer of reservoir sediment at this location (0.3 feet), and not enough to collect a sample in a lexan liner.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-8

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/1/09 FINISHED: 11/1/09
RESERVOIR WATER DEPTH: 39.9-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 03.4" W 122 ° 23' 21.1"
TOTAL DEPTH: 1.9-ft.
RESEVOIR SEDIMENT THICKNESS: 0.3-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2324.7-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING FLUID:
DRILLED WITHOUT FLUID

REASON FOR HOLE TERMINATION:
The hole was terminated because there was not a sufficient thickness of reservoir sediment to sample at this location.

HOLE COMPLETION:
Drill augers were pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

There is only a very thin layer of reservoir sediment at this location (0.3 feet), and not enough to collect a sample in a lexan liner.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-8A

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/12/09 FINISHED: 11/12/09
RESERVOIR WATER DEPTH: 55.5-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 02.6" W 122 ° 23' 41.3"
TOTAL DEPTH: 2.3-ft.
RESEVOIR SEDIMENT THICKNESS: 2.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2323.7-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
Iron Gate Reservoir. Located in the northeastern arm of the reservoir; about 4.2-miles upstream from Iron Gate Dam and about 2,200 feet downstream from outcrops of columnar basalt crossing the river.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,323.7 ft. (11/12/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	47.0	**50.7**	97.7	2.3	0	92.9	49.9	210.6	MH / 2322.5	Qr	***0.0 to 2.2 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 2.2 ft. ELASTIC SILT WITH SAND, (MH)s:** 97.7% fines with medium plasticity and rapid dilatancy; 2.7% fine sand; trace to 5% decaying organic material; maximum size fine sand; wet, dark brown, pudding-like consistency; no reaction with HCl.
										Qal	***2.2 to 2.3 feet*** ***QATERNARY ALLUVIUM - Qal (Pre-Reservoir)*** **2.2 to 2.3 ft SILTY GRAVEL WITH SAND, (GM)s:** About 50% fine, subangular to subrounded, hard gravel; about 35% fine to coarse sand; about 15% nonplastic fines to coarse sand; maximum size 12mm; wet, dark brown; no reaction with HCl.

BOTTOM OF HOLE: T.D. 2.3-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan tube sample of the reservoir sediment was collected from 0.0 to 2.2 feet for testing.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-8A

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/12/09 FINISHED: 11/12/09
RESERVOIR WATER DEPTH: 55.5-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 02.6" W 122 ° 23' 41.3"
TOTAL DEPTH: 2.3-ft.
RESEVOIR SEDIMENT THICKNESS: 2.2-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2323.7-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
58.2 feet (water depth 55.5 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run.
Attempt 1 The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. It was then pounded into the material to a depth of 2.3 feet (refusal), recovering 2.2 feet of material. One lexan tube with reservoir sediment was collected from 0.0 to 2.2 feet for testing.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir alluvium, and the collection of an undisturbed sample of reservoir sediment.

HOLE COMPLETION:
The gravity sampler was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan tube sample of the reservoir sediment was collected from 0.0 to 2.2 feet for testing.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-9

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 23.5-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 43.0" W 122 ° 25' 27.0"
TOTAL DEPTH: 3.3-ft.
RESEVOIR SEDIMENT THICKNESS: 2.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2323.5-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
Iron Gate Reservoir. Located in the northeastern arm of the reservoir; about 2.4-miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,323.5 ft. (11/11/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
											Qr	***0.0 to 2.0 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 2.0 ft. ELASTIC SILT, MH:** About 90% fines with medium plasticity and rapid dilatancy; about 10% fine sand; trace to 5% decaying organic material; maximum size fine sand; wet, dark brown, pudding-like consistency; no reaction with HCl.
											Tv	***2.0 to 3.3 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **2.0 to 3.3 ft. SANDY FAT CLAY, s(CH):** 66.6% fines with medium plasticity and rapid dilatancy; 29.3% fine sand; 4.1% fine to coarse, angular, hard gravel; maximum size 20mm; wet, firm, dark brown; no reaction with HCl. Geologic Interpretation: Very intensely weathered lapilli tuff.
	42.2	**24.4**	66.6	29.3	4.1	65.0	35.4	30.1	s(CH)	2320.2		

BOTTOM OF HOLE: T.D. 3.3-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample of the reservoir sediment was collected from 1.4 to 3.0 feet (0.6-ft. of reservoir sediment) for testing.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-9

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 23.5-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 43.0" W 122 ° 25' 27.0"
TOTAL DEPTH: 3.3-ft.
RESEVOIR SEDIMENT THICKNESS: 2.0-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2323.5-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
26.2 feet (water depth 23.5 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run.
Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler with a basket spring retainer (sand fingers) and a sock, all of which was seated within the FADC system and lowered to the water/sediment interface. The whole assembly was rotated and drilled to 3.3-feet (refusal) with recovery of 1.9 feet of material. One lexan liner sample was collected with an undisturbed reservoir sediment interval of 1.4 to 3.0-feet (0.6-ft. of reservoir sediment).

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanic rock, and the collection of an undisturbed sample of reservoir sediment.

HOLE COMPLETION:
The auger and sampler was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample of the reservoir sediment was collected from 1.4 to 3.0 feet (0.6-ft. of reservoir sediment) for testing.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-9A

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 37.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 43.0" W 122 ° 25' 30.0"
TOTAL DEPTH: 4.4-ft.
RESEVOIR SEDIMENT THICKNESS: 3.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2323.5-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
Iron Gate Reservoir. Located in the northeastern arm of the reservoir; about 2.4-miles upstream from Iron Gate Dam.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

Reservoir Water Surface Elevation:
2,323.5 ft. (11/11/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL
	42.8	**25.3**	68.1	26.8	5.1	57.5	29.9	31.2	s(CH) 2319.1	Tv

BOTTOM OF HOLE: T.D. 4.4-ft.

VISUAL CLASSIFICATION AND PHYSICAL CONDITION

0.0 to 3.8 feet
RESERVOIR SEDIMENT - Qr

0.0 to 3.8 ft. ELASTIC SILT, MH: About 95% fines with medium plasticity and rapid dilatancy; about 5% fine sand; trace to 5% decaying organic material; maximum size fine sand; wet, dark-brown to orange to dark-gray, pudding-like consistency; no reaction with HCl.

3.8 to 4.4 feet
TERTIARY VOLCANICS - Tv (Pre-Reservoir)

3.8 to 4.4 ft. SANDY FAT CLAY, s(CH): 68.1% fines with medium plasticity and rapid dilatancy; 26.8% fine sand; 5.1% fine, angular, hard gravel; maximum size 10mm; wet, firm, moderate small plant roots, dark brown; no reaction with HCl.

Geologic Interpretation: Very intensely weathered lapilli tuff.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample of the reservoir sediment was collected (after cutting) from 2.58 to 4.10 feet (1.3-ft. of reservoir sediment) for testing.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-9A

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/11/09 FINISHED: 11/11/09
RESERVOIR WATER DEPTH: 37.3-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 43.0" W 122 ° 25' 30.0"
TOTAL DEPTH: 4.4-ft.
RESEVOIR SEDIMENT THICKNESS: 3.8-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2323.5-ft.
HOLE LOGGED BY: Greg Mongano
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
40.0 feet (water depth 37.3 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run:

Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler with a basket spring retainer (sand fingers) and a sock, all of which was seated within the FADC system and lowered to the water/sediment interface. The whole assembly was rotated and drilled to 4.4-feet (refusal) with recovery of 1.9 feet of material. One lexan liner sample was collected with an undisturbed reservoir sediment interval of 2.5 to 4.1-feet (1.3-ft. of reservoir sediment).

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful penetration through the reservoir sediment into the underlying pre-reservoir volcanic rock, and the collection of an undisturbed sample of reservoir sediment.

HOLE COMPLETION:
The auger and sampler was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One lexan liner sample of the reservoir sediment was collected (after cutting) from 2.58 to 4.10 feet (1.3-ft. of reservoir sediment) for testing.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-10

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/13/09 FINISHED: 11/13/09
RESERVOIR WATER DEPTH: 65.4-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 14.5" W 122 ° 25' 58.6"
TOTAL DEPTH: 5.2-ft.
RESEVOIR SEDIMENT THICKNESS: 4.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2323.8-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
Iron Gate Reservoir. Located in the main section of the reservoir; about 1-mile upstream from Iron Gate Dam, and next to drill hole CDH-09-29.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION / ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
										Qr	***0.0 to 4.5 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 4.5 ft. ELASTIC SILT, MH:** 92.6% fines with medium plasticity and rapid dilatancy; 7.4% fine sand; trace to 5% decaying organic material; maximum size fine sand; wet, dark-brown, pudding-like consistency; no reaction with HCl.
	64.0	**28.6**	92.6	7.4	0	114.0	65.7	288.9	MH 2319.3		
	20.3	**9.1**	29.4	15.6	55.0	74.8	45.4	25.3	(GC)s 2318.6	Tv	***4.5 to 5.2 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **4.5 to 5.2 ft. CLAYEY GRAVEL WITH SAND, (GC)s:** 55.0% fine to coarse, subangular to subrounded, hard gravel; 29.4% fines with high plasticity and slow dilatancy; 15.6% fine to coarse sand; maximum size 65mm; wet, red brown, firm; no reaction with HCl. Geologic Interpretation: Very intensely weathered lapilli tuff; or, possibly very clay-rich alluvium (Qal).
5											

BOTTOM OF HOLE: T.D. 5.2-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One undisturbed lexan tube sample was collected from 2.85 to 5.2 feet (contains 1.65 feet of reservoir sediment and 0.7 feet of Tv).

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-10

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/13/09 FINISHED: 11/13/09
RESERVOIR WATER DEPTH: 65.4-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 14.5" W 122 ° 25' 58.6"
TOTAL DEPTH: 5.2-ft.
RESEVOIR SEDIMENT THICKNESS: 4.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2323.8-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface Elevation:
2,323.8 ft. (11/13/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar: 2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
68.1 feet (water depth 65.4 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run:

Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler with a basket spring retainer (sand fingers) and a sock, all of which was seated within the FADC system and lowered to the water/sediment interface. The whole assembly was rotated and drilled to 7.3-feet (refusal), recovering 1.6 feet of material.

Attempt 2 The gravity sampler method of sample collection was used. The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. It was then pounded into the material to a depth of 5.4 feet (refusal). As the lexan tube came up above water the sample dropped out (no recovery).

Attempt 3 The gravity sampler method of sample collection was used. The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. It was then pounded into the material to a depth of 5.4 feet (same as above; refusal). As the lexan tube came up above water the sample dropped out (no recovery).

Moved to slightly deeper water (65.4 feet)
Attempt 4 The gravity sampler method of sample collection was used. The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. It was then pounded into the material to a depth of 5.1 feet (refusal). As the lexan tube came up above water the sample dropped out (no recovery).

Attempt 5 The gravity sampler method of sample collection was used. The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. It was then pounded into the material to a depth of 5.2 feet (refusal) with recovery of 2.35 feet of material.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One undisturbed lexan tube sample was collected from 2.85 to 5.2 feet (contains 1.65 feet of reservoir sediment and 0.7 feet of Tv).

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-10

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/13/09 FINISHED: 11/13/09
RESERVOIR WATER DEPTH: 65.4-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 57' 14.5" W 122 ° 25' 58.6"
TOTAL DEPTH: 5.2-ft.
RESEVOIR SEDIMENT THICKNESS: 4.5-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2323.8-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon unsuccessful recovery of reservoir sediment, even though the sampler penetration through the reservoir sediment into the underlying pre-reservoir volcanics multiple times.

HOLE COMPLETION:
The auger and sampler was pulled out and the hole was left to collapse-in on itself.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

One undisturbed lexan tube sample was collected from 2.85 to 5.2 feet (contains 1.65 feet of reservoir sediment and 0.7 feet of Tv).

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-11

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/12/09 FINISHED: 11/12/09
RESERVOIR WATER DEPTH: 46.4-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 17.3" W 122 ° 24' 10.9"
TOTAL DEPTH: 3.3-ft.
RESEVOIR SEDIMENT THICKNESS: 3.1-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.5-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

ALL MEASUREMENTS ARE IN FEET. DRILL HOLE COORDINATES WERE DETERMINED USING A HAND-HELD GARMIN (VISTA MODEL) GPS. RESERVOIR ELEVATIONS WERE PROVIDED ON A CALL-IN BASIS BY PACIFICORP. WATER DEPTH AND TOP OF RESERVOIR SEDIMENT WERE MEASURED FROM THE BARGE AT THE START OF DRILLING.

PURPOSE OF HOLE:
To measure the thickness of reservoir sediment (Qr) at each location; and, to collect undisturbed samples in lexan liners for use in determining the engineering properties of reservoir sediment.

LOCATION:
Iron Gate Reservoir. Located at Jenny Creek Cove, in the northeastern arm of the reservoir; about 3-3/4-miles upstream from Iron Gate Dam, and adjacent to drill hole CDH-09-24.

EQUIPMENT MOBILIZATION:
The barge, boats, drill rig, and drilling equipment were mobilized from Reclamation's PN-Region, via trucks. The barge and drill rig were then lifted with a crane from the Long Gulch boat ramp on the southeastern side of the reservoir, about 4,000 feet upstream from Iron Gate Dam. For security purposes drilling and sampling equipment were stored at the southern end of the reservoir, behind a PacifiCorp locked gate about 1,600 feet upstream from the dam.

DRILLING BARGE:
The barge assembly was comprised of four separate segments, each having its own floatation cells. Three of the segments were connected with bolts and decking. The fourth segment, containing the restroom and geology / environmental sampling equipment was independently driven to the drilling barge and loosely attached to the barge via ropes during drilling. When fully assembled the drilling section of the barge is about 30 feet long by 15 feet wide. The barge is self-propelled and moved into position using dual 70 hp outboard Evinrude engines. The detachable segment was powered by a single outboard Suzuki four-stroke engine. The barge was secured at each drilling site by a four-point mooring system, with in-water anchors, cables, and deck winches.

DRILL RIG:
Deck-mounted Ingersoll-Rand A200 auger drill with hydraulic head.

DRILLED BY:
Reclamation's PN-Region Drill Crew
Jerry Hansen (Driller)
Cody Kelly (Helper)
Lance Robinson (Helper)
Dennis Read (Helper)

DRILLING & SAMPLING METHODS:
Drilling depth is measured from the water/sediment contact. The water/sediment contact depth was measured from the top of the drill collar, and the distance from the drill collar before each run, if possible. The reservoir water surface elevation was recorded daily by calling into PacifiCorp's Hydro-Control office. Typically water is discharged from the reservoir throughout the day to produce power, and refilled throughout the night. Reservoir water surface fluctuations were on the order of 1 to 2 feet throughout the drilling program.

DEPTH	LABORATORY DATA: % CLAY	% SILT	% FINES	% SAND	% GRAVEL	LIQUID LIMIT	PLASTICITY INDEX	% MOISTURE CONTENT	LAB CLASSIFICATION	ELEVATION	GEOLOGIC UNIT SYMBOL	VISUAL CLASSIFICATION AND PHYSICAL CONDITION
	39	**46.9**	85.9	14.1	0	78.8	35.1	154.2	MH		**Qr**	***0.0 to 3.1 feet*** ***RESERVOIR SEDIMENT - Qr*** **0.0 to 3.1 ft. ELASTIC SILT, MH:** 85.9% fines with medium plasticity and rapid dilatancy; 14.1% fine sand; trace to 5% decaying organic material; maximum size fine sand; wet, dark-brown, pudding-like consistency; no reaction with HCl. Remarks: At the contact with underlying volcanic rock is 0.1 feet of predominantly decaying organic material
										2322.4		***3.1 to 3.3 feet*** ***TERTIARY VOLCANICS - Tv (Pre-Reservoir)*** **3.1 to 3.3 ft. CLAYEY SAND, SC:** About 60% fine to medium sand; about 40% lean clay; maximum size medium sand; wet, tan, no reaction with HCl. The whole sample is about 75% decaying organic material with the remainder Clayey Sand (SC); as above.
											Tv	Geologic Interpretation: Very intensely weathered lapilli tuff overlain by a mass of pre-reservoir decaying vegetation.

BOTTOM OF HOLE: T.D. 3.3-ft.

COMMENTS:

NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample from 0.0 to 3.23 feet.

RECLAMATION
Managing Water in the West

GEOLOGIC LOG OF DRILL HOLE NO. EDH-09-11

FEATURE: KRSS
LOCATION: Iron Gate Reservoir
BEGUN: 11/12/09 FINISHED: 11/12/09
RESERVOIR WATER DEPTH: 46.4-ft.

PROJECT: Klamath
COORDINATES: N 41 ° 58' 17.3" W 122 ° 24' 10.9"
TOTAL DEPTH: 3.3-ft.
RESEVOIR SEDIMENT THICKNESS: 3.1-ft.

STATE: Oregon and California
RESERVOIR ELEVATION: * 2325.5-ft.
HOLE LOGGED BY: Mike McCulla
REVIEWED BY: M. McCulla

NOTES

Reservoir Water Surface Elevation:
2,325.5 ft. (11/12/09)
* The elevation datum PacifiCorp uses at Iron Gate Reservoir is yet to be determined by Reclamation.

Reservoir Water Surface from the Collar:
2.7 feet

Reservoir Water/Sediment contact Depth from Collar:
49.1 feet (water depth 46.4 feet)

Drilling was conducted using a continuous flight auger dry core (FADC) system with 7-7/8 inch o.d. by 3-3/4 inch i.d. by 5 foot long hollow stem flight augers on NWJ drill rods with a spade/bullet auger bit. Undisturbed samples for engineering-properties analyses were collected using a 3-1/2 inch o.d. by 3.0 inch i.d. by 5.0 foot long split tube sampler. Two lexan liners fit into the sampler at a time, and each had a 3.0 inch o.d. by 2-3/4 inch i.d. diameter and were pre-cut to 2.5 feet in length. Lexan liners were measured and weighed prior to use and cut to fit the length of recovered sediment when a liner was only partially filled. Undisturbed samples were capped, taped, and weighed with the weight of the caps and tape subtracted from the final calculations, and unit-weights per cubic foot of material were then calculated. Following collection, all lexan liner samples remained upright (vertical or near-vertical) through the storage and shipping process.

Listed below are details of drilling activities for each sampling run:

Attempt 1 Two lexan liners (each 2.5-feet long) were fitted into the split tube sampler with a basket spring retainer (sand fingers) and a sock, all of which was seated within the FADC system and lowered to the water/sediment interface. The whole assembly was rotated and drilled to 6.0-feet (refusal) with no recovery of material.

Attempt 2 The gravity sampler method of sample collection was used. The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. It was then pushed into the material to a depth of 6.8 feet (refusal) recovering 3.2 feet of material.

Attempt 3 The gravity sampler method of sample collection was used. The gravity sampler with 2-5/8" i.d. lexan tube was hooked up to a winch-line on the drill rig and lowered to the water/sediment interface. It was then pushed into the material to a depth of 7.4 feet (refusal) with recovery of 3.3 feet of material. One lexan tube sample was collected from 0.0 to 3.23 feet.

DRILLING CONDITIONS AND DRILLER'S COMMENTS:
NA

REASON FOR HOLE TERMINATION:
The hole was terminated upon successful collection of an undisturbed lexan tube sample of reservoir sediment, and penetration through the reservoir sediment into the underlying pre-reservoir volcanics.

HOLE COMPLETION:
The auger and sampler was pulled out and the hole was left to collapse-in on itself.

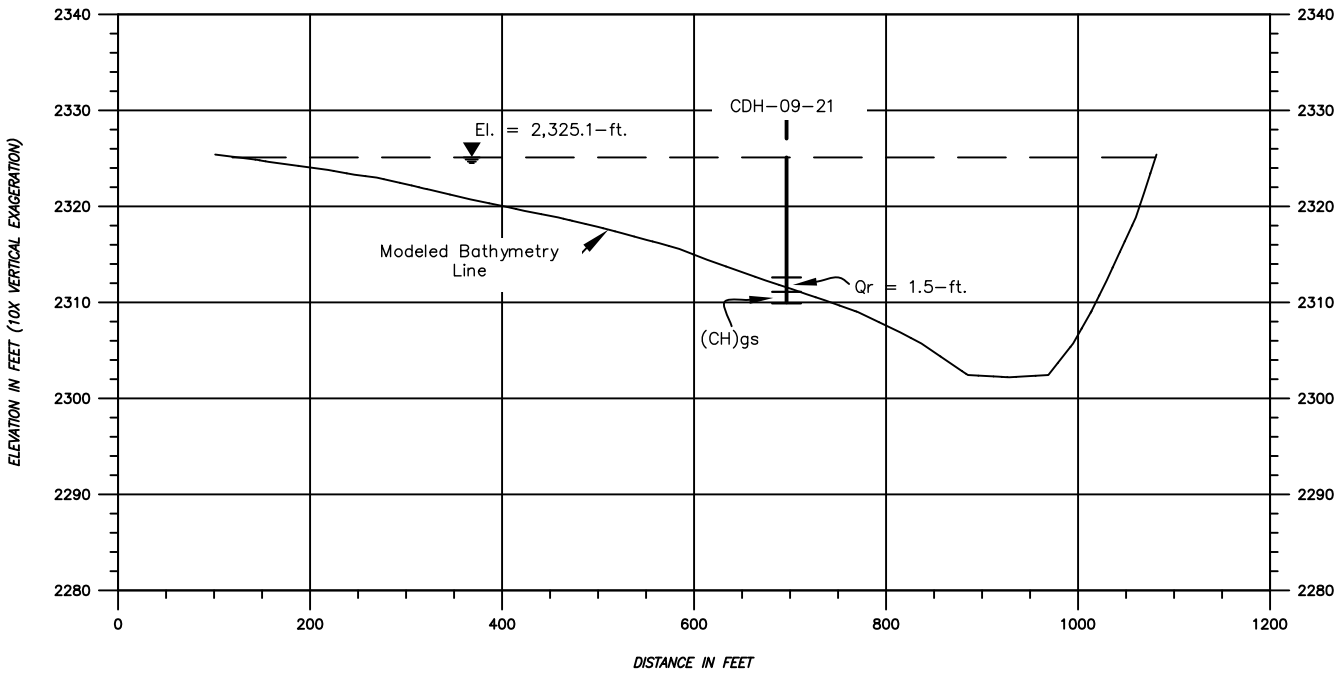
COMMENTS:

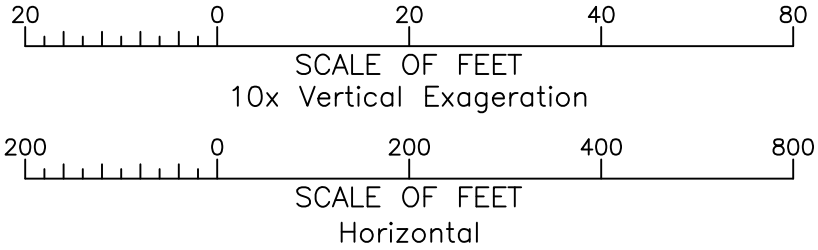
NA = Not Applicable, Not Available
NP = Nonplastic
NR = No Recovery
FADC = Flight Auger Dry Core

Lexan tube sample from 0.0 to 3.23 feet.

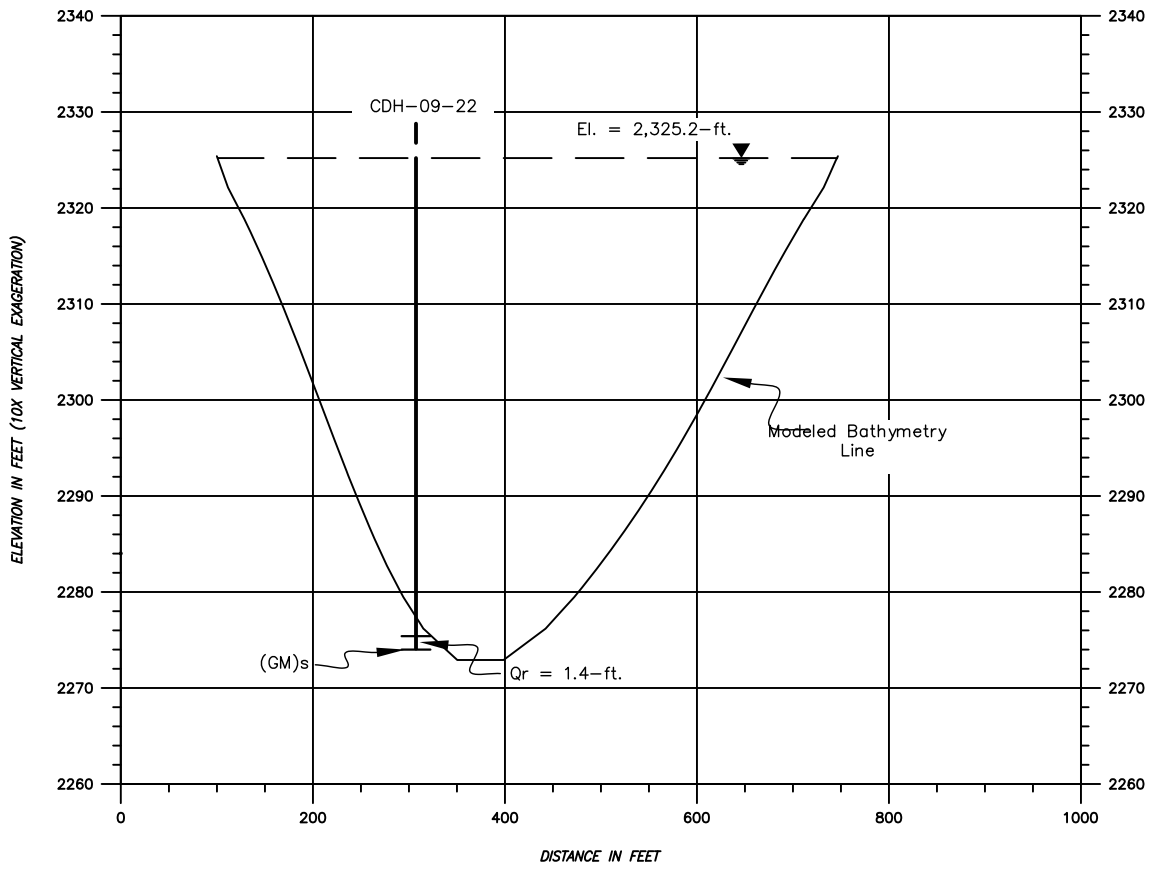
RECLAMATION
Managing Water in the West

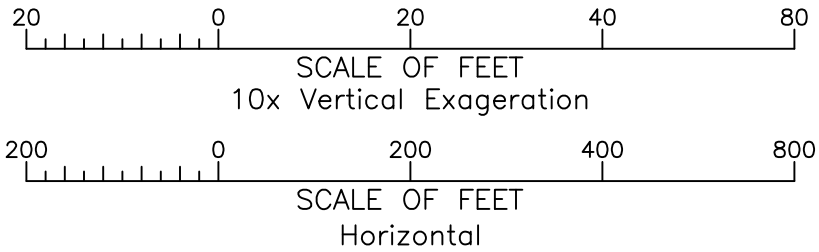
Iron Gate Section 1



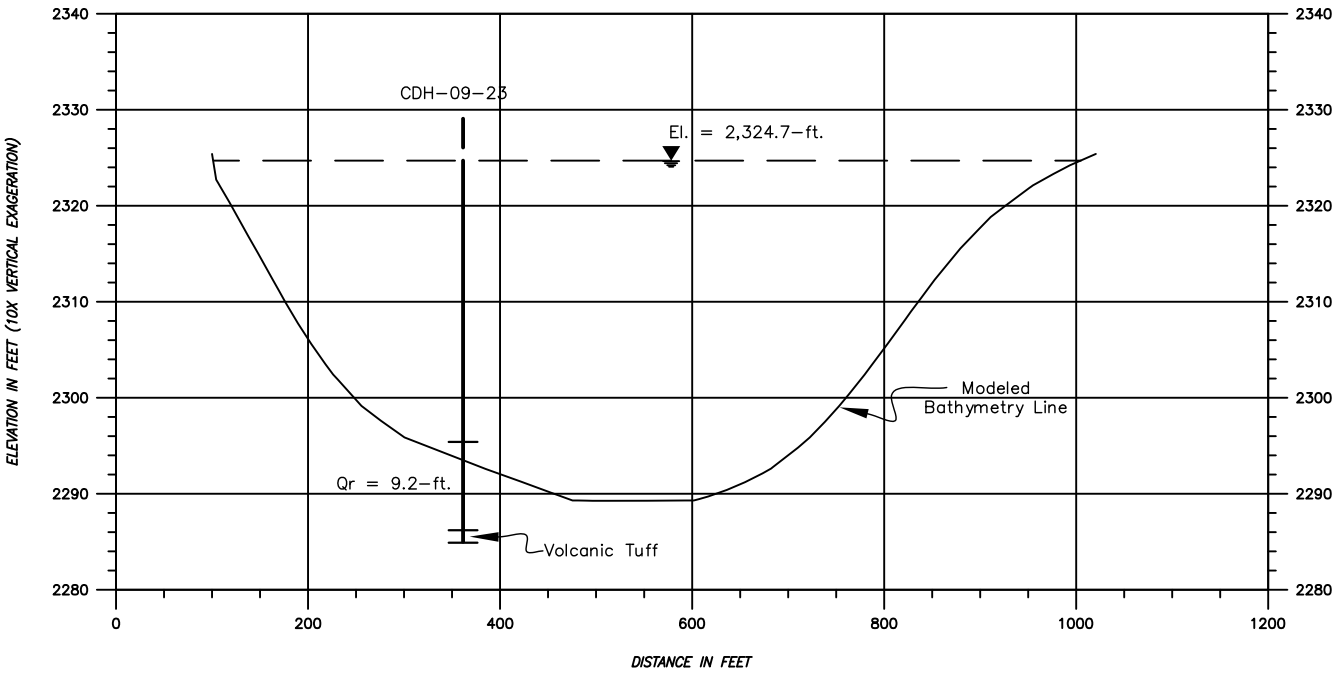


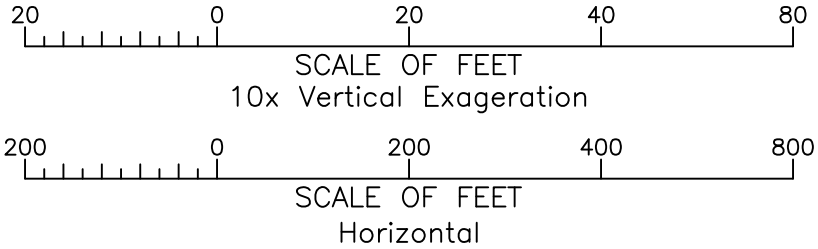
Iron Gate Section 2



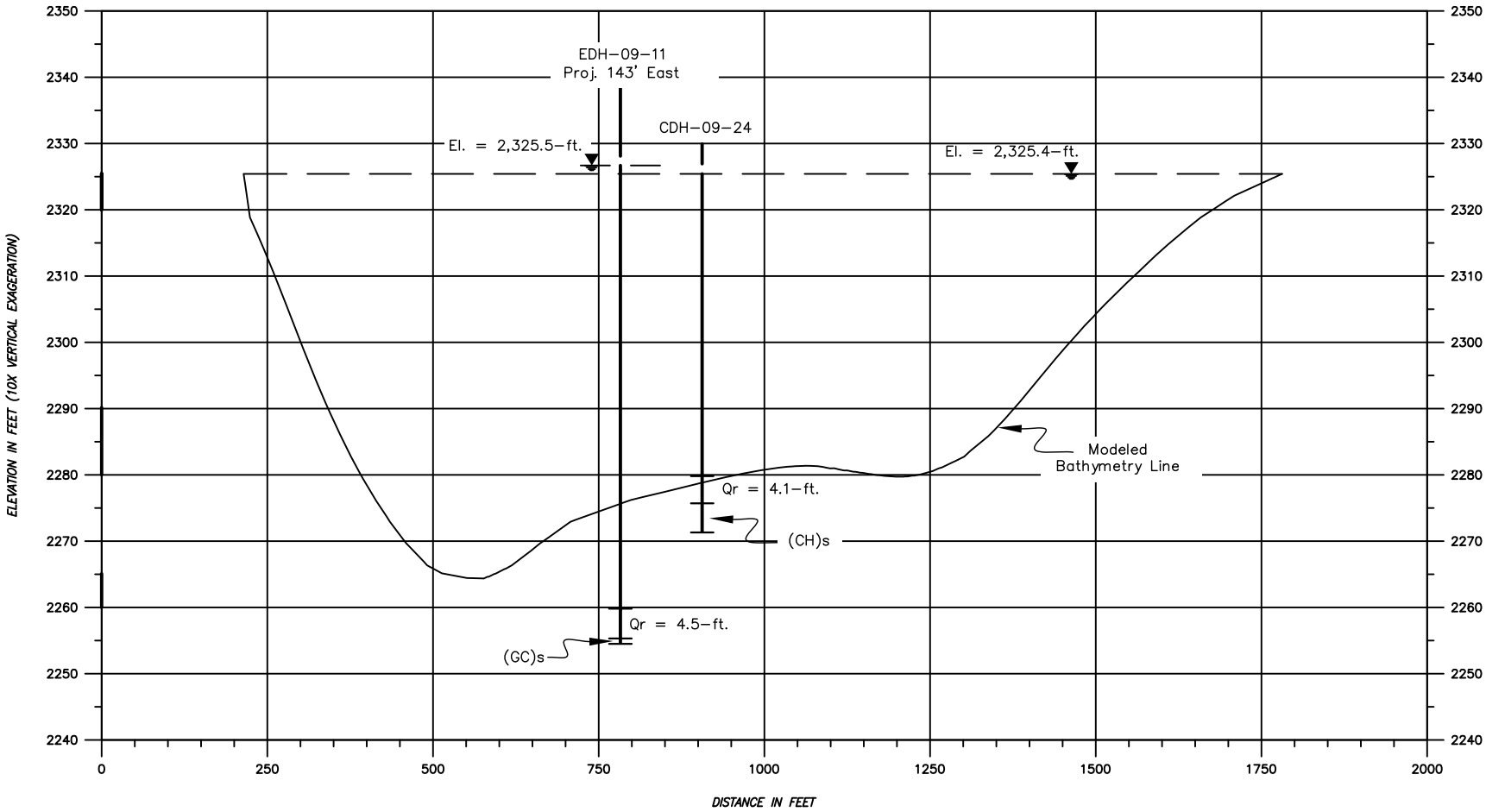


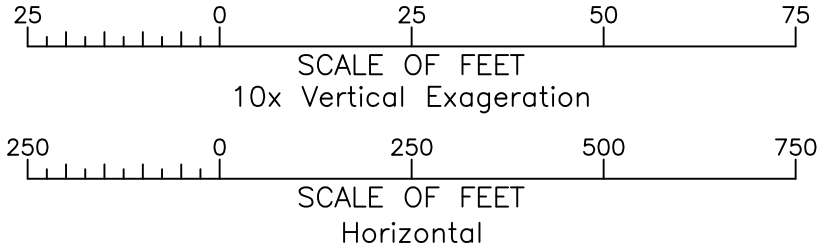
Iron Gate Section 3



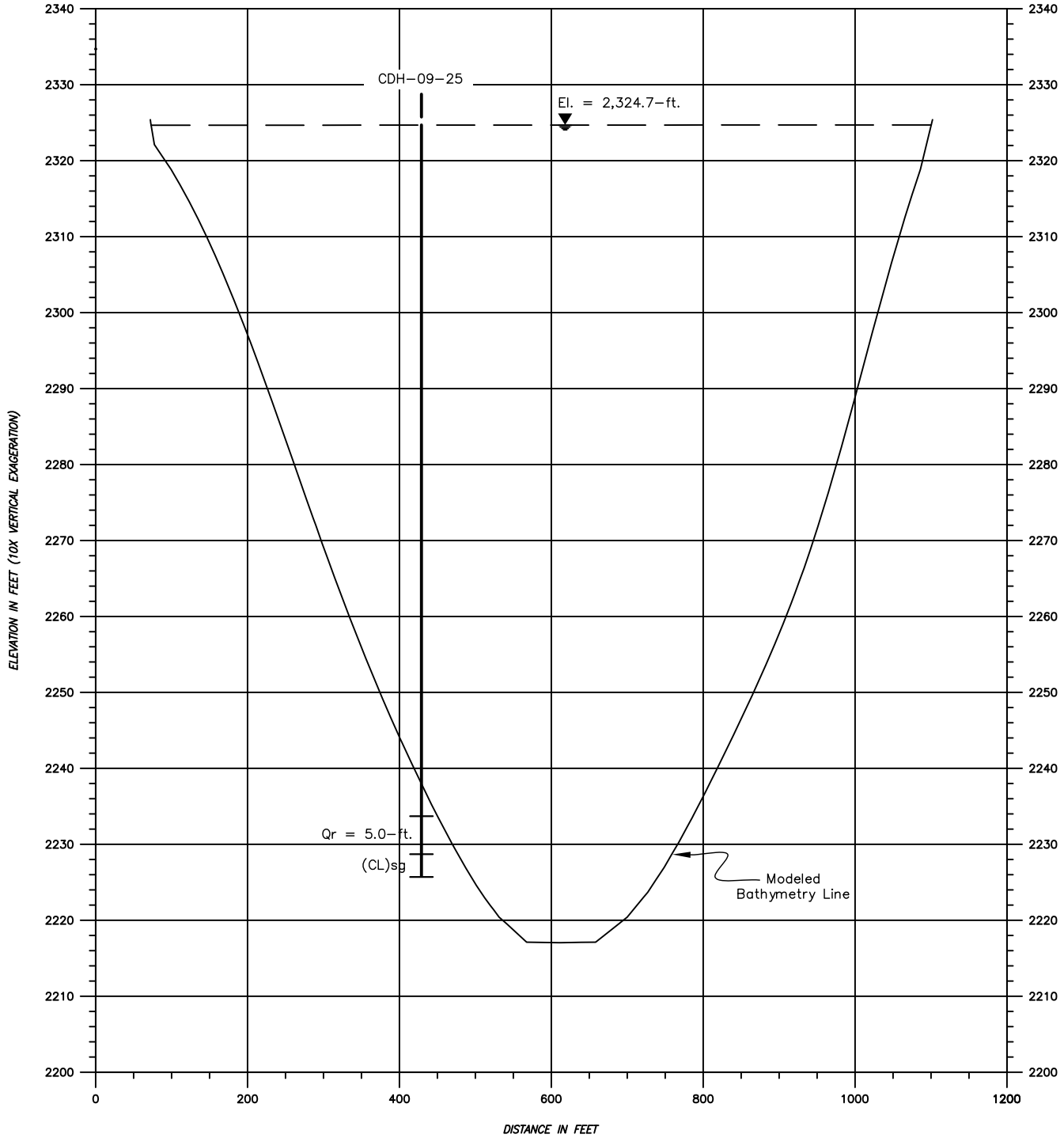


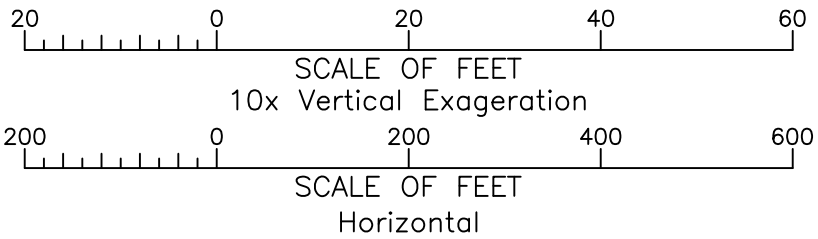
Iron Gate Section 4



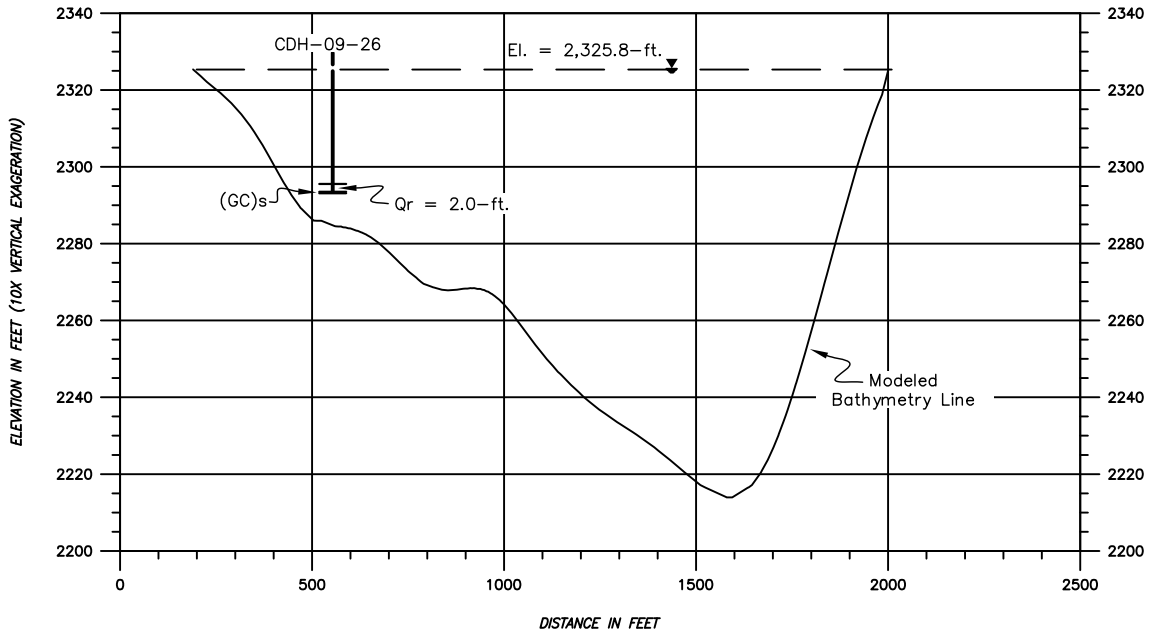


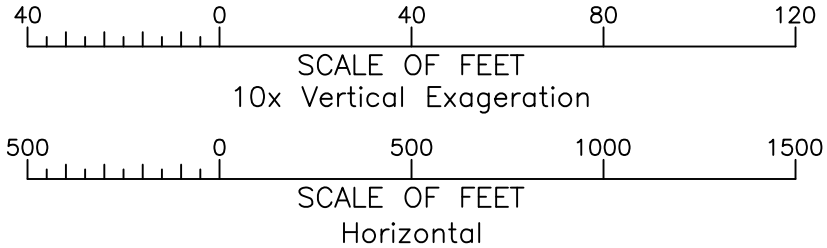
Iron Gate Section 5



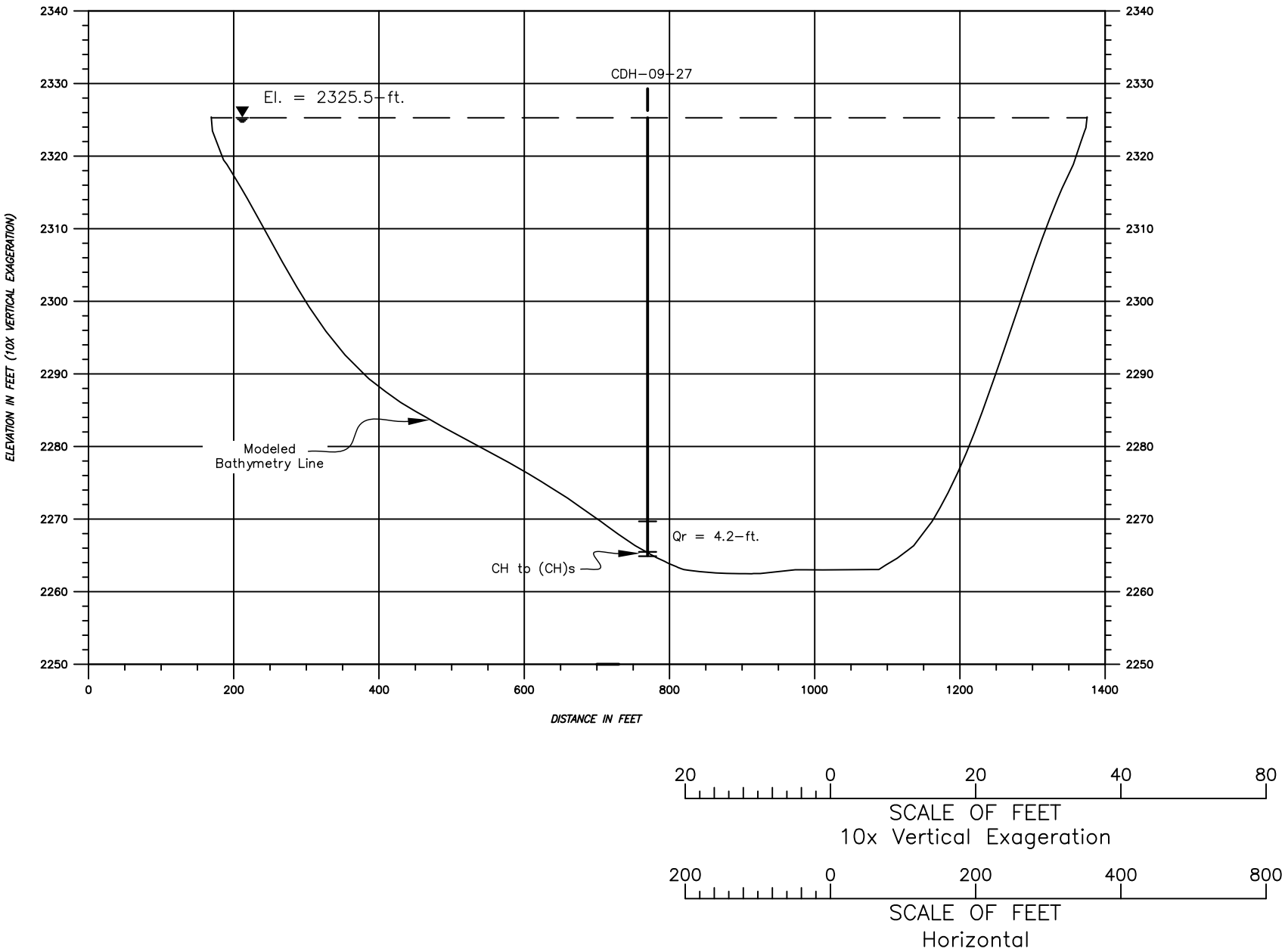


Iron Gate Section 6





Iron Gate Section 7



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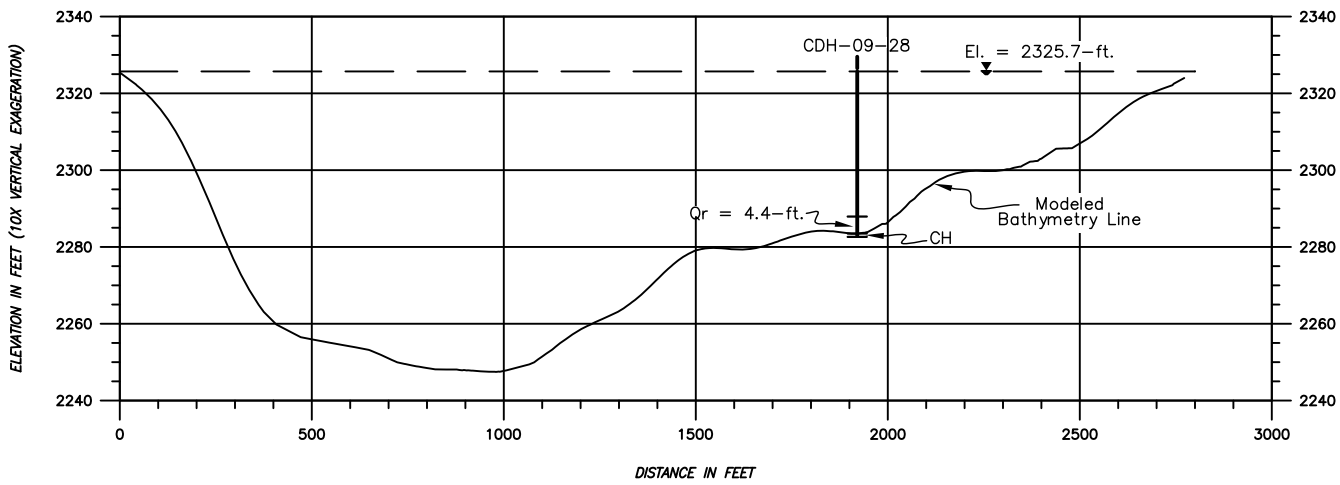
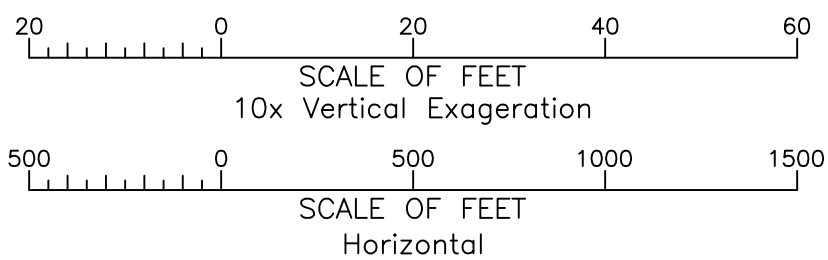
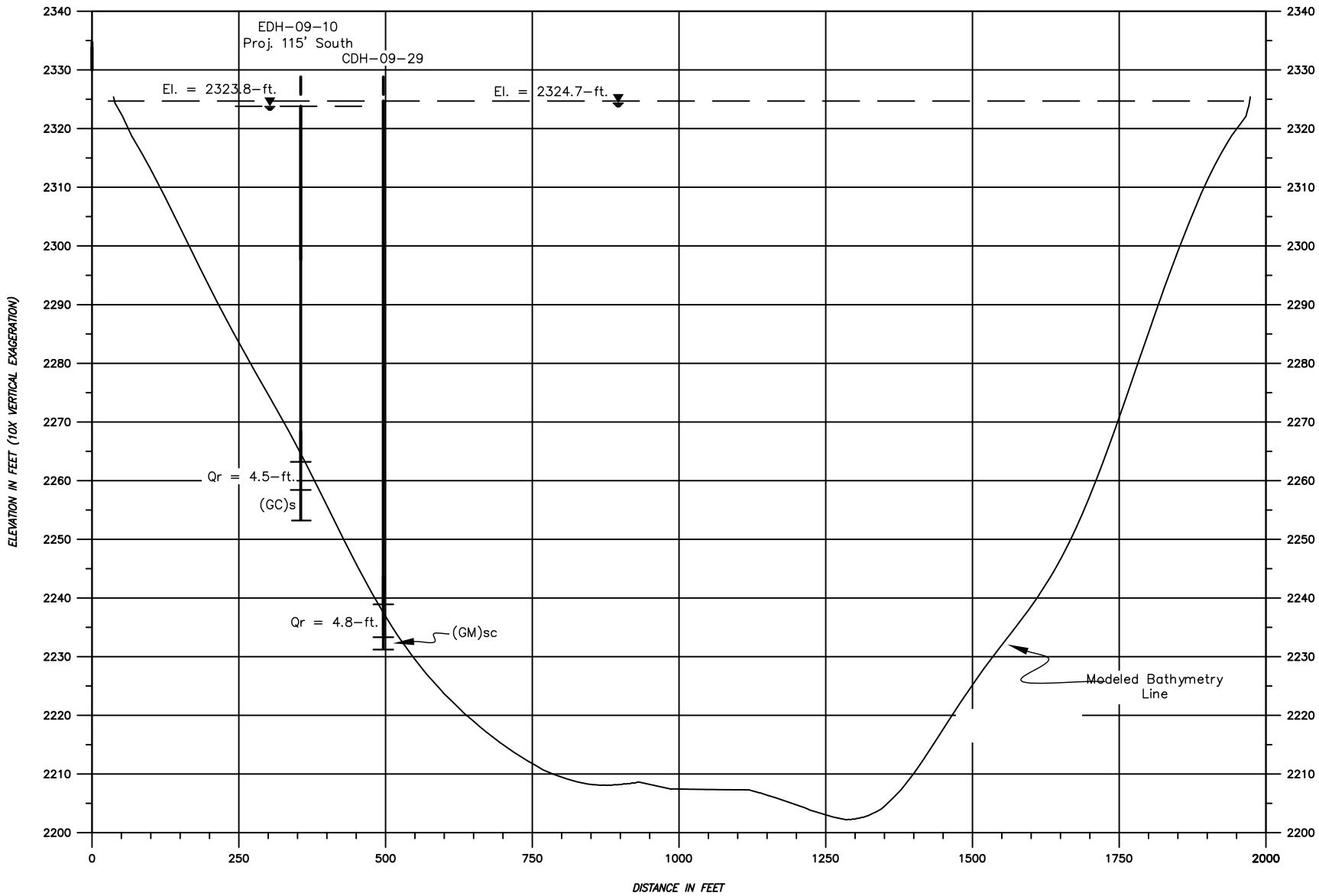
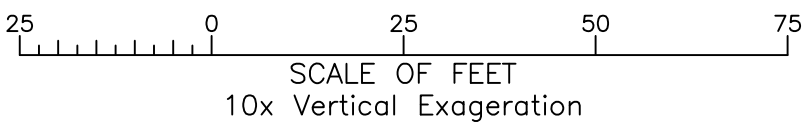
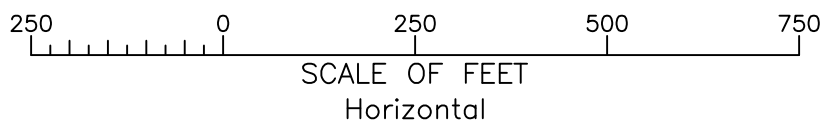




Iron Gate Section 9







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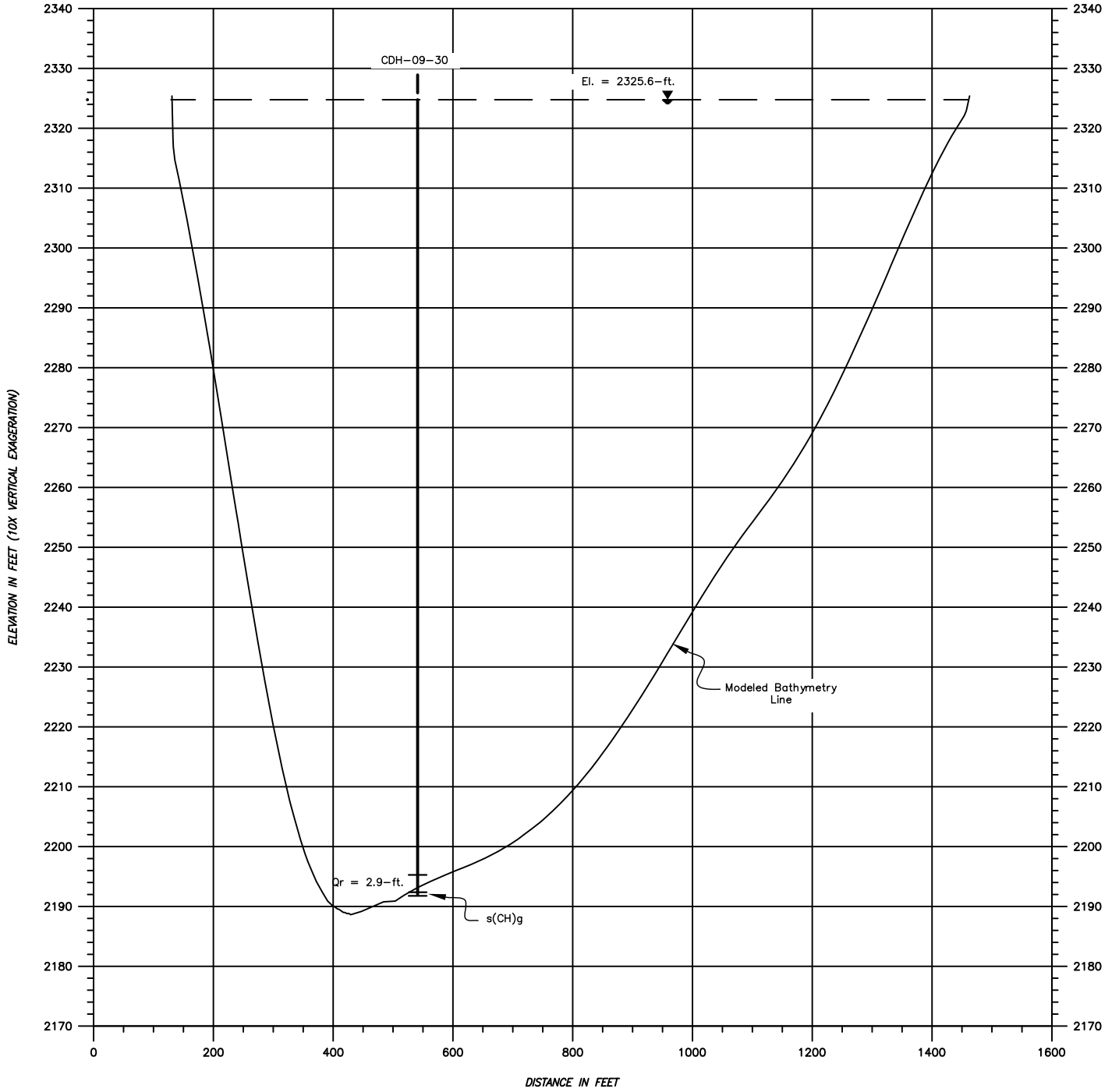

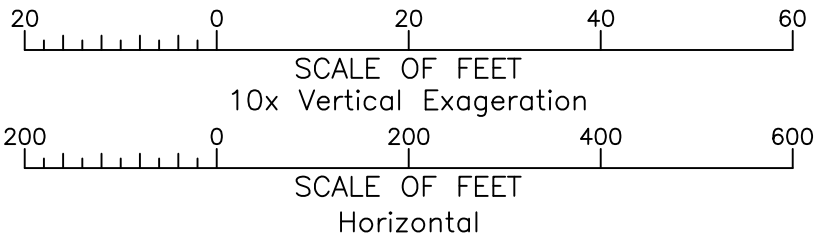

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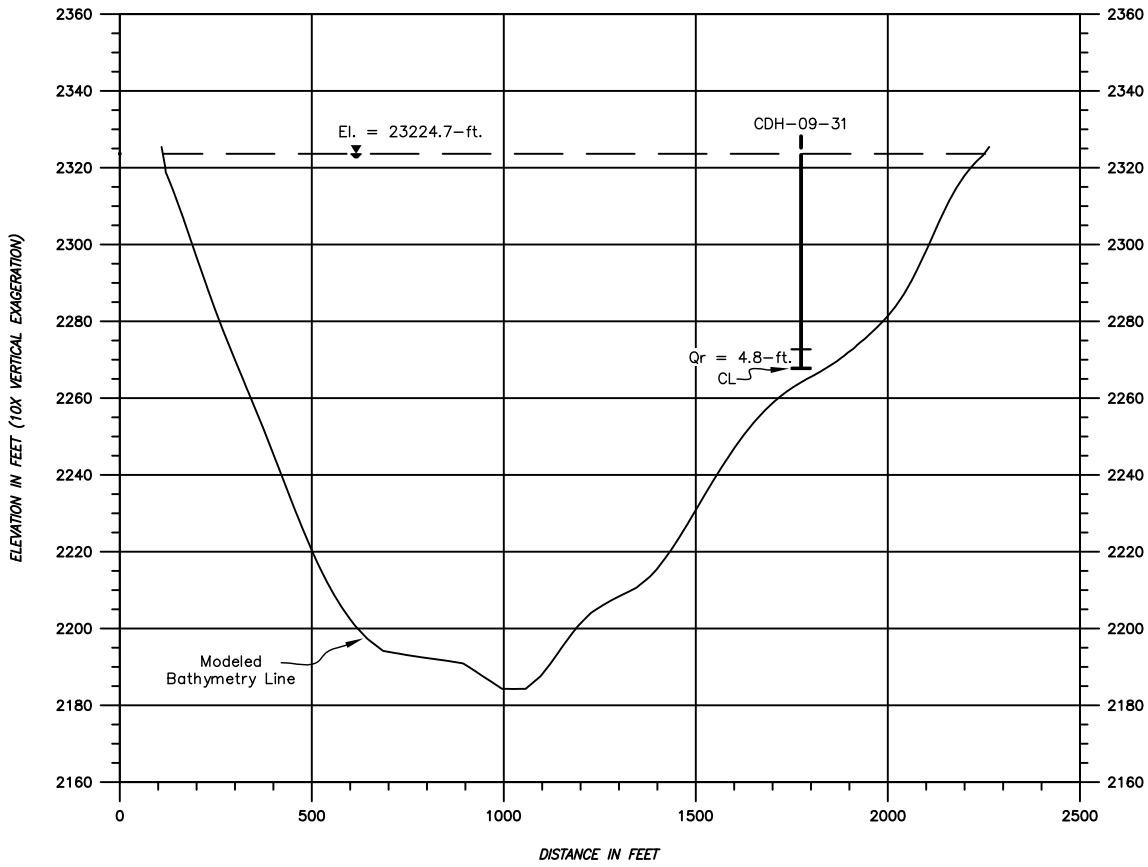

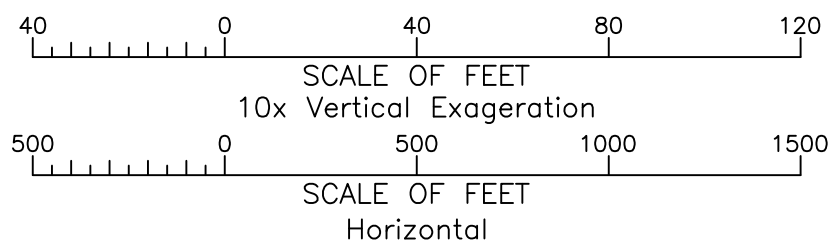

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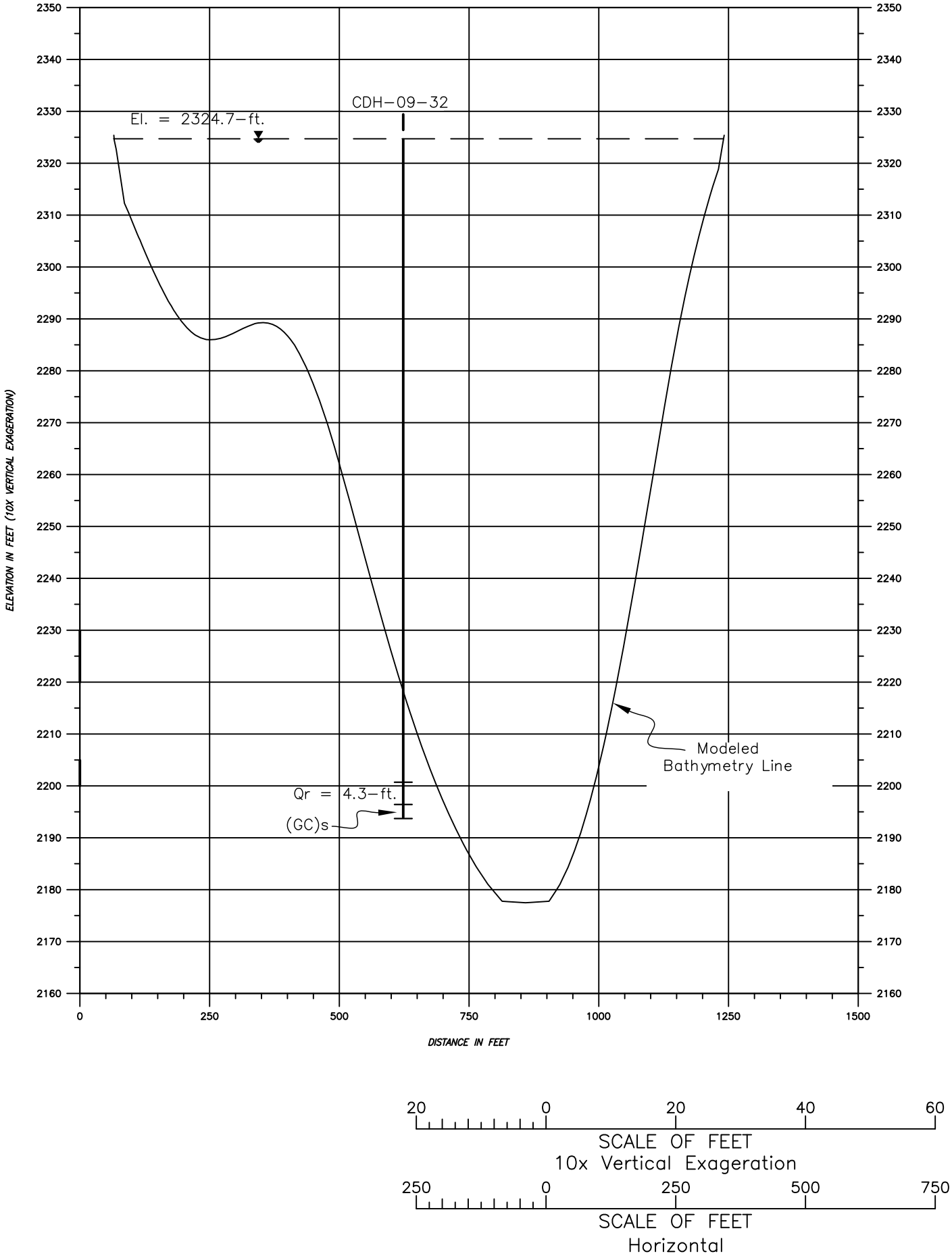
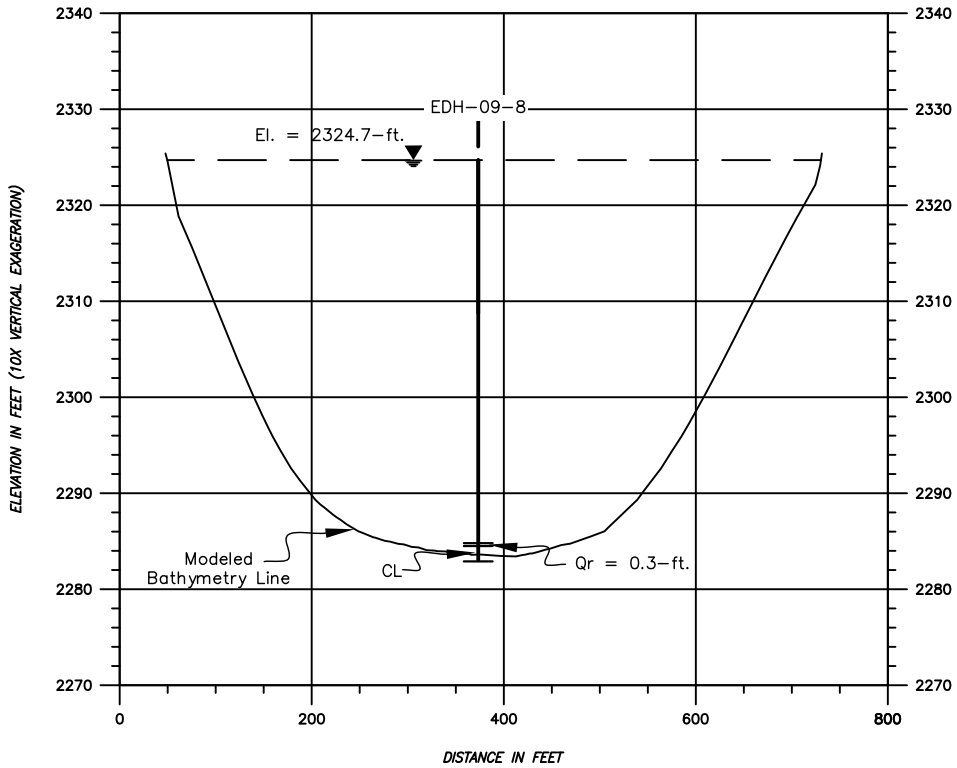
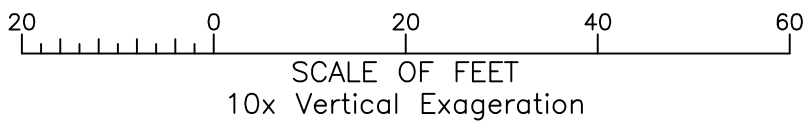
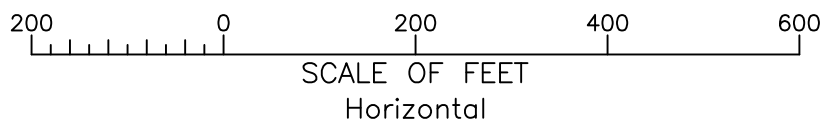


Iron Gate Section 13







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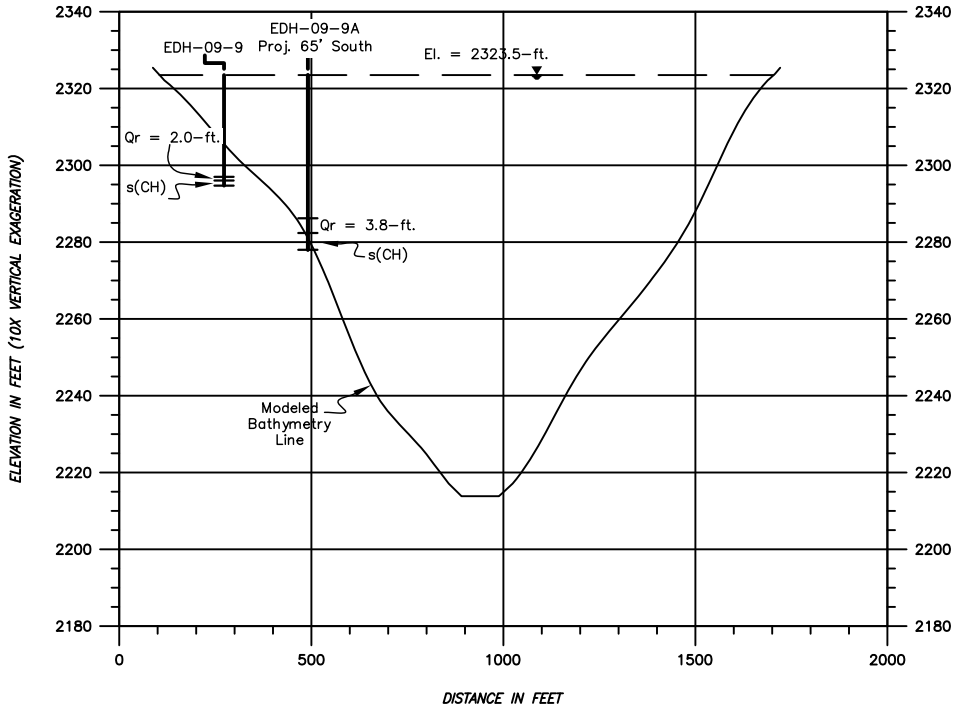
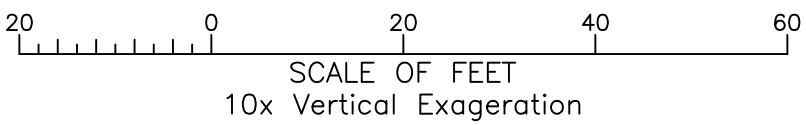
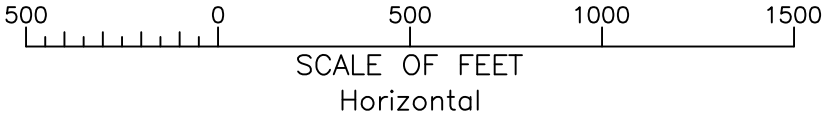
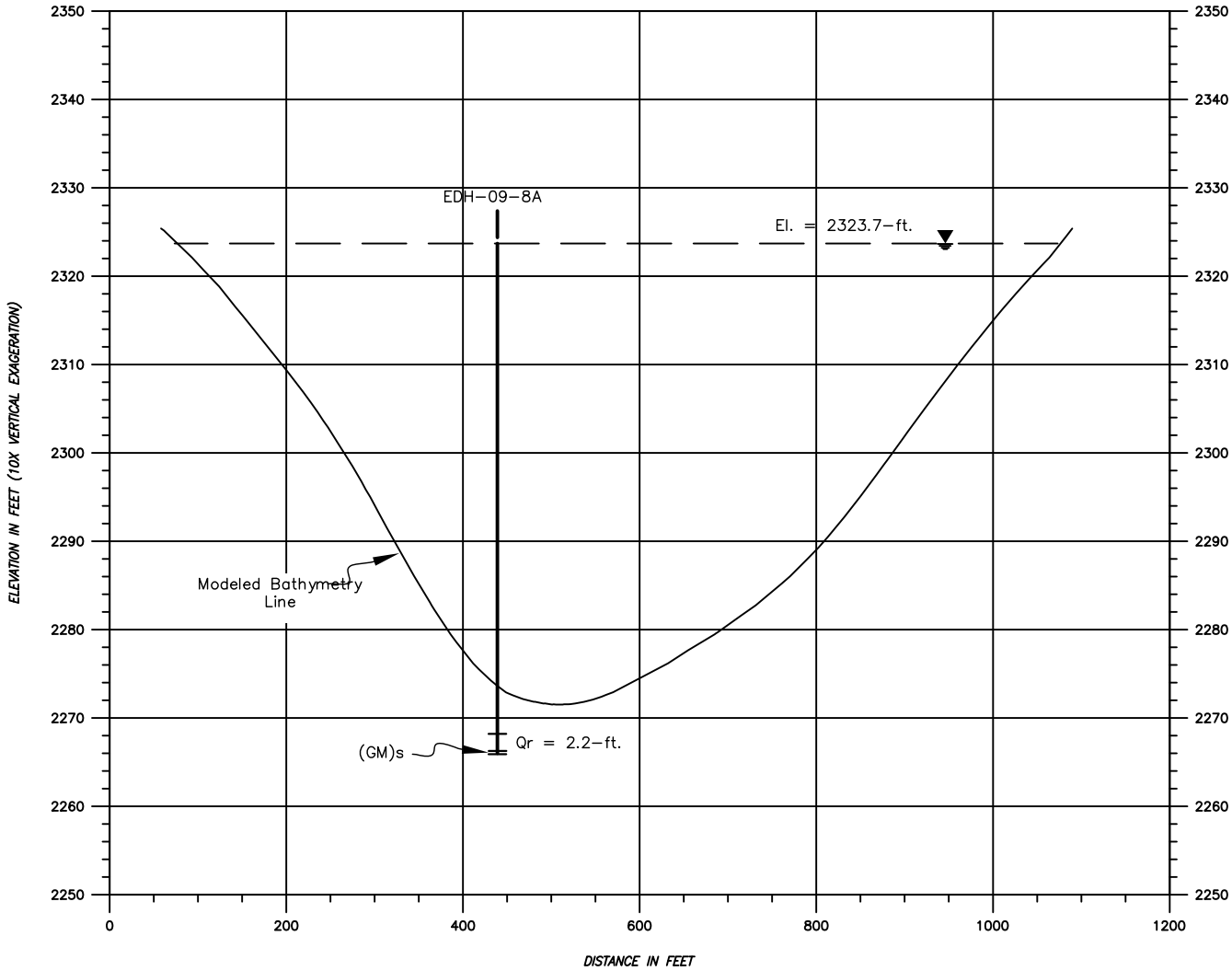
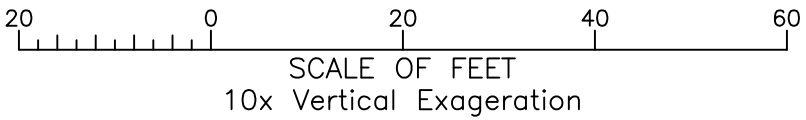


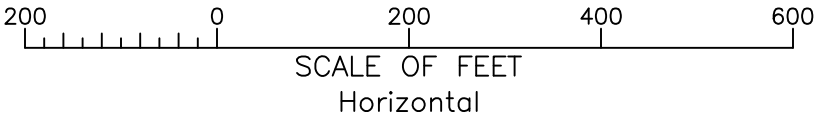




Iron Gate Section 15







Appendix C

Laboratory Data
(Gradations, Atterberg limits, and Moisture Content)

SUMMARY OF PHYSICAL PROPERTIES TEST RESULTS

Hole Number CDH-09-02 to CDH-09-8
EDH-09-01 to EDH-09-03

PROJECT Klamath

FEATURE Klamath River Sediment Study
J.C. Boyle Reservoir

DATE November 13, 2009
SHEET 1 OF 1

IDENTIFICATION			PARTICLE - SIZE FRACTION IN PERCENT							CONSISTANCY LIMITS			SPECIFIC GRAVITY				IN-PLACE UNIT WT.		COMPACTION TEST	
				FINES										PLUS NO. 4						
SAMPLE NUMBER	DEPTH (Feet) From	DEPTH (Feet) To	LAB CLASSIFI-CATION	< 0.005	Fines < .075	Sand #200 to #4	Gravel #4 to 3 inch	Cob-bles 3 inch to 5 inch	Over-size > 5 inch	Liquid Limit %	Plasti-city Index %	Field Mois-ture %	Minus No. 4	Bulk	Appar-ent	Absorp-tion %	Total Dry Unit Weight lbs/ft³	- #4 "D" Value	Max. Dry Unit Wt lbs/ft³	Opti-mum Moist-ure %
CDH-09-02	1.3	2.6	SM	5.4	9.3	85.3	0.0	0.0	0.0	NP	NP	46.2		NP = Non-Plastic						
CDH-09-02	4.4	5	SM	5.2	10.3	84.5	0.0	0.0	0.0	NP	NP	49.2		NP = Non-Plastic						
CDH-09-03	5.1	5.9	s(ML)	18.1	32.1	49.8	0.0	0.0	0.0	NP	NP	229.8		NP = Non-Plastic						
CDH-09-04A*	0	9.2	MH	41.5	54.8	3.7	0.0	0.0	0.0	169.7	77.1	373.7		**(*Strong Organic Ordor)**						
CDH-09-05	0	1.3	MH	55.6	44.4	0.0	0.0	0.0	0.0	123.5	49.7	244.2								
CDH-09-06	0	1.4	(GW-GM)s	1.6	6.6	26.2	65.6	0.0	0.0	24.2	0.4	13.9								
CDH-09-07*	0	5	MH	31.8	62.5	5.7	0.0	0.0	0.0	179.4	81.0	410.7		**(*Strong Organic Ordor)**						
CDH-09-07*	4.2	9.2	MH	35.2	57.3	7.5	0.0	0.0	0.0	165.6	53.2	412.7		**(*Strong Organic Ordor)**						
CDH-09-07*	9.2	12	MH	31.5	62.9	5.6	0.0	0.0	0.0	154.5	68.3	297.2		**(*Strong Organic Ordor)**						
CDH-09-07*	10.5	12	MH	35.4	58.4	6.2	0.0	0.0	0.0	178.2	81.9	367.6		**(*Strong Organic Ordor)**						
CDH-09-07	12	17	MH	31.6	60.1	8.3	0.0	0.0	0.0	173.2	61.3	334.8								
CDH-09-07	17	18.7	MH	46.3	48.1	5.6	0.0	0.0	0.0	192.9	68.2	270.8								
CDH-09-08*	0	0.5	MH	44.1	53.0	2.9	0.0	0.0	0.0	165.7	68.0	782.4		**(*Strong Organic Ordor)**						
CDH-09-08	0	1.7	MH	42.3	52.8	4.9	0.0	0.0	0.0	154.3	57.4	381.9								
EDH-09-01	1.3	3.2	SP-SM	3.5	7.2	89.3	0.0	0.0	0.0	NP	NP	45.5		NP = Non-Plastic						
EDH-09-01A	2.7	3.4	SM	5	9.8	85.2	0.0	0.0	0.0	NP	NP	59.8		NP = Non-Plastic						
EDH-09-02	5.8	6	s(ML)	19.3	34.7	46.0	0.0	0.0	0.0	NP	NP	212.4		NP = Non-Plastic						
EDH-09-02A	8.8	9	s(MH)	30.2	36.9	32.9	0.0	0.0	0.0	129.3	26.8	236.4								
EDH-09-03*	0	5	MH	54.7	43.6	1.7	0.0	0.0	0.0	195.4	82.8	506.5		**(*Strong Organic Ordor)**						
EDH-09-03*	7.3	7.5	MH	47.1	50.4	2.5	0.0	0.0	0.0	167.6	61.3	224.2		**(*Strong Organic Ordor)**						
EDH-09-03*	10	10.2	MH	32.5	58.3	9.2	0.0	0.0	0.0	162.2	68.8	293.1		**(*Strong Organic Ordor)**						
EDH-09-03* (Shoe)	13.9	14.1	MH	44.5	45.9	9.6	0.0	0.0	0.0	175.2	75.0	214.3		**(*Strong Organic Ordor)**						
EDH-09-03	13.5	14	MH	45.1	48.5	6.4	0.0	0.0	0.0	151.6	46.6	313.4								
EDH-09-03	14	15.5	(GM)s	5.7	12.4	30.6	51.3	0.0	0.0	65.6	25.0	32.9								

SUMMARY OF PHYSICAL PROPERTIES TEST RESULTS

Hole Number CDH-09-9A- to CDH -09-20 PROJECT Klamath FEATURE Klamath River Sediment Study DATE December 24, 2009 SHEET 2 OF 4

EDH-09-7 **Copco-1 Reservoir**

				PARTICLE - SIZE FRACTION IN PERCENT						CONSISTANCY LIMITS			SPECIFIC GRAVITY				IN-PLACE UNIT WT.		COMPACTION TEST	
	DEPTH (Feet)			FINES										PLUS NO. 4						
SAMPLE NUMBER	From	To	LAB CLASSIFI-CATION	< .005	< .075	Sand #200 to #4	Gravel #4 to 3 inch	Cob-bles 3 inch to 5 inch	Over-size > 5 inch	Liquid Limit %	Plasti-city Index %	Field Mois-ture %	Minus No. 4	Bulk	Appar-ent	Absorp-tion %	Dry Unit Weight lbs/ft³	Water Con-tent %	Max. Dry Unit Wt lbs/ft³	Opti-mum Moist-ure %
CDH-09-9A	0	4.6	MH	31.3	47.4	20.5	0.8	0.0	0.0	131.4	44.5	347.8								
CDH-09-10	0	5	(MH)s	27.8	53.4	18.8	0.0	0.0	0.0	131.1	65.8	190.5								
CDH-09-10*	5	8	MH	38.8	57.8	3.4	0.0	0.0	0.0	174.6	86.9	373.2		**(*Strong Organic Ordor)**						
CDH-09-12	0	5.4	MH	39.0	58.7	2.3	0.0	0.0	0.0	153.1	75.6	342.2								
CDH-09-12	5.4	6	MH	37.9	56.5	5.6	0.0	0.0	0.0	215.3	87.3	369.1								
CDH-09-13	0	5.7	MH	44.1	53.9	2.0	0.0	0.0	0.0	160.2	75.3	349.2								
CDH-09-13	5.7	6.5	MH	46.7	48.9	4.4	0.0	0.0	0.0	156.2	86.2	316.4								
CDH-09-14	0	1.8	MH	38.1	59.4	2.5	0.0	0.0	0.0	127.8	55.2	279.6								
CDH-09-15A	0	5	MH	75.1	24.9	0.0	0.0	0.0	0.0	148.3	74.0	304.8								
CDH-09-15A*	5	9.7	MH	60.8	33.3	5.9	0.0	0.0	0.0	165.3	77.9	287.3		**(*Strong Organic Ordor)**						
CDH-09-16*	0	7.5	MH	58.1	31.5	10.4	0.0	0.0	0.0	151.6	71.9	287.8		**(*Strong Organic Ordor)**						
CDH-09-17	0	1.2	MH	62.5	36.0	1.5	0.0	0.0	0.0	142.9	72.9	344.5								
CDH-09-18	0	8.9	MH	82.0	18.0	0.0	0.0	0.0	0.0	155.5	87.0	305.2								
CDH-09-18	8.9	10	MH	39.4	48.6	12.0	0.0	0.0	0.0	83.7	28.5	105.6								
CDH-09-19	0	4.8	MH	70.4	29.1	0.5	0.0	0.0	0.0	159.1	78.1	298.2								
CDH-09-20	0	5	MH	59.7	30.8	9.5	0.0	0.0	0.0	161.6	78.9	287.3								
CDH-09-20	5	7.4	MH	57.3	33.9	8.8	0.0	0.0	0.0	164.5	60.3	253.1								
EDH-09-07	2.8	2.9	(CL)s	37.5	34.5	28.0	0.0	0.0	0.0	44.7	21.2	40.2								

SUMMARY OF PHYSICAL PROPERTIES TEST RESULTS

Hole Number CDH-09-21- to CDH-09-32
EDH-09-08 to EDH-09-Add#1

PROJECT Klamath

FEATURE Klamath River Sediment Study
Iron Gate Reservoir

DATE December 24, 220
SHEET 3 OF 4

				PARTICLE - SIZE FRACTION IN PERCENT						CONSISTANCY LIMITS			SPECIFIC GRAVITY				IN-PLACE UNIT WT.		COMPACTION TEST	
	DEPTH (Feet)			FINES										PLUS NO. 4						
SAMPLE NUMBER	From	To	LAB CLASSIFI-CATION	< .005	< .075	Sand #200 to #4	Gravel #4 to 3 inch	Cob-bles 3 inch to 5 inch	Over-size > 5 inch	Liquid Limit %	Plasti-city Index %	Field Mois-ture %	Minus No. 4	Bulk	Appar-ent	Absorp-tion %	Dry Unit Weight lbs/ft³	Water Con-tent %	Max. Dry Unit Wt lbs/ft³	Opti-mum Moist-ure %
CDH-09-21	1.1	1.3	s(ML)	29.9	39.2	30.9	0.0	0.0	0.0	NP	NP	157.9		NP = Non-Plastic						
CDH-09-22	0	1.4	MH	42.2	48.9	8.9	0.0	0.0	0.0	97.8	46.2	276.0								
CDH-09-23	0	7.1	(MH)s	26.4	45.4	28.2	0.0	0.0	0.0	60.9	20.4	138.4								
CDH-09-23*	7.1	8.8	s(ML)	24.0	31.2	44.8	0.0	0.0	0.0	44.3	13.7	76.7		**(*Strong Organic Ordor)**						
CDH-09-23*	0	5.4	(MH)s	31.9	39.0	29.1	0.0	0.0	0.0	51.8	19.1	84.9		**(*Strong Organic Ordor)**						
CDH-09-23	5.4	7.7	(MH)s	27.5	45.7	26.8	0.0	0.0	0.0	58.5	27.8	80.7								
CDH-09-24	0	4.1	MH	39.5	46.4	14.1	0.0	0.0	0.0	68.8	33.6	97.3								
CDH-09-25	0	5	MH	64.1	26.8	9.1	0.0	0.0	0.0	126.8	54.4	321.9								
CDH-09-26	0	2	MH	71.0	26.7	2.3	0.0	0.0	0.0	128.4	75.0	332.6								
CDH-09-27	3.1	4.2	MH	67.5	30.9	1.6	0.0	0.0	0.0	130.8	71.3	308.7								
CDH-09-27	4.2	4.8	CH	64.0	21.9	14.1	0.0	0.0	0.0	79.4	54.8	47.1								
CDH-09-28*	0	1	MH	66.8	30.3	2.9	0.0	0.0	0.0	113.0	58.6	281.2		**(*Strong Organic Ordor)**						
CDH-09-29*	0	2.7	MH	75.3	17.9	6.8	0.0	0.0	0.0	141.8	61.9	355.0		**(*Strong Organic Ordor)**						
CDH-09-30	0	2.5	MH	65.8	25.6	8.6	0.0	0.0	0.0	137.1	60.6	334.2								
CDH-09-31	0	4.8	(MH)s	55.7	27.4	12.9	4.0	0.0	0.0	113.4	61.1	198.4								
CDH-09-32	0	4.3	MH	74.7	22.4	2.9	0.0	0.0	0.0	136.6	59.9	342.9								
CDH-09-32	4.3	5.1	(GC)s	9.4	10.1	23.8	56.7	0.0	0.0	46.8	21.6	21.5								
EDH-09-08	0	0.3	(MH)s	32.0	48.5	19.5	0.0	0.0	0.0	80.5	33.6	163.0								
EDH-09-08	0	0.3	(MH)s	30.0	41.4	28.6	0.0	0.0	0.0	59.2	27.2	190.9								
EDH-09-08	0.3	1.9	(GC)s	9.7	12.9	11.7	65.7	0.0	0.0	36.9	14.4	15.8								
EDH-09-08A	0	1.2	MH	47.0	50.7	2.3	0.0	0.0	0.0	92.9	49.9	210.6								
EDH-09-09	3	3.3	s(CH)	42.2	24.4	29.3	4.1	0.0	0.0	65.0	35.4	30.1								
EDH-09-09A	4.1	4.4	s(CH)	42.8	25.3	26.8	5.1	0.0	0.0	57.5	29.9	31.2								
EDH-09-10	2.8	4.5	MH	64.0	28.6	7.4	0.0	0.0	0.0	114.0	65.7	288.9								
EDH-09-10	4.5	5.2	(GC)s	20.3	9.1	15.6	55.0	0.0	0.0	74.8	45.4	25.3								
EDH-09-11*	0	3.1	MH	39.0	46.9	14.1	0.0	0.0	0.0	78.8	35.1	154.2		**(*Strong Organic Ordor)**						
EDH-09-Add#1	0	3	MH	62.8	32.5	4.7	0.0	0.0	0.0	120.7	63.3	271.8								
EDH-09-Add#1	3	3.2	(CH)s	56.2	18.5	20.7	4.6	0.0	0.0	66.4	40.4	86.7								

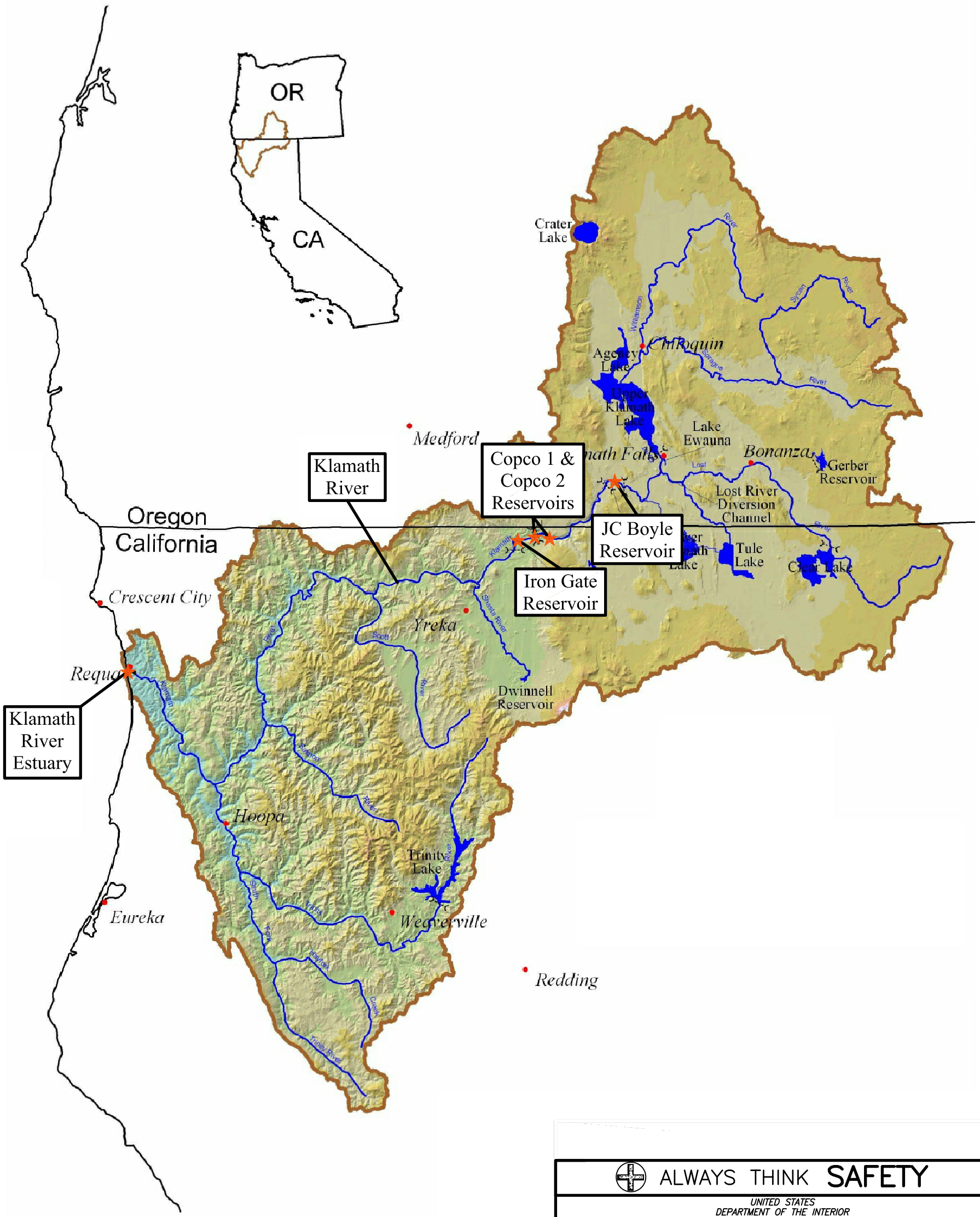
SUMMARY OF PHYSICAL PROPERTIES TEST RESULTS

Hole Number 1 & 2 PROJECT Klamath FEATURE Klamath River Sediment Study DATE January 21, 2010 SHEET 1 OF 1

				PARTICLE - SIZE FRACTION IN PERCENT						CONSISTANCY LIMITS			SPECIFIC GRAVITY				IN-PLACE UNIT WT.		COMPACTION TEST	
				FINES										PLUS NO. 4						
SAMPLE NUMBER	DEPTH (Feet) From	DEPTH (Feet) To	LAB CLASSIFI-CATION	< .005	< .075	Sand #200 to #4	Gravel #4 to 3 inch	Cob-bles 3 inch to 5 inch	Over-size > 5 inch	Liquid Limit %	Plasti-city Index %	Field Mois-ture %	Minus No. 4	Bulk	Appar-ent	Absorp-tion %	Dry Unit Weight lbs/ft³	Water Con-tent %	Max. Dry Unit Wt lbs/ft³	Opti-mum Moist-ure %
1 (Salt Water composit)			SM	8.7	34.0	55.1	2.2	0.0	0.0	33.7	9.2	54.0								
2 (Fresh Water composit)			SP-SM	1.4	6.4	91.5	0.7	0.0	0.0	NP	NP	30.5								
NP = Non-Plastic																				

Figures 1 to 5

RECLAMATION
Managing Water in the West



ALWAYS THINK **SAFETY**

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
KLAMATH PROJECT
KLAMATH RIVER – CALIFORNIA/OREGON

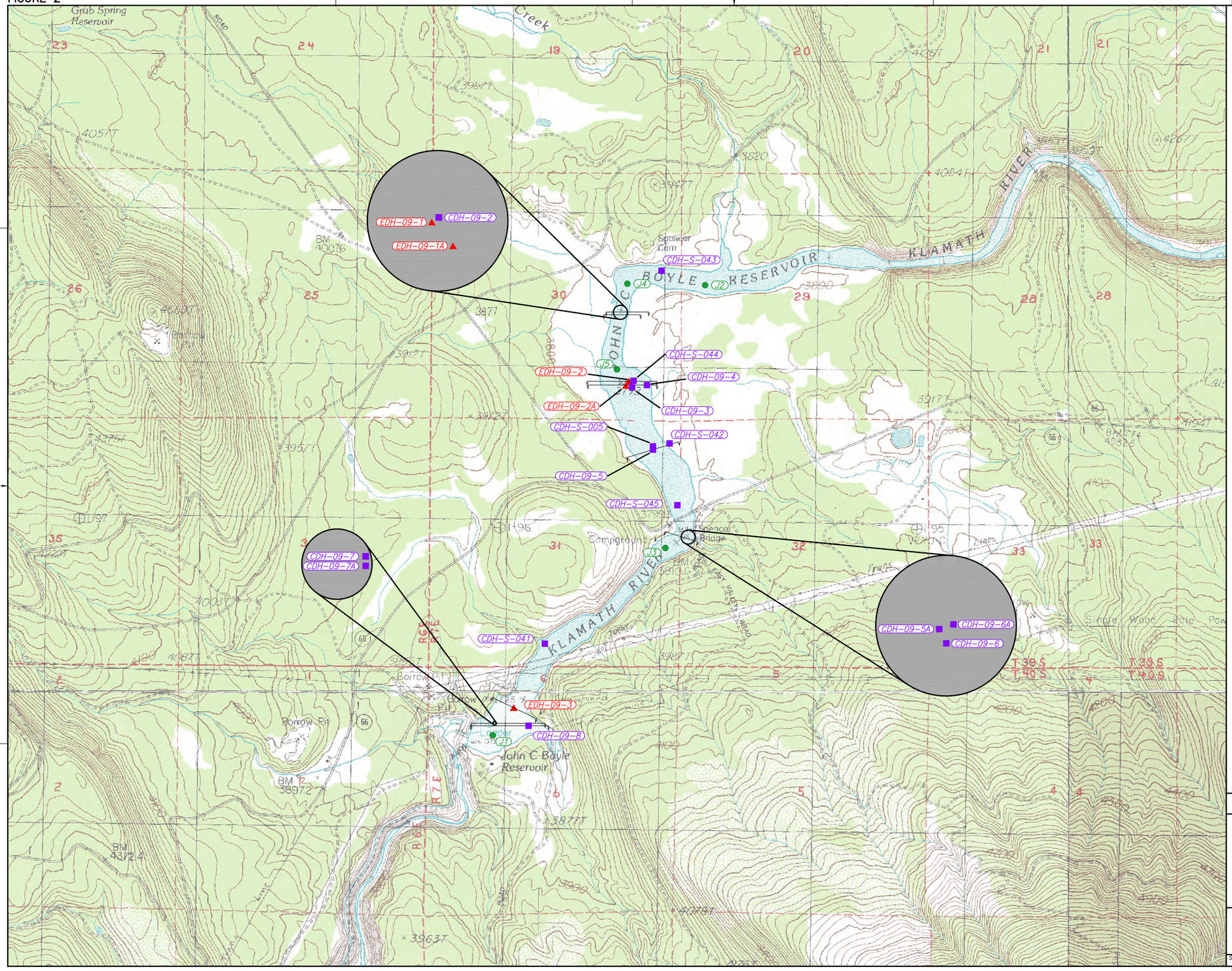
KLAMATH RIVER
SEDIMENT SAMPLING PROGRAM

LOCATION MAP
GEOLOGIC INVESTIGATIONS

SACRAMENTO, CA

FIGURE 1

FIGURE 2



RECLAMATION
Managing Water in the West

RECLAMATION
- CONTAMINANT SAMPLE LOCATION (CDH)
- ENGINEERING PROPERTIES SAMPLE LOCATION (EDH)

SHANNON AND WILSON INC.
- DRILL HOLE (J)

CROSS SECTION

N

USGS 7.5' QUADRANGLE MAP
CONTOUR INTERVAL 20 FEET

ALWAYS THINK SAFETY

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KLAMATH PROJECT
KLAMATH RIVER – CALIFORNIA/OREGON

KLAMATH RIVER SEDIMENT SAMPLING PROGRAM

JC BOYLE RESERVOIR
GEOLOGIC INVESTIGATIONS
DRILLING AND SAMPLING LOCATIONS

1000 0 1000 2000 3000
SCALE OF FEET

SACRAMENTO, CA | 2008-MM-DD | FIGURE 2

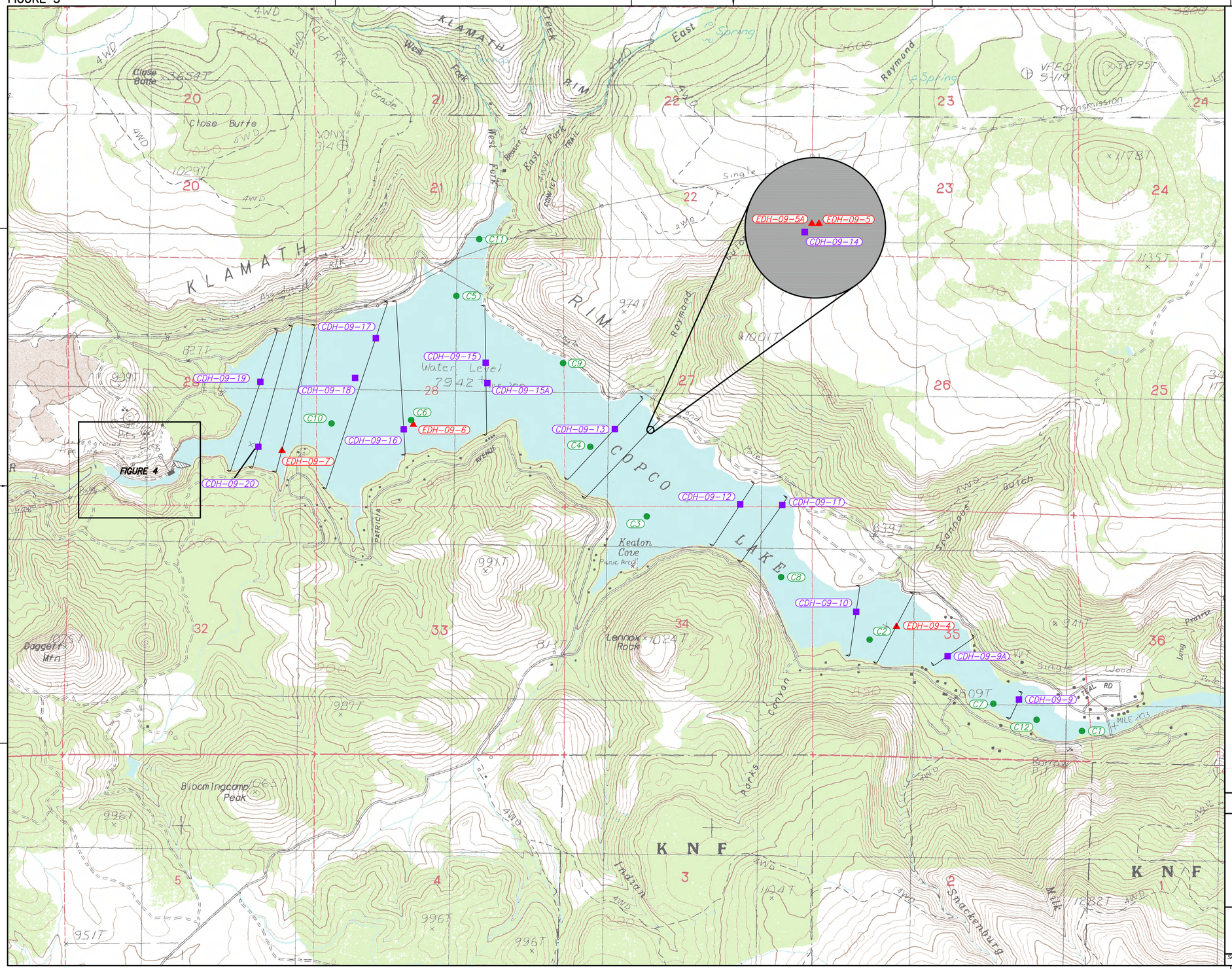
PLOTTED BY JHARRISON

DATE AND TIME PLOTTED SEPTEMBER 7, 2010 14:14

CAD SYSTEM AutoCAD Rel. 18.0s

CAD FILENAME PROJECT SETUP R1.DWG

FIGURE 3



RECLAMATION
Managing Water in the West

RECLAMATION
- CONTAMINANT SAMPLE LOCATION (CDH)
- ENGINEERING PROPERTIES SAMPLE LOCATION (EDH)

SHANNON AND WILSON INC.
- DRILL HOLE (C)

CROSS SECTION

N

USGS 7.5' QUADRANGLE MAP
CONTOUR INTERVAL 10 METERS

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
KLAMATH PROJECT
KLAMATH RIVER – CALIFORNIA/OREGON

KLAMATH RIVER SEDIMENT SAMPLING PROGRAM

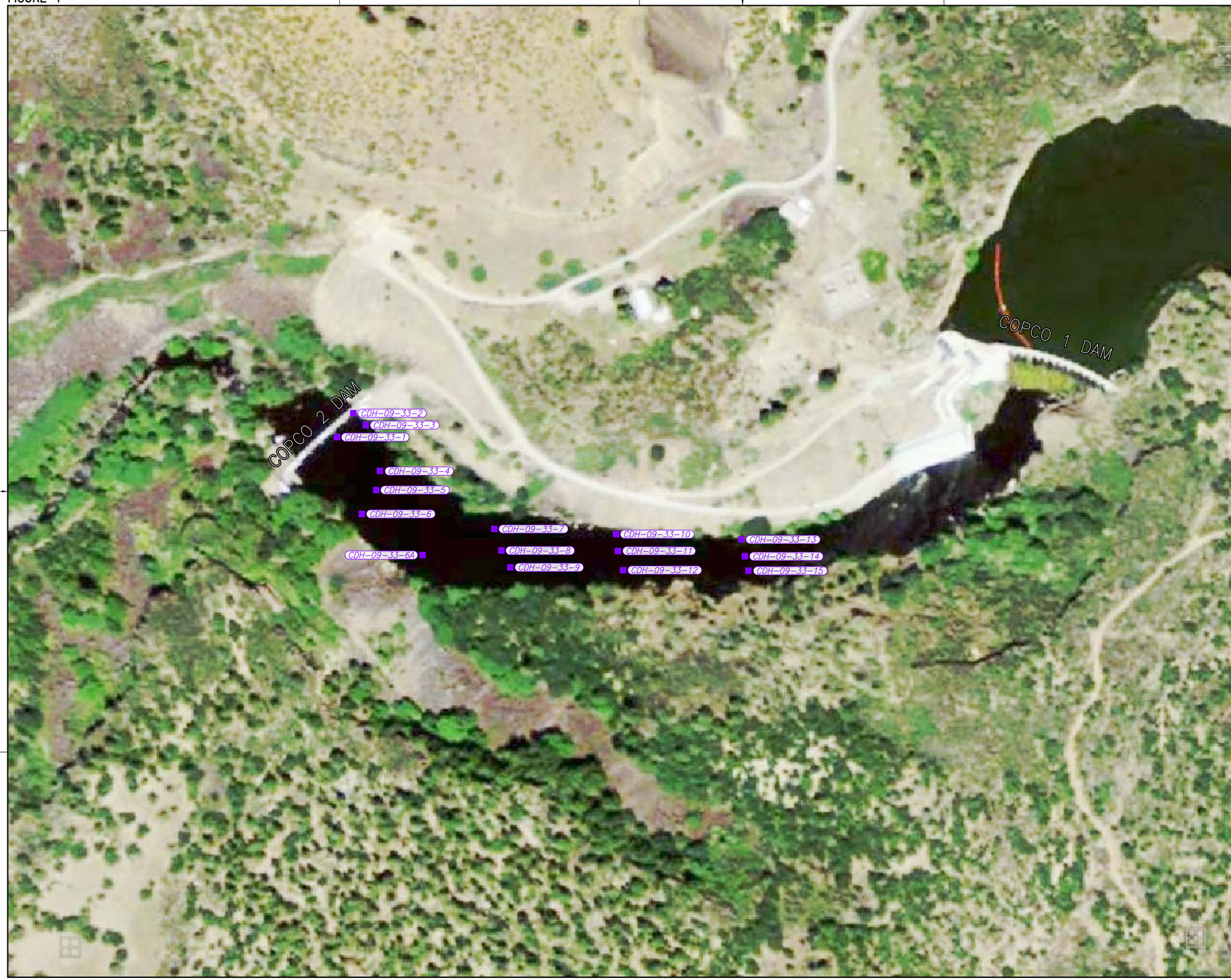
COPCO RESERVOIR
GEOLOGIC INVESTIGATIONS
DRILLING AND SAMPLING LOCATIONS

1000 0 1000 2000 3000
SCALE OF FEET

SACRAMENTO, CA | 2008-MM-DD | FIGURE 3

PLOTTED BY JHARRISON
DATE AND TIME PLOTTED SEPTEMBER 3, 2010 09:31
CAD SYSTEM AutoCAD Rel. 18.0s
CAD FILENAME PROJECT SETUP R1.DWG

FIGURE 4



RECLAMATION
Managing Water in the West

RECLAMATION
- *CONTAMINANT SAMPLE LOCATION (CDH)*

N

GOOGLE EARTH IMAGERY

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KLAMATH PROJECT
KLAMATH RIVER – CALIFORNIA/OREGON

KLAMATH RIVER
SEDIMENT SAMPLING PROGRAM

COPCO 2 RESERVOIR
GEOLOGIC INVESTIGATIONS
DRILLING AND SAMPLING LOCATIONS

100 0 100 200 300
SCALE OF FEET

SACRAMENTO, CA | 2008-MM-DD | FIGURE 4

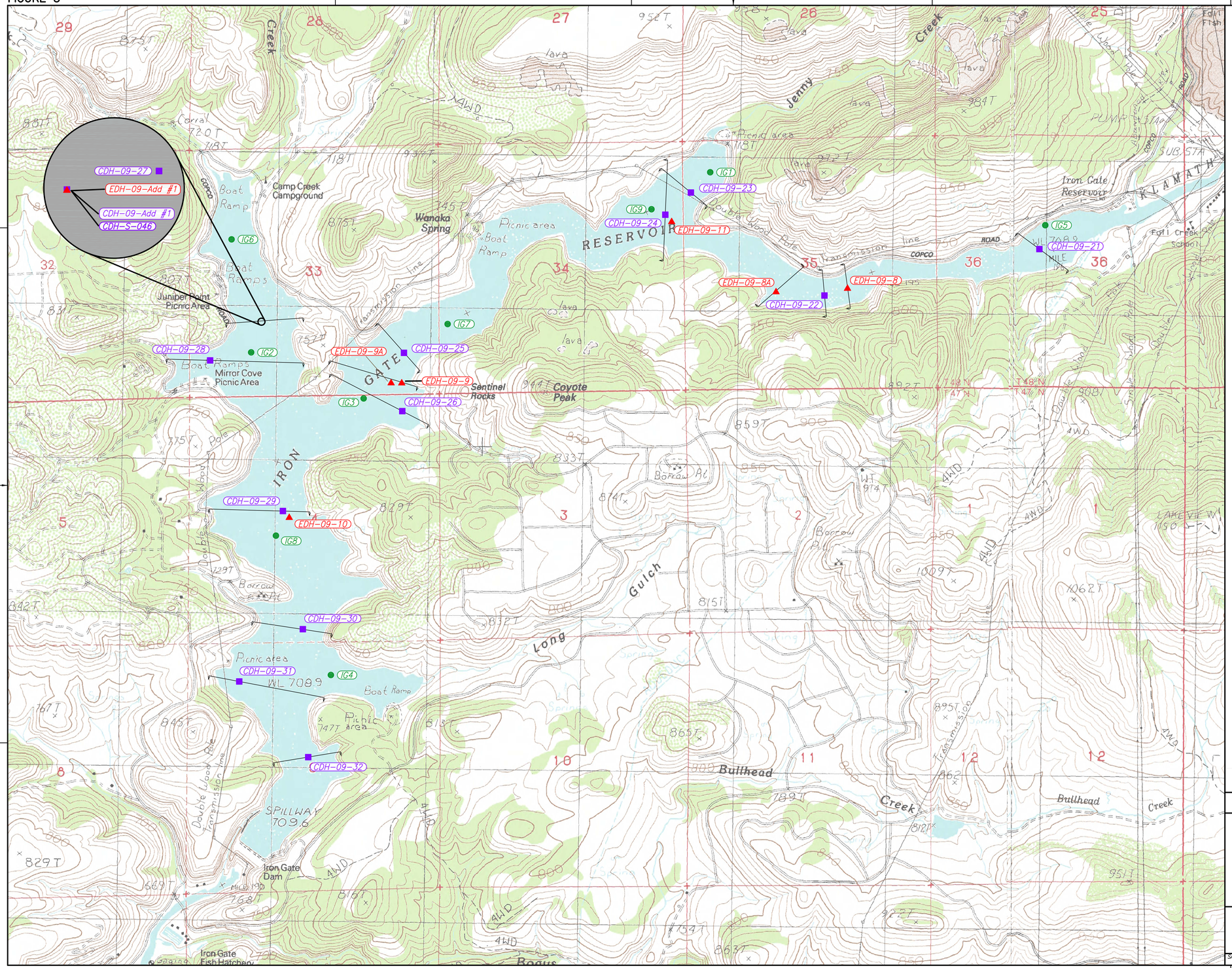
PLOTTED BY JHARRISON

DATE AND TIME PLOTTED SEPTEMBER 7, 2010 08:35

CAD SYSTEM AutoCAD Rel. 18.0s

CAD FILENAME PROJECT SETUP R1.DWG

FIGURE 5



RECLAMATION
Managing Water in the West

RECLAMATION
- CONTAMINANT SAMPLE LOCATION (CDH)
- ENGINEERING PROPERTIES SAMPLE LOCATION (EDH)

SHANNON AND WILSON INC.
- DRILL HOLE (IG)

CROSS SECTION

N

USGS 7.5' QUADRANGLE MAP
CONTOUR INTERVAL 10 METERS

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
KLAMATH PROJECT
KLAMATH RIVER – CALIFORNIA/OREGON

KLAMATH RIVER SEDIMENT SAMPLING PROGRAM

IRON GATE RESERVOIR
GEOLOGIC INVESTIGATIONS
DRILLING AND SAMPLING LOCATIONS

1000 0 1000 2000 3000
SCALE OF FEET

SACRAMENTO, CA | 2008-MM-DD | FIGURE 5

PLOTTED BY JHARRISON

DATE AND TIME PLOTTED SEPTEMBER 7, 2010 08:38

CAD SYSTEM AutoCAD Rel. 18.0s

CAD FILENAME PROJECT SETUP R1.DWG

VOLUME 2 OF 2

PHOTOGRAHS

RECLAMATION

Managing Water in the West

Reclamation (2011)
Klamath River Sediment Sampling Program
Phase 1 – Geologic Investigations

Contaminant and Geotechnical Properties Sampling
J.C. Boyle, Copco-1, Copco-2, and Iron Gate Reservoirs
and the Klamath River Estuary, Volume 2 of 2

Klamath Project, Oregon and California
Mid-Pacific Region, MP-230
Revision Two, September 2011

Reclamation (2011)
Klamath River Sediment Sampling Program
Phase 1 – Geologic Investigations

Contaminant and Geotechnical Properties Sampling
J.C. Boyle, Copco-1, Copco-2, and Iron Gate Reservoirs and the Klamath River Estuary, Volume 2 of 2

September 2011

Prepared by M. McCulla, Ph.D.
Reclamation Project Geologist (MP-230)

PHOTOGRAPHS

Following are photographs taken in support of barge and boat reservoir sediment drilling and sampling programs. The photos are organized into the following sections:

- Barge and boat launching sites at each reservoir;
- Drilling and sampling equipment and other general photographs;
- J.C. Boyle Reservoir and Dam – Local Geology;
- J.C. Boyle Reservoir and Dam – Sediment sampling;
- Copco-1 Reservoir and Dam – Local Geology;
- Copco-1 Reservoir and Dam – Sediment sampling;
- Copco-2 Reservoir and Dam – Local Geology;
- Copco-2 Reservoir and Dam – Sediment sampling;
- Iron Gate Reservoir and Dam – Local Geology; and,
- Iron Gate Reservoir and Dam – Sediment sampling.

Barge and Boat Launching Photographs

J.C. Boyle Reservoir

Photo 1. View of Reclamation's barge sections on trailers at the barge launch site, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Photo by M. McCulla, 9/30/09.

Photo 2. View of Reclamation's barge sections on trailers at the barge launch site, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Photo by M. McCulla, 9/30/09.

Photo 3. View of Reclamation's barge lift, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Photo by M. McCulla, 9/30/09.

Photo 4. View of the crane used for Reclamation's barge lift, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Photo by M. McCulla, 9/30/09.

Photo 5. View of the crane used for Reclamation's barge lift, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Photo by M. McCulla, 9/30/09.

Photo 6. View of Reclamation's barge lift, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. The crane is a GROVE TMS 500E, used by KEECO Crane and Rigging Service. Photo by M. McCulla, 9/30/09.

Photo 7. View of Reclamation's barge lift, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Photo by M. McCulla, 9/30/09.

Photo 8. View of Reclamation's barge lift, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Photo by M. McCulla, 9/30/09.

Photo 9. View of Reclamation's barge lift, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Photo by M. McCulla, 9/30/09.

Photo 10. View of Reclamation's barge lift, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Photo by M. McCulla, 9/30/09.

Photo 11. View of Reclamation's barge lift, adjacent to where Oregon State Highway 66 Bridge crosses J.C. Boyle Reservoir. Note the fresh snow on the hills in the background. Photo by M. McCulla, 9/30/09.

Photo 12. View of Reclamation's drilling barge assembly for work in J.C. Boyle Reservoir. Support barges and boats are yet to be floated. Photo by M. McCulla, 9/30/09.

Photo 13. View of Reclamation's drilling and support barge assembly moving between drilling sites in J.C. Boyle Reservoir. Photo by M. McCulla, 10/3/09.

Photo 14. View of Reclamation's drilling support barge in J.C. Boyle Reservoir. Photo by M. McCulla, 10/3/09.

Photo 15. View of the sample processing boat tied up at Topsy Campground dock, on the southwestern side of J.C. Boyle reservoir. This dock was used on a daily basis to on and off-load samples and equipment. Photo by G. Mongano, 10/14/09.

Photo 16. View of support boat docking at Topsy Campground, on the southwestern side of J. C. Boyle reservoir. Sediment in the foreground (bottom of the photo) is exposed because the reservoir water surface normally fluctuates 1 to 3 feet per day. Photo by G. Mongano, October 2009.

Copco-1 Reservoir

Photo 17. View of Gravity Consultants boat-supported drilling platforms used for sampling in Copco-1 reservoir arriving at the Keaton Cove public boat launching site on the southern side of the reservoir. Photo by M. McCulla, 11/9/09.

Photo 18. View of Gravity Consultants drilling platform with a SIMCO Earthprobe 200 drill, drill rods, and hollow-stem flight augers. Photo by M. McCulla, 11/9/09.

Photo 19. View of Gravity Consultants boat-supported drilling platforms launching into Copco-1 reservoir from the Keaton Cove public boat launching site on the southern side of the reservoir. Photo by M. McCulla, 11/9/09.

Photo 20. View of Gravity Consultants drilling platform with a SIMCO Earthprobe 200 drill and support boat setting up on EDH-09-7 sample site in Copco-1 reservoir. Photo by M. McCulla, 11/16/09.

Photo 21. View of drill rods used with the SIMCO Earthprobe 200 drill on Gravity Consultant's drilling boat in Copco-1 reservoir. Photo by G. Mongano, November 2009.

Photo 22. View of Gravity Consultants sample processing station on the drilling support boat set up on EDH-09-7 sample site in Copco-1 reservoir. Photo by M. McCulla, 11/16/09.

Photo 23. View of Gravity Consultants drilling platform with a SIMCO Earthprobe 200 drill collecting an engineering properties sample (EDH-09-7) from Copco-1 reservoir. Photo by M. McCulla, 11/16/09.

Copco-2 Reservoir

Photo 24. View of Copco-2 dam and reservoir, with the boat launching site (red circle) on the northern side of the dam. The white material floating on the water is a mix of foam and ice. Photo by M. McCulla, 12/10/09.

Photo 25. Boat launching site on the northern side of Copco-2 reservoir. Photo by M. McCulla, 12/10/09.

Photo 26. View of Reclamation's small boat used for stab and gravity sampling attempts in Copco-2 reservoir. Photo by J. Sturm, 12/10/09.

Iron Gate Reservoir

Photo 27. View of Reclamation's drilling and support barges and boats at a staging area just downstream from Iron Gate Dam. Photo by M. McCulla, 10/28/09.

Photo 28. View of the barge launching site in Long Gulch, on the southern side of Iron Gate reservoir. Photo by M. McCulla, 10/30/09.

Photo 29. View of information shown on the crane hired by Reclamation for lifting the drilling barge and support equipment into Iron Gate reservoir. Photo by M. McCulla, 10/30/09.

Photo 30. View of information shown on the crane hired by Reclamation for lifting the drilling barge and support equipment into Iron Gate reservoir. Photo by M. McCulla, 10/30/09.

Photo 31. View of the drilling barge support boats launched from the Long Gulch boat ramp on the southern side of Iron Gate reservoir. Photo by M. McCulla, 10/30/09.

Photo 32. View of the barge launching site in Long Gulch, on the southern side of Iron Gate reservoir. Photo by M. McCulla, 10/30/09.

Photo 33. View of barge launching into Iron Gate reservoir from the Long Gulch boat ramp on the southern side of the reservoir. Photo by M. McCulla, 10/30/09.

Photo 34. View of barge launching into Iron Gate reservoir from the Long Gulch boar ramp on the southern side of the reservoir. Photo by M. McCulla, 10/30/09.

Photo 35. View of Reclamation's Ingersoll-Rand A200 drill being lifted onto the barge for drilling/sampling in Iron Gate reservoir. Photo by M. McCulla, 10/30/09.

Photo 36. View of hollow-stem flight augers being lifted onto Reclamation's barge for drilling/sampling in Iron Gate reservoir. Photo by M. McCulla, 10/30/09.

Photo 37. View of Reclamation's drilling and support barge moving between sample sites in Iron Gate reservoir. Photo by M. McCulla, 10/30/09.

Photo 38. View of Reclamation's drilling and support boats loading supplies from the Mirror Cove boat launch and dock site on the northern side of Iron Gate Reservoir. Photo by M. McCulla, 11/13/09.

Drilling and Sampling Equipment and Procedures

General Photographs

Photo 39. View of Reclamation's drill crew members setting one of the four anchors used to stabilize the barge before drilling can take place. Photo by M. McCulla, 11/15/09.

Photo 40. View of Reclamation's drill crew preparing to start a flight auger dry core (FADC) sample hole. Photo by A. Warren, 10/8/09.

Photo 41. View of the drilling and support barge setup for FADC contaminant sediment sampling in front of J.C. Boyle Dam. Photo by A. Warren, 10/2/09.

Photo 42. View of Reclamation's hollow-stem FADC system drilling at EDH-09-3 in J.C. Boyle Reservoir. Photo by M. McCulla, 10/4/09.

Photo 43. View of the FADC split-tube sampler on Reclamation's drilling support barge. Photo by M. McCulla, 10/4/09.

Photo 44. View of drill crew preparing to open the FADC split-tube sampler on Reclamation's drilling support barge. Photo by M. McCulla, 10/4/09.

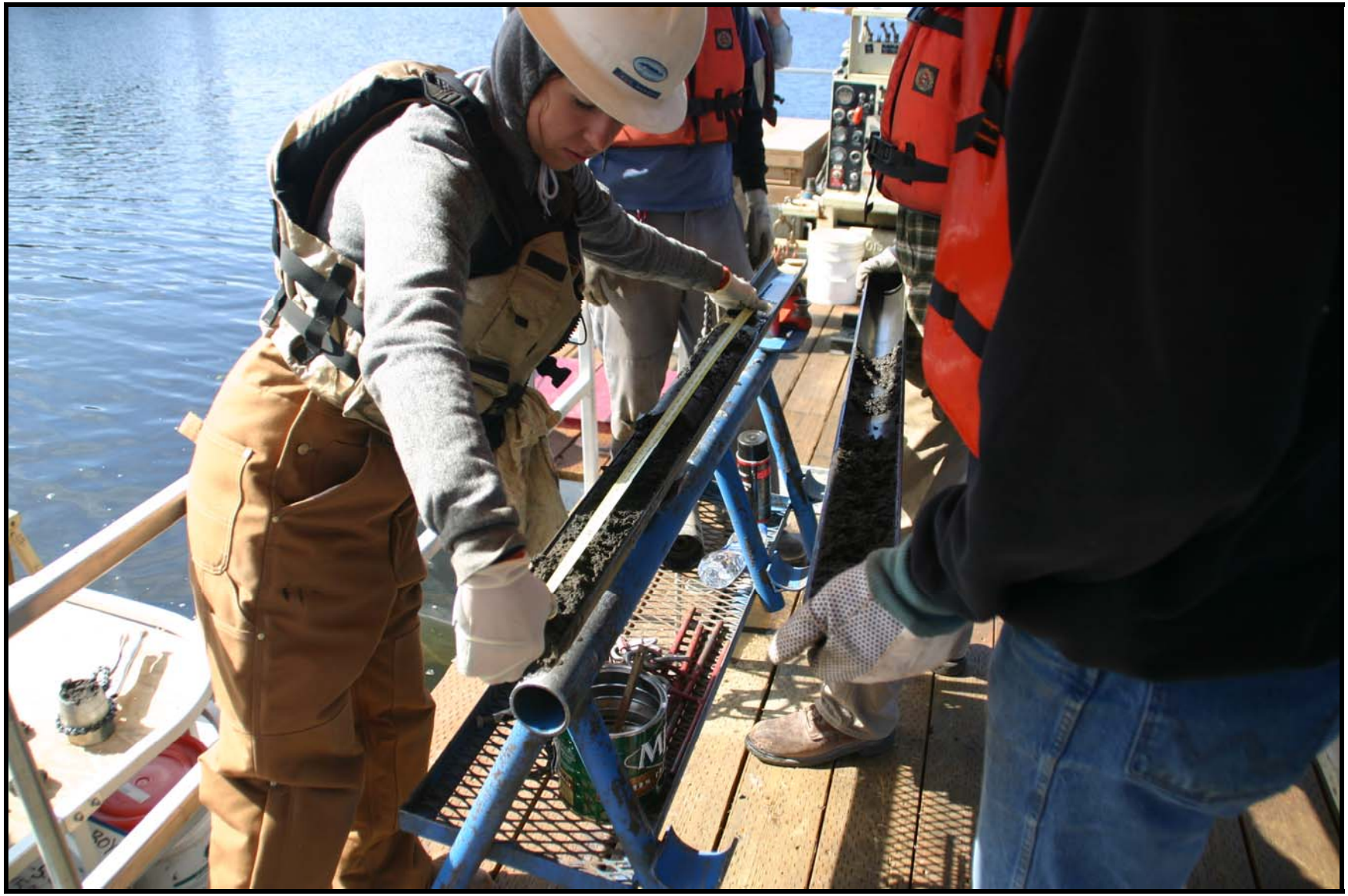
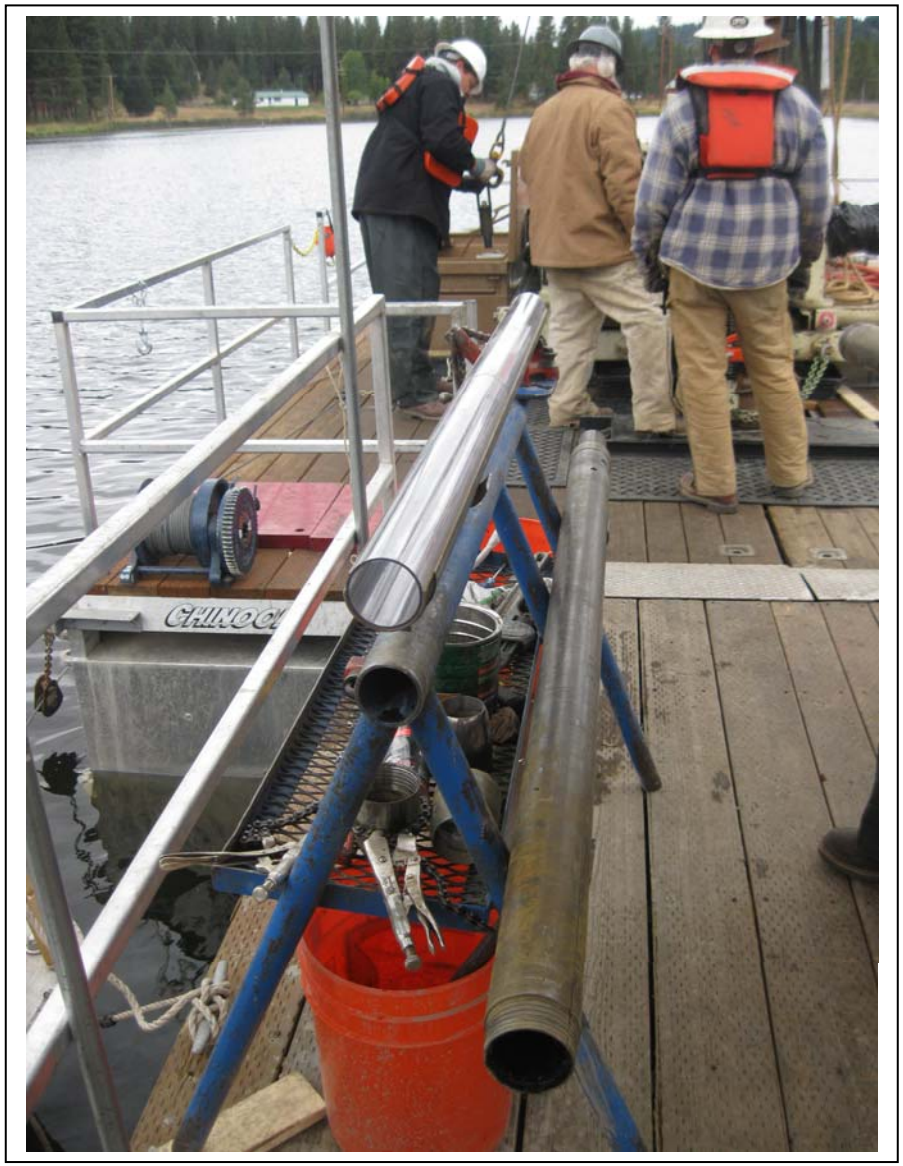


Photo 45. View of geologist measuring recovery for a contaminant sample collected using the FADC drilling system. Photo by G. Mongano, 10/1/09.

Photo 46. View of a sample of reservoir sediment collected from drill hole CDH-09-7 using the FADC split-tube system. Photo by A. Warren, 10/2/09.

Photo 47. View of the split-tube sampler for the FADC system being cleaned and decontaminated between sample runs. Photo by M. McCulla, 10/2/09.



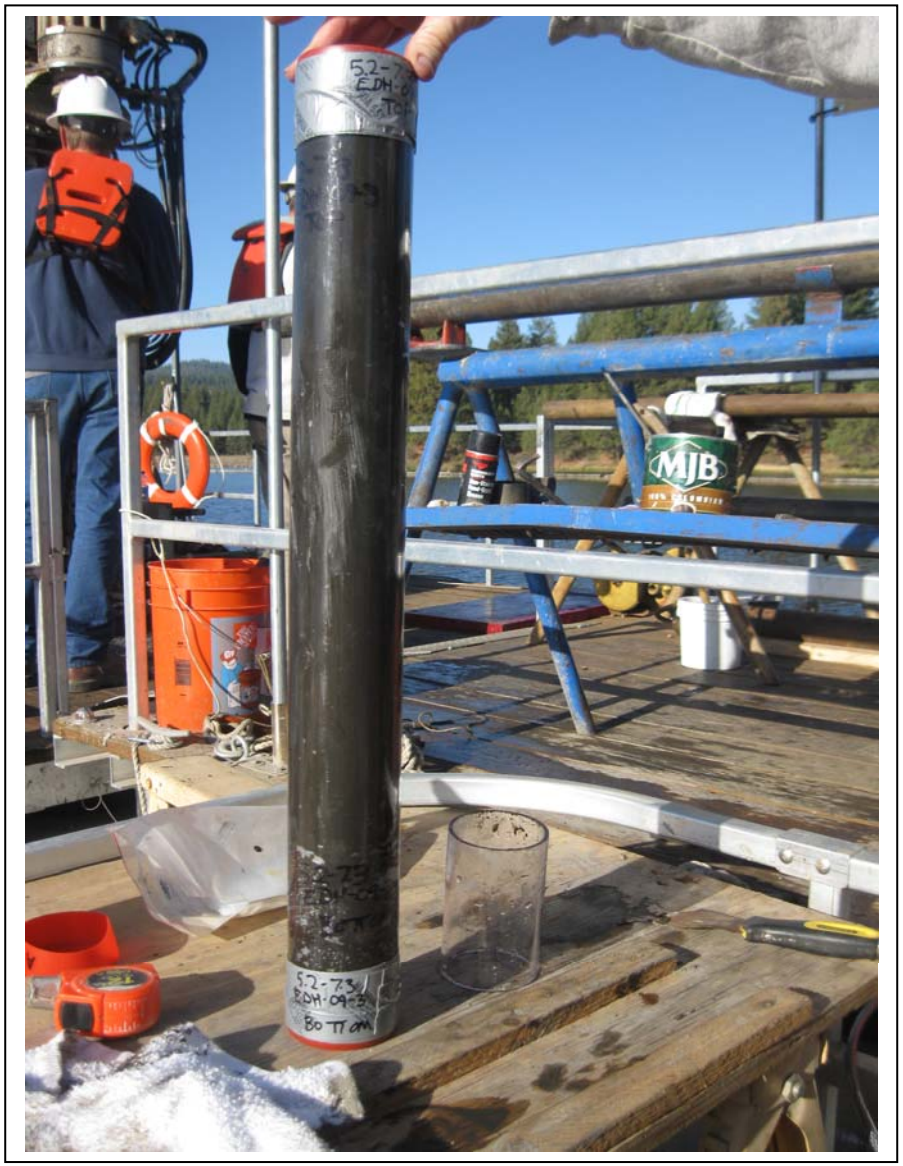
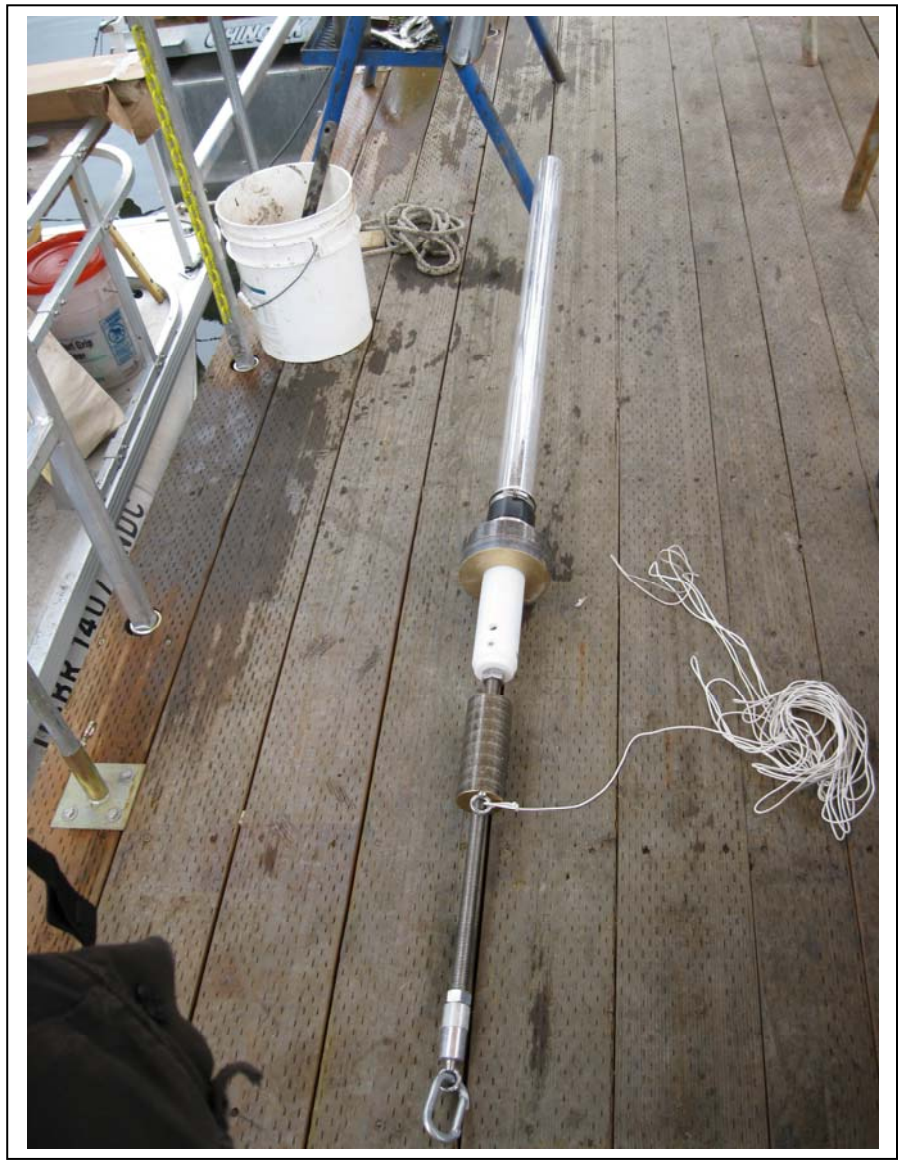


Photo 48. View of Reclamation's hollow-stem FADC system fitted with 3-inch o.d. lexan liners and collection of an undisturbed sample at EDH-09-3 in J.C. Boyle Reservoir. Photos by A. Warren, 10/4/09.



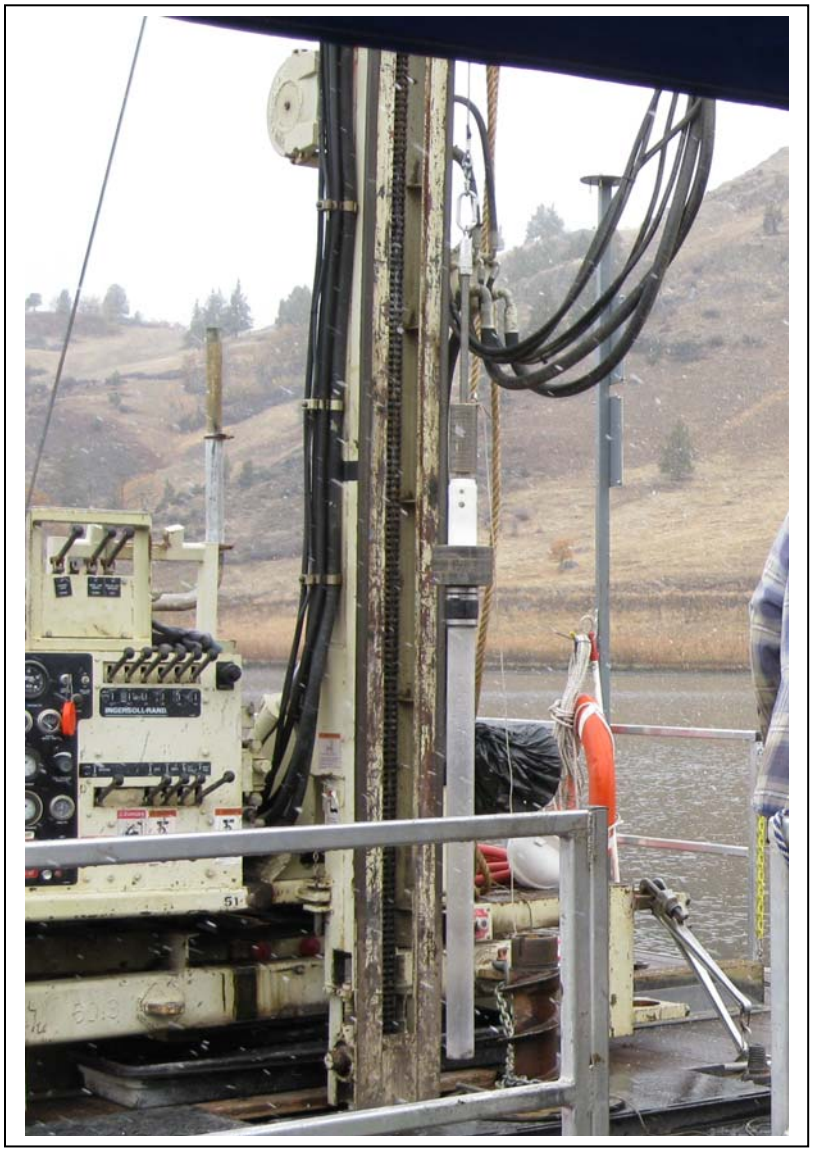


Photo 49. View of Reclamation's gravity sampler fitted with a 2 3/4-inch o.d. by 2 5/8-inch i.d. lexan tube. In the left photo the sampler is being prepared to collect contaminant samples in drill hole CDH-09-21, in Iron Gate Reservoir. The white cord connects to a slide weight that is used to help pound the sampler into the sediment. In the right photo the sampler is being used during a snow storm to collect an undisturbed sample in EDH-09-8A Photso by M. McCulla, 10/31/09.

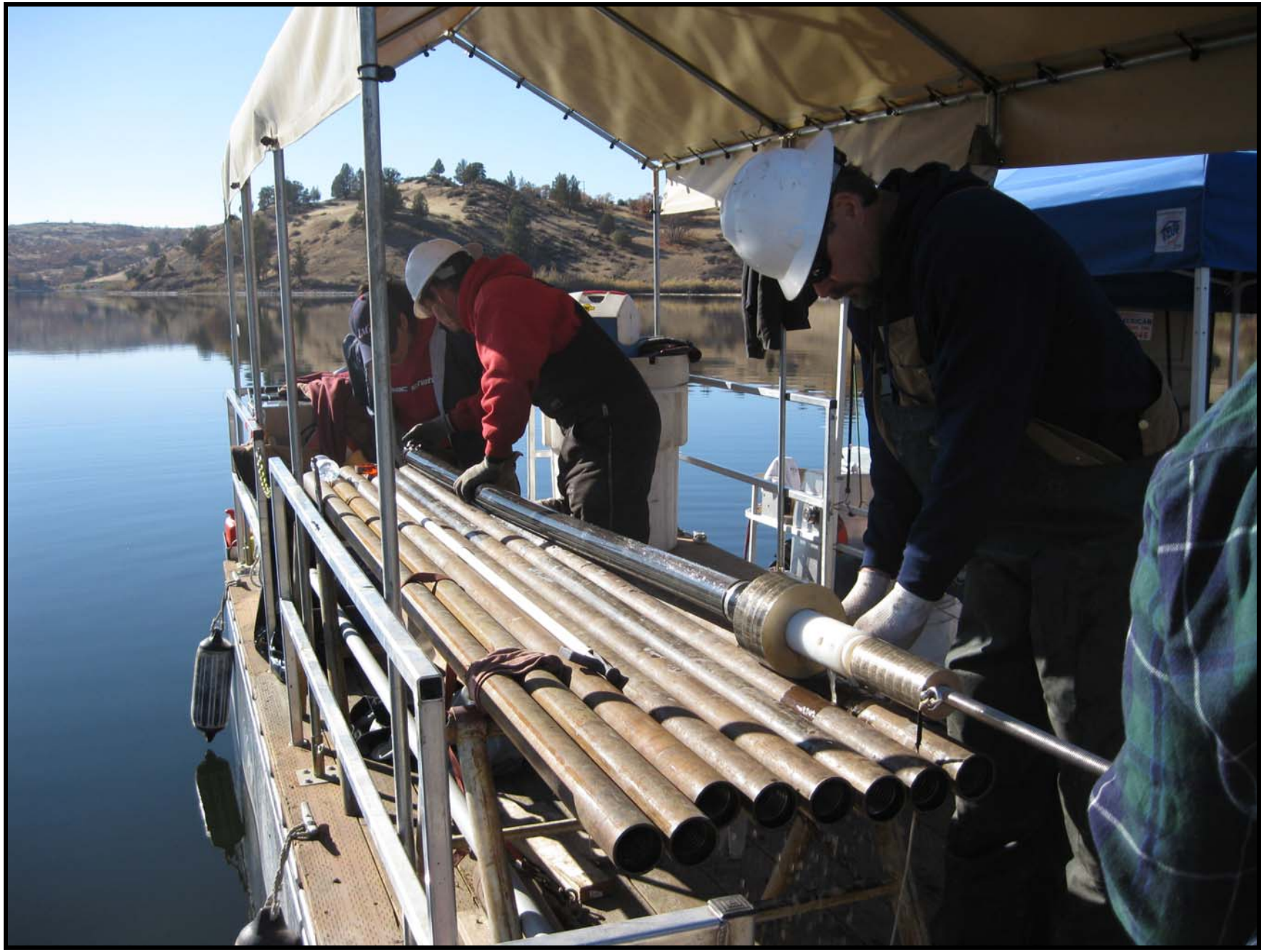
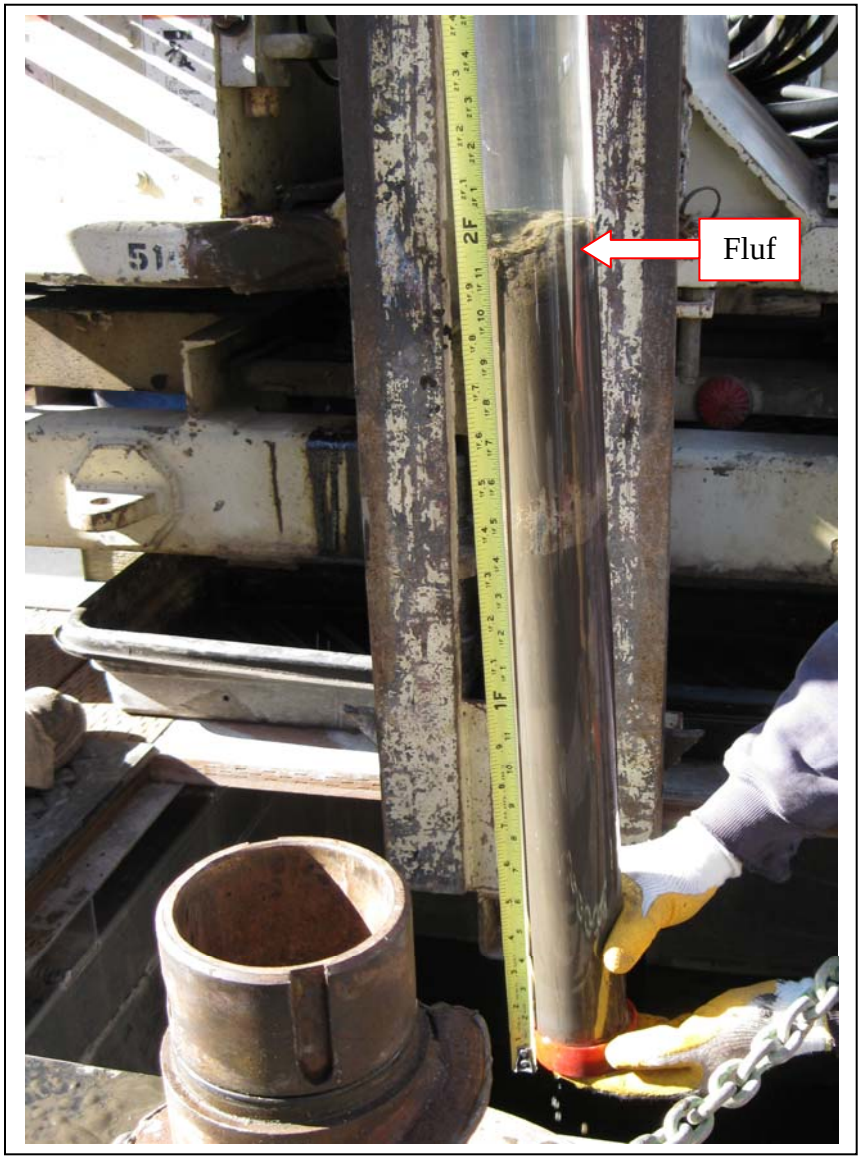


Photo 50. View of Reclamation's gravity sampler fitted with a 2 3/4-inch o.d. by 2 5/8-inch i.d. lexan tube. The sampler contains about 8-feet of sediment from Iron Gate Reservoir. Photo by M. McCulla, 11/15/09.



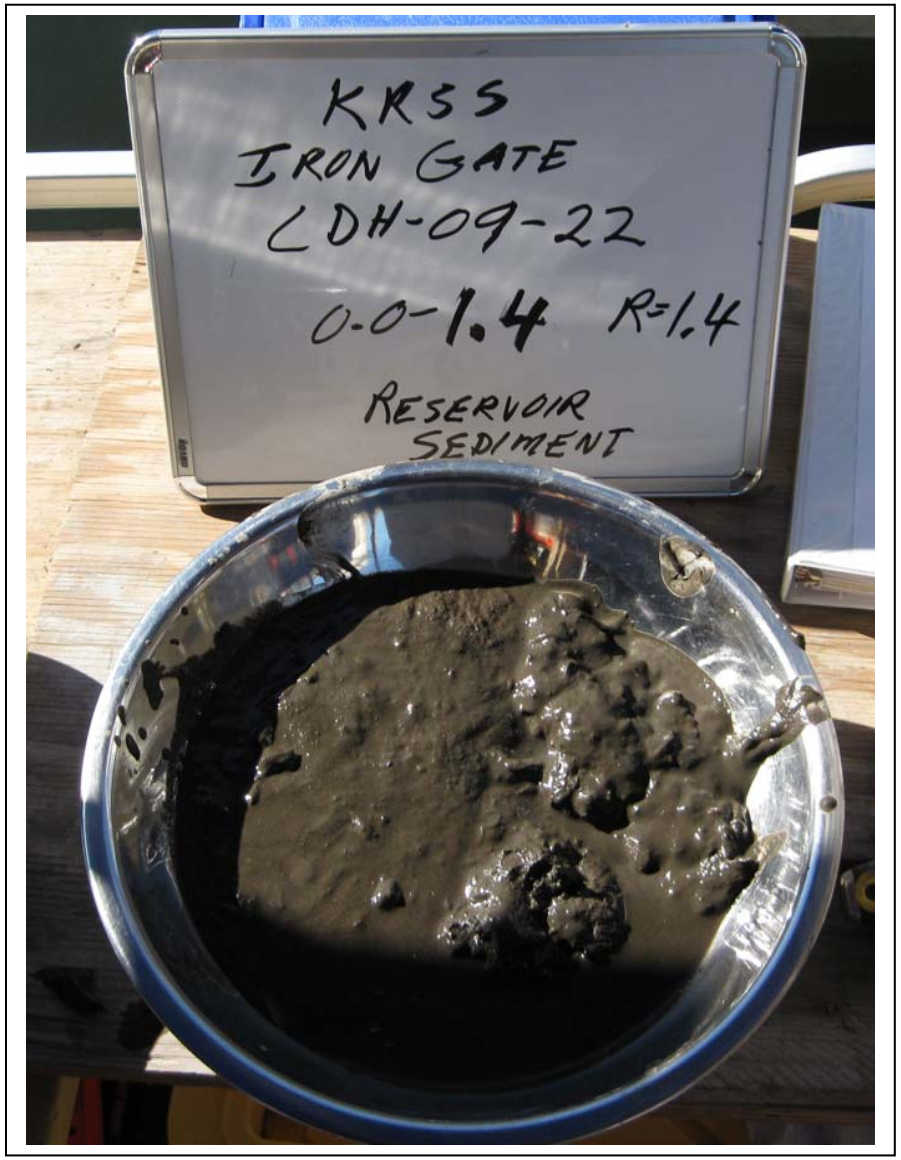


Photo 51. View of contaminant sample collected from drill hole CDH-09-22, in Iron Gate reservoir. Note that the "fluff" on top of the sample (left photo) indicates that the upper, loose, reservoir sediment was included in the sample. Photos by M. McCulla, 11/2/09.

Photo 52. View of gravity sampler being used from a support boat to collect contaminant samples from J. C. Boyle Reservoir. Photos by G. Mongano, October 2009.

Photo 53. View of Gravity Consultants push/hammer sampling system. A 4-inch o.d. by 3 ¾-inch i.d. lexan tube is set into a compression fitting that in turn screws onto 5-ft. length drill rods. The sample tube can be up to 20 feet long, but sample tubes about 8 to 12 feet long was most commonly in Copco-1 reservoir. Photo by M. McCulla, 11/9/09.

Photo 54. View of Gravity Consultants push/hammer sampling system with the 4-inch o.d. by 3 ¾-inch i.d. lexan tube and a sample retaining basket held on with pop rivets. Photo by M. McCulla, 11/9/09.

Photo 55. View of worker decontaminating a brush used to clean the 4-inch o.d. by 3 ¾-inch i.d. lexan tubes prior to collecting drive/hammer and vibracore samples. Photos by G. Mongano, November 2009.

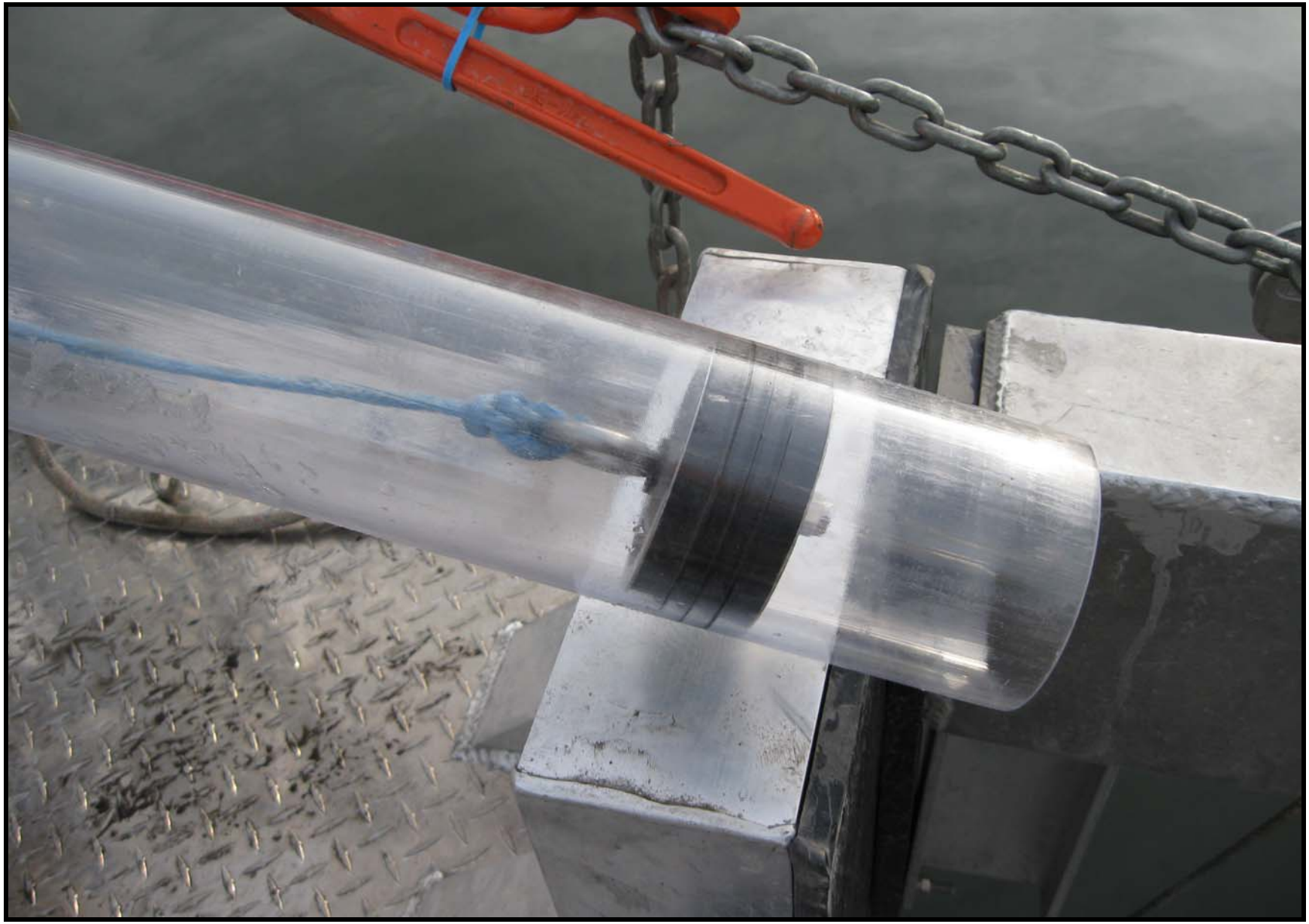


Photo 56. View of the piston-sampling mechanism that was used for the collection of a few samples from Copco-1 reservoir. The piston tied to a rope is suspended from the drilling platform, while the lexan tube is being pushed/hammered into the reservoir sediment. The piston creates a small vacuum that helps keep the sample from dropping out of the tube as it is being retrieved. Photo by M. McCulla, 11/9/09.

Photo 57. View of a contaminant sample being collected using the push/hammer method and a 4-inch o.d. by 3 ¾-inch i.d. lexan tube at drill hole CDH-09-10 in Copco-1 reservoir. Photo by M. McCulla, 11/10/09.

Photo 58. View showing the removal of a contaminant sample from the lexan tube used to collect material in drill hole CDH-09-10, Copco-1 reservoir. The sample is extracted onto a clean sheet of aluminum foil. Photos by M. McCulla, 11/10/09.

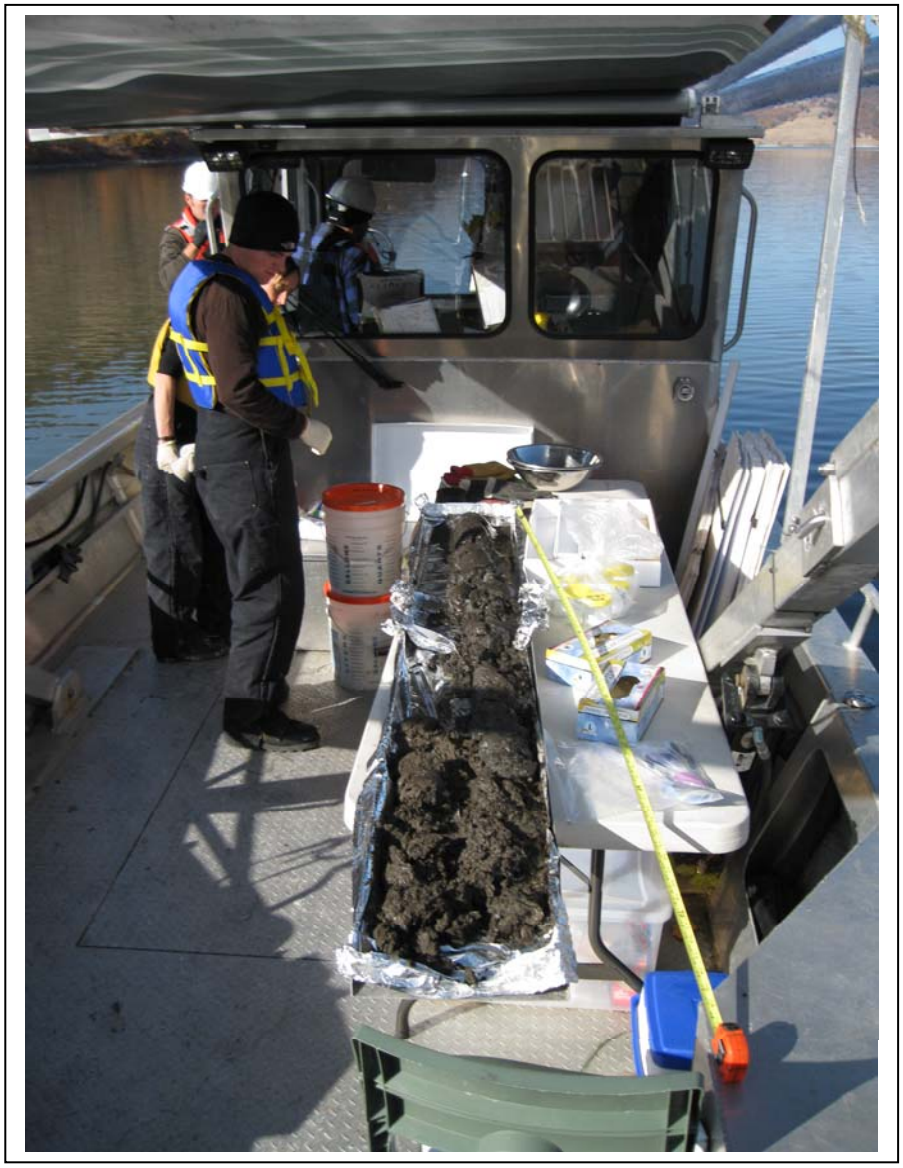


Photo 59. View showing the removal a contaminant sample from the lexan tube used to collect material from drill hole CDH-09-10 in Copco-1 reservoir (continued from the previous photo). The sample is extracted onto a clean sheet of aluminum foil. Photos by M. McCulla, 11/10/09.

Photo 60. View of Gravity Consultants vibracore unit with compression fitting for a 4-inch o.d. by 3 ¾-inch i.d. lexan tube sampler. The vibracore method was used to collect several contaminant samples from Copco-1 reservoir. Photo by M. McCulla, 11/16/09.

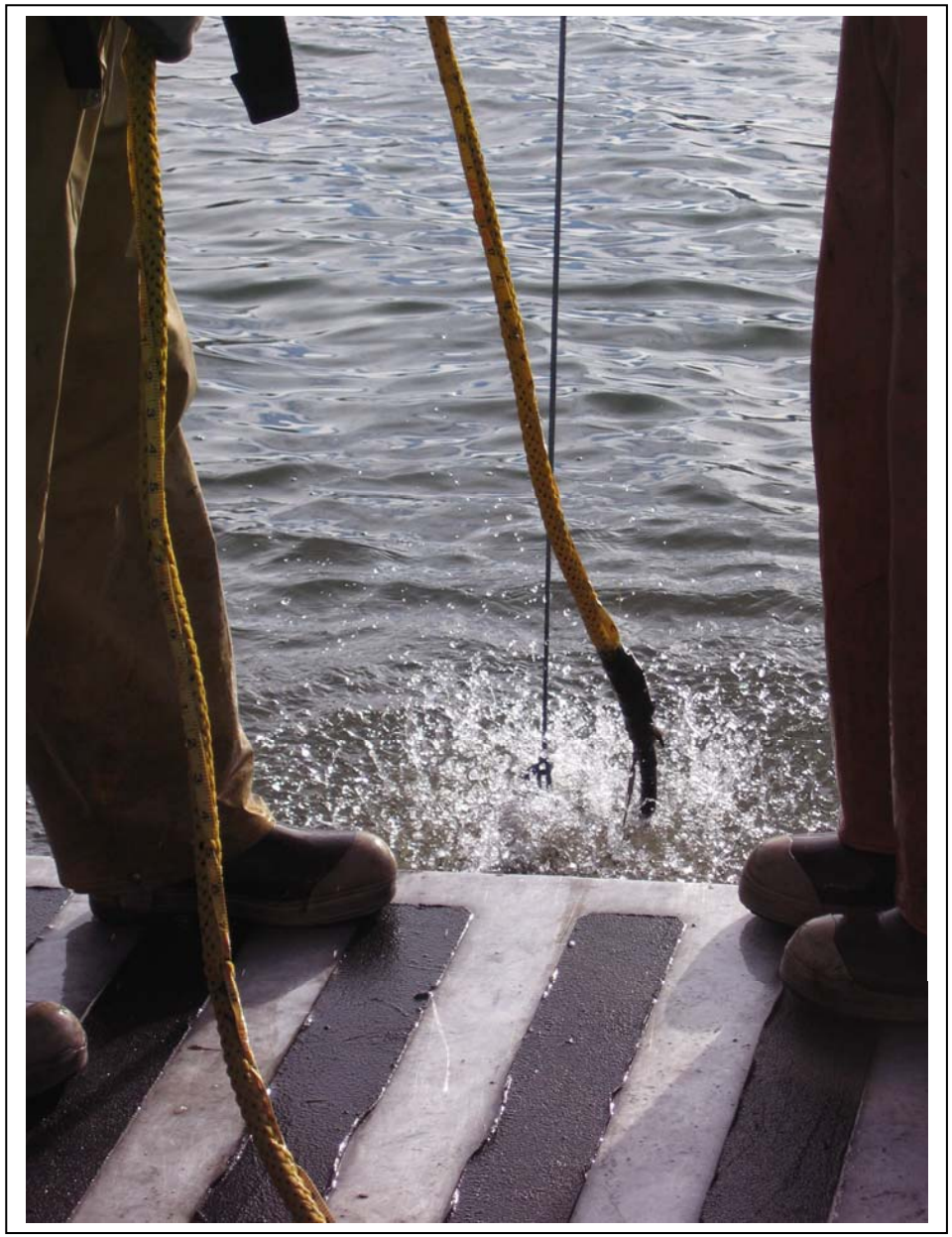


Photo 61. View of the vibracore unit with 4-inch o.d. by 3 ¾-inch i.d. lexan tube sampler preparing to take a sample (left). As the vibracore unit is activated and lowered, intense vibration agitates the water (right). Photos by G. Mongano, November 2009.

Photo 62. View of vibracore sample being retrieved from Copco-1 reservoir. Photo by G. Mongano, November 2009.

Photo 63. View of contaminant sample processing. An electric mixer (upper right) was used for sample processing on Copco-1 reservoir, and hand mixing was used during sample processing on J.C. Boyle and Iron Gate reservoirs. Photos by G. Mongano, October and November 2009.

Photo 64. Methane gas is an abundant constituent of reservoir sediment in J.C. Boyle, Copco-1, and Iron Gate reservoirs and bubbled up around the drilling barge and support boats during sampling (Iron Gate Reservoir) Photo by A. Warren, 11/2/09.

Photo 65. Methane gas is an abundant constituent of reservoir sediment in J.C. Boyle, Copco-1, and Iron Gate reservoirs and bubbled up around the drilling barge and support boats during sampling (J.C. Boyle Reservoir) Photo by A. Warren, 11/2/09.

Photo 66 View of a variety of weather environments encountered throughout the drilling program (9/30/09 through 12/12/09). This included sunny mild days, fog, heavy rain, mixed rain and snow, high winds (gusts over 30 mph) and generally freezing conditions. Photos by M. McCulla and Greg Mongano, Fall/Winter, 2009.

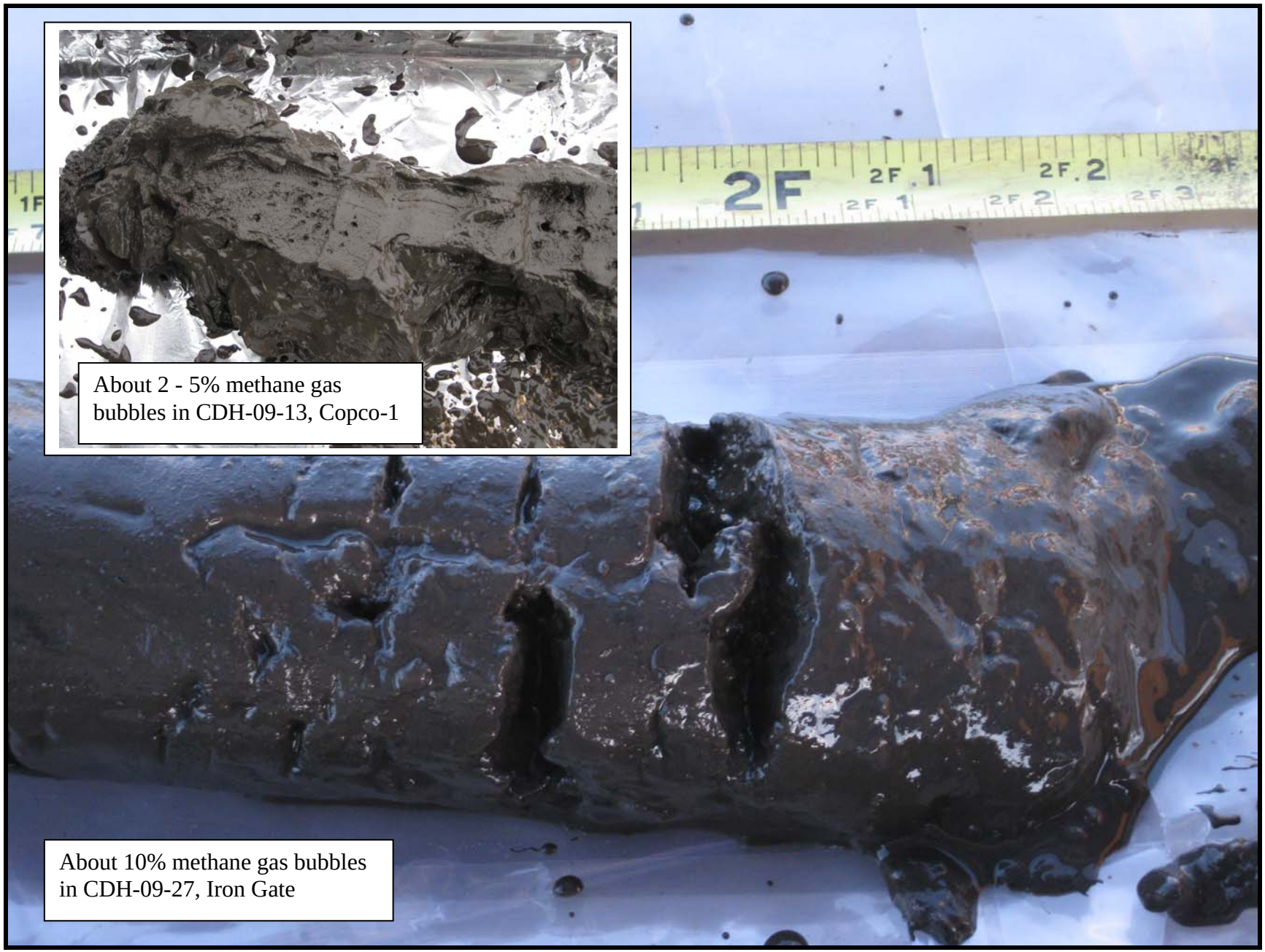


Photo 67. View of methane gas bubbles in reservoir sediment in Copco-1 and Iron Gate reservoirs. Photos by M. McCulla, 11/4/09.

J.C. Boyle Reservoir

Geology

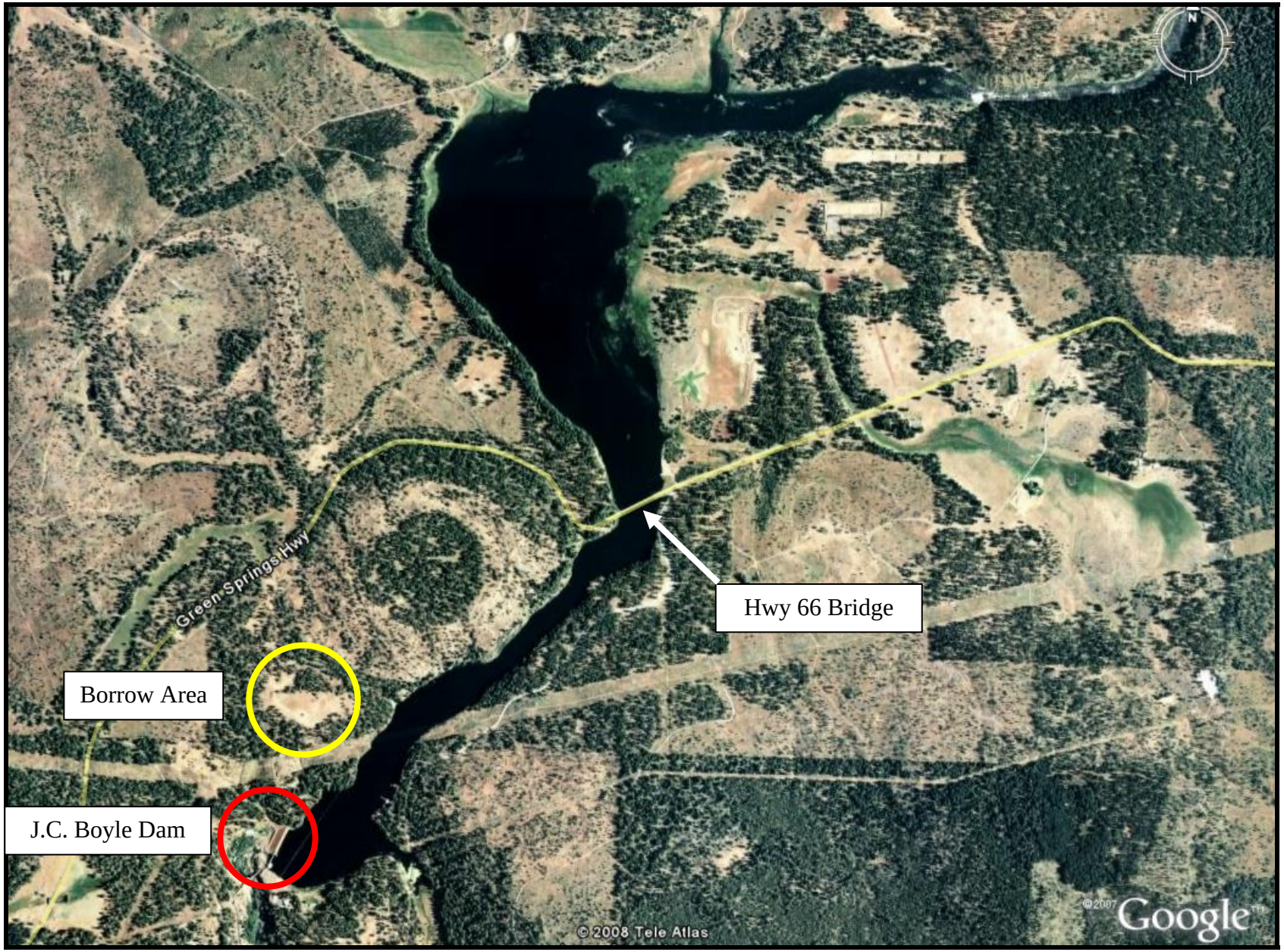


Photo 68. View of J.C. Boyle Dam and reservoir. The reservoir is long and narrow between the dam and the Hwy 66 Bridge. The sides of this section of the reservoir are lined by lava flows of basaltic andesite on top of, and against, volcaniclastic rocks. The upper area is broader with low topographic relief and is dominated by volcaniclastic rocks (tuff, lapilli tuff, and tuff breccia). Google Earth satellite imagery.

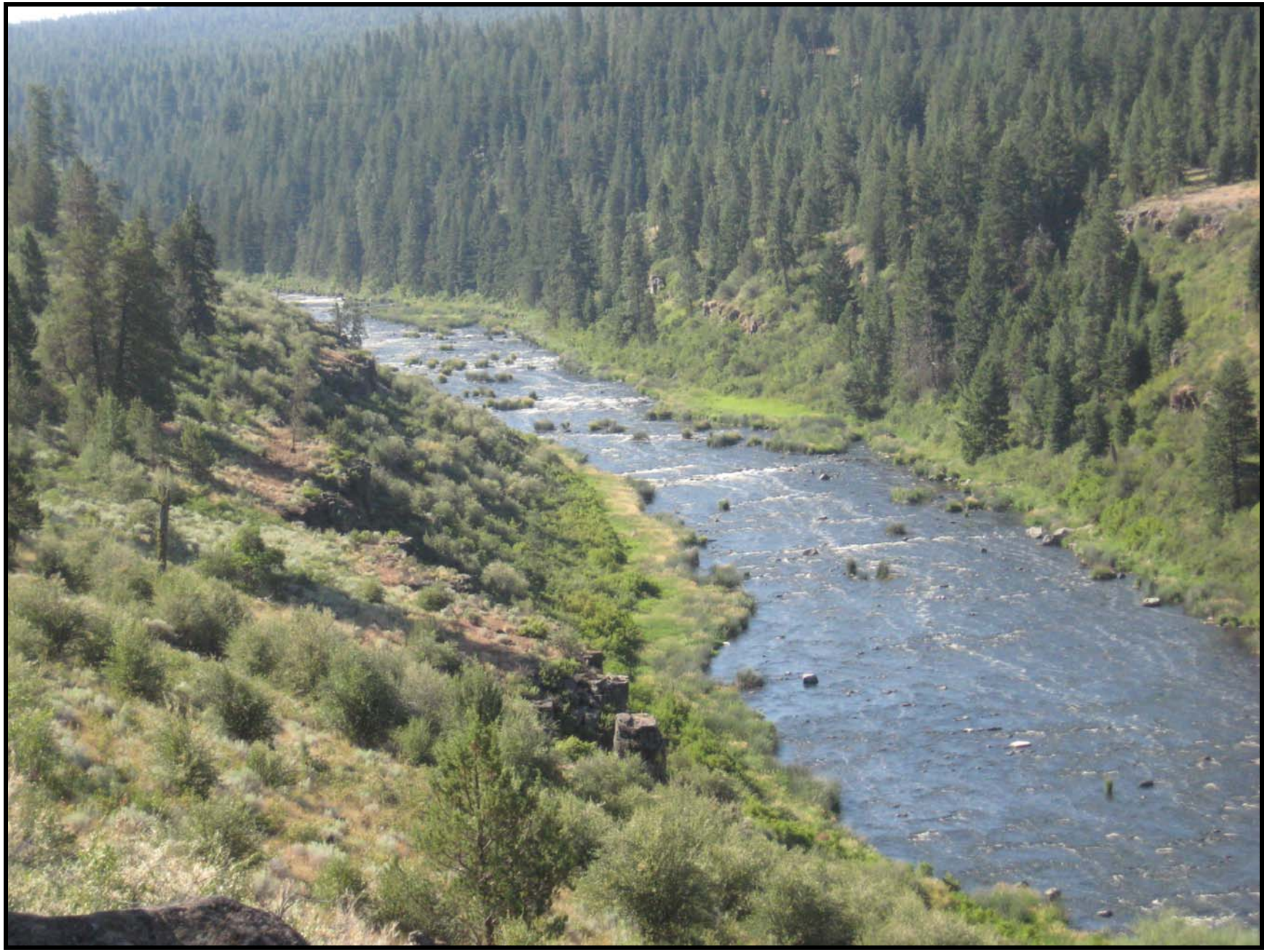


Photo 69. Upstream-looking view of the Klamath River between Keno Dam and J.C. Boyle reservoir. Note the narrow canyon composed of volcanic flows, and the coarse deposits of alluvium in the river channel. Photo by M. McCulla, 7/25/09.

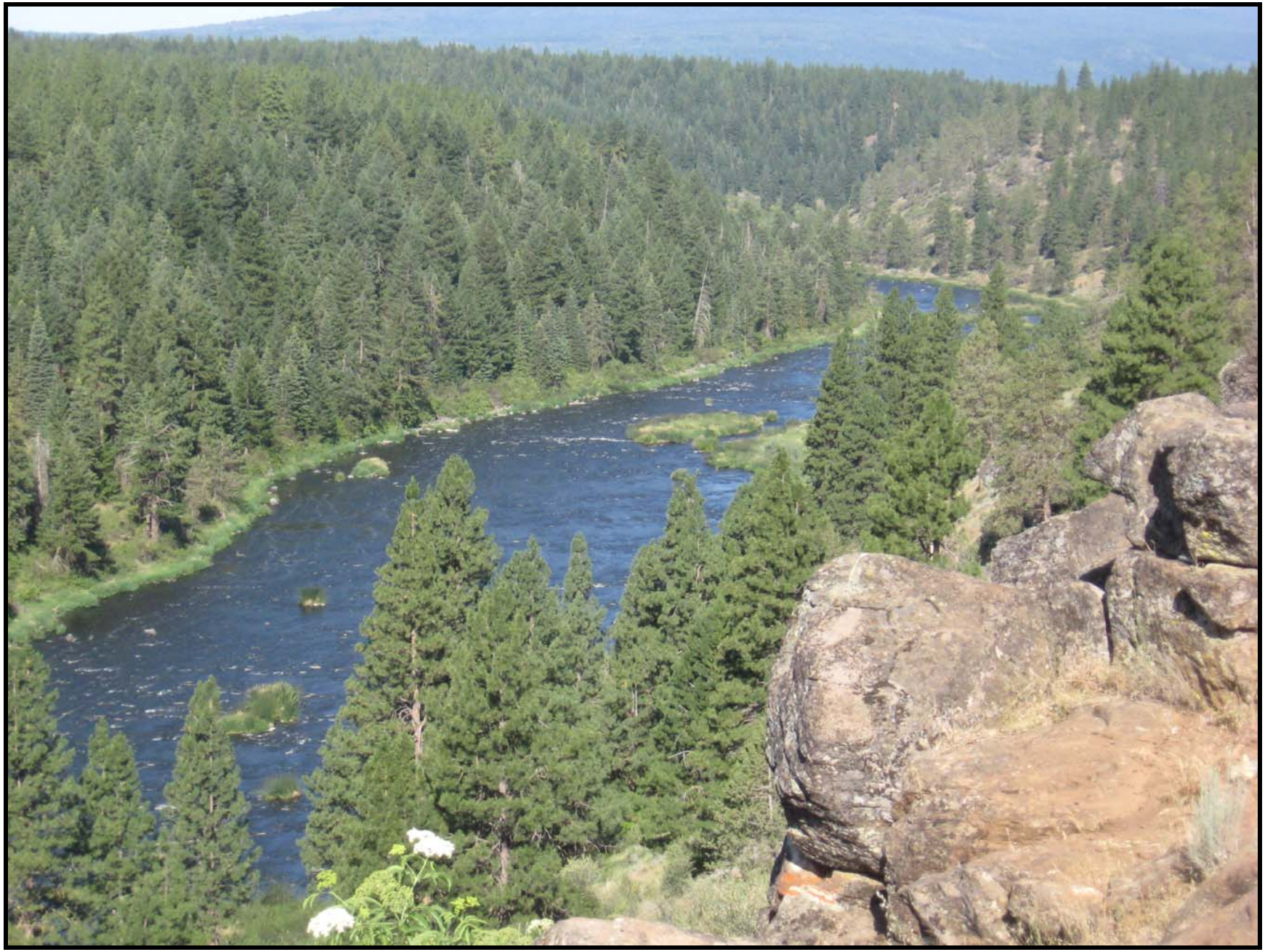


Photo 70. Downstream-looking view of the Klamath River between Keno Dam and J.C. Boyle reservoir. Note the narrow canyon composed of volcanic flows, and the coarse deposits of alluvium in the river channel. Photo by M. McCulla, 7/25/09.

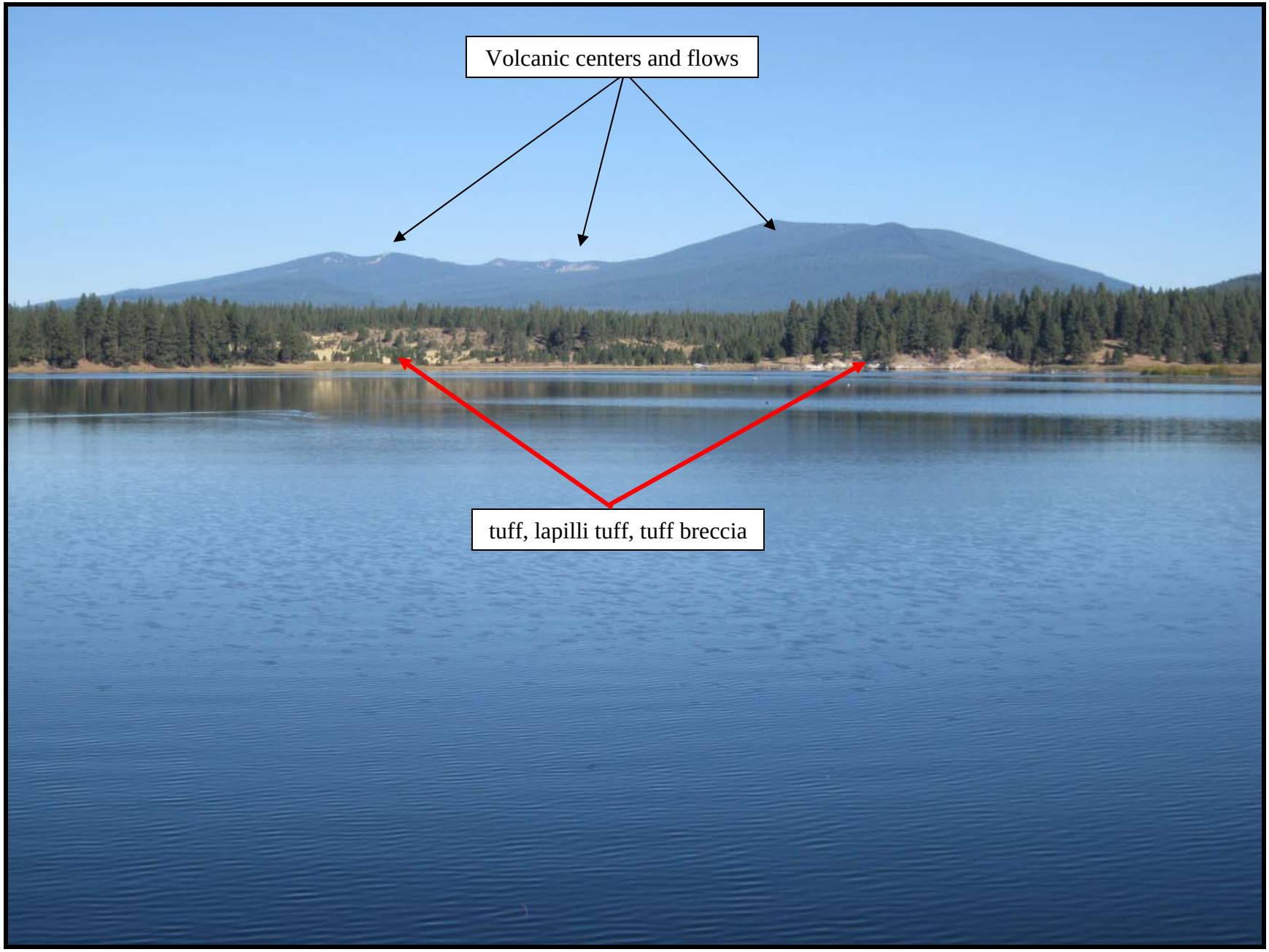


Photo 71. View across the middle to upper part of J.C. Boyle reservoir, with volcanic centers in the background and low topography composed of volcaniclastic rocks along the sides of the reservoir. Photo by M. McCulla, 10/17/09.

Photo 72. View of well-bedded volcaniclastic rocks forming the western abutment of the Hwy 66 Bridge, along the middle reach of J.C. Boyle reservoir. Photo by A. Warren, 10/6/09.

Photo 73. View of the western side of J.C. Boyle reservoir between the Hwy 66 Bridge and the Dam. Volcanic flows outcrop along the sides of the reservoir and were deposited above and against older volcaniclastic rock. Photo by M. McCulla, 10/6/09.

Photo 74. View of well-bedded volcaniclastic rock along the western side of J.C. Boyle reservoir between the Hwy 66 Bridge and the Dam. The historic Klamath River carved its channel into these volcaniclastic rocks. Lava flows were later. Photo by M. McCulla, 10/6/09.

Photo 75. View of what is believed to be the main borrow area used for construction of the dam. The area, shown on Photo 68, is along the northern side of the reservoir, approximately 1,000 feet north of the dam. Photo by M. McCulla, 7/29/09.

Photo 76. Close-up view of a deposit of Silty Gravel with Sand (GM)s in the borrow area shown in the previous photo. These deposits are interpreted as a mix of river terrace alluvial deposits and colluvium. Photo by M. McCulla, 7/29/09.

Photo 77. View of the downstream side of J. C. Boyle Dam and gated spillway. Photo by G. Mongano, 10/14/09.

Photo 78. View towards the southwest of J.C. Boyle Dam. The spillway and power penstock are in the background and the fish ladder is to the right. Photo by M. McCulla, 10/2/09.

Photo 79. View of the power penstock coming from J.C. Boyle Dam. The dam is out of view, to the left of the photo. Photo by M. McCulla, 1/21/09.

Photo 80. View of the power penstock coming from J.C. Boyle Dam. Note the massive to blocky volcanic flow rocks overlying volcaniclastic rocks. The volcaniclastic rocks are baked red by the heat of the lava flows. Photo by M. McCulla, 1/21/09.

Photo 81. View of the power penstock coming from J.C. Boyle Dam. Note the massive to blocky volcanic flow rocks overlying volcaniclastic rocks. The volcaniclastic rocks are baked red by the heat of the lava flows. Photo by M. McCulla, 1/21/09.

Photo 82. Blocky volcanic flow rock overlaying and baking older volcaniclastic rocks near J.C. Boyle Dam. Photo by M. McCulla, 1/21/09.

Photo 83. View of volcaniclastic rock (baked red) overlain by a younger blocky volcanic flow. Near the truck is an outcrop of a volcanic flow that came down the historic Klamath River channel, which was cut into these volcaniclastic rocks. Photo by M. McCulla, 1/21/09.

Photo 84. View of the Klamath River channel directly downstream from J.C. Boyle Dam. Note the coarse alluvial deposits in the channel. Photo by M. McCulla, 1/21/09.

Photo 85. Close up view of Klamath River channel deposits shown in the previous photo. Note the abundance of cobble and boulder size alluvium. Photo by M. McCulla, 1/21/09.

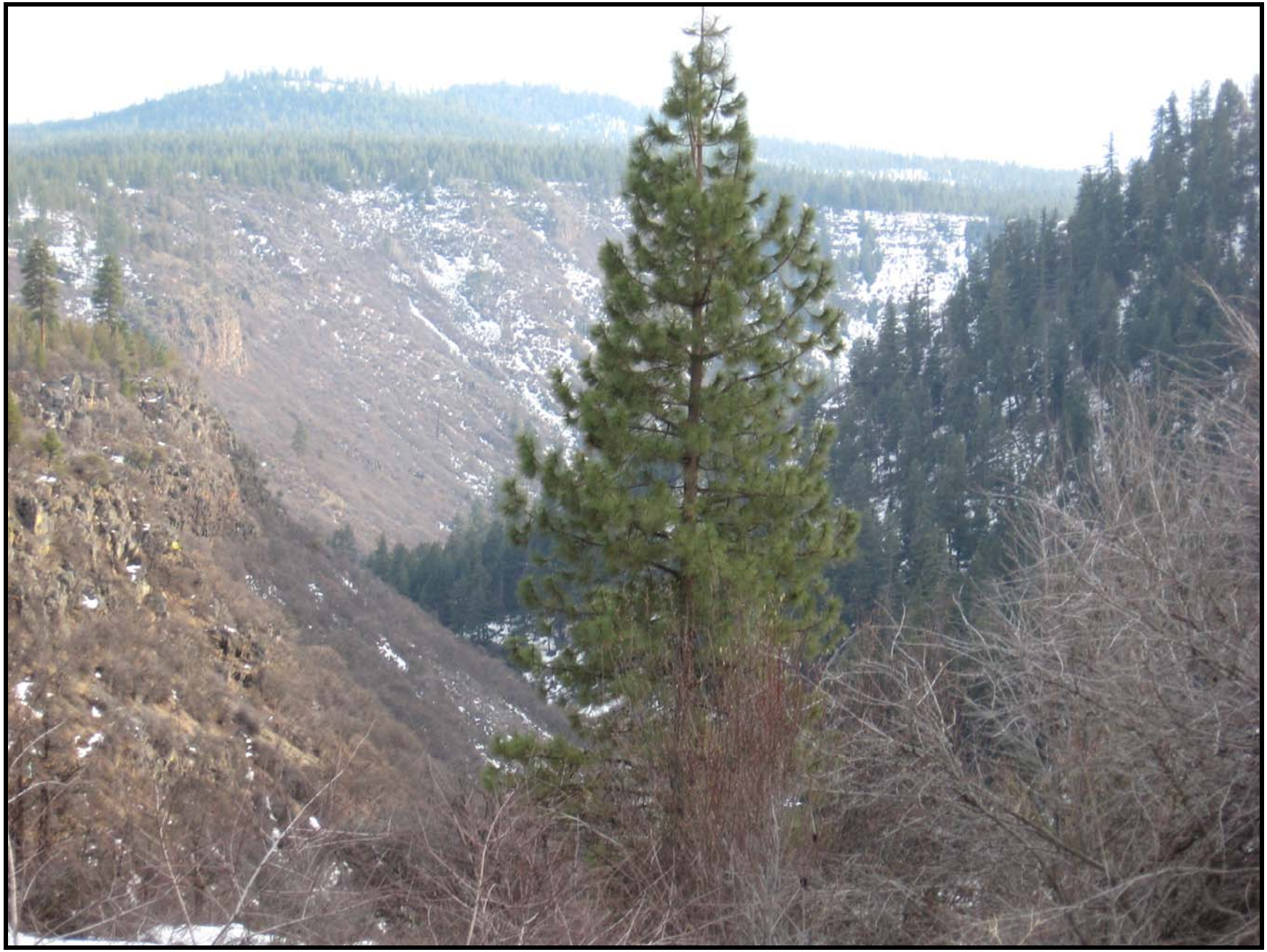


Photo 86. View of the Klamath River channel a few miles downstream from J.C. Boyle Dam. The steep terrain provides an ongoing source of coarse material to the river alluvium. Photo by M. McCulla, 1/21/09.

J.C. Boyle Reservoir

Sediment Sampling

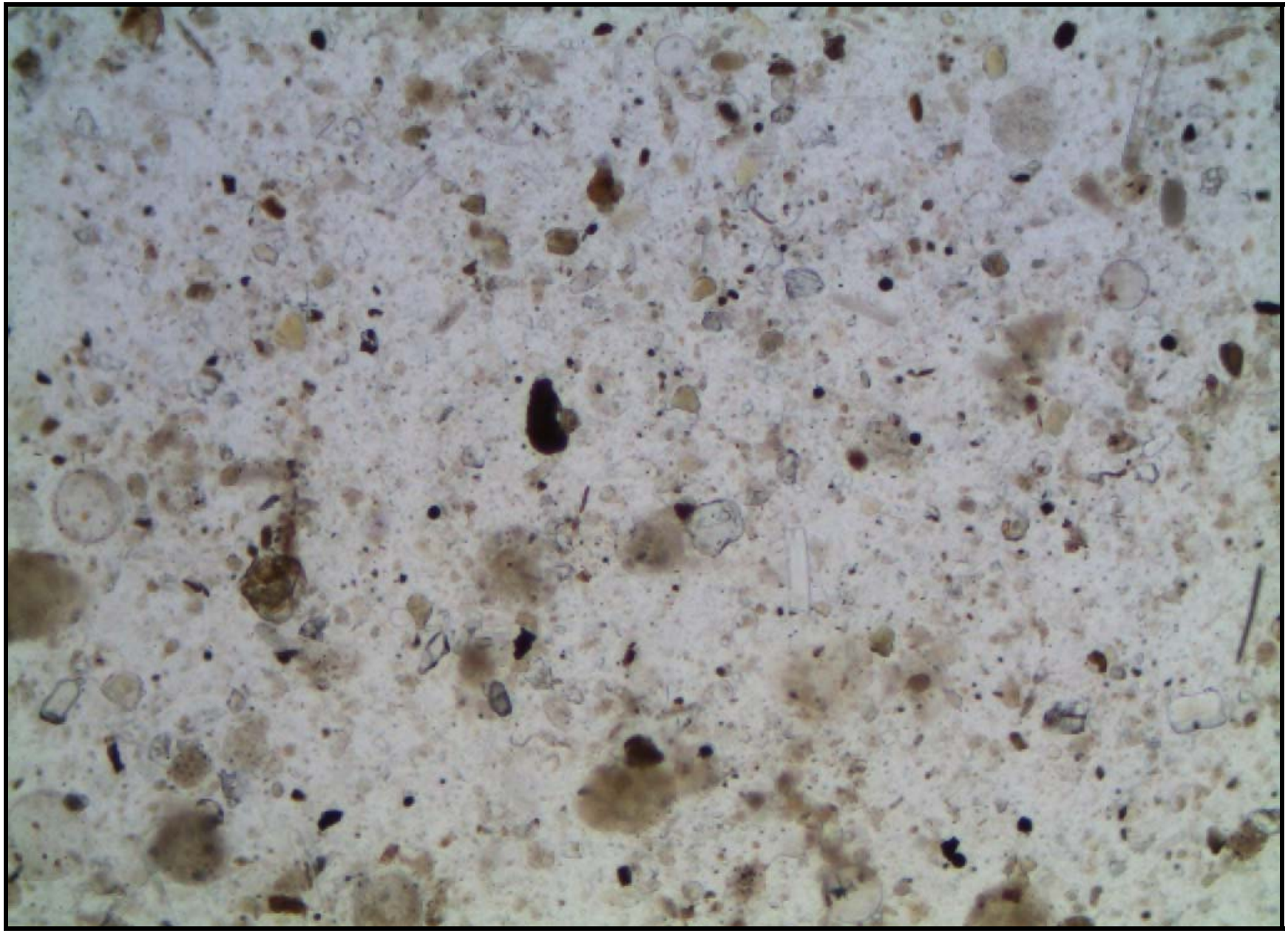


Photo 87. Photograph through microscope of reservoir sediment collected from J.C. Boyle reservoir magnified 10 times. The sediment appears to be a loosely arranged mix of silt to sand size rock particles and an abundance of diatom tests and algae. Photomicrograph provided by B. Greimann, Reclamation's Technical Service Center, Denver, CO.

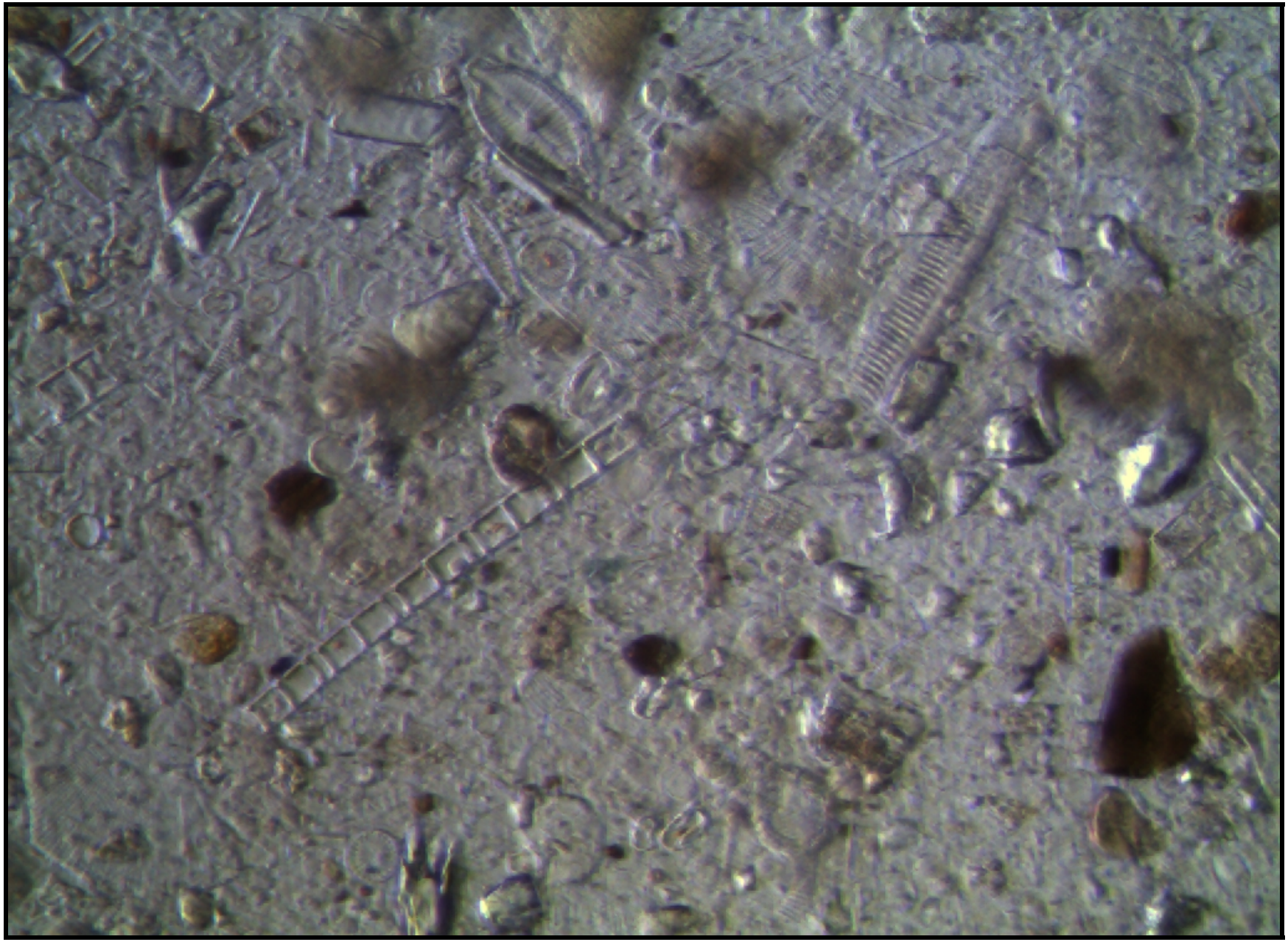


Photo 88. Photograph through microscope of reservoir sediment collected from J.C. Boyle reservoir magnified 40 times. The sediment appears to be a loosely arranged mix of silt to sand size rock particles and an abundance of diatom tests and algae. Photomicrograph provided by B. Greimann, Reclamation's Technical Service Center, Denver, CO.

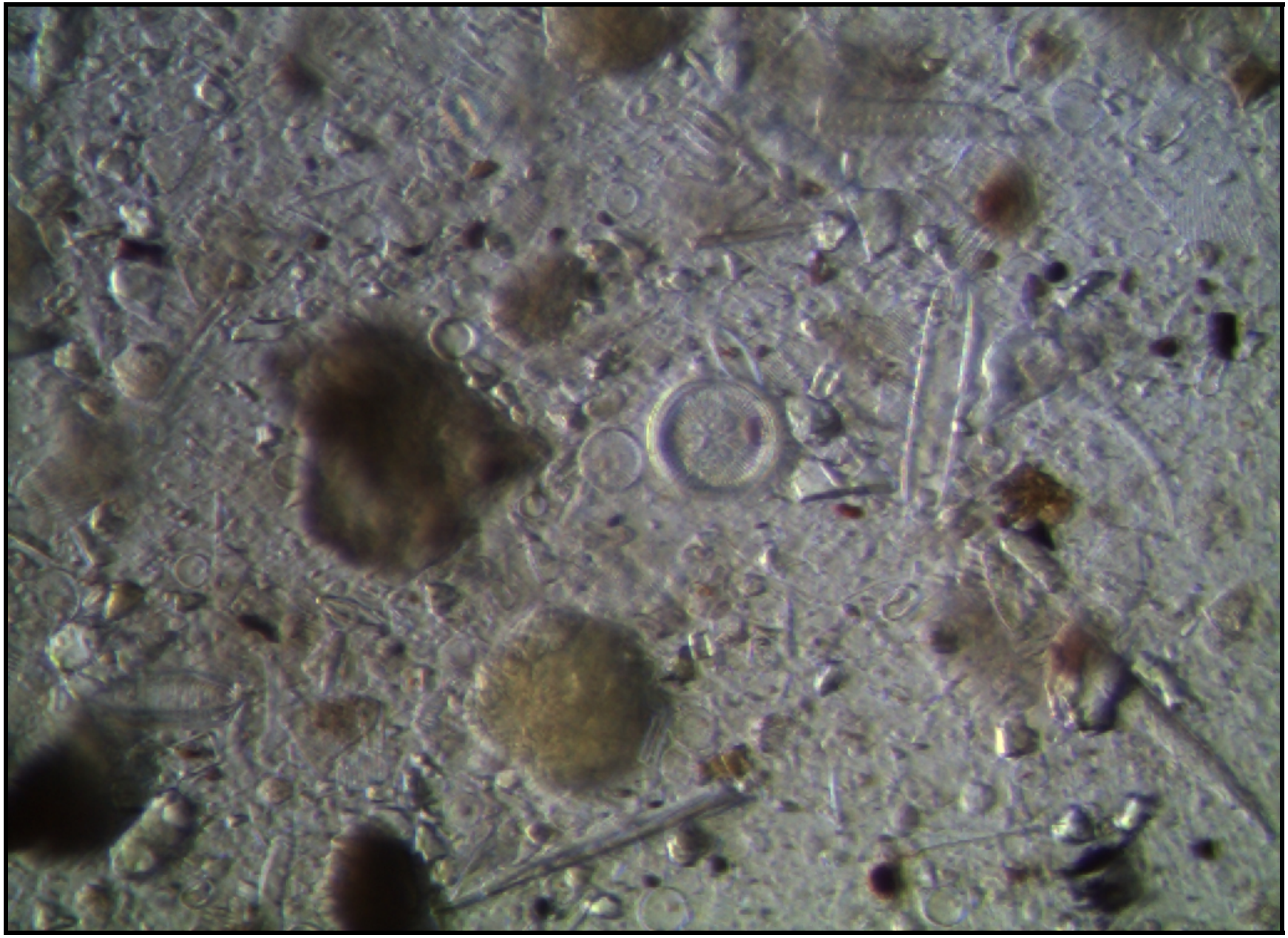


Photo 89. Photograph through microscope of reservoir sediment collected from J.C. Boyle reservoir magnified 40 times. The sediment appears to be a loosely arranged mix of silt to sand size rock particles and an abundance of diatom tests and algae. Photomicrograph provided by B. Greimann, Reclamation's Technical Service Center, Denver, CO.

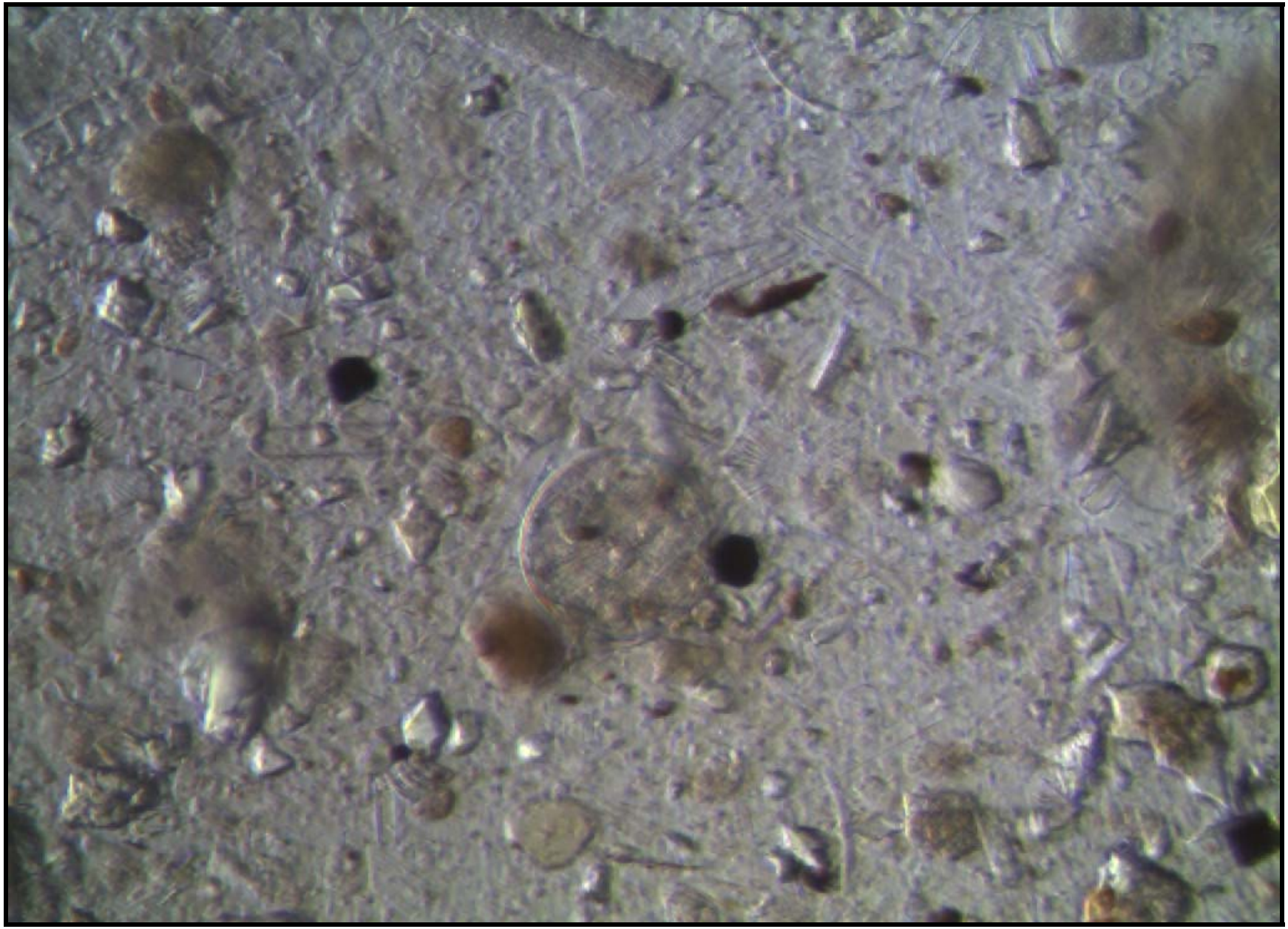


Photo 90. Photograph through microscope of reservoir sediment collected from J.C. Boyle reservoir magnified 40 times. The sediment appears to be a loosely arranged mix of silt to sand size rock particles and an abundance of diatom tests and algae. Photomicrograph provided by B. Greimann, Reclamation's Technical Service Center, Denver, CO.

Photo 91. View of the undisturbed sample of reservoir sediment collected from drill hole EDH-09-1 at a depth of 2.37 to 3.20 feet. Photo by M. McCulla, 10/16/09.

Photo 92. Close up of material shown in the previous photo. Reservoir sediment composed of Silty Sand – SM is to the left of the sediment tool and pre-reservoir alluvium is to the right. Photo by M. McCulla, 10/16/09.

Photo 93. View of undisturbed sample of reservoir sediment from drill hole EDH-09-2 at a depth of 5.06 to 5.80 feet. To the right is Sandy Silt s(ML) reservoir sediment from the sample shoe. Photo by M. McCulla, 10/16/09.

Photo 94. View of undisturbed sample of reservoir sediment collected from drill hole EDH-09-2A representing a depth of 7.25 to 9.00 feet. The tape measure separates Sandy Elastic Silt s(MH) reservoir sediment (top) from alluvium. Photo by M. McCulla, 10/17/09.

Photo 95. View of Silty Sand – SM reservoir sediment with about 15% fines. This FADC hole was the farthest upstream that the barge could navigate to in J.C. Boyle reservoir. Photo by M. McCulla, 10/15/09.

Photo 96. View of the contact between Silty Sand reservoir sediment (left of the sediment tool) and coarse Silty Gravel with Sand (GM)s alluvium (right of the tool), in drill hole CDH-09-2. Photo by M. McCulla, 10/15/09.

Photo 97. Coarse pre-reservoir Silty Gravel with Sand (GM)s alluvium (right of sediment tool) in FADC auger hole CDH-09-2. Photo by M. McCulla, 10/15/09.

Photo 98. View of Sandy Silt s(ML) reservoir sediment in CDH-09-3. This drill hole is in the transition reach of the reservoir, and laboratory analysis determined nearly equal parts of sand and silt in the sample. Photo by M. McCulla, 10/15/09.

Photo 99. View of the contact between Sandy Silt s(ML) reservoir sediment and Silty Gravel with Sand (GM)s pre-reservoir alluvium in drill hole CDH-09-3. The contact (red line) is at a depth of 6.0 feet. Photo by M. McCulla, 10/15/09.

Photo 100. View of Reclamation's drilling and support barge set up next to the J.C. Boyle reservoir shoreline at drill hole CDH-09-4. Photo by M. McCulla, 10/7/09.

Photo 101. View stumps and logs in shallow water from Reclamation's drilling barge set up for drill hole CDH-09-4. Photo by M. McCulla, 10/7/09.

Photo 102. View of FADC sample at CDH-09-4. Drilling here encountered 9.1 feet of Elastic Silt – MH reservoir sediment overlying pre-reservoir alluvium of Elastic Silt with Sand and Gravel (MH)sg. This hole was offset and drill hole CDH-09-4A was used to collect contaminant and gradation samples. Photo by M. McCulla, 10/7/09.

Photo 103. View of material encountered in drill hole CDH-09-5; 0.0 to 0.3-ft Elastic Silt – MH reservoir sediment; 0.3 to 0.9-ft Silty Gravel with Sand (GM)s pre-reservoir alluvium; and 0.9 to 2.0-ft pre-reservoir volcaniclastic Lean Clay – CL. Photo by A. Warren, 10/6/09.

Photo 104. View of material collected in CDH-09-5. The red line designates the contact between pre-reservoir alluvium (on the left) and pre-reservoir thin bedded volcaniclastic Lean Clay – CL (on the right). Photo by A.Warren, 10/6/09.

Photo 105. View of Reclamation's drilling and support barges setting up for sampling at CDH-09-6, just downstream from the Hwy 66 Bridge crossing J.C. Boyle reservoir. Photo by M. McCulla, 10/6/09.

Photo 106. View of coarse pre-reservoir alluvium composed of Silty Gravel with Sand (GM)s exposed at the surface on the bottom of the J.C. Boyle reservoir at drill hole CDH-09-6. Photo by A. Warren, 10/6/09.

Photo 107. View of mussels collected in Ekman Sampler from drill hole CDH-09-6A. Mussels were present where coarse pre-reservoir alluvium forms the reservoir bottom. Mussels were not present where reservoir sediment was greater than about a foot thick. Photo by M. McCulla, 10/7/09.

Photo 108. Close up view of mussels shown in Photo 107 from drill hole CDH-09-6A. Photo by M. McCulla, 10/7/09.

Photo 109. View of Reclamation's drilling and support barge in front of J.C. Boyle Dam, set up on drill hole CDH-09-7. The thickness of reservoir sediment here was 18.7 feet. Photo by M. McCulla, 10/2/09.

Photo 110. View of Elastic Silt – MH reservoir sediment in drill hole CDH-09-7. Photo by A. Warren, 10/2/09.

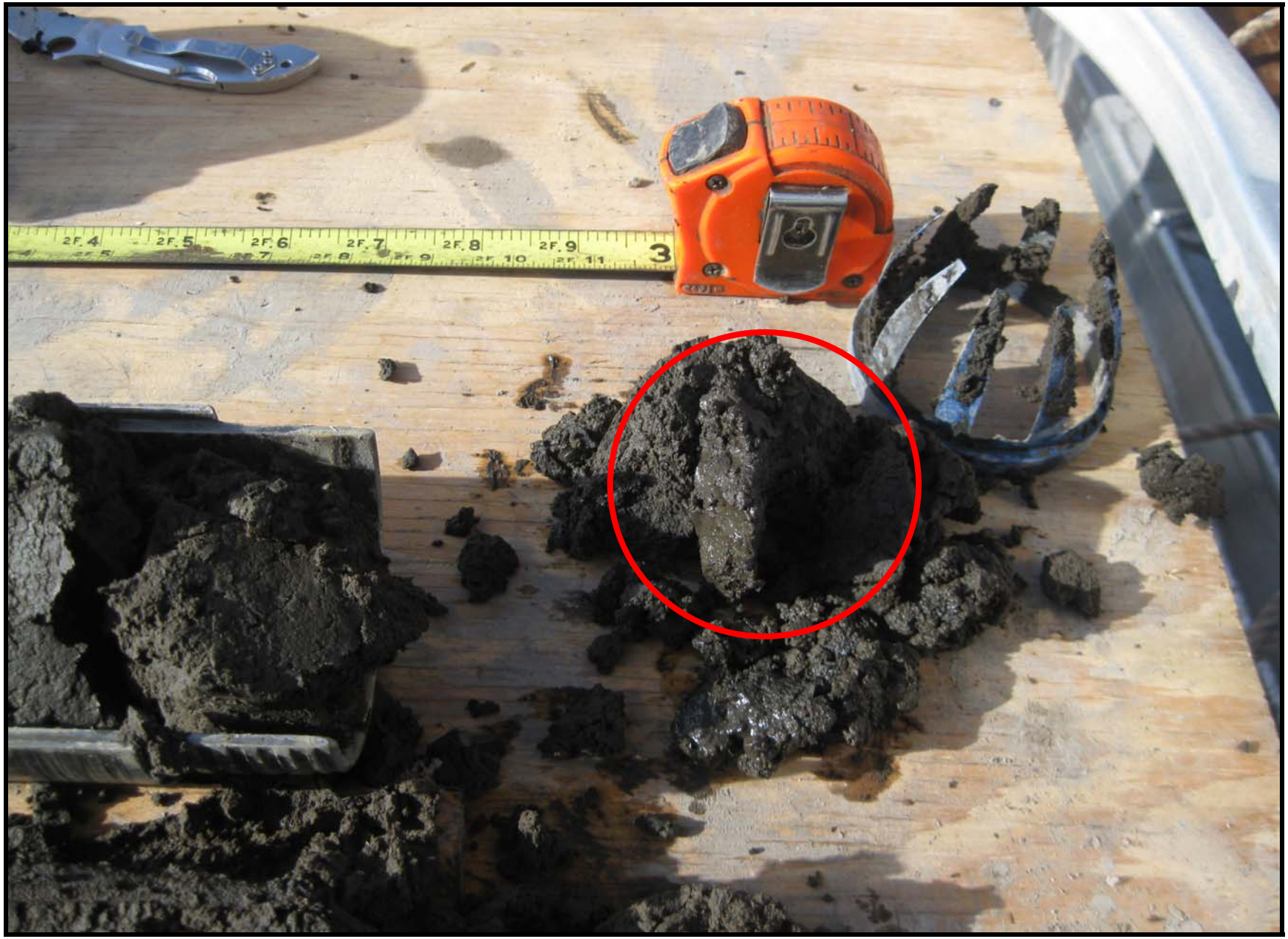


Photo 111. View of material collected at the reservoir sediment and pre-reservoir volcaniclastic contact in drill hole CDH-09-7. A 1½-inch angular piece of hard vesicular basalt (red circle) blocked the sample shoe from collecting material deeper than about 18.8 feet. Photo by A. Warren, 10/2/09.

Photo 112. View of Reclamation's drilling and support barges set up on drill hole CDH-09-8, between J.C. Boyle Dam and Topsy campground. Photo by M. McCulla, 10/3/09.

Photo 113. View of material collected in drill hole CDH-09-8. Reservoir sediment composed of Elastic Silt – MH was from 0.0 – 1.7 feet, and pre-reservoir colluvium composed of Sandy Silt with Trace Gravel s(ML) was from 1.7 – 5.0 feet. Photo by A. Warren, 10/3/09.

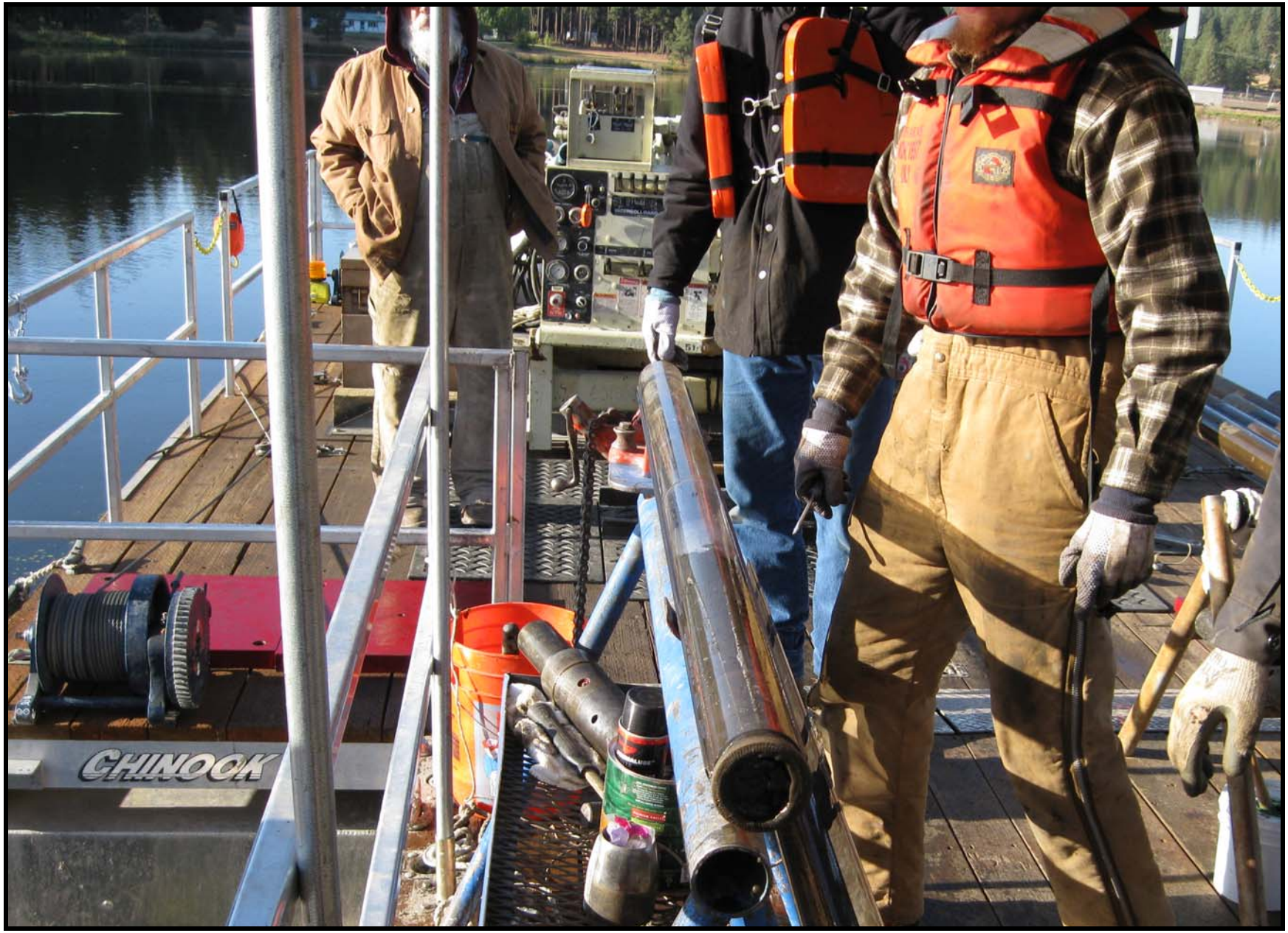


Photo 114. View of the FADC drilling system with two lexan liners filled with reservoir sediment composed of Elastic Silt – MH in drill hole EDH-09-3 near J.C. Boyle Dam. Photo by M. McCulla, 10/5/09.

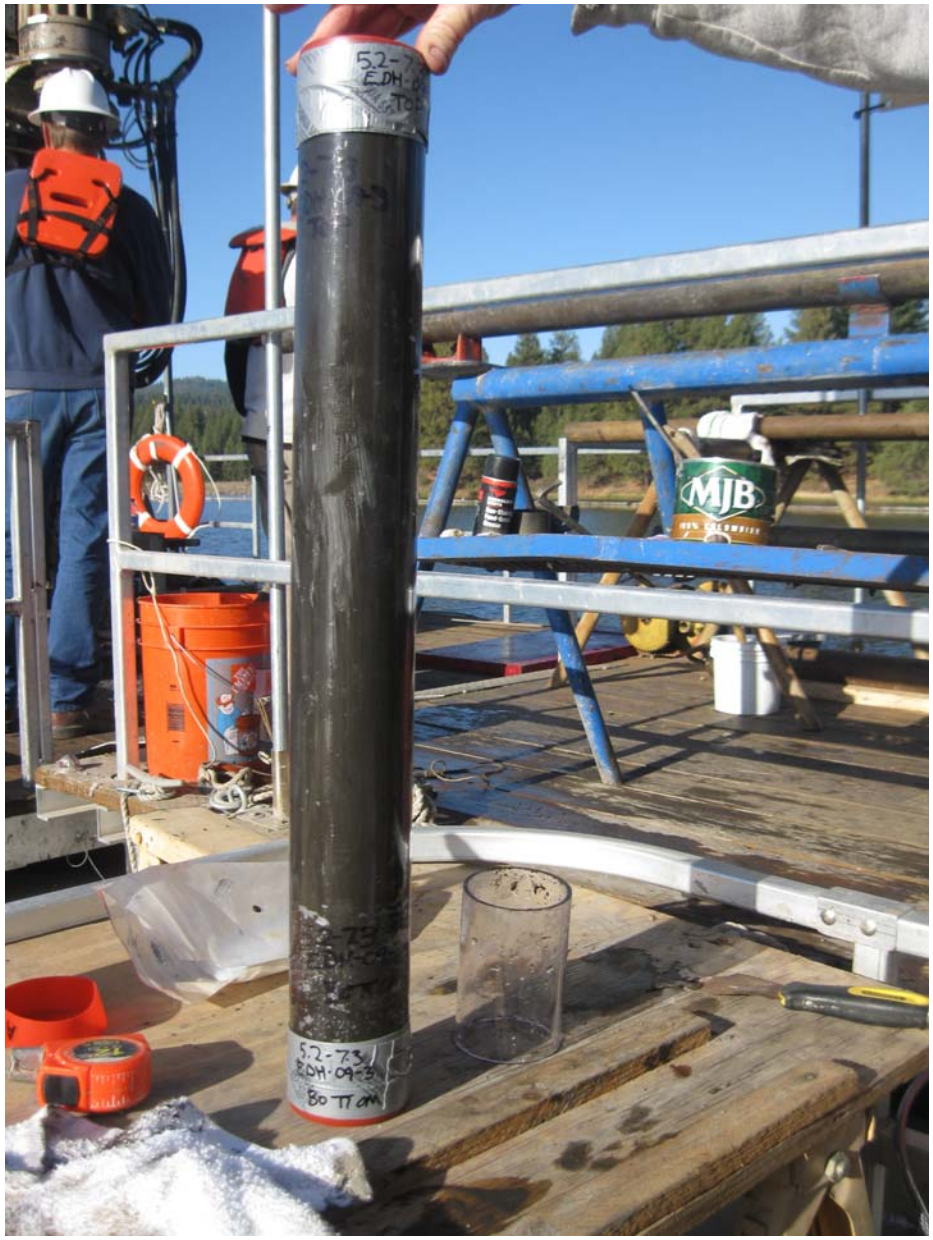


Photo 115. View of undisturbed samples of reservoir sediment composed of Elastic Silt – MH from drill hole EDH-09-3, from 5.2 – 7.3 feet (left) and from 11.4 – 13.9 feet (right). Pre-reservoir volcaniclastic Silty Gravel with Sand (GM)s and (SM)g started at a depth of 14.0 feet. Photos by A. Warren, 10/5/09.

Photo 116. View of contact in drill hole EDH-09-3 between reservoir sediment composed of Elastic Silt – MH (left of tool) and pre-reservoir volcaniclastic Silty Gravel with Sand (GM)s to Clayey Gravel with Sand (GC)s. Photos by A. Warren, 10/5/09.

Copco-1 Reservoir

Geology

Photo 117. View of a bridge crossing the Klamath River near the upstream end of Copco-1 reservoir. Photo by M. McCulla, 1/22/09.

Photo 118. Upstream view of the Klamath River from the bridge shown in the previous photo. Ridge-forming lava flows can be seen in the upper left and center. Photo by M. McCulla, 1/22/09.

Photo 119. Downstream looking view of Copco-1 reservoir from the bridge shown in Photo 117. Lava flows form the high ridges along the left and center. Photo by M. McCulla, 1/22/09.

Photo 120. View of the upstream northern (right) side of Copco-1 reservoir and private shoreline development. Photo by M. McCulla, 11/9/10.

Photo 121. View of white near-vertical shoreline cliffs, along the southern margin of Copco-1 reservoir. Note the slope failures and their proximity to private residences. Photo by M. McCulla, 11/16/09.

Photo 122. View of white near-vertical shoreline cliffs, along the southern margin of Copco-1 reservoir. Note the slope failures and their proximity to private residences. Photo by M. McCulla, 11/16/09.

Photo 123. View of white near-vertical shoreline cliffs, along the southern margin of Copco-1 reservoir. Note the slope failures and their proximity to private residences. Photo by M. McCulla, 11/16/09.

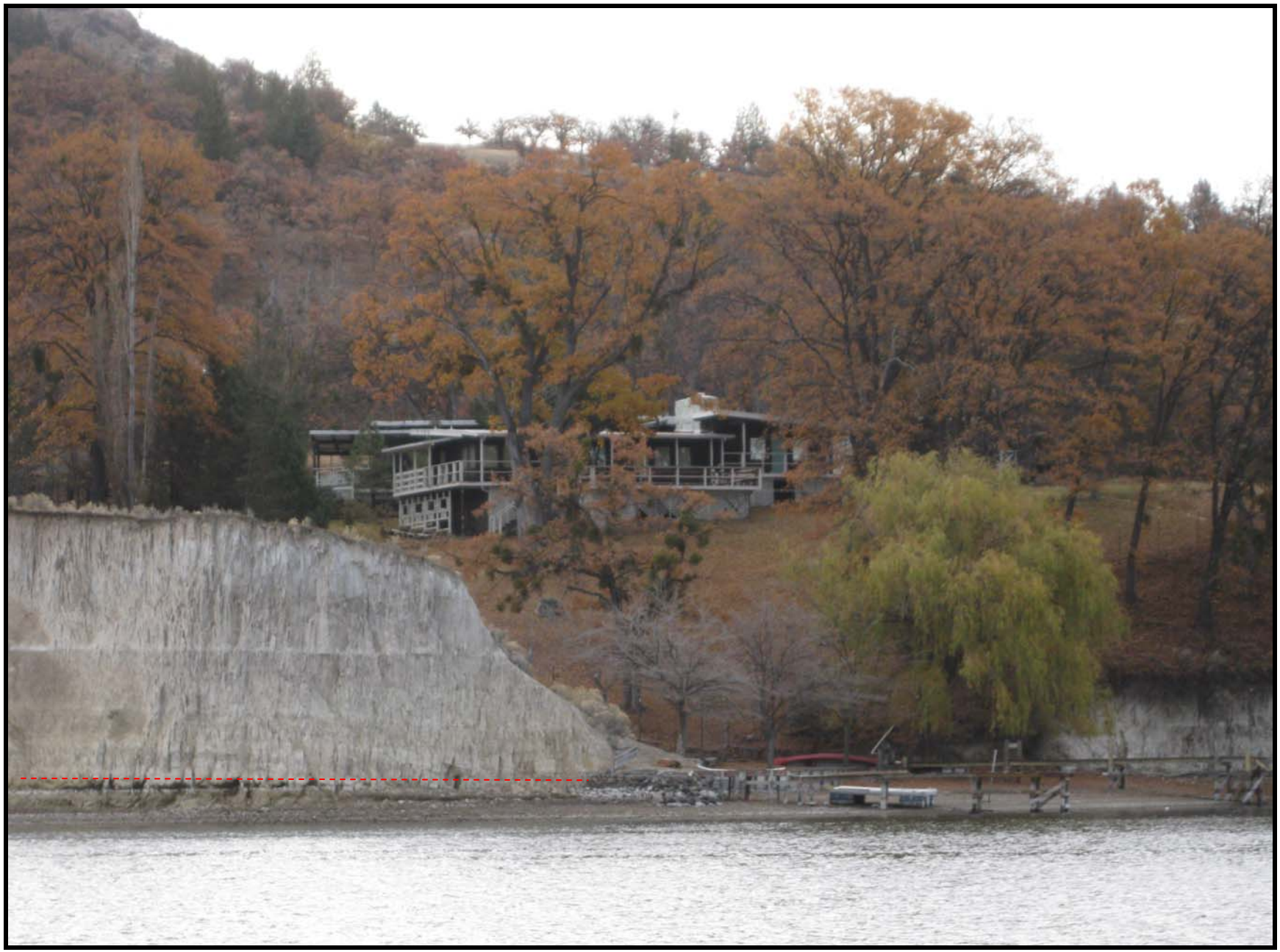


Photo 124. View of white near-vertical shoreline cliffs and private residential development along the southern margin of Copco-1 reservoir. A contact between two geologic units with potentially different hydraulic conductivity and erodibility properties may be present below the dashed red line. Photo by M. McCulla, 11/16/09.

Photo 125. View of white near-vertical shoreline cliffs and private residential development along the southern margin of Copco-1 reservoir. A contact between two geologic units with potentially different hydraulic conductivity and erodibility properties may be present below the dashed red line. Photo by M. McCulla, 11/16/09.

Photo 126. View of private residences and near-vertical shoreline cliffs along the southern side of Copco-1 reservoir. Photo by M. McCulla, 11/16/09.

Photo 127. Downstream view of Copco-1 reservoir near the dam. The massive andesitic volcanic unit shown in the center of the photo forms the right (northern) abutment of Copco-1 Dam. Photo by M. McCulla, 11/16/09.

Copco-1 Reservoir

Sediment Sampling

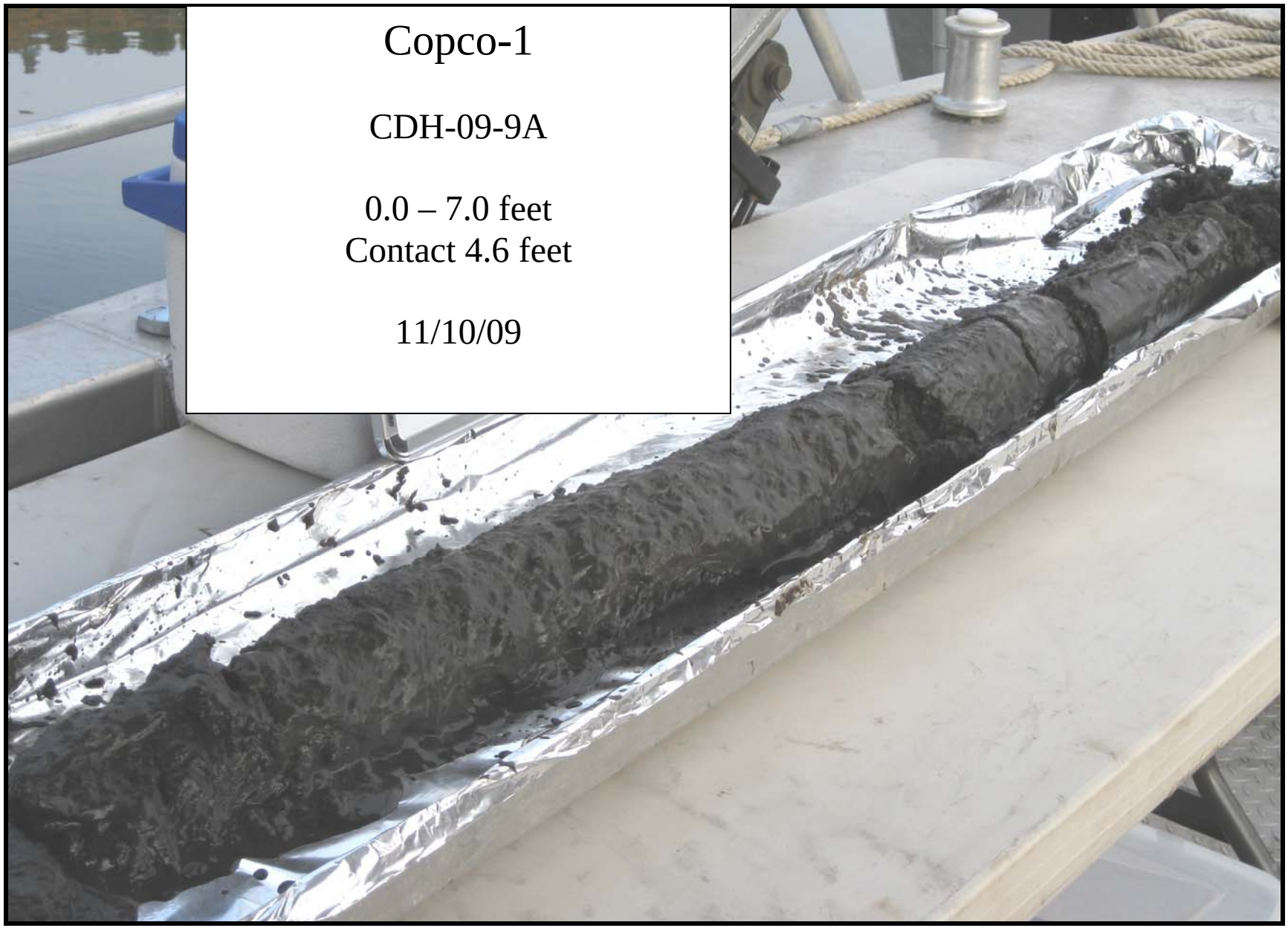


Photo 128. View of sediment sample collected from drill hole CDH-09-9A using the direct-push/hammer method with the 4.0 inch o.d. by 3-3/4 inch i.d. sample tube. The upper 4.6 feet is reservoir sediment composed of Elastic Silt with Sand (MH)s, containing about 20% fine sand, and pre-reservoir Lean Clay with Sand (CL)s is from 4.6 to 7.0 feet (the end of the hole). Photo by M. McCulla, 11/10/09.

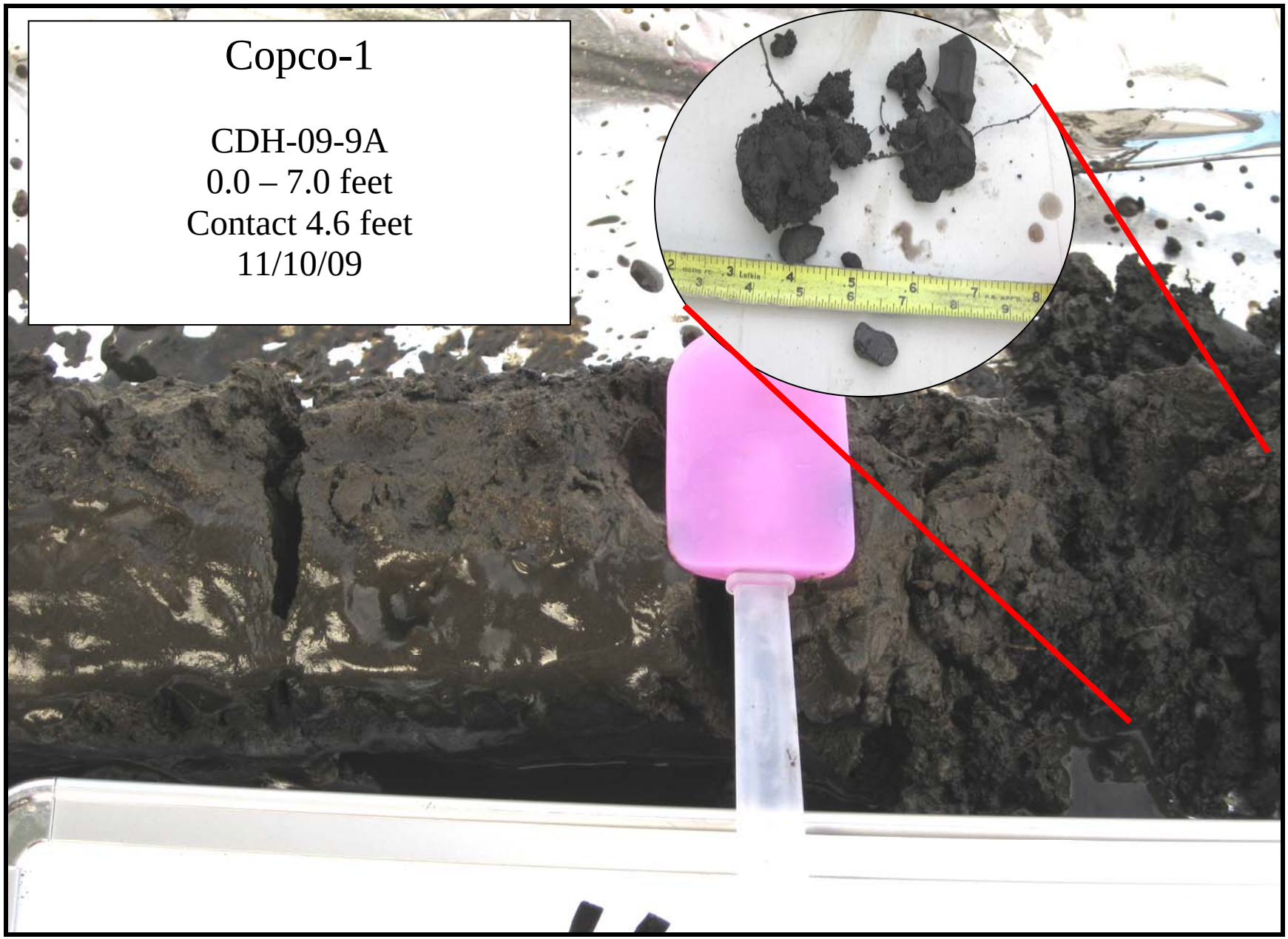


Photo 129. View of the contact between Elastic Silt with Sand (MH)s reservoir sediment left of the spatula and pre-reservoir volcaniclastic rock weathered to Lean Clay with Sand and trace gravel (CL)s to the right. The enlarged cutout shows gravel up to 10mm in size and plant roots present in the volcaniclastic rocks. Photo by M. McCulla, 11/10/09.

Copco-1
CDH-09-9A
0.0 – 7.0 feet
Contact 4.6 feet
11/10/09

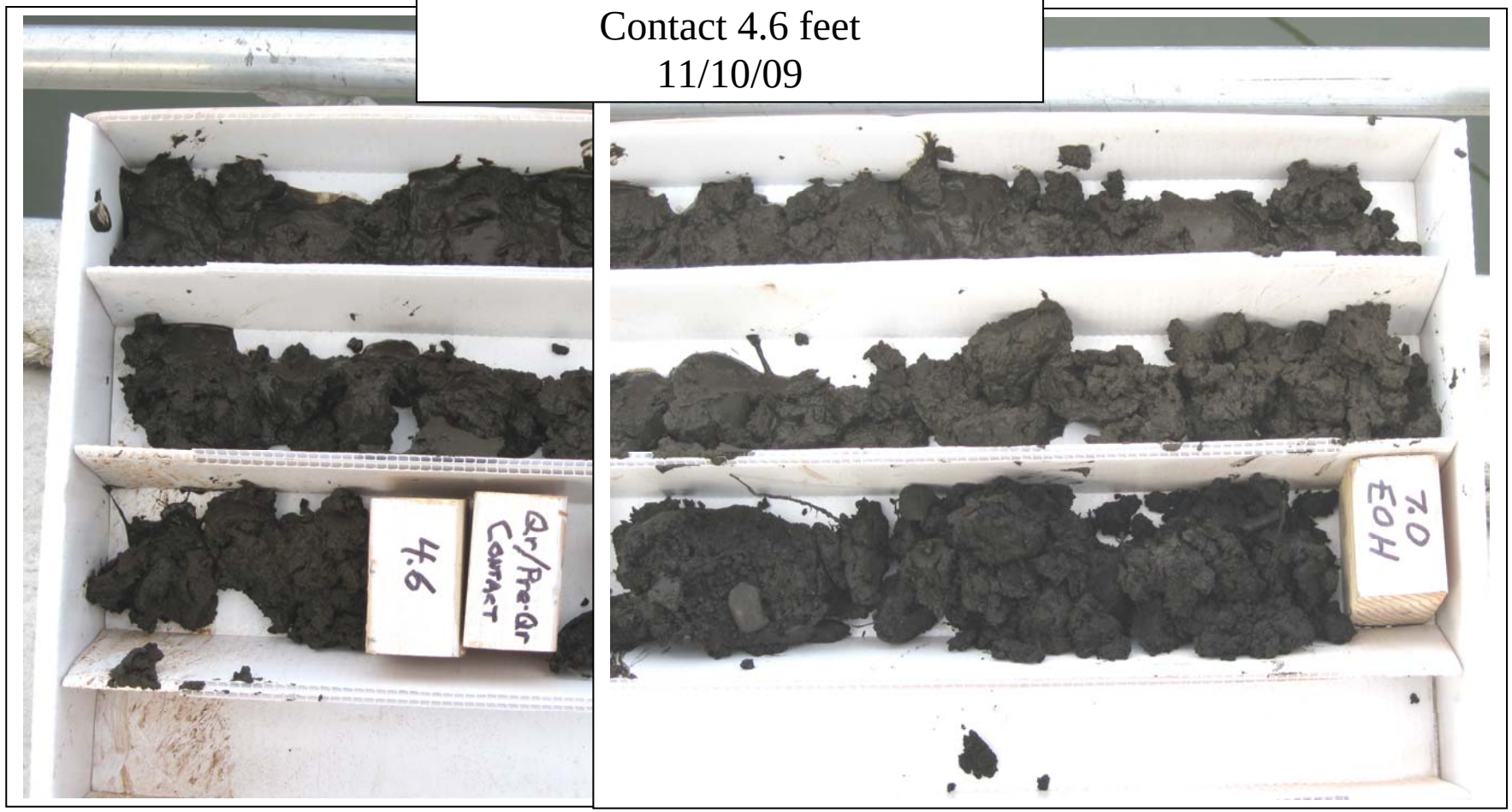


Photo 130. View of material recovered from Copco-1 reservoir in drill hole CDH-09-9A, near the upper end of the reservoir. The upper 4.6 feet is reservoir sediment composed of Elastic Silt with Sand (MH)s, containing about 20% fine sand, and pre-reservoir volcaniclastic rock weathered to Lean Clay with Sand and Trace Gravel (CL)s is from 4.6 to 7.0 feet (the end of the hole). Maximum gravel size is about 10mm. Photo by M. McCulla, 11/10/09.

Photo 131. View of sampling in Copco-1 reservoir at drill hole CDH-09-10. Two attempts were made with the direct-push/hammer method. The second attempt met refusal at 8.5 feet, recovered 7.9 feet, and the reservoir sediment / pre-reservoir sediment contact was determined to be at a depth of 8.0 feet. Photo by M. McCulla, 11/10/09.

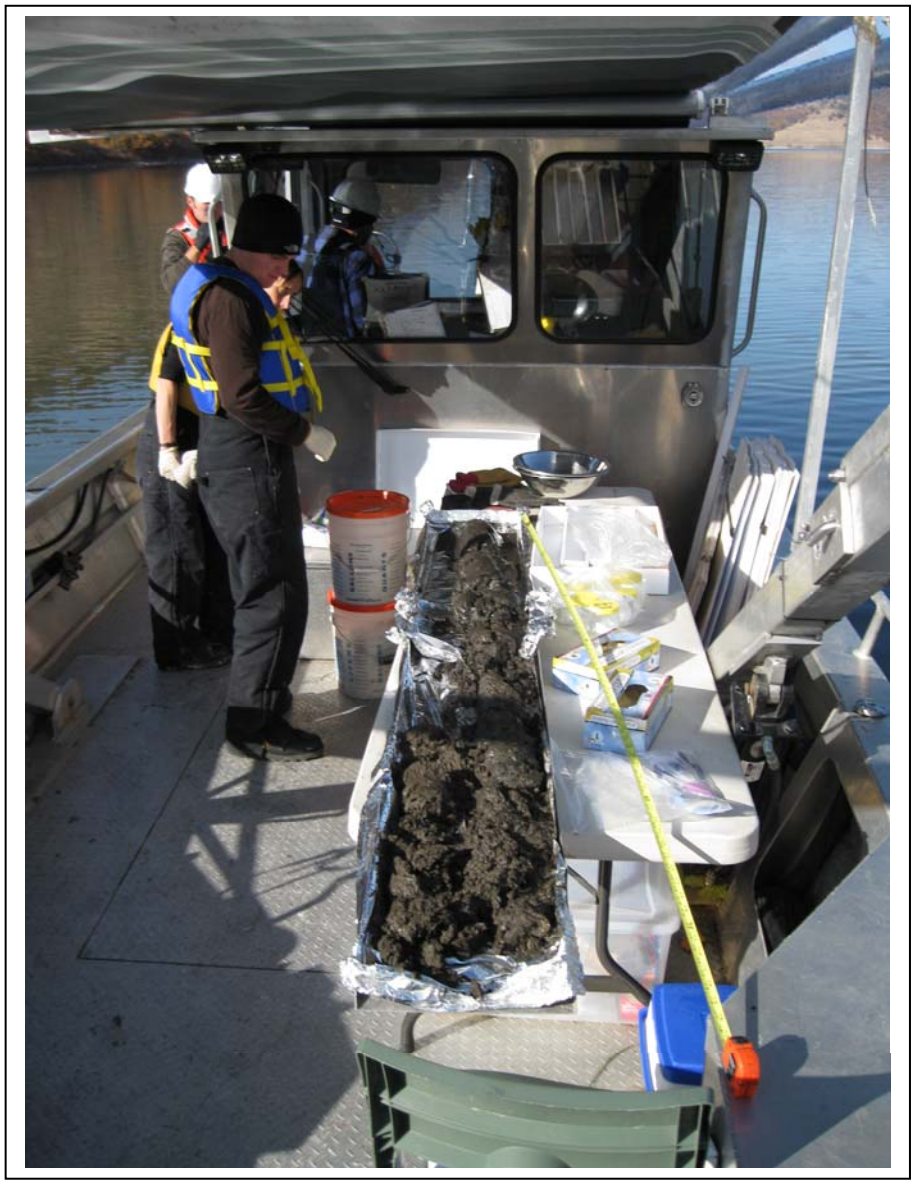


Photo 132. View of material being extracted (left) and prepared for sampling (right) from drill hole CDH-09-10 in Copco-1 reservoir. Two attempts were made with the direct-push/hammer method. The second attempt met refusal at 8.5 feet, recovered 7.9 feet, and the reservoir sediment / pre-reservoir sediment contact was determined to be at a depth of 8.0 feet. Photo by M. McCulla, 11/10/09.

Photo 133. View of material recovered from drill hole CDH-09-10 in Copco-1 reservoir. Seen here is the contact between reservoir sediment (left) and a mass of plants, wood, and roots in Silty Sand – SM (right). Photo by M. McCulla, 11/10/09.

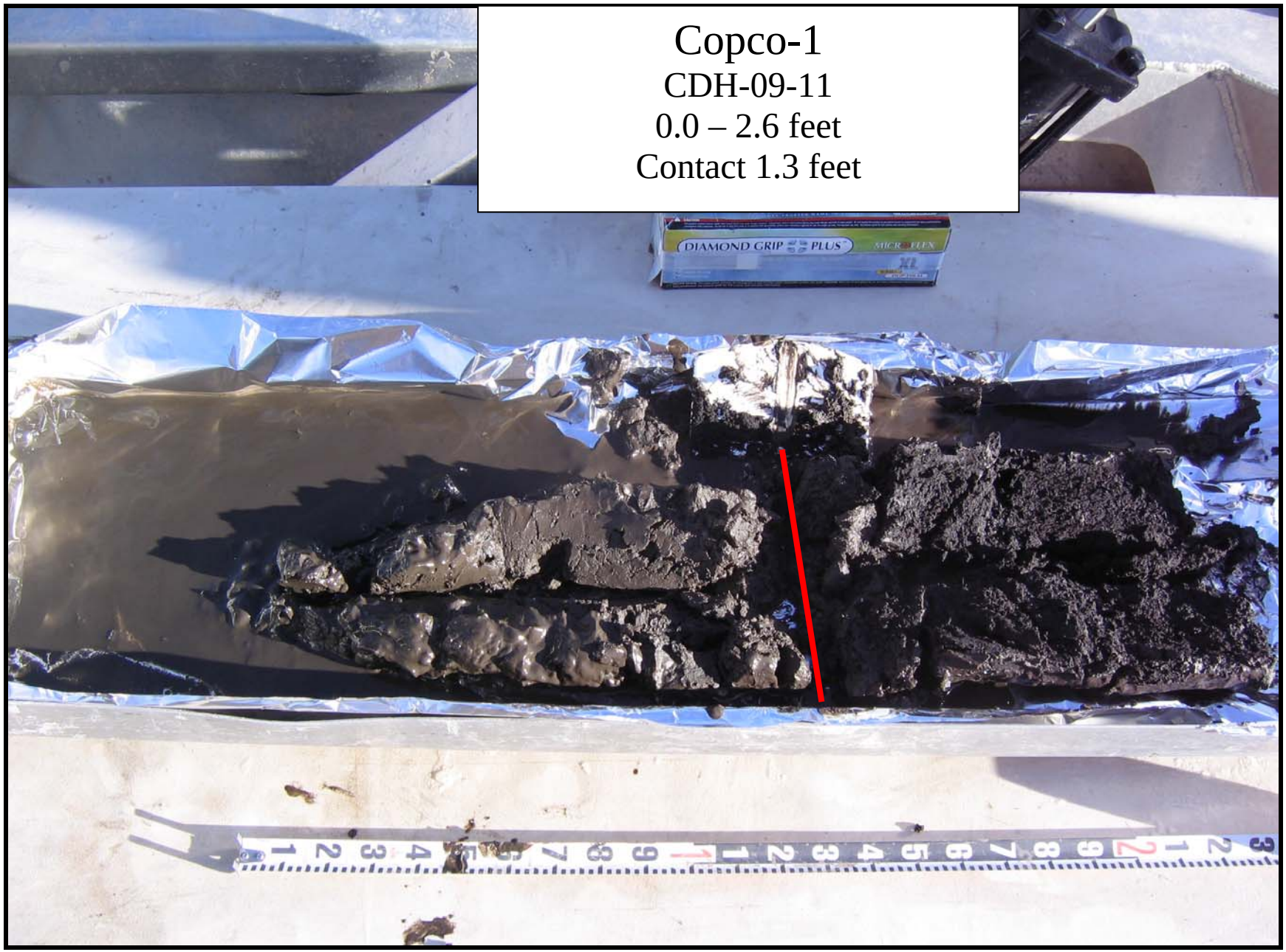


Photo 134. View of material recovered from drill hole CDH-09-11 in Copco-1 reservoir. The red line is at the contact between Elastic Silt – MH reservoir sediment (left side) and Fat Clay with Sand and Trace Gravel (CL)s (right side). Photo by G. Mongano, 11/15/09.

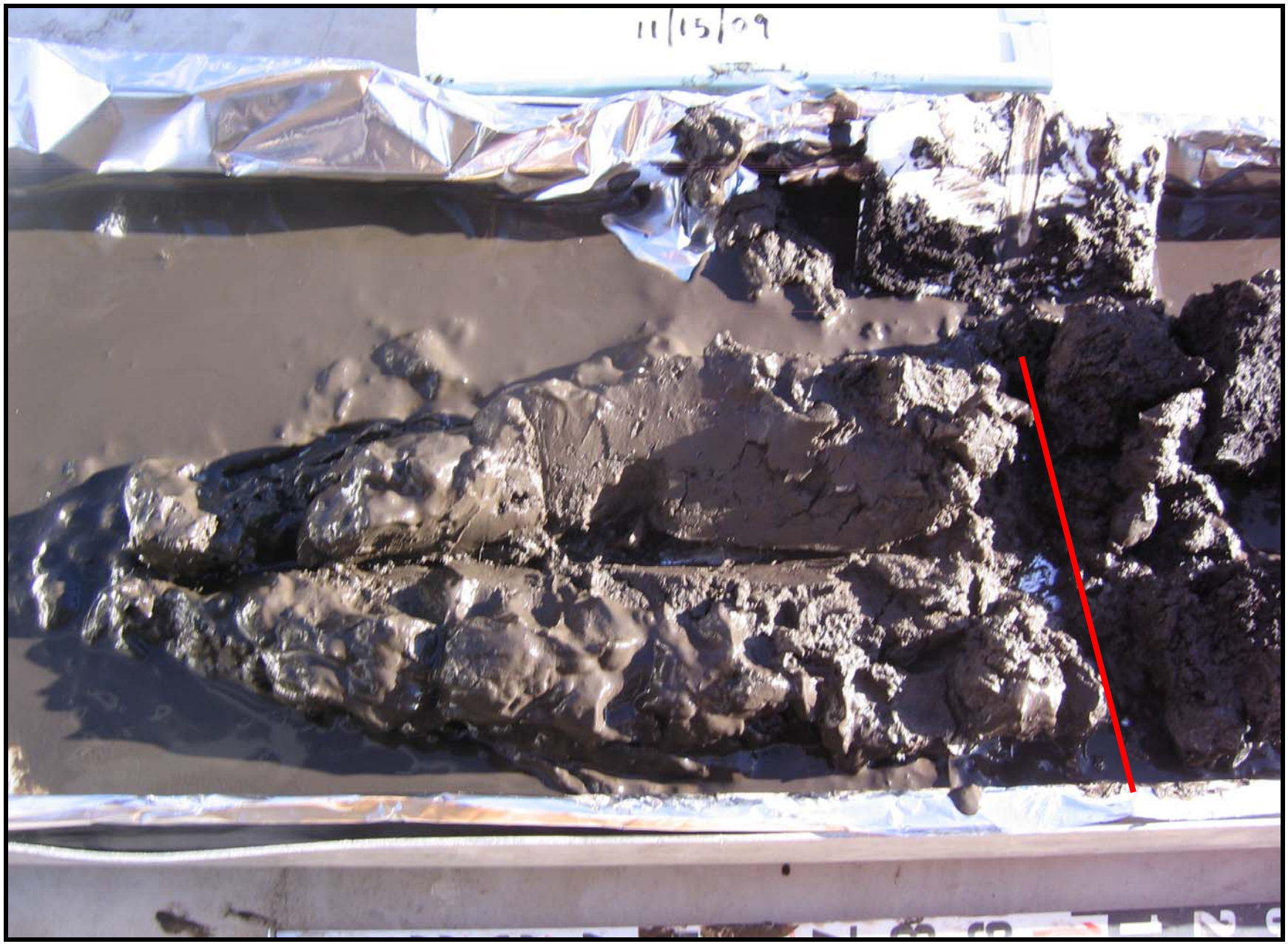


Photo 135. Close up view of material recovered from drill hole CDH-09-11 in Copco-1 reservoir. The red line is at the contact between Elastic Silt – MH reservoir sediment (left side) and Fat Clay with Sand and Trace Gravel (CL)s (right side) at a depth of 1.3 feet. Photo by G. Mongano, 11/15/09.

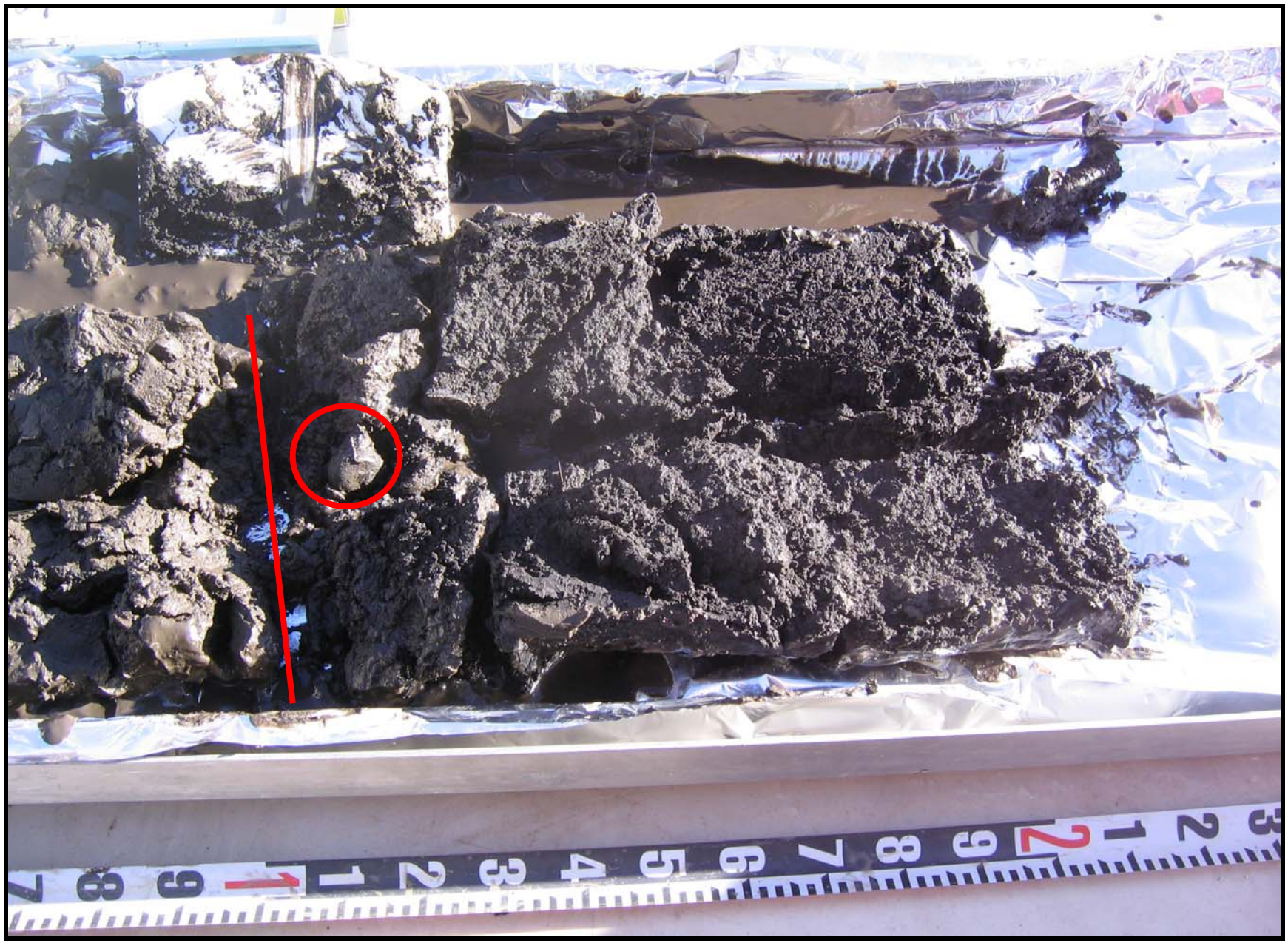


Photo 136. Close up view of material recovered from drill hole CDH-09-11 in Copco-1 reservoir. The red line is at the contact between Elastic Silt – MH reservoir sediment (left side) and Fat Clay with Sand and Trace Gravel (CL)s (right side) at a depth of 1.3 feet. Inside the red circle is a 12mm piece of hard, subrounded gravel. Photo by G. Mongano, 11/15/09.

Photo 137. View of material being extracted from drill hole CDH-09-12 in Copco-1 reservoir. The direct-push/hammer method of sampling was used, with refusal at a depth of 8 feet. The reservoir sediment / pre-reservoir contact was at a depth of 5.4 feet. Photo by M. McCulla, 11/10/09.

Photo 138. View of the material recovered from drill hole CDH-09-12 in Copco-1 reservoir. The reservoir sediment / pre-reservoir contact is at a depth of 5.4 feet (marked by the sediment tool). The pre-reservoir material is volcaniclastic rock decomposed to Silt with Sand and trace gravel (ML)s; maximum size 10mm. Photo by M. McCulla, 11/10/09.

Photo 139. View of the upper two feet of reservoir sediment collected from drill hole CDH-09-12 in Copco-1 reservoir. A gloved finger was run down the core to show that it has the consistency of pudding. Photo by M. McCulla, 11/10/09.

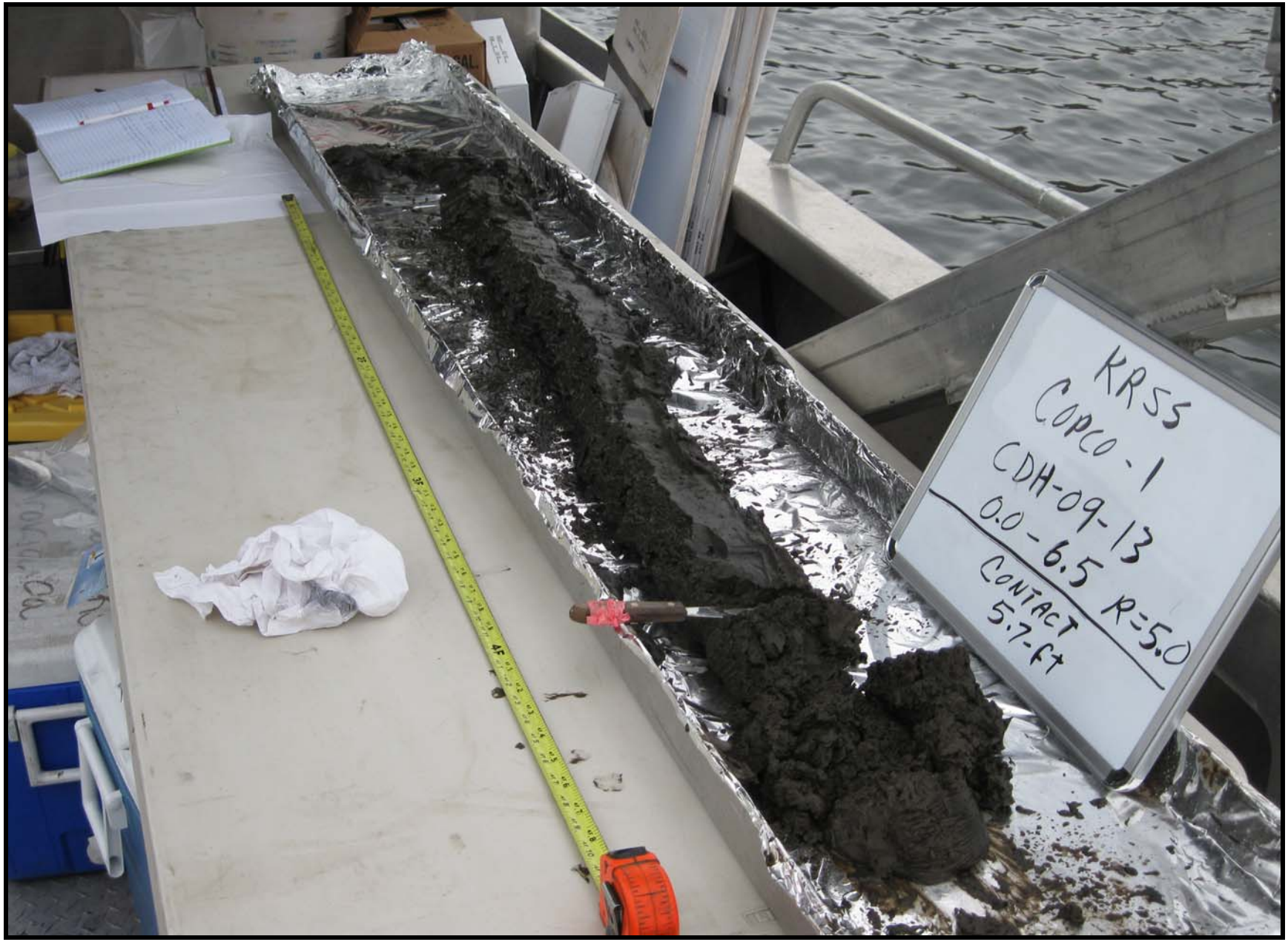


Photo 140. View of material collected from drill hole CDH-09-13 in Copco-1 reservoir. The hole was drilled to a depth of 6.5 feet and the reservoir sediment / pre-reservoir material contact was at a depth of 5.7 feet (at the sediment tool). Photo by M. McCulla, 11/11/09.

Photo 141. View of Elastic Silt – MH reservoir sediment collected from drill hole CDH-09-13. It has the consistency of pudding and contains an estimated 2% to 5% methane bubbles distributed throughout. Photo by M. McCulla, 11/11/09.

Photo 142. Close up view of Elastic Silt – MH reservoir sediment from drill hole CDH-09-13. The sediment has a consistency of pudding and contains an estimated 2% to 5% methane bubbles distributed throughout. Photo by M. McCulla, 11.11.09.

Photo 143. View of reservoir sediment and pre-reservoir material recovered from Attempt #1 for drill hole CDH-09-14 in Copco-1 reservoir. The final attempt was at a slightly different location and encountered 5.3 feet of reservoir sediment. Photo by G. Mongano, 11/15/09.

Photo 144. View of Elastic Silt – MH reservoir sediment from Attempt #1 for drill hole CDH-09-14 in Copco-1 reservoir. The final attempt was at a slightly different location and encountered 5.3 feet of reservoir sediment. Photo by G. Mongano, 11/15/09.

Photo 145. View of the contact (1.8 feet) between Elastic Silt – MH reservoir sediment (left of red line) and Clayey Sand (SC) to Silty Sand (SM) with trace gravel; maximum size 12mm; from Attempt #1 for drill hole CDH-09-14 in Copco-1 reservoir. The final attempt was at a slightly different location and encountered 5.3 feet of reservoir sediment. Photo by G. Mongano, 11/15/09.

Photo 146. View of Elastic Silt – MH reservoir sediment collected from drill hole CDH-09-15A in Copco-1 reservoir. The contact between reservoir sediment and pre-reservoir volcaniclastic rock (Silt to Lean Clay) is at a depth of 9.7 feet. Photo by G. Mongano, 11/12/09.

Photo 147. View of Elastic Silt – MH reservoir sediment collected from drill hole CDH-09-15A in Copco-1 reservoir. The contact between reservoir sediment and pre-reservoir volcaniclastic rock (Silt to Lean Clay) is at a depth of 9.7 feet. Photo by G. Mongano, 11/12/09.

Photo 148. View of material collected from drill hole CDH-09-16 in Copco-1 reservoir. Three drilling methods were used here, direct-push, hammer, and vibracore and all met refusal at a depth of 7.5 feet. The presence of matted grass from 7.2 to 7.5 feet, with refusal is interpreted as the contact with pre-reservoir volcanic rock. Photo by G. Mongano, 11/13/09.

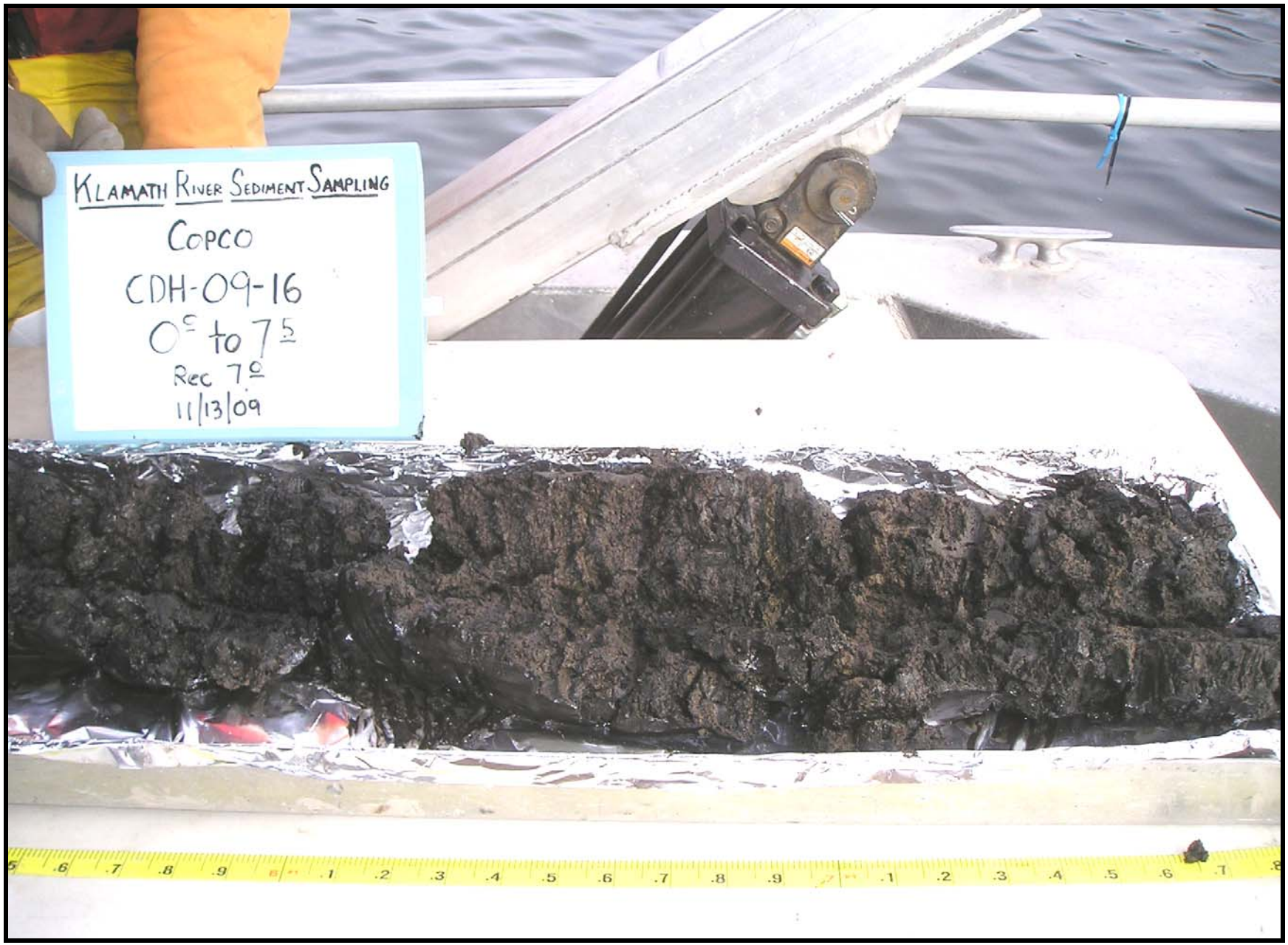


Photo 149. View of material collected from drill hole CDH-09-16 in Copco-1 reservoir. Three drilling methods were used here, direct-push, hammer, and vibracore and all met refusal at a depth of 7.5 feet. The presence of matted grass from 7.2 to 7.5 feet, with refusal is interpreted as the contact with pre-reservoir volcanic rock. Photo by G. Mongano, 11/13/09.

Photo 150. Close up view of material collected from drill hole CDH-09-16 in Copco-1 reservoir (Photo 149). Note the thin layering of the reservoir sediment with alternating dark brown and light brown color. Photo by G. Mongano, 11/13/09.

Photo 151. View of Elastic Silt – MH reservoir sediment (left of red line) in contact (at 1.3 feet) with pre-reservoir volcaniclastic rock composed of Silty Sand with Trace Gravel – SM and Sandy Lean Clay with Trace Gravel s(CL), maximum size 25mm, from drill hole CDH-09-17 in Copco-1 reservoir. Photo by G. Mongano, 11/14/09.

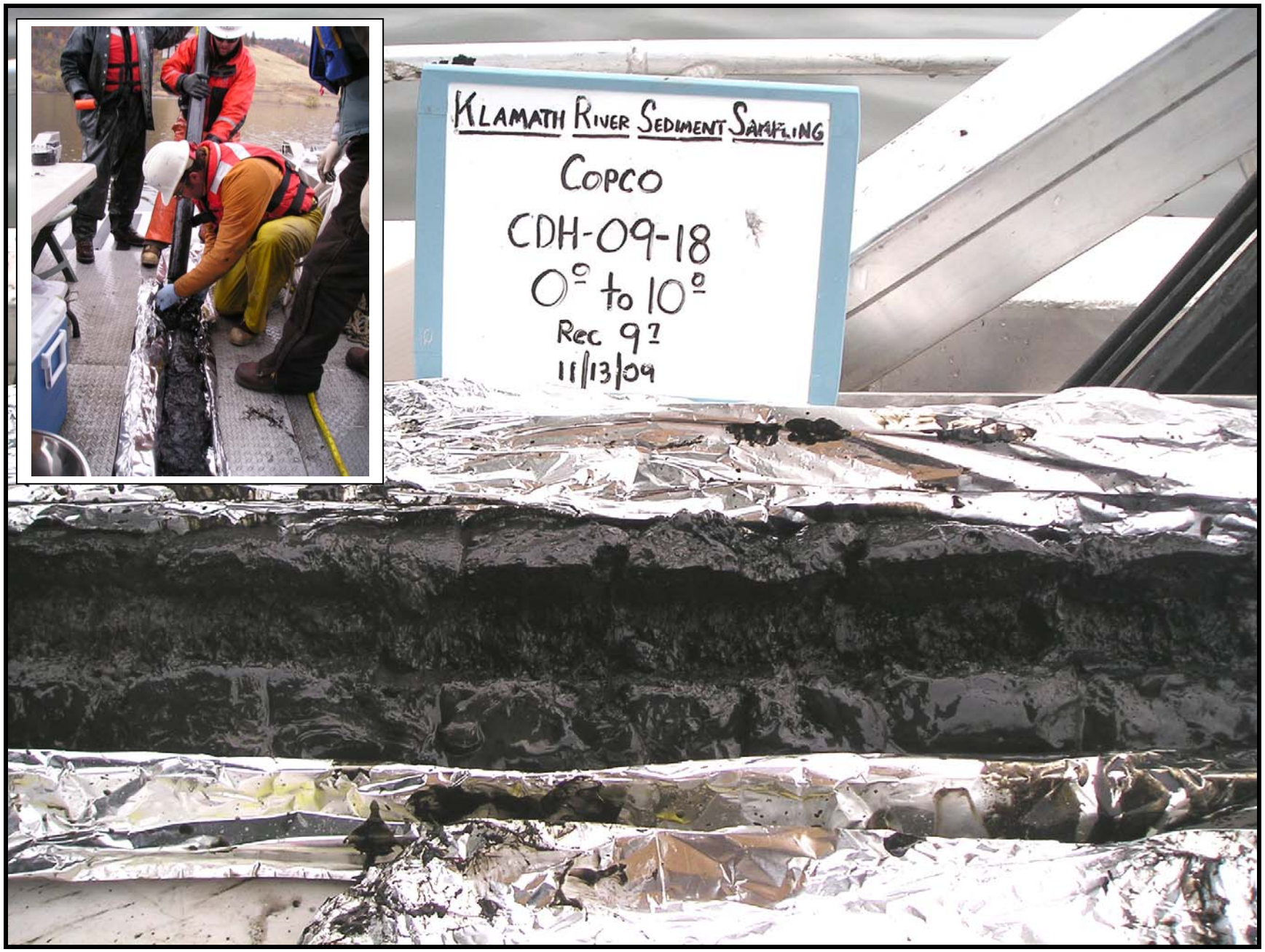


Photo 152. View of Elastic Silt – MH reservoir sediment collected from drill hole CDH-09-18 in Copco-1 reservoir. Photo by G. Mongano, 11/13/09.

Photo 153. View of Elastic Silt – MH reservoir sediment collected from drill hole CDH-09-18 in Copco-1 reservoir. Photo by G. Mongano, 11/13/09.

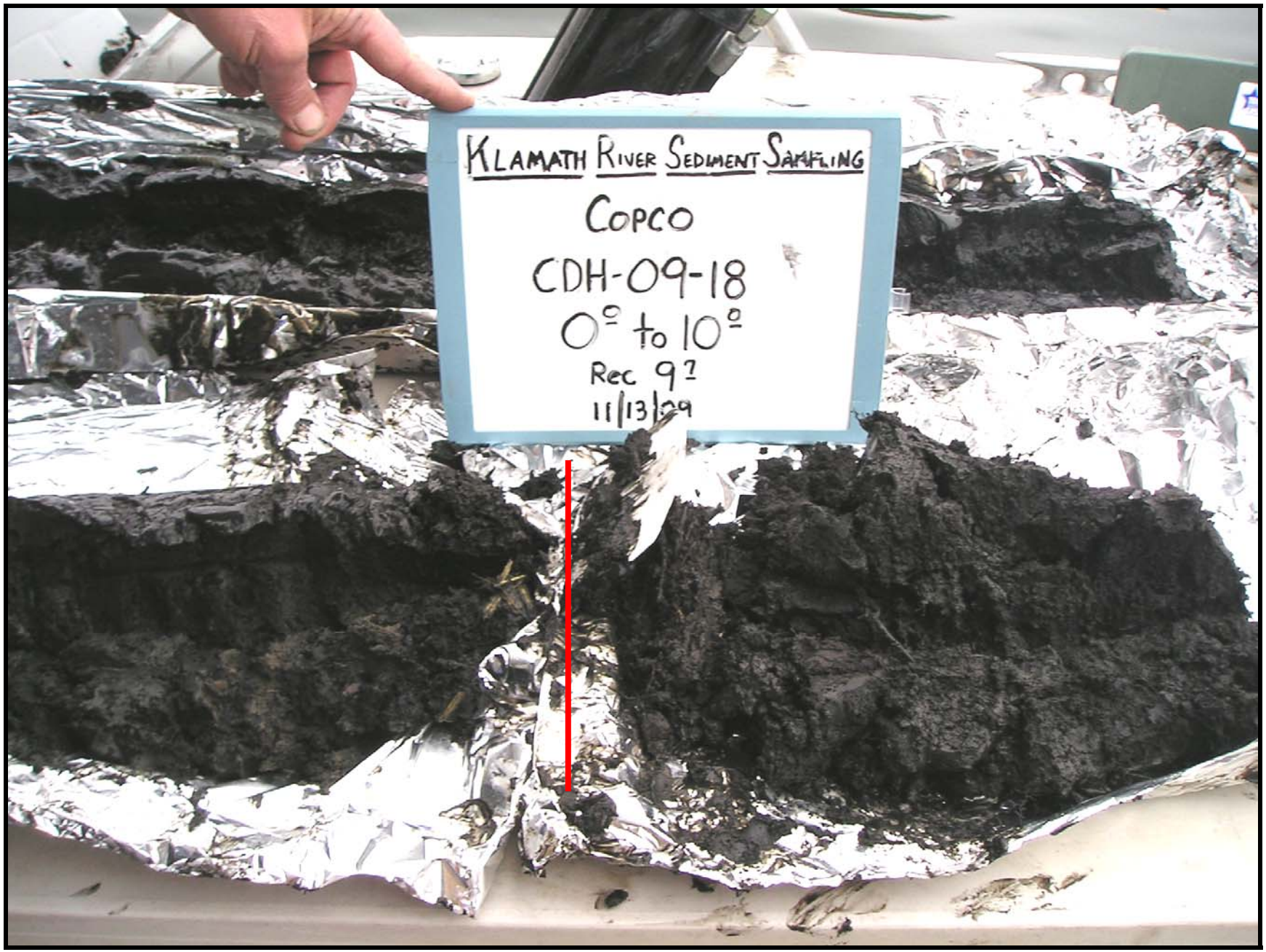


Photo 154. View of the contact between Elastic Silt – MH reservoir sediment (left of red line) and pre-reservoir weathered volcaniclastic rock (right of red line) collected from drill hole CDH-09-18 in Copco-1 reservoir. Photo by G. Mongano, 11/13/09.

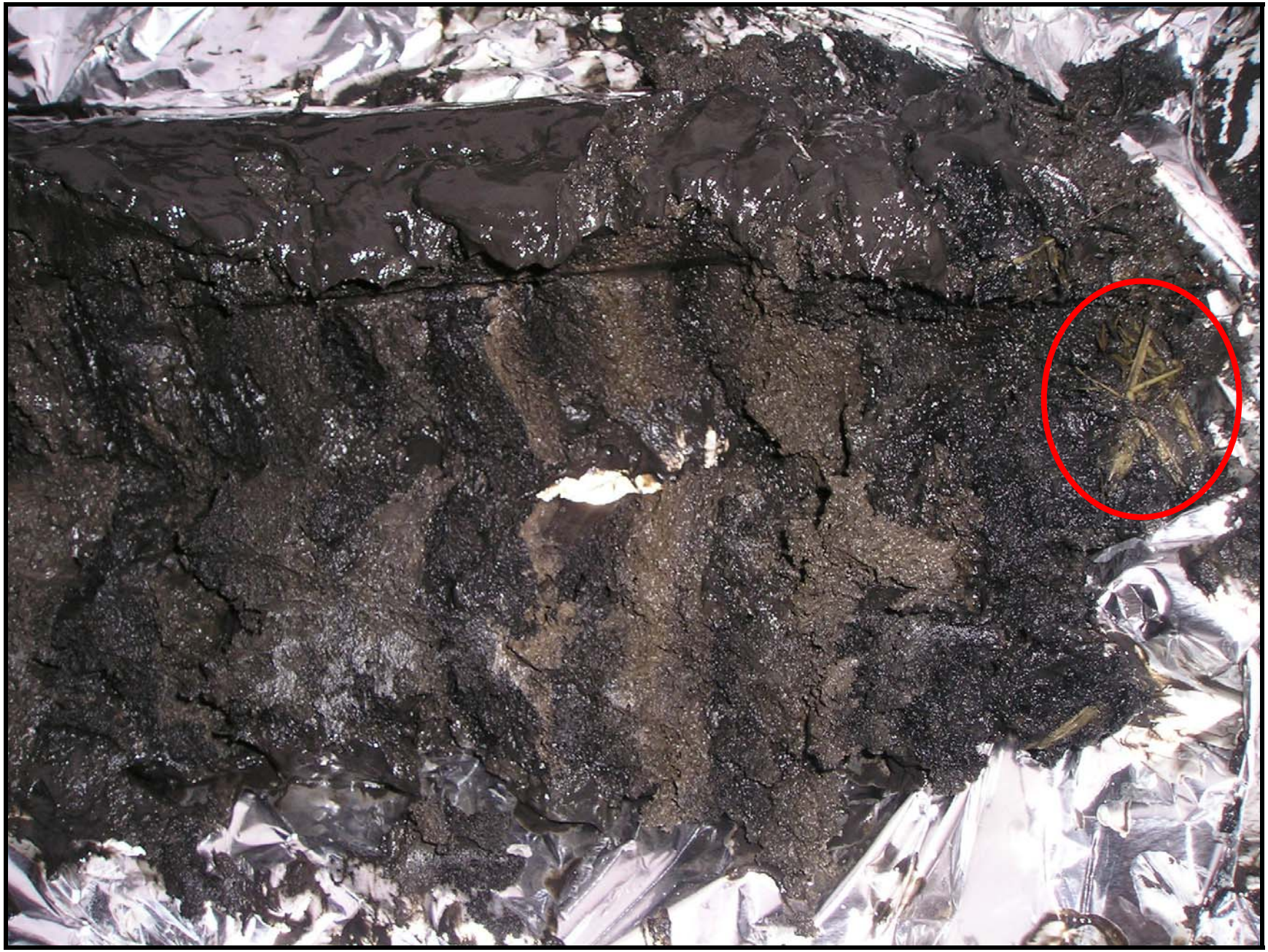


Photo 155. Close up view of layered Elastic Silt – MH reservoir sediment just above the contact with pre-reservoir volcaniclastic rocks in drill hole CDH-09-18. The plant material inside the red circle is at the contact. Photo by G. Mongano, 11/13/09.

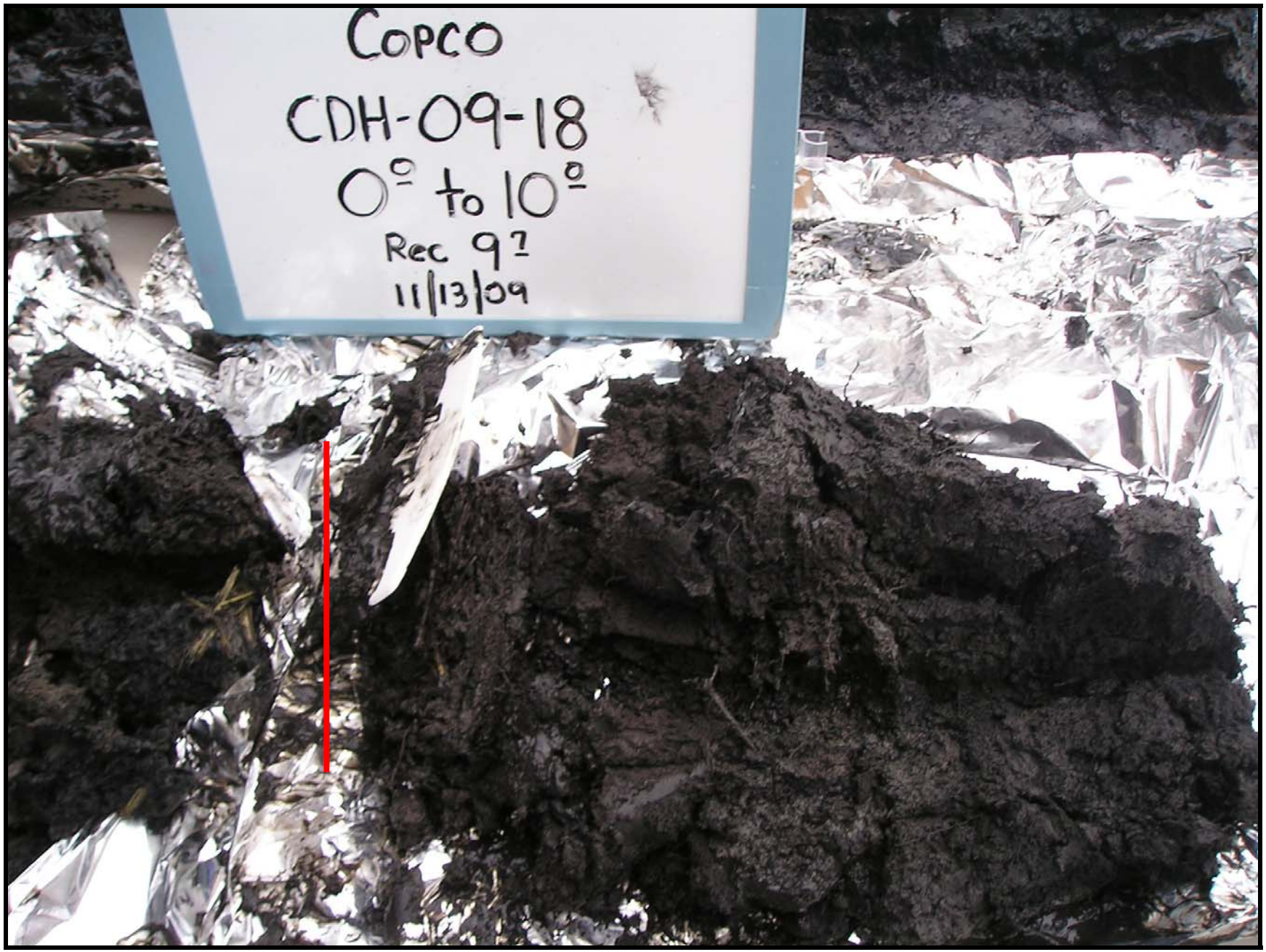


Photo 156. View of the contact between Elastic Silt – MH reservoir sediment (left of red line) and pre-reservoir weathered volcaniclastic rock (right of red line) collected from drill hole CDH-09-18 in Copco-1 reservoir. Photo by G. Mongano, 11/13/09.

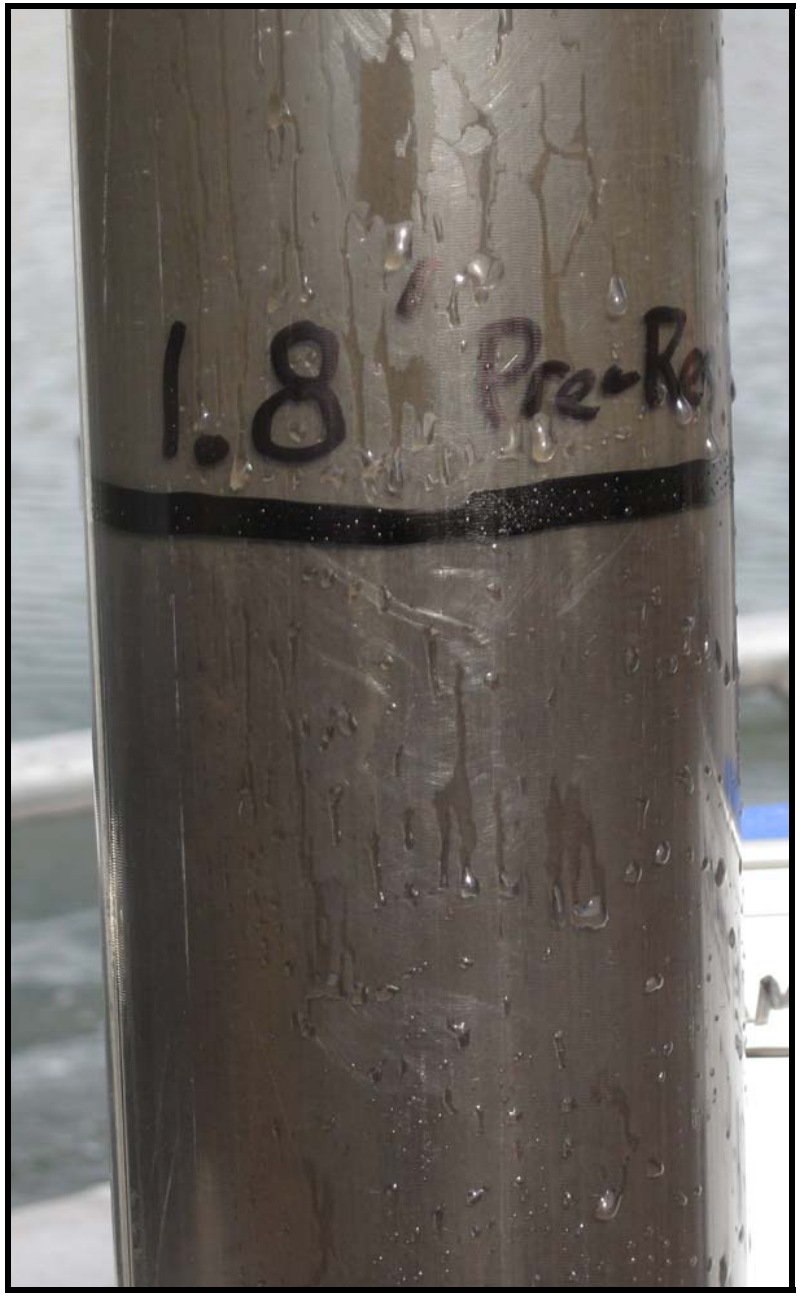


Photo 157. View of undisturbed sample (collected using the vibracore method) from drill hole EDH-09-7 in Copco-1 reservoir. The sample is from 0.0 to 2.85 feet, with a contact between Elastic Silt – MH reservoir sediment and pre-reservoir weathered volcaniclastic rock at a depth of 1.8 feet. Photo by G. Mongano, 11/16/09.

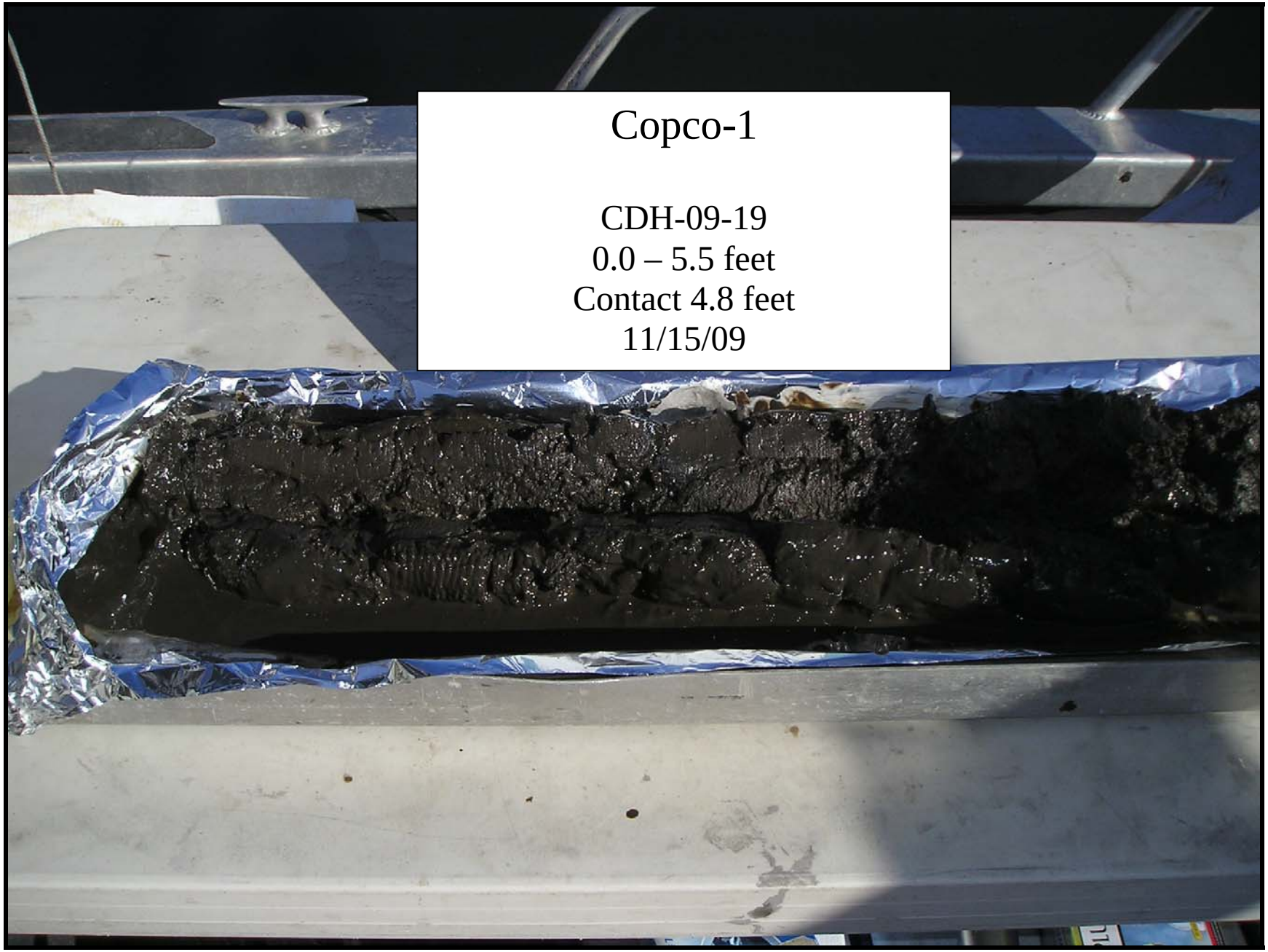


Photo 158. View of Elastic Silt – MH reservoir sediment collected from drill hole CDH-09-19 in Copco-1 reservoir. The contact with pre-reservoir weathered volcaniclastic rock is at a depth of 4.8 feet. Photo by G. Mongano, 11/14/09.

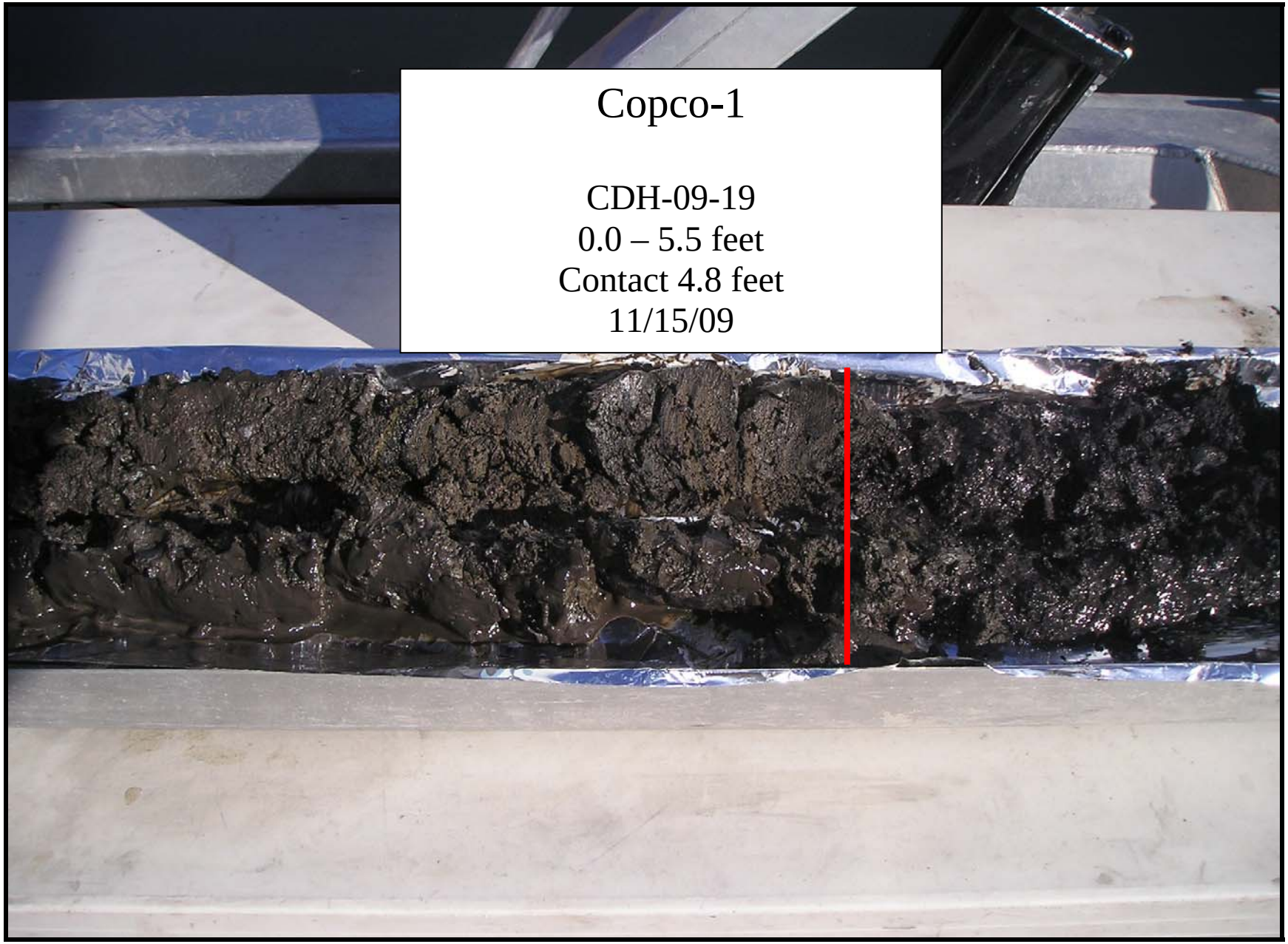


Photo 159. View of Elastic Silt – MH reservoir sediment collected from drill hole CDH-09-19 in Copco-1 reservoir. The contact with pre-reservoir weathered volcaniclastic rock is at a depth of 4.8 feet (red line). Photo by G. Mongano, 11/14/09.

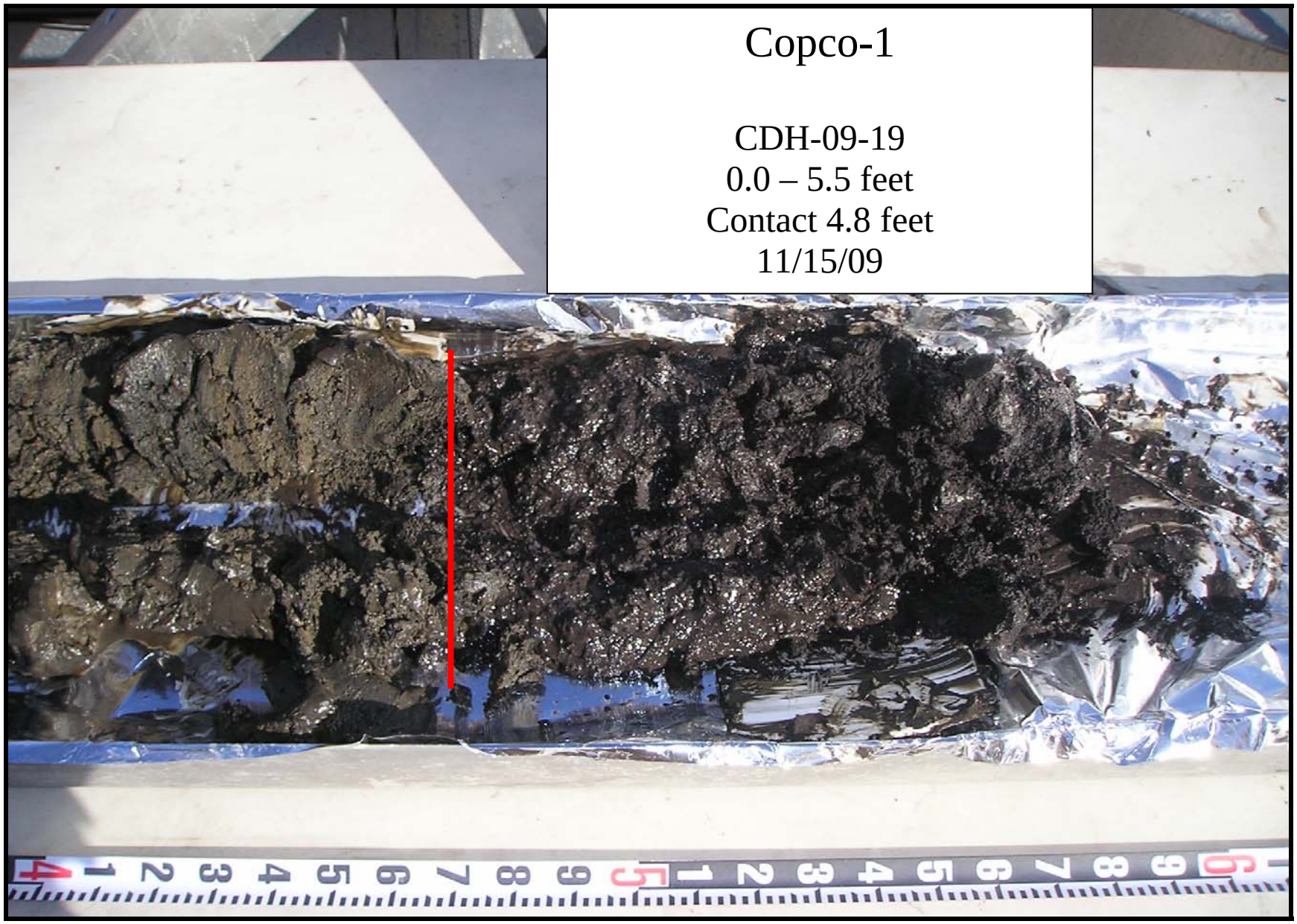


Photo 160. View of Elastic Silt – MH reservoir sediment (left of red line) and pre-reservoir weathered volcaniclastic rock (right of red line) composed of Clayey Sand – SC, Silty Sand – SM, and Fat Clay with Sand and trace gravel (CH)s, maximum size 70mm, collected from drill hole CDH-09-19 in Copco-1 reservoir. The contact with pre-reservoir weathered volcaniclastic rock is at a depth of 4.8 feet. Photo by G. Mongano, 11/14/09.

Photo 161. View of Elastic Silt – MH reservoir sediment collected from drill hole CDH-09-20 in Copco-1 reservoir. Photo by G. Mongano, 11/14/09.

Photo 162. View of Elastic Silt – MH reservoir sediment from drill hole CDH-09-20 in Copco-1 reservoir. An estimated 10% to 15% methane bubbles are distributed throughout the sediment giving it a sponge-like appearance. Photo by G. Mongano, 11/14/09.

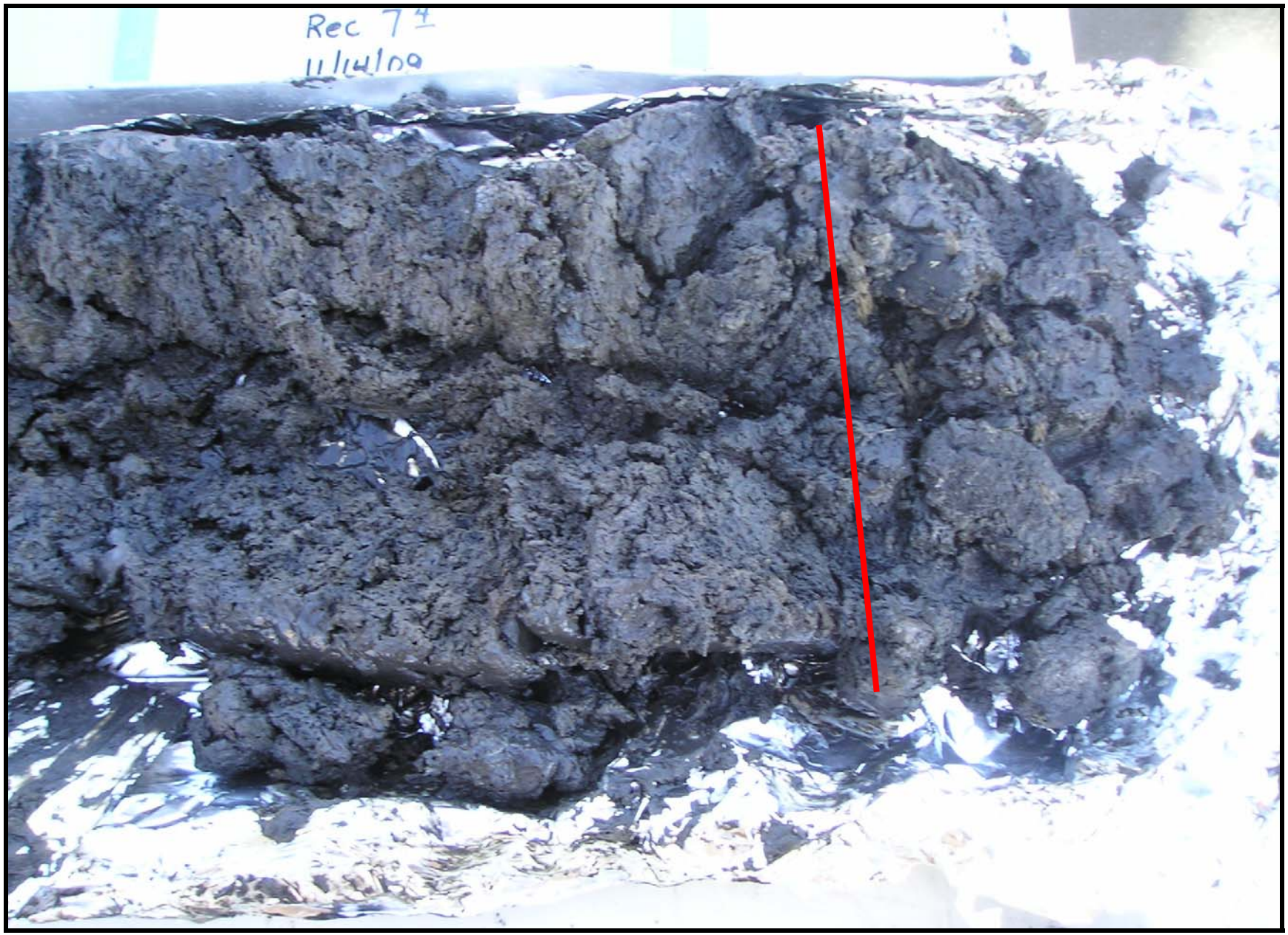


Photo 163. View of the contact (7.4 feet) between Elastic Silt – MH with 10% to 15% methane bubbles (left of red line) and pre-reservoir weathered volcaniclastic rock Lean Clay with Sand and trace gravel (CL)s, maximum gravel 12mm (right of red line) from drill hole CDH-09-20 from Copco-1 reservoir. Photo by G. Mongano, 11/14/09.

Copco-2 Reservoir Geology

Photographs

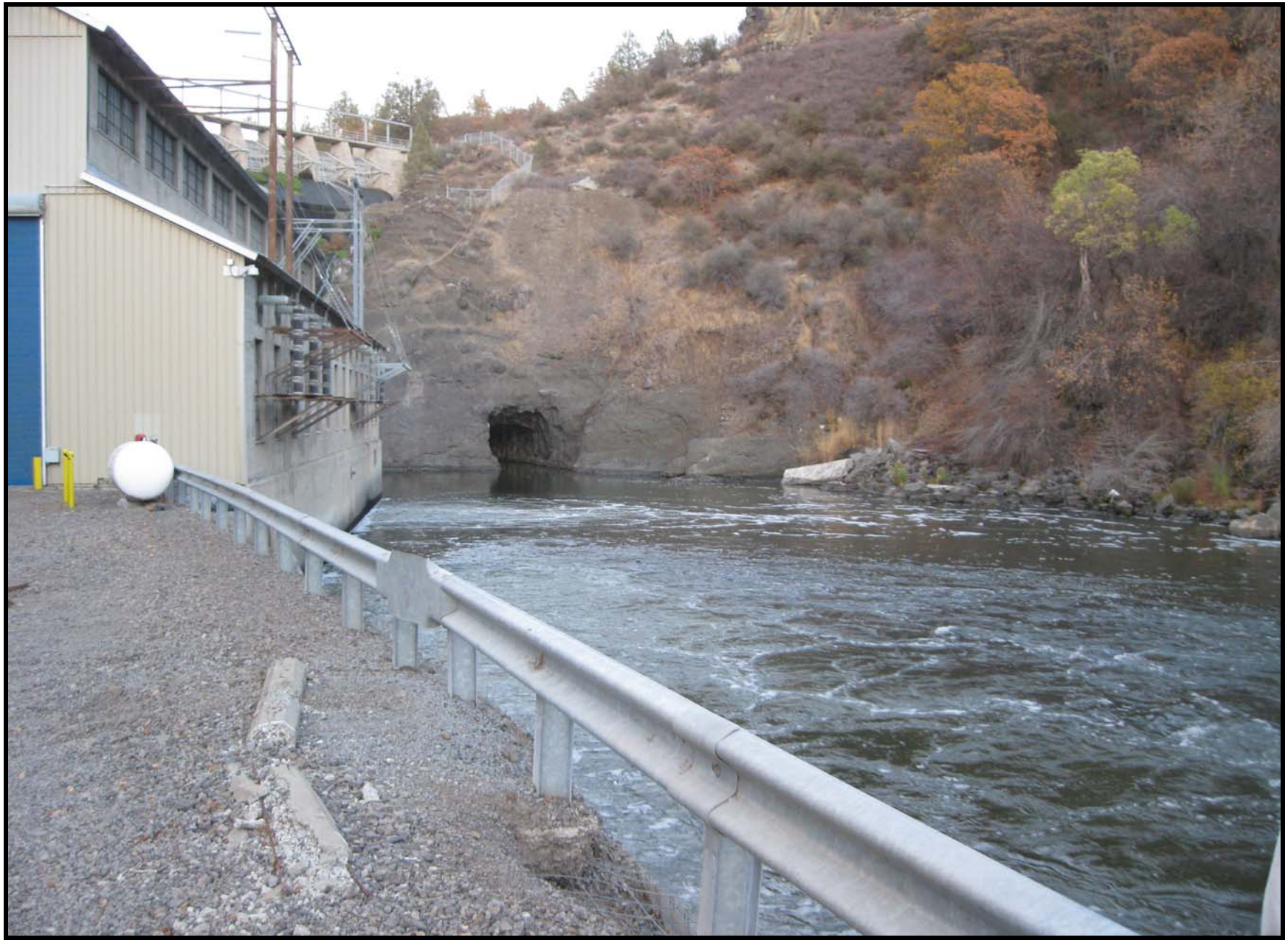


Photo 164. View of the upstream end of Copco-2 reservoir, terminating at Copco-1 Dam. Copco-1 powerhouse and outlet works are shown on the left side of the photo, and the river diversion tunnel is center. Note the rugged channel side slopes, and the turbulent, rapidly-flowing water in the reservoir. Photo by M. McCulla, 11/16/09.

Photo 165. View of the upstream end of Copco-2 reservoir, terminating at Copco-1 Dam. Copco-1 powerhouse and outlet works are shown on the left side of the photo, and the river diversion tunnel is center. Note the rugged channel side slopes, and the turbulent, rapidly-flowing water in the reservoir. Photo by M. McCulla, 11/16/09.

Photo 166. Downstream view of Copco-2 reservoir from the Copco-1 powerhouse. Note the rugged channel side slopes, and the turbulent, rapidly flowing water in the reservoir. Photo by M. McCulla, 11/16/09.

Photo 167. View of Copco-2 reservoir looking downstream towards the dam. Note the steep slopes above the channel, the coarse talus coming into the reservoir, and the turbulent, rapidly-flowing water. Photo by M. McCulla, 12/10/09.

Photo 168. View of the right side-slopes of Copco-2 reservoir next to attempted sample locations CDH-09-33-13, -14, & -15; about 1,000 feet upstream from the dam. Note the abundance of cobble and boulder size volcanic talus, and the rapidly-flowing water. Photo by M. McCulla, 12/10/09.

Photo 169. View of the right side-slopes of Copco-2 reservoir next to attempted sample locations CDH-09-33-7, 8, 9, 10, 11, & 12; about 400 to 700 feet upstream from the dam. Note the abundance of cobble and boulder size volcanic talus. Photo by M. McCulla, 12/10/09.

Photo 170. View of the right side-slopes of Copco-2 reservoir next to attempted sample locations CDH-09-33-7, 8, & 9; about 400 to 500 feet upstream from the dam. Note the abundance of boulder size volcanic talus. Photo by M. McCulla, 12/10/09.

Photo 171. View of the left side-slopes of Copco-2 reservoir next to attempted sample locations CDH-09-33-4, 5, 6, & 6A; about 400 feet upstream from the dam. Note the abundance of cobble and boulder size volcanic talus. Photo by M. McCulla, 12/10/09.

Photo 172. View of Copco-2 dam from the north (right) side of the canyon. Note the steep canyon walls and the coarse talus that forms the reservoir side-slopes. Ice is floating in front of the intake structure. Photo by M. McCulla, 12/10/09.

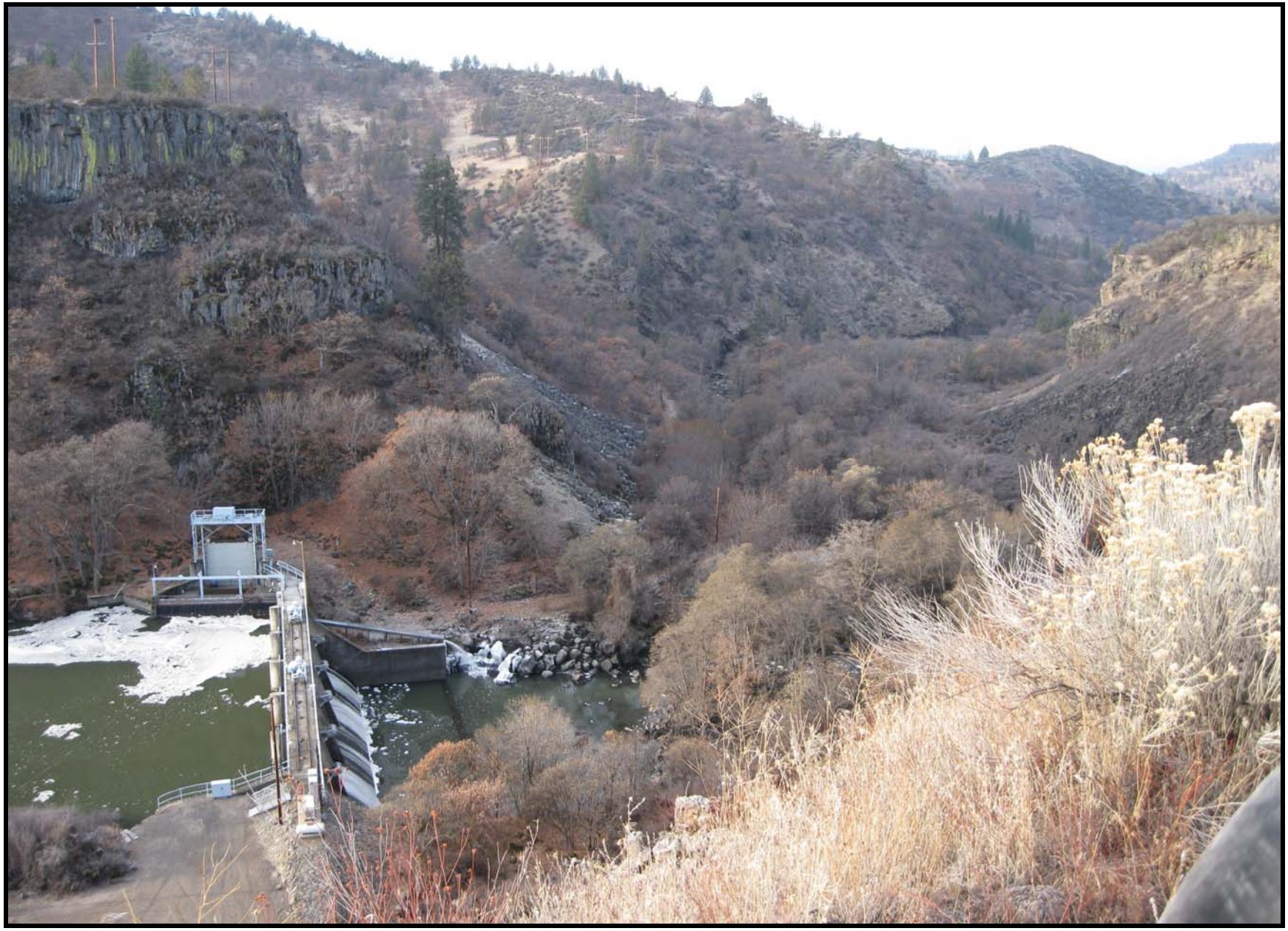


Photo 173. View of Copco-2 dam and the rugged canyon downstream, through which the Klamath River flows. River alluvium between here and Iron Gate Reservoir is expected to be coarse, with very few small pockets where fines could accumulate. Photo by M. McCulla, 12/10/09.

Photo 174. View of the rugged canyon downstream from Copco-2 dam. Here, talus composed mostly of boulders of hard volcanic rock form both sides of the Klamath River channel. Photo by J. Sturm, 12/10/09.

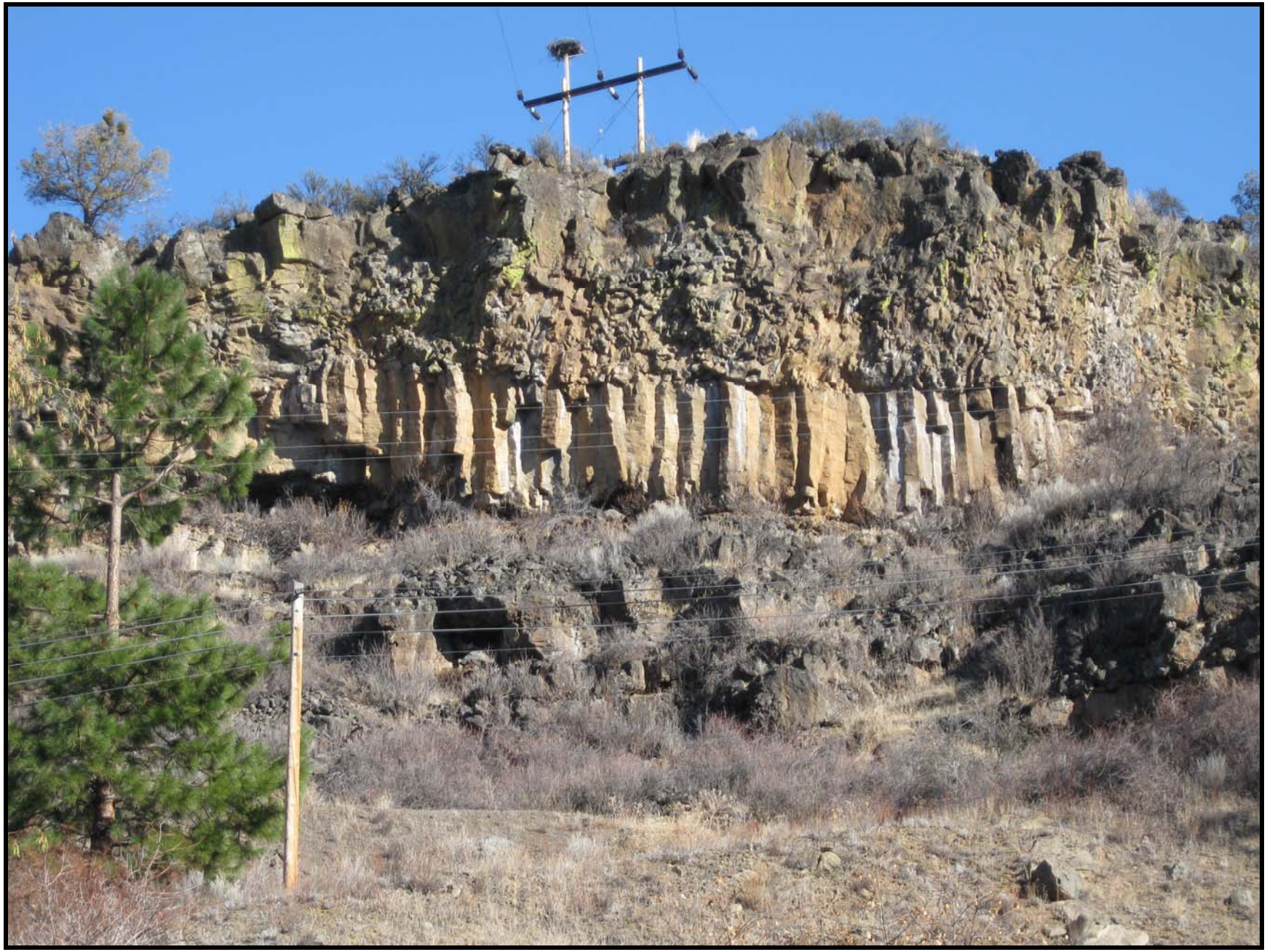


Photo 175. View of Volcanic flows that form the canyon walls above the right abutment of Copco-2 Dam. Photo by M. McCulla, 11/10/09.

Copco-2 Reservoir Sediment Sampling

Photographs

Photo 176. View of the boat launching site on the northern (right) side of Copco-2 Reservoir, a few hundred feet upstream from the dam. Photo by M. McCulla, 12/10/09.

Photo 177. View of the five spillway gates on top of Copco-2 dam and the intake structure (upper left). The first three attempted sampling locations were in front of these gates. Water depth in front of the gates is about 18 feet. Photo by J. Sturm, 12/10/09.

Photo 178. View of spillway Gates 3 & 4 from sample location CDH-09-33-1. Water depth here is about 18 feet. Photo by M. McCulla, 12/10/09.

Photo 179. View of the sampling boat in front of the intake structure at Copco-2 Dam. Note the abundance of ice near the intake. Photo by J. Sturm, 12/10/09.

Photo 180. View of the sample boat moving upstream to location CDH-09-33-7. Note the rapidly-flowing water in the channel upstream of the boat. Photo by J. Sturm, 121/10/09.

Photo 181. View of push tube sampling attempt at location CDH-09-33-7 in Cpoco-2 Reservoir. Photo by J. Sturm, 12/10/09.

Photo 182. View of a small pocket of the finest grained sediment visible during the sediment collection program. This sediment, composed of Poorly Graded Gravel with Silt, Sand, Cobbles, and Boulders was located adjacent to the boat launch site, but may have been bulldozed into its current location during dam construction. Photo by M. McCulla, 12/10/09.

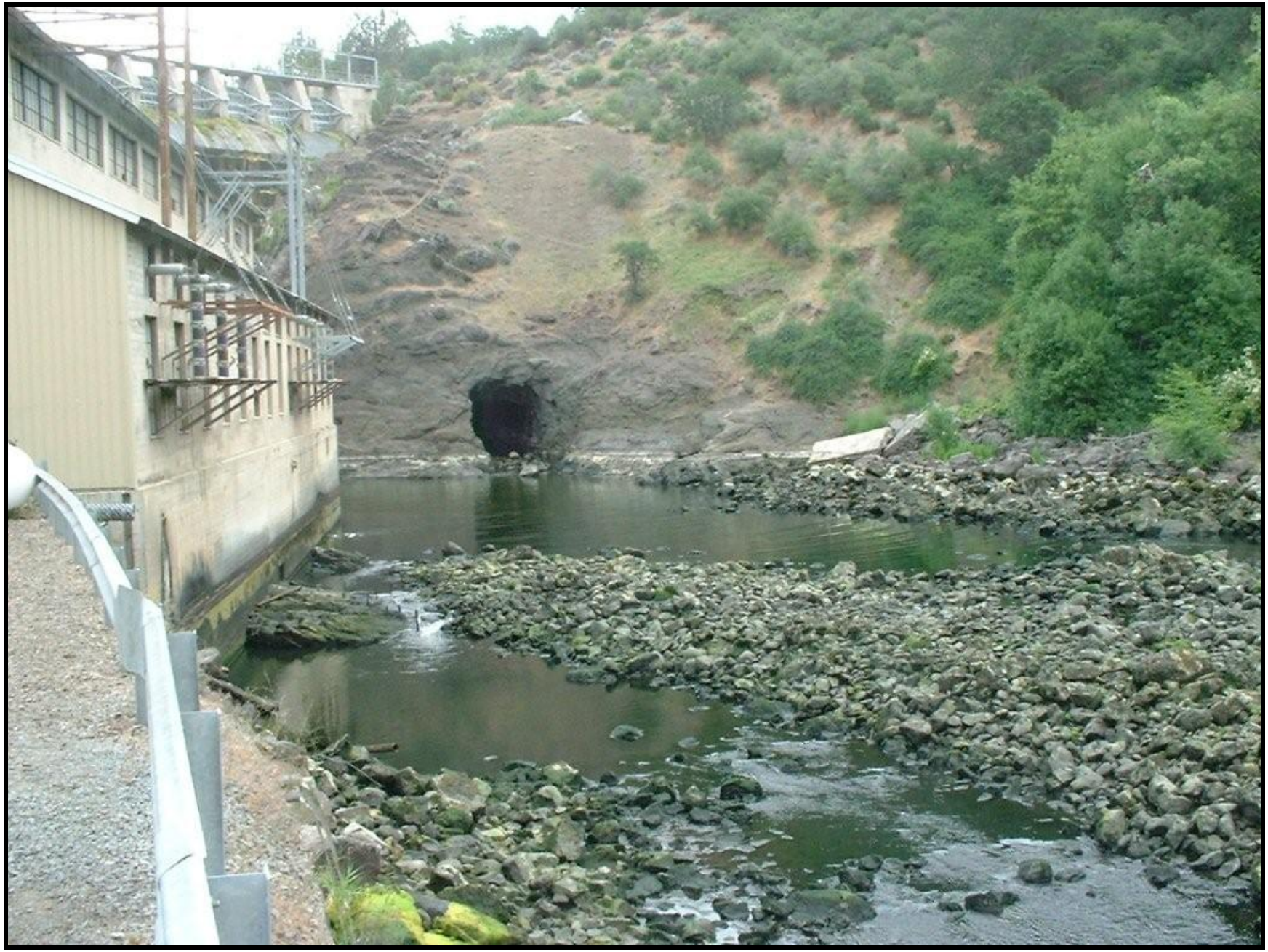


Photo 183. Upstream view of Copco-2 Reservoir bottom while it was unwatered (date unknown). Note the abundance of angular cobbles and the lack of fine grained sediment. Copco-1 Dam and powerhouse are in the upper-left. Photo provided by PacifiCorp.

Photo 184. Downstream view of Copco-2 Reservoir bottom while it was unwatered (date unknown). Note the abundance of angular cobbles and the lack of fine grained sediment. Copco-1 powerhouse and outlet works are to the right. Photo provided by PacifiCorp.

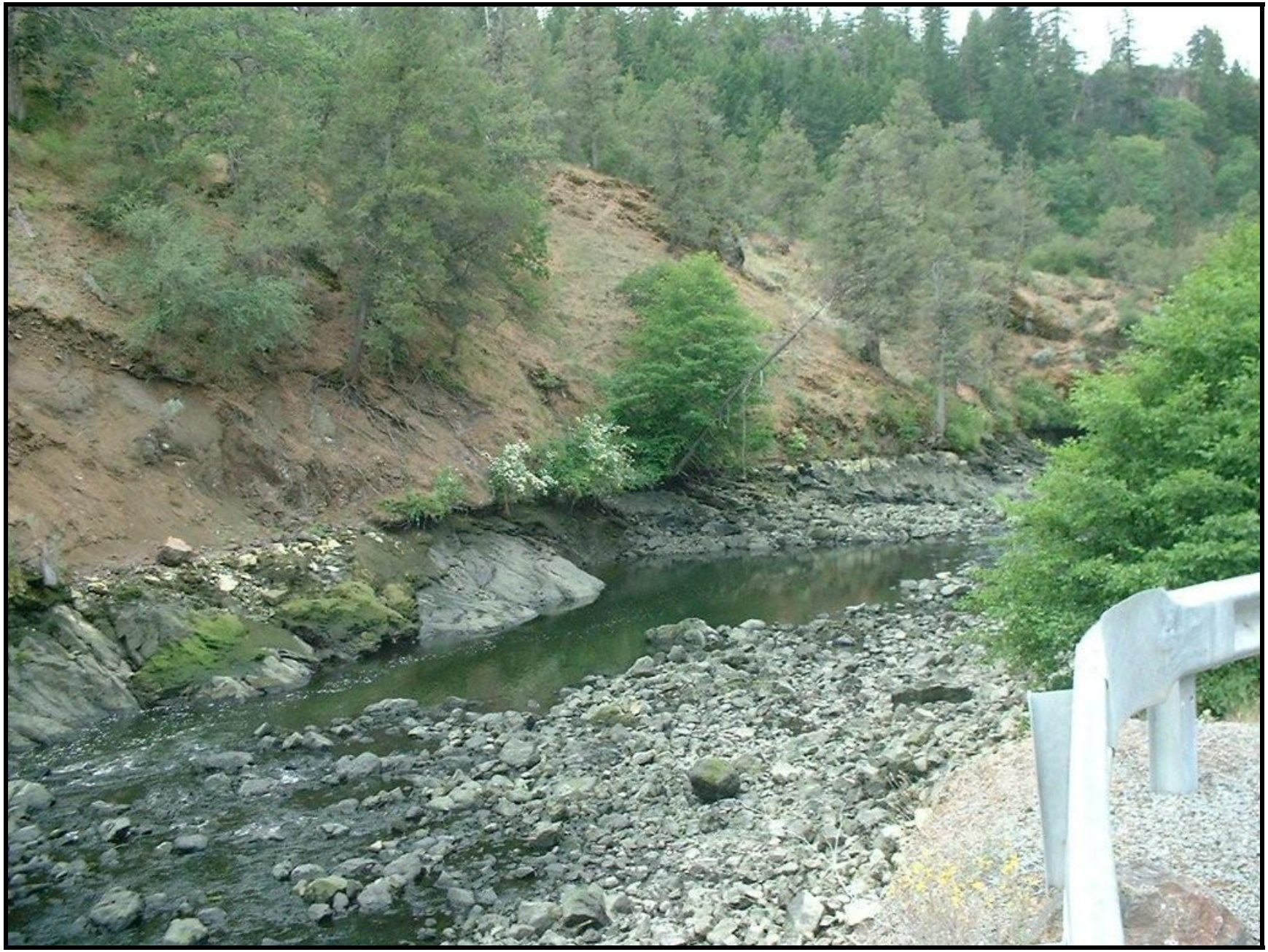


Photo 185. Downstream view of Copco-2 Reservoir bottom while it was unwatered (date unknown). Note the abundance of angular cobbles and the lack of fine grained sediment. Photo provided by PacifiCorp.

Iron Gate Reservoir Geology

Photographs

Photo 186. Upstream view of the Klamath River from a bridge about 3 miles downstream from Iron Gate Dam. White water seen in the photo is an indication of turbulent, rapidly-flowing water over coarse alluvium. Photo by M. McCulla, 6/19/10.

Photo 187. View of the Klamath River from the same bridge used for the previous photo. Coarse alluvium can be seen beneath the rapidly-flowing water. Photo by M. McCulla, 6/19/10.

Photo 188. View of marine sedimentary rocks overlain by volcanic flows, cropping out in a road cut about 3 miles downstream from Iron Gate Dam. Marine rocks mark the beginning of the Klamath Mountains Geomorphic Province. Photo by M. McCulla, 6/19/10.

Photo 189. View of the downstream face of Iron Gate Dam. The abutments of the dam are founded in Tertiary age volcanic rock. Photo by M. McCulla, 1/22/09.

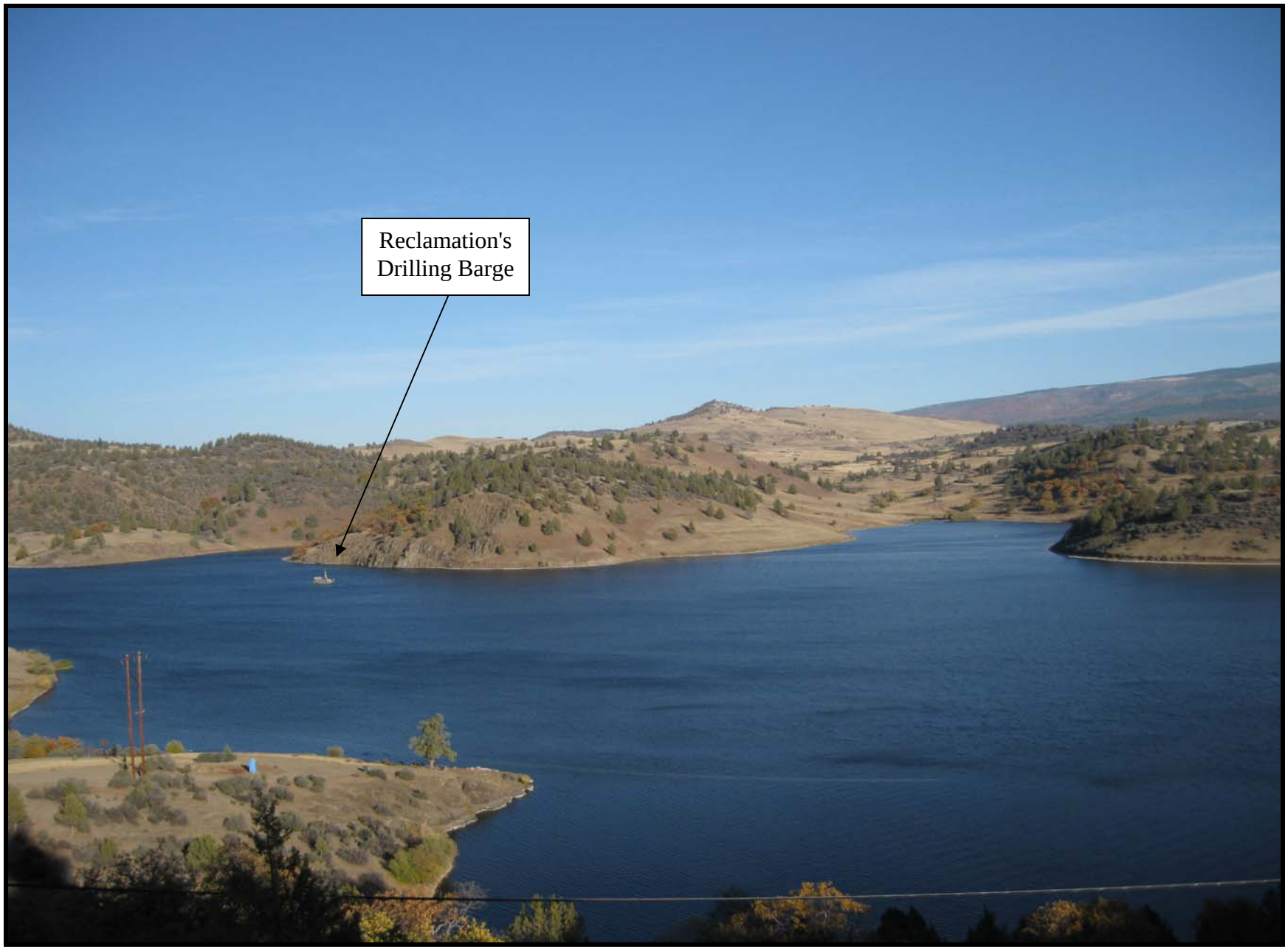


Photo 190. View of Reclamation's barge in the main stem of Iron Gate Reservoir. The reservoir is characterized by a relatively narrow channel with numerous coves and embayments typical of flooded topography. The reservoir is hosted within a complex relationship of clastic volcanic rocks, intrusive rocks, and lava flows. Photo by M. McCulla, 11/4/09.

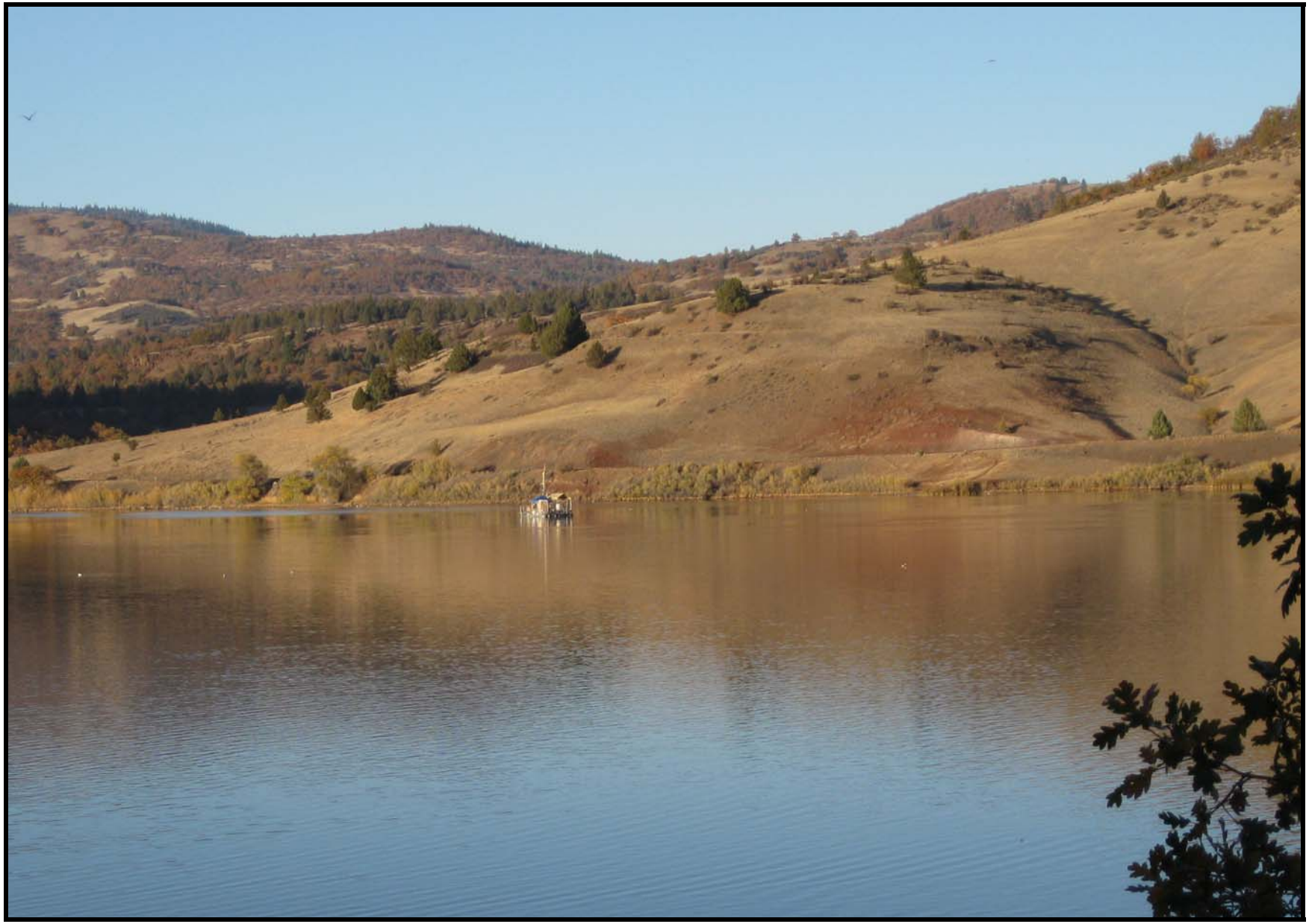


Photo 191. View of Reclamation's drilling barge setting up at drill hole CDH-09-27. Brick-red colored rock in the background may be part of a young cinder cone, along the northern side of Iron Gate Reservoir. Photo by M. McCulla, 11/3/09.

Photo 192. View of Reclamation's drilling barge setting up on drill hole CDH-09-30. Outcrops of massive volcanic flows are exposed along the southern bank. There is a strong regional-scale northeast trending joint system (red line orientation) that regularly fractures the volcanic rock (inset photo). Photo by M. McCulla, 11/4/09.

Photo 193. View of a flow of columnar jointed basalt cut by the Klamath River, about 4-½ miles upstream from Iron Gate Dam. At this point the reservoir narrows to just a few hundred feet across, and the water depth was less than ten feet. Photo by M. McCulla, 1/22/09.

Photo 194. View of "Sentinel Rock" along the southeastern side of Iron Gate Reservoir. These outcrops are remnants of coarse volcaniclastic (pyroclastic) flows. Photo by M. McCulla, 11/15/09.

Iron Gate Reservoir Sediment Sampling

Photographs

Photo 195. View of reservoir sediment / pre-reservoir volcanic contact at a depth of 1.3-feet in auger drill hole CDH-09-21. The volcanic material is tuff and lapilli tuff, weathered to Fat Clay with Gravel and Sand (CH)gs (insert). Photo by M. McCulla, 10/31/09.

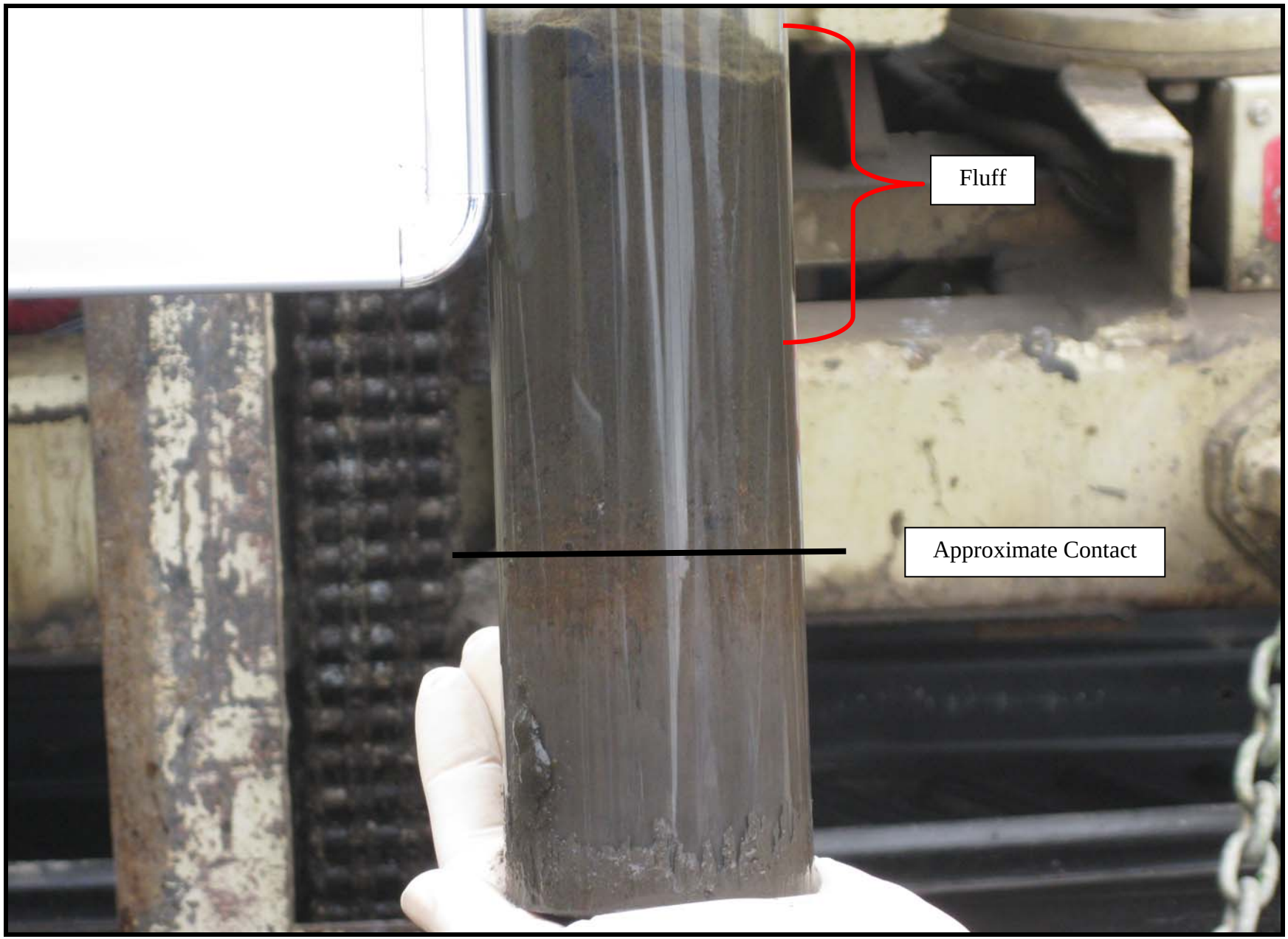


Photo 196. Following auger drilling to determine the reservoir sediment / volcanic contact a gravity sampler was used to collect contaminant samples. View of sediment collected in drill hole CDH-09-21. The black line is the approximate contact. Fluff is the upper portion of undisturbed reservoir sediment. Photo by M. McCulla, 10/31/09.

Photo 197. View of Reclamation's drilling barge set up in Iron Gate Reservoir on drill hole CDH-09-22. Photo by M. McCulla, 11/2/10.

Photo 198. View of reservoir sediment collected from drill hole CDH-09-22. The red line is the contact between reservoir sediment and pre-reservoir volcanic rock at a depth of 1.4-feet. Photo by M. McCulla, 11/2/09.

Photo 199. View of Reclamation's drilling barge set up in Iron Gate Reservoir on drill hole CDH-09-24. Volcanic rock crops out in the foreground. Photo by M. McCulla, 11/2/09.

Photo 200. View of the contact between reservoir sediment and pre-reservoir volcanic tuff and lapilli tuff at a depth of 4.1-feet in drill hole CDH-09-24. The tuff is weathered to Fat Clay with Sand and trace gravel (CH)s. Photo by M. McCulla, 11/3/09.

Photo 201. View of Reclamation's drilling barge set up in Iron Gate Reservoir at drill hole CDH-09-27. The brick-red rock to the right of the barge is cinder and ash deposits from a young volcanic cone. Photo by M. McCulla, 11/3/09.

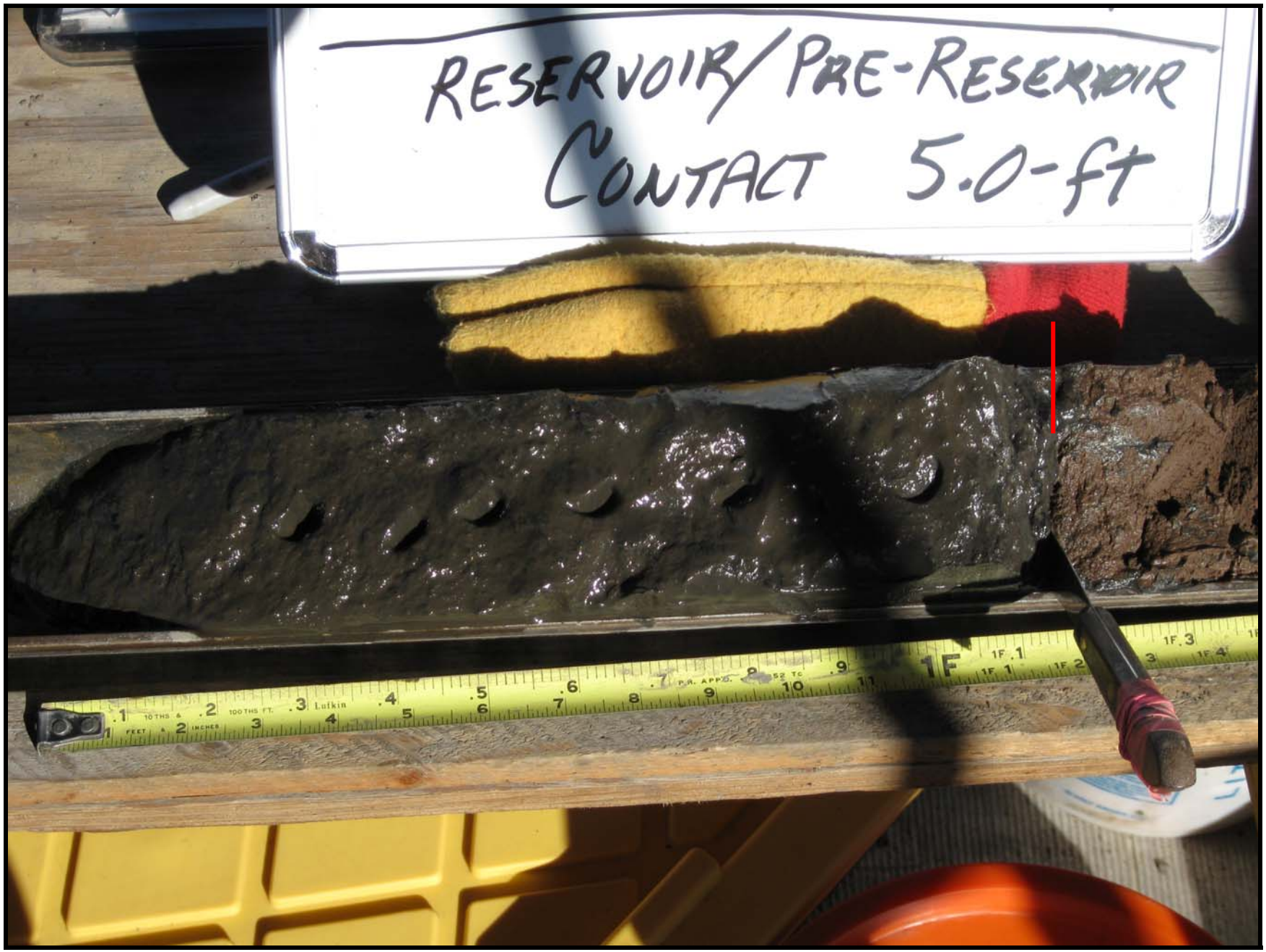


Photo 202. View of the contact between reservoir sediment (left of the red line) and pre-reservoir volcanic cinder and ash weathered to Fat Clay (right) in drill hole CDH-09-27. Photo by M. McCulla, 11/4/09.

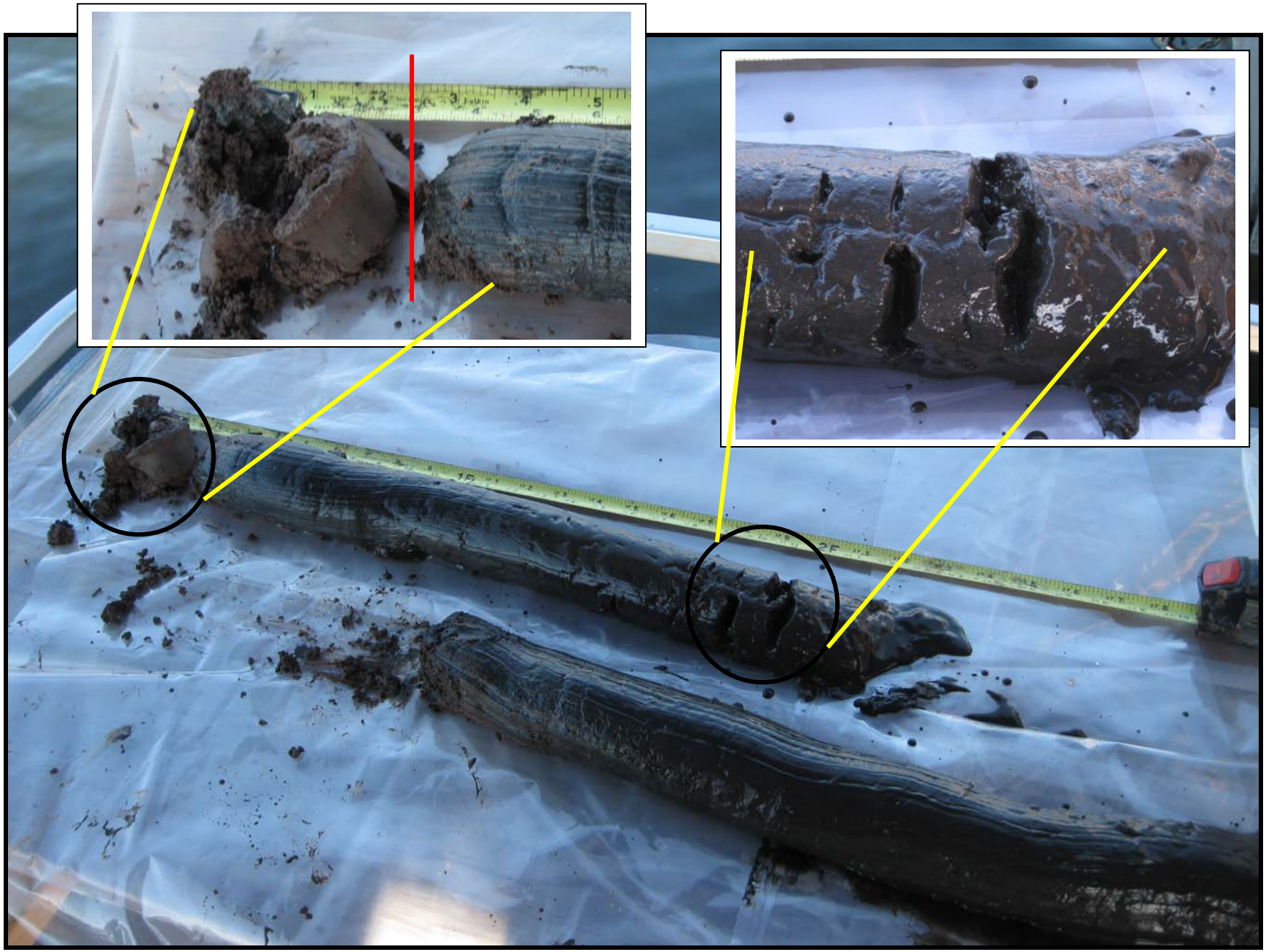


Photo 203. View of reservoir sediment collected from drill hole CDH-09-27. The contact with pre-reservoir volcanic clay is at a depth of 5.0 feet (red line in insert). Numerous large methane bubbles were present within the reservoir sediment (insert). Photo by M. McCulla, 11/4/09.

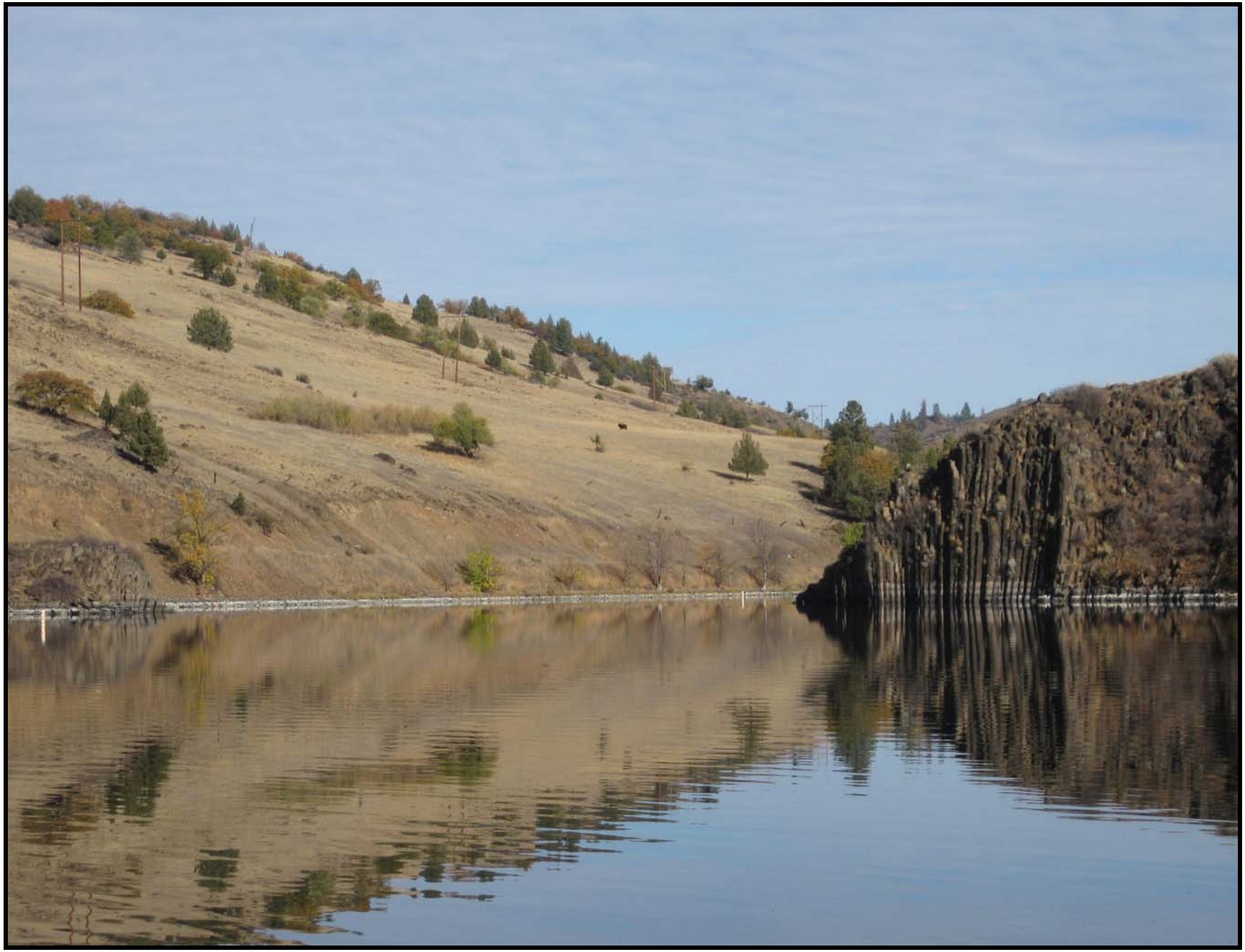


Photo 204. View from drill hole EDH-09-8 of columnar basalt in a narrow area of the reservoir about 4-½ miles upstream from Iron Gate Dam. The drill hole was located about 800 feet downstream from the narrow area. Photo by M. McCulla, 11/1/09.

Photo 205. View of 0.3-feet of reservoir sediment (MH)s present above pre-reservoir alluvium/colluvium at drill hole EDH-09-8. Due to the lack of reservoir sediment at this location, the hole was offset to EDH-09-8A, about 1,400 feet downstream. Photo by M. McCulla, 11/1/09.

Photo 206. View from drill hole EDH-09-8A, about 2,200 feet downstream of the area of columnar basalt where the reservoir narrows. The drill hole is about 4.2 miles upstream from Iron Gate Dam. Photo by M. McCulla, 11/12/09.

Photo 207. View through snow flurries of the southern shoreline of Iron Gate Reservoir from drill hole EDH-09-8A, located about 4.2 miles upstream from Iron Gate Dam. Photo by M. McCulla, 11/12/09.

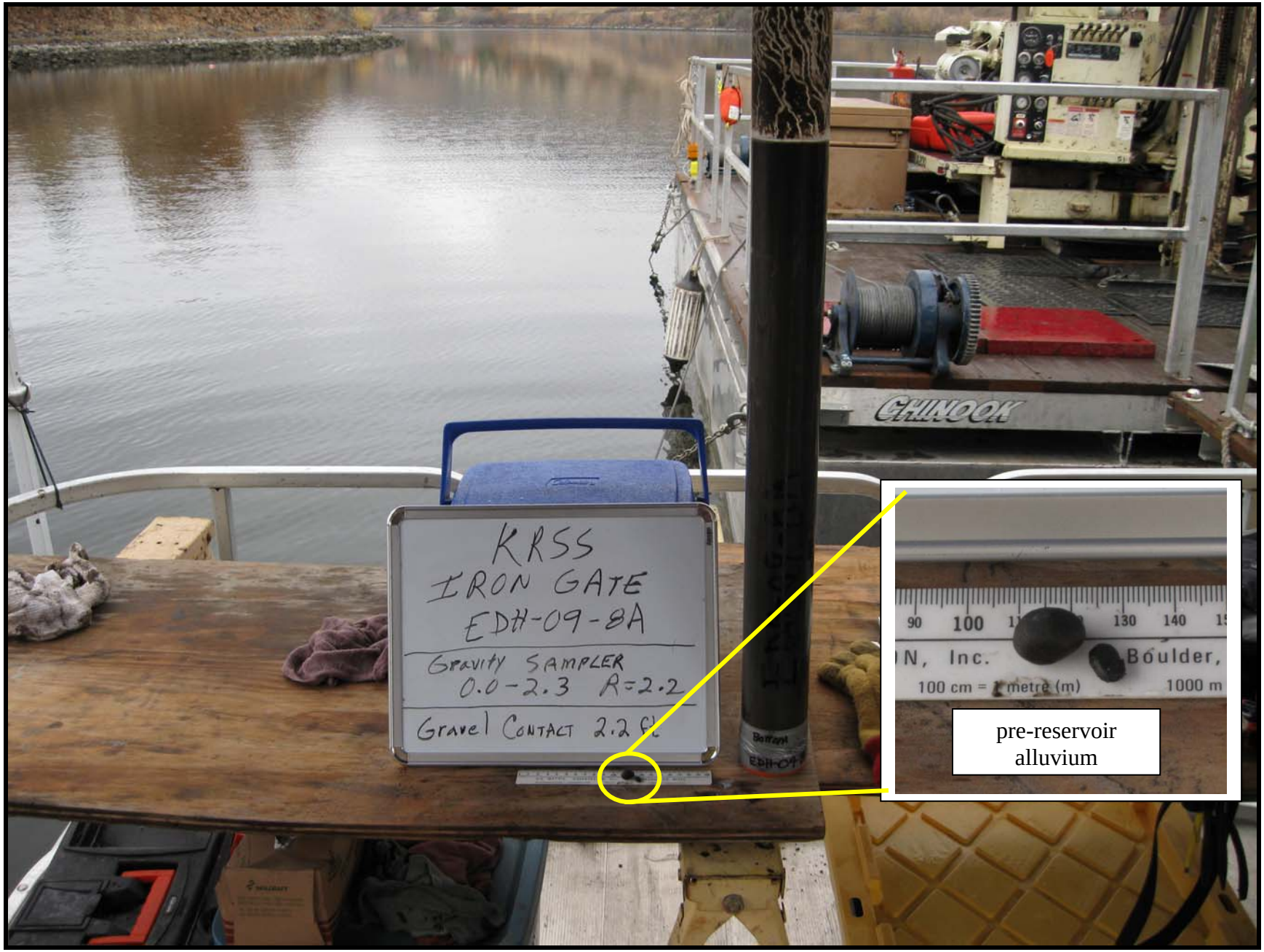


Photo 208. View of undisturbed sample of reservoir sediment from drill hole EDH-09-8A. The reservoir sediment is Elastic Silt with Sand (MH)s and the pre-reservoir alluvium is Silty Gravel with Sand (GM)s. Photo by M. McCulla, 11/12/09.

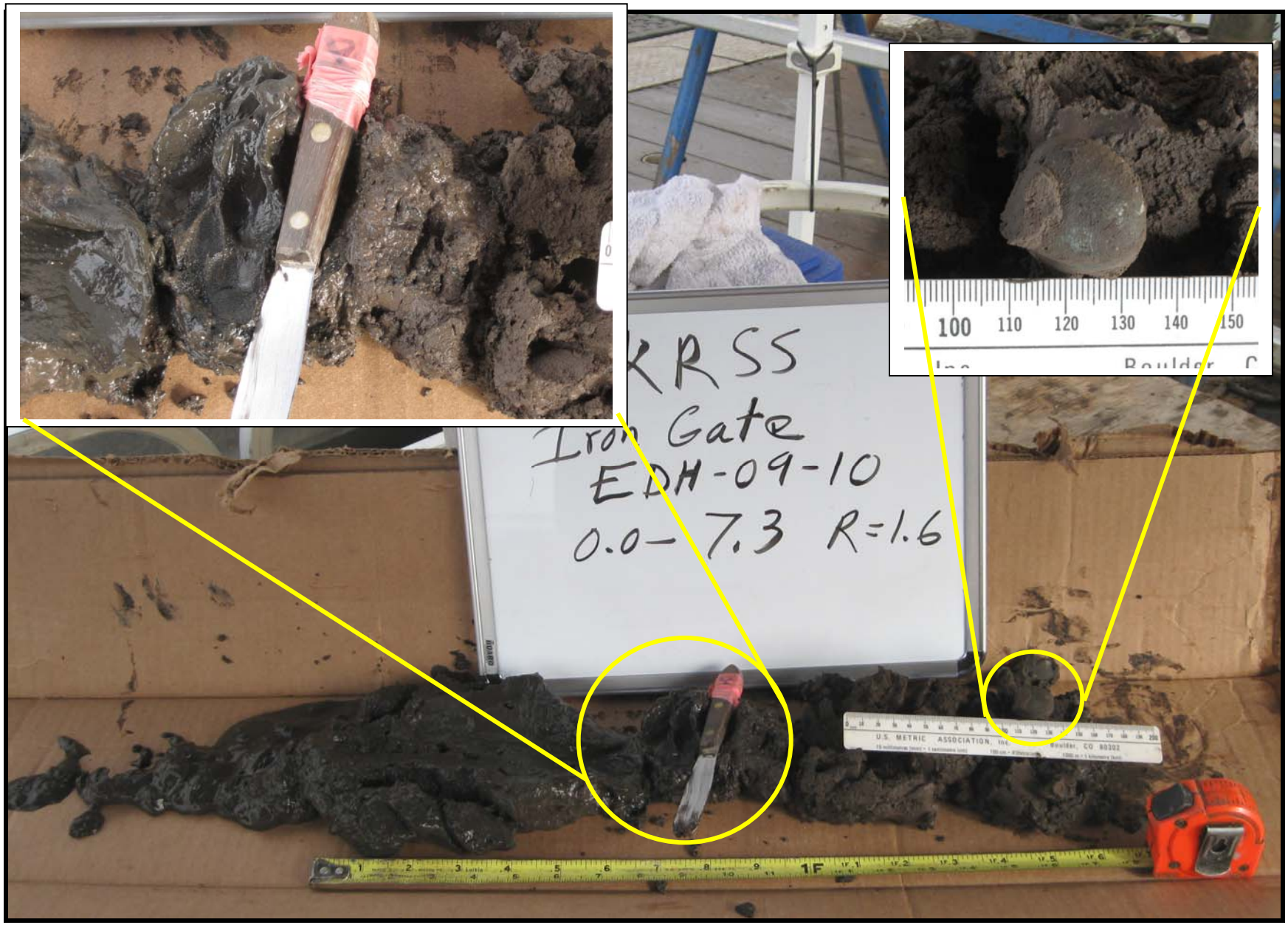


Photo 209. View of auger sample from drill hole EDH-09-10 in Iron Gate Reservoir, about 1-mile upstream from the dam. The sediment tool marks the contact between Elastic Silt – MH reservoir sediment (left) and pre-reservoir volcanic tuff and lapilli tuff weathered to Clayey Gravel with Sand (GC)s (right). Photo by M. McCulla, 11/13/09.

Photo 210. View of Reclamation's drilling barge set up at drill hole EDH-09-11, in Jenny Creek Cove, about 3-¾ miles upstream from Iron Gate Dam. Photo by M. McCulla, 11/12/09.

Photo 211. View of Elastic Silt – MH reservoir sediment in drill hole EDH-09-11. Photo by M. McCulla, 11/12/09.

Photo 212. View of Elastic Silt – MH reservoir sediment in contact (red line) with pre-reservoir volcanic tuff weathered to Clayey Sand – SC. At the contact there is a thick mat of decaying organic material. Photo by M. McCulla, 11/12/09.

Photo 213. View of Reclamation's drilling barge set up on drill hole EDH-09-Add#1, located in the Mirror Cove arm of Iron Gate Reservoir, about 2.4 miles upstream from the dam. Photo by M. McCulla, 11/14/09.

Photo 214. View of an undisturbed sample of reservoir sediment collected from drill hole EDH-09-Add#1. The material is Elastic Silt – MH with several lenses of what may be charcoal. Photo by M. McCulla, 11/14/09.

Photo 215. View of the upper part of reservoir sediment (Elastic Silt – MH) at drill hole location EDH-09-Add#1. The total thickness of reservoir sediment at this location is 3.0 feet. Photo by M. McCulla, 11/14/10.

Photo 216. View of the middle part of reservoir sediment (Elastic Silt – MH) at drill hole location EDH-09-Add#1. The total thickness of reservoir sediment at this location is 3.0 feet. Note the dark lenses of what may be charcoal. Photo by M. McCulla, 11/14/10.

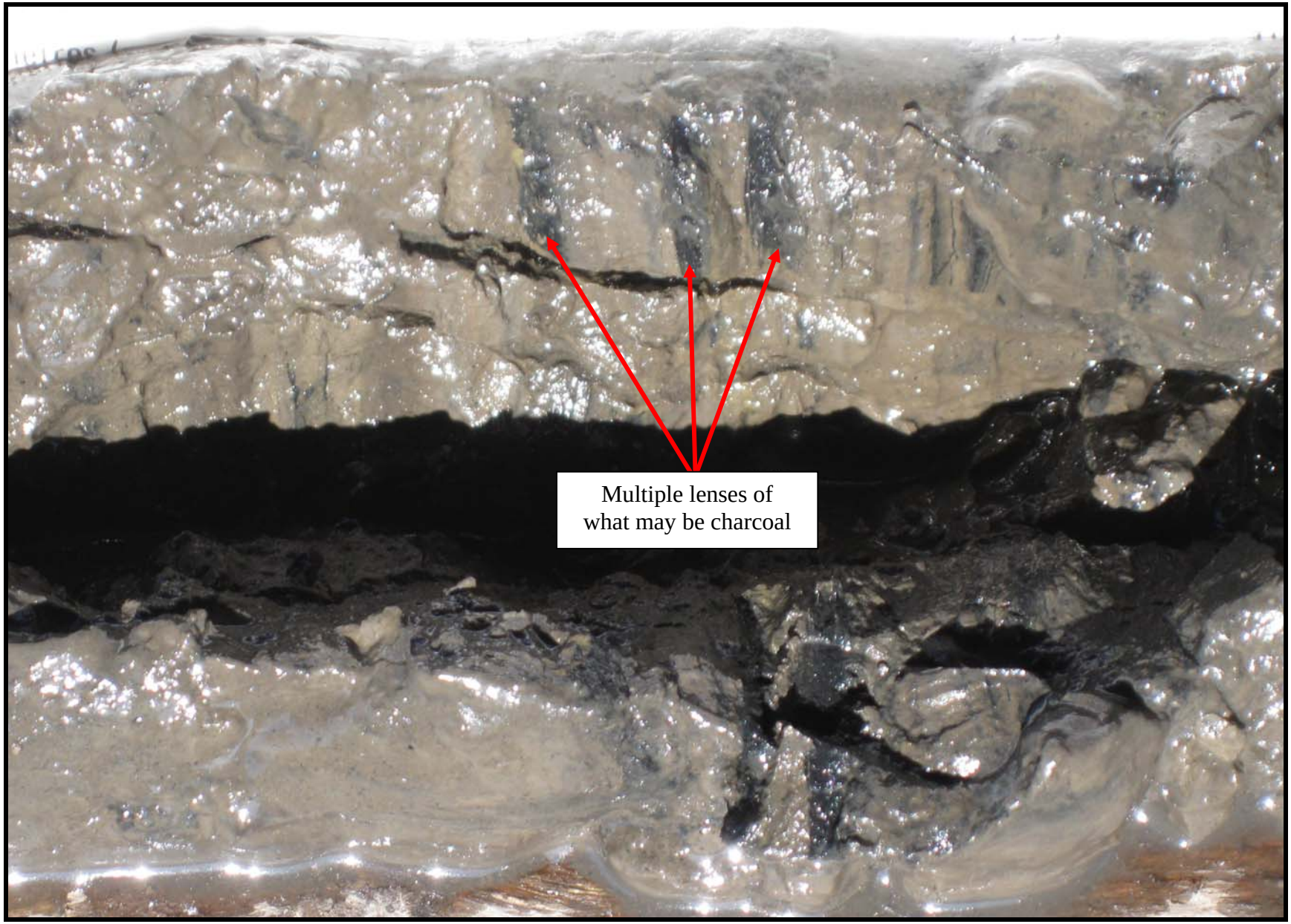


Photo 217. View of the middle part of reservoir sediment (Elastic Silt – MH) at drill hole location EDH-09-Add#1. The total thickness of reservoir sediment at this location is 3.0 feet. Note the dark lenses of what may be charcoal. Photo by M. McCulla, 11/14/10.

Photo 218 View of the contact between Elastic Silt – MH reservoir sediment left of the sediment tool, and pre-reservoir volcanic tuff weathered to Fat Clay with Sand (CH)s to the right. The contact is at a depth of 3.0 feet. Photo by M. McCulla, 11/14/09.

Lower Klamath River and Estuary

Photographs

Photo 219. View of Reclamation's boat and personnel collecting sample material from location 1A in the estuary lagoon, near the mouth of the Klamath River (Figures 10 & 11). Photo by M. McCulla, 1-12-2010.

Photo 220. View of Reclamation's boat and sampling personnel collecting material from location 1A in the estuary lagoon, near the mouth of the Klamath River (Figures 10 & 11). Sampling was carried out using a gravity sampler, with material collected in a lexan tube. Photo by M. McCulla, 1-12-2010.

Photo 221. View of the southern side of the Klamath River estuary, and sample location 1B (Figures 10 & 11). Photo by M. McCulla, 1-12-2010.

Photo 222. View of the southern side of the Klamath River estuary, and sample location 1B (Figures 10 & 11). Photo by M. McCulla, 1-12-2010.

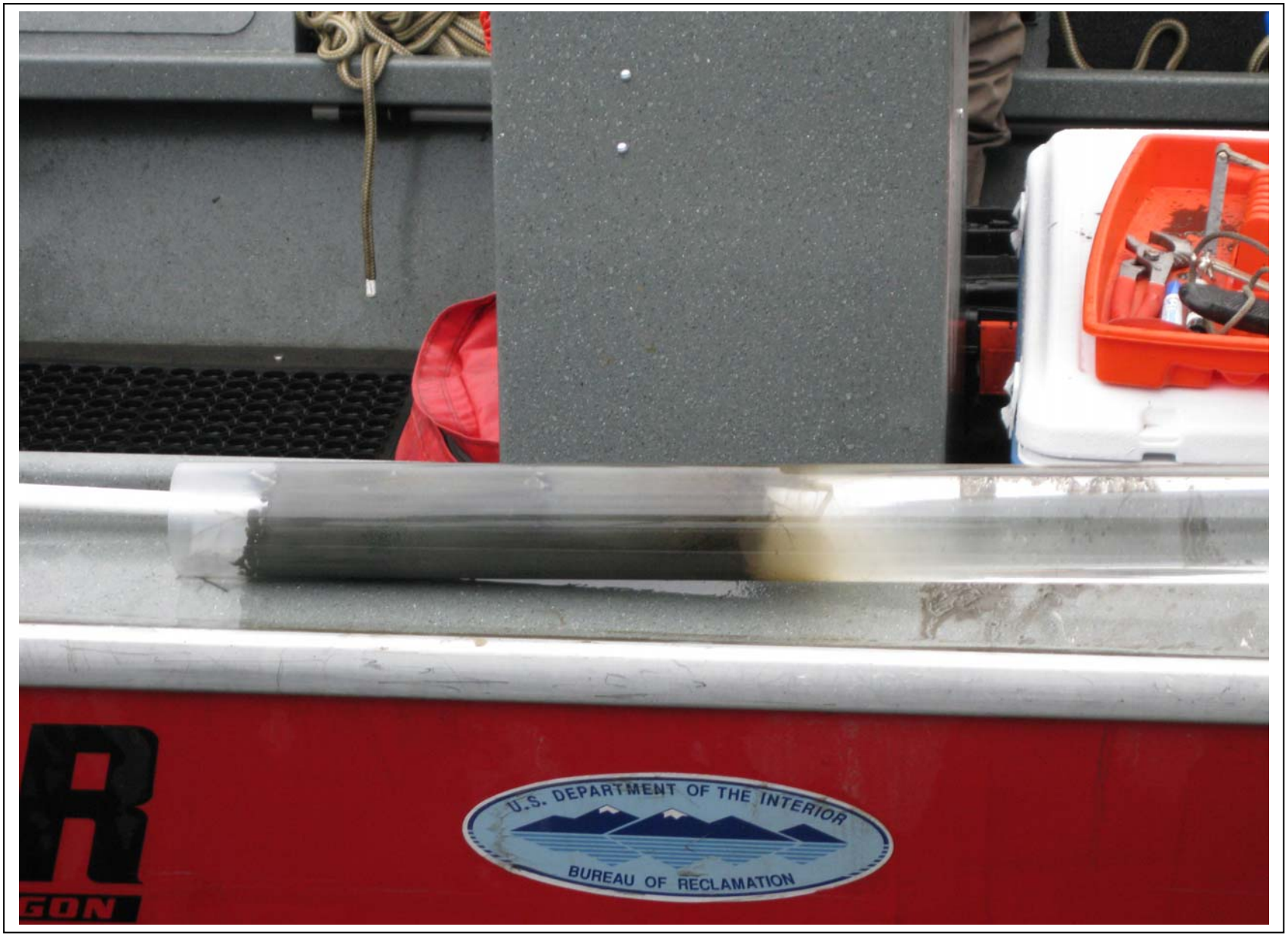


Photo 223. View of material collected in one run of the gravity sampler at location 1B in the Klamath River estuary. Photo by M. McCulla, 1-12-2010.

Photo 224. Up-river view of the Klamath River estuary, and sample location 1C (Figures 10 & 11). Photo by M. McCulla, 1-12-2010.

Photo 225. View of the southern side of the Klamath River estuary, and sample location 1C (Figures 10 & 11). Photo by M. McCulla, 1-12-2010.

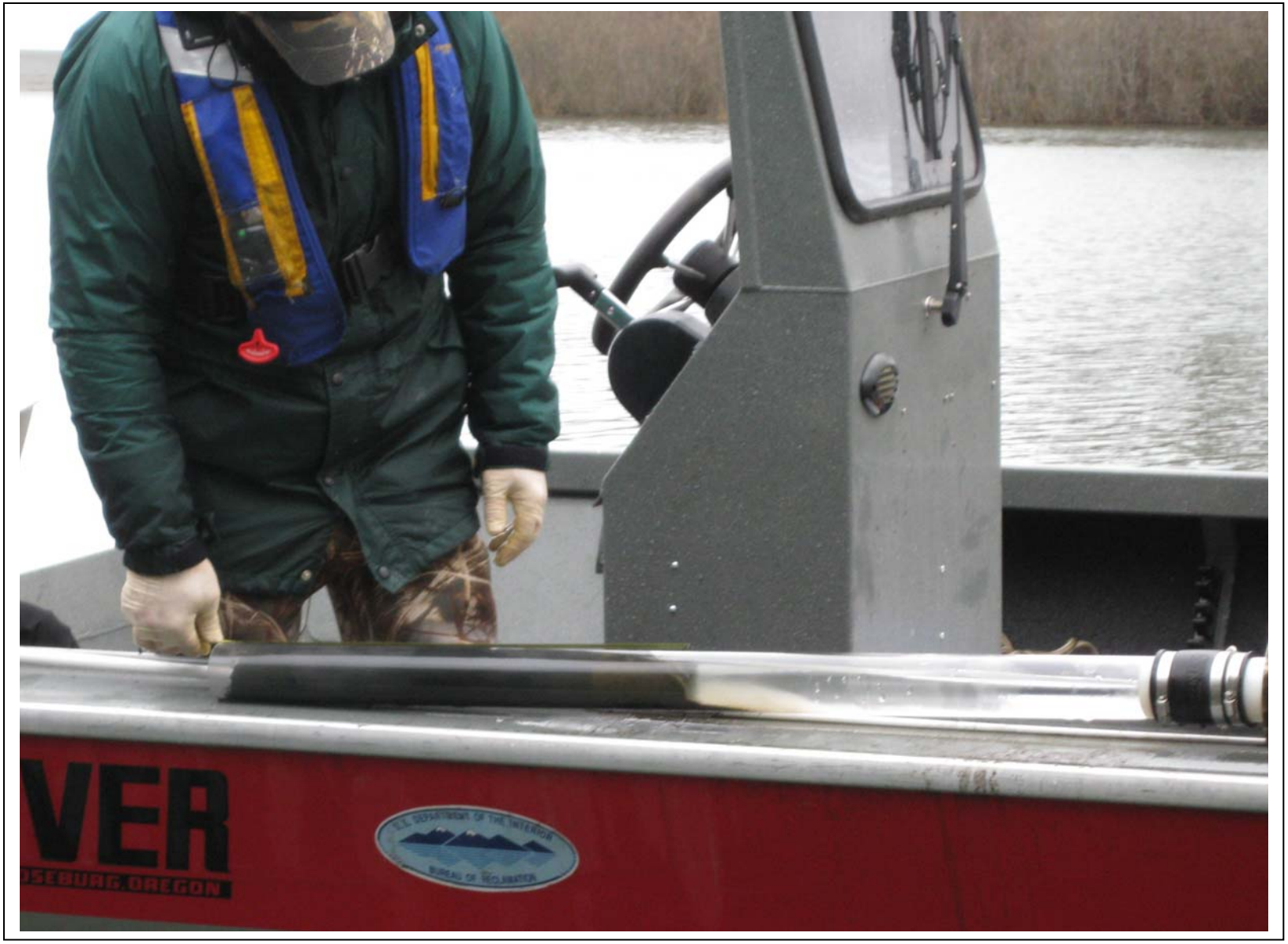


Photo 226. View of material collected in one run of the gravity sampler at location 1C in the Klamath River estuary. Photo by M. McCulla, 1-12-2010.

Photo 227. Up-river view of the southern bank of the Klamath River at composite sample location 2A (Figures 12 & 13). The material is Poorly Graded Sand with Silt (SP-SM) and overlies coarse deposits of gravel and cobbles (Photo 231). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 228. Up-river view of the southern bank of the Klamath River at sample location 2A (Figure 13). The material is Poorly Graded Sand with Silt (SP-SM) and overlies coarse deposits of gravel and cobbles (Photo 231). Sampling was accomplished both with a shovel and a push-tube sampler (Photo 230). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 229. Up-river view of the southern bank of the Klamath River at sample location 2A (Figure 13). The material is Poorly Graded Sand with Silt (SP-SM) and overlies coarse deposits of gravel and cobbles (Photo 231). Sampling was accomplished both with a shovel and a push-tube sampler (Photo 230). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 230. Up-river view of the southern bank of the Klamath River at sample location 2A (Figure 13). The material is Poorly Graded Sand with Silt (SP-SM) and overlies coarse deposits of gravel and cobbles (Photo 231). A push-tube sampler is shown in the photo. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 231. View of the southern (left) bank of the Klamath River, about 300 feet downstream from sample location 2A (Figure 13). Here deposits of matrix-supported sand, gravel, and cobbles are overlain by deposits of Poorly Graded Sand with Silt (SP-SM) and Silty Sand – SM. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

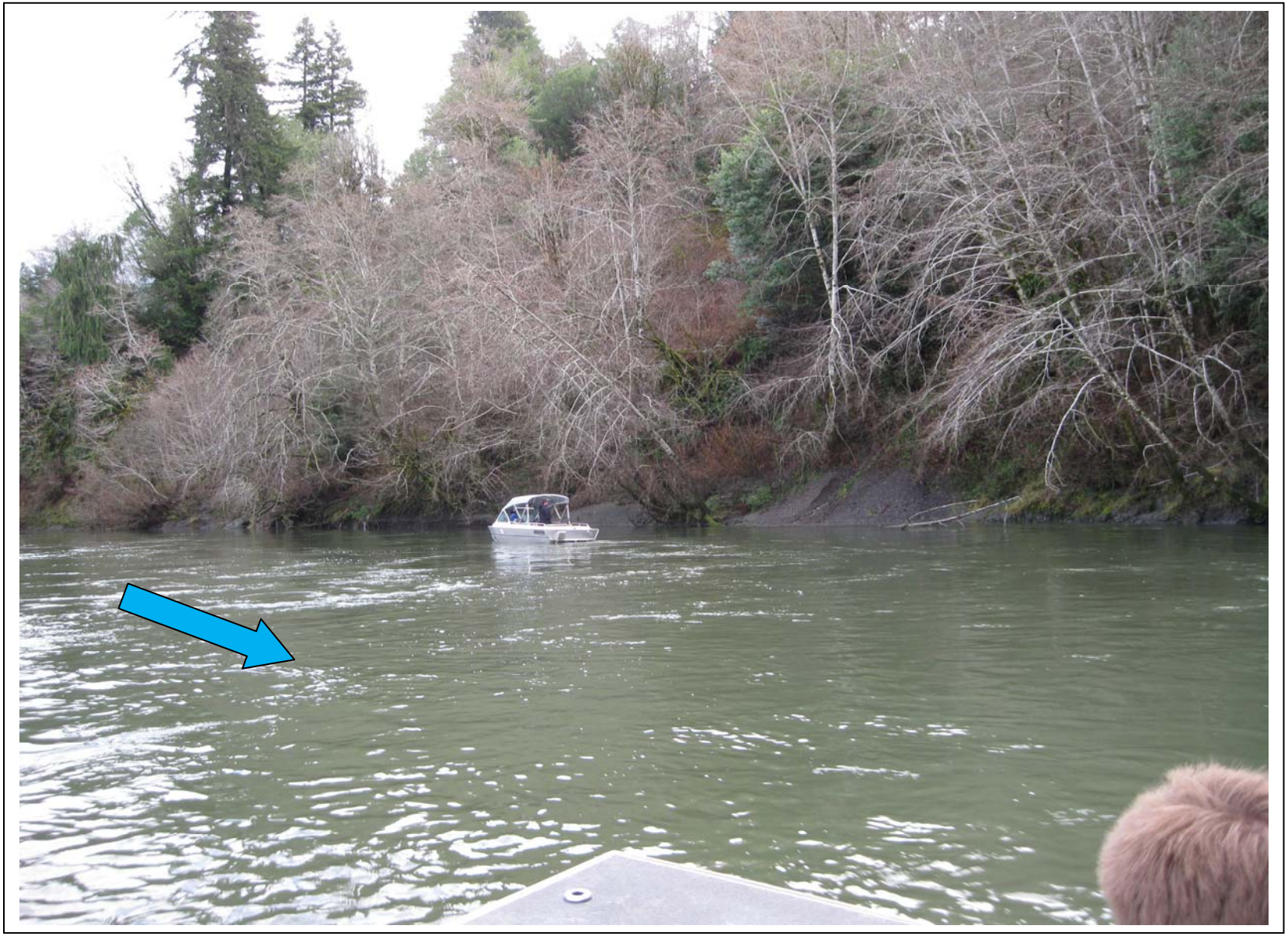


Photo 232. Up-river view of the southern bank of the Klamath River at sample location 2B (Figures 12 & 14). The material is Poorly Graded Sand with Silt (SP-SM). Sampling was accomplished with both a shovel and a push-tube sampler. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 233. Up-river view of the southern (left) bank of the Klamath River at sample location 2B and Field Note A (Figures 12 & 14). The material is Poorly Graded Sand with Silt (SP-SM). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 234. View of the southern (left) bank of the Klamath River at sample location 2B and Field Note A (Figures 12 & 14). The material is Poorly Graded Sand with Silt (SP-SM). Sampling was accomplished with both a shovel and a push-tube sampler. The blue arrow shows the direction that river water is flowing. Photo by G. Mongano, 1-12-2010.

Photo 235. View of a gravel bar on the northern (right) bank of the Klamath River, across from sample location 2B (about 3.5 miles up-river from the Hwy 101 Bridge; Figures 14 & 15). Clast-supported gravel bars along the river are frequently overlain by 2 to 4 feet of sand. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 236. View of a gravel bar on the northern (right) bank of the Klamath River, across from sample location 2B (about 3.5 miles up-river from the Hwy 101 Bridge; Figures 14 & 15). Clast-supported gravel bars along the river are frequently overlain by 2 to 4 feet of sand. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 237. View of McGarvy Creek entering the southern side of Klamath River (Field Note C; Figure 16). The blue arrow shows the direction that Klamath River water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 238. View of a gravel bar on the southern (left) side of Klamath River, at the mouth of McGarvy Creek (Field Note C; Figure 16). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 239. Close up view of the clast-supported gravel bar shown in Photo 238 on the southern (left) side of Klamath River, at the mouth of McGarvy Creek (Field Note C; Figure 16). The surface is composed mostly of coarse, subrounded, hard gravel with less fine gravel and sand. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 240. View of a gravel bar along the northern (right) bank of the Klamath River (Field Note B; Figure 16). The surface is composed mostly of coarse, subrounded, hard gravel with less fine gravel, sand, and cobbles. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

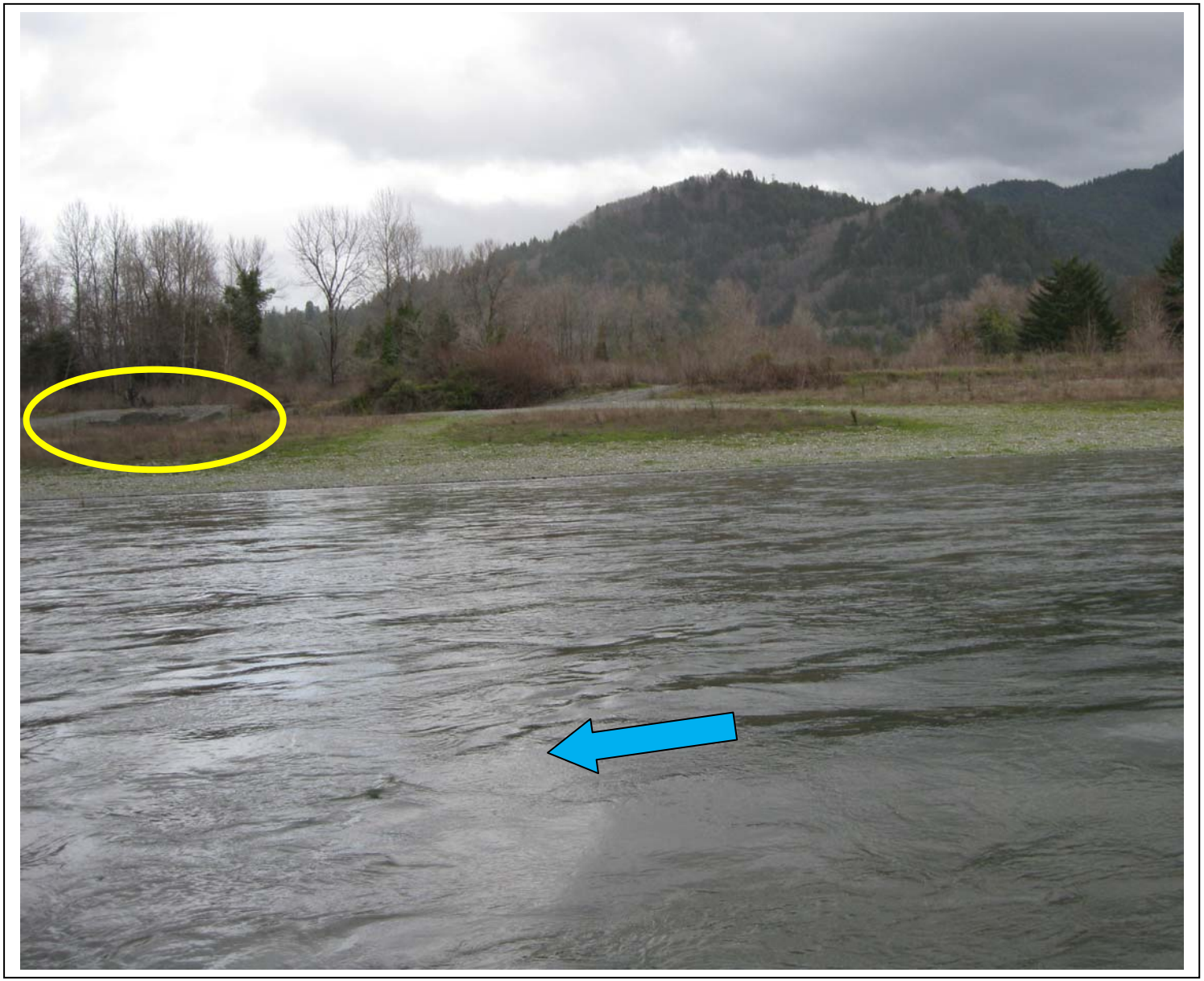


Photo 241. View of coarse gravel deposits along the northern (right) bank of the Klamath River (Field Note D; Figure 16). The area circled in yellow is a borrow site composed mostly of gravel. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 242. View of outcropping bedrock along the southern (left) bank of the Klamath River, across from Field Note B (Figure 16). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 243. View of the entrance to a cutoff channel along the southern (left) bank of Klamath River, across from Klamath Glen (Figure 17). Deposits of very coarse cobbles and gravel comprise the base of the new channel (Photo 244). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 244. View of the entrance to a cutoff channel along the southern (left) bank of Klamath River, across from Klamath Glen (Figure 17). Deposits of very coarse cobbles and gravel comprise the base of the new channel. The blue arrow shows the direction that river water is currently flowing. Photo by M. McCulla, 1-12-2010.

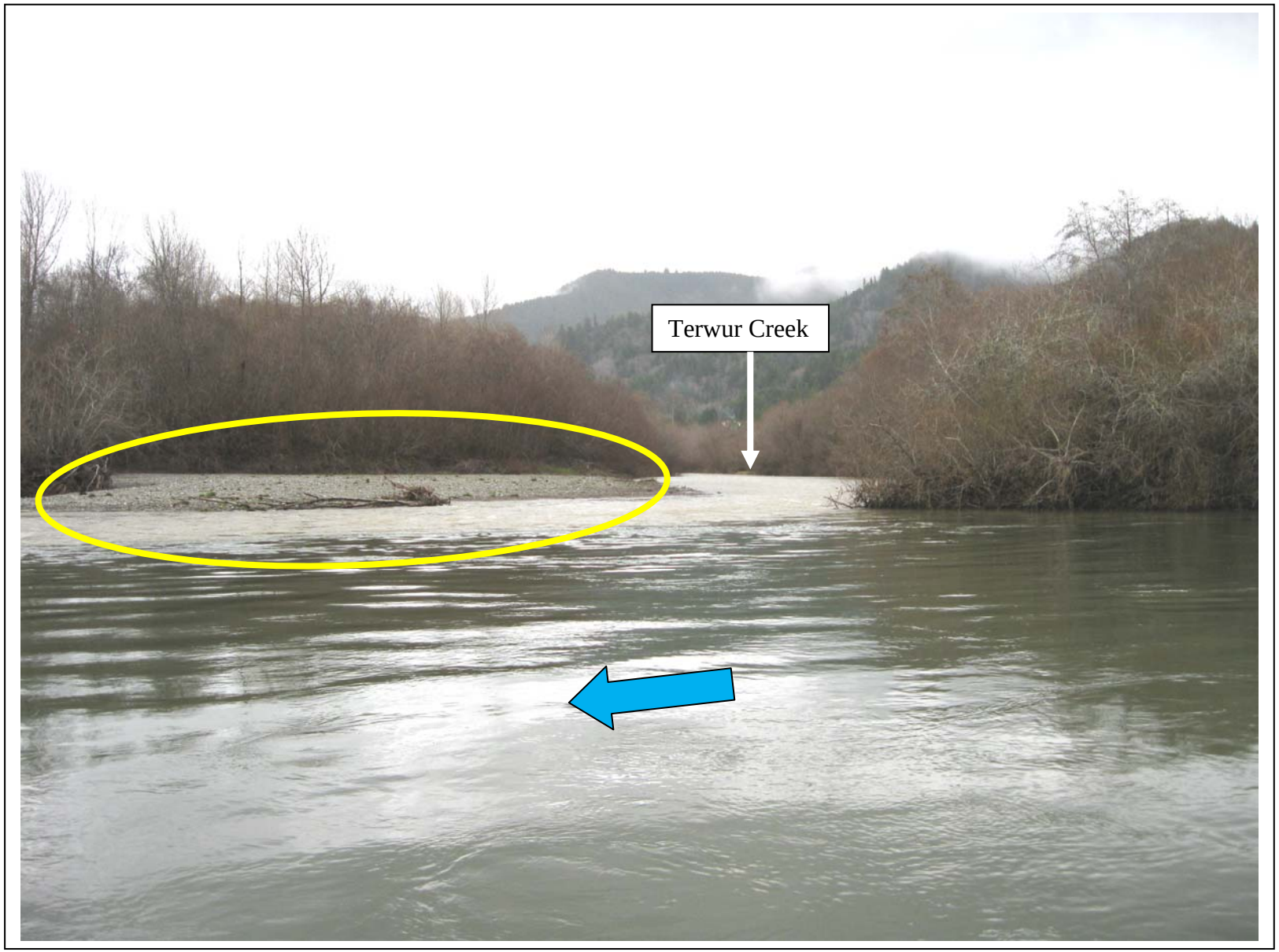


Photo 245. View at the mouth of Terwur Creek where it enters the Klamath River, at Field Note F (Figure 17). Coarse deposits of cobbles and gravel comprise the downstream side (Photo 246). The blue arrow shows the direction that Klamath River water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 246. View at the mouth of Terwur Creek as it enters the Klamath River at Field Note F (Figure 17). Coarse deposits of cobbles and gravel comprise the downstream side. The blue arrow shows the direction that Klamath River water is flowing. Photo by M. McCulla, 1-12-2010.

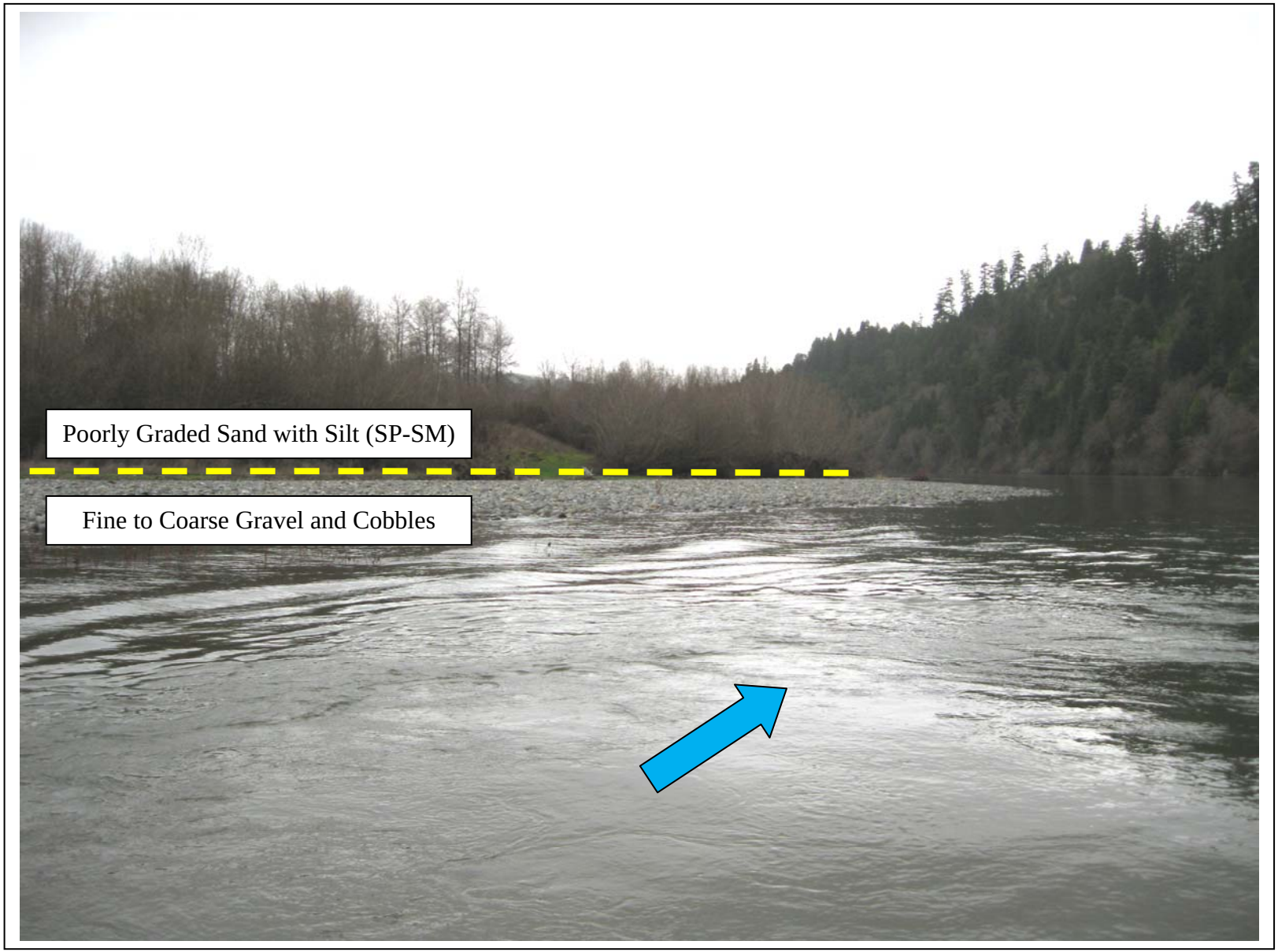


Photo 247. View of the left bank of the Klamath River at Field Note G, upstream from sample Location 2A (Figure 18). Deposits of very coarse gravel and cobbles comprise the channel bar, with overlying deposits of Poorly Graded Sand with Silt (SP-SM; Photo 248). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 248. View of the left bank of the Klamath River at Field Note G, just upstream from sample Location 2A (Figure 18). The deposits of Poorly Graded Sand with Silt (SP-SM) shown here overly coarse deposits of gravel and cobbles shown in Photo 247. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

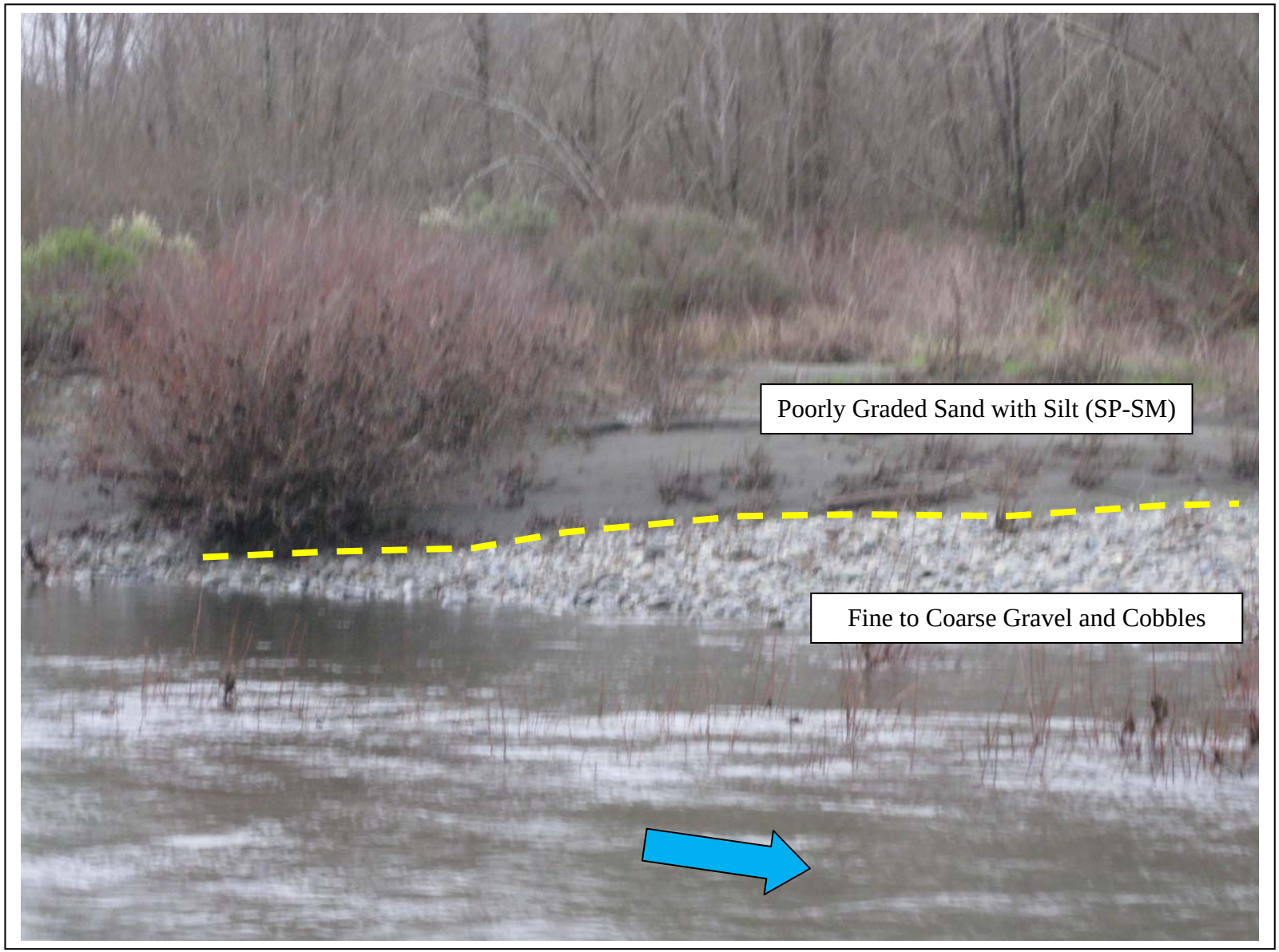


Photo 249. View of the left bank of the Klamath River at Field Note G, just upstream from sample Location 2A (Figure 18). Slightly out of focus view of coarse gravel and cobble deposits overlain by Poorly Graded Sand with Silt (SP-SM). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

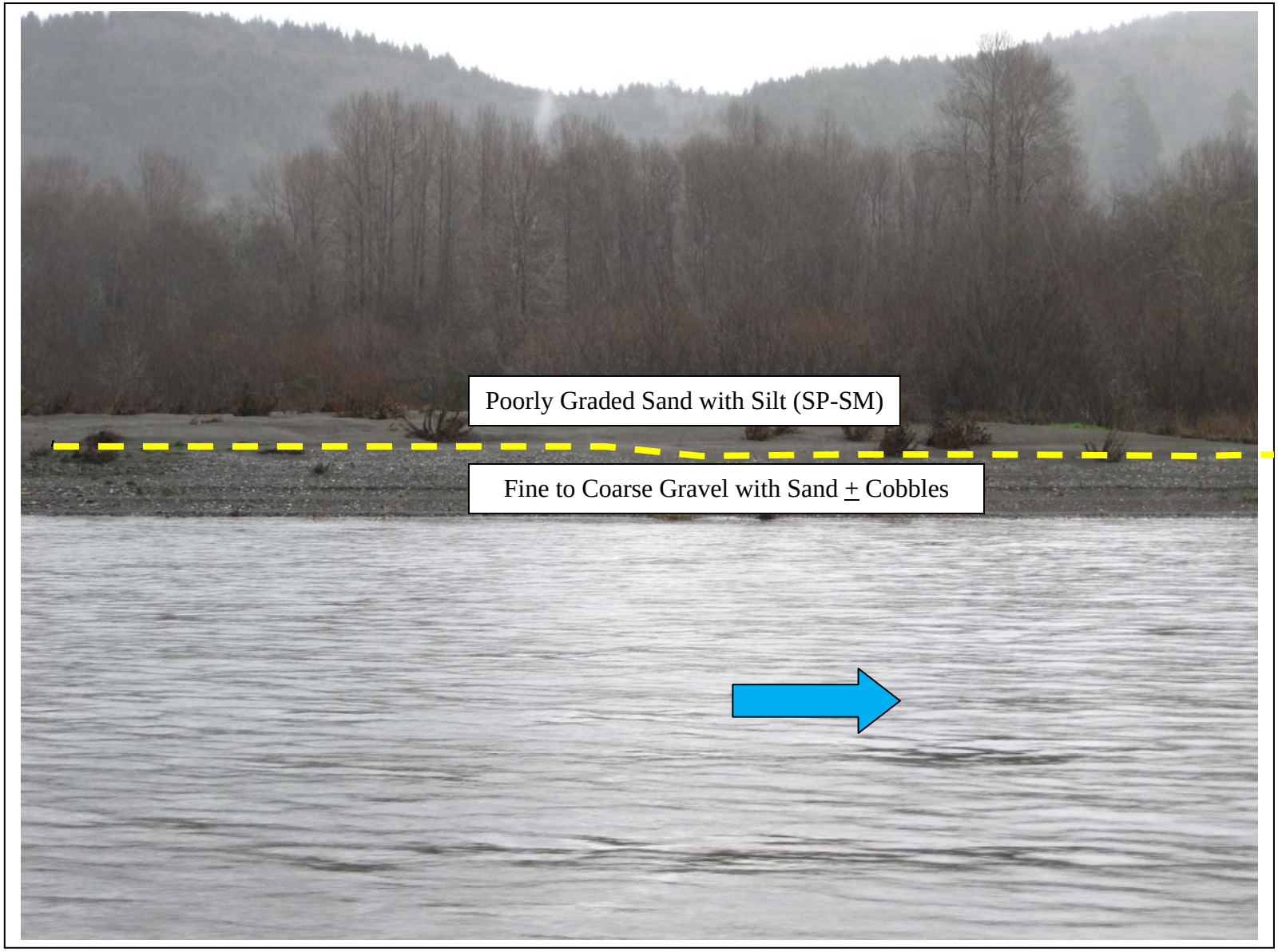


Photo 250. Gravel and sand bar in the Klamath River, about 2,500 feet upstream from the Hwy. 101 bridge (Field Note H; Figure 19). The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

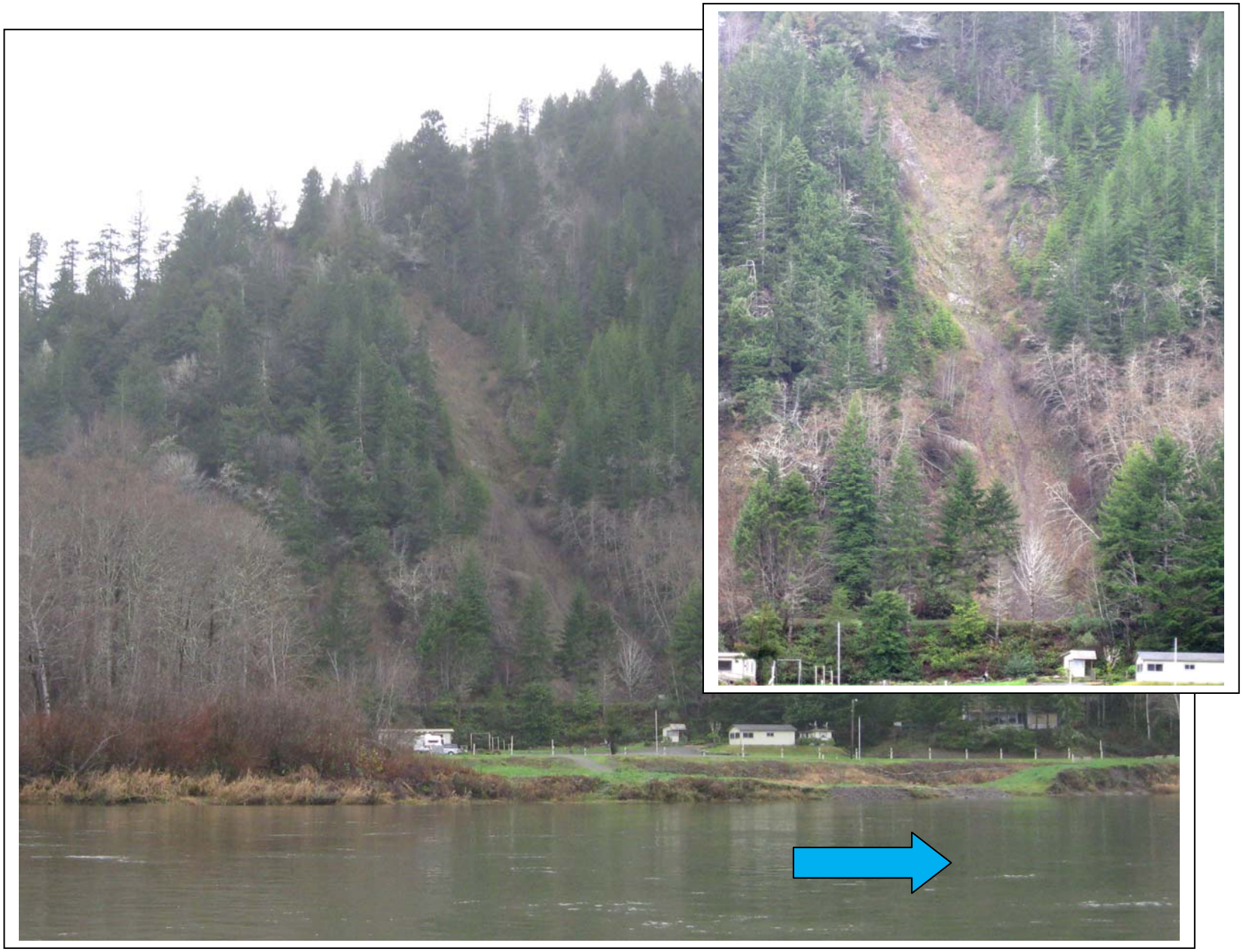


Photo 251. View of a landslide area on the southern side of the Klamath River, about 2,000 feet downstream from the Hwy. 101 bridge. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 252. View of the northern (left) bank of the Klamath River at Field Note I, near the town of Klamath (Figure 20). The bank is composed primarily of fine to coarse gravel with sand and trace cobbles. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla 1-12-2010.

Photo 253. View of the northern (left) bank of the Klamath River at Field Note J, near the town of Klamath (Figure 20). The bank is composed primarily of fine to coarse gravel with sand and trace cobbles. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla 1-12-2010.

Photo 254. View of the entrance to a cutoff channel along the upstream end of Safford Island, near the mouth of the Klamath River (Field Note K; Figure 21). Deposits of fine to coarse gravel with sand are exposed in the new channel (Photo 255). The blue arrow shows the direction that the main stem of the Klamath River is flowing. Photo by M. McCulla, 1-12-2010.

Photo 255. View of the entrance to a cutoff channel at the upstream end of Safford Island, near the mouth of the Klamath River (Field Note K; Figure 21). Deposits of fine to coarse gravel with sand comprise are exposed in the new channel (Photo 254). The large blue arrow shows the direction that the main stem of the Klamath River is flowing. Photo by M. McCulla, 1-12-2010.

Photo 256. View of the northern (right) bank of the Klamath River, near the town of Requa (Field Note L; Figure 21). Bank deposits are composed of mostly matrix-supported fine to coarse gravel with sand and cobbles. Photo by M. McCulla, 1-12-2010.

Photo 257. View of the northeastern side of Safford Island, near the mouth of the Klamath River (Field Note M; Figure 21). The bank appears to be composed of silty sand, but upstream and downstream coarser material was also exposed. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 258. View of the northeastern side of Safford Island, near the mouth of the Klamath River (Field Note N; Figure 21). Much of the bank appears to be composed of silty sand, but gravel and cobbles are also present locally. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 259. View of the northeastern side of Safford Island, near the mouth of the Klamath River (Field Note O; Figure 21). Much of the bank appears to be composed of silty sand with gravel. The blue arrow shows the direction that river water is flowing. Photo by M. McCulla, 1-12-2010.

Photo 260. View from the Keno Bridge, Keno, Oregon of sunset over the Klamath River. Photo by G. Mongano, October 2009.