JOSEPHINE COUNTY WATER MANAGEMENT
IMPROVEMENT STUDY, OREGON

SAVAGE RAPIDS DAM
SEDIMENT EVALUATION STUDY

Department of the Interior
Bureau of Reclamation

February 2001

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes.

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.

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ACKNOWLEDGMENTS

The Bureau of Reclamation would like to thank all the individuals who assisted in completing the Savage Rapids Dam Sedimentation Evaluation Study. In particular,
we would like to thank Mr. Ronald Mason (U.S. Army Corps of Engineers, Portland, Oregon) and Mr. Richard Wenning (McLaren/Hart, Chemrisk) for their valuable input throughout the study as peer reviewers. Their participation, along with the involve-ment of various government fishery agencies, is greatly appreciated. A special "thank you" goes out to the Grants Pass Irrigation District, which provided logistical support and assistance during this study. Without that support, the field work for this study could not have been completed. The staff at the Josephine County Historical Society provided access to their archives, including an extensive file of construction photo-graphs of Savage Rapids Dam, and they granted permission to reproduce their photograph of the rapids taken prior to construction of the dam. In addition, we
would like to thank everyone who helped put together the public meeting held at the Anne Basker Auditorium in Grants Pass, Oregon, on August 3, 2000. We greatly enjoyed sharing our study results with everyone who attended and participated in the meeting.

ACRONYMS AND ABBREVIATIONS

bpf	blows per foot
Corps	U.S. Army Corps of Engineers
EIS	environmental impact statement
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
ft^3/s	cubic feet per second
GPID	Grants Pass Irrigation District
GPS	global positioning system
JCWMIS	Josephine County Water Management Improvement Study
JTU	Jackson Turbidity Units
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
mm	millimeter
NAD	North American Datum
NAVD	North American Vertical Datum
NGVD	National Geodetic Vertical Datum
NTU	Nephelometric Turbidity Units
NWIS	National Water Information System
P.L.	Public Law
ppm	parts per million
PR/FES	planning report/final environmental statement
Reclamation	Bureau of Reclamation
RM	river mile
ROD	record of decision
SMCL	secondary maximum contaminant level
SVOCs	semivolatile organic compounds
TDS	total dissolved solids
TOC	total organic carbon

USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
VOCs	volatile organic compounds
yds^3	cubic yards
µg/kg	micrograms per kilogram
µg/L	micrograms per liter

Executive Summary

Savage Rapids Dam is located in southwestern Oregon, on the Rogue River, 5 miles upstream from the town of Grants Pass. The dam, owned by the Grants Pass Irrigation District (GPID), is 39 feet high and has been diverting irrigation flows since its construction in 1921. Fish ladders on the dam are old, do not meet current National Marine Fisheries Service (NMFS) fisheries criteria, and delay migrating fish. In addition, the fish screens on the north side of the dam do not comply with current NMFS fisheries criteria. Construction of two pumping plants to deliver irrigation water and removal of the dam are proposed to alleviate these fish passage problems. The pumping plants would be located immediately downstream from the fish ladders to enable GPID to deliver water to its patrons through the existing irrigation canals.
The process leading to this proposal is documented in a planning report/final environmental statement (PR/FES) filed on August 30, 1995. The PR/FES focused only on salmon and steelhead passage concerns at the dam and associated diversion facilities. The Bureau of Reclamation planned to do a detailed sediment study as part of predesign activities if the Congress approved removal of the dam and provided the necessary funding. However, a number of interested government and private entities agreed that the sediment study should begin before the predesign activities in order to expedite approval from the Congress. These entities assisted in acquiring Federal funding for this sediment evaluation study.

The purpose of this study was to determine the potential sediment-related impacts associated with removing the dam. Specific information that was developed included the following:

- An estimate of volume of sediment behind Savage Rapids Dam
- The particle size gradation and spatial distribution of reservoir sediment
- The chemical composition of the reservoir sediment
- The rate at which the reservoir sediment would erode following dam removal
- The expected rate at which eroded reservoir sediment would be transported downstream
- The location and magnitude of sediment deposition downstream from the dam

Study Reach

The reach of the Rogue River studied in detail for sediment impacts following removal of the dam was from the upstream end of Savage Rapids Reservoir (near Evans Creek) to the confluence with the Applegate River, about 12.5 miles downstream from Savage Rapids Dam. Beyond the Applegate River, the steep gradient and additional tributary inflow will function to easily transport the sediment to the Pacific Ocean, 95 miles downstream from the Applegate River confluence. The water surface drops about 100 feet in the12.5-mile study reach and contains 8 pools 10-20 feet deep and 10 pools less than 10 feet deep. During periods of low flows, water surface elevations through pools are relatively flat, and pools tend to slowly fill with sediment. During periods of high flows, pool velocities increase, and the water surface elevation through the pools has a downward slope. During these times, sediment is rapidly scoured from the channel bed of pools and transported downstream.

Data Collected

A 2-foot contour map of Savage Rapids Reservoir was developed from a bathymetric (underwater) survey of the reservoir. Similar data were also collected along the river bottom downstream from the dam to the confluence with the Applegate River. These data were used to develop river cross sections for computer modeling purposes. Additional data were collected to determine the volume, size, and chemical characteristics of sediment trapped behind Savage Rapids Dam.

Riverflows and Sediment Transport Computer Models

A river hydraulics model, HEC-RAS, developed by the U.S. Army Corps of Engineers, was applied to the study reach to provide a mechanism of predicting specific hydraulic parameters, including water surface elevation, average velocity, and water depth for any given riverflow on the Rogue River. Model results were used to compare water surface elevation, average cross section velocity, and water depth for existing reservoir conditions and for river conditions after the dam is removed.

A sediment transport model, HEC-6t, was applied to the study reach to predict those hydraulic parameters indicated for the river hydraulics model as well as erosion of reservoir sediments, sediment transport and deposition downstream, and changes in the stream channel bed. Model results were used to analyze the volume of sediment eroded from the reservoir, the rate of erosion, the rate of sediment transport downstream, and the temporary deposition along the river channel.

Results

- *Reservoir Sediment Volume Estimate* – 200,000 cubic yards (100 feet high if placed on a football field).

- *Reservoir Sediment Sizes and Distribution* – 2 percent fines (silt and clay-sized particles), 71 percent sand, and 27 percent gravel overall; cobbles from 3 to 5 inches in diameter compose up to 20 percent of the deposit found on the north shore of the reservoir. A finer-grained bar deposit is present on the south side of the reservoir but is less than 10 percent of total sediment volume.

- *Chemical Composition of Reservoir Sediment* – Testing of reservoir sediment indicated no contaminants with concentrations significantly higher than naturally occurring background levels. The chemical composition of reservoir sediment would not pose any hazard to water quality, fish and wildlife, or human uses if released downstream.

- *Rate and Extent of Reservoir Sediment Erosion* – Model results show that virtually all sediment would be eroded from the reservoir following the removal of Savage Rapids Dam. About three-fourths of the sediment would be eroded from the area immediately upstream from Savage Rapids Dam within the first year.

- *Rate of Sediment Transport Downstream* – Reservoir sediment would be transported past the Applegate river confluence within a 1- to 10-year period. The specific length of time would depend on the frequency and magnitude of high-flow events following dam removal. High and frequent floods following dam removal would cause reservoir sediment to reach the ocean within a few years.

- *Sediment Deposition Downstream* – Sediment eroded and flushed from the reservoir would be transported downstream. Sediment deposition in pools and eddies would occur during low-flow periods as it does now. Maximum deposition will range from 1 to 8 feet in river pools. However, no flooding is expected to occur because pool deposition would not cause an increase in water surface elevation. In addition, sediment deposited in pools would subsequently be scoured out and transported downstream during high-flow periods. All sediment would be eroded and eventually reach the ocean.

Sediment-Related Impacts to River Infrastructures

- *GPID Pumping Plants* – These pumping plants could be affected by the initial flushing of reservoir sediments. However, this could be prevented or mitigated by properly timing dam removal to help control sediment release and placing the pumping plant intakes to minimize exposure to sediment buildup.

- *City Water Treatment Plant Intake Structures* – High rates of sand deposition in the treatment plant could cause rapid wear on the river intake pumps and complicate the method of removing sand from the plant's sedimentation basins. This deposition of sand could be lessened by releasing sediments during the winter months when flows are higher and the treatment plant is operated at a slower pumping rate and for fewer hours per day. In addition, excessive deposition of coarse sediments in front of the treatment plant could plug the intake structure. Specific construction remedies could be implemented to lessen the potential for this impact.

Specific costs and details of mitigation of potential impacts to the pumping plants and the water treatment plant were beyond the scope of this study. Such information would be developed as part of a final design process for dam removal.

CONTENTS

Page

Figures

Appendices

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Savage Rapids Dam is located in southwestern Oregon, on the Rogue River, just 5 miles upstream from the town of Grants Pass (figure 1). Savage Rapids Dam was built in 1921 to divert riverflows for irrigation. The dam is 39 feet high and creates a backwater pool that extends ½ mile upstream during the nonirrigation season and 2-½ miles upstream during the irrigation season (figure 2). The reservoir is relatively narrow, only two to three times wider than the river. The annual mean flow of the Rogue River is 3,372 cubic feet per second (ft^3/s). The total drainage area is 2,459 square miles. The mean annual runoff is 19 inches, the highest recorded peak flow was 152,000 ft^3/s on December 23, 1962, and the lowest mean-daily flow recorded was 744 ft^3/s. Although the dam has fish ladders, these ladders are old, do not meet current fisheries criteria, and allow only limited fish passage. Dam removal has been proposed to restore fish passage to natural conditions. The dam would be replaced with two pumping plants that would deliver water to the irrigation canals. Grants Pass Irrigation District (GPID) requested a sediment study to model the potential sediment-related impacts of dam removal.

Sediment is defined as unconsolidated solid material that comes from weathering of rock and is carried by, suspended in, or deposited by water or wind. Sediment is often classified by its particle size: clay (less than 0.005 millimeter [mm]), silt (0.005 to 0.075 mm), sand (0.075 to 4.75 mm), gravel (4.75 to 75 mm), cobble (75 to 300 mm), and boulder (greater than 300 mm). All natural rivers transport a certain amount of sediment. The amount of sediment transported depends on the amount of sediment supplied from the upstream watershed and on the velocity and turbulence of the flowing river. Fine-grained sediments, such as clay and silt, are typically transported by the river while suspended in the water (figure 3) and do not compose a significant portion of the river bed ("wash load"). A river's capacity to transport wash load is typically much greater than the amount supplied. Riverbed sediments typically consist of coarse-grained particles such as sand, gravel, and cobble. Sand-sized particles can be transported by a river in suspension, if river velocities and turbulence are great enough, or rolled and bounced along the river bed as "bedload." Gravel and coarser-sized sediment particles are typically transported by a river as bedload.

Study Purpose

The purpose of this study was to determine the potential sedimentation impacts resulting from removing Savage Rapids Dam. Among the many significant concerns with this project are the volume, particle size gradation, and spatial distribution of

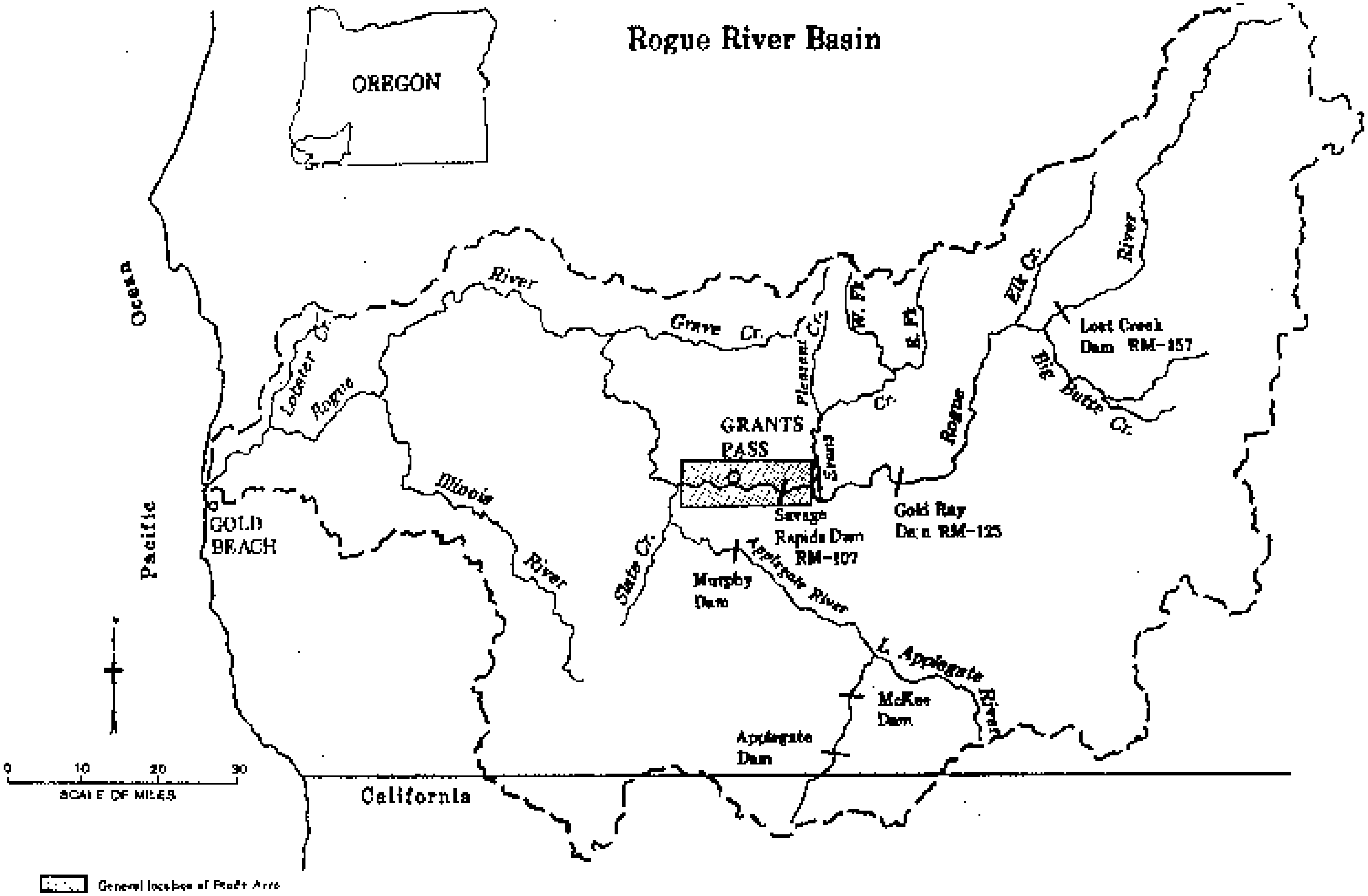

Figure 1.—Study area location map.

Figure 2.—View of Savage Rapids Dam, located on the Rogue River in southwestern Oregon, 5 miles upstream from Grants Pass. Photograph by Tim Randle on February 23, 1999. The mean-daily flow on this date was 7,400 ft^3/s (U.S. Geological Survey gauge at Grants Pass, Oregon).

sediment accumulated within the reservoir (see Appendix A), the chemical composition of the reservoir sediment (see Appendix C), and the rate at which the reservoir sediment would be eroded if the dam is removed (see Appendix B). Further, this study discusses the expected rate at which the eroded reservoir sediment would be transported down-stream, and the location and magnitude of deposition that might result downstream from the dam. Specific areas of interest include the potential for sediment deposition at the proposed GPID pumping plants and at the water intake and treatment operations for the City of Grants Pass.

Authority for the Study

Authority to conduct this investigation is provided in Public Law (P.L.) 92-199, enacted December 15, 1971 (85 Stat. 664), which authorizes the Bureau of Reclamation (Reclamation) to conduct a feasibility study of the Grants Pass Division, Rogue River Basin Project.

Events Leading to Study Initiation

Prior to 1971, Reclamation's involvement with Savage Rapids Dam and the GPID was limited to congressionally authorized emergency repairs and various modifications to the dam in 1953-54 and in 1957-58. In December 1971, the Congress passed P.L. 92-199,

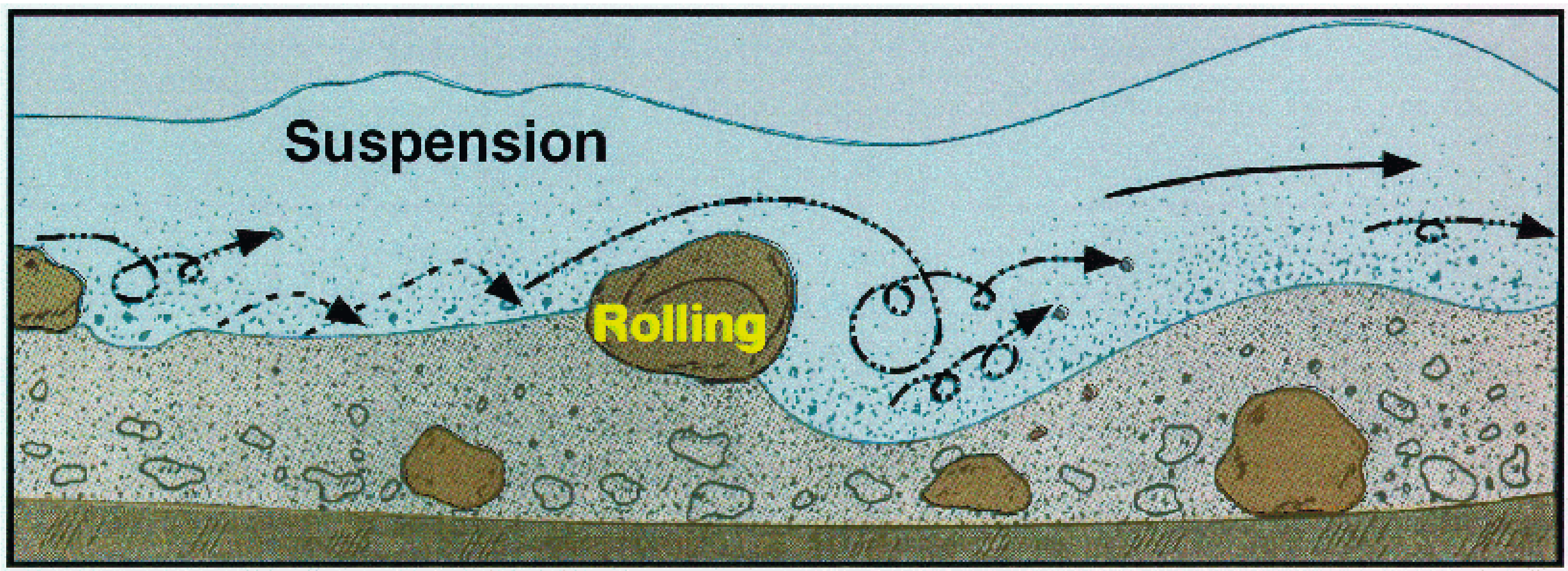

Figure 3.—Coarse sediment (sand and gravel) are transported as bedload along the river channel bottom. Fine sediment (silt and clay) are transported in suspension.

which authorizes the Secretary of the Interior to conduct a feasibility study of the Grants Pass Division, Rogue River Basin Project, Oregon. The initial study included fish passage at Savage Rapids Dam and the need to improve the existing GPID distribution system. The two studies were done concurrently.

Reclamation undertook the fish passage study. Because of the immediate need to improve fish passage, the intent was to develop an interim solution to fish passage.
All water-related problems and integration of solutions with a permanent solution to fish passage would be considered in a later phase. The results of the fish passage study were published in a special report in 1974. The Congress authorized the measures proposed in the report and appropriated funds for construction in P.L. 93-493. Reclamation completed the *Final Environmental Statement, Anadromous Fish Passage Improvements, Savage Rapids Dam, Rogue River Basin Project, Grants Pass Division-Oregon (INT-FES 76-26)* and made it available to the public on May 18, 1976.

Not all the interim measures identified in the report were implemented. Some work was done on the south fish ladder, but a solicitation for bids to replace the north fish ladder received only one response, which exceeded available funds. In November 1979, it was decided to use the remaining funds to replace the north side fish screens and defer further work on the fish ladders until a permanent resolution of the fish passage issue could be achieved.

A plan formulation working document (Reclamation, 1979) provided some information on the second phase of the study. Following public review, it was concluded that a Federal project to improve irrigation should be deferred. The fisheries part of the study was continued until 1984, when further work was deferred because of uncertainty regarding potential development of hydropower at the dam. It eventually became clear that the State of Oregon would not amend existing legislation to allow hydropower development at the dam. This stopped the Federal Energy Regulatory Commission application and provided impetus to proceed with finding a permanent solution to fish passage problems.

In early March and April of 1987, Josephine County, GPID, and the City of Grants Pass solicited the Commissioner of Reclamation and the Oregon congressional delegation to provide funds for Reclamation to reopen investigations authorized by P.L. 92-199. The Congress provided funding in fiscal year 1989 for the current investigation, called the Josephine County Water Management Improvement Study (JCWMIS), which was initiated at that time. The primary objectives of the JCWMIS were to (1) identify a permanent solution to salmon and steelhead passage problems at Savage Rapids Dam and (2) help resolve conflicts over water uses in Josephine County. Reclamation prepared and distributed a progress report on the fishery portion in May 1992 and a report on GPID water management in December 1992.

On January 5, 1994, the GPID Board voted to remove Savage Rapids Dam if certain conditions, including capital and operational funding, water availability guarantees, and protection from liability exposures, could be met. In March 1994, GPID submitted a water management plan (Newton, 1994) to the Oregon Water Resources Commission. It was anticipated that any water conservation/management alternatives suggested in the report would be privately funded. Accordingly, Reclamation did not prepare a report on water management options for consideration by the Congress.

A planning report/final environmental statement (PR/FES), filed on August 30, 1995, and subsequent record of decision (ROD), signed on March 14, 1997, focused only on salmon and steelhead passage concerns at the dam and the associated diversion facilities. The environmental statement (FES) concluded that fish passage and protective facilities at Savage Rapids Dam were inadequate and caused a significant loss of salmon and steelhead. The FES also included a preferred alternative (Pumping Alternative) that included removal of the existing dam. This alternative provided the greatest net economic benefits consistent with protecting the Rogue River fisheries. Also, it would result in the re-establishment of a free-flowing reach of river while providing new electrically driven irrigation diversion pumping facilities.

With the completion of the PR/FES and ROD, Reclamation considered its study of alternatives to improve salmon and steelhead passage at Savage Rapids Dam and the evaluation of those alternatives under the National Environmental Policy Act to be complete. Reclamation chose not to pursue authorization and funding to implement the PR/FES Preferred Alternative because of a lack of strong local consensus.

After completion of the PR/FES, the Oregon Legislature passed a law directing establishment of a task force to review the findings of the report and to make recommenda-tions. That task force completed its work and recommended a dam retention option. The task force based its recommendation largely on sediment-related concerns which resulted from documented examples of sediment damage to other North American rivers where dams were either demolished or breached by high water. Concerns regarding the accumulated sediment behind Savage Rapids Dam continued to be expressed by the chairman of the task force following release of the task force recommendations. The following sediment-related issues were discussed by the task force.

(1) The sediment may contain hazardous contaminants from upstream mining and other human activities.

(2) The sediment might plug pumps or cause elevated maintenance costs for pumps proposed for construction immediately downstream from the dam to supply water to the GPID.

(3) Release of the sediment could affect fisheries and fish habitat downstream from the dam.

(4) Release of sediment could affect the municipal water supply system of the City of Grants Pass, which is located 5 miles downstream from the dam.

(5) Release of the sediment could cause barriers to safe navigation of the Rogue River downstream from the dam.

Sportfish Heritage funded sampling and testing of the sediment behind the dam in 1998, and McLaren/Hart conducted the sampling under contract. McLaren/Hart checked for the presence of toxic metals and volatile organic compounds (VOCs). The Environ-mental Protection Agency reviewed the McLaren/Hart (Sportfish Heritage) report and concluded that the data contained therein indicated that release of the sediments would present minimal ecological risk from VOCs or heavy metals contamination.

Reclamation originally planned to do a detailed sediment study as part of predesign activities if the Congress approved the removal of the dam and provided adequate funding to do so. However, GPID, the Oregon Water Resources Department, National Marine Fisheries Service, WaterWatch, and others agreed that the sediment study should occur sooner (to accomplish that goal). These entities assisted in acquiring Federal funding for this sediment evaluation study.

Description of the Study Area

Savage Rapids Dam and the GPID service area are within the lower part of the middle Rogue River basin, which includes most of Josephine County and a large part of Jackson County. The middle Rogue is surrounded by mountains, and more than three-fourths of the basin is forest or timberland. The Rogue River is a designated wild and scenic waterway from its junction with the Applegate River, just west of Grants Pass, Oregon, downstream to Lobster Creek Bridge, about 10 miles upstream from the mouth of the river.

Nearly one-half of the total basin area and most of the basin population is contained in the central valley region. Medford, Oregon, the largest city in the region, is located about 30 miles southeast of Grants Pass. Most of the usable land within the valley is well developed and fully utilized within the limits imposed by climatic conditions, soils, topographic features, availability of water, and planning and zoning constraints.

Of the total drainage area upstream from Savage Rapids Dam, 30 percent (686 square miles) is regulated by Lost Creek Reservoir, primarily a flood control reservoir built and maintained by the U.S. Army Corps of Engineers (Corps). A few other reservoirs, such as Emigrant Lake, may also trap a small amount of sediment that would otherwise be delivered to the Rogue River. However, these drainage areas are small relative to that of the Rogue River, and they were not within the scope of this study. Lost Creek Reservoir, which began storage in February 1977, reduces flood peaks at Savage Rapids Dam by storing water during high flood peaks. Lost Creek Dam also traps virtually all of the sediment transported into the reservoir by the Rogue River during these peak flows. Therefore, virtually no sediment from the uppermost Rogue River drainage gets past Lost Creek Dam.

The Applegate River enters the Rogue River 12.5 miles downstream from Savage Rapids Dam. This tributary contributes large quantities of sediment (sand and gravel) to the Rogue River. Just downstream from the confluence with the Applegate River, the Rogue River enters Hellgate Canyon, a steep, narrow, bedrock canyon that is 65 miles long. The Rogue River exits the canyon approximately 30 miles from the ocean, and the slope of the river flattens out. The Illinois River enters the Rogue River just downstream from the canyon mouth and contributes additional water and sediment to the river.

Description of Savage Rapids Dam and Reservoir

Savage Rapids Dam, built in 1921 to divert riverflows for irrigation, is located at approximate river mile (RM) 107.6 on the Rogue River, at the Jackson and Josephine County line in southwestern Oregon about 5 miles east of (upstream from) Grants Pass, Oregon. The dam is a combination gravity and multiple arch concrete dam with a crest length of 464 feet and a structural height (total height of the dam from the foundation to the top of the crest, including the stop logs) of 39 feet (Reclamation, 1997). The hydraulic height of the dam (height of the structure from the original channel bed elevation to the crest of the dam) is 30 feet. The crest elevation of the dam is 957.6 feet in the 1988 North American Vertical Datum (NAVD) (elevation 953.0 in the 1929 National Geodetic Vertical Datum [NGVD]). The river outlet for the dam consists of two 7- by-16-foot radial gates with a combined capacity of 6,000 ft^3/s. Fish ladders are present on both ends of the structure, with the north ladder located on the right abutment of the dam and the south ladder located on the left, adjacent to the headworks for the Gravity Canal.

The permanent pool impounded behind the dam extends about ½ mile upstream from the dam at low flow if the stop logs are removed. Here, a natural formation in the riverbed creates a small riffle. The river flows as a natural stream above the riffle. The spillway crest of the dam contains 16 bays that are numbered sequentially from right to left, beginning at the pumping plant located on the right end of the dam (Russell, 1950). "Stoplogs" are placed in these bays during the irrigation season to enlarge the reservoir pool by raising the hydraulic height 11 feet to elevation 968.6 feet (1988 NAVD) (elevation 964.0 in the 1929 NGVD) for irrigation deliveries. This rise in the reservoir water surface extends the reservoir about another 2 miles upstream to RM 110.6 (near the confluence with Evans Creek) for the duration of the irrigation season that typically extends from about mid-May to about mid-October each year. The stoplogs are removed at the end of the irrigation season, which returns the section of the reservoir upstream from Savage Rapids Park to free-flowing river conditions from the late fall to early spring.

Savage Rapids Reservoir Sedimentation History

When water enters the reservoir behind a dam, flow velocity and turbulence decrease and sediment tends to deposit. The typical water storage volume behind a diversion dam is small, and the pool behind a diversion dam tends to fill with sediment in the first few years of operation. After this initial sediment filling, virtually all sediment transported by the river into the reservoir passes the dam. The reservoir probably filled with sediment to its storage capacity within the first few years of operation, and it is full now.

Nearly all the sediment is naturally transported during periods of high flow on the Rogue River. High flow typically occurs during winter floods and the spring snowmelt runoff when the stop logs are removed. Because the reservoir pool is lowered and extends only ½ mile upstream during these high flow periods, river conditions exist up-stream from the public boat ramp at Savage Rapids Park (see figure 10 in Appendix B). These river conditions cause high velocities relative to the reservoir velocities behind the dam (but no higher than downstream from the dam). High velocities mean the dam does not cause sediment deposition in the upper 2 miles of the reservoir (from the public boat ramp to Evans Creek) during this period. It is possible that a small amount of sediment gets deposited in the upstream end of the reservoir during the irrigation season. However, this sediment would be transported toward the dam during the nonirrigation season, when the reservoir is drawn down. Reclamation's drill crew confirmed the overall pattern of sedimentation when it collected field samples of the reservoir sediment, and divers visually confirmed, by observing the bottom, that the dam does not cause sediment to be permanently deposited in the upper 2 miles of the reservoir.

A riffle existed at the dam site before dam construction. (See figure 11 in Appendix B.) A river pool, which is now filled with sediment, existed immediately upstream from the riffle. If the dam caused sediment deposition in the upper 2 miles of the reservoir, any other pools that existed would have quickly filled in with sediment and would also now be buried. However, the survey of the reservoir bottom found several pools that exist upstream from the public boat ramp. This further supports the belief that the dam does not cause permanent reservoir sedimentation upstream from the public boat ramp. Therefore, the sediment deposition caused by Savage Rapids Dam occurs in the ½-mile reach just upstream from the dam to the public boat ramp.

Coarse sediment (sand and gravel), which travels as bedload, has deposited in the ½-mile reach immediately upstream from the dam. Fine sediment (silt and clay) is easily suspended in the water column and carried past the dam. This permanent deposition of coarse sediment probably occurred within the first few years after the dam was built. All sediment entering the reservoir since that time (mostly during high flows) passes the dam. Visual observations confirm that even gravel-sized sediment is being transported past the dam (see figure 13 in Appendix B).

History of Mining Upstream From Savage Rapids Dam

Two mining areas lie partially within the Rogue River basin (see figure 1 in Appendix C). These include the Klamath Mountains and western Cascades mining areas. Three subareas within the Klamath Mountains mining area are upstream from Savage Rapids Dam. These are the Greenback-Tri-County area (which is located primarily in the Evans Creek Basin); the Gold Hill-Applegate-Waldo area that includes the Applegate River Basin downstream from the dam and numerous mines east of the town of Rogue River and the lower end of Bear Creek; and the Ashland area (which is located in the upper Bear Creek Basin) south of Medford (see Appendix C).

Most of the mines, other than placer mines, ceased working by 1940. Therefore, any materials discharged during active mining would be relatively deep in the reservoir sediment or not present at all. Dredging of placer deposits upstream from Savage Rapids Dam in the main stem of the river and on the lower reaches of many of its larger tributaries continued through the 1940s, and several continued into the 1950s and 1960s. There were also several large hydraulic operations in the basin (Brooks and Ramp, 1968).

Study Reach Evaluated

Sediment that is transported past the confluence with the Applegate River would be transported all the way to the Pacific Ocean, 95 miles downstream (see figure 1). Total stream power is an indicator of the river's ability to transport sediment (transport capacity). The total stream power is higher everywhere downstream from the Applegate River confluence (RM 95) than in the 12.5-mile reach from Savage Rapids Dam to the Applegate River confluence (see figure 4 in Appendix B). Any sediments that get transported past the Applegate River would keep moving through Hellgate Canyon. Just downstream from the mouth of Hellgate Canyon, the Rogue River becomes less steep, which would reduce sediment transport capacity. However, tributary flows from the Illinois River maintain the river's capacity to transport sediment at a relatively high level. Therefore, the reach of river studied in detail for sediment impacts following removal of the dam was from the upstream end of Savage Rapids Reservoir (near Evans Creek) to the confluence with the Applegate River.

Characteristics of the Study Reach

The Rogue River is a relatively steep, gravel- and cobble-bed river and consists of a series of pools, riffles, and rapids. In the 12.5-mile reach of river between the reservoir and the confluence with the Applegate River, the drop in water surface is just over 100 feet (see figure 2 in Appendix B). Eight of the pools in this reach are 10-20 feet deep (during low flow periods), and the remaining 10 pools are shallow (less than 10 feet deep).

Pools have greater depths and slower velocities than riffles, which have shallow depths, high velocities, and greater sediment transport capacity. During periods of low flows, water surface elevations through pools are relatively flat, velocities are low, and pools tend to slowly fill in with sediment (see figure 9 in Appendix B). During periods of high flows, such as the spring snowmelt or winter storms, the water surface slope through the pools increases, velocities increase, and sediment is eroded from the pools. Sediment is rapidly scoured from the channel bed of pools and transported down-stream. This natural process was observed at the U.S. Geological Survey (USGS) gauge cross section near Grants Pass (see figure 7 in Appendix B). During a winter storm in 1996-97, the channel bed at this section scoured out 6 feet and subsequently filled back in during low flow periods of the following year.

Types of Data Collected

A 2-foot contour map of Savage Rapids Reservoir was developed based on a sonar survey of the reservoir completed in July 1999 by Reclamation. (See attachments A and B in Appendix B.) The survey was performed from a raft equipped with a high-precision global positioning system and depth-sounding equipment. Using the same equipment, data were also collected along the river bottom downstream from the dam to the confluence with the Applegate River. These data were used to develop river cross sections for computer modeling purposes.

Additional data were collected to determine the volume, size, and chemical character-istics of sediments trapped behind Savage Rapids Dam (see figure 2 in Appendix A). Reclamation divers visually inspected the reservoir bottom for the presence of sediments in various parts of the reservoir. Concurrently, a drill rig was mounted on a barge to measure the thickness of reservoir sediments and collect samples for size and chemical analysis. These data, collected in the year-round reservoir pool, were combined with previous data collected by McLaren/Hart from adjacent bay deposits and along the margins of the reservoir.

Reservoir Sediment Volume

Reclamation surveyed 17 cross sections in Savage Rapids Reservoir in 1992 and estimated the reservoir sediment volume to be 516,000 cubic yards (yds^3) (Blanton, 1992). This study was performed during the irrigation season (while the stoplogs were in place), and Blanton assumed that sediments had deposited along the entire 2.5-mile-long reservoir. Pre-dam topographic maps of the reservoir basin do not exist, and the 1992 study did not have the benefit of any measured sediment thicknesses to determine the elevation of the pre-dam river bed. Sediment sampling was limited to the collection of five samples along the rim of the reservoir. Therefore, the 1992 study estimated a pre-dam river bottom by assuming a constant slope through the entire reservoir (2.5 miles) based solely on the lowest elevations among the 17 surveyed sections. In view of the general lack of available data and the assumptions made to estimate the pre-dam river thalweg (deepest point in the channel), the 1992 estimate was adequate for the appraisal-level study for which it was originally intended. However, based on the methods used to compute the sediment volume, it is apparent that several problems are inherent in this analysis. The method did not account for the pool and riffle complex that existed before the reservoir filling. Assuming a constant slope for the original river bottom overestimated sediment deposition in areas that are actually bedrock or riffles and underestimated areas which were actually pools that had filled with sediment. Because the reservoir has trapped sediments only in the ½-mile reach upstream from the dam, the 1992 volume estimate within the upper portion of the reservoir overestimated the actual sediment volume. The 1992 study underestimated the sediment volume in the lower reservoir (½-mile reach immediately upstream from the dam). Because of limited data and the resulting assumptions, the sediment volume estimate from the 1992 study was only accurate to the order of magnitude (hundreds of thousands of cubic yards) but not to the nearest hundred thousand cubic yards. Therefore, the volume estimate from the previous 1992 study is not comparable to the new volume estimate from this study because much more information was collected for this study.

Following the 1992 Reclamation study, McLaren/Hart collected data on the size and thickness of reservoir sediments (McLaren/Hart, 1998). These data were collected on exposed sediment bars along the margins of the reservoir during the nonirrigation season. The sediment volume within the sampled area was estimated to be 138,000 yds^3. McLaren/Hart noted that this volume estimate was 2.5 times greater than Reclamation's previous estimate of 55,000 yds^3 (Blanton, 1992) for the same ½-mile reach. The McLaren/Hart data were then extrapolated further upstream to include the same 2 ½-mile full-pool reservoir area as that used in the original Reclamation estimate. McLaren/Hart (1998) estimated that:

> *The total volume of sediment currently impounded. . .upstream of the Savage Rapids Dam is likely in excess of the 600,000 yds^3, and perhaps as much as 1,000,000 yds^3, based on the Reclamation estimate.*

Because the McLaren/Hart estimate was based on an extrapolation of the 1992 Reclamation estimate, this study also did not account for the fact that sediments are not trapped upstream from the public boat ramp.

Based on the new reservoir sediment data and observations by Reclamation and the previous data collected by McLaren/Hart, the volume of reservoir sediments is estimated to be 200,000 yds^3 (Appendix A). If this volume were placed on a football field, it would reach 100 feet high. This sediment volume is also roughly equivalent to 2 years of sediment load transported by the Rogue River at Grants Pass (Appendix B). Currently, this sediment load accounts for 70 percent of the transport capacity of the Rogue River at Grants Pass, assuming 30 percent of the sediment load is trapped upstream, in Lost Creek Reservoir.

Reservoir Sediment Sizes

Reservoir sediment consists mostly of sand and gravel (see figure 2 in Appendix A). Increases in turbidity are primarily caused by silt and clay-sized sediments that make up a very small portion (2 percent) of the reservoir sediment volume. Cobbles ranging in size from 3 to 5 inches in diameter and composing an estimated 5 to 20 percent by volume of the deposit were observed during geologic mapping of sediment exposures along the north shore of the reservoir.

Samples obtained from a finer-grained bar deposit on the south side of the reservoir show somewhat higher concentrations of fines (silt and clay) and average about 7.5 percent by weight with a maximum fines content of 20.7 percent noted in one sample (McLaren/Hart, 1998). This bar represents less than 10 percent of the total sediment volume stored behind Savage Rapids Dam. Downstream impacts from the higher fines content in the bar should be minimal because the south bar is located on an elevated bedrock shelf that forms the south rim of the reservoir. The bar is exposed at low reservoir elevations such as those anticipated during dam removal and erosion. Downstream transport of the south bar is not expected under low-flow conditions in the Rogue River. The south bar can be inundated and a portion of the existing sediment can be eroded and new sediment can be deposited during periods of high flow such as winter floods or spring runoff. But the high volume of riverflows needed to inundate the bar would tend to dilute the fines content and minimize any potential downstream impacts.

Contaminant Testing of Reservoir Sediment

A large amount of contamination was not expected in Savage Rapids Reservoir sediment because contaminants typically attach to finer-sized sediments, and these make up only 2 percent of the sediment behind the dam. Testing of reservoir sediment showed that there were no contaminants found with concentrations significantly higher than naturally occurring background levels (Appendix C). The chemical composition of reservoir sediment would not pose any hazard to water quality, fish and wildlife, or human uses if released from the reservoir.

Lower Columbia River screening levels for each chemical have been developed for use in the Pacific Northwest rivers. These screening levels provide a maximum concentra-tion of chemical presence in river sediments that is considered acceptable. Sediments must be tested for chemicals-of-concern before they can be released if active sources of contamination are determined to be present (Corps et al., 1998). The testing is based on the Lower Columbia River Interagency Dredge Material Framework. The sediment behind Savage Rapids Dam was probably trapped within the first few years following the initial filling of the reservoir in 1921. Because a substantial amount of mining was done upstream from the dam during the early 1900s, reservoir sediment was tested for numerous chemicals-of-concern to determine if there was any risk in releasing the sediments.

Reservoir sediments along the channel margins in the ½ mile upstream from the dam were analyzed for chemicals-of-concern by McLaren/Hart (McLaren/Hart, 1998). The McLaren/Hart study found that levels of arsenic, cadmium, mercury, copper, lead, and zinc were all well below screening levels (compare tables 3 and 5 in Appendix C), except for the concentration of copper in one sample. Additional samples collected by Reclamation from deep in the reservoir pool were also tested for cadmium, arsenic, copper, lead, mercury, zinc, and iron. The data show that the chemicals-of-concern are well below screening levels and in the same range as natural background levels. While there is no screening level for iron, comparisons were made to levels downstream from a site where extensive mining has been done. These comparisons show that levels of iron in the reservoir sediment are well below even background levels.

Riverflows and Sediment Transport

River Hydraulics Computer Model

A river hydraulics model, HEC-RAS (Corps), was applied to the study reach (Brunner, 1997). This model can predict the following hydraulic parameters for any given discharge on the Rogue River:

- Water surface elevation
- Average velocity
- Water depth for any given discharge on the Rogue River

The data needed to create the model were channel geometry in the reservoir, channel geometry downstream from the dam to the confluence with the Applegate River, channel roughness (a flow resistance parameter), and water discharge. This model was calibrated to measured data to ensure its capability to accurately predict hydraulic parameters (see figure 8 in Appendix B). Model results were used to compare water surface elevation, average cross section velocity, and water depth for existing reservoir conditions and for river conditions after the dam is removed.

Sediment Transport Computer Model

A sediment transport model, HEC-6t (Thomas, 1993), was applied to the study reach. This model can predict not only hydraulic parameters but also:

- Erosion of reservoir sediments
- Sediment transport and deposition downstream
- Changes in the channel bed

In addition to the hydraulic data listed in the previous section, the sediment data required by the model include the natural sediment supply of the Rogue River upstream from the dam, the size and thickness of sediment present on the reservoir and river bottom, and a hydrograph depicting riverflows over a period of time. Model results were used to analyze the volume of sediment eroded from the reservoir, the rate of erosion, the rate of sediment transport downstream, and the temporary deposition along the river channel.

Riverflows Following Dam Removal

The exact riverflows (timing, magnitude, and duration) following dam removal are unknown, but the historic flows on the Rogue River can be used as an indicator of what can be expected to happen. Riverflows have been recorded since 1939 at a USGS gauging station near Grants Pass, Oregon (see figure 16 in Appendix B).

Flood peaks on the Rogue River typically occur from November to March, with most occurring in December and January (Appendix D). The largest mean daily flow recorded on the Rogue River prior to construction of Lost Creek Reservoir was 124,000 ft^3/s (instantaneous peak of 152,000 ft^3/s) in December 1964. Local records and photographs document the large portions of Rogue River, Oregon, that were inundated and the numerous homes that were destroyed. The magnitude of flood peaks has been significantly reduced following construction of Lost Creek Dam. The largest flood since Lost Creek Dam was constructed occurred during January 1997. The mean daily flow reached 69,000 ft^3/s (instantaneous peak of 90,800 ft^3/s) in January 1997.

Riverflows Used to Model Dam Removal

The magnitude of riverflows following dam removal will determine how fast the reservoir sediment is transported downstream. The higher the peak flows that occur, the quicker sediment will be transported to the ocean. Looking at the historic data since Lost Creek Dam was constructed (see figure 16 in Appendix B), a period of dry years (where very few winter storms occurred) started in the late 1980s. Before and after this period, several wet years were recorded during which numerous winter storms occurred. Two possible extremes were modeled: (1) dam removal followed by several dry years as occurred in the late 1980s and (2) dam removal followed by the wettest year that was recorded (1996-97 water year), followed by subsequent wet years (Appendix B). The modeling of both hydrologic extremes assumed two dam removal scenarios: (1) the dam would be removed in May (at the beginning of the summer low flows and the start of the irrigation season); and (2) the dam would be removed in November (after the irrigation season but at the start of the winter flood season).

Rate and Extent of Reservoir Sediment Erosion

Savage Rapids Reservoir is only two to three times wider than the natural river channel in the ½-mile reach just upstream from the dam. This means that nearly all the reservoir sediment trapped behind the dam would be eroded by the river rather than stranded as the water surface elevation of the river quickly decreases following dam removal. However, small sediment deposits may permanently remain along the margins of the reservoir.

An initial flushing of reservoir sediment would occur immediately following removal of the dam. This flushing occurs because, as the dam is removed, the river would seek a lower base level and begin incising through the sediment deposits behind the dam. This incision process and sediment flushing would continue until a stable slope is reached upstream from the dam site. This flushing would cause sediment concentra-tions[1] downstream from the dam site to significantly increase for a short duration of time immediately following dam removal (figure 4). After the initial flushing, successively higher flows would be required to erode more sediment from the reservoir deposits immediately upstream from the dam and again increase the sediment load to the downstream river channel. Sediment concentrations will be much higher than natural conditions during the first flood following dam removal. These high concen-trations will tend to decrease toward natural levels with each subsequent flood. Between floods, sediment concentrations will be relatively low.

At the present time, no detailed plan has been formulated regarding the timing and sequence of dam removal. Various dam removal plans could be considered to evaluate the following sediment design parameters:

- The amount of sediment that could be sluiced through the radial gates before dam removal
- The season or month the dam removal would begin in accordance with in-river work periods
- The length of time over which the dam would be removed
- The length of dam section(s) that would be removed or permanently left in place[2]

For this study, it was assumed that the dam would be removed in a manner that would allow all reservoir sediments to begin eroding immediately following dam removal. Under this assumption, reservoir sediments would erode during the low-flow summer season when the transport capacity of the downstream river channel would be at its

[1] Sediment concentration refers to the mass of sediment transported by the river per unit volume of water. Sand-sized sediment is transported in suspension through riffles, rapids, and short pools where velocity and turbulence are high. Coarse-sized sediment (gravel and cobble) is transported as bedload.

[2] The plan in the PR/FES calls for full removal; pieces could be left on the abutments for historic interpretation and as a cost-saving measure.

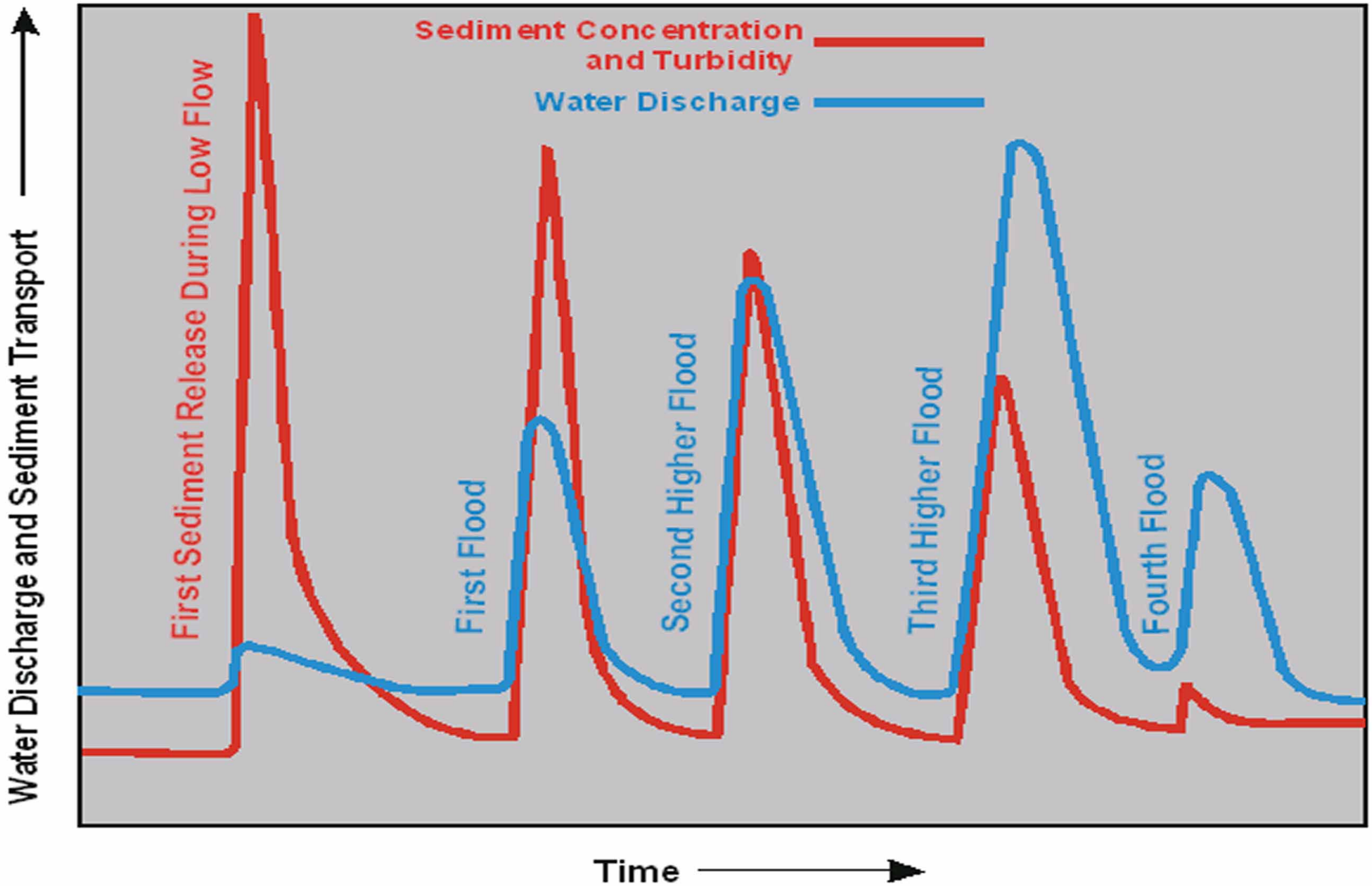

Figure 4.--Conceptual depiction of the relationship of wter discharge and sediment transport in the downstream river channel following removal of a dam.

lowest. This would result in the maximum amount of deposition in the river channel downstream (especially pools and eddies). In contrast, if the reservoir sediment erosion could begin during the high-flow winter season, the amount of sediment deposition on the riverbed would be considerably less.

Model results show that if Savage Rapids Dam is removed, virtually all the sediment would be eroded from the reservoir (see figure 21 in Appendix B). Regardless of when the dam is removed and whether a series of dry or wet years follows removal (based on historical flows), about three-fourths of the reservoir sediment would be eroded from the area immediately upstream from Savage Rapids Dam within the first year.

Sediment Transport

The sediment that is eroded and flushed from the reservoir would be transported downstream. This sediment would temporarily deposit in areas of low velocity, such as pools and eddies (zones of recirculating flow). As sediment deposits along the bottom of pools and eddies (decreasing water depths), river velocities will increase until the velocities become so high that sediment is transported through the reach rather than deposited. Sediment deposition in pools and eddies would occur during low-flow periods, as it does now. Sediment would subsequently be scoured out and transported downstream during high-flow periods. All the sediment would be eroded and eventually reach the ocean.

The reservoir sediment would be transported past the Applegate River confluence (12.5 miles downstream from the dam) within a 1- to 10-year period. The length of time would depend on the frequency and magnitude of high-flow events following dam removal (see figure 22 in Appendix B). The 1-year period would require an extremely wet year with several high flows following dam removal, and the 10-year period would result if several dry years with very few or no high flow peaks followed dam removal. Maximum deposition levels would occur at various times following dam removal but not everywhere at once (see Appendix B, attachment F). Maximum deposition levels will range from 1 to 8 feet in river pools. No flooding as a result of the dam removal is predicted because all deposition would occur in river pools, and deposition in river pools would not cause an increase in water surface elevation. The time required for the sediment to reach the ocean depends on the frequency and magnitude of high-flow events. Most sediment transport would occur during floods. If flood magnitudes following dam removal are high and floods occur frequently, the reservoir sediment would reach the ocean within a few years. If the flood magnitudes are low or floods occur infrequently, the reservoir sediment would reach the ocean over a much longer period of time. Under either scenario, sediment concentration and transport rates would be relatively low and near natural levels between floods.

River Channel Following Dam Removal

Prior to the dam, a riffle existed at the dam site, and a pool was formed immediately upstream from the riffle (see figure 11 in Appendix B). These river features would be restored as the reservoir sediment that currently covers them is eroded and transported downstream. The water surface elevation in the ½-mile reach upstream from the dam would be lowered to near the pre-dam elevation if the dam were to be removed (see figure 23 in Appendix B) and would look much different from the way it looks today (Appendix B). However, upstream from the public boat ramp, the water surface elevation would look the same as it now looks during the nonirrigation season when the stoplogs are pulled out and the reservoir is lowered back to the permanent pool level.

The velocities through the dam site following dam removal were also estimated (see figure 24 in Appendix B). Three possible scenarios were evaluated to determine how removing all the dam versus only a portion of the dam would impact velocities (Appendix B). Looking at the cross section immediately downstream from the dam, most of the channel bottom to the left of bays 10 and 11 (where radial gates now exist) is composed of bedrock that would still exist after removing the dam. The results show that by removing bays 1 through 11, velocities will not exceed 10 feet per second at flows lower than 30,000 ft^3/s. Existing velocities in Pierce Riffle, approximately 1 mile downstream from the dam, do not typically exceed 8 feet per second.

Sediment-Related Impacts to River Infrastructures as a Result of Dam Removal

In addition to the environmental impacts resulting from periods of high sediment concentration and from temporary deposition along the riverbed following dam removal, there are concerns about the impacts to specific structures located along the Rogue River downstream from the dam (Appendix B). Sediment-related impacts are addressed in this study for the structures listed below:

- Two pumping plants would be constructed (one on each side of the river) immediately downstream from the dam to enable the GPID to deliver water to its patrons through the irrigation canals during and after dam removal (see figure 25 in Appendix B).
- The existing Grants Pass city water treatment plant and intake structures are located about 5 miles downstream from the dam (see figure 26 in Appendix B).

Irrigation Pumping Plants.—If the dam were removed during the irrigation season and the reservoir sediment were allowed to erode downstream, sediment concentrations in the river channel (downstream from the dam) would be higher than normal. Because the new pumping plants would be located just downstream from the dam, there is concern that

sediment would deposit around the fish screens, at the pump intake, and in the intake channels between the river and pumping plants. If sand entered the pumping plant, it could damage the pumps through abrasion and potentially deposit along the irrigation canals. Fine sediment (silt and clay) would not damage the pumps or deposit in the canals. The best way to eliminate or minimize these potential impacts is to prevent coarse sediment from depositing around the fish screens or entering the pumping plants. This would be accomplished by locating the pumping plants along
the river channel where the river velocities are relatively high and parallel to the fish screens. A low-elevation submerged training wall could be constructed in the channel to divert coarse sediments, which are transported as bed load, away from the fish screens. Temporary dredge pumps could also be employed to remove sediment from the fish screens and pumps, if necessary.

If the reservoir sediment is allowed to erode during the nonirrigation season, it would not impact the pumps or the irrigation canals because they would not be in operation. Some sediment may deposit around the fish screens or intake channel, but that sediment could be removed prior to the beginning of the next irrigation season.

Additional sediment would erode after the initial flushing of the reservoir sediment, but only during high-flow periods that would most likely occur during the nonirrigation season when the pumping plants would not be in operation. Riverflows and natural sediment loads would tend to be low during the irrigation season. In fact, very little coarse sediment would be transported during the low-flow (irrigation) season. Therefore, sediment impacts on the pumping plants would be minimal after the initial flushing of reservoir sediment has occurred following dam removal.

City Water Treatment Plant Intake Structures.—The concentrations of sand being transported by the river vary with depth and with location across the channel. Sand concentrations are much greater near the riverbed than near the water surface and tend to be greater along the outside of river bends than along the inside of bends. The intake structure for the city water treatment plant is located on the outside of a river bend and is relatively deep in the water. However, intake structures are normally designed to minimize (to the extent possible) the entrainment of coarse sediment. For computa-tional purposes, the concentration of sand entering the treatment plant was assumed to be equal to the mean concentration in the river. Sand transport computations for the river indicate that riverflows have to exceed 21,000 ft^3/s before gravel and sand can be transported by the river and sand concentrations are high enough to enter the treatment plant (Appendix B).

As mentioned above, sediment concentrations would be greatest if the reservoir sedi-ments are first allowed to erode and be transported downstream during the irrigation season when riverflows tend to be low. As sediment is transported downstream by riverflows, some sediment would deposit in river pools and eddies (especially during low flows). This would diminish peak concentrations in the downstream direction. Because the Grants Pass city water treatment plant is located 5 miles downstream from the dam and because there are several deep pools in this reach, sediment concentrations would be less at the treatment plant than at the irrigation pumping plants.

In general, getting suspended fine sediment (silt and clay) to settle out of water diverted from the river can sometimes be a difficult task for water treatment plants, especially if the concentrations are high. However, the percentage of fine sediment trapped behind Savage Rapids Dam is very low (2 percent)[3], so it should not pose a significant problem for the city water treatment plant. Coarse sediment would rapidly settle at the treat-ment plant, but large settling volumes would require additional dredging and disposal. This would lead to increased labor costs. The reservoir sediment is predominantly sand (71 percent), and the volume of sand entering the treatment plant during the initial flushing of reservoir sediment would likely increase. In general, gravel-sized sediment would be too coarse to enter the treatment plant.

Water enters the Grants Pass Water Treatment Plant when river water is pumped directly into the intake structure, which is located on the right bank of the river (looking downstream). This water contains a certain concentration of sediment, all of which will eventually settle out in the plant as part of the treatment process. The amount of sand that would be deposited within the treatment plant from water pumped from the river following dam removal is difficult to predict with certainty. There are no measurements of sand transport by the Rogue River in the vicinity of the treatment plant intake structure. Also, the concentration of sand entering the treatment plant relative to the sand concentration in the river is not known. However, it is known that under existing conditions the amount of sand that gets pumped into the water treatment plant is generally between 5 to 15 cubic yards per year (G.A. Geer, City of Grants Pass, written communication, September 1, 2000), and nearly all of that volume enters during high-flow periods. Most of the sand in the existing riverbed is covered by gravel. Because it takes a fairly high flow to transport gravel, sand remains trapped at low flows, and the concentrations of sand transported by the river are near zero. However, when riverflows are high enough to transport the gravel on the surface of the riverbed, the sand transport rates dramatically increase and continue to increase exponentially with additional increases in riverflow.

The reservoir sediments would begin to erode during the removal of Savage Rapids Dam, even at low flows, in response to the higher river velocities through the former reservoir area. Sand and gravel-sized sediments would be transported downstream, but the volume would tend to diminish because sediment particles would temporarily deposit in river pools during periods of low flow. The river pools would progressively fill (in the downstream direction) to their sediment storage capacity. Consequently, a significant portion of the reservoir sediments would be temporarily stored in these river pools. The sand and gravel that is transported past the river pools would eventually reach the intake structure, and sand concentrations in the river would be temporarily high. The

[3] The fines would go immediately and not be a long-term problem.

concentrations of sand in the river would reduce as the peak of the sand wave passed the intake structure during the low-flow period. Sand concentrations would remain low until riverflows were high enough to transport the sand that would be temporarily stored in the river pools. Sand concentrations would be temporarily very high during high riverflows.

Sediment model results for high-water years following dam removal indicate that 80 cubic yards of sand could deposit in the treatment plant within the first year following dam removal (see figure 27 in Appendix B). Peak rates of sand deposition could exceed 10 cubic yards per day for a few days and exceed 30 cubic yards over a 1-week period. Actual sand deposition volumes may be much less than the model predictions. Based on the assumed hydrology, sand deposition volumes would decrease to 20 cubic yards during the second year following dam removal. After that, deposition volumes would be nearly the same as under existing conditions. Sand deposition rates in the treatment plant would be less if dam removal were followed by low-water years, but the duration of impacts would be extended to several years.

High rates of sand deposition in the treatment plant could cause rapid wear on the river intake pumps and complicate the method of removing sand from the plant's three sedimentation basins. From the perspective of the city water treatment plant, it would be best to release sediment from the reservoir during the period November through March. This would allow for large portions of the sediment to be quickly transported past the treatment plant during high-flow periods. The water treatment plant is operated during these months at a slower pumping rate and for fewer hours per day (G.A. Geer, City of Grants Pass, written communication, September 1, 2000). The combination of a slower pumping rate and fewer hours of daily operation would lessen the impact of sand-sized sediment on the pumps and sedimentation basins.

There is concern that excessive deposition of coarse sediments in the vicinity of the water treatment plant could plug the intake structure. If this were to occur, a dredge would have to be employed to remove the coarse sediments. As a preventive measure, a submerged guide wall could be constructed in the channel that would force riverflows of high sediment concentration near the bed to flow past the intake structure. Water flowing near the river surface would have a lower sediment concentration than flow near the bed. This water would flow over the wall and tend to flush the area around the intake structure.

All the sediment-related impacts at the city water treatment plant can be handled but at additional cost. These additional operating costs are difficult to estimate without knowing the future hydrology and the details of the dam removal plan, but these costs could be measured through a monitoring program. The results of this study, relative to the potential impact of sediment transport and deposition, would have to be addressed in future analyses detailing when and how the dam would be removed. Mitigation of adverse impacts that could occur at the Grants Pass city water treatment plant, or anywhere else, could be explored as part of the final design process.

Sediment Monitoring Recommendations.—This study identifies the potential sediment impacts if Savage Rapids Dam is removed. If a dam removal plan is implemented, the following recommendations for data collection would provide necessary information for monitoring the actual sediment impacts during and following dam removal:

- Detailed mapping of the eight deep river pools between the dam and the Applegate River
- Sampling bed material of the eight deep river pools between the dam and the Applegate River
- Continued measuring of discharge at the USGS gauging station
- Measuring bed load and suspended-sediment concentrations at the USGS gauging station at Grants Pass
- Continuous measuring of turbidity during and after dam removal at three locations: (1) the highway bridge at the town of Rogue River, (2) immediately downstream from Savage Rapids Dam, and (3) the Grants Pass city water treatment plant river intake

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LIST OF CONTRIBUTORS

The study documented by this report was performed by hydraulic and sedimentation engineers, geologists, water quality specialists, and hydrologists from the Bureau of Reclamation (Reclamation). The principal contributors to this study and specific sections of the corresponding report are listed below along with their technical area of expertise. The geologist was located in Reclamation's Pacific Northwest Regional Office in Boise, Idaho, while the remainder of the technical disciplines were located in Reclamation's Technical Service Center in Denver, Colorado.

Contributor	Technical discipline	Report sections
Jennifer A. Bountry	Hydraulic Engineer/ Sedimentation and River Hydraulics Group	Main body, Appendix B - Hydraulic and Sediment Transport Analysis and Modeling for Savage Rapids Dam Sediment Study
Timothy J. Randle	Hydraulic Engineer/ Sedimentation and River Hydraulics Group	Main body, Appendix B - Hydraulic and Sediment Transport Analysis and Modeling for Savage Rapids Dam Sediment Study
Richard Link	Geologist/Geology Exploration and Instrumentation Group	Main body, Appendix A - Geology
James Yahnke	Hydrologist/Land Suitability and Water Quality Group	Main body, Appendix C - Water and Sediment Quality Considerations Related to the Potential Savage Rapids Dam Removal
Kenneth L. Bullard	Hydrologist/Flood Hydrology Group	Main body, Appendix D - Hydrology
Robert Black	Study Manager/Resource Management and Planning Group	Executive summary, main body
Robert Rood	Technical Writer - Editor/ Technical Communications Group	Overall report
Sharon Leffel	Editorial Assistant/Technical Communications Group	Overall report
Bill White	Illustrator/Visual Presentations Group	Overall report

Technical Review

Peer review allows an outside party to provide technical review that can be incorporated and addressed throughout the course of a study. At the start of the Savage Rapids Dam Sediment Evaluation Study, the peer reviewers' participation included reviewing the initial plan of study and suggesting additional tasks that would be beneficial. During the analysis phase of the study, the peer reviewers provided comments on the hydrologic analysis of the Rogue River, the determination of the volume and sizes of reservoir sediment, the analysis to determine if contaminants were present in reservoir sediments, and the determination of the downstream impacts from the release of reservoir sediments if the dam were removed. As a result of the peer reviewers' suggestions, the following tasks were completed:

- The U.S. Army Corps of Engineers' regulated return flow computations were adapted for the hydrologic analysis.
- The reservoir volume analysis was expanded to clearly document the previous studies done on Savage Rapids Reservoir sediment.
- The sediment transport model was further calibrated.
- The reservoir sediment was evaluated for contaminants based on the Lower Columbia River Interagency Dredge Material Framework.
- Analysis of the river channel following dam removal and recommendations for future studies were incorporated into this report.

The draft document dated November 2000 was sent to several technical specialists for final technical review. The individuals listed below participated in the technical review of this study.

Area of review	Peer reviewer
Initial plan of study	Mr. Mark Siipola, U.S. Army Corps of Engineers, Portland District, Portland, Oregon
Entire study and report	Mr. Ron Mason, U.S. Army Corps of Engineers, Portland District, Portland, Oregon Mr. Richard J. Wenning, *McLaren/Hart* and *ChemRisk*, Alameda, California, San Francisco, California
Appendix B - Hydraulic and Sediment Transport Analysis and Modeling for Savage Rapids Dam Sediment Study	Jianchun Huang, Sedimentation and River Hydraulics, Technical Service Center, Bureau of Reclamation, Denver, Colorado

Appendix A

GEOLOGY

by Richard Link
Geologist

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Contents – Appendix A

Page

Tables

Figures

Attachments

Purpose of Study and Scope of Work

The Bureau of Reclamation's (Reclamation) multidisciplinary evaluation of the sediment stored behind Savage Rapids Dam included a geologic investigation of the reservoir area upstream from the dam. This investigation builds upon earlier work completed in 1998 by ChemRisk, a service of McLaren/Hart, Inc., for Sportfish Heritage of Grants Pass, Oregon. Use of the McLaren/Hart data in this report is with the express written permission of Sportfish Heritage, within the specifications of their letter dated June 8, 1999. The purposes of Reclamation's geologic investigation conducted in 1999 were to:

- Develop a conceptual model of reservoir conditions and the depositional environment based on geologic mapping of the reservoir rim, underwater examination of reservoir bottom conditions, and interpretation of bathymetric surveys of the reservoir bottom
- Estimate the geometry and volume of the reservoir sediment through measurement of sediment thickness and interpretation of reservoir bathymetric surveys
- Determine the physical properties of the sediment particles, including particle size distribution, soil plasticity, and particle density, as determined from laboratory testing of field samples
- Verify the results of the McLaren/Hart (1998) investigation by screening selected field samples for contamination with heavy metals and other toxins

This appendix of the multidisciplinary report discusses, in detail, the first three of the above-listed study purposes and the work conducted to accomplish those goals. The results of screening for heavy metals and toxin contamination are deferred to the discussion of water quality issues appearing in Appendix C.

The geologic investigation was conducted in distinct phases, which were directly related to reservoir operations and the water surface elevation of the reservoir impounded behind Savage Rapids Dam. The initial phase consisted of reconnaissance-level geologic mapping of the entire reservoir area extending upstream from Savage Rapids Dam to the confluence of the Rogue River with Evans Creek, a primary tributary stream located just upstream from the upper end of the reservoir, near river mile (RM) 110.6. The geologic mapping conducted on May 18, 1999, was timed to coincide with low reservoir levels resulting from concurrent installation of stoplogs along the crest of the dam. Installation of the stoplogs necessitated opening the low-level radial gates of the dam. The geologic mapping was performed using both ground observation of exposures and a jet boat reconnaissance of the entire reservoir length.

Staff from the Sedimentation and River Hydraulics Group of Reclamation's Technical Service Center in Denver, Colorado, conducted bathymetric surveys of the reservoir bottom in early July 1999. The bathymetric data were compiled to develop a topographic map of much of the reservoir bottom from Savage Rapids Dam upstream to near the confluence with Evans Creek.

From September 20 through October 5, 1999, staff from the Geology, Exploration and Instrumentation Group of Reclamation's Pacific Northwest Regional Office in Boise, Idaho, conducted the main geologic investigation of the sediment stored behind Savage Rapids Dam. This work entailed drilling 12 holes from a floating drilling platform located in the reservoir upstream from the dam. The total drilling footage completed in this investigation was 396.6 feet. Laboratory tests were performed on 25 field samples to determine standard properties of the reservoir sediments and on 4 samples to screen for heavy metals content.

The field investigations and the results of the study are presented in the following sections of this appendix.

Location

Savage Rapids Dam is located approximately at RM 107.3 on the Rogue River at the Jackson and Josephine County line in southwestern Oregon, about 5 miles east of Grants Pass (Water and Power Resources Service, 1981). The dam is located in the SE ¼ of the SE ¼ of Section 24, Township 36 South, Range 5 West. Savage Rapids Dam is a combination gravity and multiple arch concrete dam with a crest length of 464 feet and a structural height of 39 feet (Reclamation, 1997). The hydraulic height of the dam (height of the structure from the original channel bed elevation to the crest of the dam) is 30 feet. The crest elevation of the dam is 957.6 feet in the 1988 North American Vertical Datum (NAVD) but 953.0 feet in the 1929 National Geodetic Vertical Datum (NGVD). The spillway crest is fitted with 16 stoplog bays which raise the crest 11 feet, to elevation 968.6 feet (964.0 feet in the 1929 NGVD), for irrigation deliveries. The stoplog bays are numbered sequentially from right to left beginning at the pumping plant, located on the right end of the dam (Russell, 1950). The river outlet for the dam consists of two 7-by-16-foot radial gates, with a total capacity of 6,000 cubic feet per second. Fish ladders are present on both ends of the structure, with the north ladder located on the right abutment of the dam and the south ladder located on the left, adjacent to the headworks for the Gravity Canal.

The permanent pool impounded behind the dam extends about 3,000 feet upstream from the dam to a point just upstream from the boat launch at Savage Rapids Park, located on the left rim of the reservoir. The water surface elevation of the reservoir is raised about 11 feet during the irrigation season by the installation of stoplogs across the crest of the dam. This rise in the reservoir water surface extends the reservoir about 15,000 feet upstream to approximately RM 110.6 for the duration of the irrigation season, which typically extends from about mid-May to about mid-October each year. The stoplogs are removed at the end of the irrigation season, and the section of the reservoir upstream from Savage Rapids Park returns to free-flowing river conditions from the late fall to early spring.

Surveys and Base Map

The geologic investigation of the sediment stored behind Savage Rapids Dam entailed the integration of newly collected field data with the results obtained from previous work at the site. The previous work was conducted using several different survey datums, and compilation of these various data bases into one consistent datum was needed before analysis of the sediment type and volume could be undertaken. A key element in this compilation was to use the same survey datum as that used in the hydraulics and sediment transport analyses (see Appendix B).

The following sections describe the field surveys performed in the 1999 sedimentation study and the processes used to convert previous work to the datums used for this report. The last section describes the process used to generate the base map and special considerations used to fill in gaps in the data and the adjustments made to fit data collected in earlier studies.

1999 Field and Bathymetric Surveys

The 1999 Reclamation field surveys were collected using the 1983 North American Datum (NAD), Oregon South Zone state plane horizontal grid. Vertical positions were obtained using the NAVD of 1988. The bulk of the survey work was performed for the hydraulic and sediment transport studies. The work included bathymetric surveys of the reservoir and portions of the Rogue River downstream from the dam (from Pierce Riffle to the confluence with the Applegate River) and land surveys to tie into existing survey control points and various features of Savage Rapids Dam. These surveys are described in greater detail in the discussion of stream hydraulics and sediment transport (see Appendix B). The following discussion addresses the application of the survey data to the geologic analyses of the sediment character and volume.

Reclamation staff conducted the bathymetric surveys using a cataraft equipped with a small out-board motor, a Raytheon sonar depth sounder, and a survey-grade Trimble global positioning system (GPS) receiver set up with a radio link to the boat to record the position of each depth sounding. Note that the bathymetric survey did not extend into the forebay area immediately upstream from the dam because flows in the Rogue River were being passed through bays 1 through 4 on the right end of the dam at the time of the survey in early July 1999. The resulting current made it unsafe to enter the forebay with the cataraft. Staff from the Sedimentation and River Hydraulics Group of

Reclamation's Technical Service Center in Denver, Colorado, compiled the depth soundings and prepared a bathymetric map of the reservoir bottom at a scale of 1 inch equals 100 feet and a contour interval of 2 feet. This map was then used to interpret reservoir conditions on the basis of the bottom morphology and to select locations for subsequent drilling and sampling of the reservoir sediments. The bathymetric map has been used as the base map for the geologic investigation (see drawing 448-100-17 in attachment A), as is discussed in the following section. This base map was used to prepare a series of geologic cross sections through the reservoir area for calculation of the volume of the sediment stored behind Savage Rapids Dam.

Upon completion of the drilling program, Ms. Roberta Robles of the Rogue Valley Council of Governments in Central Point, Oregon, performed additional surveying to obtain final locations for the drill holes. Ms. Robles used a Trimble survey-grade GPS receiver. This survey also used the 1983 NAD and the 1988 NAVD to maintain consistency with the earlier work conducted for the hydraulic and sediment transport analyses. Note that three drill holes (AP-99-1, -3, and -12) were not surveyed. The marker buoys placed after completion of holes AP-99-1 and 99-3 were stolen or displaced by vandals prior to the survey. Hole AP-99-12 was drilled over the weekend, following completion of the survey. Field locations for these holes were taken using a recreational-grade Garmin 12 GPS receiver, but these locations have not been used on the base map because the GPS locations have too large an error. The locations shown on the map are based on triangulated field positions using landmarks along the shoreline, but they are more accurately located than were the Garman 12 GPS locations. The locations of these three holes appearing on the respective geologic logs in attachment B have been measured from the plotted locations on the base map.

Conversion of Earlier Work to 1999 Survey Datums

Use of the 1983 NAD and the 1988 NAVD provided consistency between the geologic and hydraulic portions of the 1999 sedimentation study but required conversion of all previous work at the dam to the more recent datums. The processes used to convert the older data to the current survey datums are discussed in the following sections.

The as-built plan of Savage Rapids Dam (drawing 712-D-9) is based on the original 1922 plan of the dam (file drawing 256C or Reclamation drawing 712-100-58) and has no reference to a horizontal coordinate system. Vertical positioning of the dam is tied to the 1929 NGVD, based on a U.S. Geological Survey (USGS) monument (brass cap NGS J257, 1954) on the left end of the dam. The elevation shown on the brass cap (elevation 968 feet) agrees closely with the crest elevation of the dam shown on drawing 712-D-9 (elevation 968.0 feet). Note that the reservoir water surface gauge on the pumping plant on the right end of the dam also is tied to the 1929 NGVD.

The plan of the dam was converted to the 1983 NAD/1988 NAVD using land surveys conducted at the dam as part of the bathymetric survey of the reservoir. The land survey tied in brass cap NGS J257 to the 1983 NAD datum and obtained positions for several prominent features of the dam, including the corners of the right abutment pumping plant. These points were used to position the plan of the dam on the base map within the 1983 NAD horizontal grid (Oregon South Zone). Conversion of the 1929 NGVD to the more recent 1988 NAVD was accomplished by surveying several locations along the crest of the structure, including the brass cap, and comparing them to the older elevations. This comparison showed that the 1988 NAVD was 4.6 feet higher than the 1929 NGVD, and a conversion factor of plus 4.6 feet was added to all elevations derived from the 1929 datum, including reservoir elevations measured at the right abutment staff gauge during the drilling program.

The conversion of the hole locations from the McLaren/Hart (1998) investigation to the 1983 NAD/1988 NAVD involved a more detailed process. A private surveying contractor, Max H. Hull Surveying, of Grants Pass, Oregon, located these holes for Sportfish Heritage, Inc., and the survey data is used in this report with the express permission of Sportfish Heritage. Vertical control in that survey was based on a local coordinate grid system using U.S. Coastal and Geodetic Survey brass cap 968 J 2571934 (elevation 968.785 feet), located near the left end of the dam (Max H. Hull Surveying, personal communication). Two parallel processes were used to convert these hole locations to the 1983 NAD and 1988 NAVD for inclusion on the base map. A graphical analysis was performed in which the outline of the dam and hole locations were digitized from figure 2-1 of the McLaren/Hart report (1998) and then overlaid onto the same outline on drawing 448-100-17 (the base map) in attachment A. This process worked well, except for holes SB-4 and -5, which had been truncated off the right margin of figure 2-1 in the Pacific Northwest region file copy of the McLaren/Hart report. While this graphical analysis achieved a suitable best fit for horizontal locations of the drill holes, spatial control of vertical elevations for the drill holes could not be obtained through this process.

Max H. Hull Surveying used a local grid based on a brass cap monument located on the left end of the dam to survey the 1998 McLaren/Hart drill holes. Vertical elevations reported for the holes are based on the elevation for the brass cap, which appears to be in the 1929 NGVD. Horizontal coordinates were converted to the 1983 NAD by plotting the surveyed locations of the drill holes, brass cap, and points taken on the dam onto the base map prepared for this study (drawing 448-100-17). The 1998 surveyed hole locations were then compared to the digitized locations appearing in the McLaren/Hart report and adjusted to a best fit. The surveyed locations provided by Max H. Hull Surveying were used to plot the McLaren/Hart drill holes on drawing 448-100-17 in all instances where survey date were available.

Surveyed locations were not reported for drill holes NB-15 and -16, and the locations shown on the base map are those obtained from the graphical analysis of the location map in the 1998 McLaren/Hart report. Because vertical elevations are also not available for holes NB-15 and -16, the top of each hole was arbitrarily fitted to match the reservoir bottom elevation appearing in the 1999 bathymetric surveys. Note that the surveyed elevations of the 1998 McLaren/Hart drill holes do not coincide with the reservoir bottom surface, as determined from Reclamation's 1999 bathymetric surveys, and are typically 2 to 3 feet higher than the corresponding bathymetric data. This discrepancy in elevation may result from a datum error in conversion of the local survey, which is assumed to be the 1929 NGVD system, to the 1988 NAVD elevations. A comparison of the elevations for the brass caps used in both the 1998 and 1999 field surveys shows a vertical difference of 0.785 foot, which would not account for all of the 2- to 3-foot discrepancies noted between the 1998 elevations and the 1999 bathymetry. Possible discrepancies in elevation cannot be further resolved without additional field work to locate all brass cap survey monuments, verify their identification, and resurvey their locations. This work could be conducted as part of final design data collection efforts, if deemed necessary.

Lacking any positive indication of a significant survey datum bust, the drill holes have been plotted at their surveyed collar elevations on the geologic sections prepared for this study. Alternately, this difference in elevation may be related to scouring of the reservoir bottom during large floods experienced during the 1998-99 winter season. The sediment within the reservoir rises to nearly the top of the concrete portion of the dam, particularly on the right side, and significant scouring of the upstream bar deposit could have occurred during large flood events.

Compilation of Bathymetric Base Map

The base map developed for this study is a compilation of data from a number of different sources. The outline of the dam and appurtenant structures has been digitized from Reclamation drawings 1313-D-1 and -2, which are based on 1972 surveys at the dam. The outline of the dam was fitted to the 1983 NAD Oregon South Zone state plane coordinate system using the physical features of the dam, as discussed in the previous section. Contours of the reservoir bottom have been developed from Reclamation's 1999 bathymetric survey. The base map has been prepared with a contour interval of 2 feet and has a scale of 1 inch equals 100 feet. The base map includes the locations of all holes drilled by both McLaren/Hart, Inc., in 1998, and by Reclamation in 1999, using the processes described in the previous section.

Bathymetric data were not collected in the forebay immediately upstream from the dam because of safety considerations. The four stoplog bays were open on the extreme right end of the dam at the time of the 1999 survey, and this resulted in strong currents. Where available, older contours (1972), shown on drawings 1313-D-1 and -2, have been digitized for the forebay area. These contours are spaced on an approximate interval of 5 feet. A conversion to the 1988 NAVD was required to complete the forebay portion of the contour map because the 1972 contours were surveyed in the 1929 NGVD. The conversion factor of 4.6 feet, determined from 1999 field surveys of the dam (see previous section), was rounded to 5 feet to simplify the process of converting the 1972 contours to the newer datum. The converted 1972 contours have been highlighted using a dashed line on the base map to distinguish them from the newer contours based on the 1999 bathymetric data, which are shown with a solid contour line.

Geologic Investigations

This section summarizes previous geologic investigations and related work conducted at Savage Rapids Dam. Copies of all referenced reports are maintained in the technical files of the Geology, Exploration and Instrumentation Group in Boise, Idaho. Also described in this section are the investigation strategy, field methodology, and laboratory testing procedures used in the current Reclamation investigation of the reservoir sediments stored behind the structure.

Previous Investigations

1950 Reclamation Investigation.—Reclamation undertook a geologic reconnaissance of Savage Rapids Dam in 1950 in preparation for rehabilitation and betterment of the structure that was subsequently completed between 1953 and 1955 (Reclamation, 1997). The reconnaissance included geologic mapping of the exposed foundation of the dam and its abutments. Note that exploratory drilling of test holes was not conducted as part of this study. A geologic map and cross section were developed from field mapping and from construction drawings and field notes of the dam dating from original con-struction in 1921 and 1922. The original drawings and notes were found in the files of the Grants Pass Irrigation District (GPID). The results of the reconnaissance are presented in a geologic report by Russell (1950). Subsequently, the construction drawings have been microfilmed by Reclamation.

1981 Reclamation Safety Evaluation of Existing Dams Examination.—An engineering geological evaluation of Savage Rapids Dam was conducted in 1981 as part of Reclamation's Safety Evaluation of Existing Dams (SEED) program. A certified engineering geologist (D.H. Jepsen), retained by Goodson and Associates, Inc., under contract to Reclamation, performed this evaluation. This evaluation addressed foundation conditions and performance based on an onsite examination and a review of existing documentation, including Russell's earlier report (1950). The evaluation also examined local seismicity and reservoir rim stability for Savage Rapids Dam. Based on information available at the time of the evaluation, there were no dam safety deficiencies identified for the foundation other than an operations and maintenance issue concerning continued scouring of the cemented gravel downstream from the spillway apron on the right end of the dam. The review of reservoir rim stability did not document the presence of any landslides upstream from Savage Rapids Dam. An engineering geological report by Goodson and Associates (1981) presented the findings of the evaluation.

1992 Reclamation Reservoir Survey.—Reclamation performed a reservoir sedimentation study of the Rogue River upstream from Savage Rapids Dam in 1992. This study consisted of the survey of 17 unmonumented cross sections between the dam and RM 110, under full reservoir conditions, and the collection of 5 surface sediment samples obtained from the exposed shoreline between Savage Rapids Dam and Savage Creek.

Because no pre-dam topography exists for the reservoir, the pre-dam thalweg of the river was estimated using the base elevation of the dam. The elevation is as shown on construction drawings and on 1923 USGS topography and river profiles located upstream from the reservoir area. Pre-dam cross sections were then extrapolated from the estimated thalweg and compared to the measured 1992 cross sections to arrive at an estimate of the sediment stored behind Savage Rapids Dam. A volume of 320 acre-feet (i.e., 516,267 cubic yards [yd^3]) of stored sediment was calculated, assuming full reservoir pool conditions behind the dam. A memorandum report documenting the reservoir surveys and sediment volume calculations was completed in 1992 (Blanton, June 12, 1992).

GPID staff collected the surface sediment samples from the exposed shoreline along the reservoir prior to stoplog installation and filling of the reservoir in April 1992. The samples were transferred to the Reclamation office in Denver, Colorado, and tested for standard properties, including gradation, and screened for trace elements. Trace elements were within baseline ranges for the elements tested. The results of the laboratory testing are discussed in a second memorandum report (Blanton, November 20, 1992).

1998 McLaren/Hart, Inc., Investigation.—ChemRisk, a service of McLaren/Hart, Inc., under contract to Sportfish Heritage of Grants Pass, Oregon, undertook additional investigation of the reservoir area upstream from Savage Rapids Dam in 1998. This investigation entailed drilling 13 sample holes along the exposed surface of an extensive bar deposit along the north bank (i.e., right bank when looking in the downstream direction) of the reservoir and 5 additional holes along a finer-grained sediment bar on the south bank. Laboratory testing was performed on 50 field samples and included testing for both standard engineering properties and over 40 chemical analytes, including pesticides and heavy metal contaminants. While elevated levels were measured for some of the analytes, none of the detected levels was high enough to trigger a more detailed Tier II contaminant evaluation, as established by the *Dredged Material Evaluation Framework* (U.S. Army Corps of Engineers [Corps] et al., 1998).

The McLaren/Hart report (1998) also reviewed the earlier reservoir sediment volume estimated by Reclamation (Blanton, June 12, 1992) and recalculated the volume based on the additional data obtained from their exploratory drilling. These data were then extrapolated further upstream from the test drilling to include the same full-pool reservoir area as that used in the original Reclamation estimate (i.e., through reservoir cross section 17 near RM 110). The McLaren/Hart sediment analysis derived a range of volume estimates varying from over 600,000 to as much as 1,000,000 yd^3.

Current Investigation

The current Reclamation investigation of the reservoir sediments impounded behind Savage Rapids Dam built upon the previous work by McLaren/Hart, Inc. (1998), by expanding exploration of the sediments to the permanently submerged portion of the reservoir through use of a floating drilling platform. In addition to further defining the geometry of the north bank sediment bar in the central part of the reservoir, most of the drill holes extended sampling upstream through the permanent reservoir pool impounded by the concrete crest of the dam. This permanent reservoir pool extends about 3,000 feet upstream from the dam above the mouth of Savage Creek at Savage Rapids Park. Geologic mapping, drilling, testing, and sampling collection conducted for this investigation were performed by staff from the Geology, Exploration and Instrumentation Group of Reclamation's Pacific Northwest Regional Office, Boise, Idaho.

Geologic Mapping.—Reconnaissance-level geologic mapping was conducted for the reservoir area extending upstream from Savage Rapids Dam to the confluence of the Rogue River with Evans Creek, a primary tributary stream located just upstream from the upper end of the reservoir, near RM 110.7. The geologic mapping was conducted on May 18, 1999, and was timed to coincide with low reservoir levels resulting from concurrent installation of stoplogs along the crest of the dam, which necessitated opening of the low-level radial gates at the dam. The geologic mapping for the entire reservoir length was conducted using a locally procured jet boat from Hellgate Excursions, Inc., of Grants Pass, Oregon. Additional mapping included ground observation of exposures adjacent to and immediately upstream from the dam, which was accomplished following completion of the jet boat reconnaissance.

A suitable base map for the reservoir could not be located, other than the Rogue River, Oregon, 7.5-minute provisional quadrangle map published by USGS. Color, laminated photocopies were made from 1996 aerial photographs of the reservoir area obtained from the United States Bureau of Land Management office in Medford, Oregon, and used as a base for the reconnaissance mapping. The results of the reconnaissance-level mapping appear on the geologic map of the reservoir, figure 1. (See "Site Geology," below.)

Drilling and Sampling Methods.—

*Drilling Equipment.—*Exploratory drilling was conducted using an Ingersoll-Rand A200 skid-mounted drill, operating from a custom-built drilling platform floating on pontoons. The assembled platform measured approximately 21 feet wide by 20 feet long by 3.5 feet high. The platform included an 8-by-10-foot deck extension which projected out from the midpoint of the platform and functioned as a work area for the drill crew to stack drill rods and accessory tools. An outboard motor was used to propel the platform. The drill rig and platform were hauled to the site in sections on transport trucks and assembled at Savage Rapids Park with the aid of an overhead crane provided by R.A. Cook Crane Service of Grants Pass, Oregon. When fully loaded, the drilling platform weighed about 21,000 pounds and drafted about 30 to 36 inches of water. Photograph 1 shows the drilling platform in operation at Savage Rapids Dam.

Drilling and sampling of the reservoir sediments was conducted using nominal10-inch outside diameter (6.25-inch insider diameter) hollow-stem flight augers. Flight augers were selected as the primary drilling technique to minimize disturbance of the lake bottom. Their use resulted in minimal induced turbidity of the reservoir water. Rotary drilling techniques were available as a backup procedure at Savage Rapids Reservoir in the event that drilling with hollow-stem flight augers proved unsuccessful.

Photograph 1.—Savage Rapids Dam, Rogue River Basin Project, Oregon. View downstream showing Reclamation's custom built, floating drilling platform in operation on drill hole AP-99-10. Drilling equipment consists of a skid-mounted Ingersoll-Rand T200 rotary drill, which was used to advance 10-inch outside diameter, hollow-stem flight augers to a bottom depth of 27.8 feet below the lake surface in this hole. The spillway and pumping plant portions of Savage Rapids Dam are present in the background of this photograph. (Reclamation photograph by Richard Link; September 30, 1999.)

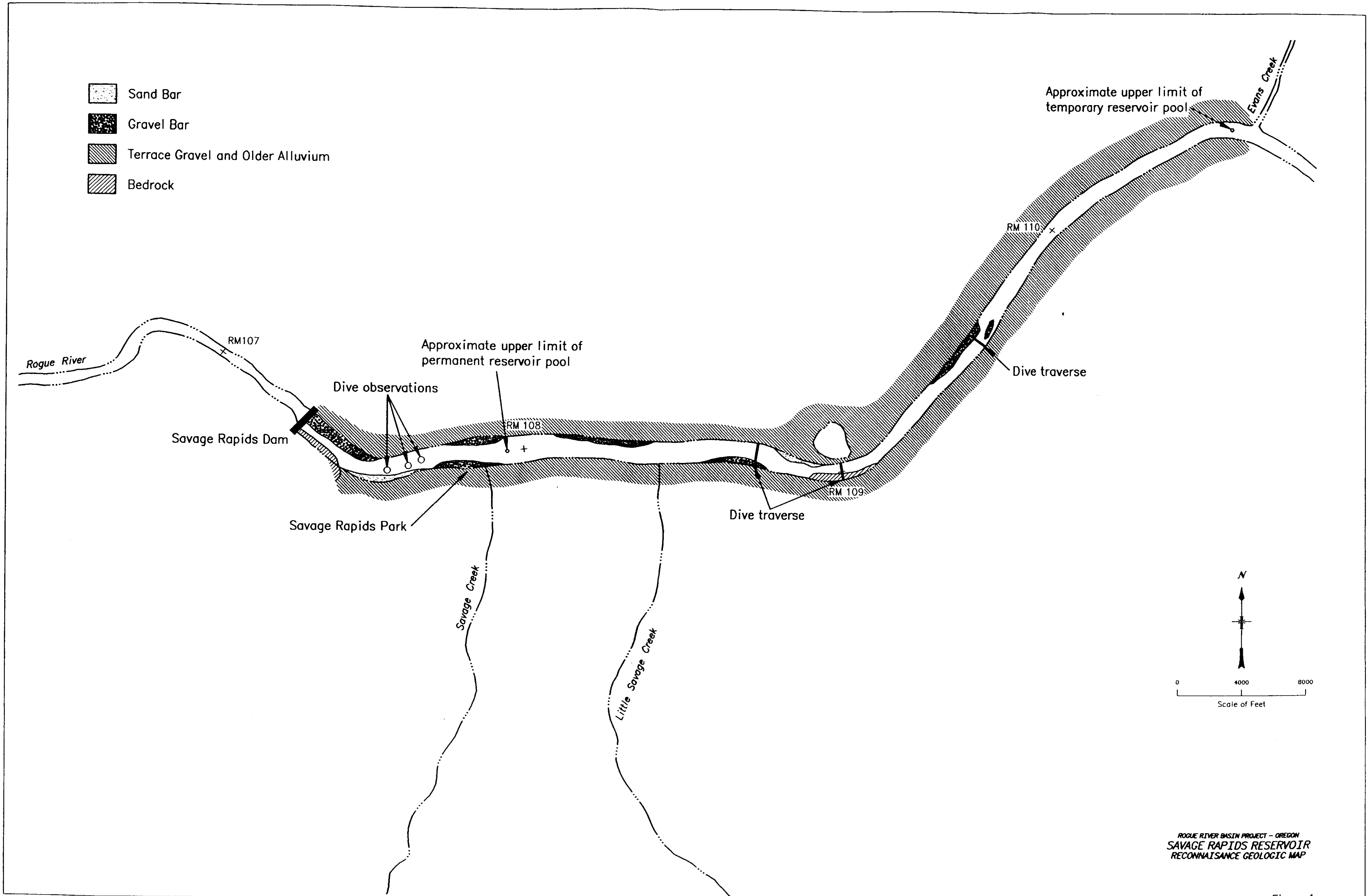

Sand Bar
Gravel Bar
Terrace Gravel and Older Alluvium
Bedrock
Rogue River
RM107
Savage Rapids Dam
Dive observations
Approximate upper limit of
permanent reservoir pool
RM 108
Savage Rapids Park
Savage Creek
Little Savage Creek
Dive traverse
RM 109
Dive traverse
RM 110
Approximate upper limit of
temporary reservoir pool
Evans Creek
N
0
4000
8000
Scale of Feet
ROGUE RIVER BASIN PROJECT – OREGON
SAVAGE RAPIDS RESERVOIR
RECONNAISANCE GEOLOGIC MAP

Figure 1

There was concern that the large gravel and cobble material known to exist in the gravel bar on the right abutment of the dam and in the upstream reservoir might prevent advancement of the drill tools or the collection of field samples. Drilling with the hollow-stem flight augers was successful, and the backup rotary drilling tools were never employed in the field investigation.

Testing and Sampling.—Drive samples were collected using split-tube barrels measuring 2.75, 3, and 3.5 inches in diameter and 2 feet long, mounted on Nw Mobilok drill rods. Samples were collected by driving the spilt-tube barrel into the lake bottom with a 350-pound safety hammer dropped a vertical distance of about 30 inches. The hammer was raised using a cathead and manila rope. The sample interval typically varied from 1.5 to 2.0 feet, depending on the resistance of the sediment being sampled. Field notes maintained during sampling included the number of hammer blows delivered through the sample interval and any irregularities noted during testing, such as settlement of the drill string under the weight of the hammer and excess slough in the sample tube. Sample recovery was poor in the first two drill holes (AP-99-1 and -2), and a number of methods were experimented with until a suitable technique was developed to obtain adequate sample recovery. The most satisfactory method employed a 3-inch inside diameter split-tube fitted with a basket catcher with very closely spaced fingers. The sample barrel interior was sprayed with PAM aerosol vegetable cooking coating, and a baffle of plastic wrap was installed behind the basket catcher. In addition, the sampler was allowed to rest at the bottom of each sample interval for a minimum of 10 to 15 minutes to improve adhesion of the sample to the inside of the sample tube before the sample was retrieved from the bottom of the hole. This last measure proved to be the most effective in improving sample recovery.

Field samples were logged in the field and classified as to soil type using the Unified Soil Classification System (USCS), as defined in *Designation USBR 5005-86, Procedure for Determining Unified Soil Classification - Visual Method* (Reclamation, 1990). Select samples were also photographed in the field to further document physical properties of the reservoir sediment, including particle size distribution, stratification, and other internal structures. Samples were labeled in the field and stored in ziploc freezer bags for subsequent laboratory testing.

Contaminant Sampling and Procedures.—Reclamation's investigation of the reservoir sediments impounded behind Savage Rapids Dam included contaminant screening of select field samples to verify the earlier results obtained by McLaren/Hart (1998) and to extend testing into the upstream portions of the reservoir that were not included in the previous work. Contaminant sampling required special sampling equipment and handling procedures to obtain valid samples and laboratory test results. The special equipment and procedures are discussed in the following paragraphs, along with modifications to the methodology made onsite during field sampling.

Contaminant sampling was conducted near the end of the field investigation after the bulk of the conventional sampling for standard engineering properties had been completed.

Contaminant sampling was initially conducted using a 2.75-inch id split-tube, stainless steel barrel measuring 2.0 feet long. Initial sampling at Savage Rapids using conventional sampling equipment had demonstrated that samples could not be recovered without the use of a basket catcher and a plastic-wrap baffle placed behind the catcher. Use of flapper valves had been attempted but proved totally ineffective. A teflon-coated basket was installed in the stainless steel barrel for contaminant sampling. A gallon of de-ionized water mixed with about 1.25 fluid ounces of Liqui-Nox detergent was used to decontaminate the stainless steel barrel for each sample interval. The barrel was then rinsed in a spray of de-ionized water. The de-ionized water was obtained from the Reclamation water quality laboratory in Boise, Idaho. A complete record of barrel decontamination and contaminant sample handling was maintained onsite during the field investigation, and the log book has been placed in the technical files of the Geology, Exploration and Instrumentation Group in Boise, Idaho.

Repeated attempts to sample with the stainless steel barrel failed to recover any reservoir sediment, and it became evident that the fingers of the teflon-coated basket catcher were too widely spaced to retain the sample inside the barrel. After consultation with the technical staff at Reclamation's Technical Service Center in Denver, Colorado, it was decided to conduct the contaminant sampling with the same equipment that had already proven successful in the collection of the conventional samples. Decontamination procedures were identical to those described above. This change in methodology entailed the use of a nonstainless steel sample barrel and an uncoated steel basket catcher. A sample of the wash water was retained for testing to evaluate potential background contaminant levels of the nonstainless steel barrel and basket.

Even with the change to the conventional sampling equipment, generally poor recovery continued in the contaminant sample intervals. As a final measure to improve recovery to acceptable levels, the interior of the barrel was sprayed with PAM aerosol vegetable cooking coating. This coating proved to be very effective in improving sample recovery and should not have adversely affected the results of the laboratory contaminant testing.

Conventional sampling in the reservoir behind Savage Rapids Dam established the presence of a large pothole in the river bottom, about 1,800 feet upstream from the dam, which had been infilled with reservoir sediment. Drilling demonstrated that the pothole extended at least 10 feet below the base elevation of the dam, suggesting that the pothole would have acted as a trap for any contaminants migrating downriver from upstream mining districts. The bulk of the contaminant sampling was concentrated in this area in drill hole AP-99-12, although one sample taken at the upstream end of the permanent reservoir pool at Savage Rapids Park was also collected for testing. Due to the thickness of sediment present in the pothole, contaminant sampling was alternated with conventional sampling to expedite drilling. The pre-dam river bed was encountered in a conventional sampling interval with a sample barrel that had not been decontaminated. However, as this sample represented the material directly on the old river bed and had the highest likelihood of containing contaminants, the sample was submitted to the lab with appropriate notes about the history and condition of the sample and its test equipment.

All contaminant samples were stored in sterilized samples jars and placed on ice until shipping to Reclamation's laboratory at the Technical Service Center in Denver, Colorado. The samples were shipped with appropriate chain-of-custody documentation and field notes on decontamination and sampling procedures. The results of the laboratory testing are discussed in Appendix C.

Hole Abandonment.—All the holes drilled in Savage Rapids Reservoir were decommissioned and abandoned upon completion, without installation of instrumentation. Reverse circulation of the auger string was used to backfill all holes with cuttings removed during drilling operations. This hole abandonment procedure was in accordance with the directions of the Oregon Division of State Lands, as expressed during the process of obtaining Reclamation's remove-and-fill permit. The permit was obtained as part of the National Environmental Policy Act compliance for the field investigation.

Laboratory Testing.—Field samples were evaluated on the basis of percent recovery and mass of retained material in the sample tube. Then, 25 samples were submitted for laboratory testing to determine standard physical and engineering properties. Included in the laboratory testing program were (1) particle size distribution, including hydrometer for the minus No. 200 sieve fraction; (2) soil plasticity, or Atterberg limits; (3) fall diameter of sand-size and finer material; and (4) specific gravity of the minus No. 4 fraction. Initial testing of the sediment samples showed extremely low concentrations of the silt and clay fractions, and the requirement for the hydrometer, Atterberg limits, and fall diameter were canceled because sample mass was insufficient to perform these tests. The laboratory testing was performed under contract with Materials Testing and Inspection, Inc., a private, certified testing laboratory in Boise, Idaho. All test procedures conformed to Reclamation standard laboratory test designations, as described in *The Earth Manual, Part 2* (Reclamation, 1990). At the recommendation of Mr. Mark Siipola of the Corps in Portland, Oregon, the test procedure for particle size distribution was modified to include the addition of the No. 230 sieve (i.e., 0.063-millimeter [mm] particle diameter). This diameter corresponds to the demarcation between very fine sand and silt, and high concentrations of material passing the No. 230 sieve have been shown to be detrimental to fish. The concentrations passing the No. 230 sieve are shown in the center columns of the respective geologic logs of the 12 holes drilled for this investigation.

Laboratory soil classifications were developed for each sample interval using the USCS, as defined in *Designation USBR 5000-86, Procedure for Determining Unified Soil Classification - Laboratory Method* (Reclamation, 1990). Geologic logs have been prepared for each drill hole and include both the visual and laboratory soil classifications for
the samples. These logs appear in attachment B of this appendix. The results of the laboratory tests are also reported on the gradation test plots appearing in attachment C of this appendix. All samples have been retained for future reference at the Pacific Northwest Regional Office in Boise, Idaho.

Site Geology

The following discussion of the site geology for Savage Rapids Dam and Reservoir is based on published geologic mapping of the area, supplemented by site-specific observations reported in various Reclamation documents for the dam. Published geologic mapping specific to the dam and reservoir is not available, although both areas are included on the geologic maps of central Jackson (Beaulieu and Hughes, 1977) and Josephine (Ramp and Petersen, 1979) Counties and on larger-scale maps by the USGS (Smith and others, 1982). These maps form the primary references for the site geology at Savage Rapids Dam. Site-specific observations reported by Russell (1950) and Goodson and Associates (1981) discuss the immediate vicinity of the dam, while field observations of the reservoir area were made specifically for this study. The McLaren/ Hart report (1998) also discusses the reservoir geology immediately upstream from the dam.

Bedrock Units

The foundation bedrock of Savage Rapids Dam and its reservoir consists of variably metamorphosed volcanic and sedimentary rocks of the Applegate Group, which is generally accepted to range from Paleozoic to Triassic in age (Beaulieu and Hughes, 1977; Ramp and Petersen, 1979; Smith et al., 1982). Geologic mapping of the unit has identified two distinct rock sequences within the Applegate: (1) a dominantly volcanic sequence of altered lava, pillow lava, flow breccia, pyroclastics, and tuff with minor sedimentary interbeds and (2) an altered sequence of predominantly sedimentary rocks, including tuffaceous argillite, chert, siltstone, sandstone, conglomerate, and limestone with minor interbeds of volcanics. Deposition of the Applegate occurred under marine and volcanic island arc conditions adjacent to the continental margin. The age of the Applegate has been established as Early Permian to Late Triassic on the basis of fossils recovered from the metasedimentary sequence (Ramp and Petersen, 1979).

Thrust faults have been mapped in the Applegate Group, and these thrusts are repeatedly truncated by high-angle faults. Both the volcanic and sedimentary sequences have been variably metamorphosed, probably in conjunction with the intrusion of igneous plutons and associated dikes into the formation. Several plutons composed of diorite have been mapped in the area, including one in the nearby Evans Creek drainage, at the upper end of the reservoir, and one very large pluton, down-stream, near the town of Grants Pass. Heavily mineralized zones occur in association with the plutons and dikes, and much of the early history of the Rogue River Valley involved extraction of ores from these deposits. Lava flows are commonly altered to greenstone and greenschist (Smith and others, 1982), while the metasedimentary sequence includes argillite, shale, schist, and marble. Donati and others (1996) studied the Applegate Group farther to the south, near the California border, and have established the timing of the deformation and metamorphism as the Middle Jurassic, around 173 Ma, based on radiometric dates.

Metavolcanic Rocks (TrPzmv).—Outcrops of metavolcanic rocks of the Applegate Group are exposed on the left abutment of Savage Rapids Dam, extending about 1,100 feet upstream and 300 feet downstream from the structure. Most of the south ladder is also founded on the metavolcanics, as are the headworks for the Gravity Canal on the south end of the dam. Russell (1950) demonstrated that the metavolcanics extend northward out into the river channel beneath the dam to the south end of spillway bay 5 (the numbering of the bays begins with bay 1 on the north end of the dam and progresses to bay 16 on the south end). Russell based his description on his geologic mapping at the dam site and a review of construction records on file at the office of the GPID. Construction of the low-level radial gate outlets in spillway bays 10 and 11 required rock excavation through the metavolcanics to approximate elevation 938.6 (i.e., elevation 934.0 in the 1929 NGVD). Bedrock outcrops were visible on the right abutment of spillway bay 10 when the low-level outlet was opened for stoplog installation in May 1999. Mapping of reservoir geology and site conditions in 1999 located hard outcrops of metavolcanics along the south bank of the Rogue River at RM 109.0, at the Have A Nice Day R.V. Park and campground, as shown in photograph 2. Subsequent examination of the area by Reclamation divers confirmed submerged outcrops of the metavolcanics extending about 50 feet out into the river from the south bank (see attachment D for the dive team report). The manager of the R.V. park indicated that the outcrops exposed along the riverbank had appeared after heavy scouring of the area during the November 1998 flood. This flood had inundated the R.V. park and nearly overtopped State Highway 99 at that location.

Russell (1950) describes the foundation rock as dark gray-green diabase dikes and greenstone, with bands of serpentine. He noted that the diabase and greenstone were hard and resistant to erosion, while the serpentine was softer and suffered from "etching out." Subsequent review of the site by Goodson and Associates (1981) showed that the bulk of the metavolcanics consisted of greenstone with a generally fine-grained groundmass with neither prominent crystals nor inclusions. Thin dikes and stringers of quartz were noted in the metavolcanics on the left abutment, upstream from the dam, during the 1999 Reclamation investigation.

Outcrops of the metavolcanics are generally hard (H3), requiring a heavy hammer blow to break off corners of the exposures (Reclamation, 1998). The degree of weathering was

*Photograph 2.—**Savage Rapids Dam, Rogue River Basin Project, Oregon**. View upstream showing metavolcanic bedrock outcrops of the Applegate Group exposed along the south shoreline of Savage Rapids Reservoir at the Have A Nice Day RV Park and campground near RM 109.0. These outcrops were exposed by scouring during flooding which occurred in November 1998 and project about 50 feet out into the reservoir from the left bank, as documented in a later underwater traverse performed at this site by divers from the Pacific Northwest Region Dive Team. (Reclamation photograph by Richard Link; May 18, 1999.)*

difficult to evaluate on the basis of surface exposures and the fine-grained groundmass. The condition of the rock was logged as slightly weathered (W3) where corners of outcrops were broken off with a rock hammer. Oxidation was generally limited to the surface of the exposure, and the hammer rang when striking heavy blows to the outcrop. Weathering probably extends into the moderately weathered range where more intensely metamorphosed materials are present in the foundation. The metavolcanics are slightly to very slightly fractured (FD2), with fracture surfaces typically spaced from about 1 to 4 feet apart. Fractures commonly occurred in two prominent joint sets that are near vertical and subhorizontal, imparting a very blocky appearance to the outcrops.

Prominent bedrock shelves or benches were observed forming along subhorizontal fracture surfaces at several locations on the left abutment, upstream from the dam. Localized zones of intense to very intense fracturing were noted at scattered locations on the abutment.

Metasedimentary Rocks (TrPzms).—During the course of the 1999 Reclamation field investigation, outcrops of metasedimentary rocks of the Applegate Group were observed within the reservoir area upstream from Savage Rapids Dam. While retrieving drilling equipment at the site of hole AP-99-1, the Reclamation dive team reported a submerged outcrop of metaconglomerate on the reservoir bottom. This site is about 1,300 feet upstream from the dam, near RM 107.60. (See drawing 448-100-17 for location.) The dive report describes the outcrop as "a bold exposure of in situ conglomerate." (See attachment D for the dive team report.) Additional outcrops of the metasedimentary rocks probably occur in the reservoir upstream from RM 109.0, where the Rogue River intercepts the trend of a prominent band of metasediments mapped by Beaulieu and Hughes (1977) and by Smith and others (1982). If outcrops are present in this area, they are submerged and have not been noted in spot observations by the divers.

Surficial Materials

Surficial deposits at Savage Rapids Dam and upstream along the reservoir consist of several distinct units of alluvium that are Quaternary in age. The alluvium is dominated by older terraces that flank both sides of the reservoir and underlie the north end of the dam. Younger alluvium within the channel of the Rogue River is largely submerged by the reservoir impounded by Savage Rapids Dam. Included in the surficial deposits are the reservoir sediments that have accumulated behind the dam since completion of construction in 1922. Each of these alluvial units is described in the following paragraphs.

Terrace Gravels and Older Alluvium (Qtg).—Prominent terraces of older river channel alluvium (Qtg) flank both sides of the Rogue River within the reservoir area and form the right abutment of the dam. Mapping by Beaulieu and Hughes (1977) shows that these older alluvial deposits extend upstream along both banks of the Rogue River for the entire length of the reservoir. Russell (1950) researched construction-era drawings and notes on file in the GPID Office and reported that cemented gravels form the foundation of the dam beginning at spillway bay 5 and extending north to the right abutment beneath the existing pumping plant. His report noted that outcrops of bedrock were observed protruding through the alluvium in the foundation of bays 4 and 5 and suggested that the alluvium cover overlying bedrock was very thin in this portion of the foundation. The thickness of the cemented gravel probably increases toward the right abutment, but no exploratory drilling has been performed in this area to determine the depth to the underlying Applegate Group metavolcanics.

The older terrace gravels (Qtg) are best known from exposures on the right abutment of the dam. Russell examined these outcrops in 1950 and described them as gravel and cobbles ranging from 25 to 150 mm (1 to 6 inches) in diameter, with scattered boulders from 300 to 600 mm (1 to 2 feet) in size. The matrix of the deposit was a mixture of sand, silt, and clay. The terrace gravels are only crudely stratified, and prominent bedding planes are generally lacking. Upstream from the dam, discontinuous interbeds and lenses of sand and fine-grained silt and clay were noted along the shoreline during the 1999 field investigation.

Downstream from the dam, Russell (1950) noted that the terrace gravels (Qtg) were cemented with a fine-grained white material, possibly clay or silica. These exposures formed near vertical slopes and had experienced very little erosion since construction of the dam 30 years earlier. Inspection of these outcrops in 1999 confirmed Russell's observation. Goodson and Associates (1981) noted that the cementation appears to weaken when saturated and exposed, allowing the terrace gravel to yield more rapidly to erosion. This weakening of the cementation probably resulted in the erosion of a deep pothole along the downstream toe of the dam during the first 30 years of operation.

This pothole was backfilled and covered with a reinforced concrete apron during Reclamation's rehabilitation of Savage Rapids Dam from 1953 to 1955 (Goodson and Associates, 1981). Reclamation's Pacific Northwest Dive Team continues to perform periodic underwater examinations of the apron and adjacent area to monitor scouring and erosion of the cemented gravel foundation. Upstream from the dam, the degree of cementation within the terrace gravel is much more variable, and many areas appear to have little or no cementation. Russell (1950) noted that the terrace gravel is very compact and very difficult to dislodge with a pick, even where little or no cementation is present. The 1999 reservoir reconnaissance confirmed this observation and noted many areas along the shoreline where wave action had severely undercut the bank, resulting in very steep to overhanging banks, particularly along the north rim of the reservoir (see photograph 3). Exposures along the south shoreline are more limited because of the large number of structures along the water's edge, including revetments, retaining walls, docks, and slope protection.

Russell (1950) noted that the terrace gravels (Qtg) are overlain by a bed of alluvium upstream from the dam. This bed included scattered large boulders. This upper bed has not been differentiated for this study and is included within the terrace gravels. A review of published literature suggests that this upper bed may represent deposits left by the floods of 1861 and/or 1964. Beaulieu and Hughes (1977) mapped the extent of the floods based on limited field observations and data from a 1965 Corps study and show that extensive flooding occurred along the reservoir margin in both events. They report that the 1861 flood approximated a 100-year flood event, while the 1964 flood was on the scale of a 50-year event.

Younger Alluvium (Qal).—The younger alluvium (Qal) consists of alluvial materials deposited within the active channel of the Rogue River. These materials are primarily gravel, cobbles, and boulders mixed with lesser volumes of sand and very minor fines. In addition to channel deposits along the thalweg and active channel, the younger alluvium includes numerous bar deposits of chiefly gravel and cobbles, with sand and finer-grained bars of sand and silt along the margins of the active channel. The younger

*Photograph 3.—**Savage Rapids Dam, Rogue River Basin Project, Oregon**. View upstream toward the north bank of the reservoir near RM 107.0 showing exposures of the cemented terrace gravels and older alluvium. Wave action has eroded more weakly cemented materials near the base of the slope, forming a prominent overhang which is highlighted by a deep shadow in this photograph. Note the large volume of cobbles and boulders exposed along the shoreline in this section of the terrace gravels and older alluvium. (Reclamation photograph by Richard Link; May 18, 1999.)*

alluvium is best exposed along the banks of the Rogue River downstream from Savage Rapids Dam and upstream from the reservoir. Included within the younger alluvium are small alluvial fan/delta deposits within the main river channel occurring at the confluence of larger tributary streams.

The younger alluvium (Qal) is not present within the footprint of Savage Rapids Dam. Mapping and research of archival records by Russell (1950) suggest that the foundation was cleared of all loose material prior to construction of the dam. A pre-construction era photograph of Savage Rapids (see photograph 4), obtained from the Josephine County Historical Society in Grants Pass, Oregon, shows that the river channel at and upstream from the dam site consisted of a long riffle composed chiefly of cobbles, boulders, and bedrock knobs. Finer-grained deposits of gravel and sand may have been present upstream from the riffle but are not visible in the photograph.

*Photograph 4.—**Savage Rapids Dam, Rogue River Basin Project, Oregon**. A pre-dam view of Savage Rapids prior to construction of the dam in 1921 and 1922. The riffle seen in the photograph was named after the Savage family, who owned a homestead on the south or left bank of the Rogue River in this vicinity. Outcrops of metavolcanic rock of the Applegate Group are present in the foreground, while cemented terrace gravels and older alluvium form the north bank, seen in the distance. (Photograph courtesy of the Josephine County Historical Society, Grants Pass, Oregon.)*

Reservoir Sediments (Qrs).—The reservoir sediments (Qrs) consist of sediment impounded in the Rogue River behind Savage Rapids Dam since construction of the dam in 1921 and 1922. Because the primary focus of the 1999 Reclamation field investigation was the characterization of the materials composing the reservoir sediments and the determination of their distribution and extent, only a brief summary of these materials is presented here. The reservoir sediments are described in detail in the "Geology of Reservoir Sediments" section.

Test drilling conducted in the reservoir area by McLaren/Hart in 1998 and by Reclamation in 1999 established the presence of a very hard river bottom throughout the permanent reservoir pool, extending about 3,000 feet upstream from the dam. Complete refusal of the flight augers occurred during drilling wherever this river bottom was encountered. This refusal zone is assumed to represent the top of the pre-dam riverbed for the purposes of this report. All materials overlying this hard river bottom have been incorporated within the reservoir sediments (Qrs), including any finer-grained younger alluvium (Qal) that may have been present in the Rogue River channel prior to construction of Savage Rapids Dam.

Geology of Reservoir Sediments

This section describes the physical character and extent of the sediments impounded behind Savage Rapids Dam, based on field samples and laboratory test data collected during Reclamation’s investigation of the site in 1999. Data obtained in earlier studies of the site are incorporated in this discussion. A conceptual model has been developed to provide a framework for deposition of the sediments within the reservoir area.

Conceptual Model of Depositional Environment

A conceptual model for sediment deposition in the reservoir area is presented in this section to illustrate the logic used in the analysis of the sediment volume, discussed later in this report. (See "Sediment Volume.") This conceptual model is based on the observations made in the field during low reservoir level conditions in May 1999, the 1999 bathymetric surveys of the reservoir bottom, the borehole data collected during the field investigation, underwater observations, and a review of reservoir operations.

Reservoir Operation Summary.—The operation of the reservoir behind Savage Rapids Dam plays a key role in the accumulation of sediment upstream from the structure and must be accounted for in any model of sediment deposition. The concrete spillway section of the dam has a crest elevation of 957.6 (elevation 953.0 feet in the 1929 NGVD), which results in a permanent reservoir pool extending about 3,000 feet upstream from the dam to about RM 107.95, based on field observations of the upstream reservoir area made in May 1999. The permanent reservoir pool extends to just upstream from Savage Rapids Park, which is located on the south bank of the Rogue River at the confluence with Savage Creek.

The reservoir water surface is raised about 11.0 feet, to elevation 968.6 feet (elevation 964.0 feet in the 1929 NGVD), through the installation of stoplogs in the 16 bays along the spillway crest. This water surface increase results in a temporary pool which extends the reservoir approximately 15,000 feet farther up the Rogue River, to about RM 110.6, for the duration of the irrigation season. Stoplog installation typically occurs in about mid-May in a normal water year, but can vary, depending on the projected water supply from snow pack and the amount of spring precipitation supplying moisture to the irrigated farm land in the area (Dan Shepard, personal communication; September 1999). In 1992, the Rogue River Basin experienced drought conditions which required an earlier filling of the reservoir, permitting Reclamation to conduct its initial survey of the reservoir under full reservoir pool conditions from April 21 through 24 (Blanton, June 12, 1992). To meet the downstream demand of the GPID, the reservoir is maintained at the full pool elevation for the duration of the irrigation season, which typically extends to about mid-October each year. As with installation, the timing for removal of the stoplogs varies, depending on the downstream water user needs and fall precipitation in the area. The stoplogs must be removed prior to the onset of the winter flood season to prevent damage to the stoplog brackets and loss of stoplog sections. Backwater effects of flooding with the stoplogs in place include inundation of private property along the upstream reservoir margin. The winter flood season commonly starts about November 1 of each year. With the removal of the stoplogs, the Rogue River is returned to free-flowing, riverine conditions upstream from Savage Rapids Park (upstream from approximate RM 107.95).

Sediment deposition within the reservoir impounded by Savage Rapids Dam occurs in response to the operational level of the reservoir pool. Operation of the reservoir water surface varies on a seasonal basis and results in two distinct and separate locales for sediment deposition:

- Deposition in the permanent pool immediately upstream from the dam during the irrigation off-season
- Deposition within the upper reservoir during the irrigation season

Each of these depositional locales is discussed separately in the following sections.

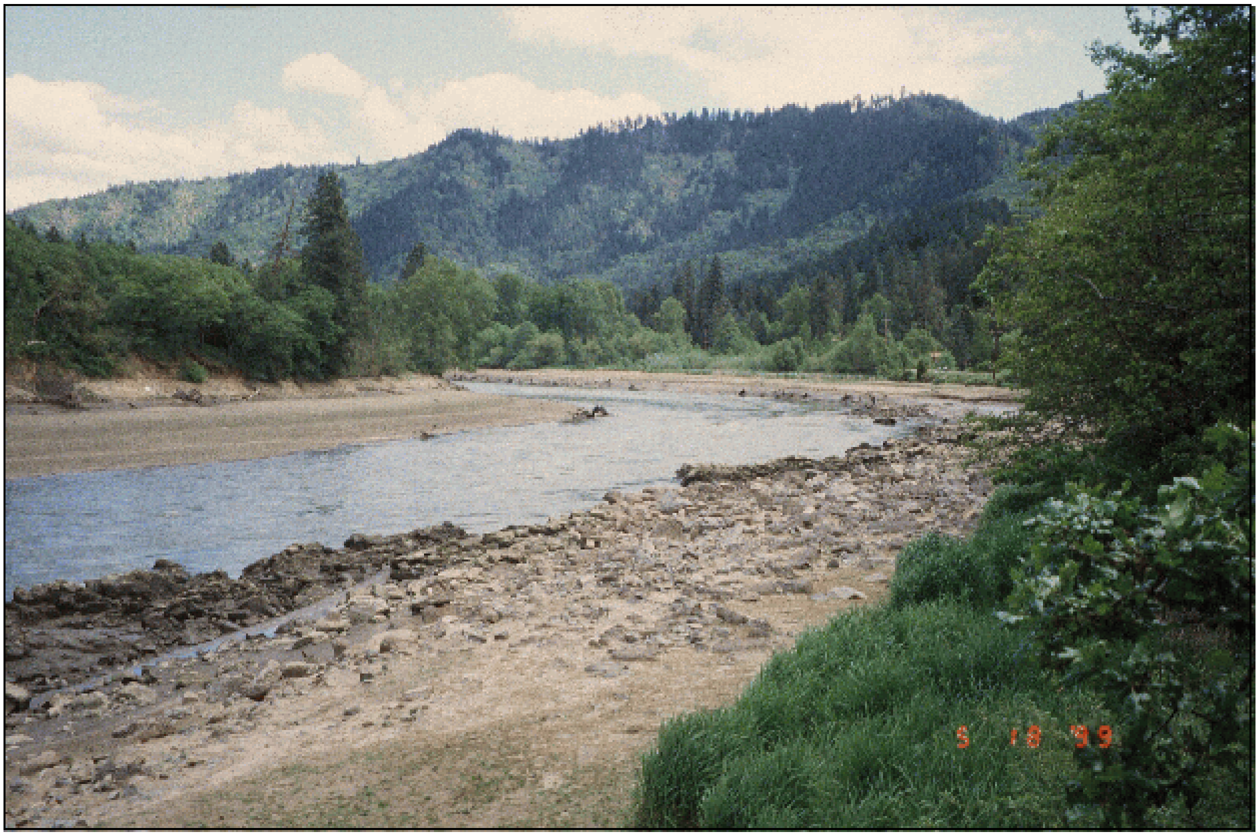
Deposition in the Permanent Reservoir Pool.—Sediment is deposited in the permanent reservoir pool upstream from Savage Rapids Dam following removal of the spillway stoplogs, permitting accumulation of sediment in the reach extending about 3,000 feet upstream from the dam to just above Savage Rapids Park, near RM 107.95. This sediment accumulation occurs from about mid-October to about mid-May each year and is associated with winter and early spring floods and the onset of the spring runoff within the river basin.

Reclamation’s 1999 bathymetric survey of the Rogue River showed that the permanent reservoir pool is generally broad and flat bottomed, particularly in the reach from about RM 107.6 to the upper end of the permanent pool upstream from Savage Rapids Park, near RM 107.95. A contour map of the reservoir bottom for this reach of the river developed from the bathymetric survey appears on drawing 448-100-17. This reservoir bottom morphology strongly suggests sediment accumulation in this river reach. Test drilling completed by Reclamation in 1999 verified the sediment deposition suggested by the bathymetry and identified the presence of a buried pothole or pool at RM 107.91. The test drilling determined the bottom elevation of this pool to be at about elevation 924.0, which is 6.6 feet deeper than the deepest point of the dam foundation. Russell (1950) shows the lowest point in the foundation occurs at about elevation 930.6 (elevation 926.0 in the 1929 NGVD) near the junction of spillway bays 4 and 5 on his cross section of the dam. This cross section is based on original construction notes he located in the files of the GPID. Since completion of the dam, sediment has completely filled this deep pool. Contaminant sampling conducted during the 1999 Reclamation field investigation was concentrated in this buried pool because it would have acted as a natural trap for any heavy metals and other contaminants migrating down the Rogue River from upstream mining districts. The results of the contaminant testing are discussed in Appendix C.

The Rogue River makes a prominent bend to the northwest at about RM 107.6, and the reservoir bottom morphology becomes more complex downstream from the bend. The south reservoir shoreline consists of continuous outcrops of metavolcanics from the Applegate Group (TrPzmv), and a prominent channel has formed along the contact between the bedrock and the reservoir sediments (Qrs). This channel extends downstream to the low-level outlet for the dam in spillway bays 10 and 11 and likely has formed in response to the annual opening of the outlet to permit installation of the stoplogs in the spillway bays. Opening of the low-level radial gates develops a high-velocity flow which likely scours the loose reservoir sediments upstream from the dam, forming the prominent channel seen in the bathymetry. The south side of the channel is lined with bedrock, while the north side consists of reservoir sediments which form a prominent bar along the north side of the reservoir, as shown in photograph 5. This bar has developed in response to lower velocities and current eddies on the inside curve of the bend in the river channel and extends downstream to Savage Rapids Dam (see the reservoir bathymetry on drawing 448-100-17). This bar, termed the north bar in this report, was the target of much of the drilling and testing conducted by McLaren/Hart in 1998. Drilling in the 1999 Reclamation field investigation was limited to a few holes to determine the configuration of the bar deposit as it tapers to the bedrock outcrops on the south side of the reservoir. This north bar and the sediments present upstream in the flat-bottomed reach of the permanent pool, discussed above, compose the bulk of the sediments that have accumulated behind Savage Rapids Dam.

A second bar deposit occurs on the south bank of the reservoir about 2,500 feet upstream from Savage Rapids Dam. This deposit, referred to as the south bar in this report, has formed over a prominent bedrock shelf along the water’s edge. This bar appears to have accumulated in an eddy area of low velocity because most of the sediment in the deposit is fine sand and silt, with varying proportions of minor gravel and clay. McLaren/Hart conducted five explorations (SB-1 through -5, inclusive) in the south bar during their 1998 field investigation. The 1999 study by Reclamation did not further examine the south bar because the results of the earlier McLaren/Hart report (1998) appeared to adequately cover the extent of the deposit. The very shallow depth of water overlying the south bar also precluded access for Reclamation’s floating drilling platform.

The storage capacity for additional sediment within the permanent pool behind Savage Rapids Dam is very limited because much of the reservoir has been infilled nearly to the crest elevation of the spillway. The infilling of the permanent pool is most visible on the north end of the dam, where the downstream end of the north bar laps onto the



*Photograph 5.—**Savage Rapids Dam, Rogue River Basin Project, Oregon**. View upstream showing the permanent pool upstream from the dam, drawn down for stoplog installation. This photograph illustrates the geology of the permanent pool, with bedrock outcrops of the Applegate Group present in the foreground along the south shoreline. These outcrops are buried by fine sand and silt forming the south bar in the distance. The north bar is exposed at the base of the opposite bank and is composed of variably mixed sand and gravel with cobbles which also compose much of the reservoir floor beneath the channel, shown in the center of the photograph. (Reclamation photograph by Richard Link; May 18, 1999.)*

spillway crest, as shown in photograph 6. This photo was taken in May 1999 at low pool conditions during installation of the stoplogs in the spillway bays. It clearly illustrates how the north bar sediments onlap the spillway section of the dam. Continued sediment storage is practical at only two locations within the permanent reservoir pool—the channel upstream from the low-level radial gate outlets, discussed above, and the intake to the pumping plant on the right end of the dam. The channel upstream from the radial gates represents the largest area available for additional sediment accumulation, but annual opening of the gates to permit stoplog installation under low pool conditions probably restricts the volume of significant permanent deposition within the channel. The high velocities generated within the reservoir when the low-level gates are opened probably flush any sediment accumulated in the channel and move it downstream from the dam on an annual basis. A small, conical depression in the configuration of the north bar was also observed immediately upstream from the pumping plant on the north end of the dam at the plant intake structure, as shown in photograph 7. This depression likely forms in response to operation of the plant during the irrigation season and,

*Photograph 6.—**Savage Rapids Dam, Rogue River Basin Project, Oregon**. View across Savage Rapids Dam toward the north bank showing the reservoir drawn down for installation of stoplogs across the spillway of the dam. Sediment has infilled the reservoir to the point that the north bar is lapping onto the concrete spillway, as can be seen in the distance, adjacent to the pumping plant. The bedrock outcrop forming the right abutment of the low-level radial gate outlet is exposed near the center of the photograph. (Reclamation photograph by Richard Link; May 18, 1999.)*

similarly to the low-level radial gates, the velocity of the water entering the pumping plant helps restrict the accumulation of sediment at this location. The depression at the plant intakes is small and represents a very small portion of the total volume of the permanent reservoir pool.

Based on these observations, the sediment storage space of the reservoir behind Savage Rapids Dam is essentially full and has been full for several decades. Therefore, the sediment loads being transported downstream from the dam are essentially equal to the loads being supplied to the reservoir from upstream. Currently, the sediment load of the Rogue River at Savage Rapids is less than the natural conditions because a significant portion of the natural sediment load is being trapped upstream in Lost Creek Reservoir.

Deposition in Temporary Reservoir Pool.—Deposition occurs in the temporary reservoir pool in response to installation of the stoplogs across the crest of the spillway.

*Photograph 7.—**Savage Rapids Dam, Rogue River Basin Project, Oregon**. View toward the north abutment of the dam and the pumping plant showing the conical depression formed in the surface of the north bar as a result of operation of the plant intakes. The reservoir is drawn down below the normal operational level to permit stoplog installation. Much of the surface of the north bar consists of a thin veneer of fine sand and silt which is similar to that observed upstream on the left shoreline at the south bar. (Reclamation photograph by Richard Link; May 18, 1999.)*

Deposition in the temporary reservoir is associated with the waning of the spring runoff, scattered summer thunderstorm flood events, and low flow periods on the Rogue River. Riverflows are regulated by the Corps at Lost Creek Dam, upstream from Savage Rapids. The temporary reservoir area is returned to free-flowing river conditions in the fall, when the stoplogs are removed from the spillway crest.

Bathymetric surveys show a change in the morphology of the reservoir bottom upstream from Savage Rapids Park, beginning at about RM 107.95. The river bottom transitions at this point from the generally broad, flat-bottomed profile, seen in the permanent reservoir area, to a series of steep riffles alternating with pools of varying depth. (See the reservoir bathymetry contour map included in attachment B.) This riffle-and-pool morphology of Appendix B appears to be characteristic of the temporary reservoir bottom. Prominent pools are observed in the reservoir bathymetry at RM 108.20, 108.87, 109.27, 109.67, and 110.22. The riffle-and-pool morphology observed in the temporary reservoir area is comparable to that observed in the 1999 Reclamation surveys of the Rogue River, downstream from Savage Rapids Dam to the confluence with the Applegate River. The bathymetric data suggest that sediments in the temporary reservoir have not accumulated to the point that the pool sections have filled, as was observed downstream at RM 107.91 in test drilling conducted in the permanent reservoir area.

During the 1999 Reclamation field investigation, the Pacific Northwest Region Dive Team examined the temporary reservoir bottom to confirm that bottom conditions were as suggested by the bathymetry. Dive traverses were conducted at RM 108.72, 109.00, and 109.63, along with three spot observations in the permanent reservoir area. Their report is included as attachment D of this appendix. At RM 109.63, the reservoir bottom was composed chiefly of hard, subrounded cobbles, with bedrock outcrops present along the south bank. The outcrop continued underwater into the reservoir itself. The cobbles varied from 100 to 250 mm (i.e., 4 to 10 inches) in diameter and included minor gravel with very little sand. The coarse-grained character of the reservoir bottom continued downstream to the next traverse, located at RM 109.0. The divers reported a mix of cobbles and gravel at this traverse, with most of the material occurring as 75- to 200-mm (3- to 8-inch) diameter cobbles. They noted a maximum dimension of 300 mm (12 inches) in this traverse. As at RM 109.63, the traverse at RM 109.00 disclosed bedrock outcrops along the south bank of the river. The outcrops extended 50 feet north into the reservoir. The gravel and cobble deposit lapped onto the bedrock outcrop of hard metavolcanics at that point in the traverse. The traverse at RM 108.72 noted that the reservoir bottom consisted of hard, subrounded gravel and cobbles generally less than 125 mm (5 inches) in diameter. A maximum particle dimension of 250 mm (10 inches) was observed during the traverse.

These dive traverses document a very coarse-grained bottom in the temporary reservoir area upstream from Savage Rapids Dam and are consistent with the riffle-and-pool morphology observed in the bathymetric surveys. Photograph 8 shows coarse-grained gravel and cobble bars observed at a riffle near RM 109.6 during low reservoir pool conditions in May 1999. The dive observations indicate a trend of declining particle size with distance downstream, transitioning from predominantly cobbles in the upstream portion of the temporary reservoir at RM 109.63 to a finer-grained mix of gravel and cobbles at RM 108.72. These observations also suggest that significant sediment deposition does not occur in much of the temporary reservoir area when the reservoir water surface is elevated for the irrigation season. The coarse-grained materials observed in the dive traverses are high-energy deposits which accumulate in active river channels. Deposition of these materials cannot occur under elevated reservoir water surface conditions because the slack water of the reservoir lacks the energy required to transport the material. The coarse gravel and cobbles probably are deposited on a limited scale at the upper end of the reservoir, near RM 110.6, where the Rogue River enters Savage Rapids Reservoir. The low-velocity environment of the reservoir prevents any further movement of the material downstream until the end of the irrigation season, when the stoplogs are removed from the dam and the temporary reservoir is returned to free-flowing conditions. Material which has accumulated near RM 110.6 can then be moved downstream by winter storm events and spring runoff. This transport of coarse gravel and cobbles is generally restricted to storm events and high streamflows.

*Photograph 8.—**Savage Rapids Dam, Rogue River Basin Project, Oregon**. View upstream showing a prominent riffle exposed near RM 109.0. Reservoir pool elevation is lowered for stoplog installation. The bars exposed at this elevation consist chiefly of coarse gravel and cobbles indicative of a high-energy depositional environment. This portion of the reservoir is returned to free-flowing river conditions when the stoplogs are removed from the crest of the dam at the end of the irrigation season. These bars represent river channel deposition and are analogous to bar deposits seen elsewhere on the Rogue River upstream and downstream from Savage Rapids. (Reclamation photograph by Richard Link; May 18, 1999.)*

Low-flow periods are common during the irrigation off-season, and little transport of coarse materials can occur under these conditions. Many of the very large cobble sizes observed in the dive traverses, such as the 10- to 12-inch diameter material, probably are moved only during infrequent, large storm events where sufficient velocities can be generated to mobilize the coarse riverbed. The coarse-grained bed material observed in the dive traverses is better classified as river alluvium (i.e., younger alluvium - Qal, described earlier) than as reservoir sediment and is probably very similar to alluvial deposits present in the free-flowing portions of the Rogue River both upstream and downstream from Savage Rapids Reservoir.

Medium- and fine-grained sediment is deposited on a limited basis in the temporary reservoir area when the water surface is raised for the irrigation season. Operation of Savage Rapids Dam during the irrigation season includes flow over the dam through spillway bays 1 through 4, which is intended to attract migrating anadromous fish to the north and south fish ladders (Dan Shepard, personal communication; September 1999). This flow is accomplished by leaving the topmost stoplogs out of each of the bays, resulting in a low-velocity current in the upstream reservoir. Although incapable of moving the coarse-grained bed material described above, the current does permit downstream transport of sand and fines into the reservoir. These finer-grained deposits occur mainly as a thin, discontinuous veneer on the reservoir bottom or as scattered small bars of sand and fines, as reported by the dive team. The dive traverse at RM 109.63, near the upstream end of the reservoir, did not observe any deposits of finer-grained material at that location. Mapping at the next downstream traverse, at RM 109.0, noted scattered, small bars composed of fine to medium sand. These small bars were localized and were less than 12 inches thick. Additional deposits of medium to coarse sand were observed at RM 108.72, where the sand occurred as irregular accumulations generally less than 15 feet in the longest dimension. These irregular deposits covered about 15 percent of the reservoir bottom at this location.

The finer-grained deposits were also noted at spot observations made farther downstream, within the permanent reservoir pool downstream from Savage Rapids Park. At RM 107.69, the divers noted a thin veneer of soft silt and organic debris covering the surface of the reservoir bottom. The veneer was from 4 to 6 inches thick. The surficial veneer continued downstream to RM 107.67, where the divers noted about 5 to 10 percent organic material in the veneer. The layer was about 2 to 9 inches thick and was underlain by a second layer of soft, medium- to fine-grained sand about 18 inches thick. The soft veneer of silt and organics was also described at the most downstream spot observation, RM 107.60. The thickness of the silt layer was measured to vary from about 1 to 2 inches thick at this spot observation.

Deposition of the finer-grained material in the temporary reservoir area is a transient process, active only while the water surface is elevated for the irrigation season, from about mid-May to about mid-October each year. Removal of the stoplogs returns the Rogue River to free-flowing conditions upstream from Savage Rapids Park. The finer-grained deposits are then flushed out of the temporary reservoir area by the higher velocity riverine environment, augmented by high-volume winter floods and spring runoff during the nonirrigation portion of the year. Mapping of the surface of the north bar, immediately upstream from the dam, during stoplog installation in May 1999 did not disclose any fine-grained deposits on the bar, suggesting that the winter floods are also capable of flushing the thin veneer seen in the permanent reservoir pool, particularly during large flood events. These fine-grained deposits are probably carried over the dam and downstream into the Rogue River during flood events.

Sediment Characterization

This section describes the physical properties and the soil types of the reservoir sediment based on field samples and laboratory testing conducted as part of the 1999

Reclamation evaluation of reservoir sedimentation. These data are then compared with results from previous studies at Savage Rapids Dam. A summary of the materials composing the south bar is included to complete this discussion of the reservoir sediments, although no new explorations were conducted at that site.

Summary of Physical Properties.—The following discussion of the physical properties of the sediments trapped in the reservoir behind Savage Rapids Dam is based on field observations of samples retrieved from the material and on laboratory tests conducted on representative field samples. Field descriptions and laboratory classifi-cations of the individual samples appear on the geologic logs of the drill holes in attachment B of this appendix.

Geologic mapping, observation of field samples, and laboratory testing indicate that the reservoir sediments at Savage Rapids Dam fall into one of three broad categories of materials:

- Mixed sand and gravel with 15 percent or greater gravel concentrations
- Sand with minor (less than 15 percent) gravel
- Sand with silt and minor clay

The mixed sand and gravel category constitutes the bulk of the reservoir sediment at Savage Rapids Dam, including both the floor of the permanent reservoir pool and the north bar. Samples collected in this area typically contain 15 to 56 percent gravel, by weight, and 30 percent is the average. Cobbles are also present in this material, as indicated by geologic mapping of the surface of the north bar and conditions encountered during drilling, including sampler refusal and infrequent recovery of particle sizes greater than 75 mm (3 inches) in diameter. Mapping of the surface of the north bar during low water conditions in May 1999 disclosed a variable cobble content ranging from about 20 percent, by volume, at the upstream end of the bar, gradually decreasing to about 5 percent at the downstream end, where the north bar lapped onto the spillway section of the dam, as shown on photograph 9. The maximum particle size observed on the bar was 250 mm (5 inches). The largest particle recovered from test drilling measured 110 mm (4.4 inches). Fines (very fine sand, silt, and clay passing the No. 200 sieve) occur in very low concentrations within the mixed sand and gravel category, ranging from 1 to 4 percent by weight and averaging 2 percent.

Sand with minor gravel occurs mainly within the buried pothole or pool at RM 107.91 (drill hole AP-99-3) and as apparently discontinuous lenses and layers in the north bar (AP-99-8). The gravel content in this group is significantly lower than in the mixed sand and gravel category, ranging from 5 to 13 percent by weight, with an average value of 8 percent. The maximum particle size recovered from these samples was 60 mm

Photograph 9.—***Savage Rapids Dam, Rogue River Basin Project, Oregon***. *View downstream toward Savage Rapids Dam showing the exposed surface of the north bar during stoplog installation on the spillway crest. This photograph shows the coarse-grained character of the sediments composing the north bar, which consists of variably mixed sand and gravel with cobbles. The volume of cobbles was field estimated at about 20 percent by volume at the upstream end of the bar, grading to about 5 percent at its downstream terminus at the spillway. This photograph shows the surface conditions near the approximate midpoint of the north bar. (Reclamation photograph by Richard Link; May 18, 1999.)*

(2.4 inches). No cobbles were present in the limited number of samples collected from this category. The fines content was very similar to that observed in the mixed sand and gravel category, varying from 1 to 3 percent by weight of the sample, with an average concentration of 2 percent.

Discussions held between Reclamation staff and peer reviewers while planning the field investigation determined that the fraction of soil particles finer than 0.063 mm in diameter (i.e., silt and clay particles passing the No. 230 sieve) was particularly detrimental to anadromous fish. This sieve size is not normally included in the standard Reclamation sieve set used to determine soil gradations but was included in this study to specifically address potential adverse impacts to the fisheries in the Rogue River. Results for individual samples are reported in the center column of the respective geologic logs in attachment B. Measured values for the minus 230 fraction are very low, as can be expected from the low concentrations for fines discussed above. The silt and clay particles compose only from 0.01 to 1.1 percent, by weight, of the samples of both the mixed sand and gravel and the sand with minor gravel categories. The average silt and clay concentration for the samples was 0.2 percent.

Additional laboratory testing was conducted to determine the specific gravity of sand-, silt-, and clay-sized soil particles (i.e., those particles passing the No. 4 sieve) present in the field samples. The measured specific gravity of the mixed sand and gravel category ranged from a minimum of 2.666 to a maximum of 2.884, with an average of 2.729. Samples collected from the sand with minor gravel group had similar values, ranging from 2.685 to 2.740, and an average specific gravity of 2.719.

A qualitative assessment of the in-place conditions of the reservoir sediments can be made on the basis of field logging of soil samples and observation of downhole conditions during drilling operations. The density of the reservoir sediments ranges from low to moderate, as indicated by a generally rapid penetration rate of the auger string during drilling. Hard spots were noted in most holes, but these areas probably indicate the presence of cobbles within the deposit. Shallow refusal was attained in hole AP-99-4, where a large rock or buried log was encountered about 1.9 feet into the reservoir sediments. This hole was sited near the north shoreline of the reservoir and likely intercepted a section of riprap armor which had been dumped along the reservoir rim at this location. Refusal was also uniformly attained at the base of the reservoir sediments at or near the contact with the pre-dam bed of the Rogue River. The large diameters of the sample barrels used in this investigation precluded the use of the standard penetration test, but blowcounts were informally recorded for most sample intervals to attain a relative gauge of the in-place density of the sediments. Blowcounts ranged from a minimum of 3 blows per foot (bpf) to a maximum of 33 bpf in the 25 test intervals where penetration was recorded. The average blowcount for these tests was 17 bpf. These data further suggest that the reservoir sediments have a low to moderate in-place density and that the deposits would be readily susceptible to erosion under free-flowing river conditions in the event that Savage Rapids Dam is removed. Note that higher blowcounts were obtained where the sample intervals intercepted the pre-dam riverbed, but these intervals are not included in the statistics presented above. The refusal intervals were commonly characterized by the sample barrel rebounding with no penetration under the weight of the 350-pound hammer falling a distance of about 30 inches. Testing was uniformly discontinued once sampler refusal was achieved.

The reservoir sediments are massive to crudely stratified, and bedding planes were generally lacking in most samples. Most of the samples were field logged as heterogeneous (27 of 32 samples), while 1 was described as homogeneous. Four samples were logged as stratified, with the thickness of individual layers varying from 90 to 500 mm (0.3 to 1.7 feet). Note that the entire thickness of the individual layers was not recovered, and these reported thicknesses are minimum values. Only the top and bottom of each layer were sampled, and generally a gap of at least 1 foot was left between samples.

The reservoir sediments present on the reservoir floor and in the north bar probably have a relatively high permeability, based on the gradations obtained during laboratory testing and the very small concentration of fines present in the material. This interpretation is supported by field observation of the north bar during low water conditions while stop-logs were being installed in May 1999. The sand and gravel composing the north bar drained rapidly with lowering of the reservoir pool. The bar surface was mapped within 3 to 4 hours of exposure of the bar as the reservoir lowered and much of the area drained. The bar surface supported foot traffic during mapping and had drained sufficiently so that footprints did not form on the bar, except in the more sandy materials at the downstream end of the bar. Because of the relatively low in-place density of the deposit, the bar surface probably would not have supported heavy equipment travel without prolonged exposure.

The third category of materials present in the reservoir behind Savage Rapids Dam consists of sand with silt and minor clay. These materials form the south bar along the left reservoir rim and also occur as a surficial layer in the immediate proximity of the surface depression at the pumping plant intake structure on the right end of the dam. These materials were not encountered in the 1999 field investigation conducted by Reclamation, and present knowledge of the materials is based on the data collected by McLaren/Hart (1998). Field descriptions of these materials indicate the deposit consists chiefly of sand and silt, as shown on the borehole logs included in their report. Gravel concentrations were estimated in the field at up to 10 percent in several of the samples. Photograph 10 shows the exposed surface of the south bar during low reservoir pool conditions while stoplogs were being installed across the spillway crest in May 1999.

Distribution of Soil Types.—Reclamation's 1999 field investigation collected a total of 32 samples of the reservoir sediments stored behind Savage Rapids Dam. Of these samples, 25 were deemed representative of the deposit based on sample recovery and were submitted for laboratory testing to determine standard physical properties. The samples were assigned soil types based on the USCS (Reclamation, 1990, Designation USBR 5000-86) derived from analysis of sieve data obtained in the laboratory tests. The laboratory data have been reported on the respective geologic logs of the drill holes appearing in attachment B and have been compiled on gradation test charts which have been included in attachment C.

Table 1 lists the laboratory soil classifications of the reservoir sediment and the computed fraction of the deposit represented by each soil type, based on the total number of samples collected.

Table 1.—Distribution of reservoir sediment soil types at Savage Rapids Dam

Soil type	SP	(SP)g	(SW)g	(GP)s	(GW)s
Number of samples	5	13	3	3	1
Percent of deposit	20	52	12	12	4

*Photograph 10.—**Savage Rapids Dam, Rogue River Basin Project, Oregon**. View upstream showing the surface of the south bar as exposed while the reservoir pool was low during stoplog installation. The south bar consists of fine sand and silt, based on earlier explorations by McLaren/Hart (1998) and is underlain by bedrock of the Applegate Group at depths ranging from 6.5 to 14.8 feet in five test borings drilled at this site. (Reclamation photograph by Richard Link; May 18, 1999.)*

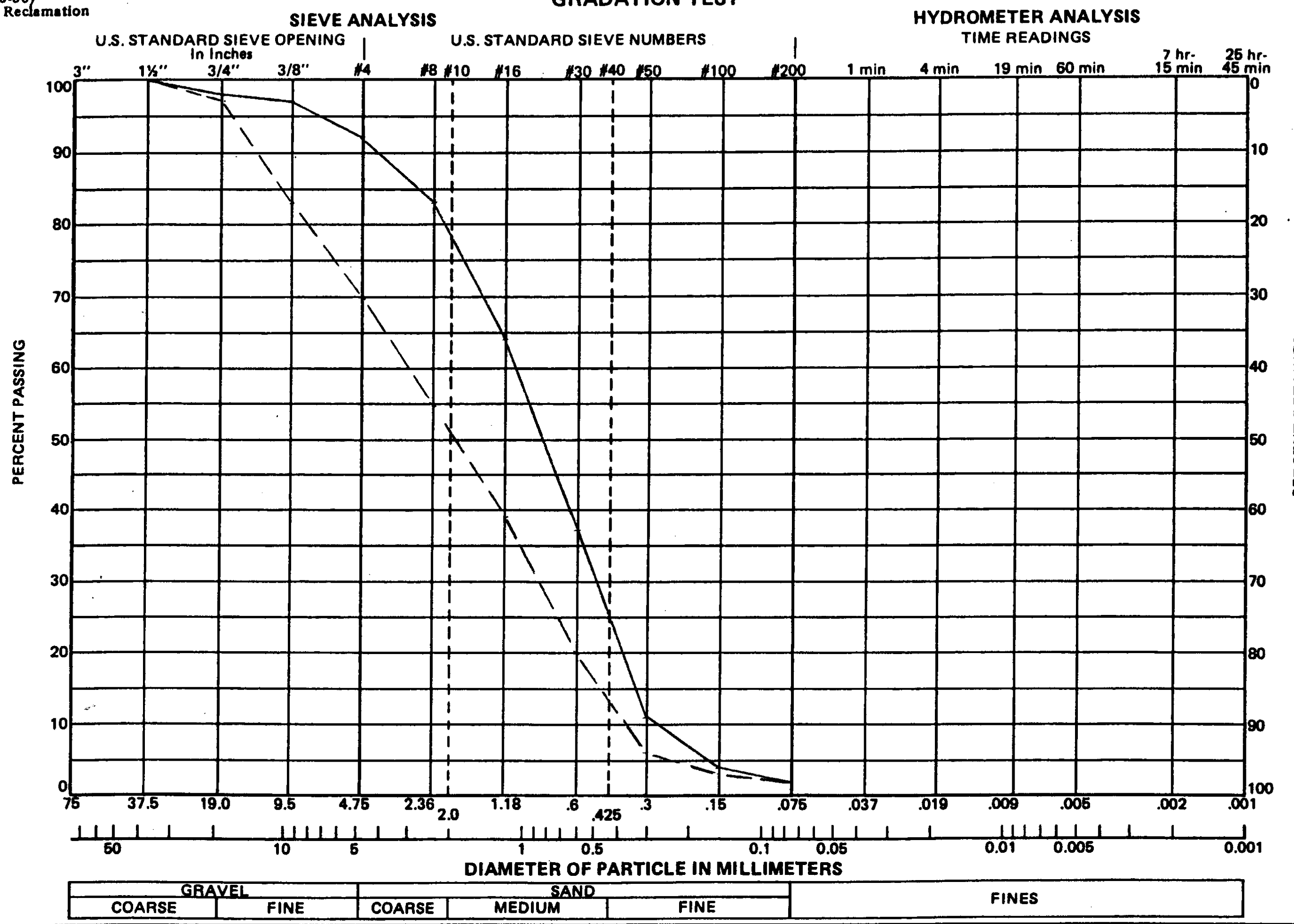
In the "Sediment Characterization" section of this appendix, reservoir sediments were subdivided into three broad categories of materials, only two of which were encountered during the 1999 Reclamation field investigation. The mixed sand and gravel category consists of materials having the following laboratory classifications from table 1: poorly graded sand with gravel (SP)g, well-graded sand with gravel (SW)g, poorly graded gravel with sand (GP)s, and well-graded gravel with sand (GW)s. The sand with minor gravel category is represented by poorly graded sand (SP) in table 1.

Average gradations were computed for both the mixed sand and gravel and the sand with minor gravel categories for use in computer modeling of erosion and downstream transport of the reservoir sediments in the event that Savage Rapids Dam is removed. Figure 2 also includes derived laboratory soil classifications for each average gradation and tabulates the percentages of gravel, sand, and fines.

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR 5000-86



SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☐ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
Sand with minor gravel			SP	8	90	2						————
Mixed sand and gravel			(SP)g	30	68	2						— — — —

PREPARED BY R. Link
CHECKED BY
FIGURE G-2

Figure 2.—Computed average gradations for reservoir sediments at Savage Rapids Dam.

The laboratory test data were analyzed for both the mixed sand and gravel and the sand with minor gravel categories to assess the variation in mean particle diameter, or D50, in the field samples (table 2). This diameter is useful in evaluating erosion and transport of the reservoir sediments under a dam removal scenario.

Table 2.—Variation of D50[1] (in mm) in reservoir sediments at Savage Rapids Dam

Soil category	$D50_{max}$	$D50_{min}$	$D50_{avg}$
Mixed sand and gravel	6.20	0.51	2.35
Sand with minor gravel	1.10	0.61	0.84

[1] The mean particle diameter, or D50, is an expression of the average particle size of a sediment obtained graphically by locating the diameter associated with the midpoint of the particle-size distribution; the D50 is the middlemost diameter that is larger than 50 percent of the particle size distribution for a given sample and smaller than the other 50 percent; the mean particle diameter is commonly expressed in millimeters. The $D50_{max}$ is the largest D50 diameter observed in all gradation tests for a soil category, while the $D50_{min}$ is the smallest D50 diameter; the $D50_{avg}$ is the computed average for all D50 diameters calculated for a soil category.

Reclamation's 1999 field investigation was conducted to expand upon earlier work that was performed by McLaren/Hart (1998) at the site. Comparison of the data collected by Reclamation with field descriptions of the reservoir sediments appearing on the geologic logs of boreholes in the McLaren/Hart report shows a close correlation of materials in the reservoir area and in the north bar. A comparison of laboratory test data for the reservoir sediment was also planned, but the records for the earlier work could not be located (Edward Fendick, personal communication; October 1999) and have not been incorporated into the discussions presented in this report. Table A2-1 of the McLaren/ Hart report (1998) does include a list of the percent of silt and clay particles passing the No. 230 sieve. Table 3 compares the data from the McLaren/ Hart report with that obtained in 1999 by Reclamation. The Reclamation data collected from the reservoir floor and the north bank correlate well with the McLaren/Hart data, as can be seen in table 2. Data for the south bank obtained by McLaren/Hart are also included in the table because this area provided the highest concentration of silt and clay observed at Savage Rapids. The south bar was not tested in the Reclamation program, and no new data are available.

Sediment Volume

One of the objectives of the 1999 Reclamation field investigation was to develop a more refined estimate of the volume of reservoir sediments stored behind Savage Rapids Dam. The estimate was based on the bathymetric surveys of the reservoir basin and the measured thicknesses of sediment determined from test drilling. This section discusses

Table 3.—Summary of reservoir sediment silt/clay content at Savage Rapids Dam

Percent fines (% passing No. 230 sieve)	Reservoir floor and north bar		South bar
	McLaren/Hart (1998)	Reclamation (1999)	McLaren/Hart (1998)
Minus No. 230_{max}	2.5	1.1	20.7
Minus No. 230_{min}	0.1	0.01	0.2
Minus No. 230_{avg}	0.7	0.2	7.5

the methodology used to develop the estimate, presents the results of the volumetric analysis, and provides further discussion of the volume of material per soil type present in the reservoir sediments.

Method.—The estimate of the volume of reservoir sediment stored behind Savage Rapids Dam was prepared using a series of 20 geologic cross sections drawn through the permanent reservoir pool, extending upstream from the dam to about RM 107.95. The locations of the cross sections are shown on the bathymetric map of the reservoir on drawing 448-100-17 in attachment A of this report. The individual cross sections appear on drawings 448-100-18 and -19. The topography of the reservoir bottom shown on the cross sections is drawn from Reclamation's 1999 bathymetric survey. The geometry of the sediment prism was approximated using the measured thickness of the sediments as determined from exploratory drilling, including both the earlier work by McLaren/Hart (1998) and the 1999 explorations completed by Reclamation. The lateral limits of the sediment prism were approximated by projecting the side slopes of the reservoir down until the bottom elevation of the drill hole was intercepted, as illustrated on sections A-A' and L-L' (see drawings 448-100-18 and -19, respectively). The end area of the sediment prism on each cross section was then computed using AutoCad version 14. Note that the computed end areas for the sediment prisms are shown on each cross section. Volume segments were then calculated by projecting each end area half the lateral distance upstream and downstream to the next available cross section.

Additional cross sections were drawn where large distances separated individual drill hole data. The bottom of the reservoir sediments was then approximated by averaging the base elevations of drill holes on adjacent sections upstream and downstream (see section P-P' on drawing 448-100-19 as an example).

In many cross sections, the projection of one or both of the reservoir side slopes intercepted the drill holes above the bottom elevation of the hole, indicating that the reservoir side slopes must steepen at some unknown point below the surface of the sediments. The sediment prism was adjusted by arbitrarily selecting a distance midway between the drill hole stick log on the cross section and the assumed contact of the reservoir side slope with the top of the reservoir prism. The base elevation of the drill hole was then extended laterally to this arbitrary point and the side slope was connected to the arbitrary point to define the side of the sediment prism, as shown on cross section B-B'. Several cross sections required adjusting both sides of the sediment prism to reach the base elevation of the drill hole. This system effectively averages the difference in observed elevations of the sediment prism and is repeatable from section to section but may introduce some error into the end area computations. A review of the affected cross sections indicates that this adjustment is conservative and probably overestimates the calculated end areas in most instances. Further definition of the sediment prism geometry can be accomplished only with additional exploration at the site and is probably not warranted based on (1) the limited improvement to the volume estimate that could be attained through this work and (2) the anticipated costs that would be incurred for the investigation.

Cross section A-A' is the first section drawn upstream from the dam and requires additional explanation. The base of the sediment prism is shown deeper than the depth of refusal recorded for drill hole NB-2 (McLaren/Hart, 1998). The base elevation was adjusted to the bottom of the dam reported by Russell (1950) to account for that portion of the reservoir sediment between the cross section and the dam which is deeper than hole NB-2. This adjustment overestimates the volume of sediment present upstream from the cross section, but accounts for sediment downstream of the cross section that would otherwise have been left out of the estimate. Savage Rapids Dam includes a series of seven inclined concrete arches beneath spillway bays 1 through 7, which extend upstream from the dam and slope downward to intercept the old river bed about 50 feet upstream from the structure. The volume computation for cross section A-A' does not take these arches into account, and the volume of the arches has been included with that calculated for the reservoir sediments. The volume of the concrete arches is relatively small compared to that computed for the reservoir, and its inclusion does not significantly impact the volume estimate.

The volume estimate also includes computation of the materials composing the south bar, based on the drill hole data obtained by McLaren/Hart (1998). This volume was estimated using the methodology described above. The south extent of the deposit is poorly constrained because the south bar extends into the shoreline, and portions of the deposit lie beyond the reservoir margin and outside the bounds of the bathymetric survey. The southern extent of the deposit was approximated from aerial photographs and field notes taken during reconnaissance of the reservoir. The surface of the deposit was extended to the left on cross sections H-H' and I-I' to account for the presence of materials beyond the present reservoir limits, as indicated by dashed ground lines on the cross sections. The volume estimate for the south bar probably contains the highest potential error of any of the computations for Savage Rapids because of the uncertainty of the southern limits of the deposit.

Volume Estimate.—The end areas, projected lateral distances, and computed volume segments described in the preceding section were compiled in an Excel spreadsheet to obtain an estimate of the total sediment volume present in the reservoir upstream from Savage Rapids Dam. These data are summarized in table 4. The total volume of reservoir sediment present behind Savage Rapids Dam is estimated at approximately 200,000 yd^3, including the south bar.

This estimate differs from the previous Reclamation volume estimate (Blanton, June 12, 1992) in a key area. The previous study assumed sediment accumulation for the entire length of the temporary reservoir pool for computation of the volume of sediment stored behind Savage Rapids Dam and did not account for the seasonal operation of the reservoir. Bathymetric data collected in 1999 shows that the reservoir bottom in the temporary pool consists of a series of riffles and pools. This reservoir bottom morphology is not consistent with significant sediment accumulation which would result in infilling of the pool reaches, as presented in the conceptual model of sediment deposition. Dive traverses conducted in the temporary pool in 1999 demonstrate that the reservoir bottom consists chiefly of coarse-grained gravel and cobbles which are representative of high-energy river channel conditions, not the slack-water environment expected in a reservoir. These coarse-grained deposits are analogous to alluvial deposits present in the river upstream from the reservoir and to those that were probably present in the Rogue River prior to construction of Savage Rapids Dam.

These observations do not support significant reservoir sediment accumulation in the temporary reservoir pool from RM 107.95 to the upstream end of the reservoir near RM 110.6. Limited sediment deposition occurring while the reservoir is elevated to the temporary pool level is most likely eroded out and moved downstream once that section of the reservoir is returned to free-flowing river conditions at the end of the irrigation season and the temporary pool area is exposed to winter floods and the spring runoff.

Additional discrepancy in the sediment volume resulted from the method that Blanton (June 12, 1992) was forced to use. The method normally used to compute sediment volume relies on having the pre-dam topography, which is not available for Savage Rapids. Lacking any pre-dam topography of the reservoir area, drill hole data, dive examinations, or geomorphic investigations, Blanton averaged the slope or gradient of the Rogue River through the reservoir to define the pre-dam elevation of the riverbed. He used 1923 USGS contour data to establish the upstream end point above the reservoir and site topography for Savage Rapids Dam to define the riverbed elevation at the downstream end. Comparing this estimated slope with the 17 measured cross sections he obtained in 1992, Blanton assumed that any 1992 data with elevations higher than his estimated pre-dam riverbed slope represented sediment accumulation within the reservoir. Field data collected in 1999 for the present study, including the bathymetric surveys and dive observations, demonstrate that the Rogue River channel consists of a series of relatively steep riffles alternating with generally flat pool sections rather than the gently sloping gradient estimated by Blanton. The effect of the sloping gradient is to overestimate the sediment volume because relatively extensive high spots in the river channel formed by cobble and boulder armoring or bedrock outcrops that

Table 4.—Estimated volume of reservoir sediments at Savage Rapids Dam

Geologic section	Reservoir floor and north bar				South bar			
	End area (ft²)[1]	Length u/s[2] (feet)	Length d/s[3] (feet)	Volume (ft³)[4]	End area (ft²)	Length u/s (feet)	Length d/s (feet)	Volume (ft³)
A-A'	3,042	25.9	79.9	321,844	0	0	0	0
B-B'	2,611	30.5	25.9	2,611	0	0	0	0
C-C'	2,123	62.7	30.5	197,864	0	0	0	0
D-D'	1,919	69.4	62.7	253,500	0	0	0	0
E-E'	2,319	71.4	69.4	326,515	0	0	0	0
F-F'	2,003	75.3	71.4	293,840	0	0	0	0
G-G'	2,311	75.5	75.3	348,499	0	0	0	0
H-H'	2,625	52.3	75.5	335,475	137	72.4	92.3	22,564
I-I'	2,087	59.6	52.3	233,535	715	72.3	72.4	103,460
J-J'	2,109	55.4	59.6	242,535	447	74.1	72.3	65,441
K-K'	1,011	46.6	55.4	103,122	418	58	74.1	55,218
L-L'	1,000	78.2	46.6	124,800	696	94.6	58	106,210
M-M'	1,993	71.6	78.2	298,551	635	83.4	94.6	113,030
N-N'	1,365	83.5	71.6	211,712	0	0	0	0
O-O'	1,995	108.8	83.5	383,639	0	0	0	0
P-P'	2,199	109.5	108.8	480,042	0	0	0	0
Q-Q'	1,930	102.6	109.5	409,353	0	0	0	0
R-R'	547	104.8	102.6	113,448	0	0	0	0
S-S'	262	97.4	104.8	52,976	0	0	0	0
T-T'	149	97.4	97.4	29,025	0	0	0	0
		Subtotal (ft³)		4,762,885				465,923
		Total volume (ft³)						5,228,808
		Total volume (yd³)						193,660

[1] Square feet.
[2] Upstream from geologic section.
[3] Downstream from geologic section.
[4] Cubic feet.

are resistant to erosion are included in the sediment computations. Blanton (June 12, 1992) estimated a volume of 320 acre-feet (516,267 yd^3) for the sediments stored behind Savage Rapids Dam, which is more than double the quantity estimated in the present study.

McLaren/Hart (1998) measured the thickness of the reservoir sediment at the north and south bars and prepared a volume estimate based on that data. Their calculated volume for that portion of the reservoir was 138,000 yd^3 of sediment. A comparison with the earlier study by Blanton (June 12, 1992) showed that McLaren/Hart's volume calculation was about 2.5 times that of Blanton's estimate for the same portion of the reservoir. Based on this difference in volumes, McLaren/Hart estimated that the total sediment volume for the entire reservoir, including the temporary pool area, could vary from 600,000 to 1,000,000 yd^3. The volume estimate prepared for the present Reclamation study agrees well with that of McLaren/Hart for the portion of the reservoir encompassing the north and south bars (i.e., cross sections A-A' through M-M', inclusive, in table 4). The total volume calculated in the present study is slightly less than 137,000 yd^3 for the same reach of the reservoir that was examined by McLaren/Hart. The primary difference between the McLaren/Hart study and the present study is that the McLaren/Hart estimates used Blanton's (June 12, 1992) assumption that sediment deposition occurred within the entire length of the reservoir, including the temporary pool area. Data collected for the present study do not support significant sediment accumulation in the temporary pool upstream from Savage Rapids Park, as discussed above. These data indicate that sediment deposition is only significant in the permanent pool which extends from Savage Rapids Dam upstream to the park, and this difference results in a considerably smaller sediment volume than in either of the previous two studies.

Volume per Soil Type.—Using the total estimated volume of sediment present in the reservoir at Savage Rapids calculated in table 4, an additional analysis was performed to evaluate that volume distributed among the various soil types identified within the reservoir sediment. This analysis used the distribution of reservoir sediment soil types shown in table 1 and estimated the volume of each type. The soil types present in the south bar have been approximated based on field descriptions of the materials reported on the respective geologic logs for drill holes SB-1 through -5 in McLaren/Hart (1998) and the laboratory test data available for the minus No. 230 fraction of the samples. These materials are listed as silty sand (SM) and sandy silt s(ML) in table 5.

Table 5.—Distribution of reservoir sediment volume per soil type

	SP	(SP)g	(SW)g	(GP)s	(GW)s	SM & s(ML) [1]
Volume (yd^3)	36,352	94,516	21,811	21,811	7,271	17,256

[1] Estimated composition of south bar materials based on field descriptions in McLaren/Hart (1998).

Conclusions and Recommendations

The reservoir sedimentation investigation conducted by Reclamation in 1999 included bathymetric mapping to determine the geometry of the reservoir bottom, recon-naissance geologic mapping of the reservoir rim during low reservoir pool elevation, drilling of 12 exploration holes to measure the thickness of reservoir sediments and determine their composition, and underwater mapping to document reservoir bottom conditions, particularly in the upper reach of the reservoir. This investigation demonstrates that the reservoir sediments are predominantly a variable mixture of coarse-grained sand and gravel with cobbles. Fines consisting of very fine sand, silt, and clay are present in very low concentrations in the dominantly coarse-grained deposit. These data agree well with previous investigations conducted at the dam by McLaren/Hart in 1998. Finer-grained deposits of silty sand and sandy silt are present at the south bar on the left reservoir rim upstream from the dam and as a thin veneer at the intake of the pumping plant located on the right abutment of the dam. These materials compose less than 10 percent of the total volume of sediment present behind Savage Rapids Dam.

The total volume of sediment stored behind Savage Rapids Dam is estimated at approximately 200,000 yd^3, based both on data collected in this investigation and on previous investigations at the site. Data and field observations obtained for this study do not support significant sediment accumulation in the temporary reservoir pool formed between RM 107.95 and RM 110.6 when the stoplogs are installed across the crest of the dam. While discontinuous bars of sand and silt were observed on the reservoir bottom in this reach, these deposits probably do not survive exposure to winter floods and spring runoff when the stoplogs are removed and the reservoir is returned to free-flowing river conditions at the end of the irrigation season. Under-water examination of the bottom conditions of the temporary pool area show the reservoir floor is chiefly coarse-grained gravel and cobbles which are too large to be transported in the low-energy, slack-water conditions prevalent in the reservoir. These deposits are more analogous to the river channel deposits present in the Rogue River upstream and downstream from the reservoir pool.

Because the current study indicates that upon removal of Savage Rapids Dam there would be less sediment released than originally anticipated, all downstream effects would be less than indicated in the *Planning Report/Final Environmental Statement (PR/FES), Fish Passage Improvements, Savage Rapids Dam, Josephine Water Management Improvement Study*, completed in 1995.

The bathymetric surveys show that the permanent reservoir pool, extending about 3,000 feet upstream from the dam to RM 107.95, near Savage Rapids Park, has very little capacity to store additional sediment. The reservoir at Savage Rapids is essentially full and has been full for several decades. Sediment loads transported by the Rogue River downstream from the dam are essentially equal to the upstream supply. The present upstream supply to the reservoir is less than the natural historic load because a significant portion of the natural sediment load is being trapped upstream in Lost Creek Reservoir.

Additional exploration of the pumping plant sites proposed as the preferred alternative to replace Savage Rapids Dam should be considered. Investigations of Savage Rapids Dam (Russell, 1950) show that the north end of the dam foundation consists of variably cemented gravel and cobbles which historically have been susceptible to scouring and erosion. Site explorations should be conducted to determine if these cemented gravels are present in the foundations of the pumping plants and to evaluate the depth beneath the gravels to competent bedrock.

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Attachment A

GEOLOGIC DRAWINGS

GENERAL GEOLOGIC LEGEND

Qrs	Holocene Reservoir Sediments. Post-Savage Rapids Dam reservoir sediments deposited by the Rogue River and its tributary streams. Consists chiefly of variably mixed sand and gravel with cobbles; includes interbeds and lenses of sand with minor gravel and prominent bar on left or south reservoir rim composed of sand and silt with minor clay. Massive to crudely stratified with bedding planes generally lacking in recovered samples; thickness of individual layers varies from 0.3 to greater than 2 ft (maximum sample length). Maximum thickness is about 20 ft in both the north bar along the right reservoir rim upstream of the dam and in a buried pool or pothole about 300 ft upstream of the north bar.
Qal	Quaternary Younger Alluvium. Unconsolidated river channel alluvium and bars deposited by the Rogue River and its tributary streams. Consists chiefly of gravel, cobbles and boulders with sand and minor silt; described on basis of exposures upstream and downstream from reservoir as explorations uniformly attained refusal at top of unit. Construction records indicate that unit was stripped from foundation prior to construction of Savage Rapids Dam.
Qtg	Quaternary Terrace Gravel and Older Alluvium. Older alluvium of the Rogue River forming prominent terraces flanking reservoir margins. Consists chiefly of gravel and cobbles with boulders in a matrix of sand, silt and clay; crudely stratified with prominent bedding planes lacking; layers and lenses of sand, silt and clay observed along reservoir shoreline upstream from dam. Variably cemented with silica and/or clay, forming relatively flat to very steep to overhanging banks along the reservoir rim. Forms foundation of dam right of spillway bay 5; subject to erosion and scouring along downstream toe of dam; thickness of unit in dam foundation is unknown.
TrPzms	Paleozoic to Triassic Metasediments. Metamorphosed and altered sedimentary rocks of the Applegate Group. Consists chiefly of metaconglomerate in submerged outcrops observed in the reservoir about 1300 ft upstream of Savage Rapids Dam; unit is not exposed in surface outcrops along the reservoir rim.
TrPzmv	Paleozoic to Triassic Metavolcanics. Metamorphosed and altered volcanic rocks of the Applegate Group. Consists chiefly of greenstone with interbeds of serpentine in the vicinity of Savage Rapids Dam with a fine-grained groundmass lacking prominent crystals or inclusions; generally slightly weathered and hard, requiring a heavy hammer blow to break field specimens; typically slightly to very slightly fractured with fracture surfaces spaced about 1 to 4 ft apart. Unit forms the foundation and left abutment of the dam and extends about 1100 ft upstream of the dam along the left or south rim of the reservoir.

GENERAL GEOLOGIC EXPLANATION

DH-90-20 ●	Drill hole location and number.
A — A'	Location of geologic section.
— —?—	Geologic contact. Queried where inferred. Dotted where concealed.
1011 sq ft	Calculated end area for prism of reservoir sediment.
DH-90-20 *EL 3220.5* *(Proj 11' N)*	Drill hole number, elevation at ground surface at collar of drill hole, and distance and direction of projection.
(stick log)	Stick log of drillhole. dashed when projected more than ten feet to the section.
Qrs	Geologic symbol.
83.5	Total depth of drill hole.

GENERAL GEOLOGIC NOTES

1. Geologic descriptors used in this report are defined in the "Engineering Geology Field Manual", Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998).
2. The Unified Soil Classification System (Designations USBR 5000-86 and 5005-86; U.S. Bureau of Reclamation, 1990) was used to describe nonindurated, uncemented earth materials sampled in the explorations; letter classification symbols shown on the logs are group symbols of the Unified Soil Classification System based on field and laboratory classifications.
3. General Geologic Legend, Explanation and Notes to accompany the following drawings:

   448-100-17 448-100-18 448-100-19
4. The survey control appearing on the accompanying drawings uses horizontal control from the NAD 1983, Oregon South State Plane Zone 3602 and vertical elevations from the NAVD 1988 datum. Elevations based on the older NGVD 1929 vertical datum have been converted to the NAVD 1988 using a factor of +4.6 ft, based on USBR field surveys conducted at the dam in 1999.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

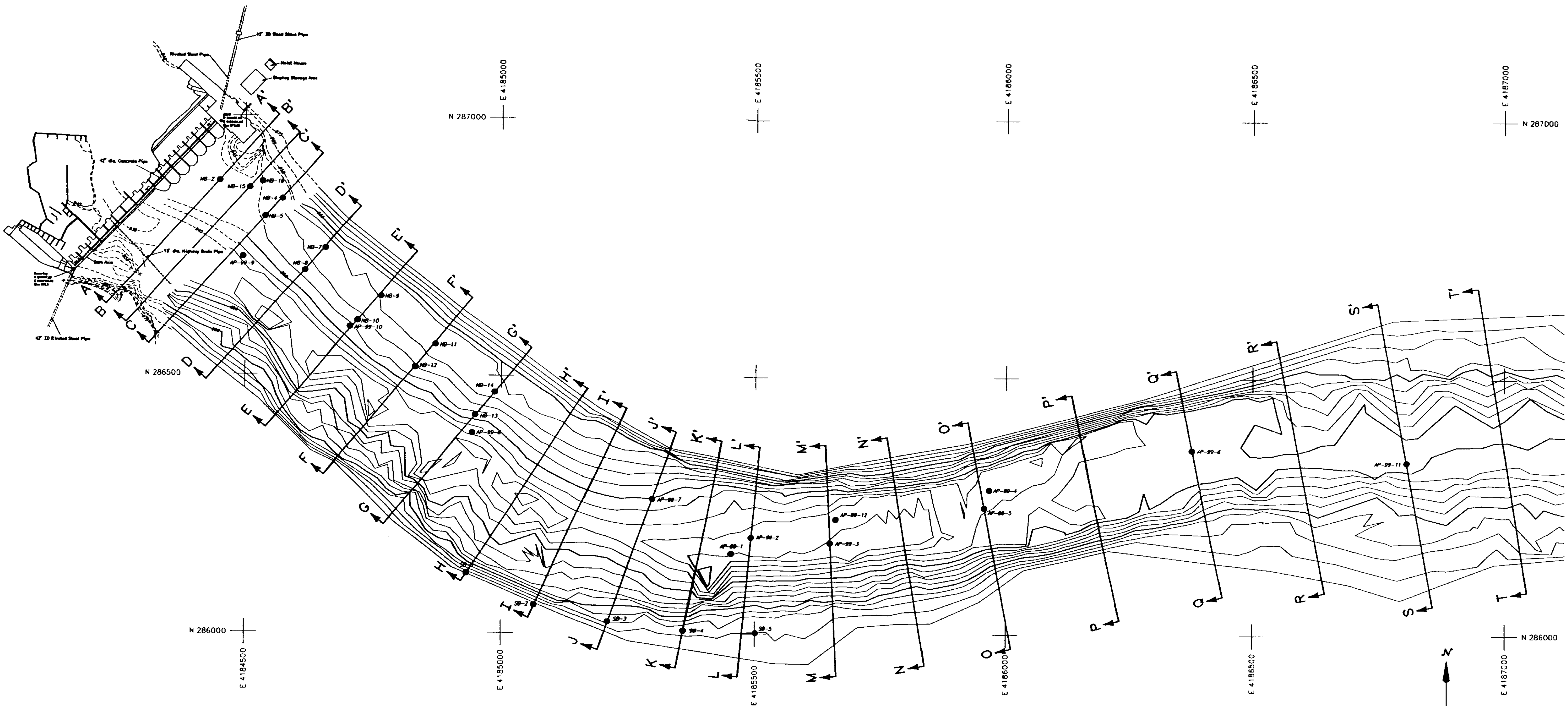
ROGUE RIVER BASIN PROJECT – OREGON

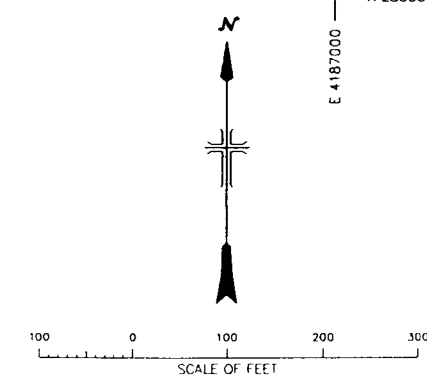
SAVAGE RAPIDS DAM

GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES

GEOLOGY R. LINK
DRAWN T. ENGLAND TECH APPROVAL
CHECKED APPROVED
PROGRAM MANAGER

CADD SYSTEM ACAD v14	CADD FILENAME \savage rapids\448-16	DATE PLOTTED 4-11-00
BOISE, IDAHO	NOVEMBER 1999	448-100-16





Notes:

1. Refer to dwg 448–100–16 for General Geologic Legend, Explanation and Notes.
2. Refer to dwg 448–100–18 for geologic sections A–A' through K–K' inclusive.
3. Refer to dwg 448–100–19 for geologic sections L–L' through T–T' inclusive.
4. Outline of dam and appurtenant structures taken from dwgs 1313–D–1 and –2 using 1999 USBR field surveys to established the dam within the 1983 NAD and 1988 NAVD State Plane grid, Oregon South Zone.
5. Dashed contours within the forebay area are taken from 1972 contours shown on dwgs 1313–D–1 and –2, as no 1999 bathymetric surveys were conducted in the forebay. The 1972 contour elevations have been adjusted to the 1988 NAVD datum using a conversion factor of +5 feet.
6. The locations of McLaren / Hart drill holes (designations NB– and SB–) are based on field survey data by Max H. Hull Land Surveying with permission from Sportfish Heritage, Inc. Holes not included in the survey have been best fit using the sketch map in the McLaren / Hart report (1998).
7. Elevations of the McLaren / Hart drill holes have been adjusted to the 1988 NAVD datum using a conversion factor of +4.6 feet, based on 1999 USBR field surveys at the dam.

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ROGUE RIVER BASIN PROJECT – OREGON

SAVAGE RAPIDS DAM
SEDIMENTATION STUDY
BATHYMETRIC MAP OF PERMANENT RESERVOIR AND LOCATIONS OF EXPLORATIONS AND SECTIONS

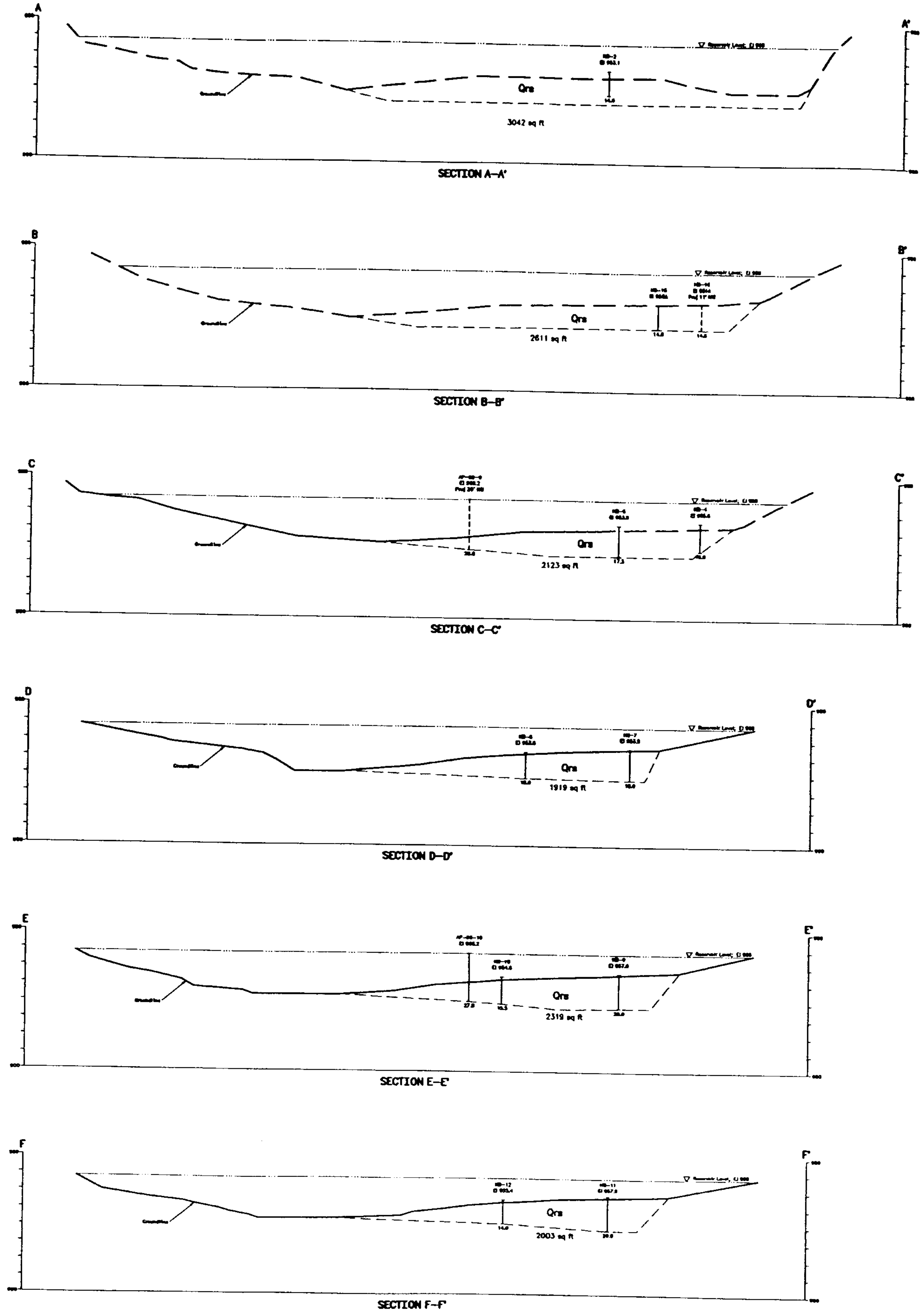
GEOLOGY R.LINK

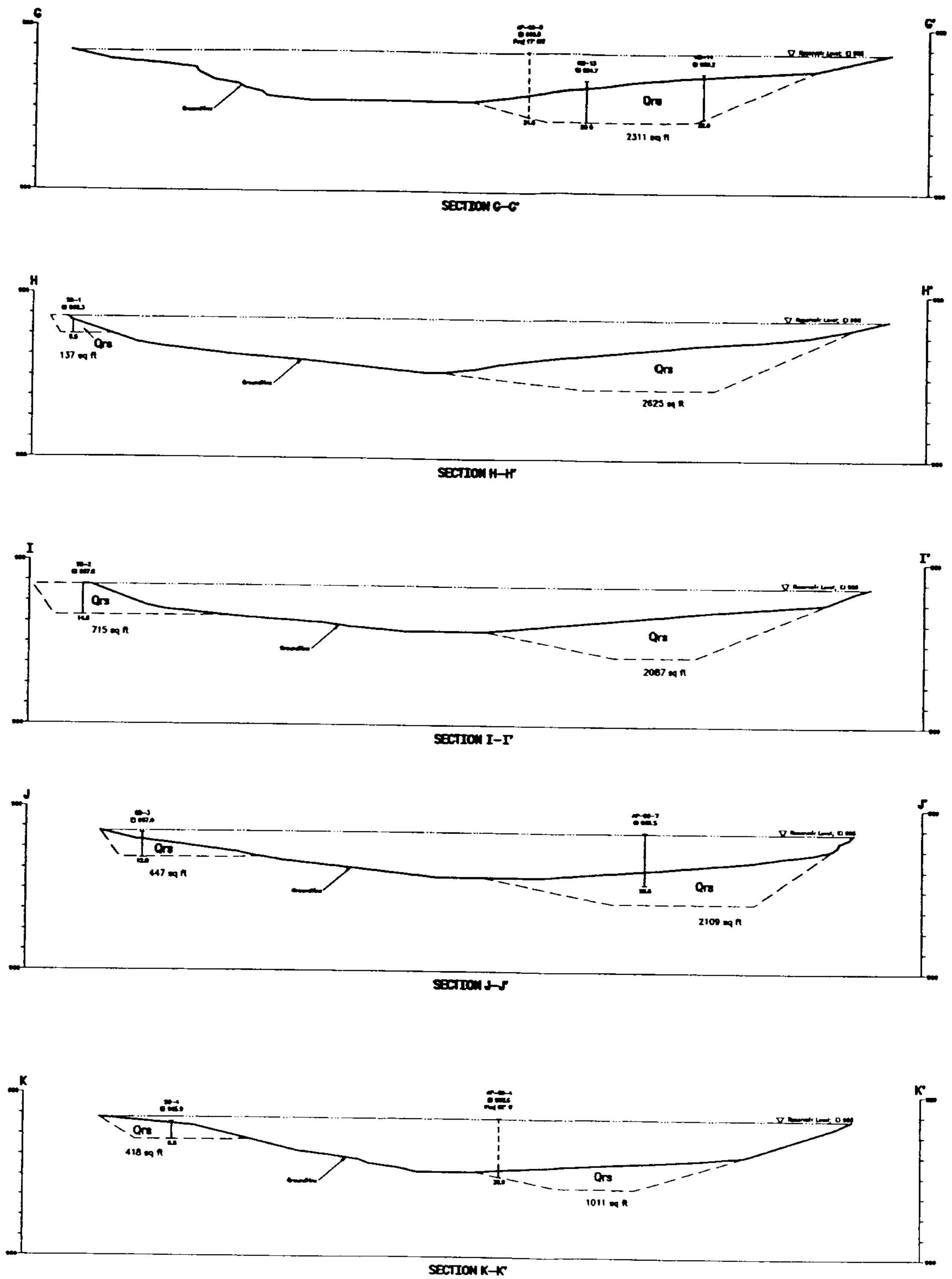
DRAWN T.ENGLAND TECH. APPROVAL

CHECKED APPROVED

PROGRAM MANAGER

CADD SYSTEM ACAD v14	CADD FILENAME	DATE PLOTTED 4-11-00
BOISE, IDAHO	NOVEMBER 1999 SHEET 1 OF 1	448–100–17





Notes:

1. Refer to dwg 448-100-16 for General Geologic Explanation, Legend and Notes.
2. Refer to dwg 448-100-17 for locations of cross sections and explorations.
3. Dashed groundline is based on data from 1972 contours

40 0 40 80 120
SCALE OF FEET

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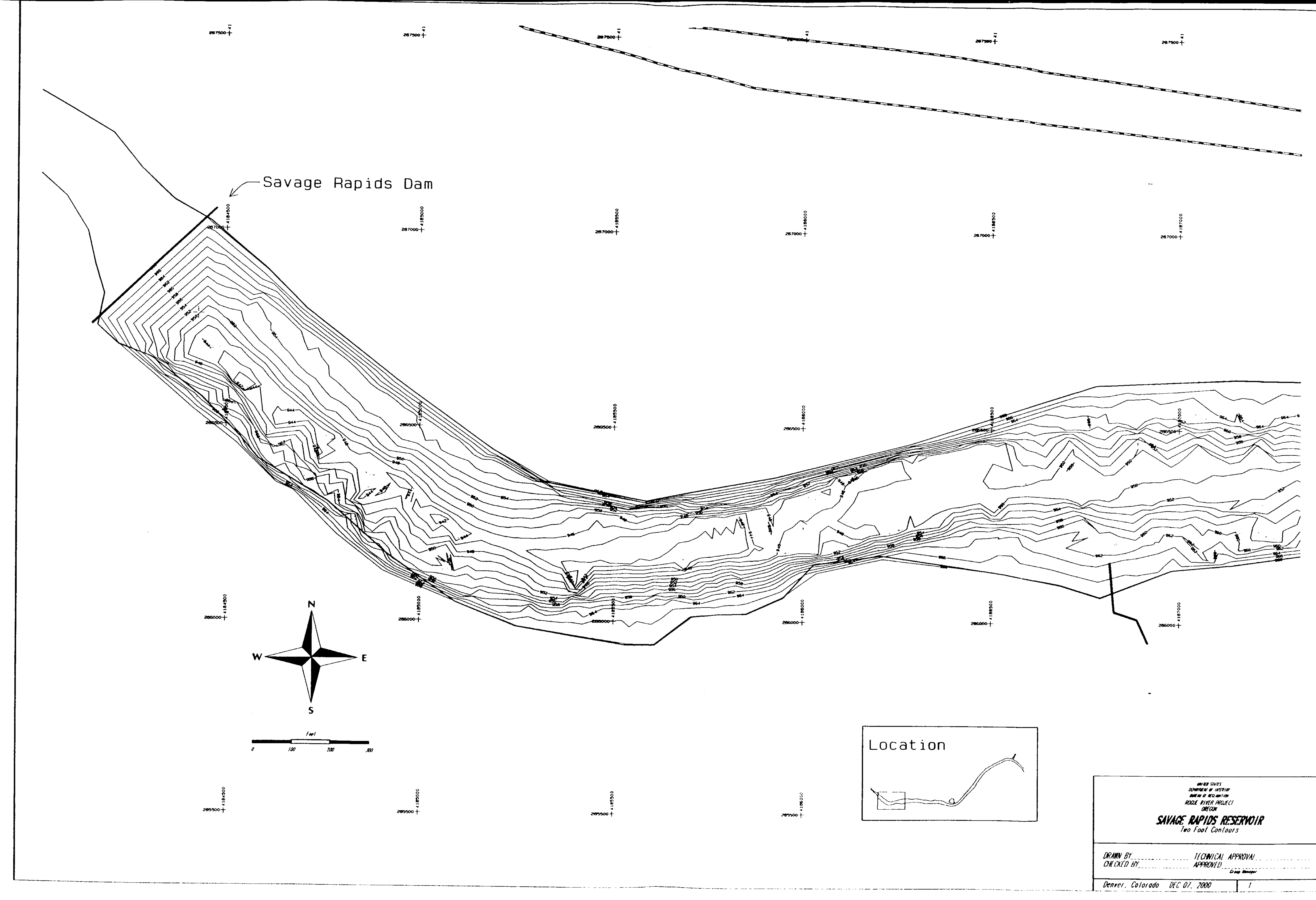
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
ROGUE RIVER BASIN PROJECT - OREGON

SAVAGE RAPIDS DAM
SEDIMENTATION STUDY
GEOLOGIC SECTIONS A-A' THROUGH K-K'

GEOLOGY R. LINK
DRAWN J. ENGLAND — TECH APPROVAL
CHECKED — APPROVED
PROGRAM MANAGER

CADD SYSTEM ACAD r14	CADD FILE NAME	DATE PLOTTED 4-11-00
BOISE, IDAHO	NOVEMBER 1999	448-100-18

SHEET 1 OF 1



Savage Rapids Dam
N
S
E
W
Feet
0
100
200
300
Location
UNITED STATES
DEPARTMENT OF INTERIOR
BUREAU OF RECLAMATION
ROGUE RIVER PROJECT
OREGON
SAVAGE RAPIDS RESERVOIR
Two Foot Contours
DRAWN BY
CHECKED BY
TECHNICAL APPROVAL
APPROVED
Group Manager
Denver, Colorado DEC 07, 2000
1

Attachment B

GEOLOGIC LOGS OF DRILL HOLES

SUMMARY OF TEST DRILLING

FEATURE Savage Rapids Dam **PROJECT** Rogue River Basin **STATE** Oregon

Hole Number	Location	Coordinates North	Coordinates East	Collar Elev.	Depth of Hole	Date Completed	Depth of Water Date Measured	Remarks
AP-99-1		286,156	4,185,451	968.6	28.9'	9-23-99		
AP-99-2		286,187.3	4,185,491.8	968.6	35.7'	9-24-99		
AP-99-3		286,178	4,185,652	968.6	45.7'	9-25-99		
AP-99-4		286,281.5	4,185,966.5	968.8	26.5'	9-27-99		
AP-99-5		286,246.4	4,185,957.2	968.8	43.5'	9-27-99		
AP-99-6		286,360.3	4,186,378.2	968.5	36.9'	9-28-99		
AP-99-7		286,262.3	4,185,296.6	968.5	25.6'	9-29-99		
AP-99-8		286,388.3	4,184,943.8	968.5	31.6'	9-29-99		
AP-99-9		286,728.3	4,184,496.1	968.2	28.8'	9-30-99		
AP-99-10		286,592.5	4,184,704.9	968.2	27.8'	9-30-99		
AP-99-11		286,337.6	4,186,806.9	967.8	22.5'	10-1-99		
AP-99-12		286,224	4,185,663	968.7	43.1'	10-2-99		

Note: Horizontal coordinates are reported in the NAD 1983 datum; vertical coordinates are reported in the NAVD 1988 datum and are based on the reservoir gage located on the right side of the spillway crest near the pumping plant; the reservoir gage is referenced to the 1929 NGVD and elevations have been corrected to the 1988 NAVD using a conversion factor of +4.6 feet.

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-1

SHEET 1 OF 1

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-23-99 FINISHED: 9-23-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286156 E 4185451
TOTAL DEPTH: 28.9
DEPTH TO BEDROCK: 28.9

STATE: Oregon
GROUND ELEVATION: 968.6
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. 2.5' intervals starting at top of river bed using 3.5" I.D. split-tube sample barrel fitted with basket catcher, 350-lbm safety hammer and cathead with rope.

DRILLING CONDITIONS
0.0-26.5': Set AP through reservoir water.
26.5-28.9': Slow and rough; sampler appeared to bounce on bedrock surface. AP under heavy torque, springing free when loosening drill head for sampling; drill string sank to reservoir bottom. Retrieved string with aid of dive team.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-23	6"	28.9	28.9

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION
Retrieved AP from reservoir bottom, reversing auger rotation to move cuttings back down hole.

LOG

DEPTH	TYPE OF HOLE	% CORE RECOVERY	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0.0-26.5					Water	942.1
26.5-28.9	DS	13	n/a	n/a	Qrs	939.7
28.9	BOTTOM OF HOLE					

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-26.5': WATER.

26.5-28.9': RESERVOIR SEDIMENTS (Qrs).

Poor recovery. Sample composed of gravel and cobble; insufficient sample mass to perform a soil classification. Recovered sample consists of about 50% fine to coarse, hard, subangular to subrounded gravel; about 50% fine, hard, subangular cobble (single particle); trace of fine to medium, hard, subangular to subrounded sand, trace of nonplastic fines; maximum dimension, 100 mm; wet, dark gray; heterogeneous, dimensions of cobble are 90 by 60 by 100 mm; sand and fines occur as thin, dark brown coatings on larger particles; particle composition is chiefly basalt and metavolcanics with minor quartz; no reaction with HCl.
NOTE: Sample interval may be exaggerated as sampler appeared to bounce along sloping bedrock surface while driving with 350-lbm hammer.

28.9': BOTTOM OF HOLE. Underwater examination of site showed bedrock outcrops of strongly cemented conglomerate overlain by thin veneer of reservoir sediments; particles could not be dislodged from cemented matrix with heavy hammer blows.

NOTES:

1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998).

2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers
DS = Drive Sample
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)
n/a = Not available; insufficient sample mass to perform soil classification.

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-2

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-24-99 FINISHED: 9-24-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286187.3 E 4185491.8
TOTAL DEPTH: 35.7
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.6
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. continuous intervals starting at top of lake bed using 3.5" I.D. split-tube sample barrel fitted with basket catcher, 350-lbm safety hammer and cathead with rope.

SAMPLE INTERVALS

25.0-27.0'	3.75" DS
27.0-29.0'	3.75" DS
29.0-31.0'	3.75" DS
"	3" DS
33.7-35.7'	3.75" DS

DRILLING CONDITIONS
0.0-25.0': Set AP through reservoir water.
25.0-29.0': Slow and soft with rough areas. No recovery in sample from 26.9-29.0'; tripped back in with smaller 3" I.D. barrel equipped with flapper valve; no recovery in second attempt.
29.0-35.7': Slow and rough; drilling platform whipping back and forth; hole at or very near limit of drilling equipment. About 1.0' of slough in hole after cleanout run to 33.7'; inserted chopping bit and flushed slough from hole. No recovery in sample interval from 33.7-35.7'; fingers of basket catcher for barrel were too widely spaced to retain sample.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-24	6"	35.7	33.7

LOG

DEPTH	TYPE OF HOLE	% CORE RECOVERY	% MINUS #230	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0.0-25.0						Water	943.6 (at 25)
25.0-27.0	DS	40	0.07	(GP)sc	(GP)s	Qrs	
27.0-29.0	DS	0		NoRec	NoRec	Qrs	
29.0-31.0	DS	10		n/a	n/a	Qrs	
31.0-33.7	AP					Qrs	
33.7-35.7	DS	0		NoRec	NoRec	Qrs	932.9 (at 35.7)
	BOTTOM OF HOLE						

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-25.0': WATER.

25.0-35.7': RESERVOIR SEDIMENTS (Qrs).

25.0-27.0': POORLY GRADED GRAVEL WITH SAND AND COBBLES (GP)sc. About 65% fine to coarse, hard, subangular to rounded gravel; about 35% fine to coarse, hard, angular to subrounded sand; about 5% nonplastic fines; includes single cobble measuring 110 by 100 by 80 mm (comprises about 50% of the sample by volume); maximum dimension, 110 mm; wet, dark gray to dark brown; includes fine, oxidized organic debris; heterogeneous, loose; no reaction with HCl.
LAB TEST DATA: 50% gravel, 48% sand, 2% fines; Cu = 27.78, Cc = 0.14; SpG = 2.703; laboratory classification of sample is POORLY GRADED GRAVEL WITH SAND (GP)s.

27.0-29.0': No recovery. Second sample attempt in this interval using flapper valve also had no recovery. Residue on flapper valve consisted entirely of fine to medium sand with minor silt.

29.0-31.0': Poor recovery. Sample composed of gravel and sand; insufficient sample mass to perform a soil classification. Recovered sample consists of about 85% fine to coarse, hard, subangular to subrounded gravel; about 15% fine to coarse, hard, angular to subrounded sand; trace of nonplastic fines; maximum dimension, 70 mm; wet, dark gray; heterogeneous; particle composition is chiefly basalt and metavolcanics with minor quartz; no reaction with HCl.

33.7-35.7': No recovery. Sample recovery limited to several fine gravel and sand particles lodged in the basket catcher of the sampler.

35.7': BOTTOM OF HOLE. Hole drilling very hard and rough; at or very near the limit of the drilling equipment.

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers
DS = Drive Sample
NoRec = No Recovery
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)
n/a = not available; insufficient sample mass to perform soil classification

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-2

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-24-99 FINISHED: 9-24-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286187.3 E 4185491.8
TOTAL DEPTH: 35.7
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.6
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES	CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)	
FLUID RETURN AND COLOR No fluid used. WATER LEVEL DURING DRILLING Water level stayed at reservoir surface, i.e., 0.0'. HOLE COMPLETION Retrieved AP from reservoir bottom, reversing auger rotation to move cuttings back down hole.	NOTES: 1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998). 2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".	

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-3

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-25-99 FINISHED: 9-25-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286178 E 4185652
TOTAL DEPTH: 45.7
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.6
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. continuous intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle, 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval.

SAMPLE INTERVALS
26.8-28.8' 3" DS
30.2-32.2' 3" DS
32.5-34.5' 3" DS
35.3-37.3' 3" DS
37.8-39.8' 3" DS
41.7-43.7' 3" DS

DRILLING CONDITIONS
0.0-26.8': Set AP through reservoir water.
26.8-32.5': Slow and very rough. Drilling platform twisting back and forth while augering; hole going crooked at 30', pulled back on augers to straighten out hole.
32.5-37.8': Fast and smooth with rough areas from 35.3-37.8'.
37.8-45.7': Slow and rough; platform rocking about and augers jamming during drilling; repeatedly reverse auger rotation to clear jams. Augers refused at 45.7'.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-25	6"	45.7	45.7

LOG

TYPE OF HOLE	% CORE RECOVERY	% MINUS #230	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
					Water	941.8
DS	25	0.1	(GP)s	(SP)g		
AP						
DS	65	0.3	(SP)g	SP		
DS	50	0.2	SP	SP		
AP						
DS	55	0.03	SP	(SP)g	Qrs	
AP						
DS	55	0.03	(SP)g	SP		
AP						
DS	45	1.1	(SP)g	SP		
AP						922.9

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-26.8': WATER.

26.8-45.7': RESERVOIR SEDIMENTS (Qrs).

26.8-28.8': POORLY GRADED GRAVEL WITH SAND (GP)s. About 80% fine to coarse, hard, subangular to rounded gravel; about 20% fine to coarse, hard, angular to subrounded sand; trace of fines; maximum size, 60 mm; wet, dark gray; includes minor fine, oxidized organic debris with scattered fresh roots; heterogeneous, loose; particle composition consists of basalt and metavolcanics with minor quartz; no reaction with HCl.
LAB TEST DATA: 76% sand, 22% gravel, 2% fines; Cu = 3.13, Cc = 0.75; SpG = 2.703; laboratory classification of sample is POORLY GRADED SAND WITH GRAVEL (SP)g.

30.2-32.2': POORLY GRADED SAND WITH GRAVEL (SP)g. About 85% fine to coarse, hard, angular to subrounded sand; about 15% predominantly fine, hard, subangular to subrounded gravel; trace of fines; maximum size, 35 mm; wet, dark gray speckled white; heterogeneous, loose; particle composition consists of basalt, metavolcanics, quartz, mica and feldspar; no reaction with HCl.
LAB TEST DATA: 93% sand, 6% gravel, 1% fines; Cu = 3.44, Cc = 1.02; SpG = 2.707; laboratory classification of sample is POORLY GRADED SAND (SP).

32.5-34.5': POORLY GRADED SAND (SP). About 90% fine to coarse, hard angular to subrounded sand; about 10% fine to coarse, hard, subangular to rounded gravel; trace of fines; maximum size, 45 mm; wet, dark gray to dark brown; includes fine, oxidized organic debris; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 92% sand, 5% gravel, 3% fines; Cu = 4.05, Cc = 0.99; SpG

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers.
DS = Drive Sample
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-3

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-25-99 FINISHED: 9-25-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286178 E 4185652
TOTAL DEPTH: 45.7
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.6
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION
Retrieved AP from reservoir bottom, reversing auger rotation to move cuttings back down hole.

CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)

= 2.723.

35.3-37.3': POORLY GRADED SAND (SP). About 90% fine to coarse, hard, angular to rounded sand; about 10% predominantly fine, hard, subangular to rounded gravel; trace of fines; maximum size, 20 mm; wet, dark gray; includes fine, oxidized organic debris; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 69% sand, 29% gravel, 2% fines; Cu = 8.21, Cc = 0.80; SpG = 2.750; laboratory classification of sample is POORLY GRADED SAND WITH GRAVEL (SP)g.

37.8-39.8': POORLY GRADED SAND WITH GRAVEL (SP)g. About 85% fine to coarse, hard, angular to rounded sand; about 15% fine to coarse, hard, angular to rounded gravel; trace of fines; maximum size, 45 mm; wet, dark gray; includes fine, oxidized organic debris; heterogeneous, loose, gravel particles concentrated in bottom 0.4' of sample, no evidence of obvious bedding plane at that point; particle composition consists of basalt, metavolcanics, quartz and agate; no reaction with HCl.
LAB TEST DATA: 88% sand, 10% gravel, 2% fines; Cu = 4.67, Cc = 0.60; SpG = 2.740; laboratory classification of sample is POORLY GRADED SAND (SP).

41.7-43.7': POORLY GRADED SAND WITH GRAVEL (SP)g. About 80% fine to coarse, hard, angular to rounded sand; about 15% predominantly fine, hard, subangular to rounded gravel; about 5% nonplastic fines; maximum size, 30 mm; wet, dark gray; includes fine, oxidized organic debris; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 91% sand, 8% gravel, 1% fines; Cu = 5.56, Cc = 1.28; SpG = 2.738; laboratory classification of sample is POORLY GRADED SAND (SP).

45.7': BOTTOM OF HOLE. Hole drilling very hard and rough from 39.8 to 45.7'; augers refused at 45.7'.

NOTES:
1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998).

2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-4

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-27-99 FINISHED: 9-27-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286281.5 E 4185966.5
TOTAL DEPTH: 26.5
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.8
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. continuous intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle, 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval.

SAMPLE INTERVALS
24.6-26.2' 3" DS

DRILLING CONDITIONS
0.0-24.6': Set AP through reservoir water.
24.6-26.5': Slow and very rough. Drilling platform twisting back and forth while augering. Augers refused at 26.5'; moved drilling platform to center of reservoir and started a new hole.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-27	6"	26.5	26.5

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION
Retrieved AP from reservoir bottom, reversing auger rotation to move cuttings back down hole.

DEPTH	TYPE OF HOLE	% CORE RECOVERY	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0–24.6					Water	
24.6						944.2
24.6–26.5	DS	0	NoRec	NoRec	Qrs	
26.5						942.3
BOTTOM OF HOLE						

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-24.6': WATER.

24.6-26.5': RESERVOIR SEDIMENTS (Qrs).

24.6-26.2': No recovery. Lake bottom felt soft when setting drill string for sampling.

26.5': BOTTOM OF HOLE. Augers refused at 26.5' in cleanout run following drive sample. Hole may have intercepted block of riprap slope protection observed along right shoreline of reservoir at this location.

NOTES:

1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998).

2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers
DS = Drive Sample
NoRec = No Recovery
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-5

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-27-99 FINISHED: 9-27-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286246.4 E 4185957.2
TOTAL DEPTH: 43.5
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.8
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. 2-foot intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle. 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval.

SAMPLE INTERVALS
23.0-25.8' 3" DS
26.6-28.6' 3" DS
31.4-33.4' 3" DS
35.8-37.8' 3" DS
39.9-41.9' 3" DS

DRILLING CONDITIONS
0.0-23.0': Set AP through reservoir water.
23.0-26.6': Fast and smooth.
26.6-40.4': Slow and smooth with rough areas.
40.4-43.5': Slow and very rough; drilled extremely hard from 42.5-43.5'. Augers refused at 43.5'.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-27	6"	43.5	43.5

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION
Retrieved AP from

LOG

DEPTH	TYPE OF HOLE	% CORE RECOVERY	% MINUS #230	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0.0-23.0						Water	945.8
23.0-25.8	DS	0		NoRec	NoRec	Qrs	
25.8-26.6	AP						
26.6-28.6	DS	40	<0.06	SP	(SP)g		
28.6-31.4	AP						
31.4-33.4	DS	45	0.08	(GP)s	(GP)s		
33.4-35.8	AP						
35.8-37.8	DS	30	0.4	(SP)g	(SP)g		
37.8-39.9	AP						
39.9-41.9	DS	0		NoRec	NoRec		
41.9-43.5	AP						925.3
BOTTOM OF HOLE							

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-23.0': WATER.

23.0-43.5': RESERVOIR SEDIMENTS (Qrs).

23.0-25.8': No recovery. Lake bottom felt soft when setting drill string for sample interval; overdrove sampler additional 0.8' to improve recovery with no success.

26.6-28.6': POORLY GRADED SAND (SP). About 90% fine to coarse, hard, angular to subrounded sand; about 10% predominantly fine, hard, subangular to subrounded gravel; trace of fines; maximum size, 40 mm; wet, dark gray speckled white; includes fine, oxidized organic debris; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 84% sand, 15% gravel, 1% fines; Cu = 4.00, Cc = 0.79; SpG = 2.695; laboratory classification of sample is POORLY GRADED SAND WITH GRAVEL (SP)g.

31.4-33.4': POORLY GRADED GRAVEL WITH SAND (GP)s. About 55% fine to coarse, hard, angular to subrounded gravel; about 45% fine to coarse, hard, subangular to subrounded sand; trace of fines; maximum size, 60 mm; wet, dark gray; heterogeneous, loose to dense; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 51% gravel, 49% sand, 0% fines; Cu = 5.00, Cc = 0.56; SpG = 2.742.

35.8-37.8': POORLY GRADED SAND WITH GRAVEL (SP)g. About 85% predominantly medium to coarse, hard, angular to subrounded sand; about 15% fine to coarse, hard, subangular to rounded gravel; trace of fines; maximum size, 30 mm; wet, dark gray; includes fine, oxidized organic debris; stratified, top 0.3' of sample consists of about 95% predominantly fine sand with about 5% fines, loose to dense; particle

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers.
DS = Drive Sample
Cs = Casing
I.D. = Inside Diameter
Cu = Coefficient of Uniformity
SpG = Specific Gravity (minus #4 fraction)
NoRec = No recovery
Sz = Size of Casing
O.D. = Outside Diameter
Cc = Coefficient of Curvature

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-5

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-27-99 FINISHED: 9-27-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286246.4 E 4185957.2
TOTAL DEPTH: 43.5
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.8
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES	CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)	
reservoir bottom, reversing auger rotation to move cuttings back down hole.	composition consists of basalt, metavolcanics, quartz and mica; no reaction with HCl. LAB TEST DATA: 75% sand, 21% gravel, 4% fines; Cu = 7.38, Cc = 0.51; SpG = 2.727. 39.9-41.9': No recovery. Sampler drove very easily; residue trapped behind basket catcher consisted of medium to coarse sand and fine gravel, similar to bottom half of previous sample. 43.5': BOTTOM OF HOLE. Hole drilling very hard and rough from 42.5 to 43.5'; augers refused at 43.5'. NOTES: 1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998). 2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".	

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-6

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-28-99 FINISHED: 9-28-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286360.3 E 4186378.2
TOTAL DEPTH: 36.9
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.5
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. 3-foot intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle, 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval.

SAMPLE INTERVALS
18.0-20.2' 3" DS
21.7-23.7' 3" DS
25.9-27.9' 3" DS
31.1-33.1' 3" DS
36.0-36.9' 3" DS

DRILLING CONDITIONS
0.0-18.0': Set AP through reservoir water.
18.0-25.9': Slow and smooth; rougher from 20.7-21.7'.
25.9-35.7': Slow and rough.
35.7-36.9': Slow and very rough; drilled very hard with drill at or very near limit of equipment. DS rebounding with no penetration at 36.9'.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-28	6"	36.9	36.0

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

LOG

DEPTH	TYPE OF HOLE	% CORE RECOVERY	% MINUS #230	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0.0-18.0						Water	950.5
18.0-20.2	DS	11		n/a	n/a	Qrs	
	AP						
21.7-23.7	DS	55	0.1	(SP) g	(SP) g		
	AP						
25.9-27.9	DS	60	0.3	(SP) g	(SP) g		
	AP						
31.1-33.1	DS	45	0.1	(GP) s	(SP) g		
	AP						
36.0-36.9	DS	0		NoRec	NoRec		931.6

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-18.0': WATER.

18.0-36.9': RESERVOIR SEDIMENTS (Qrs).

18.0-20.2': Poor recovery. Sample composed of gravel and sand; insufficient sample mass to perform soil classification. Recovered sample consists of predominantly coarse, hard, angular to rounded gravel and predominantly medium to coarse, hard, angular to rounded sand; maximum size, 70 mm; wet, dark brown; heterogeneous, loose; particle composition consists of basalt, quartz and metavolcanics; no reaction with HCl.
NOTE: Sampler sank 0.2' under weight of drill rods at start of sample interval; drove sampler from 18.2-20.2' with safety hammer.

21.7-23.7': POORLY GRADED SAND WITH GRAVEL (SP)g. About 75% fine to coarse, hard, angular to subrounded sand; about 20% fine to coarse, hard, subangular to rounded gravel; about 5% nonplastic fines; maximum size, 25 mm; wet, dark gray to dark brown; includes fine, oxidized organic debris; homogeneous, loose to dense; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 79% sand, 17% gravel, 4% fines; Cu = 3.55, Cc = 1.06; SpG = 2.666.

25.9-27.9': POORLY GRADED SAND WITH GRAVEL (SP)g. About 85% fine to coarse, hard, angular to rounded sand; about 15% fine to coarse, hard, subangular to rounded gravel; trace of fines; maximum size, 40 mm; wet, dark gray speckled white; includes fine, oxidized organic debris; heterogeneous, loose to dense; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 67% sand, 32% gravel, 1% fines; Cu = 4.71, Cc = 0.73; SpG = 2.884.

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers.
DS = Drive Sample
NoRec = No recovery
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)
n/a = Not available; insufficient sample mass to perform soil classification.

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-6

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-28-99 FINISHED: 9-28-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286360.3 E 4186378.2
TOTAL DEPTH: 36.9
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.5
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES	CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)	
HOLE COMPLETION Retrieved AP from reservoir bottom, reversing auger rotation to move cuttings back down hole.	31.1-33.1': POORLY GRADED GRAVEL WITH SAND (GP)s. About 60% fine to coarse, hard, subangular to rounded gravel; about 40% fine to coarse, hard, angular to rounded sand; trace of fines; maximum size, 40 mm; wet, dark gray; includes fine, oxidized organic debris; heterogeneous, loose to dense; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl. LAB TEST DATA: 61% sand, 37% gravel, 2% fines; Cu = 10.00, Cc = 0.86; SpG = 2.754; laboratory classification of sample is POORLY GRADED SAND WITH GRAVEL (SP)g. 36.0-36.9': No recovery. Sampler rebounding with no penetration at 36.9'. 36.9': BOTTOM OF HOLE. Hole drilling very hard and rough from 35.7-36.0'. NOTES: 1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998). 2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".	

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-7

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-29-99 FINISHED: 9-29-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286262.3 E 4185296.6
TOTAL DEPTH: 25.6
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.5
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. 2-foot intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle. 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval.

SAMPLE INTERVALS
18.3-20.8' 3" DS
22.6-24.6' 3" DS

DRILLING CONDITIONS
0.0-18.3': Set AP through reservoir water. Top of lake bed very soft, as determined with weighted line.
18.3-22.5': Slow and smooth.
22.6-25.6': Slow and very rough. Augers refused at 25.6'.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-29	6"	25.6	25.6

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION
Retrieved AP from reservoir bottom, reversing auger rotation to move cuttings back down hole.

LOG

DEPTH	TYPE OF HOLE	% CORE RECOVERY	% MINUS #230	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0-18.3						Water	
18.3							950.2
18.3-20.8	DS	16	0.02	(GP)s	(GP)s	Qrs	
20.8-22.6	AP					Qrs	
22.6-24.6	DS	45	0.01	(SP)g	(SP)g	Qrs	
24.6-25.6	AP					Qrs	
25.6	BOTTOM OF HOLE						942.9

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-18.3': WATER.

18.3-25.6': RESERVOIR SEDIMENTS (Qrs).

18.3-20.8': POORLY GRADED GRAVEL WITH SAND (GP)s. About 85% fine to coarse, hard, subangular to subrounded gravel; about 15% fine to coarse, hard, angular to rounded sand; trace of fines; maximum size, 70 mm; wet, dark gray; includes fine, oxidized organic debris; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 56% gravel, 43% sand, 1% fines; Cu = 14.14, Cc = 0.52; SpG = 2.714.
NOTE: Sampler sank 0.3' under weight of drill rods at start of sample interval; drove sampler from 18.6-20.8' with safety hammer.

22.6-24.6': POORLY GRADED SAND WITH GRAVEL (SP)g. About 85% fine to coarse, hard, angular to subrounded sand; about 15% fine to coarse, hard, subangular to rounded gravel; trace of fines; maximum size, 40 mm; wet, dark gray; heterogeneous, loose; particle composition consists of basalt, metavolcanics, quartz and andesite; no reaction with HCl.
LAB TEST DATA: 72% sand, 27% gravel, 1% fines; Cu = 4.50, Cc = 0.75; SpG = 2.718.

25.6': BOTTOM OF HOLE. Hole drilling very hard and rough from 22.5-25.6'; augers refused at 25.6'.

NOTES:
1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998).

2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers
DS = Drive Sample
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-7

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-29-99 FINISHED: 9-29-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286252.3 E 4185296.6
TOTAL DEPTH: 25.6
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.5
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)	
prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".	

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-8

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-29-99 FINISHED: 9-29-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286388.3 E 4184943.8
TOTAL DEPTH: 31.6
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.5
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. 3-foot intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle, 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval.

SAMPLE INTERVALS
17.5-20.0' 3" DS
22.0-24.0' 3" DS
25.9-27.9' 3" DS
29.9-31.6' 3" DS

DRILLING CONDITIONS
0.0-17.5': Set AP through reservoir water. Top of lake bed very soft, as determined with weighted line.
17.5-22.0': Slow and rough.
22.0-31.6': Slow and smooth with rough areas below 24.9'. Sampler rebounding with no penetration at 31.6'; augers refused at 30.9' during cleanout run.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-29	6"	31.6	30.9

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION

LOG

DEPTH	TYPE OF HOLE	% CORE RECOVERY	% MINUS #230	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0.0-17.5						Water	951.0
17.5-20.0	DS	15		n/a	n/a	Qrs	
20.0-22.0	AP						
22.0-24.0	DS	35	0.1	SP	(SP) g		
24.0-25.9	AP						
25.9-27.9	DS	75	0.1	(SP) g	SP		
27.9-29.9	AP						
29.9-31.6	DS	71	0.3	(GP) s	(SP) g		936.9

BOTTOM OF HOLE

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-17.5': WATER.

17.5-31.6': RESERVOIR SEDIMENTS (Qrs).

17.5-20.0': Poor recovery. Sample composed of gravel and sand; insufficient sample mass to perform a soil classification. Recovered sample consists of about 95% fine to coarse, hard, subangular to rounded gravel; about 5% predominantly coarse, hard, angular to rounded sand; maximum size, 55 mm; wet, dark gray; heterogeneous, loose; particle composition consists of basalt, metavolcanics and minor quartz; no reaction with HCl.

22.0-24.0': POORLY GRADED SAND (SP). About 90% fine to coarse, hard, angular to subrounded sand; about 10% fine to coarse, hard, subangular to subrounded gravel; trace of fines; maximum size, 30 mm; wet, dark gray; includes minor, fine, oxidized organic debris; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl. LAB TEST DATA: 78% sand, 21% gravel, 1% fines; Cu = 4.85, Cc = 0.78; SpG = 2.700; laboratory classification of sample is POORLY GRADED SAND WITH GRAVEL (SP)g.

25.9-27.9': POORLY GRADED SAND WITH GRAVEL (SP)g. About 75% fine to coarse, hard, angular to rounded sand; about 25% fine to coarse, hard, subangular to rounded gravel; trace of fines; maximum size, 60 mm; wet, dark gray; heterogeneous, loose to dense; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl. LAB TEST DATA: 84% sand, 13% gravel, 3% fines; Cu = 4.05, Cc = 0.86; SpG = 2.685; laboratory classification of sample is POORLY GRADED SAND (SP).

29.9-31.6': POORLY GRADED GRAVEL WITH SAND (GP)s. About 55% fine to

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers
DS = Drive Sample
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)
n/a = Not available; insufficient sample mass to perform soil classification.

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-8

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-29-99 FINISHED: 9-29-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286388.3 E 4184943.8
TOTAL DEPTH: 31.6
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.5
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES	CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)	
Retrieved AP from reservoir bottom, reversing auger rotation to move cuttings back down hole.	coarse, hard, subangular to subrounded gravel; about 40% fine to coarse, hard, angular to rounded sand; about 5% nonplastic fines; maximum size, 65 mm; wet, dark gray; includes fine, oxidized organic debris; stratified, top half of sample consists chiefly of fine to medium sand while bottom half consists of coarse sand and gravel, no obvious bedding planes noted in sample; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl. LAB TEST DATA: 74% sand, 22% gravel, 4% fines; Cu = 7.62, Cc = 0.84; SpG = 2.739; laboratory classification of sample is POORLY GRADED SAND WITH GRAVEL (SP)g. 31.6': BOTTOM OF HOLE. Hole drilling very hard and rough from 30.4-30.9'; sampler rebounding with no penetration at 31.6'; augers refused at 30.9' during cleanout run. NOTES: 1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998). 2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".	

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-9

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-30-99 FINISHED: 9-30-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286728.3 E 4184496.1
TOTAL DEPTH: 28.8
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.2
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: A. Link
REVIEWED BY:

DEPTH	TYPE OF HOLE	% CORE RECOVERY	% MINUS #230	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0–21.0						Water	947.2
21.0–23.0	DS	0		NoRec	NoRec	Qrs	
23.0–24.7	AP					Qrs	
24.7–26.7	DS	55	0.1	(GP)s	(SW)g	Qrs	
26.7–28.1	AP					Qrs	
28.8	BOTTOM OF HOLE						939.4

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. 2-foot intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle, 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval.

SAMPLE INTERVALS
21.0-23.0' 3" DS
24.7-26.7' 3" DS
28.1-28.4' 3" DS

DRILLING CONDITIONS
0.0-21.0': Set AP through reservoir water. Top of lake bed very soft, as determined with weighted line.
21.0-28.1': Slow and smooth.
28.1-28.8': Slow and rough. Sampler rebounding with no penetration at 28.4'; augers refused at 28.8' during cleanout run.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-30	6"	28.8	28.8

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION
Retrieved AP from reservoir bottom.

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-21.0': WATER.

21.0-28.8': RESERVOIR SEDIMENTS (Qrs).

21.0-23.0': No recovery. Sample recovery limited to gravel particle 40 mm in diameter lodged behind basket catcher of sample barrel.

24.7-26.7': POORLY GRADED GRAVEL WITH SAND (GP)s. About 60% fine to coarse, hard, subangular to subrounded gravel; about 40% fine to coarse, hard, angular to rounded sand; trace of fines; maximum size, 45 mm; wet, dark gray; includes minor, fine, oxidized organic debris; heterogeneous, loose; particle composition consists of basalt, metavolcanics, and quartz with minor granitics; no reaction with HCl.
LAB TEST DATA: 69% sand, 29% gravel, 2% fines; Cu = 7.86, Cc = 1.04; SpG = 2.715; laboratory classification of sample is WELL-GRADED SAND WITH GRAVEL (SW)g.

28.1-28.4': POORLY GRADED GRAVEL WITH SAND (GP)s. About 55% fine to coarse, hard, subangular to rounded gravel; about 45% fine to coarse, hard, subangular to rounded sand; trace of fines; maximum size, 40 mm; wet, dark gray; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
CENTER COLUMN DATA: Type of Hole = DS; % Core Recovery = 67%; Visual Class = (GP)s; Lab Class = none, sample was not submitted for lab testing.

28.8': BOTTOM OF HOLE. Hole drilling very hard and rough from 28.1-28.8'; sampler rebounding with no penetration at 28.4'; augers refused at 28.8' during cleanout run.

NOTES:
1. Geologic descriptors are defined in the Engineering Geology Field Manual.

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers
DS = Drive Sample
NoRec = No recovery
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-9

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-30-99 FINISHED: 9-30-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286728.3 E 4184496.1
TOTAL DEPTH: 28.8
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.2
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES	CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)	
reversing auger rotation to move cuttings back down hole.	Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998). 2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".	

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-10

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-30-99 FINISHED: 9-30-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286592.5 E 4184704.9
TOTAL DEPTH: 27.8
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.2
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. 3-foot intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle. 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval.

SAMPLE INTERVALS
14.5-16.5' 3" DS
20.7-22.7' 3" DS
25.5-27.4' 3" DS

DRILLING CONDITIONS
0.0-14.5': Set AP through reservoir water.
14.5-25.2': Slow and smooth.
25.2-27.8': Slow and rough. Sampler rebounding with no penetration at 27.4'; augers refused at 27.8' during cleanout run.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
9-30	6"	27.8	27.8

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION
Retrieved AP from reservoir bottom, reversing auger rotation to move cuttings back down hole.

LOG

DEPTH	TYPE OF HOLE	% CORE RECOVERY	% MINUS #230	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0.0-14.5						Water	
14.5							953.7
14.5-16.5	DS	0		NoRec	NoRec		
16.5-20.7	AP						
20.7-22.7	DS	70	0.05	(SP) g	(SP) g	Qrs	
22.7-25.5	AP						
25.5-27.4	DS	53	0.05	(GP) s	(GW) s		
27.8			BOTTOM OF HOLE				940.4

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-14.5': WATER.

14.5-27.8': RESERVOIR SEDIMENTS (Qrs).

14.5-16.5': No recovery. Thin residue of fine to medium sand trapped behind basket catcher of sample barrel.

20.7-22.7': POORLY GRADED SAND WITH GRAVEL (SP)g. About 65% fine to coarse, hard, angular to rounded sand; about 35% fine to coarse, hard, angular to rounded gravel; trace of fines; maximum size, 75 mm; wet, dark gray; includes minor, fine, oxidized organic debris; heterogeneous, dense; particle composition consists of basalt, metavolcanics and quartz with minor granitics; no reaction with HCl. LAB TEST DATA: 80% sand, 19% gravel, 1% fines; Cu = 4.00, Cc = 1.00; SpG = 2.752.

25.5-27.4': POORLY GRADED GRAVEL WITH SAND (GP)s. About 65% fine to coarse, hard, subangular to rounded gravel; about 35% fine to coarse, hard, angular to rounded sand; trace of fines; maximum size, 50 mm; wet, dark gray; includes minor, fine, oxidized organic debris; heterogeneous, loose to dense; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl. LAB TEST DATA: 54% gravel, 45% sand, 1% fines; Cu = 6.85, Cc = 1.35; SpG = 2.739; laboratory classification of sample is WELL-GRADED GRAVEL WITH SAND (GW)s.

27.8': BOTTOM OF HOLE. Hole drilling very hard and rough from 25.2-27.8'; sampler rebounding with no penetration at 27.4'; augers refused at 27.8' during cleanout run.

NOTES:
1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers.
DS = Drive Sample
NoRec = No Recovery
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-10

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 9-30-99 FINISHED: 9-30-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286592.5 E 4184704.9
TOTAL DEPTH: 27.8
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.2
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)	
Reclamation, 1998). 2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".	

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-11

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 10-1-99 FINISHED: 10-1-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286337.6 E 4186806.9
TOTAL DEPTH: 22.5
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 967.8
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

DEPTH	TYPE OF HOLE	% CORE RECOVERY	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0–17.5					Water	950.3
17.5–19.7	DS *	27	(GP)s	-	Qrs	
19.7–21.0	AP					
21.0–22.5	DS	7	n/a	n/a		945.3
	BOTTOM OF HOLE					

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill.

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. 3-foot intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle, 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval. Heavy metals sampler decontaminated using de-ionized water mixed with 1.25 fluid oz. of Liqui-Nox detergent.

SAMPLE INTERVALS
17.5-19.7' 3" DS
21.0-22.5' 3" DS

DRILLING CONDITIONS
0.0-17.5': Set AP through reservoir water.
17.5-21.0': Slow and smooth.
21.0-22.5': Slow and rough. Sampler rebounding with no penetration at 22.5'; augers refused at 21.1' during cleanout run.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
10-1	6"	22.5	21.1

FLUID RETURN AND COLOR
No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION
Retrieved AP from

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-17.5': WATER.

17.5-22.5': RESERVOIR SEDIMENTS (Qrs).

17.5-19.7': POORLY GRADED GRAVEL WITH SAND (GP)s. About 85% fine to coarse, hard, subangular to rounded gravel; about 15% fine to coarse, hard, angular to rounded sand; trace of fines; maximum size, 60 mm; wet, dark gray; includes minor, fine, oxidized organic debris; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
NOTES: (1) Sampler sank 0.2' under weight of drill rods at start of sample interval; drove sampler from 17.7-19.7' with safety hammer. (2) This sample submitted for laboratory testing for heavy metals contamination.

21.0-22.5': Poor recovery. Sample composed of gravel and sand; insufficient sample mass to perform a soil classification. Recovered sample consists of about 85% fine to coarse, hard, angular to rounded sand; about 15% fine, hard, subrounded gravel; trace of fines; maximum size, 10 mm; wet, dark gray; heterogeneous, dense; no reaction with HCl.

22.5': BOTTOM OF HOLE. Hole drilling very hard and rough from 21.0-21.1'; sampler rebounding with no penetration at 22.5'; augers refused at 21.1' during cleanout run.

NOTES:
1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998).

2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers
DS = Drive Sample
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)
n/a = Not available; insufficient sample mass to perform soil classification
* = Sample submitted for heavy metals testing

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-11

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 10-1-99 FINISHED: 10-1-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286337.6 E 4186805.9
TOTAL DEPTH: 22.5
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 967.8
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES	CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)	
reservoir bottom, reversing auger rotation to move cuttings back down hole.	prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".	

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-12

FEATURE: Savage Rapids Dam
LOCATION: Reservoir
BEGUN: 10-2-99 FINISHED: 10-2-99
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:

PROJECT: Rogue River Basin
COORDINATES: N 286224 E 4185663
TOTAL DEPTH: 43.1
DEPTH TO BEDROCK:

STATE: Oregon
GROUND ELEVATION: 968.7
ANGLE FROM HORIZONTAL: 90 AZIMUTH:
HOLE LOGGED BY: R. Link
REVIEWED BY:

NOTES

PURPOSE OF HOLE
To determine the composition and volume of sediments stored behind Savage Rapids Dam.

DRILL EQUIPMENT
Ingersoll-Rand A200 skid-mounted drill. .

DRILLER
Drill Foreman Kevin Herrmann.

DRILL SETUP
Set up on Savage Rapids Reservoir using custom-built floating drilling platform equipped with pontoons and 35-hp outboard motor.

DRILLING METHODS
Drilled with 10" O.D., 6.25" I.D. hollow-stem flight augers (AP). Took drive samples on approx. 3-foot intervals starting at top of lake bed using 3" I.D. split-tube sample barrel sprayed with PAM aerosol vegetable coating and fitted with basket catcher and plastic baffle, 140-lbm safety hammer and cathead with rope. Sampler allowed to set on hole bottom for 10 minutes before retrieval (15 minutes for heavy metals samples).
Heavy metals sampler decontaminated using de-ionized water mixed with 1.25 fluid oz. of Liqui-Nox detergent prior to each interval, except from 41.1-43.1'.

SAMPLE INTERVALS
26.1-28.9' 3" DS
30.8-32.8' 3" DS
35.7-37.7' 3" DS
41.1-43.1' 3" DS

DRILLING CONDITIONS
0.0-26.1': Set AP through reservoir water.
26.1-31.0': Slow and smooth with several rough and hard areas.
31.0-36.1': Slow and hard.
36.1-41.0': Slow and smooth with minor rough areas.
41.0-43.1': Slow and rough. Augers refused at 42.7' during cleanout run.

CASING RECORD

1999 Date	AP Sz	Depth Hole	Depth AP
10-2	6"	43.1	42.7

FLUID RETURN AND COLOR

LOG

DEPTH	TYPE OF HOLE	% CORE RECOVERY	% MINUS #230	VISUAL CLASS	LAB CLASS	FLD CLASS/LITH	ELEVATION
0.0-26.1						Water	942.6
26.1-28.9	DS *	36	0.05	(SP) g	(SP) g	Qrs	
	AP.						
30.8-32.8	DS	45	0.06	SP	(SP) g		
	AP						
35.7-37.7	DS *	55	0.2	(SP) g	(SW) g		
	AP						
41.1-43.1	DS *	50	0.2	(SP) g	(SW) g		925.6
	BOTTOM OF HOLE						

CLASSIFICATION AND PHYSICAL CONDITION

The measuring point for this drill hole was the reservoir water surface; all depths reported on this log correspond to the same measurements reported by the driller.

0.0-26.1': WATER.

26.1-43.1': RESERVOIR SEDIMENTS (Qrs).

26.1-28.9': POORLY GRADED SAND WITH GRAVEL (SP)g. About 85% fine to coarse, hard, angular to rounded sand; about 15% predominantly fine, hard, subangular to rounded gravel; trace of fines; maximum size, 30 mm; wet, dark gray; includes several fragments of mostly weathered and discolored to partially oxidized wood measuring up to 110 by 40 by 70 mm in size; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 69% sand, 30% gravel, 1% fines; Cu = 4.47, 0.61; SpG = 2.700.
NOTES: (1) Sampler sank 0.8' under weight of drill rods at start of sample interval; drove sampler from 26.9-28.9' with safety hammer. (2) This sample submitted for laboratory testing for heavy metals contamination.

30.8-32.8': POORLY GRADED SAND (SP)g. About 90% fine to coarse, hard, angular to rounded sand; about 10% fine to coarse, hard, subangular to rounded gravel; trace of fines; maximum size, 55 mm; wet, dark gray; includes minor, fine, oxidized organic debris; heterogeneous, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 78% sand, 21% gravel, 1% fines; Cu = 4.47, Cc = 0.94; SpG = 2.709.

35.7-37.7': POORLY GRADED SAND WITH GRAVEL (SP)g. About 85% fine to coarse, hard, angular to rounded sand; about 15% fine, hard, subangular to rounded gravel; trace of fines; maximum size, 15 mm; wet, dark gray; includes minor, fine, oxidized organic debris; stratified, top 0.3' of sample consists of fine to medium sand with about 35%

COMMENTS:

AP = 10" O.D., 6.25" I.D. hollow-stem flight augers
DS = Drive Sample
Cs = Casing
Sz = Size of Casing
I.D. = Inside Diameter
O.D. = Outside Diameter
Cu = Coefficient of Uniformity
Cc = Coefficient of Curvature
SpG = Specific Gravity (minus #4 fraction)
* = Sample submitted for heavy metals testing

GEOLOGIC LOG OF DRILL HOLE NO. AP-99-12

FEATURE: Savage Rapids Dam	PROJECT: Rogue River Basin	STATE: Oregon
LOCATION: Reservoir	COORDINATES: N 286224 E 4185663	GROUND ELEVATION: 968.7
BEGUN: 10-2-99 FINISHED: 10-2-99	TOTAL DEPTH: 43.1	ANGLE FROM HORIZONTAL: 90 AZIMUTH:
DEPTH AND ELEV. OF WATER LEVEL AND DATE MEASURED:	DEPTH TO BEDROCK:	HOLE LOGGED BY: R. Link
		REVIEWED BY:

NOTES

No fluid used.

WATER LEVEL DURING DRILLING
Water level stayed at reservoir surface, i.e., 0.0'.

HOLE COMPLETION
Retrieved AP from reservoir bottom, reversing auger rotation to move cuttings back down hole.

CLASSIFICATION AND PHYSICAL CONDITION (CONTINUED)

nonplastic fines with rapid dilatancy and weak reaction with HCl, loose; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 69% sand, 28% gravel, 3% fines; Cu = 13.81, Cc = 1.10; SpG = 2.727; laboratory classification of sample is WELL-GRADED SAND WITH GRAVEL (SW)g.
NOTE: This sample submitted for laboratory testing for heavy metals contamination; heavy metals sample taken from top 0.3' of interval.

41.1-43.1': POORLY GRADED SAND WITH GRAVEL (SP)g. About 60% fine to coarse, hard, subangular to rounded sand; about 30% fine to coarse, hard, angular to rounded gravel; about 5% nonplastic fines with rapid dilatancy; maximum size, 70 mm; wet, dark gray; stratified, noted crude layering in sample with gravel fraction concentrated in bottom 0.4' of sample, dense; particle composition consists of basalt, metavolcanics and quartz; no reaction with HCl.
LAB TEST DATA: 72% sand, 25% gravel, 3% fines; Cu = 7.25, Cc = 1.24; SpG = 2.749; laboratory classification of sample is WELL-GRADED SAND WITH GRAVEL (SW)g.
NOTE: This sample submitted for laboratory testing for heavy metals contamination; sample barrel was not decontaminated prior to interval, but hole attained refusal prior to next scheduled heavy metals sample interval.

43.1': BOTTOM OF HOLE. Hole drilling very hard and rough from 41.1-42.7'; augers refused at 42.7' during cleanout run.

NOTES:

1. Geologic descriptors are defined in the Engineering Geology Field Manual, Second Edition, Volume 1 (U.S. Bureau of Reclamation, 1998).

2. Samples were logged in the field using Designation USBR 5005-86, "Procedure for Determining Unified Soil Classification (Visual Method)"; laboratory classifications have been prepared using Designation USBR 5000-86, "Procedure for Determining Unified Soil Classification (Laboratory Method)".

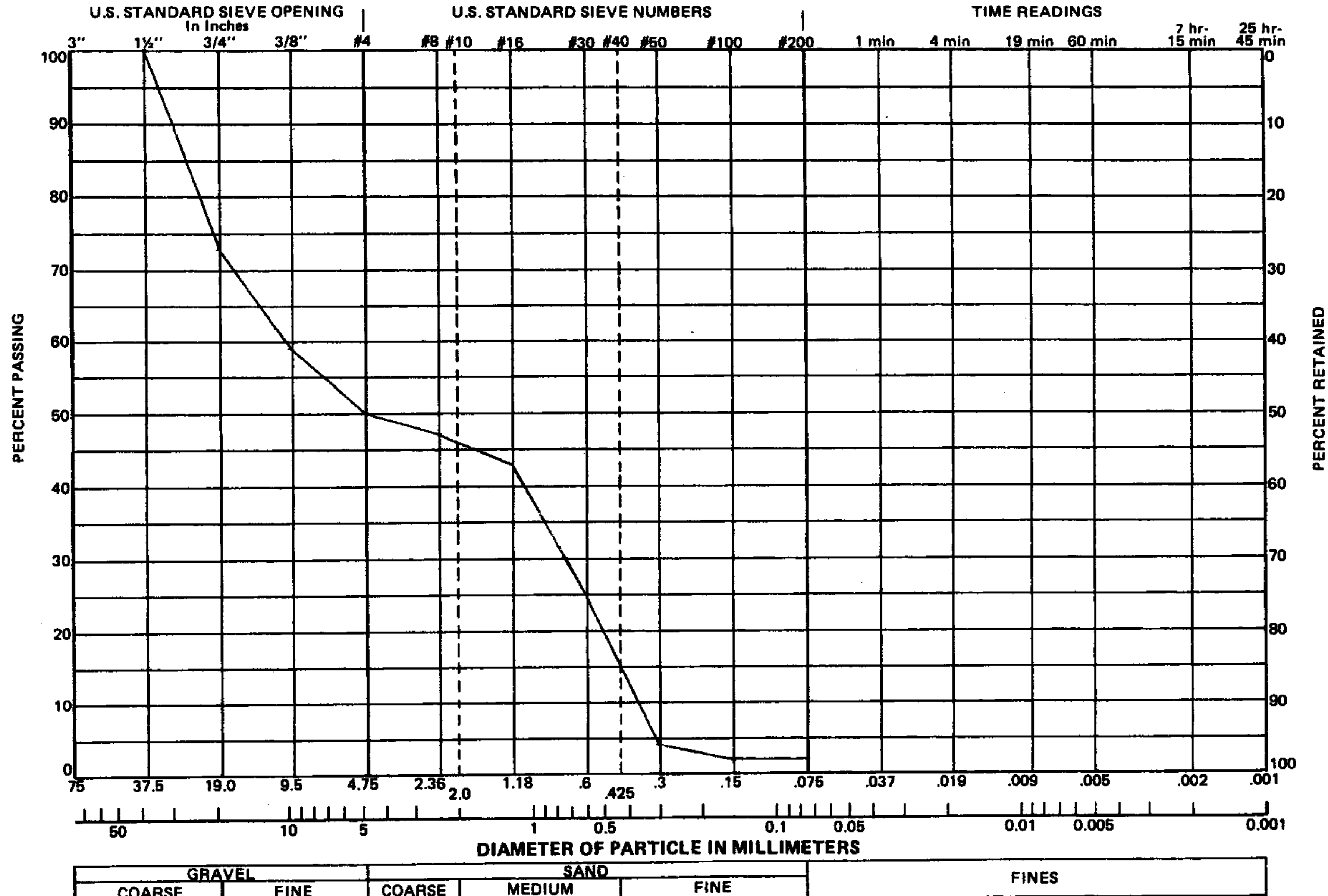
Attachment C

LABORATORY TEST DATA

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __



PREPARED BY ________

CHECKED BY ________

FIGURE ________

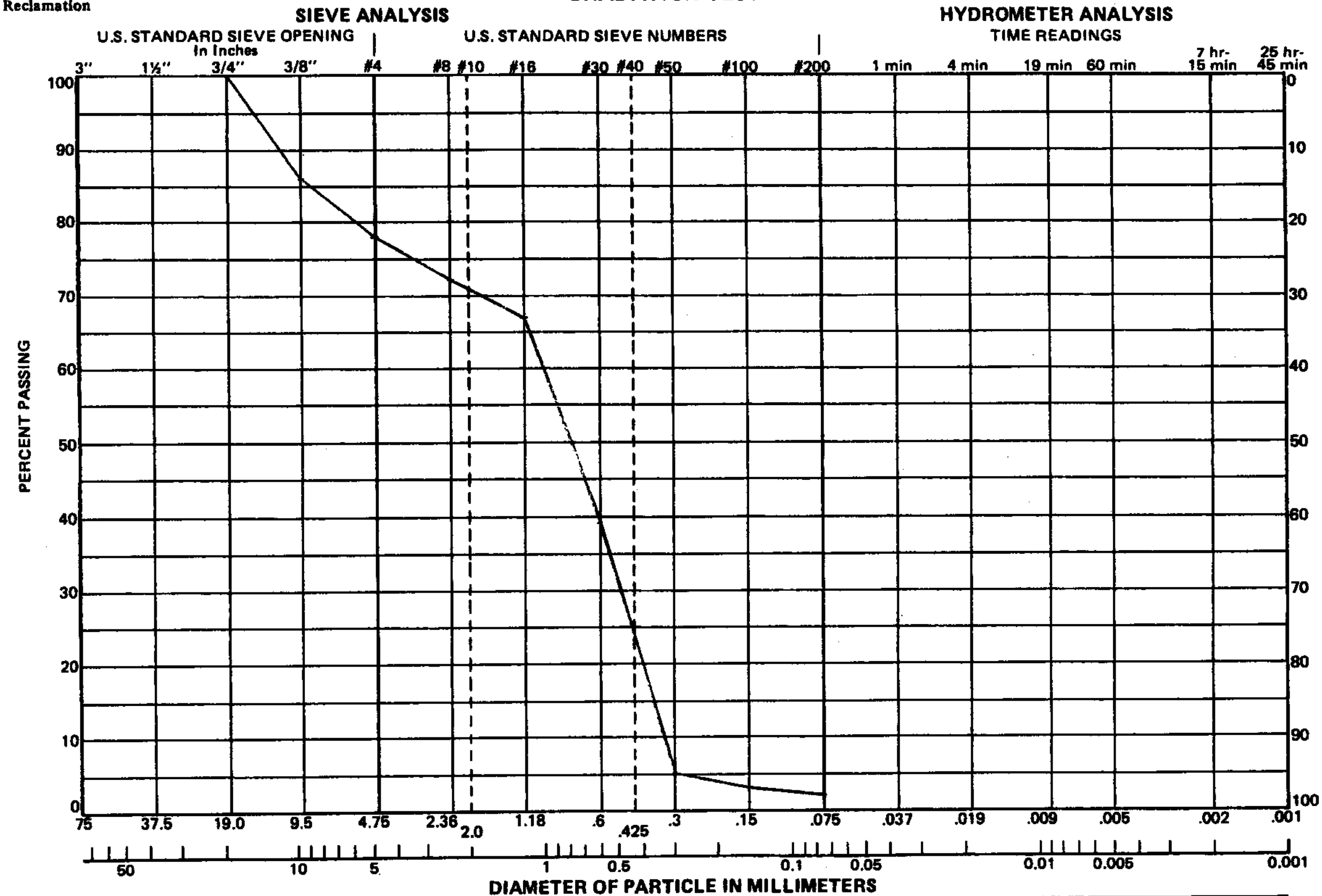
SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	AP-94-2	25.0-27.6	(GP)s	50	48	2				2.703		

GPO 852-232

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER
	AP-99-3	26.8-28.8	SP	22	76	2				2.703	

NOTES: ____________

PREPARED BY ____________

CHECKED BY ____________

FIGURE ____________

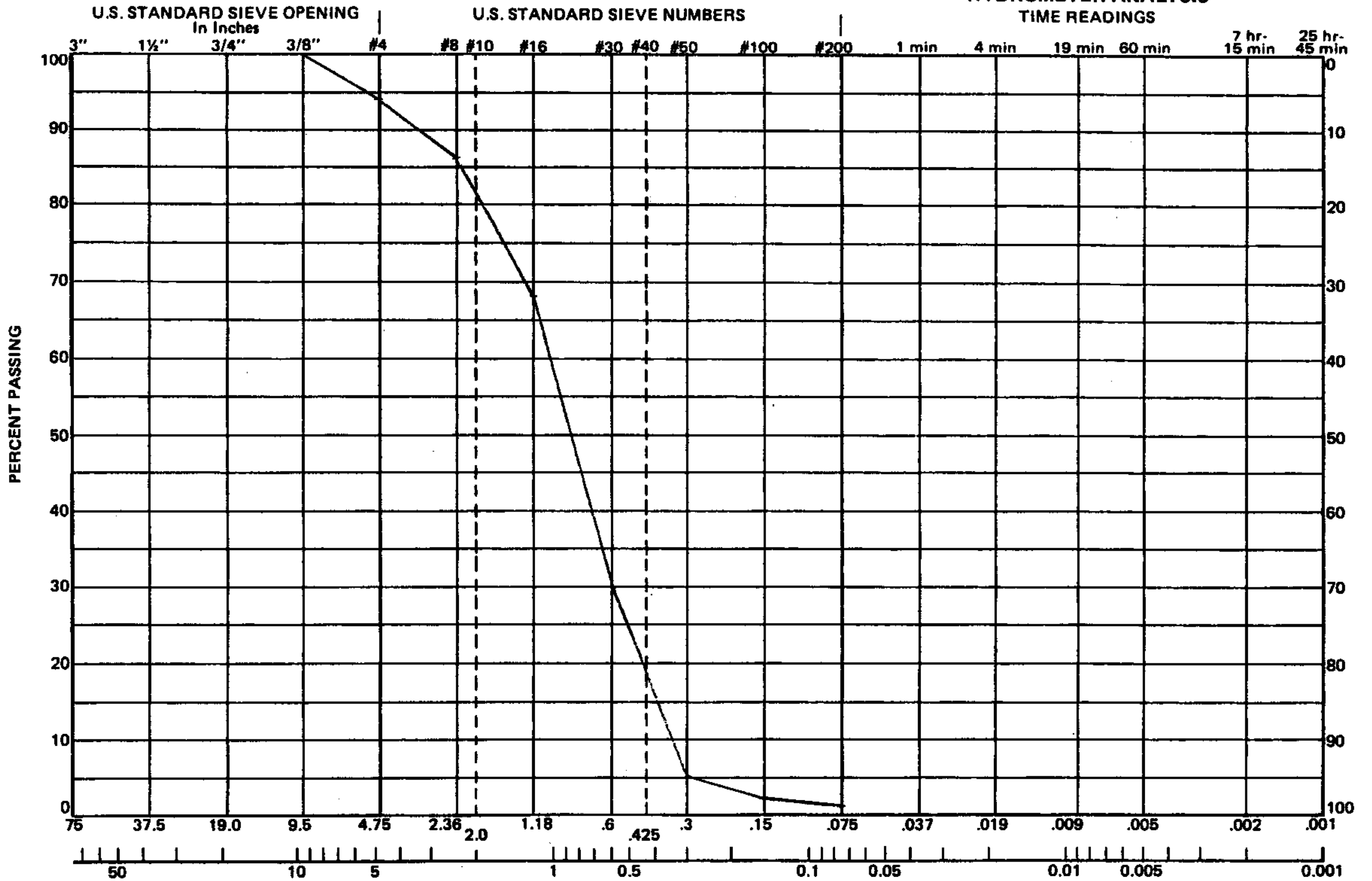
GPO 8..-232

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __

SIEVE ANALYSIS | HYDROMETER ANALYSIS



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	NV-92-3	30.2-32.2	SP	6	93	1				[illegible]		

PREPARED BY ____________

CHECKED BY ____________

FIGURE ____________

7-1415 (10-86)
Bureau of Reclamation

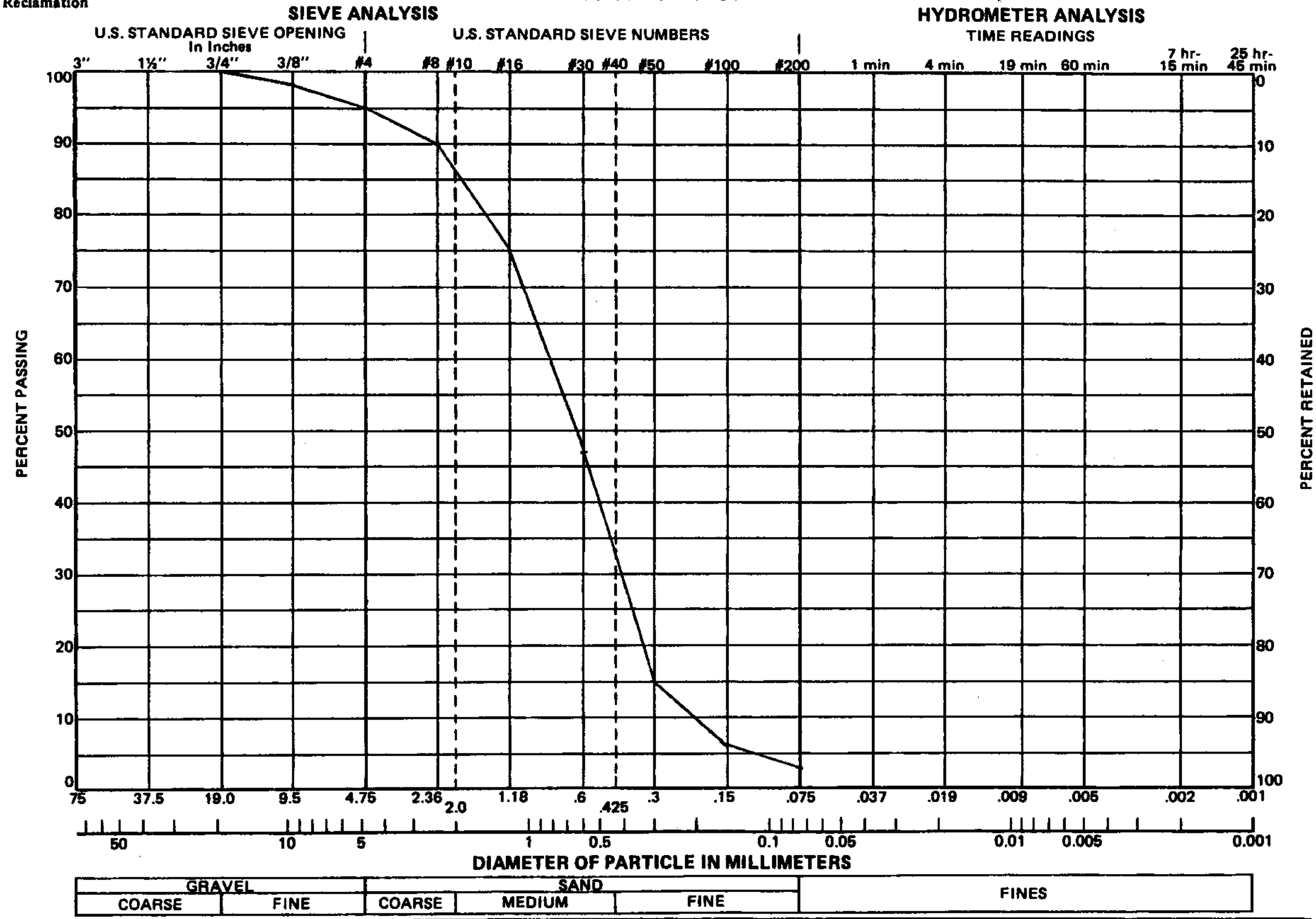
GRADATION TEST

Designation USBR ________ __ __

PREPARED BY ________

CHECKED BY ________

FIGURE ________



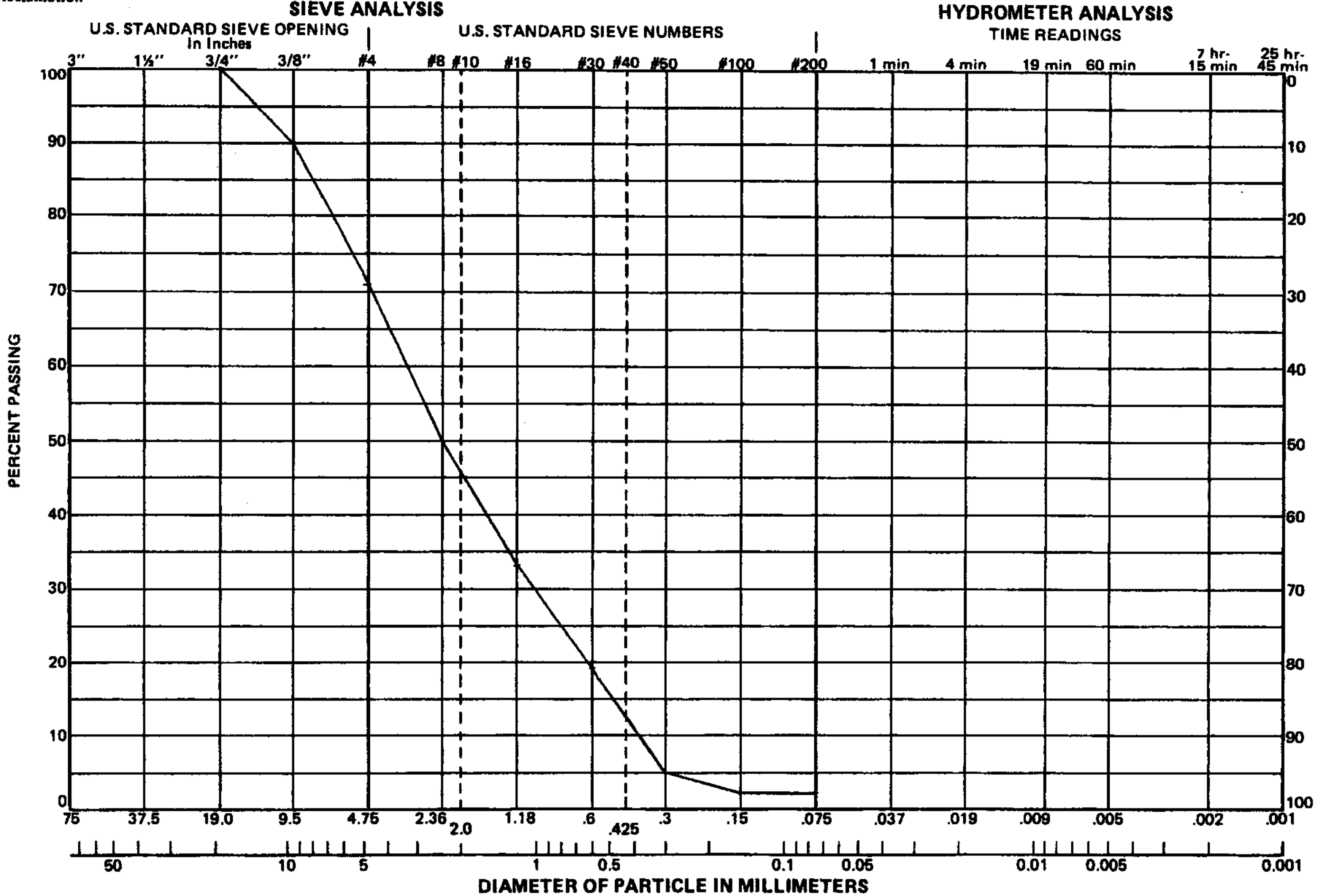
SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION				ATTERBERG LIMITS			SPECIFIC GRAVITY		NOTES:
			GROUP SYMBOL	% GRAVEL	% SAND	% FINES	LL (%)	PI (%)	SL (%)	MINUS NO. 4	OTHER	
	AP-99-2	32.5-34.5	SP	5	92	3				2.723		

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __

PREPARED BY ________ CHECKED BY ________ FIGURE ________



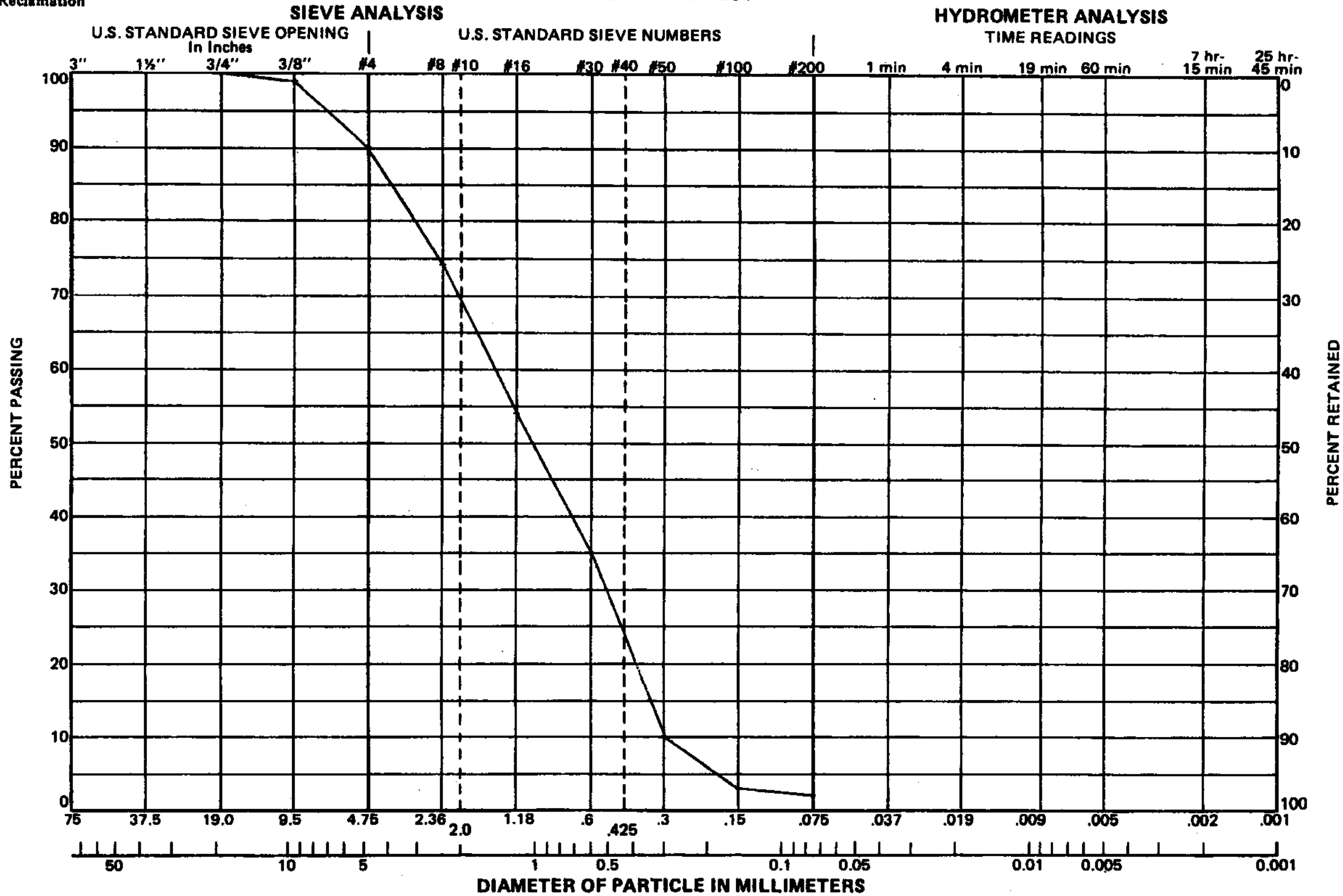
GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-3	35.3-37.3	(SP)g	29	69	2				2.750		

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	AP-99-3	37.8-39.8	SP	10	88	2				2.940		

PREPARED BY ________

CHECKED BY ________

FIGURE ________

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Bureau of Reclamation

GRADATION TEST

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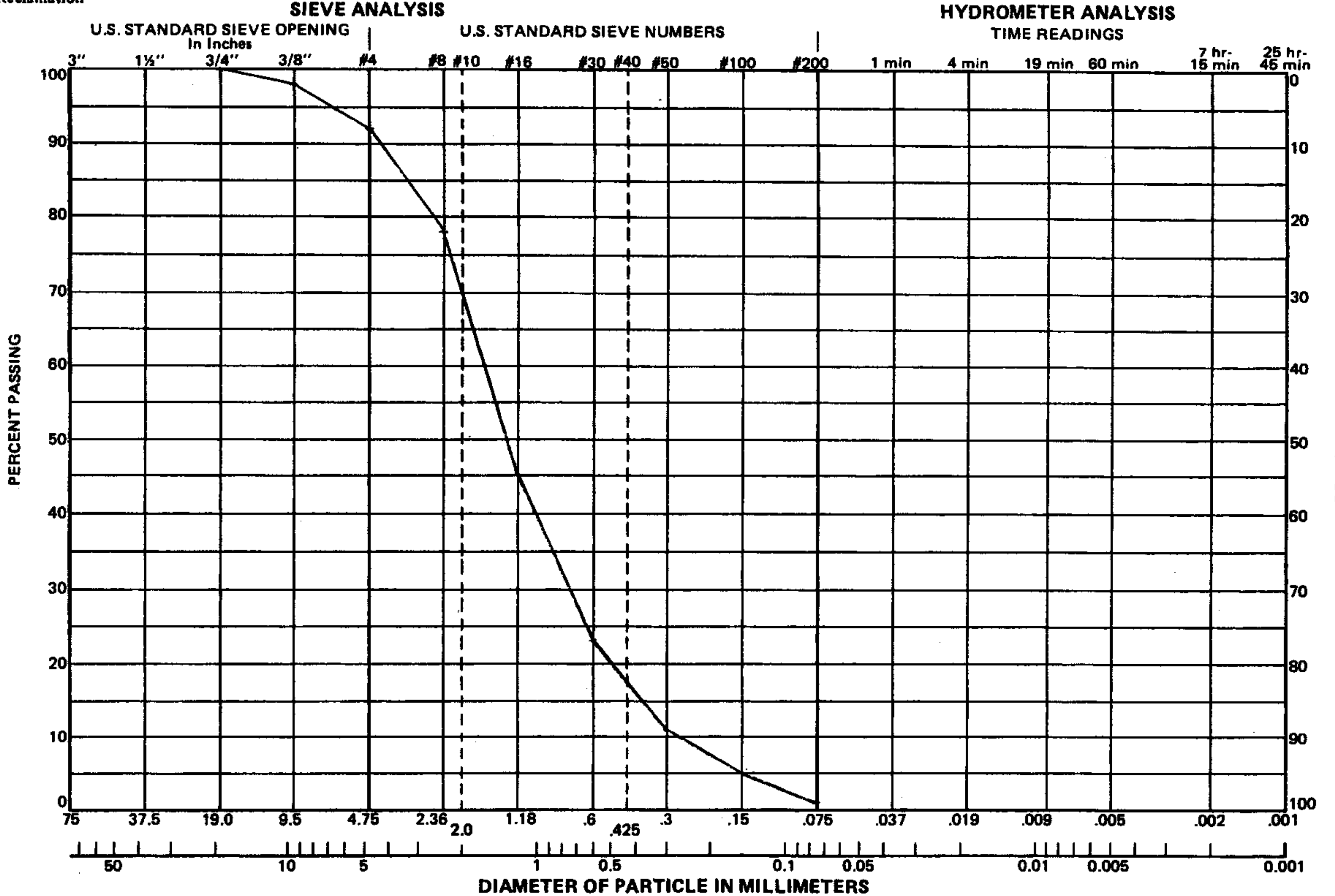

GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

PREPARED BY ________

CHECKED BY ________

FIGURE ________

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-3	41.7-43.7	SP	8	91	1				2.738		

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7-1415 (10-86)
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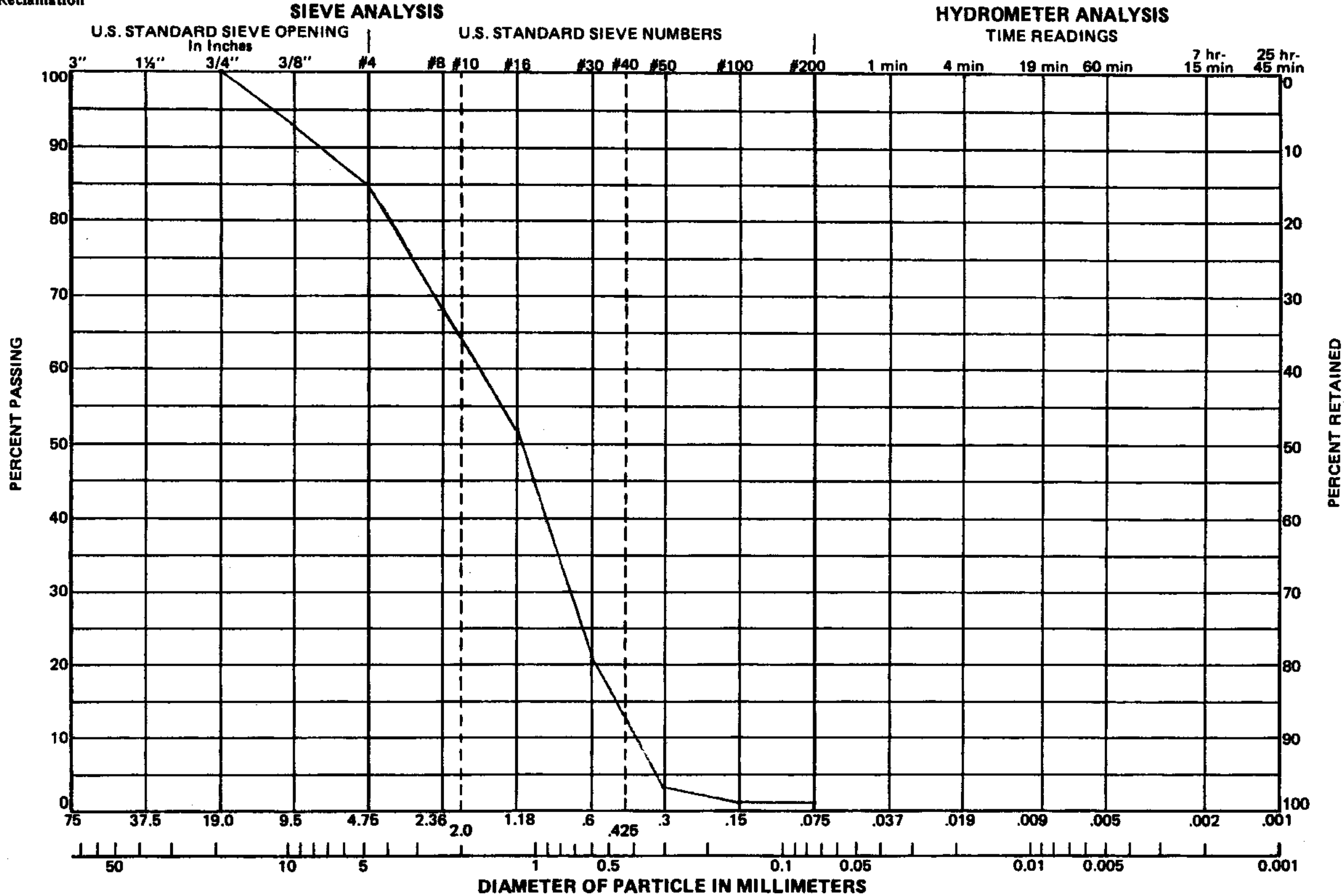
GRADATION TEST

Designation USBR ________ __ __



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	AP-99-5	26.6-28.6	(SP)a	15	84	1				2.645		

PREPARED BY ________
CHECKED BY ________
FIGURE ________

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7-1415 (10-86)
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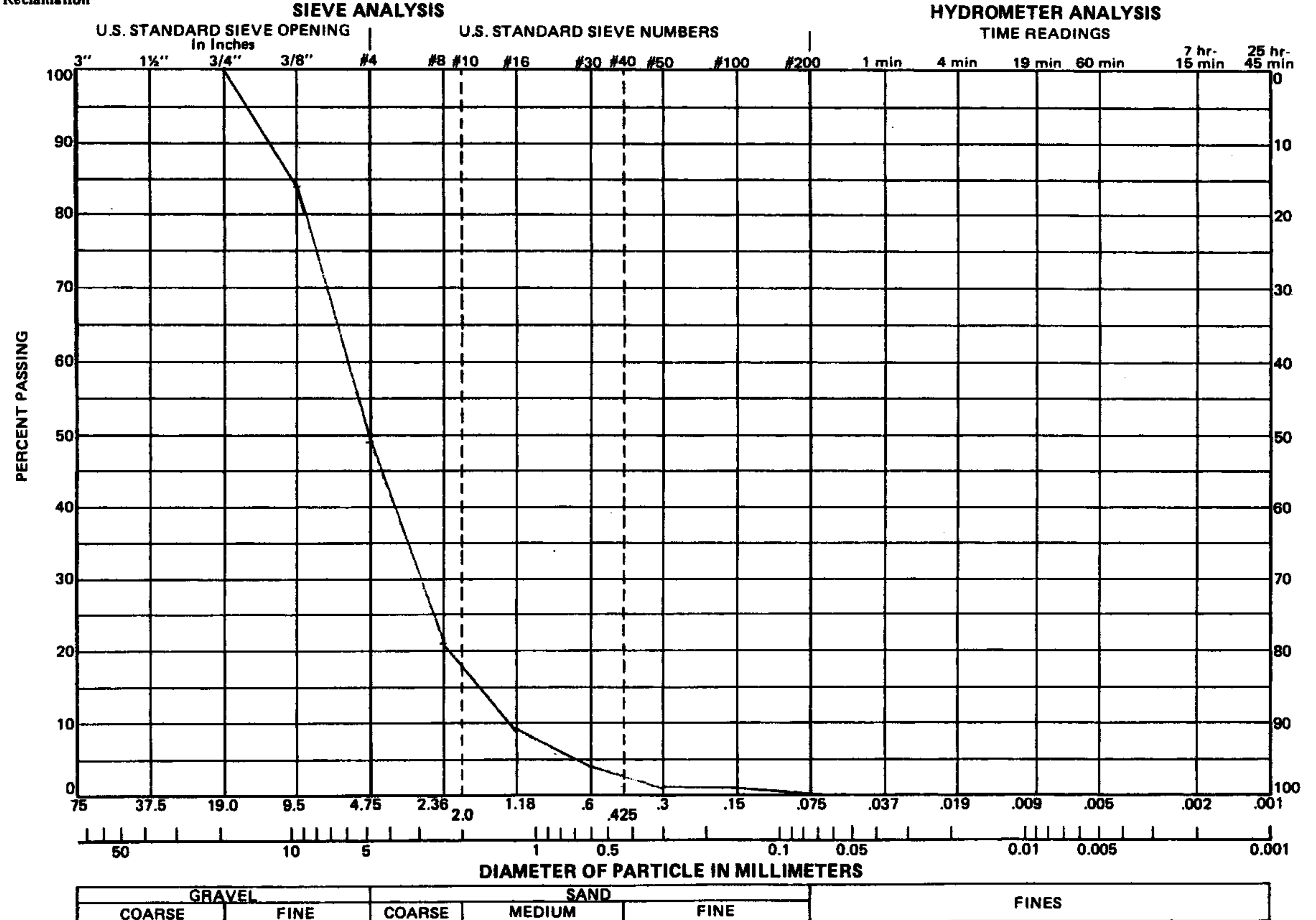
GRADATION TEST

Designation USBR ________ __ __

PREPARED BY ________

CHECKED BY ________

FIGURE ________



SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-5	31.4-33.4	[illegible]	51	49	0				2.742		

GPO 852-232

7-1415 (10-86)
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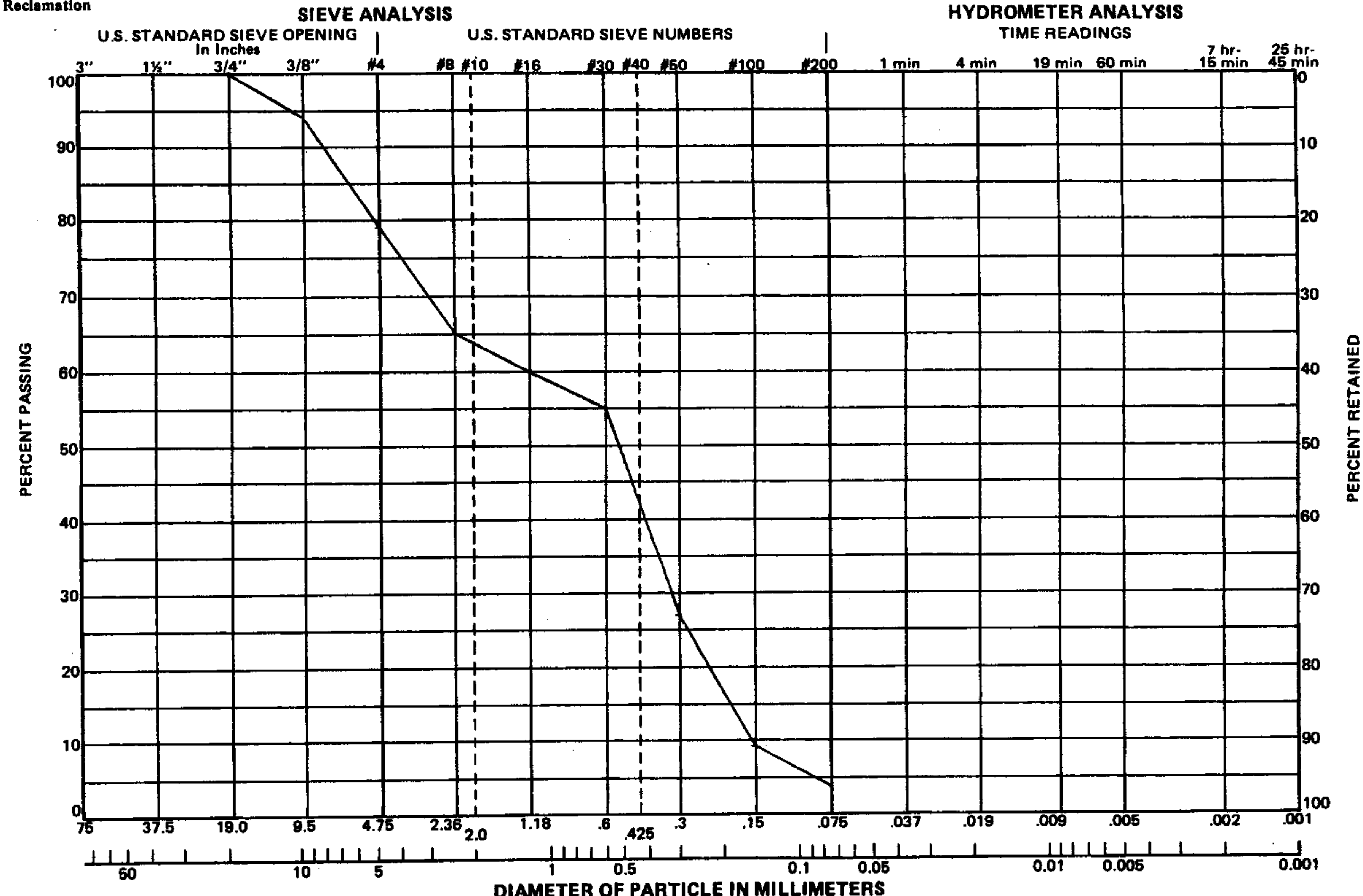
GRADATION TEST

Designation USBR ________ — —

PREPARED BY ________

CHECKED BY ________

FIGURE ________



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99.5	35.8-37.8	[illegible]	21	75	4				2.727		

GPO 852-232

7-1415 (10-86)
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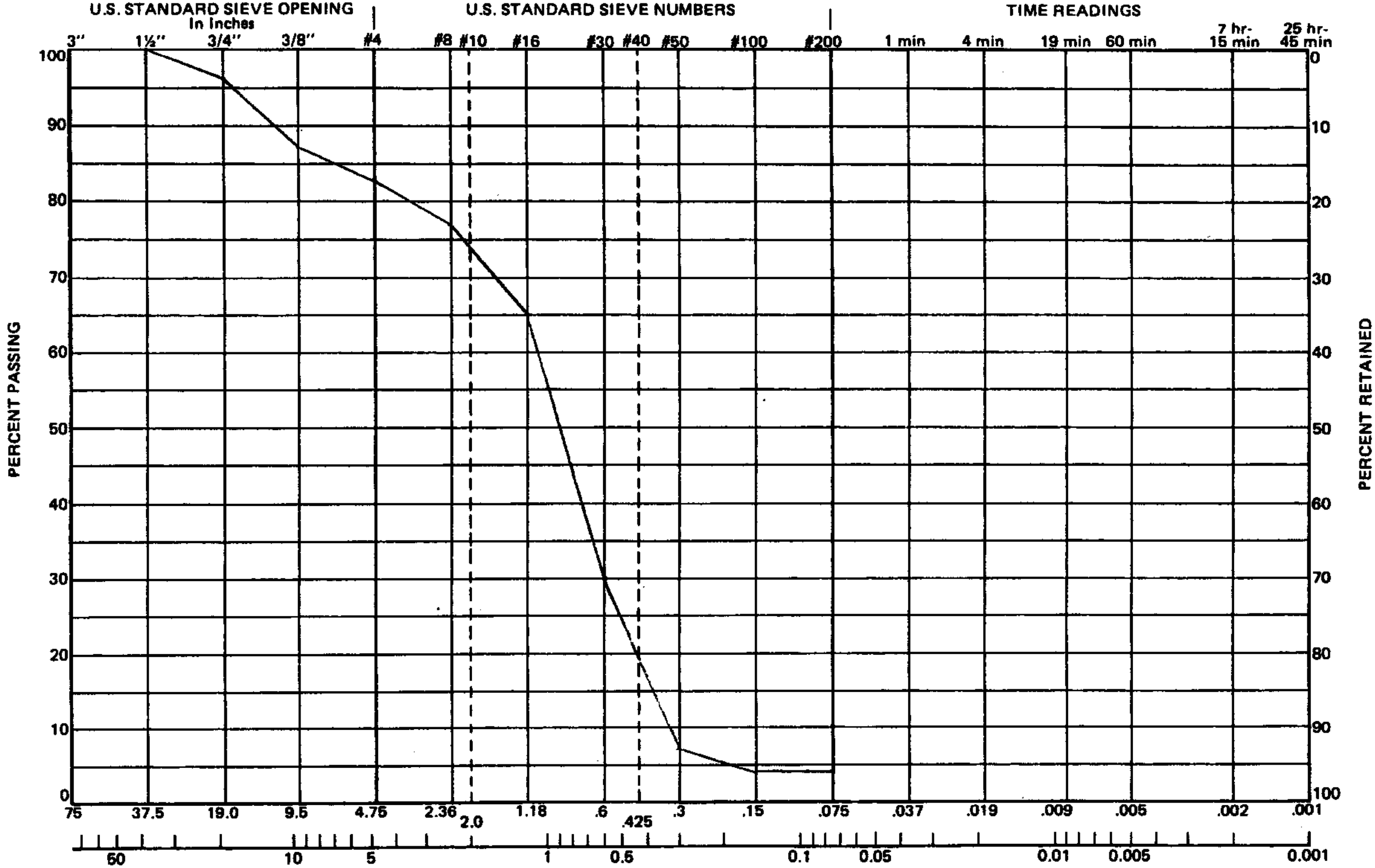
GRADATION TEST

Designation USBR ______

PREPARED BY ______ CHECKED BY ______ FIGURE ______

SIEVE ANALYSIS / HYDROMETER ANALYSIS



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	AP-99-6	21.7-23.7	SP	17	79	4				2.666		

GPO 852-232

7-1415 (10-86)
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GRADATION TEST

Designation USBR ________ __ __

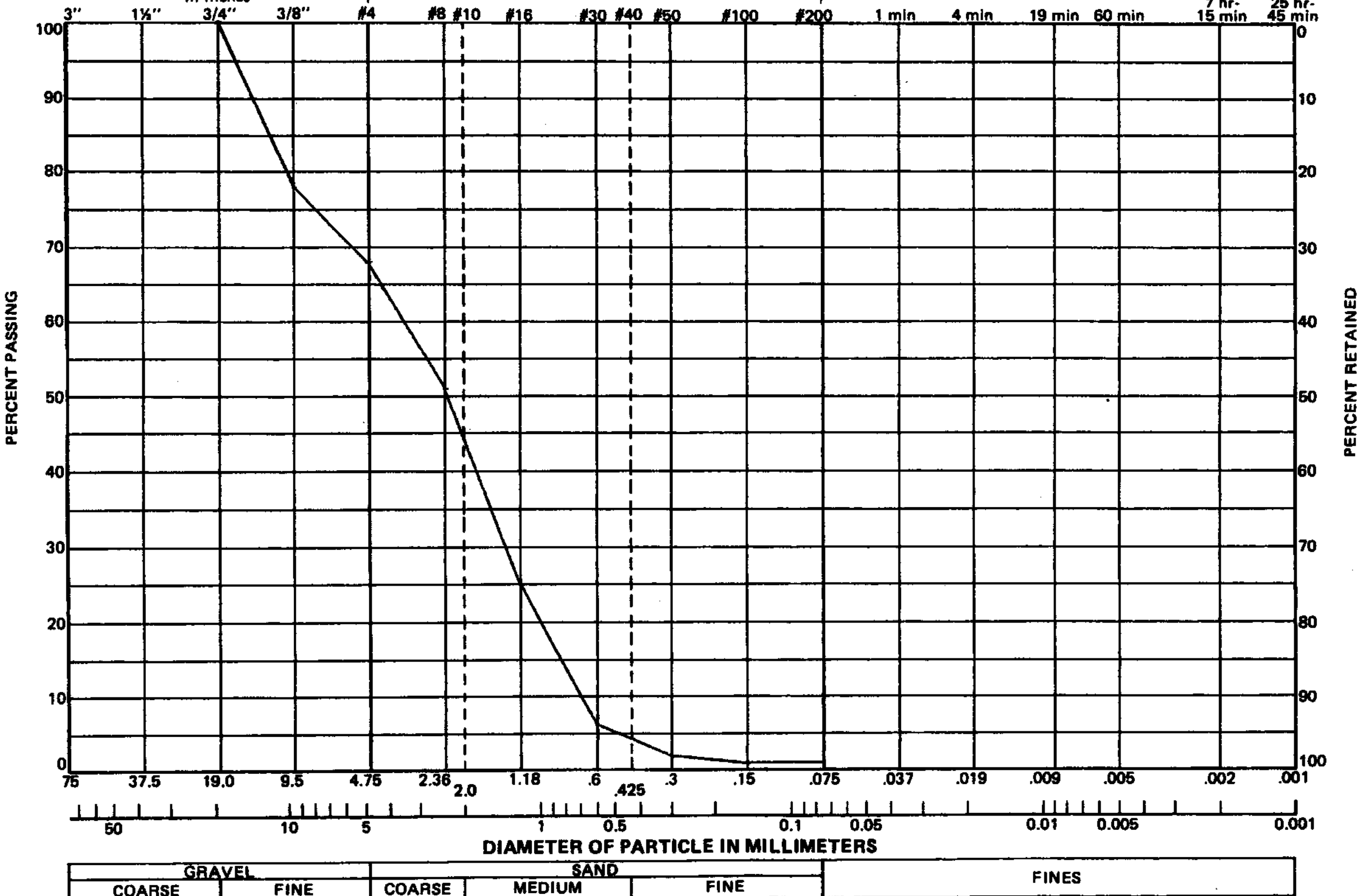
PREPARED BY ________

CHECKED BY ________

FIGURE ________

SIEVE ANALYSIS

HYDROMETER ANALYSIS



SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-6	25.9-27.9	(SP)g	32	67	1				2.884		

GPO ... 132

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __

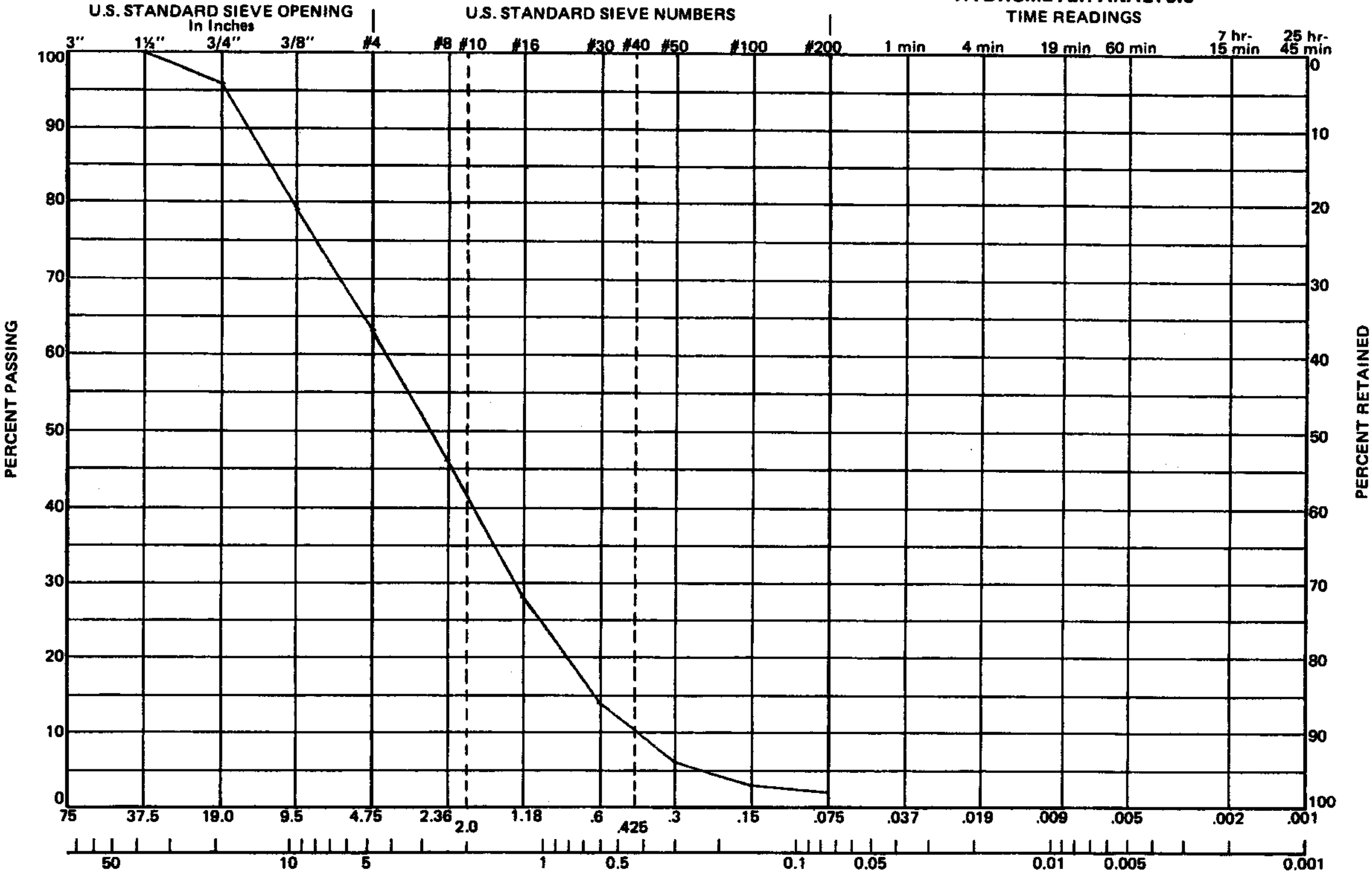
PREPARED BY ________

CHECKED BY ________

FIGURE ________

SIEVE ANALYSIS

HYDROMETER ANALYSIS



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-6	31.1-33.1	(SP)	37	61	2				2.754		

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7-1415 (10-86)
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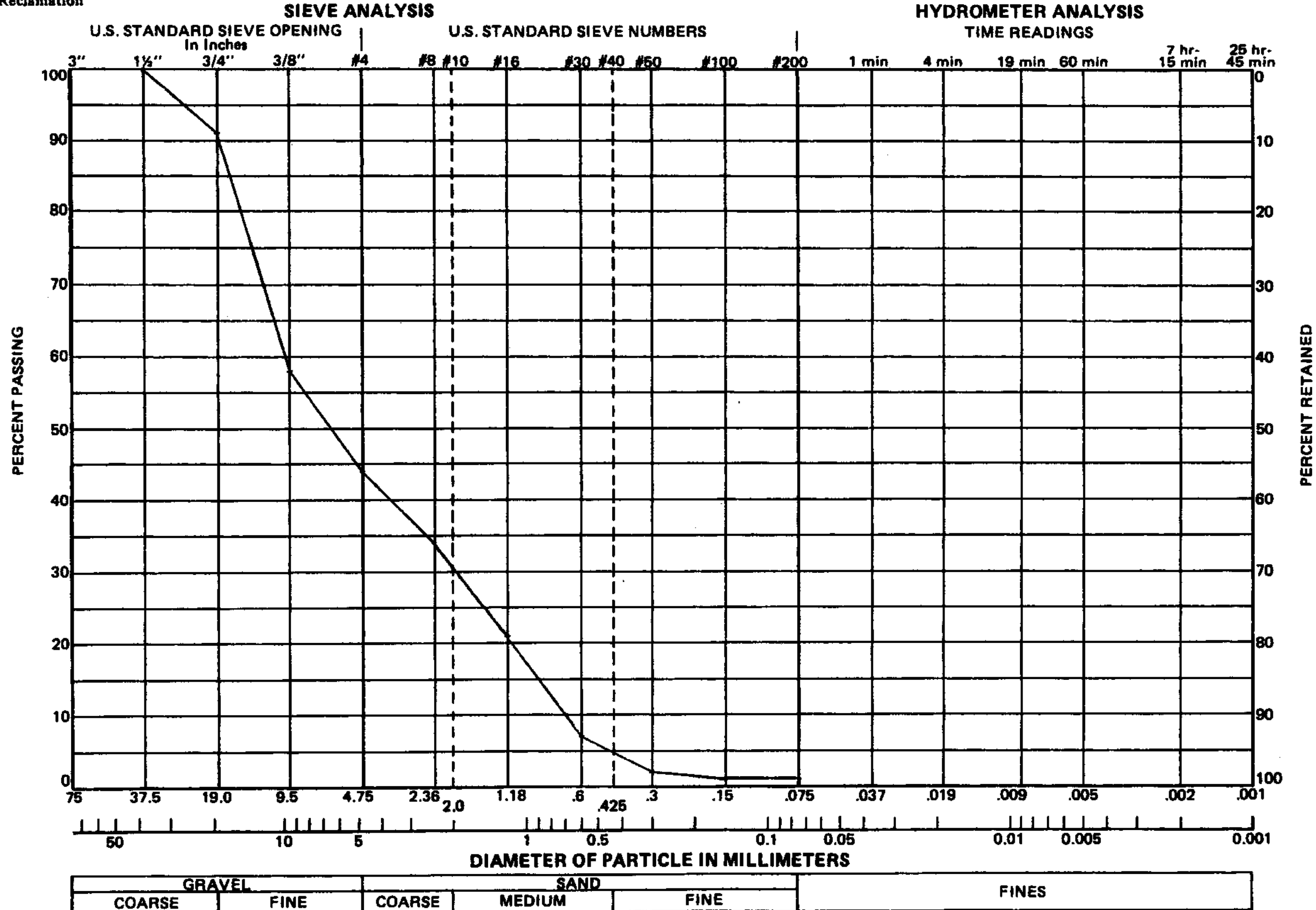
GRADATION TEST

Designation USBR ________ __ __

PREPARED BY ________ CHECKED BY ________ FIGURE ________



SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-7	18.3-20.8	[illegible]	56	43	1				2.714		

GPO

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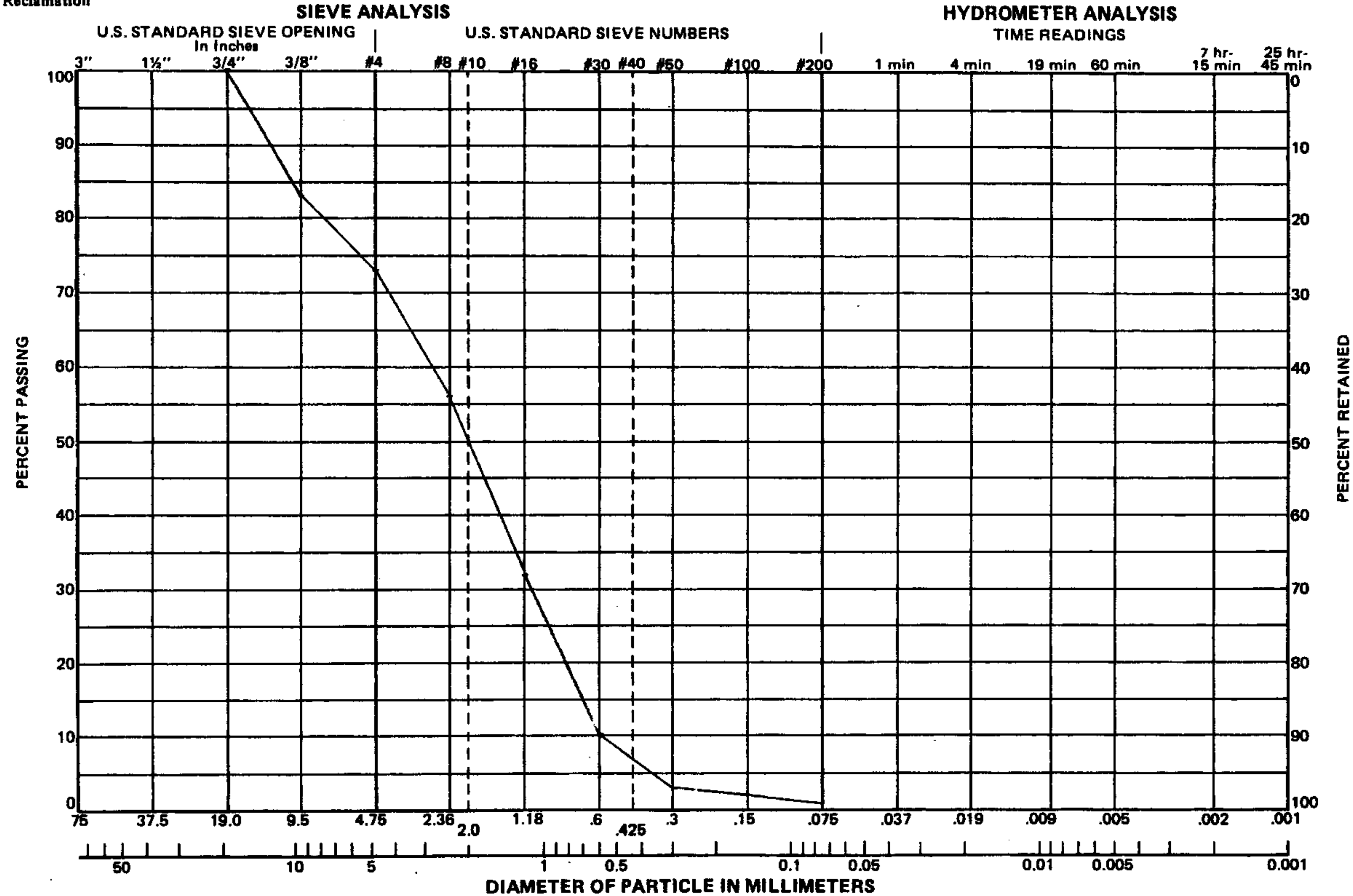
GRADATION TEST

Designation USBR ________ __ __



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

PREPARED BY ________

CHECKED BY ________

FIGURE ________

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-7	22.6-24.6	(SP)	27	72	1				2.718		

GPO 852-232

7-1415 (10-86)
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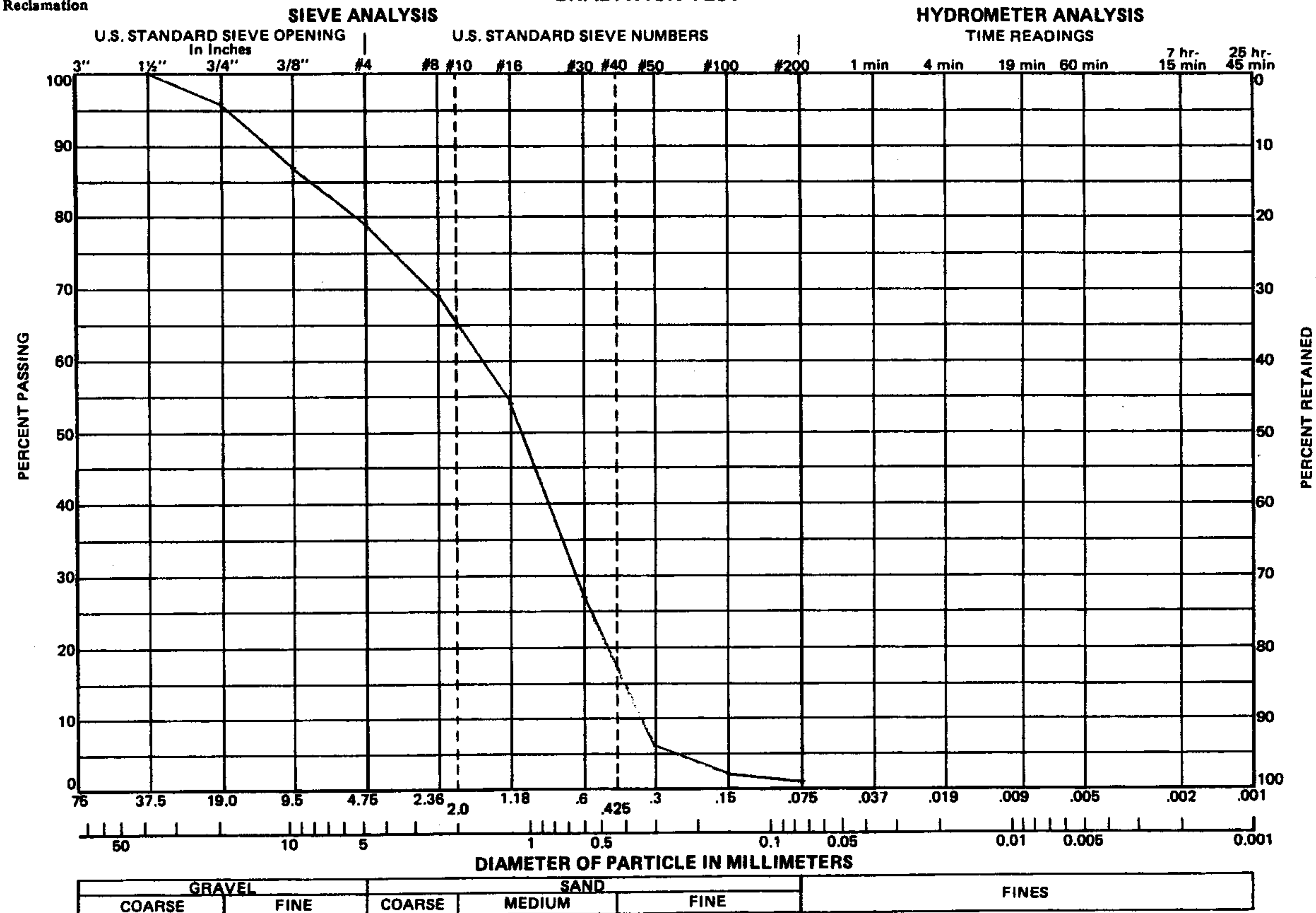
GRADATION TEST

Designation USBR ________ __ __



PREPARED BY ________

CHECKED BY ________

FIGURE ________

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	AV-99-S	22.0-24.0	[illegible]	[illegible]	78	1				2.400		

GPO ... 32

7-1415 (10-86)
Bureau of Reclamation

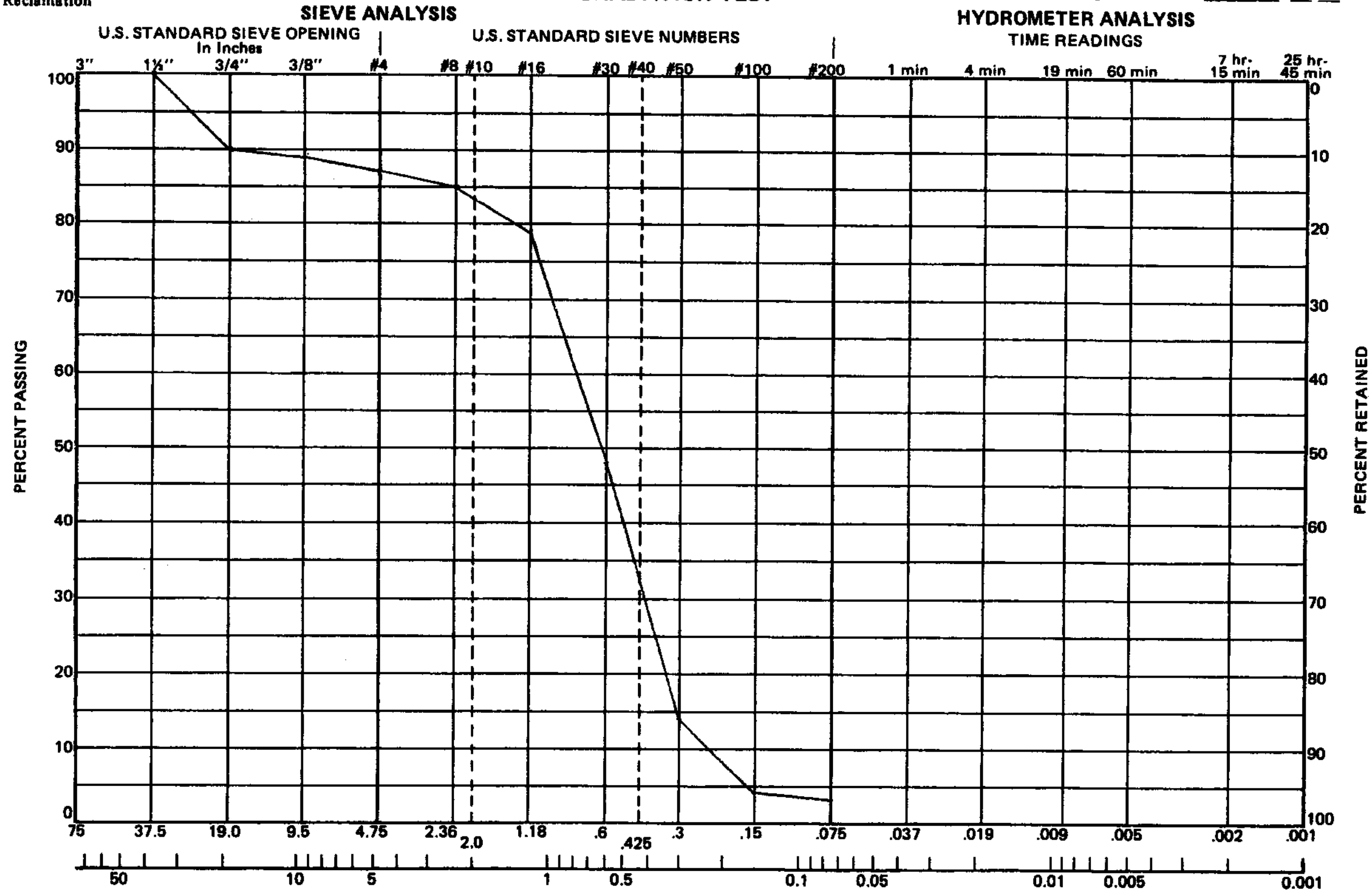
GRADATION TEST

Designation USBR ________ __ __

PREPARED BY ________

CHECKED BY ________

FIGURE ________



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

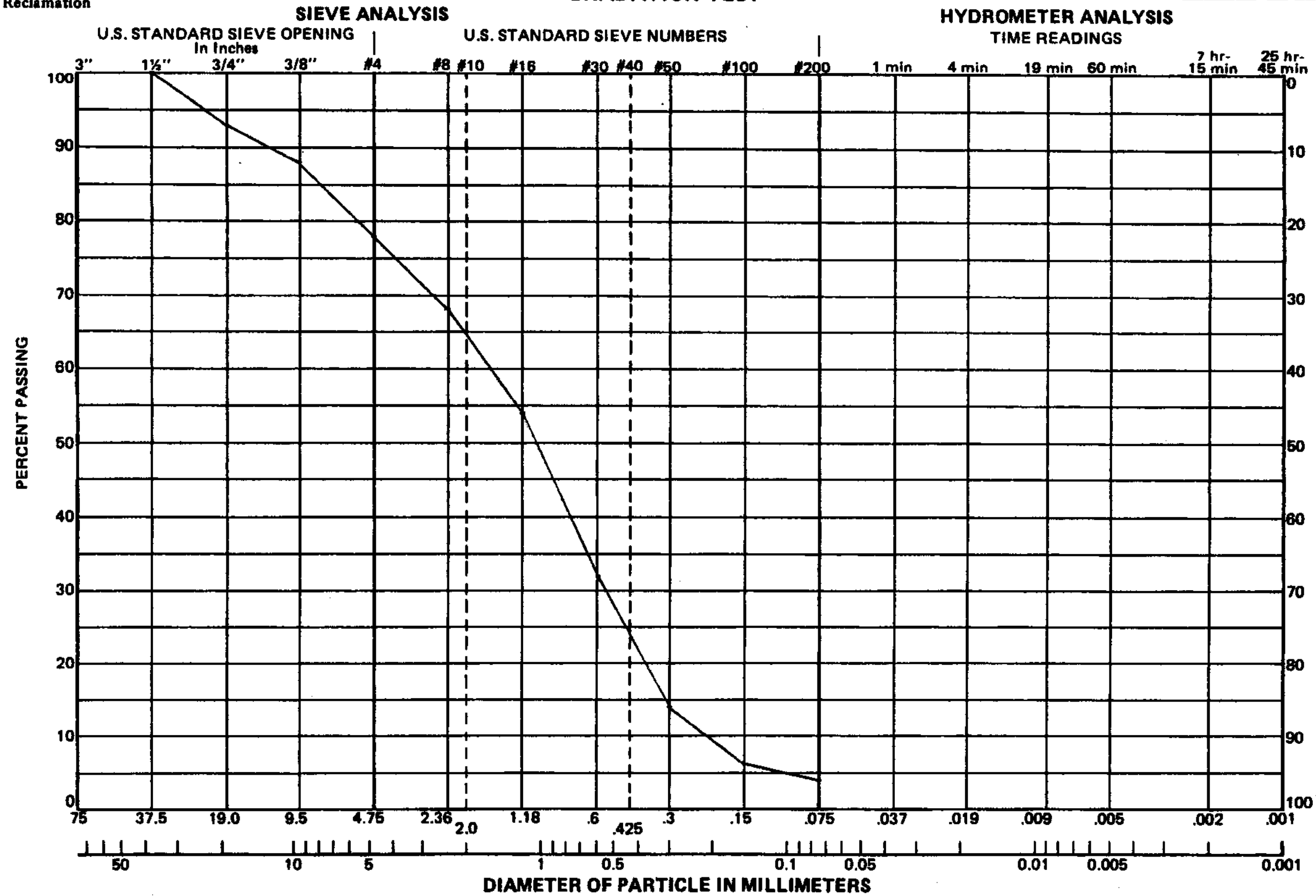
SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	AP-99-8	25.9-27.9	[illegible]	13	84	3				2.685		

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __

PREPARED BY ________ CHECKED BY ________ FIGURE ________



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-8	29.9-31.6	(SP)g	22	74	4				2.739		

GPO 852-232

7-1415 (10-86)
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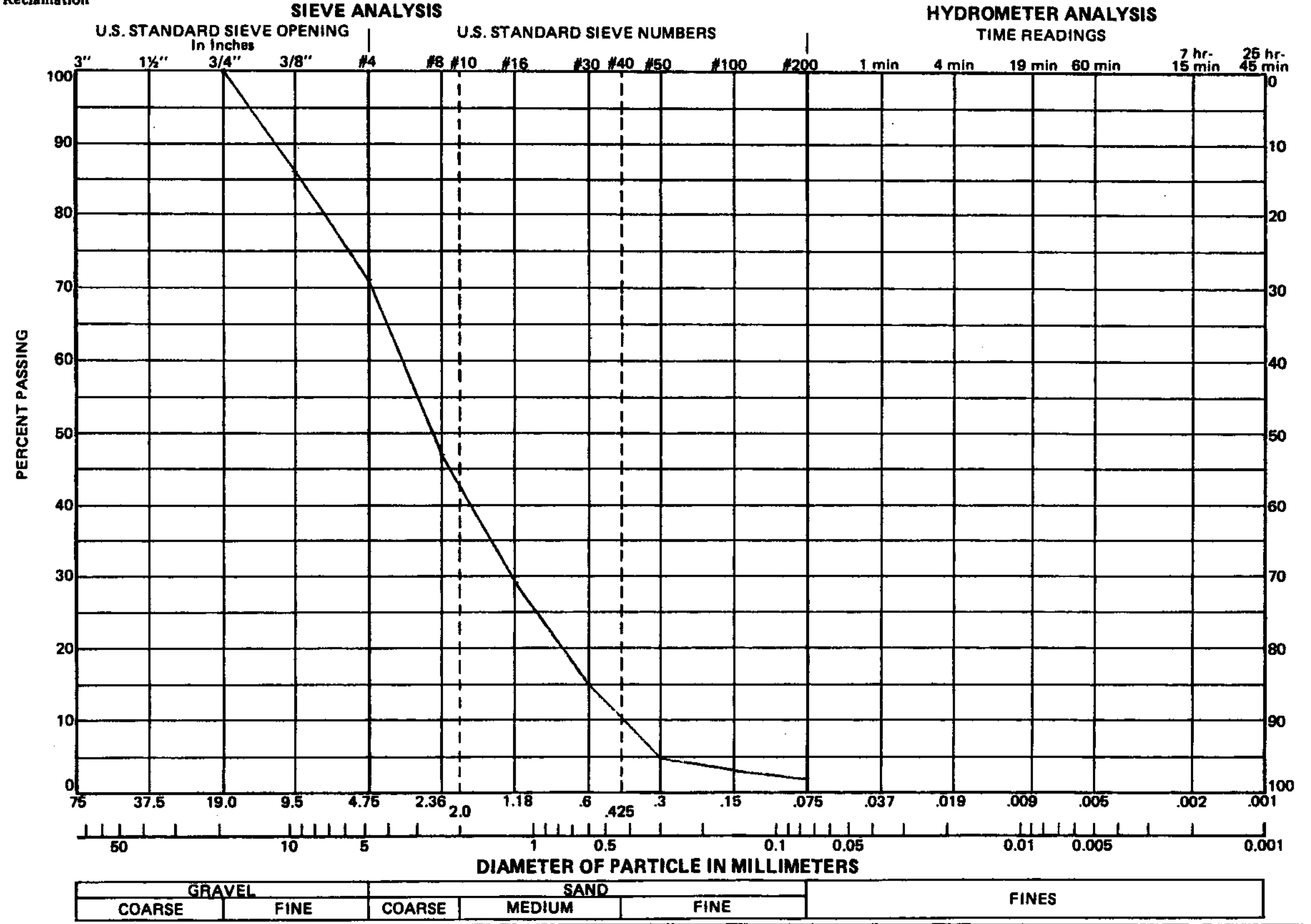
GRADATION TEST

Designation USBR ________ __ __



SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-9	24.7-26.7	(SW)g	29	69	2				2.715		

PREPARED BY ________

CHECKED BY ________

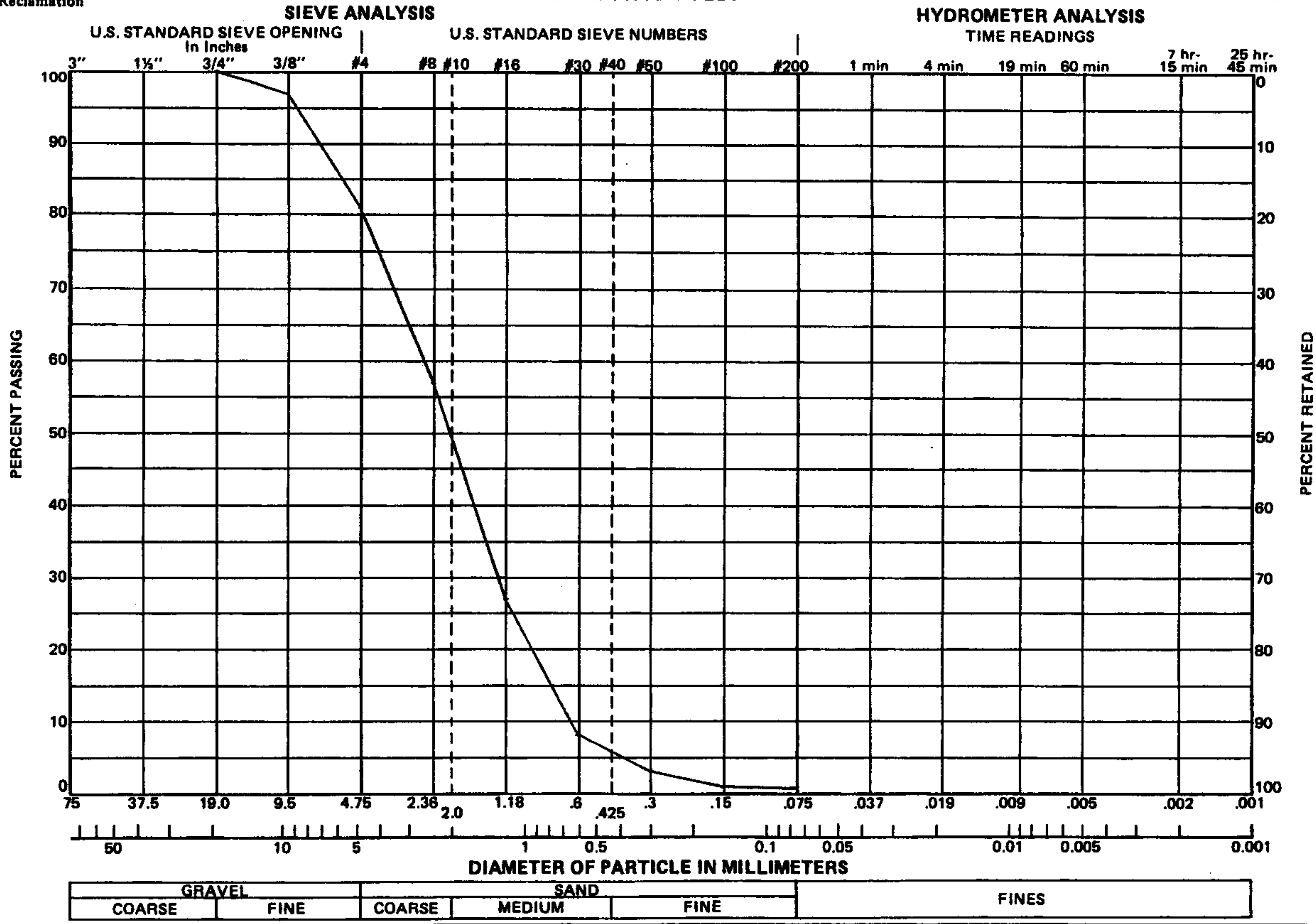
FIGURE ________

GPO 852-232

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __



SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	AP-99-10	20.7-22.7	(SP)g	19	80	1				2.752		

PREPARED BY ________

CHECKED BY ________

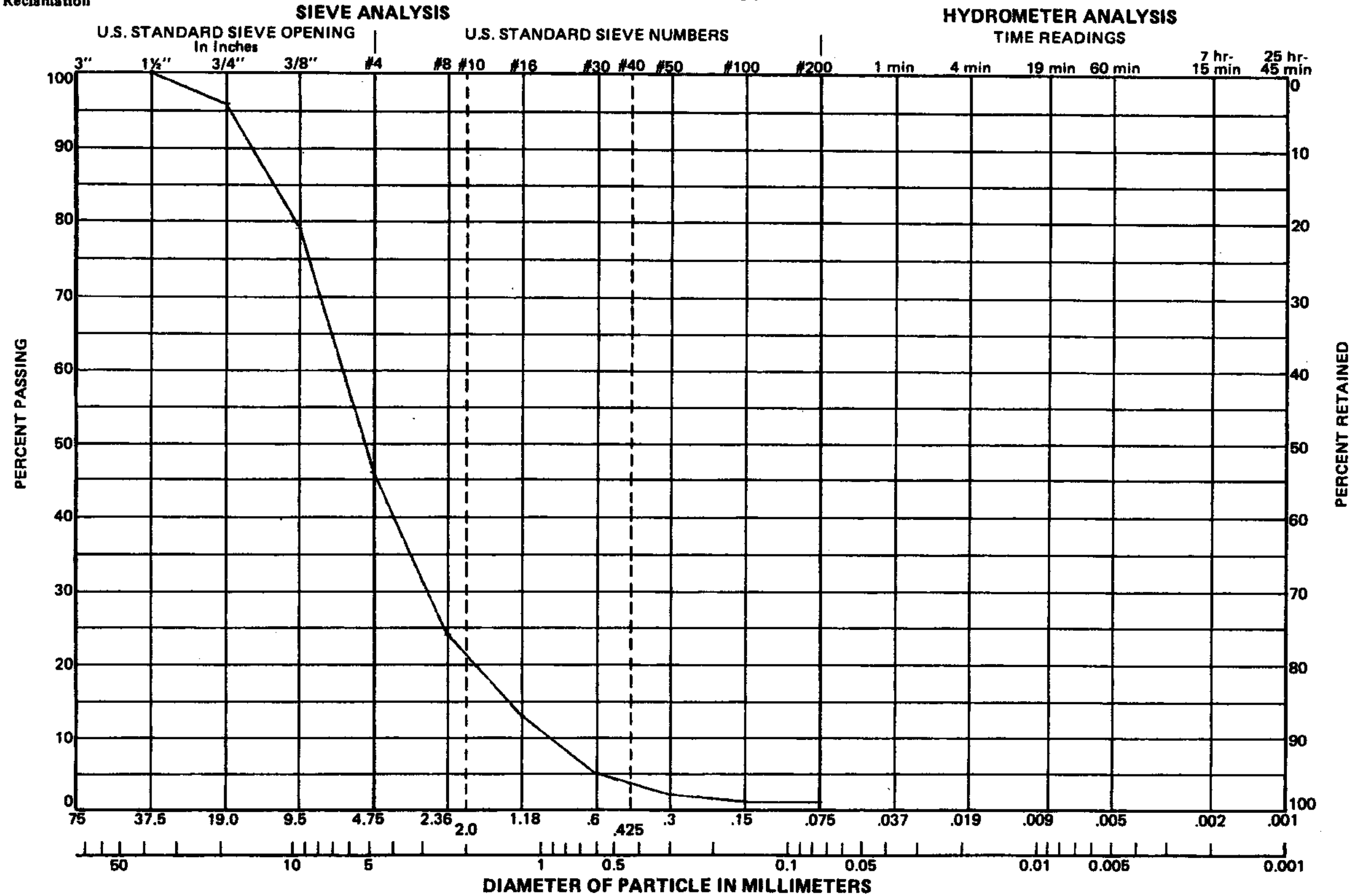
FIGURE ________

GPO 852-232

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __



GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	AP-99-10	25.5-27.4	(Gw)s	54	45	1				2.739		

PREPARED BY ____________

CHECKED BY ____________

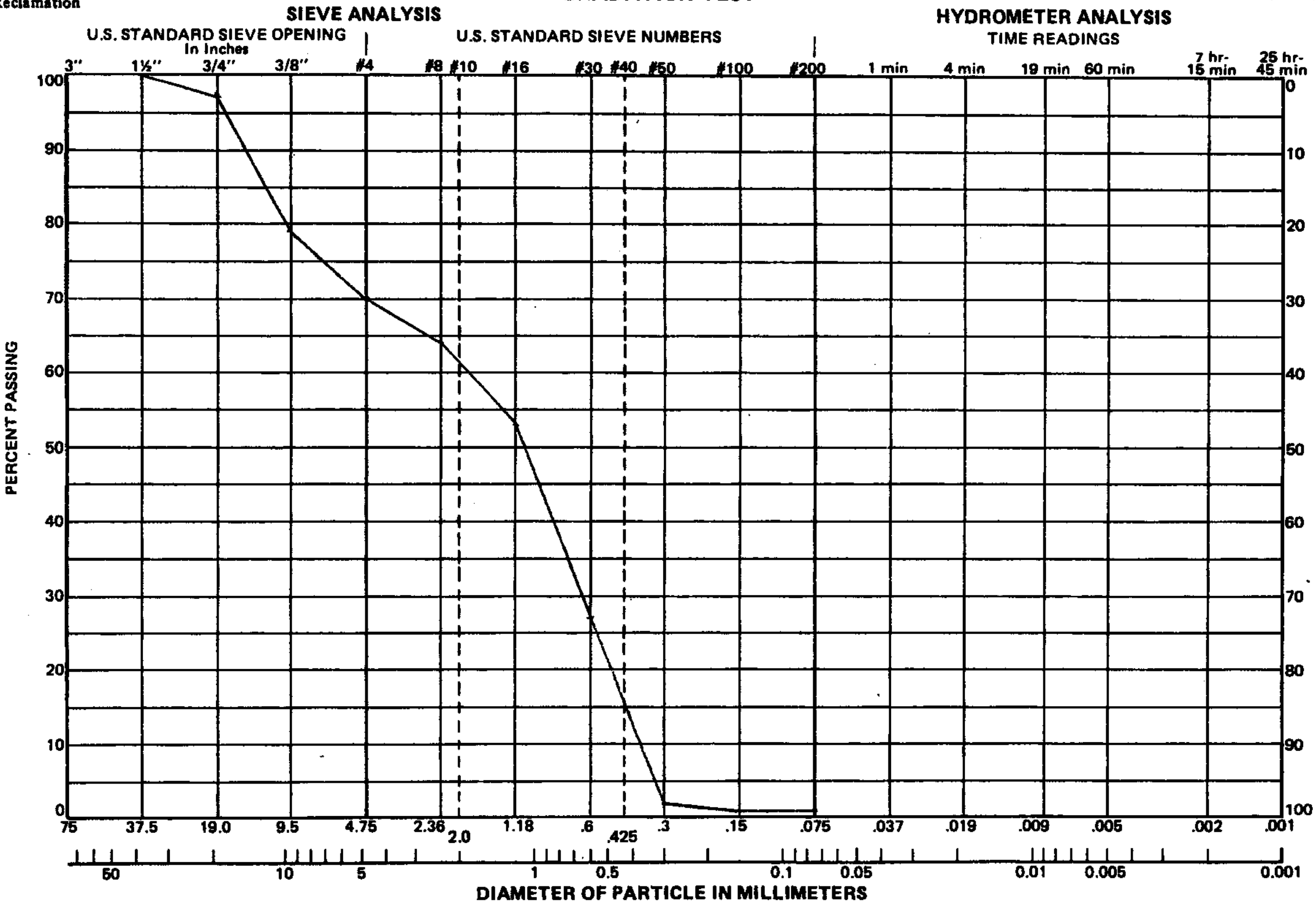
FIGURE ____________

GPO 852-232

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

Designation USBR ________ __ __



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SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-12	26.1-28.9	(SP)g	30	69	1				2.700		

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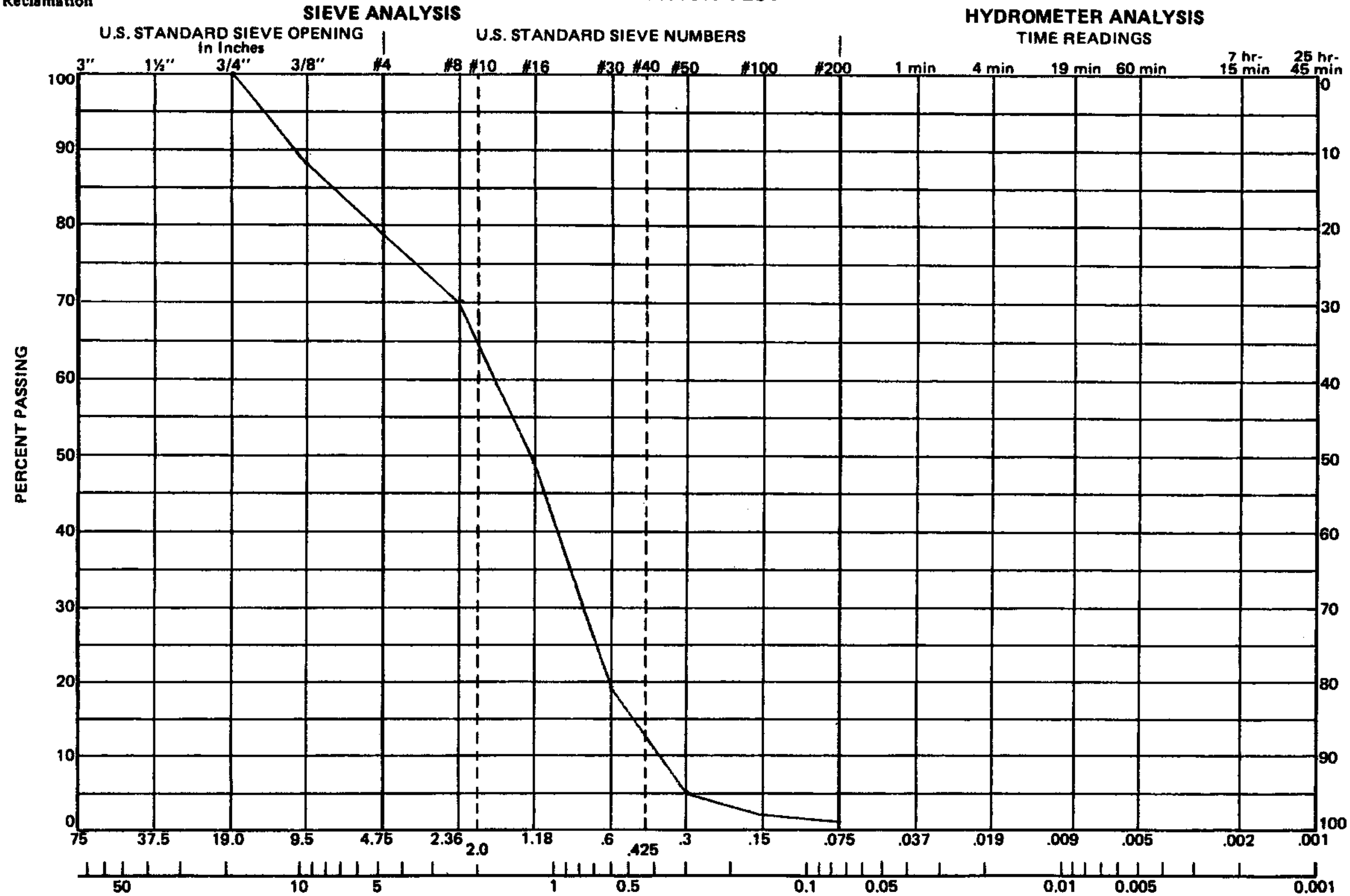

GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	AP-99-12	30.8-32.8	(SP)g	21	78	1				2.709		

GPO 852-232

7-1415 (10-86)
Bureau of Reclamation

GRADATION TEST

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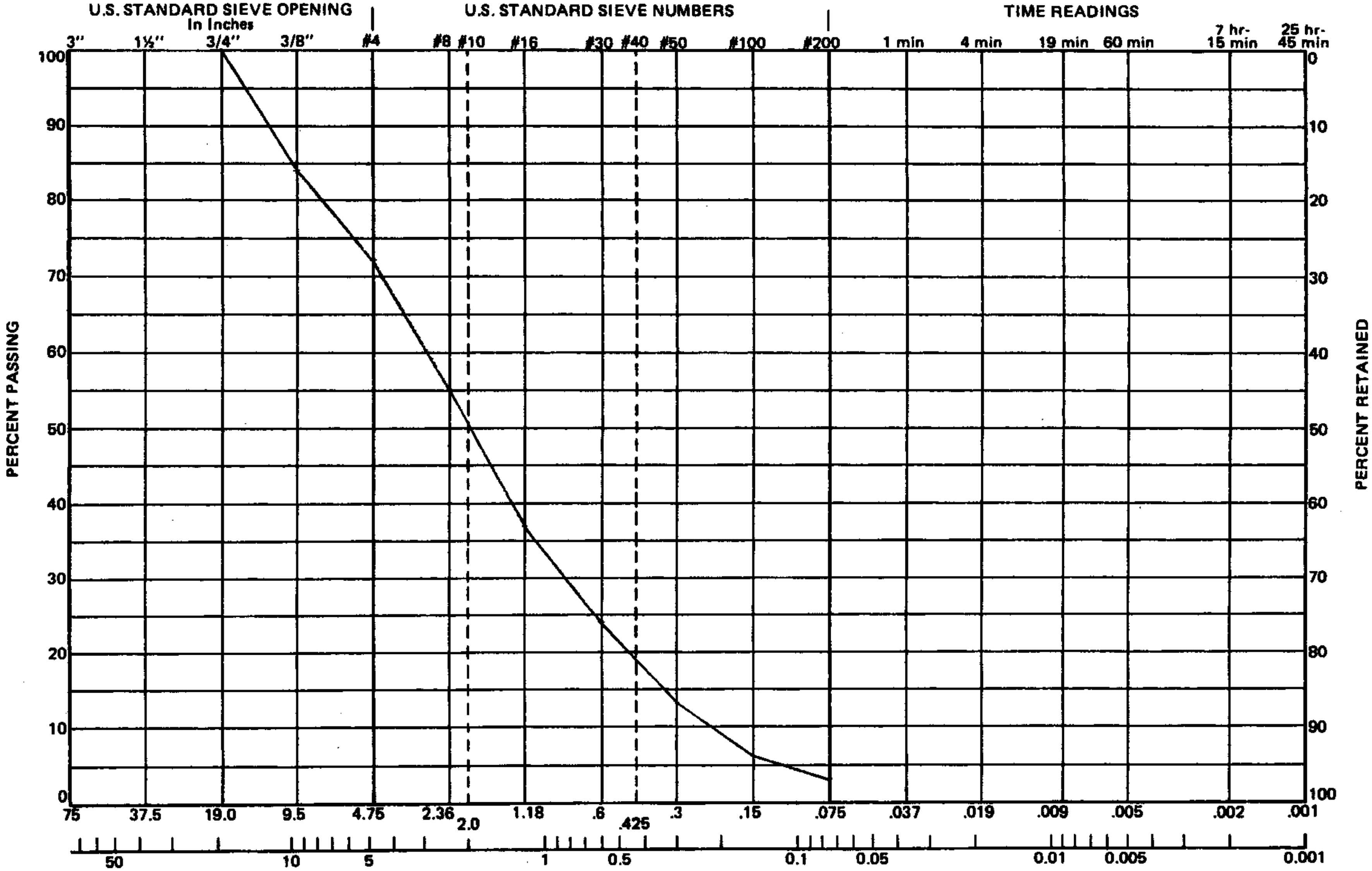
SIEVE ANALYSIS

HYDROMETER ANALYSIS



DIAMETER OF PARTICLE IN MILLIMETERS

GRAVEL		SAND			FINES
COARSE	FINE	COARSE	MEDIUM	FINE	

SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY MINUS NO. 4	OTHER	NOTES:
	AP-99-12	35.7-37.7	(SW)g	28	69	3				2.727		

PREPARED BY ________ CHECKED BY ________ FIGURE ________

GPO 852-232

7-1415 (10-86)
Bureau of Reclamation

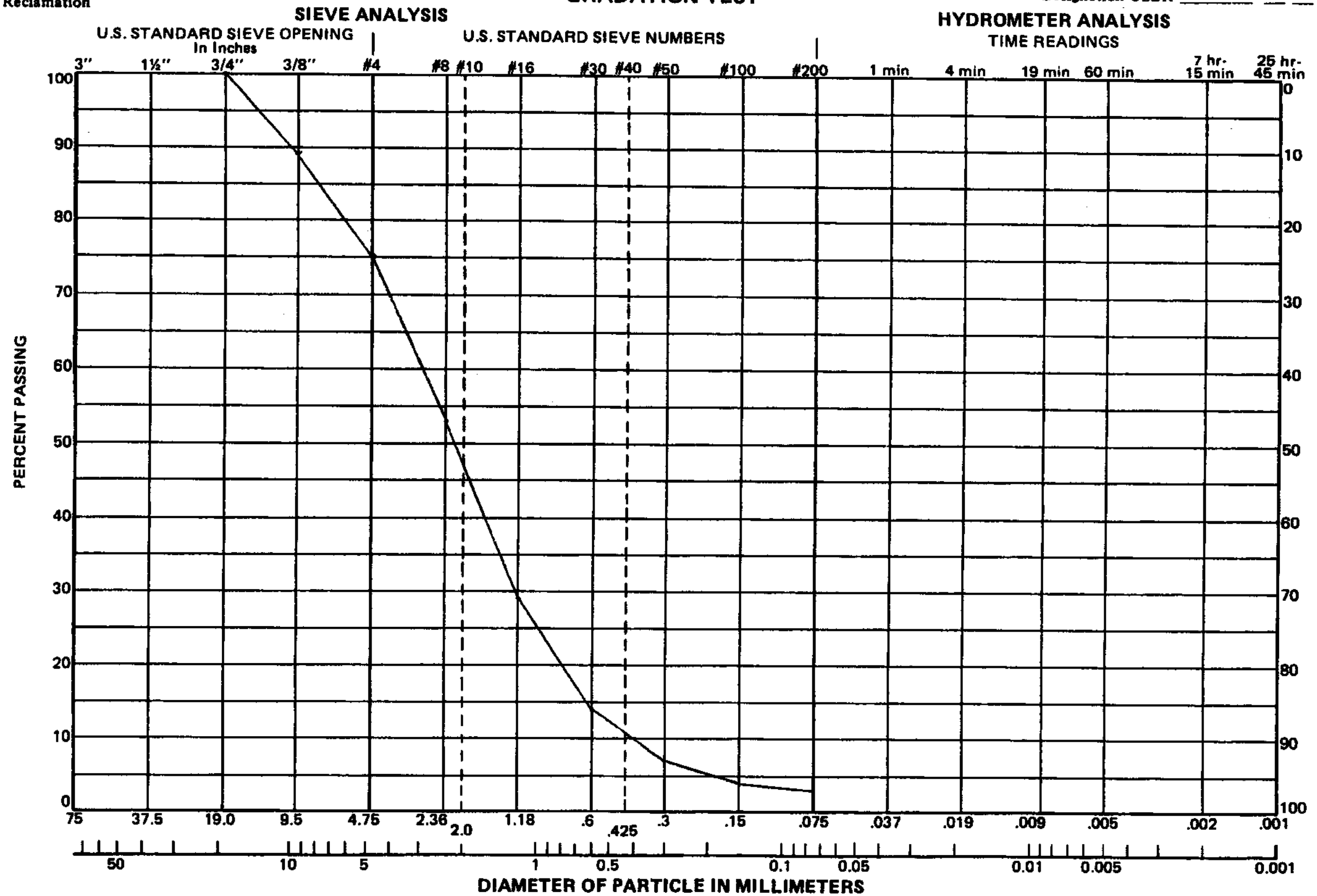
GRADATION TEST

Designation USBR ________

PREPARED BY ________

CHECKED BY ________

FIGURE ________



SAMPLE NO.	HOLE NO.	ELEV. OR DEPTH ☒ft ☐m	UNIFIED SOIL CLASSIFICATION: GROUP SYMBOL	% GRAVEL	% SAND	% FINES	ATTERBERG LIMITS: LL (%)	PI (%)	SL (%)	SPECIFIC GRAVITY: MINUS NO. 4	OTHER	NOTES:
	NP-99-12	41.1-43.1	(SW)g	25	72	3				2.749		

Attachment D

UNDERWATER MAPPING OF RESERVOIR CONDITIONS

United States Department of the Interior

BUREAU OF RECLAMATION
Pacific Northwest Region
1150 North Curtis Road, Suite 100
Boise, Idaho 83706-1234

IN REPLY REFER TO:

PN-3600
PRJ-12.00

JAN 25 2000

MEMORANDUM

To: Area Manager, Lower Columbia Area Office, Portland OR
Attention: LCA-1000 (Glover)

From: Brent H. Carter, PN Regional Geologist/Underwater Inspection Team Leader (PN-3600) Boise ID

Subject: Underwater Documentation of River Bottom Conditions Upstream of Savage Rapids Dam, September 24 through 25, 1999, Grants Pass Project, Oregon

General

The purpose of these underwater examinations was to observe and document river bottom conditions in the Rogue River upstream of Savage Rapids Dam to complement the ongoing sedimentation study. The PN Regional Drill Crew was concurrently performing explorations by drilling methods, from a barge, to sample representative bottom sediments accumulated overlying bedrock. This data will be utilized to estimate the volume of unconsolidated, potentially contaminated alluvial materials that will need to be evaluated for disposal under the removal schemes for Savage Rapids Dam.

Three diving traverses and three spot inspections were completed during the underwater work on September 24 and 25, 1999. PN Regional Underwater Inspection Team members participating in the examinations were Boise divers Mark Albl (PN-3233), Dennis Hawkins (PN-3425), and Brent Carter (PN-3600), Dive Master/Team Leader, and Grand Coulee diver Randy Harris (GCP-5600).

Water temperature was 57 degrees Fahrenheit. Underwater visibility was very good with recognition to four feet. The river elevation was about 964.0 feet (1929 NVGD datum) during the diving activities. The weather was mild, with air temperature 60 to 75 degrees Fahrenheit.

Background

No underwater examinations had been accomplished by U.S. Bureau of Reclamation divers in the Rogue River upstream of Savage Rapids prior to these investigations.

Examination Results

The locations of the underwater documentation traverses are referenced by river mile. Three traverses and three spot examinations were completed.

Traverse at River Mile 108.72

The underwater survey was accomplished from the south side of the river to the north side. At this location the river width was about 390 feet. Water depth varied from 8 to10 feet, with the bottom topography being fairly flat. Hard, subrounded gravels and cobbles to 10 inches in diameter, but mostly less than 5 inches, mantled the river bottom. Minor medium- to coarse-grained sand occurred in localized concentrations, of usually less than 15 feet in irregular configuration, to about 15 percent of the surface area within the gravel and cobbles.

Traverse at River Mile 109.00

At this location the Rogue River was about 230 feet in width. The underwater traverse was completed from the south shore to the north shore. Water depth varied from 10 to 26 feet. Along the south side of the river channel, bold outcrops of hard, *in situ* metavolcanics were exposed. The traverse started on the rock exposures that continued underwater for about 50 feet to the maximum depth of 26 feet. Beyond the 26-foot depth, the channel bottom was veneered with chiefly subrounded, gravel and cobbles to 12 inches in size, but were mostly 3 to 8 inches. Scattered, very small alluvial bars, less than 12 inches in thickness, of fine to medium sand were observed locally. The river bottom configuration to the north, from the maximum depth of 26 feet, gradually sloped upward to the depth of about 10 feet at the north shore.

Traverse at River Mile 109.63

This traverse was initiated on the north bank and progressed to the south shore. The river was about 310 feet wide at this location. Maximum water depth was 10 feet adjacent to the south bank of the river, but was generally 5 to 7 feet deep on the north side of the channel. Discontinuous exposures of *in situ* bedrock were observed along the south river bank and continued underwater. Most of the channel bottom was mantled with hard, subrounded cobbles to 10 inches in size, but were mostly 4 to 10 inches. Very little sand was noted.

Site Location at River Mile 107.60

This reconnoiter dive observed a previous drill location (drill hole AP-99-1) where a 30-foot string of auger flights had been lost off the barge. The site was in about 26 feet of water, with a bold exposure of *in situ* conglomerate immediately adjacent to the underwater drill location. The river bottom was covered with sandy gravel with the maximum size of about 2 inches. The gravel sizes were dominate with about 35 percent medium- to coarse-grained sand. Loose silt mantled the unconsolidated gravels from 1 to 2 inches in depth. Some organics were present in the overlying silts.

Site Location at River Mile 107.67

This site was the next location for the barge sample hole (marker buoy for drill hole AP-99-3). The water depth was 26 feet. The bottom was fairly smooth with a surficial layer of soft silt to depths of 2 to 9 inches. Organic debris in the silt was mostly 5 to 10 percent leaf, twig, and woody fragments. Fine- to medium-grained sand was underlying the silt. The loose sand was probed to depths of 18 inches with manual pressure.

Site Location at River Mile 107.69

This site location was made about midway between the marker buoys for AP-99-3 and AP-99-5. The water depth at this location was 20 feet. The river bottom was flat with 4 to 6 inches of soft silt veneering the surface. Some organic debris was present in the silt. Underlying the silt was compact gravelly sand with maximum size of 2 inches. Fine- to medium-grained sand predominated with about 30 percent subrounded gravel.

Conclusions

The three river traverses between River Mile 108.72 to 109.63 documented chiefly coarse-grained alluvium mantling the channel bottom of the Rogue River. These materials were mostly hard, subrounded gravels and cobbles with minor amounts of fine to coarse-grained sand. Exposures of bedrock were observed along the south side of the river channel at River Mile 109.00 and 109.63 traverses

Three site locations were examined adjacent to drill hole locations from River Mile 107.60 to 107.69 on the lower end of the reservoir near the dam. Where bottom conditions were observed, the reservoir sediments were veneered with shallow thicknesses of soft silt overlying generally loose, sand to gravelly sand to sandy gravel. The surficial river bottom silts often contained varying amounts of organic debris consisting of leaves, twigs, and tree fragments.

cc: Manager, Lower Columbia Area (Bend) Field Office, Bend OR
Attention: BFO-3200 (Magers)
PN-3000 (Beckmann), PN-3200 (Marriott), PN-3609 (Link)

Appendix B

Hydraulic and Sediment Transport Analysis and Modeling

by Jennifer Bountry and Timothy Randle
Hydraulic Engineers

U.S. Bureau of Reclamation
Technical Service Center
Denver, Colorado

CONTENTS – APPENDIX B

Tables

Figures

Figures (continued)

Attachments

Attachment

HYDRAULIC AND SEDIMENT TRANSPORT ANALYSIS AND MODELING FOR SAVAGE RAPIDS DAM SEDIMENT STUDY

Introduction

This report provides documentation for the analysis and modeling of the sediment impacts on the Rogue River that would result from the potential removal of Savage Rapids Dam, located 5 miles upstream from Grants Pass, Oregon (figure 1). A conceptual model of the Rogue River was developed during and after data collection. Formulating a conceptual model helps in understanding the natural processes of the Rogue River and how these natural processes will be affected by the removal of Savage Rapids Dam. Next, field data were collected in Savage Rapids Reservoir and in the 12.5-mile river reach downstream from Savage Rapids Dam to the confluence with the Applegate River. For the analysis, hydraulic and sedimentation models were used to estimate the expected rate at which reservoir sediments would be eroded and transported downstream following a dam removal and the location and magnitude of deposition that might result downstream from the damsite. In addition, the hydraulic properties at the dam site and the potential sediment impacts to downstream water intake infrastructures following dam removal were evaluated.

Data Collection

Hydraulics and Sedimentation Study Reach

The Rogue River is a relatively steep, gravel- and cobble-bed river consisting of a series of pools, riffles, and rapids. For the hydraulics and sedimentation study, the modeled reach extends from the upstream boundary of the full Savage Rapids Reservoir pool (river mile [RM] 110.6) to the confluence with the Applegate River (RM 95)12.5 miles downstream from Savage Rapids Dam (RM 107.6). (See figure 2.) In the 12.5-mile reach downstream from the dam, the drop in channel bed is nearly 100 feet. Eight of the river pools that exist between Savage Rapids Dam and the confluence with the Applegate River are 10-20 feet deep, but most are shallow pools followed by steep riffles or rapids.

Observations in the field noted that there is a large, unmeasured influx of sediment at the confluence with the Applegate River. The Applegate River was chosen as the downstream boundary because it would be nearly impossible to distinguish the transport of sediment eroded from an upstream dam removal versus the influx of sediment from the Applegate River. Also, the sediment transport capacity of the Rogue River increases downstream from the confluence through Hellgate Canyon.

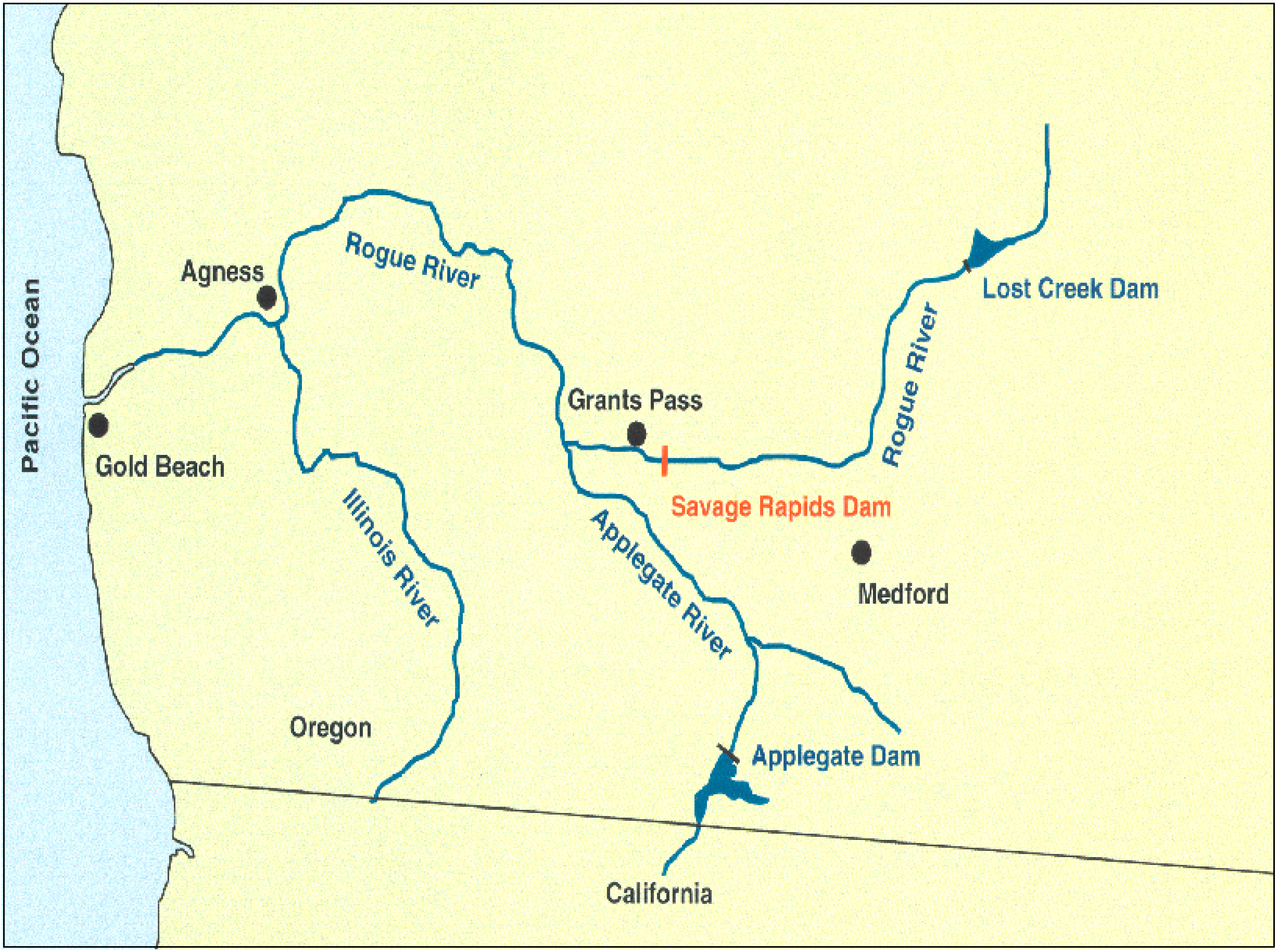


Figure 1.—Savage Rapids Dam is located on the Rogue River in Oregon, 5 miles upstream from the town of Grants Pass.

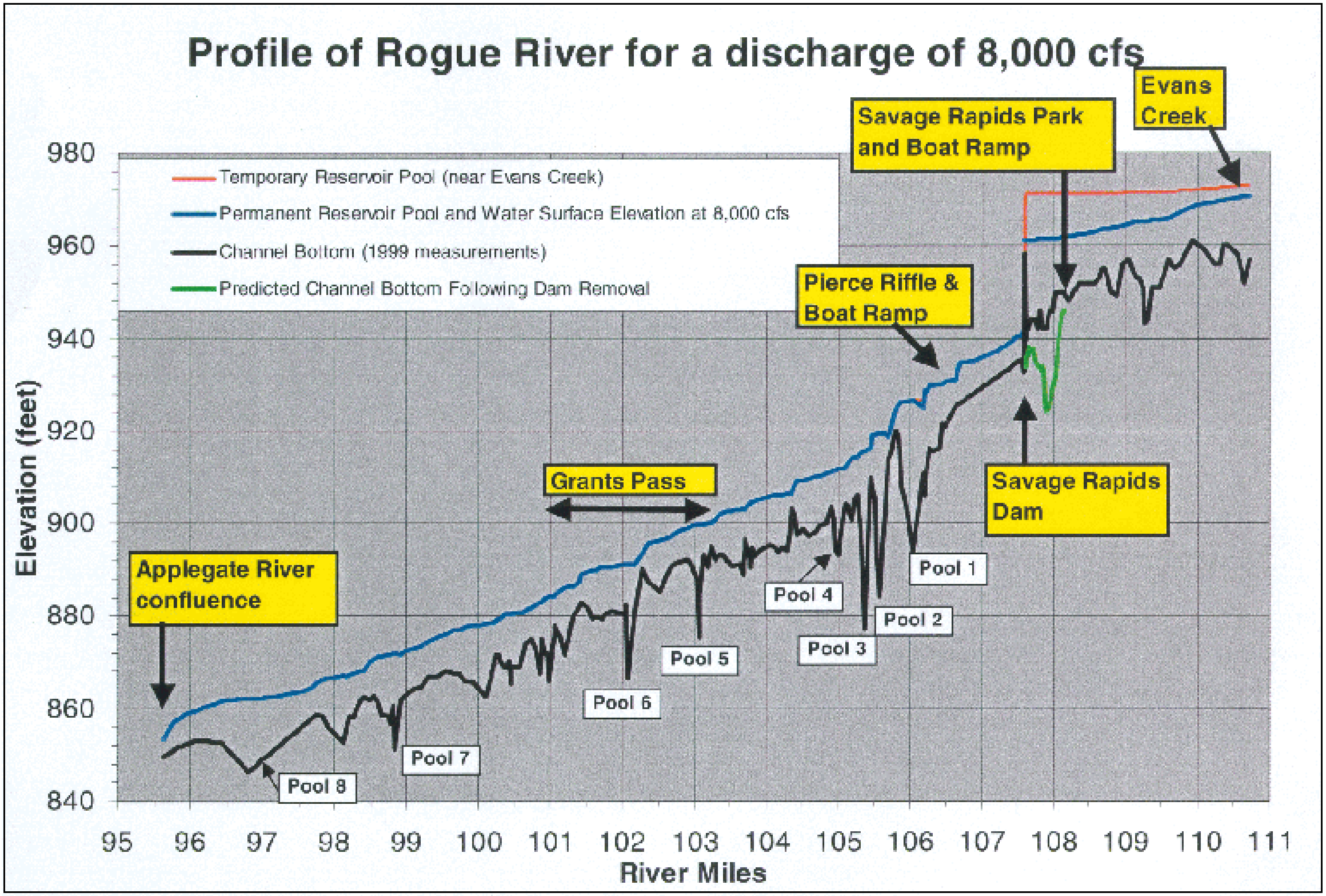


Figure 2.—The Rogue River is a steep, gravel- and cobble-bed river consisting of a series of pools, riffles, and rapids. This profile represents the reach of river from the upstream end of the full Savage Rapids Reservoir pool (RM 110.6) to the confluence with the Applegate River, 12.5 miles downstream from Savage Rapids Dam. The full reservoir pool (shown in red) exists during the irrigation season when stoplogs are used to raise the water surface elevation of the reservoir 11 feet. This extends the backwater pool from ½ mile (near the public boat ramp) to nearly 3 miles at the confluence with Evans Creek.

Sediment Transport Capacity

Sediments that are transported past the confluence with the Applegate River would be transported all the way to the Pacific Ocean, another 95 miles downstream (see figure 1). The slope of the Rogue River is generally steep, but the river slope is less steep in the reach between Grants Pass, Oregon, and the head of Hellgate Canyon (figure 3). The river slope remains steep through Hellgate Canyon, where it averages 0.0024. Just downstream from the mouth of Hellgate Canyon, the slope of the Rogue River flattens out to an average of 0.0008, which would typically reduce sediment transport capacity. However, tributary flows from the Illinois River maintain the river's capacity to transport sediment at a relatively high level. The high transport capacity of the Rogue can be illustrated by looking at the total stream power of the river (water discharge multiplied by channel slope) (figure 4). Because the stream power is higher everywhere downstream from the Applegate River confluence (RM 95 to 0) than between Savage Rapids Dam and the Applegate River (RM 107.6 to 95), any sediments that get transported past the Applegate River will eventually get transported to the Pacific Ocean.

Savage Rapids Reservoir Cross Sections

The Bureau of Reclamation (Reclamation) completed a bathymetric survey of Savage Rapids Reservoir in July 1999 (see map in attachment A). The survey extends from the dam (RM 107.6) upstream to the confluence with Evans Creek (RM 110.6). The survey was performed from a cataraft equipped with global positioning system (GPS) and depth-sounding equipment (figure 5). The channel depths measured in the reservoir were converted to channel bottom elevations by subtracting the depths from the corresponding measured water surface elevations. A 2-foot contour map was then produced for the reservoir bottom using the survey data (see attachment B).

Using the bathymetric data, cross sections were interpreted in the 3,000-foot-long permanent reservoir pool. These cross sections (labeled A through T) were used in the hydraulic and sedimentation model as input data (see attachment A). Additional cross sections were developed in the temporary pool to extend the model another 2.5 miles upstream to the confluence with Evans Creek. Immediately upstream from the dam, several areas of bedrock exist along the left side (looking downstream), and data could not be collected because of safety and access concerns. For this area, a contour map developed for proposed rehabilitation of the dam was used to interpret channel bottom elevations (Reclamation, 1997).

Rogue River Cross Sections Downstream from Savage Rapids Dam to the Applegate River

Survey data of the Rogue River channel bottom were needed downstream from Savage Rapids Dam to document the existing river channel conditions. At the start of the study,

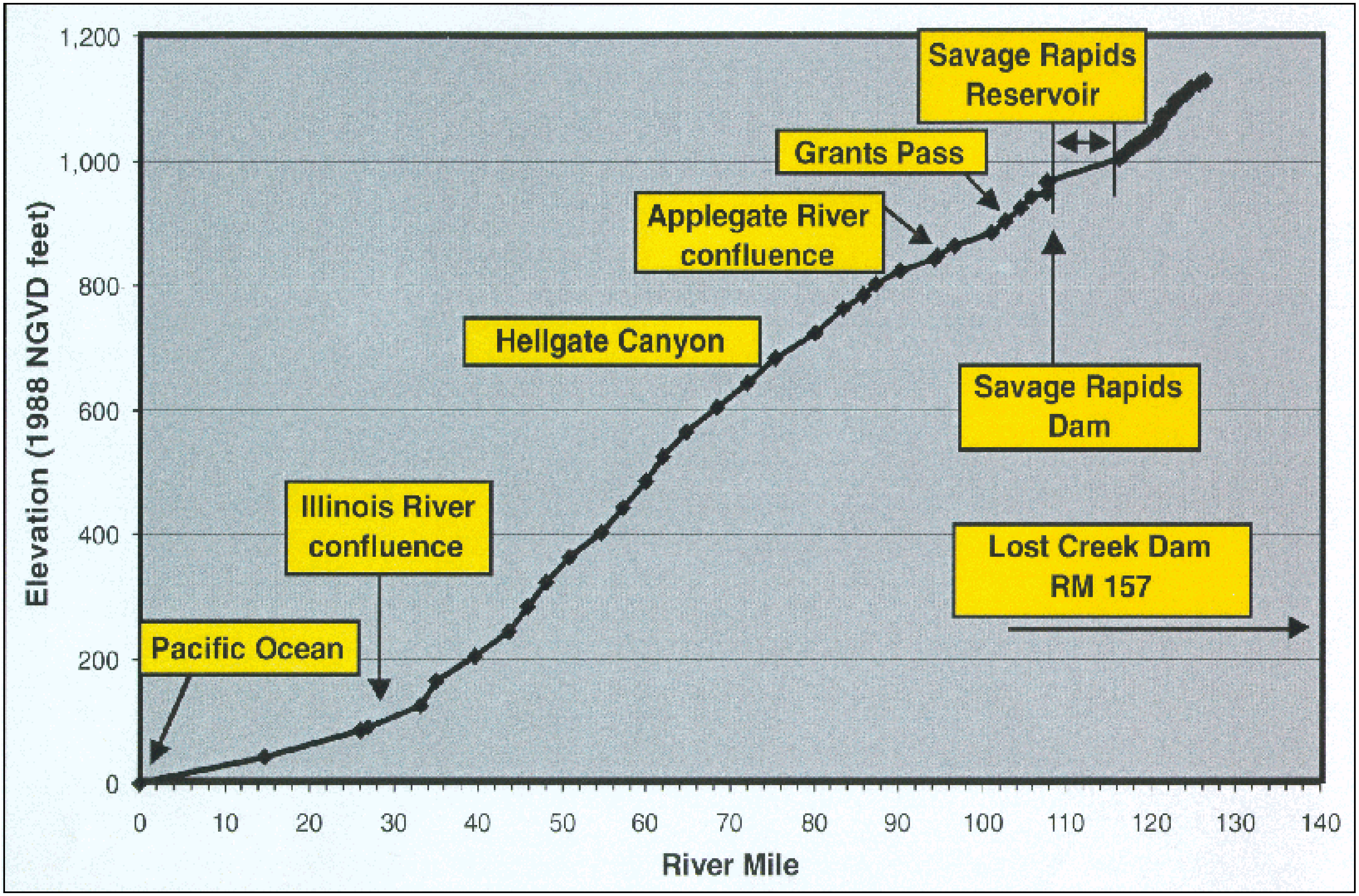


Figure 3.—A longitudinal profile shows the increase in slope downstream from the Applegate River confluence as the Rogue River passes through Hellgate Canyon. In the 30-mile river reach from the mouth of the canyon to the Pacific Ocean, the slope of the Rogue River flattens out.

study, a set of data from a 1991 Flood

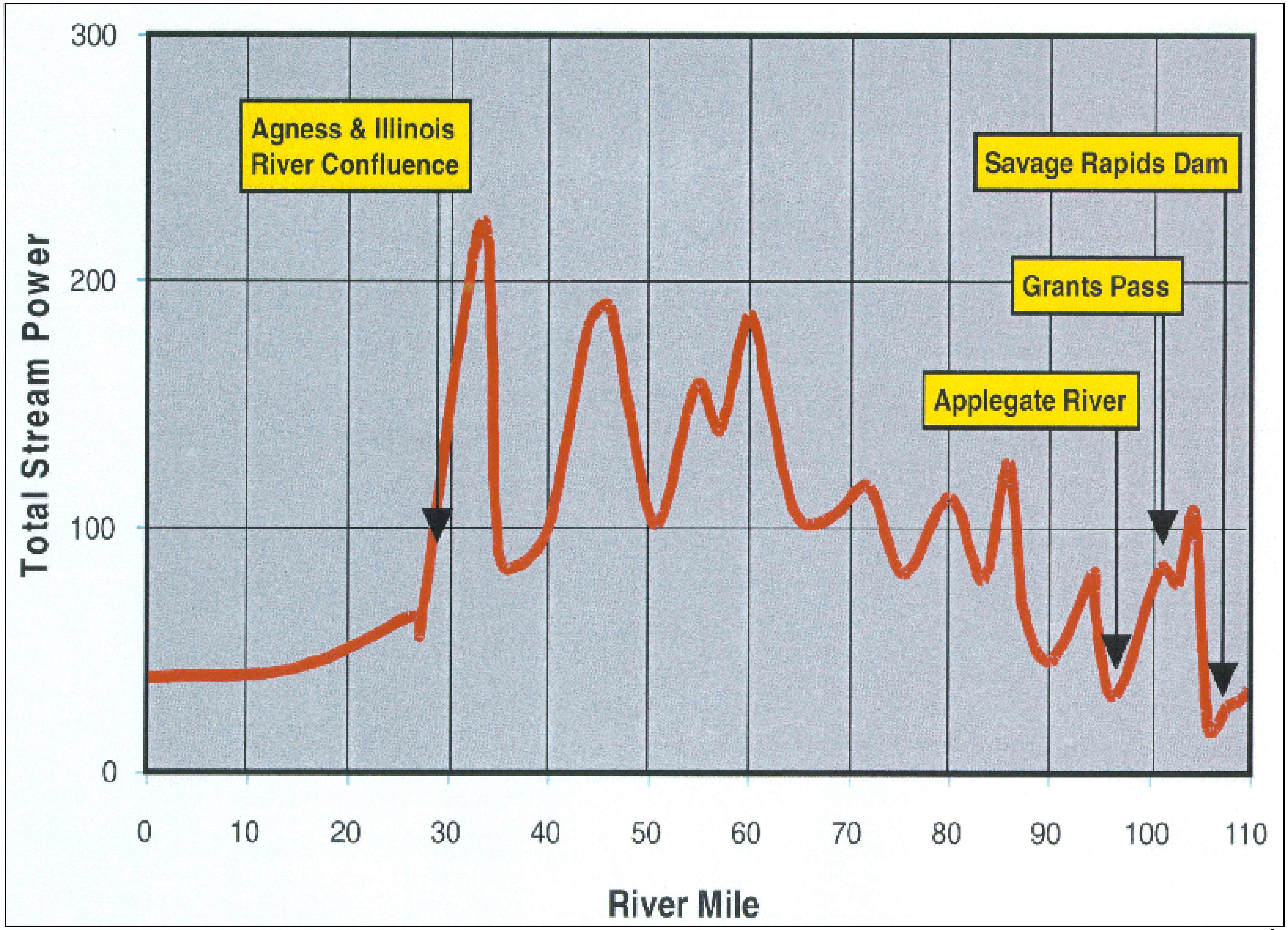


Figure 4.—Total stream power is an indicator of the sediment transport capacity on the Rogue River. Total stream power is computed by multiplying discharge by channel slope.

Figure 5.—A cataraft equipped with GPS survey equipment and a depth sounder was used to survey Savage Rapids Reservoir and the river bottom downstream from the dam to the Applegate River (12 miles).

a set of data from a 1991 Flood Insurance Study was known to exist that provided cross sections perpendicular to the flow from the dam site downstream to the confluence with the Applegate River. To supplement this data, hydrographic data defining the water surface and channel bottom were collected in July 1999 from Pierce Riffle (1 mile downstream from the dam at RM 106.5) to the confluence with the Applegate River (RM 95).

For the first mile downstream from Savage Rapids Dam, the water is shallow and turbulent and has limited boat access. For this reason, survey data were not collected in this reach. However, water surface elevations just downstream from the dam and at the top and bottom of Pierce Riffle were collected to approximate the channel slope in this reach and the drop through Pierce Riffle. Pierce Riffle, surveyed on June 7, 2000, has a measured drop in water surface elevation of 5 feet (discharge of 3,560 cubic feet per second [ft^3/s]).

To perform the survey, a boat ramp just downstream from Pierce Riffle was used to launch a cataraft equipped with a depth sounder and GPS survey equipment. The depth sounder records the channel depth at the same time the GPS equipment records the water surface elevation and horizontal position of each measurement. Because of the high banks and vegetative cover on either side of the channel, it would be difficult to run cross section lines from the boat and maintain a GPS signal (to satellites in the sky) along the shorelines of the river. Even by staying in the center of the channel, a GPS signal lock could not be maintained near the bridges at Grant's Pass. Instead of using GPS, traditional total station surveying could be combined with the sonar measurements on the survey boat, but it would be very time consuming to clear vegetation and difficult to obtain property access permission. Instead, a longitudinal profile along the deepest part of the channel (thalweg) was run with the cataraft to record the water surface and channel bottom slope. These data were to be combined with the U.S. Army Corps of Engineers (Corps) and Federal Emergency Management Agency (FEMA) cross section data.

Unfortunately, after careful evaluation of the available river cross section data, it was determined that the data could not be used because it was outdated, poorly documented, and contained little detail in the study reach. The cross sections were surveyed in 1979 for a Flood Insurance Study by the FEMA. The cross sections were provided in HEC-2 format, a hydraulic computer program developed by the Corps. In addition, longitudinal plots of both channel bottom and water surface profiles were provided as part of the FEMA report.

Both sets of FEMA channel bottom elevation data were plotted against the Reclamation channel bottom and water surface elevations measured in 1999 to determine if the FEMA data were feasible to use (figure 6). While the average slope of the river channel was similar, in many places the old channel bottom measurements plotted above the existing water surface, and riffles were located on top of pools. Although one possible explanation is that the channel bottom may have changed, it is more likely that there is a problem in matching up the locations of the data sets or that there are inaccuracies within the previous data. The previous data had little explanation on where cross sections were located, other than at a few places, such as bridges and the dam. In addition, there were only two cross sections per river mile in the study reach, and only half of the sections had detailed bathymetric data in the river channel. However, the cross sections did provide out-of-water topography (based on a contour map developed from September 30, 1978, aerial photographs), which was not done in the July 1999 survey.

Based on the limited data available, cross section input data for the models were developed by calibration with the water surface elevations measured in 1999. The data collected in 1999 document the channel thalweg and water surface elevation corresponding to a discharge of 3,870 ft^3/s. In the pool just upstream from the Applegate River, the depth sounder broke, but water surface elevations and visual observations were recorded. The FEMA cross sections document the out-of-water

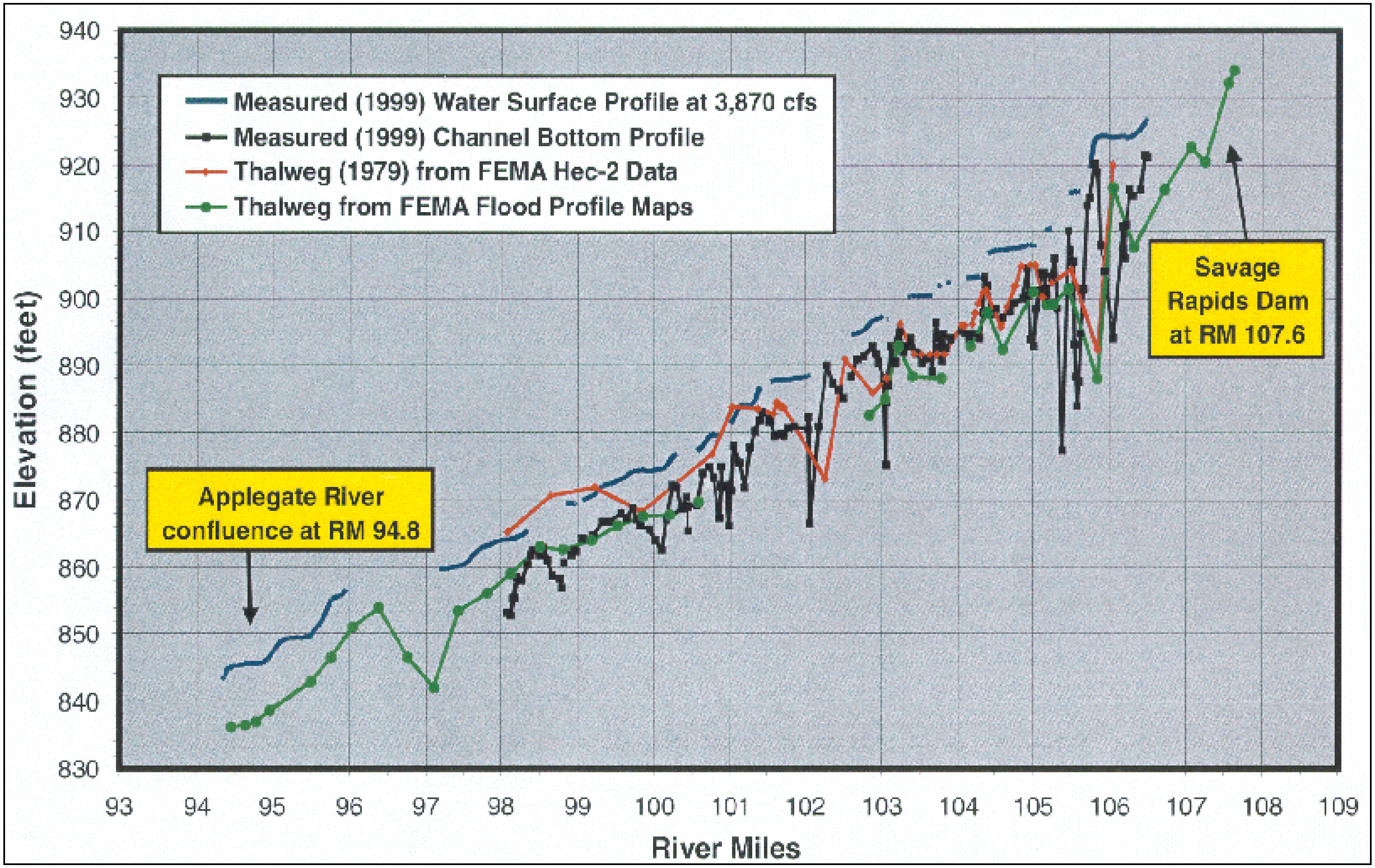


Figure 6.—Survey data collected by Reclamation downstream from Savage Rapids Dam in 1999 was compared to two sets of channel bottom data from a 1979 FEMA flood profile study. In many places, the FEMA channel bottom plots above the existing water surface, and the two sets of FEMA data are not consistent. The FEMA data were not able to be used for this sedimentation study because of the inaccuracies in the data sets, the limited documentation on the development of the data, and because only one cross section per river mile contained detailed underwater data in the river channel.

topography downstream from the dam. In this reach of river, the out-of-water topography consists of steep banks and cliffs that would not have changed since 1978, the year the photographs were taken that were used to develop this portion of the data. In addition, the width of the river channel was digitized from the U.S. Geological Survey (USGS) quadrangle maps to interpret wetted channel width at locations where depth measurements were taken in 1999. Because the banks on the Rogue River are steep, water depth increases much more rapidly than the wetted width during floods. Therefore, the wetted width interpretations from the quadrangle maps are accurate for modeling purposes. Finally, cross section shapes were evaluated based on the model calibration and cross section measurements documented at the USGS gauge site downstream from the dam (RM 102). It was noted that the pool cross section at the USGS gauging station had a triangular shape (figure 7).

Two types of cross sections were needed to represent the river channel downstream from the dam. Based on the longitudinal profile survey of 1999, the river channel consists of alternating pools and riffles (figure 3). The largest factors influencing the hydraulics of a pool section are the wetted width and water depth. Based on data collected for channel depth, wetted width at the water's surface, channel shape, and general out-of-water topography, cross sections were developed at each of the locations where a measurement was taken in 1999. Once the sections were developed, they were calibrated to adjust the only portion of the section not measured, the bottom width. A roughness coefficient of 0.035 was used in the river channel and was not changed during the calibration. Using the Corps' Hydrologic Engineering Center's River Analysis System (HEC-RAS) model version 2.2 (Brunner, 1997), the bottom width at each section was adjusted until the computed water surface elevation matched the measured water surface elevation for a discharge of 3,870 ft^3/s (discharge recorded during the 1999 survey). A table of computed river hydraulics for the calibrated cross sections and Savage Rapids Reservoir cross sections for the discharge during the survey is presented in attachment C.

To model the hydraulics through riffles and rapids, trapezoidal cross sections were developed. One cross section was always located at the top of the rapid (upstream end), representing the hydraulic control for the upstream pool, and the other at the bottom of the rapid (downstream end), representing the start of the next pool downstream. The drop in water surface elevation through the riffles and rapids was measured during the 1999 survey.

The methodology used to develop the cross sections downstream from the dam for model input did require some approximation of channel geometry. However, the channel thalweg, water depth, and wetted width were measured, so the only estimation remaining was the bottom width of each section. Because the bottom width was calibrated using a known water surface elevation, the hydraulic parameters computed through each section are accurate for the detail required in this study. Although a more detailed survey of the river channel downstream from the dam would be useful, the logistics of this type of survey would be difficult. Because the Rogue River is constrained by high cliffs and tree cover, survey capability with GPS equipment from bank

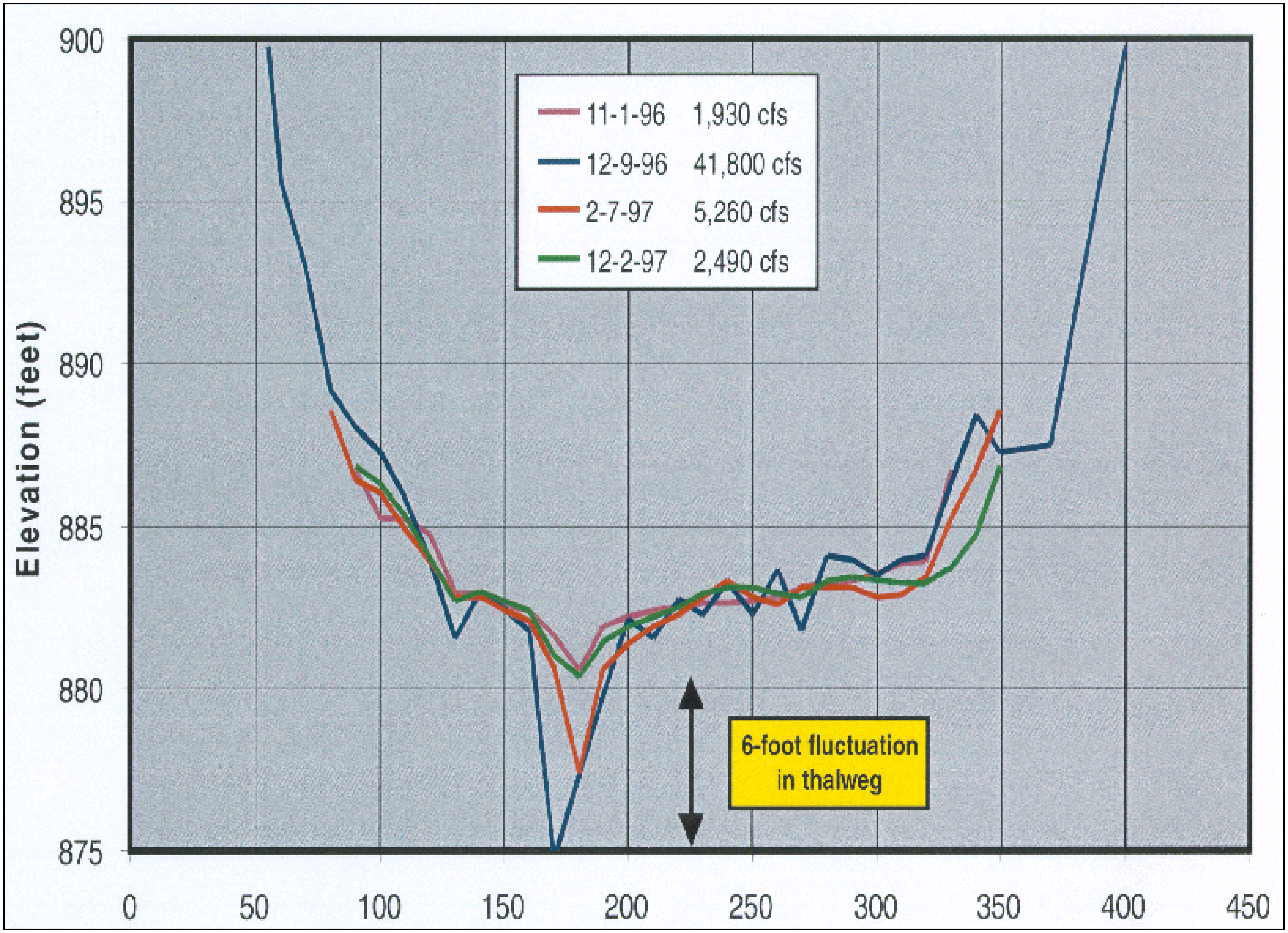


Figure 7.—Measured cross section profiles of the USGS gauging station were compared for a flood that occurred during the winter of 1996-97.

to bank would be limited. Traditional total station surveying techniques could be used but would be time consuming and, therefore, more expensive. However, it would be both beneficial and efficient to choose river pools between the dam and the Applegate River to survey in more detail. This survey data could be used to verify the calibrated cross sections and document the river channel geometry prior to releasing the reservoir sediments and for monitoring purposes.

Hydraulic and Sedimentation Model Analyses

Hydraulic Model

A Corps' river hydraulics model, HEC-RAS Version 2.2 (Brunner, 1998), was applied to the study reach. HEC-RAS is a one-dimensional, steady flow backwater model that computes hydraulic parameters for any given cross section at any discharge. The data needed to create the model were channel geometry in the reservoir, channel geometry down-stream from the dam to the confluence with the Applegate River, channel roughness (parameters that increase flow resistance), and water discharge. The model was calibrated to measured water surface elevation data to ensure its capability to accurately predict hydraulic parameters at any discharge of interest (figure 8). Model results were used to compare water surface elevation, average velocity, and water depth for existing river and reservoir conditions to conditions after the dam is removed.

For this analysis, a combination of subcritical flow in the pool cross sections and critical flow through the riffles and rapids were modeled. A downstream boundary condition (necessary for subcritical flow regime computations) of critical depth was used at the cross section farthest downstream. For pool cross sections, a roughness coefficient of 0.035 was used. During low flow periods, every pool water surface elevation is relatively flat and is a function of the water surface elevation at the top of the rapid immediately downstream from each pool, also referred to as hydraulic control. The water depth at these hydraulic control sections is at the minimum specific energy (critical depth) and can be computed directly because it is a function of only the channel geometry and discharge (not channel roughness). Therefore, the hydraulics in one pool are independent of another. During high flow periods, the slope of the water surface through many of the shallow pools (typically less than 10 feet deep) becomes steeper because at high flows, many of the smaller riffles get drowned out and no longer function as hydraulic controls (figure 9).

Dam Removal Sedimentation Model

A sediment transport model, HEC-6t (Thomas, 1996), was applied to the study reach to simulate the removal of Savage Rapids Dam. The 15-mile reach of river modeled was from the upstream end of the reservoir to the confluence with the Applegate River. The

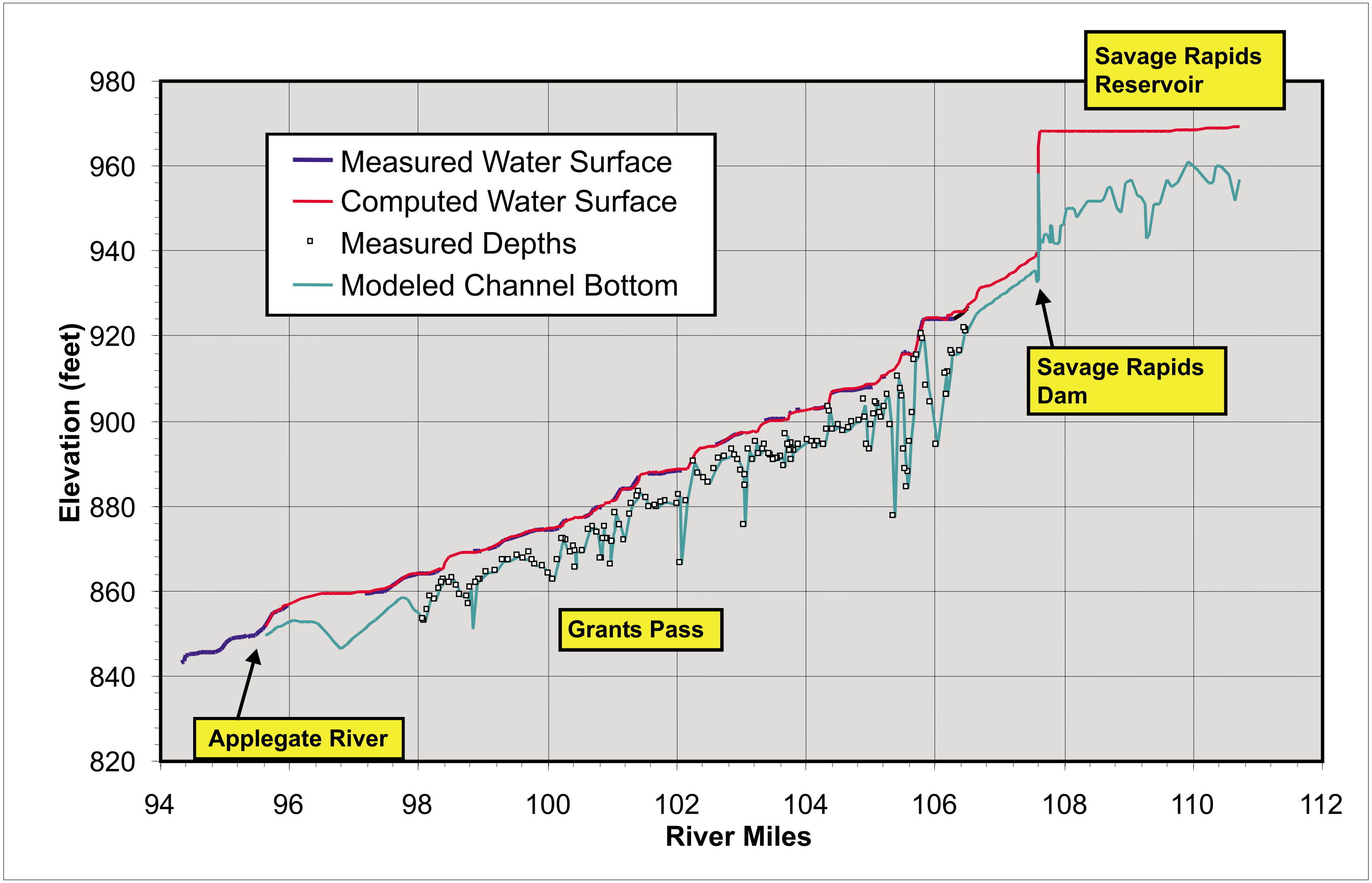


Figure 8. - The hydraulic model was calibrated to the measured water surface elevation data to ensure its capability to accurately predict hydraulic parameters at any discharge of interest. Calibration results show that the computed water surface elevation match very closely to the measured data.

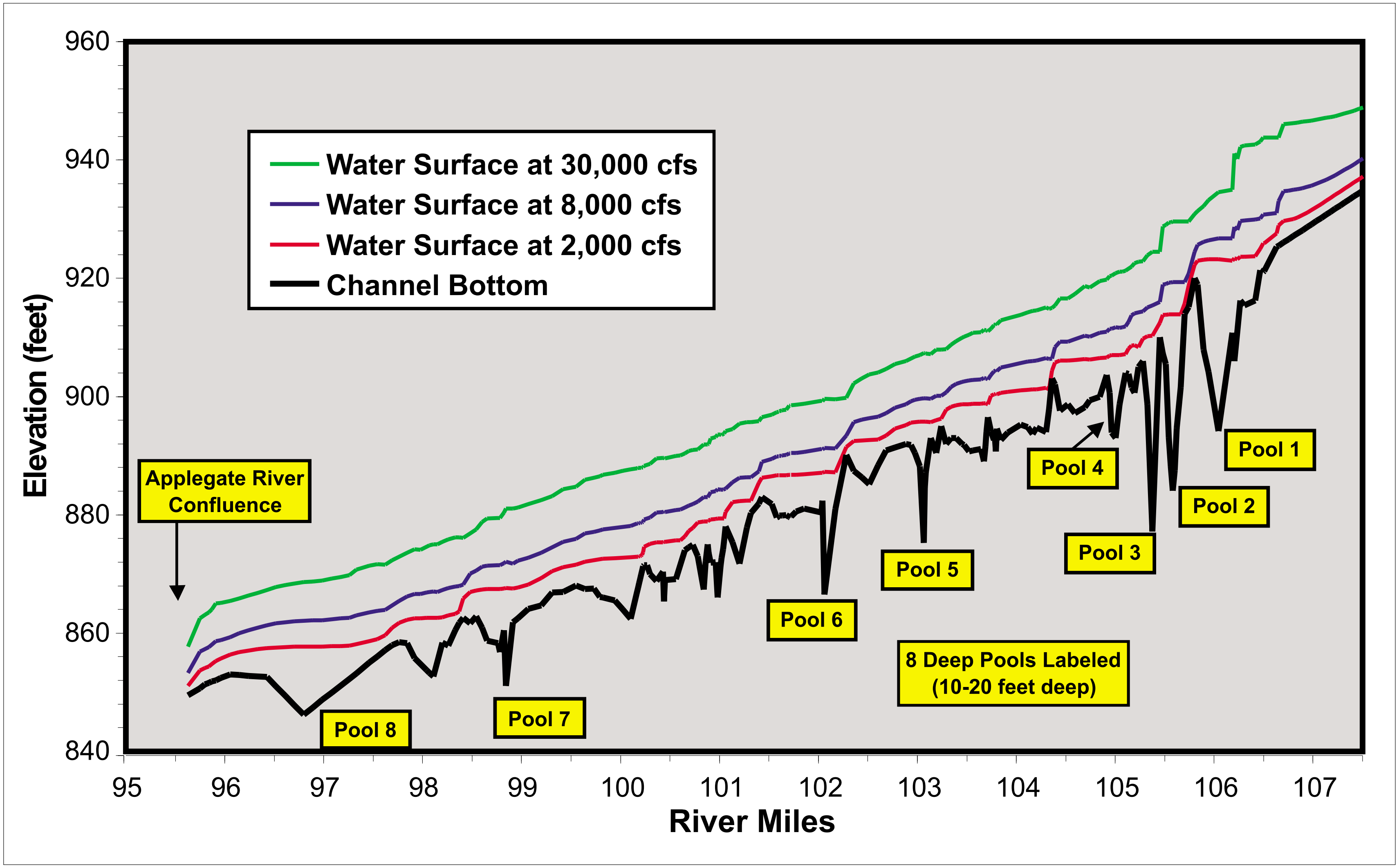


Figure 9. - During low-flow periods, pool water surface elevations are relatively flat and are controlled by the top of each riffle or rapid immediately downstream. During high-flow periods, the slope of the water surface through many of the pools becomes steeper, and smaller riffles get drowned out and no longer function as hydraulic controls.

additional data needed for the sediment model were the size and thickness of sediment present on the reservoir and river bottom, the natural upstream sediment supply of the Rogue River at the dam, and a hydrograph depicting riverflows over a period of time. Model input files are stored at Reclamation's Denver Office.

Model results were used to analyze the rate of erosion, the volume of sediments eroded from the reservoir, and the rate of transport of these sediments downstream. At this time, a specific dam removal study that details the timing and sequence of dam removal has not been initiated. Alternatives for removing the dam range from removing it very quickly, over a period of months, to removing it gradually, over a period of years. For this study, it was assumed the dam had just been removed, and all the reservoir sediments could immediately begin eroding downstream.

The use of steady-flow models is considered appropriate for this study because the dam would be removed in a controlled way that would not generate a flood wave. Also, the shape (duration and peak) of natural flood waves that would typically occur on the Rogue River probably would not change much as they flowed through the 12-mile study reach. For the hydraulic model, the assumption of steady flow is entirely adequate for the calibration of the cross-section geometries. For the sediment transport model, a series of short-duration, steady flows were used to simulate naturally occurring flood waves.

Filling of Savage Rapids Reservoir

The purpose of diversion dams is to divert water, so these dams are typically small compared to dams used for flood control or water storage. Therefore, the pool behind a diversion dam tends to fill with sediment in the first few years of operation. After filling, virtually all sediment transported by the river into the reservoir passes the dam. Therefore, Savage Rapids Dam, built in 1921, would be expected to have filled with sediment long ago.

On the Rogue River, nearly all the sediment is naturally transported during periods of high flow. High flow typically occurs during winter floods and the spring snowmelt runoff. Because the reservoir pool is lowered and extends only a ½ mile upstream during these high-flow periods, river conditions exist upstream from the public ramp (figure 10). These river conditions cause high velocities, and high velocities mean the dam does not cause sediment deposition in the upper 2 miles of the reservoir (from the public boat ramp to Evans Creek). Observations made by divers, who traversed the channel bottom, and visual observations made above water while the reservoir pool was lowered for stoplog installation, confirmed that no sediment is being stored in the upper 2 miles of the reservoir.

Also, before the dam was built, a riffle existed at the dam site and a river pool, which is now buried with sediment, existed just upstream at RM 107.91 (figure 11). If the dam

Figure 10. - After the stoplogs are removed following the irrigation season, riverine conditions exist upstream from the public boat ramp in Savage Rapids Reservoir.

Figure 11. - This photograph shows the pre-dam river channel at the current location of Savage Rapids Dam. Prior to the construction of the dam, a riffle existed at the dam site, which created a pool immediately upstream.

caused sediment deposition in the upper 2 miles of the reservoir, any other pools that existed would have quickly filled in with sediment and would also now be buried. However, the survey of the reservoir bottom found several pools that exist upstream from the public boat ramp. This further supports the concept that sediment does not deposit upstream from the public boat ramp. Therefore, the sediment deposition caused by Savage Rapids Dam occurs in the ½-mile reach just upstream from the dam.

Coarse sediment (sand and gravel), which travels as bedload, has deposited in this ½-mile reach (figure 12). Fine sediment (silt and clay) is easily suspended in the water column and carried past the dam. This permanent sediment deposition probably occurred within the first few years after the dam was built. Since that time, all the sediment entering the reservoir, mostly during high flows, passes the dam. Visual observations during a reservoir drawdown confirm that even gravel-sized sediment is being transported past the dam (figure 13).

Inflowing Sediment Load

In addition to predicting the transport and deposition of reservoir sediment following a dam removal, the sediment model must also account for the transport of the natural upstream sediment supply of the river. Because most of the sediment supply carried by the Rogue River consists of sand and gravel, most sediment is transported as bedload. Unfortunately, there are no bedload measurements downstream from Savage Rapids Dam. To estimate what the natural sediment load is, the HEC-6t model was used to determine the sediment transport capacity.

While the typical process of scour and fill occurs along the channel bed during and following high flow periods, the Rogue River (upstream from the Applegate River) does not have excessive amounts of sediment stored along the channel margins. This is not a result of sediment being trapped behind Savage Rapids Dam, because the year-round reservoir filled long ago and has been passing the river's sediment through for several decades. In addition, Lost Creek Reservoir (located 50 miles upstream from Savage Rapids Dam) traps sediment from 30 percent of the Rogue River watershed that is upstream from Grants Pass, Oregon. A few other reservoirs, such as Emigrant Lake, may also trap a small amount of sediment that would otherwise be delivered to the Rogue River. However, these drainage areas are small relative to that of the Rogue River, and they were not within the scope of this study. This implies that the transport capacity of the river is larger than the amount of sediment currently supplied at Grants Pass. Therefore, it would be reasonable to assume that the present-day sediment load is equal to 70 percent of the total sediment transport capacity. The transport capacity was computed for a variety of flows to develop a relationship between discharge and present-day sediment load for input to the HEC-6t model (figure 14).

Based on the computed sediment-discharge rating curve for incoming sediment load, the average annual sediment load of the Rogue River was computed and used as the input boundary conditions for the sediment model. Mean daily flows since 1977 (when Lost Creek Dam was completed) were used to compute the present-day average annual

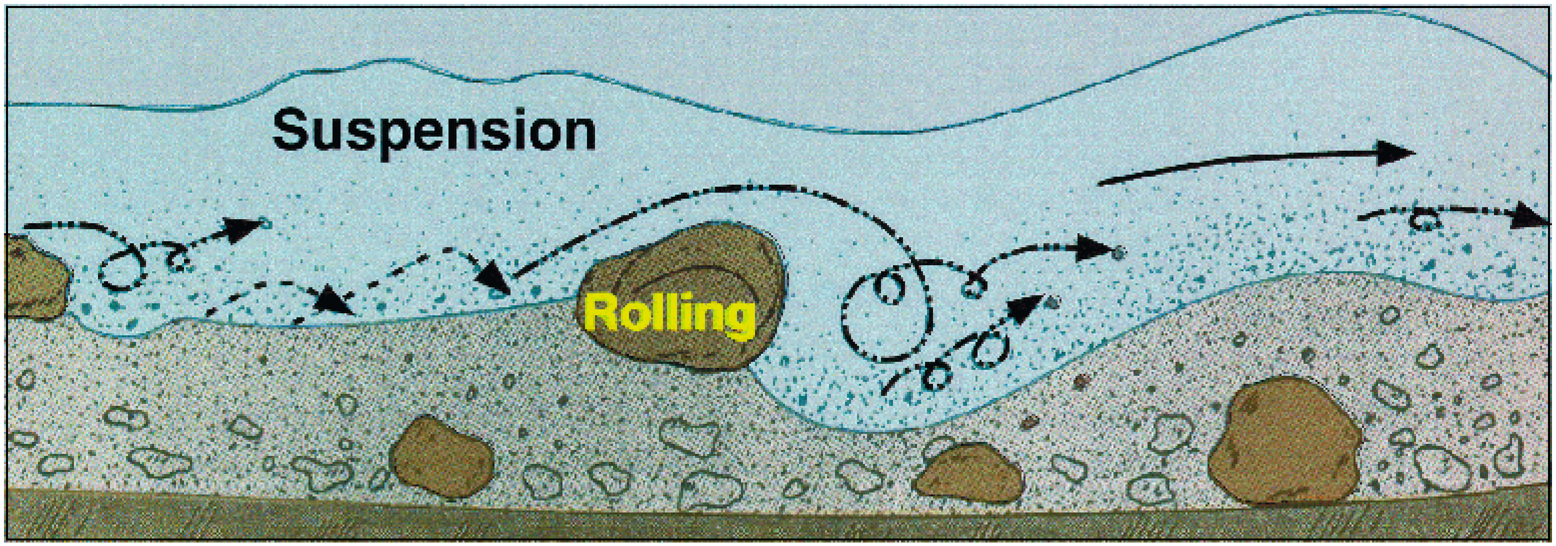


Figure 12.—Coarse sediment (sand and gravel) are transported as bedload along the river channel bottom. Fine sediment (silt and clay) are transported in suspension.

Figure 13. - Upstream face of Savage Rapids Dam - During a reservoir drawdown in May 1999, gravel-sized sediment was observed on the crest of the dam, indicating that sediment is transported past the dam during spillway releases.

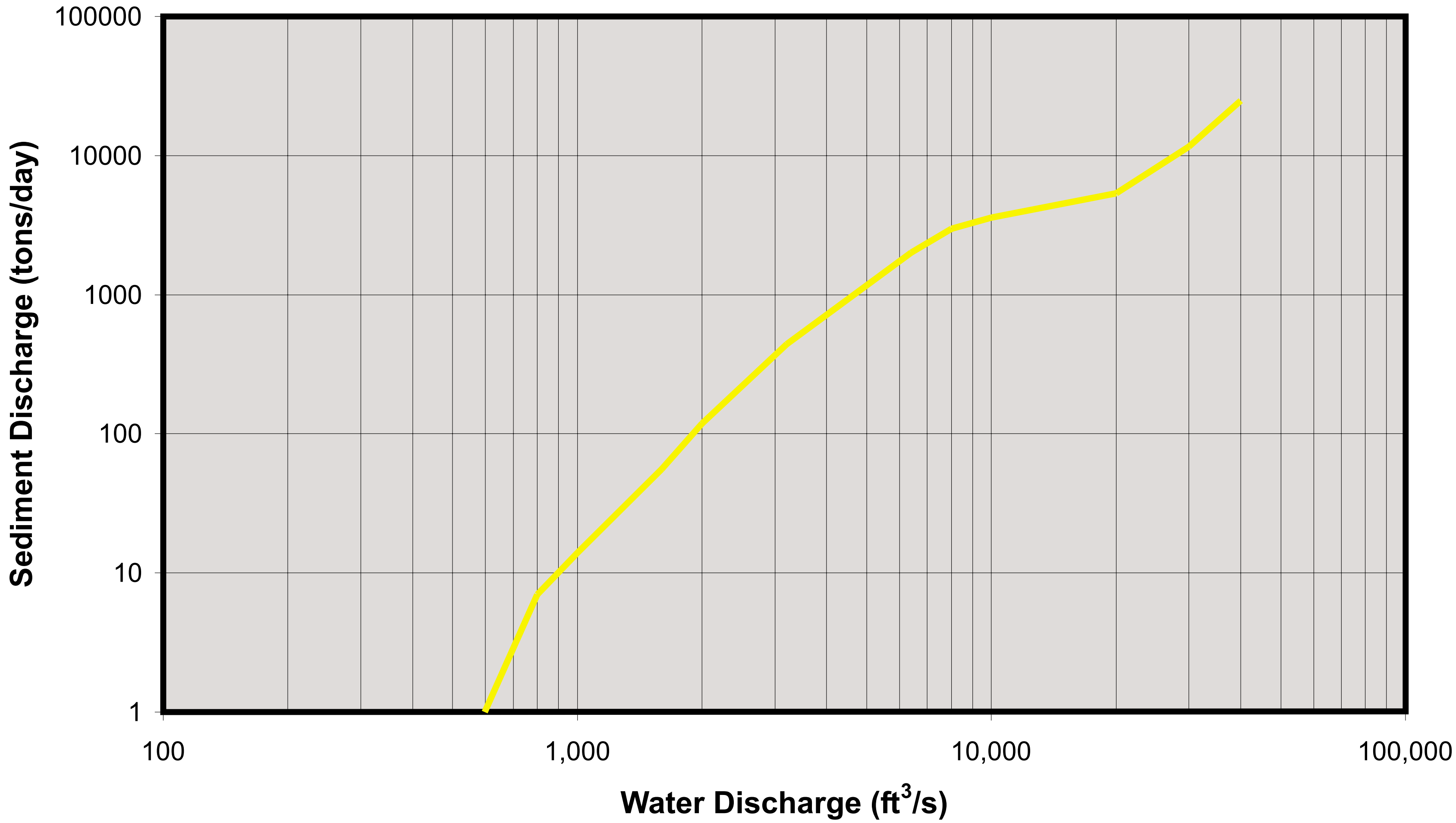


Figure 14. - the sediment transport capacity was computed using the HEC-6t sediment model for a variety of flows to develop a relationship between discharge and incoming sediment load of the Rogue River near Grants Pass, Oregon.

sediment load, approximately 100,000 cubic yards (yds^3). The sediment load accounts for 70 percent of the transport capacity. While there is no true average year on a river, the 200,000 yds^3 of reservoir sediments trapped behind the dam is roughly equivalent to two average years of sediment load carried by the Rogue River at Grants Pass. This volume quickly diminishes in scale as the river travels downstream past the confluences with the Applegate and Illinois Rivers, both large contributors of sediment to the Rogue River.

To ensure that the calculation of average annual sediment load was not overestimated or underestimated as a result of using mean daily flows rather than hourly flows (higher peak values), a comparison was made using hourly data from a winter 1996-97 storm (figure 15). Because two separate flow peaks occurred, the mean daily load actually overestimated the load computed with hourly values by 3 percent. In general, the mean-daily load would approximate sediment load values very well for the Rogue River, based on this comparison.

Modeled Hydrograph of Riverflows Following Dam Removal

The riverflows following dam removal are an unknown, but the historic flows on the Rogue River can be used as an indicator of what can be expected to happen in the future. Riverflows have been recorded since 1939 at a USGS gauging station near Grants Pass, Oregon (figure 16). Flood peaks on the Rogue River typically occur from November to March, with most occurring in December and January. The largest mean daily flow recorded on the Rogue prior to construction of Lost Creek Reservoir was 124,000 ft^3/s (instantaneous peak of 152,000 ft^3/s) in December 1964. Local records and photographs document that large portions of Rogue River, Oregon, were inundated, and numerous homes were destroyed. Following the construction of Lost Creek Dam, the frequency of flood peaks has declined significantly, as seen in the winter flood of 1996-97 (figure 17). The largest flood since Lost Creek Dam was constructed occurred during January 1997, when the mean daily flow reached 69,000 ft^3/s (instantaneous peak of 90,800 ft^3/s).

The Rogue River naturally transports sediments during high flows, when velocities and water depths increase, thus increasing the capacity of the river to transport material. Larger particles, such as sand and gravel, which are common particle sizes in the Rogue River, are transported along the channel bed and are therefore called "bed material." Smaller particles, such as silt and clay, are transported in suspension and are called "suspended material." The amount of sediment transported depends on both the size of the sediment and the unit stream power (velocity times slope) of the river. As flows recede and transport capacity is reduced, sediment is temporarily deposited along the channel bed in slow velocity zones, such as pools or eddies (areas of recirculating flow). This cycle is a natural process along the Rogue River. During wet years consisting of numerous high flows, more sediment is transported and reworked downstream than during dry years when very few high flows occur.

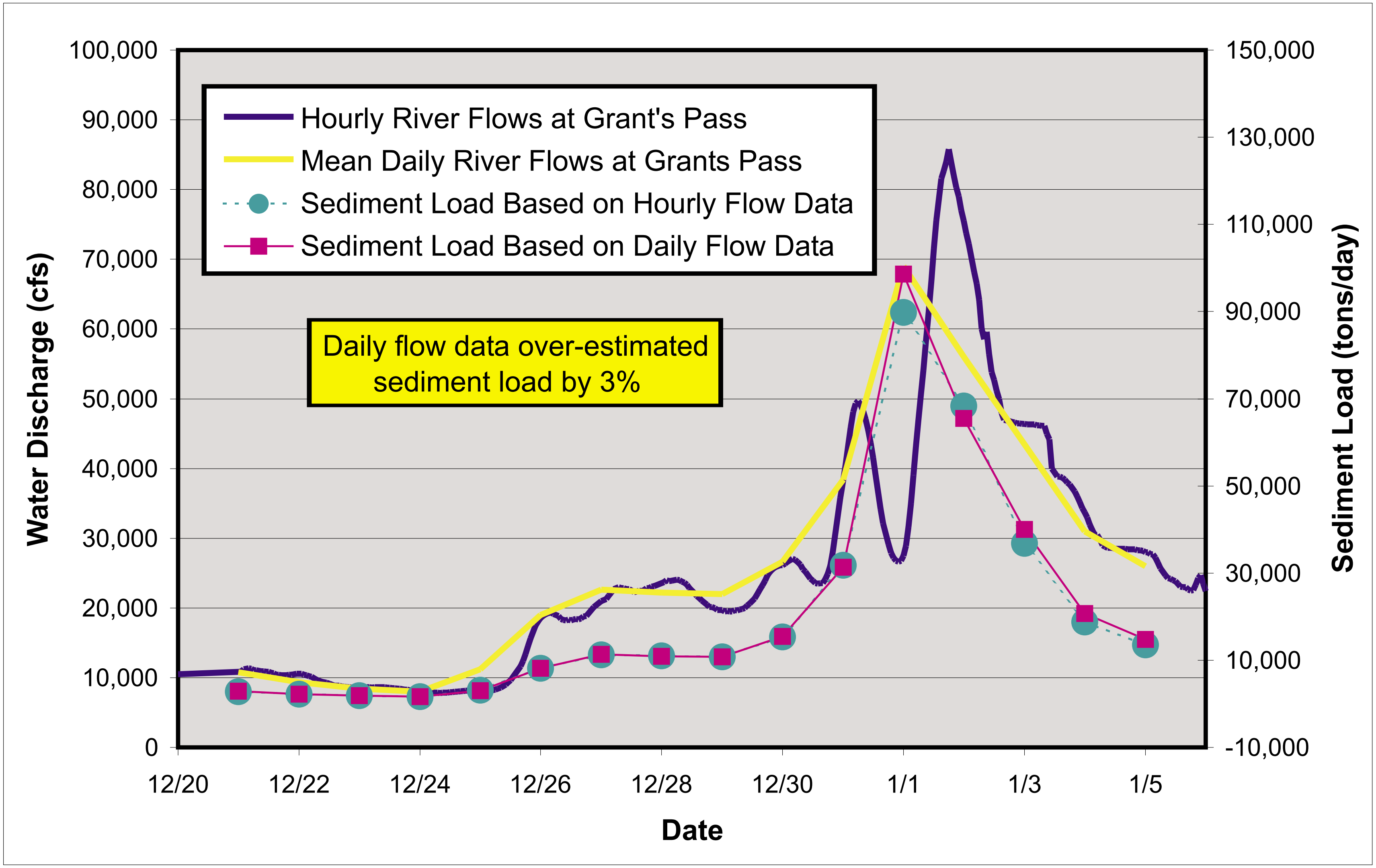


Figure 15. - A comparison between predicted sediment load using mean daily flows versus hourly flow data was done for the largest flood that has occurred on the Rogue River at Savage Rapids Dam since Lost Creek Dam was constructed in 1977. The results showed that both sediment load computation methods produced similar results. In this particular flood, there were 2 peaks, which causes the sediment load computations using the mean daily flow values to be greater since the mean daily flows (shown in yellow) essentially lump the two flood peaks (shown in dark blue) into one flood.

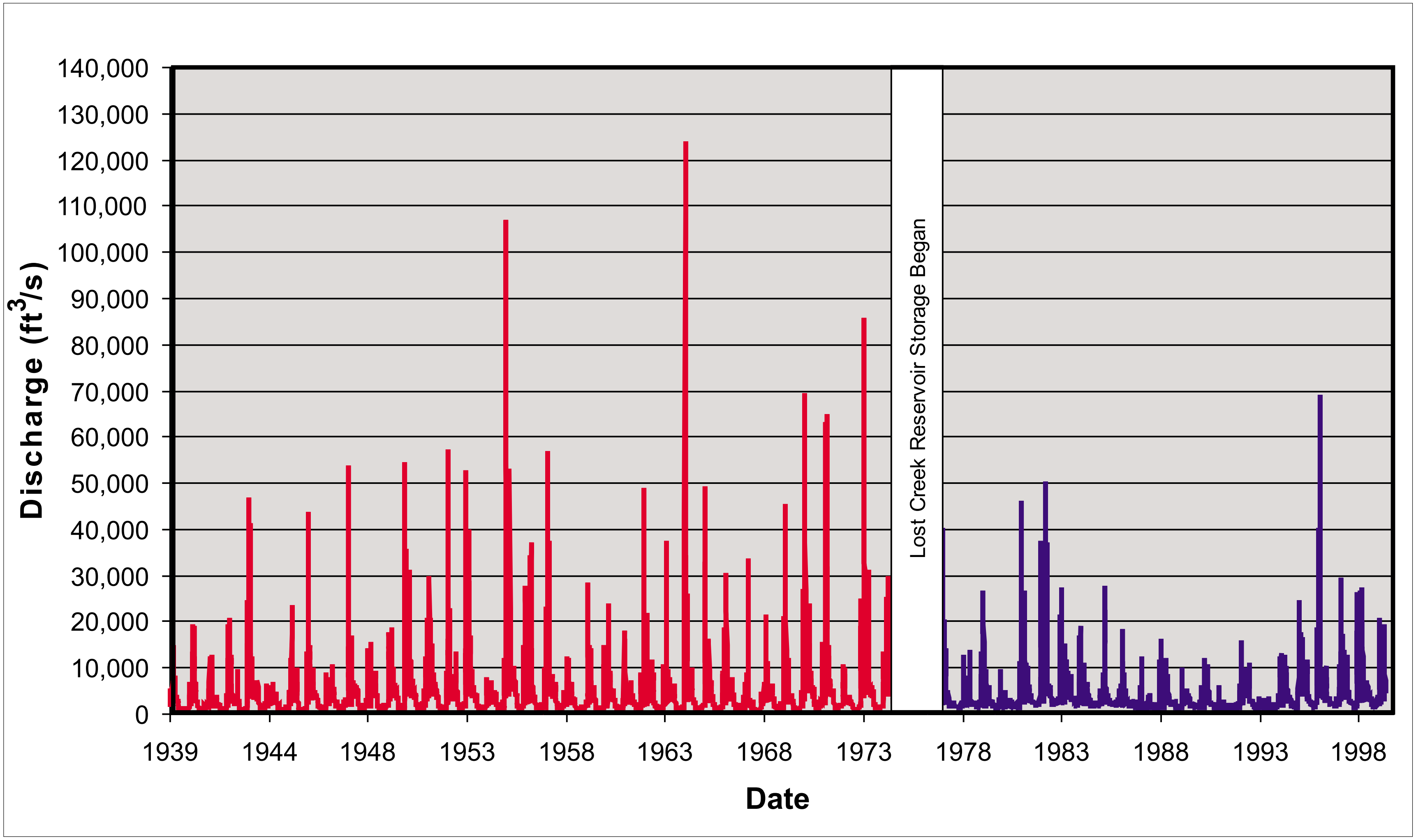


Figure 16. - Riverflows have been recorded on the Rogue river at the USGS gauging station at Grants Pass, Oregon, since 1939. In February 1977, storage in Lost Creek Reservoir (a flood control reservoir located 50 miles upstream from Savage Rapids Dam) began resulting in a reduction of flood peaks at Grants Pass. Since Lost Creek Dam was built, the largest flood occurred during the winter of 1996-97. Several years during the late 1980s and early 1990s had very few peak flows during the winter flood season.

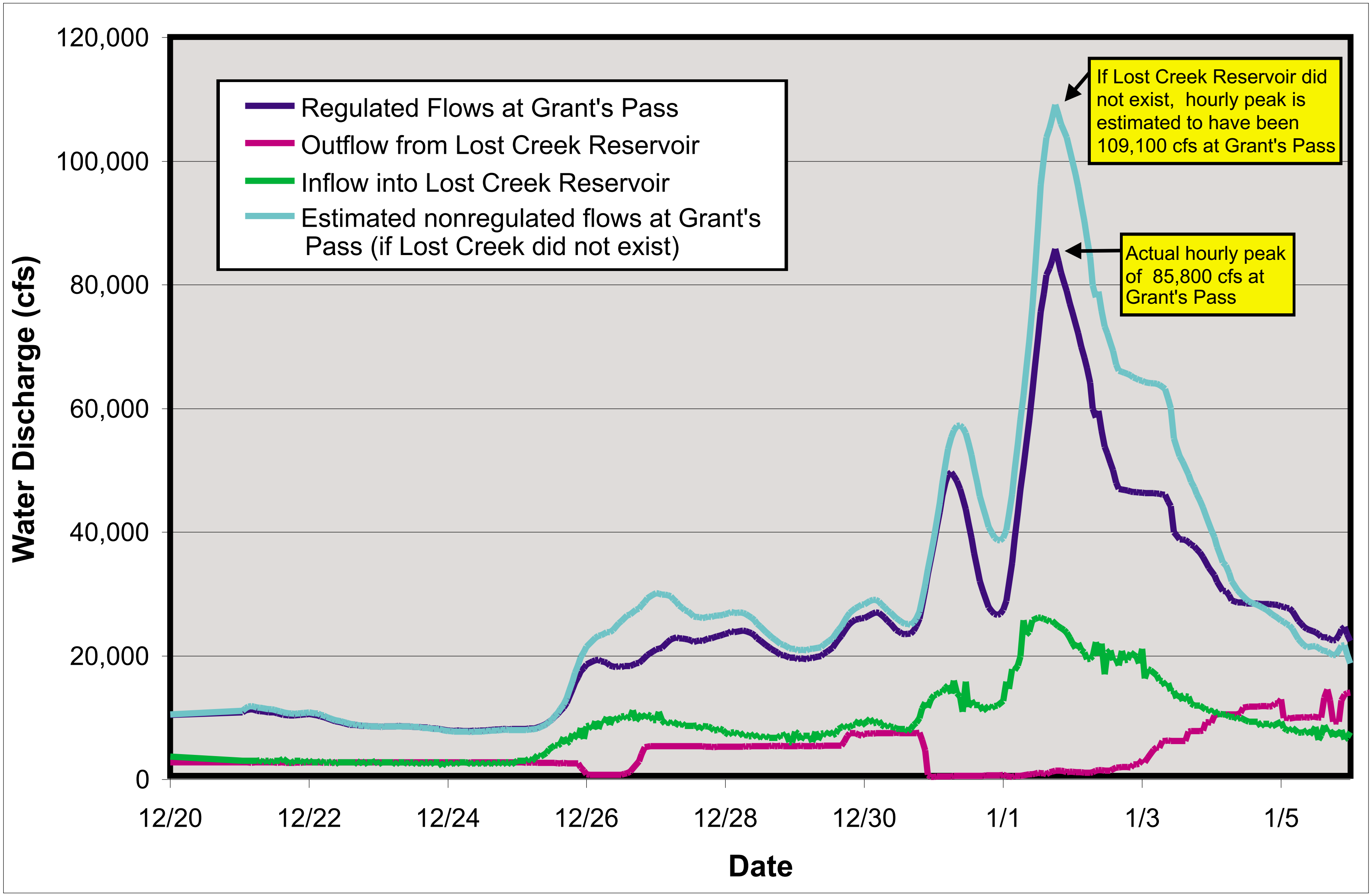


Figure 17. - Following the construction of Lost Creek Dam, the frequency of flood peaks at Grants Pass have been significantly reduced. However, during large peak flows, such as the one depicted in the winter 1996-97 hydrograph above, flows at Grants Pass are still large in magnitude even with the regulation at Lost Creek Reservoir.

Riverflows following dam removal will determine how fast the reservoir sediment is transported downstream. The more frequent the peak flows and the greater their magnitude, the quicker sediments will be transported to the ocean. Looking at the historic data since Lost Creek Dam was constructed (see figure 16), a period of dry years (where very few winter storms occurred) started in the late 1980s. Before and after this period, several wet years were recorded when numerous winter storms occurred. Two possible extremes were modeled: (1) dam removal followed by several dry years, as occurred in the late 1980s, and (2) dam removal followed by the wettest year that was recorded (winter of 1996-97), followed by subsequent wet years. Both scenarios used the period of record data (in chronological order) since 1977 because these are realistic flow values that actually occurred on the Rogue River.

The first scenario represents the extreme of starting the dam removal and reservoir sediment erosion at the beginning of the dry years on the Rogue River, as seen in the historical data. The hydrograph starts at the first year of the dry cycle in 1987 and ends with the wet year cycle (figure 18). When the end of the period of record was reached in year 2000, the hydrograph data were wrapped to include the 1977 to 1987 data. The second scenario represents the other extreme of starting the dam removal in a year with the highest recorded mean-daily flow, 69,000 ft^3/s (winter 1996), followed by several wet years (1997-2000) and ending with the drought that started in the late 1980s (figure 19). Both hydrologic extremes modeled a possible dam removal in May (the summer low flows and the irrigation season start in May) and in November (after the irrigation season but at the start of the winter flood season).

Model Priming

The manual for HEC-6 states that if the calculated sediment model results do not follow the observed trends, the user must "prime" the model (Corps, 1993). There are eight downstream river pools between Savage Rapids Dam and the Applegate River that are prone to significant sediment deposition because of their relatively low sediment transport capacity. The initial sediment model results showed that these eight river pools would fill to capacity as a result of the release of reservoir sediments following a dam removal (attachment D). However, measured data indicate that the annual sediment load currently getting past the dam during high flows has not caused these pools to fill up. If this model result were true, these pools would have filled long ago from the natural sediment load of the river. Priming the model allows the user to stabilize the model for natural conditions (estimated incoming sediment load), and then model only the net change from a significant event, such as the removal of a dam.

Although the initial results could not be used to model the dam removal until model priming is done, the results can be used to approximate the maximum sediment storage capacity of these eight pools (table 1). This capacity of 280,300 yds^3 accounts for 61 per-cent of the total storage capacity downstream from the dam and is nearly 1.5 times the reservoir sediment volume. The remaining 39 percent of sediment storage capacity is in the 10 shallow pools and several eddies that exist throughout the reach.

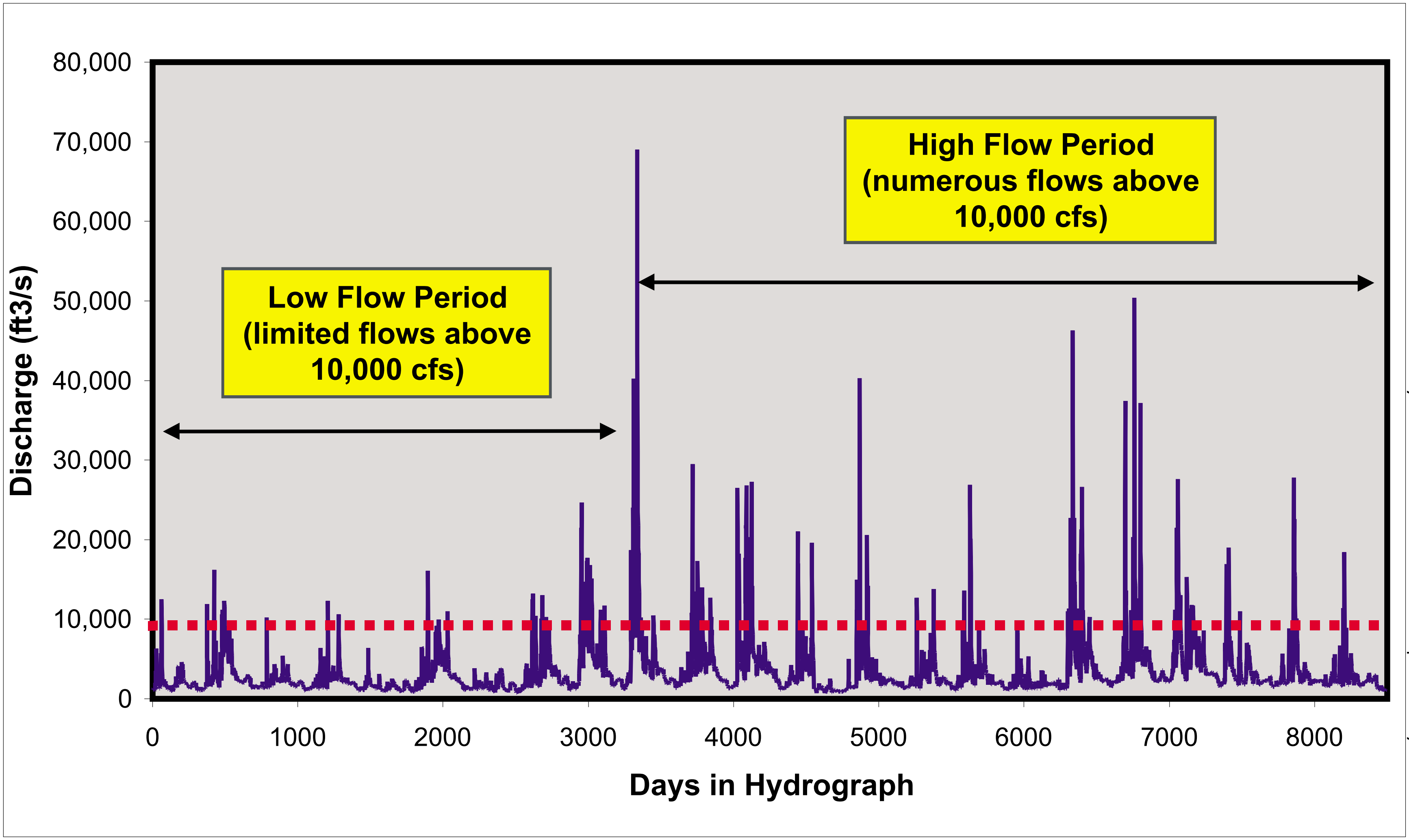


Figure 18. - Hydrograph A represents one possible scenario of riveflows following dam removal. This hydrograph begins with a dam removal followed by a dry period where very few peak flows occur during the winter flood season. This hydrograph was created using actual USGS data at the gauging station at Grants Pass since 1977 when Lost Creek was established.

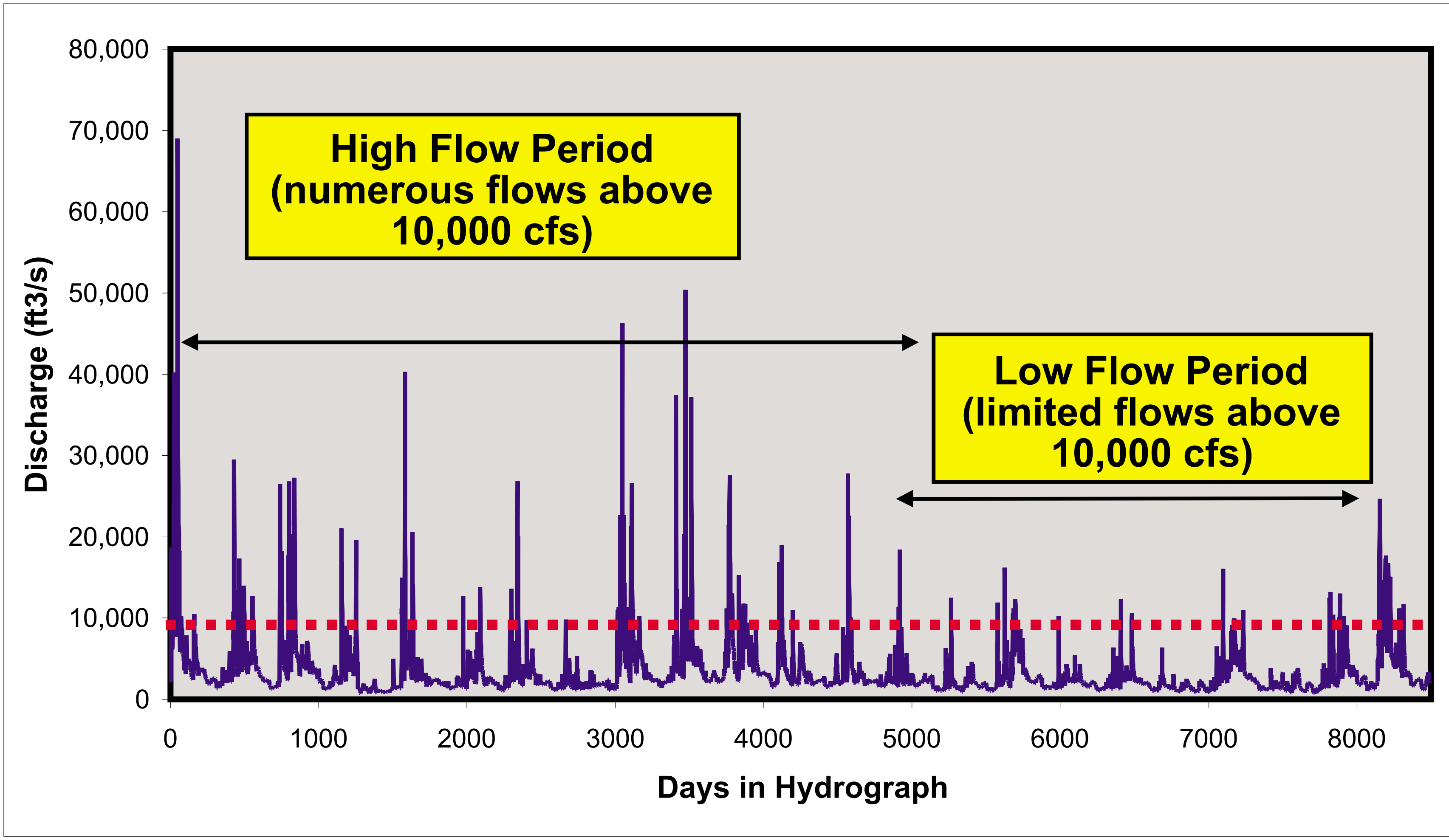


Figure 19. - Hydrograph B represents one possible scenario of riverflows following dam removal. This hydrograph begins with a dam removal followed by a wet period where several peak flows occur during the winter flood season. This hydrograph was created using actual USGS data at the gauging station at Grants Pass since 1977 when Lost Creek was established.

Table 1. — Maximum sediment storage capacity of deep river pools downstream from Savage Rapids Dam

	River mile location (middle of pool)	Maximum sediment storage capacity (yds³)	Cumulative sediment storage capacity (yds³)	Cumulative % of total storage downstream (Dam to Applegate River)
Savage Rapids Dam	107.60	—	—	
Pool 1	106.04	69,600	69,600	15
Pool 2	105.58	32,600	102,200	22
Pool 3	105.37	35,600	137,800	30
Pool 4	105.00	300	138,100	30
Pool 5	103.06	14,900	153,000	33
Pool 6	102.06	28,000	181,000	39
Pool 7	98.78	25,300	206,300	45
Pool 8	96.79	74,000	280,300	61
Applegate River	95.00	—	—	

To prime the model, a flow hydrograph was created that consisted of approximately 1-½ years of a constant flow of 8,000 ft^3/s, followed by the period of flow record in chronological order from 1977 to the present (24-½ years). A constant flow of 8,000 ft^3/s was chosen to start the priming run because it allows the model to initially stabilize at a flow that is large relative to typical low flows but smaller than typical peak flows on the Rogue River. After modeling a series of several floods, deposition from the natural Rogue River sediment load occurred mainly in the eight river pools with depths greater than 10 feet (attachment E). The final geometry from the model priming run was used as the input geometry for modeling the various dam removal scenarios.

Study Results and Discussion

Erosion of Reservoir Sediments

Savage Rapids Reservoir is only 2 to 3 times wider than the surrounding river channel. This means most of the reservoir sediment trapped behind the dam would be eroded by the river rather than stranded as the water surface elevation of the river quickly decreases following dam removal. Small sediment deposits may permanently remain along the margins of the reservoir.

An initial flushing of reservoir sediment would occur immediately following removal of the dam. This flushing occurs because, as the dam is removed, the river would begin incising through the sediment deposits behind the dam. This incision process and sediment flushing would continue until a stable slope is reached upstream from the dam site. This flushing would cause sediment concentrations[1] downstream from the dam to significantly increase for a short duration immediately following dam removal (figure 20). After the initial flushing, successively higher flows would be required to again increase the sediment load to the downstream river channel. As the reservoir sediments were transported past the Applegate, the concentration levels as a result of removing the dam would gradually diminish over time. Sediment concentrations will be much higher than natural conditions during the first flood following dam removal. These high concentrations will tend to decrease toward natural levels with each subsequent flood. Between floods, sediment concentrations will be relatively low.

Model results show that if Savage Rapid Dam is removed, virtually all the sediment would be eroded from the reservoir (figure 21). Regardless of when the dam is removed and what magnitudes of flows occur, about three-fourths of the reservoir sediment will be eroded within the first year after dam removal.

Transport of Reservoir Sediments Downstream from Dam

The volume of reservoir sediment stored behind Savage Rapids Dam is about 200,000 yds^3, and the sediment storage capacity of the reservoir is essentially full (Appendix A). Therefore, most of sediment that enters the reservoir from upstream is transported through the reservoir, and net sediment volume in the reservoir never significantly changes. The river pools downstream from the dam temporarily store a portion of the sediment during low flow periods, but this sediment tends to be flushed (scouring the pools) by high river velocities during floods. This natural process was observed at the USGS gauge cross section near Grants Pass (see figure 7). During a winter storm in 1996–97, the channel bed at this section scoured out 6 feet and subsequently filled back in during low-flow periods in the following year. The channel bed in this river pool was scoured 6 feet during the first peak flood in December, 41,200 ft^3/s (a second peak flood, in January, reached 69,000 ft^3/s). During the following year, this pool slowly filled back in with sediment to its pre-flood conditions.

The sediment that is eroded and flushed from the reservoir (following a dam removal) would be transported downstream. This sediment would temporarily deposit in pools and eddies (zones of recirculating flow). As sediment deposits along the bottom of pools and eddies (decreasing water depths), river velocities would increase until the velocities become so high that sediment would be transported through the reach rather than deposited. Sediment deposition in pools and eddies would most likely occur during low-flow periods. Subsequently, the sediment would be scoured out and transported downstream during high-flow periods. Eventually, all the sediment would be eroded and reach the ocean.

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[1] Sediment concentration refers to the mass of sediment transported by the river per unit volume of water. Sand-sized sediment is transported in suspension through riffles, rapids, and short pools where velocities and turbulence are high. Coarse-sized sediment (gravel and cobble) is transported as bed load.

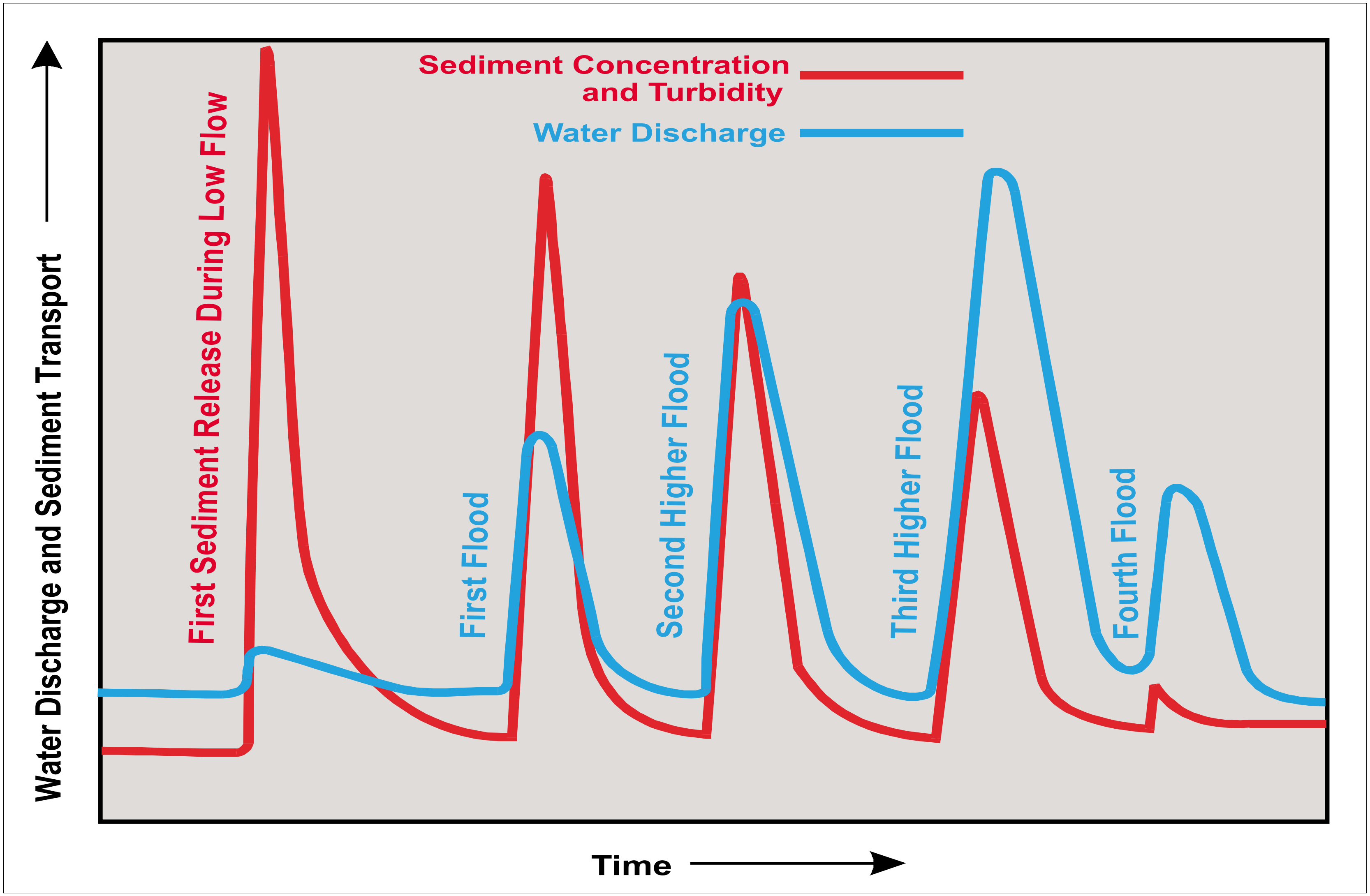

Figure 20. - Conceptual depiction of the relationship of water discharge and sediment transport in the downstream river channel folloing removal of a dam.

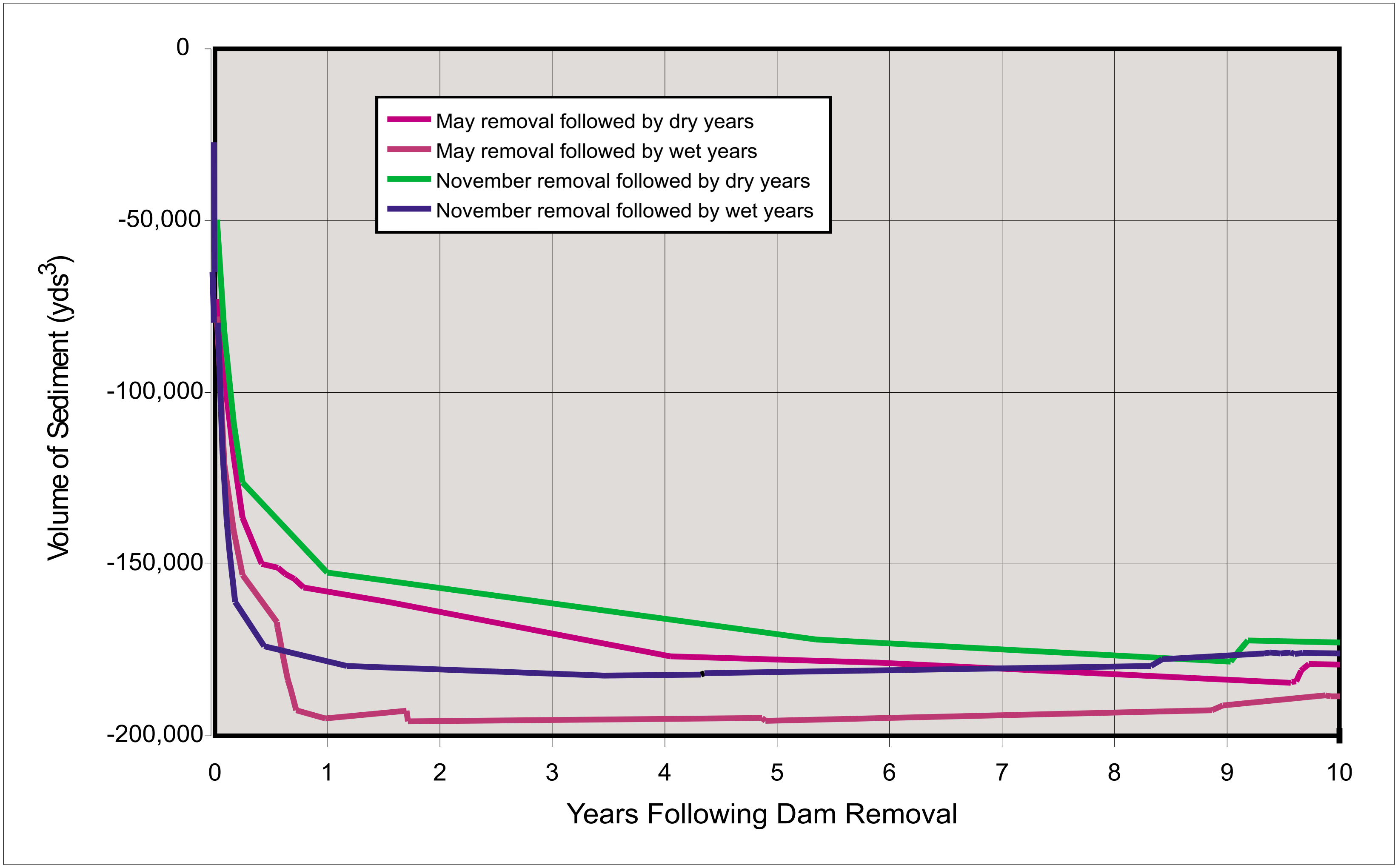

Figure 21. - This plot shows the volume and rate of sediment eroded from the reservoir following each of the four dam removal scenarios. Regardless of the hydrology in the first few months following dam removal, at least three-fourths of th reservoir sediment will be eroded in the first year. The time period before the remaining reservoir sediment would be eroded depends on the frequency and magnitude of peak flows following dam removal.

The reservoir sediment would be transported downstream from the Applegate River within a 1- to 10-year period, depending on the frequency and magnitude of high-flow periods following dam removal (figure 22). The 1-year timeframe represents the dam removal followed by an extremely wet year with several high flows, and 10 years would be a dam removal followed by several dry years with very few or no high flows. Most sediment transport would occur during floods. If flood magnitudes following dam removal are high and floods occur frequently, the reservoir sediment would reach the ocean within a few years. If the flood magnitudes are low or floods occur infrequently, the reservoir sediment would reach the ocean over a much longer period of time. Under either scenario, sediment concentration and transport rates would be relatively low and near natural levels between floods.

As the sediment wave moves downstream, maximum deposition levels will occur at various times following dam removal, but not all at once. To show exactly how the sediment wave moves through the river system, a series of model results at selected time periods following dam removal was generated. The results for the dam removal in May followed by several dry years (very few high flows) is presented as individual hard copy plots (attachment F).

Attachment F includes longitudinal plots of the first 5 miles downstream from the dam showing channel bottom elevation, water surface elevation for reference, and the sediment deposition at each particular time period. The results indicate that deposition levels will range from 1 to 8 feet in river pools. Even during maximum deposition, pools that exist today will continue to exist following dam removal. Therefore, no flooding as a result of the dam removal is predicted to occur because all of the deposi-tions will occur in river pools, which will not cause any increases in water surface elevation. Areas downstream from the dam that are currently high-velocity areas, such as riffles or very shallow pools, would be subject to only minor deposition. Reservoir sediment would be transported fairly quickly through these areas during high-flow periods.

As indicated by the Rogue River stream power figure (figure 4), once the sediment passes the confluence with the Applegate River, it would be transported all the way to the Pacific Ocean. A study completed by the Corps documents that most of sediment found at Gold Beach, near the mouth of the Rogue, is sand and gravel-sized sediment, indicating that the sediment behind Savage Rapids Dam would be easily transported to the ocean (Corps, 1997). As the sediment travels through Hellgate Canyon, some temporary deposition could occur, but because of the steep slope of the canyon and narrow widths, sediment transport capacity would be very high, and sediment would probably travel through quickly (see figure 3). The amount of time for the sediments to reach the ocean depends on the frequency and magnitude of high-flow events. If several high flows were to occur immediately following dam removal, reservoir sediments would reach the ocean within a few years. However, if a long period of low flows occurs following dam removal, it could take decades for all the reservoir sediment to reach the ocean. As the sediment reaches the Pacific Ocean, the reservoir sediment

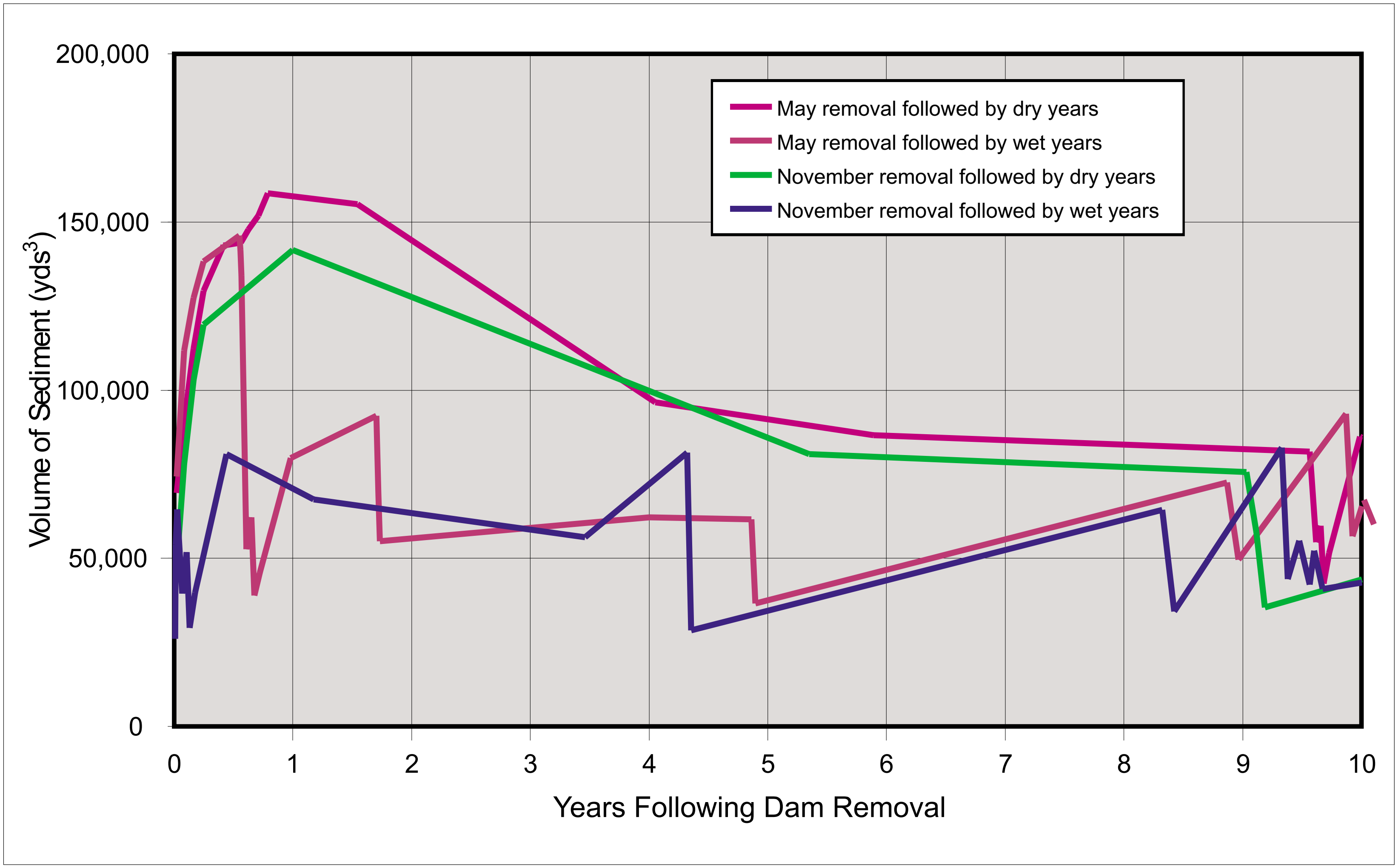

Figure 22. - This plot shows the volume of reservoir sediment deposited in river pools in the 12.5-mile reach of river downstream from the dam for each of the four dam removal scenarios. Based on these results, the reservoir sediment will temporarily deposit in river pools but will be transported downstream from the Applegate River within a 1- to 10-year period.

load would diminish in size relative to the natural sediment load carried in by the Rogue River and its two main tributaries (Applegate and Illinois).

Predicted River Channel in Savage Rapid Reservoir Following Dam Removal

Prior to the dam, a riffle existed at the dam site, and there was a pool immediately upstream (see figure 11). These river features would be restored as the sediment that currently buries them is eroded and transported downstream. If the dam were to be removed, the water surface elevation in the ½-mile reach upstream from the dam would be lowered to near the pre-dam elevation (figure 23) and would look much different from the way it looks today. However, upstream from the public boat ramp, the new water surface elevation would be essentially the same as it is today during the non-irrigation season when the stoplogs are pulled out and the reservoir is lowered to the permanent pool level.

The velocities through the dam site following a dam removal were also estimated (figure 24). Three possible scenarios were evaluated to determine if removing the entire dam versus only a portion of the dam would impact velocities. Most of the river channel south of bays 10 and 11 (where radial gates now exist) is bedrock that would still exist after removing the dam. The results show that if bays 1 through 11 were removed, velocities would never exceed 10 feet per second at flows lower than 30,000 ft^3/s. Existing velocities in Pierce Riffle, approximately 1 mile downstream, do not typically exceed 8 feet per second.

Sediment-Related Impacts to River Infrastructures as a Result of Dam Removal

In addition to the environmental impacts resulting from periods of high sediment concentration (weight or volume of sediment transported by a stream in a unit of time) and from temporary deposition along the riverbed following dam removal, there are concerns about the impacts to specific structures located along the Rogue River downstream from the dam (attachment B). Sediment-related impacts are addressed in this study for the structures listed below:

- Two pumping plants would be constructed (one on each side of the river) immediately downstream from the dam to enable the Grants Pass Irrigation District to deliver water to its members through the irrigation canals during and after dam removal (figure 25).

- The existing Grants Pass city water treatment plant and intake structures are located about 5 miles downstream from the dam (figure 26).

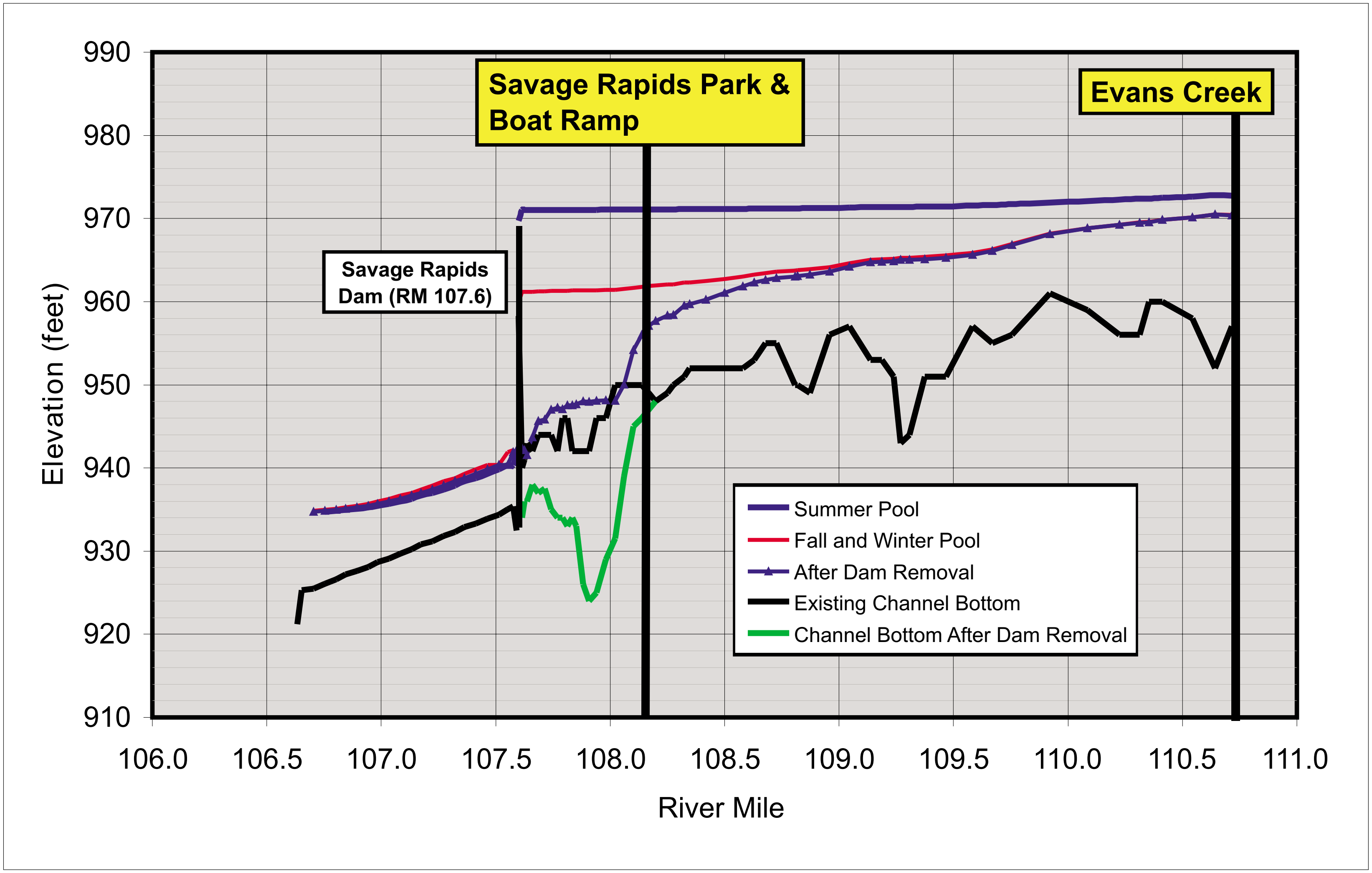

Figure 23. - This plot shows the channel bottom and water surface elevation for Savage Rapids Reservoir for both existing conditions and following dam removal. The water surface elevation and channel bottom will change significantly in the ½-mile reach upstream from the dam that is currently the permanent reservoir pool. However, upstream from the public boat ramp, the river would be essentially the same as it is today during the nonirrigation season in the fall and winter.

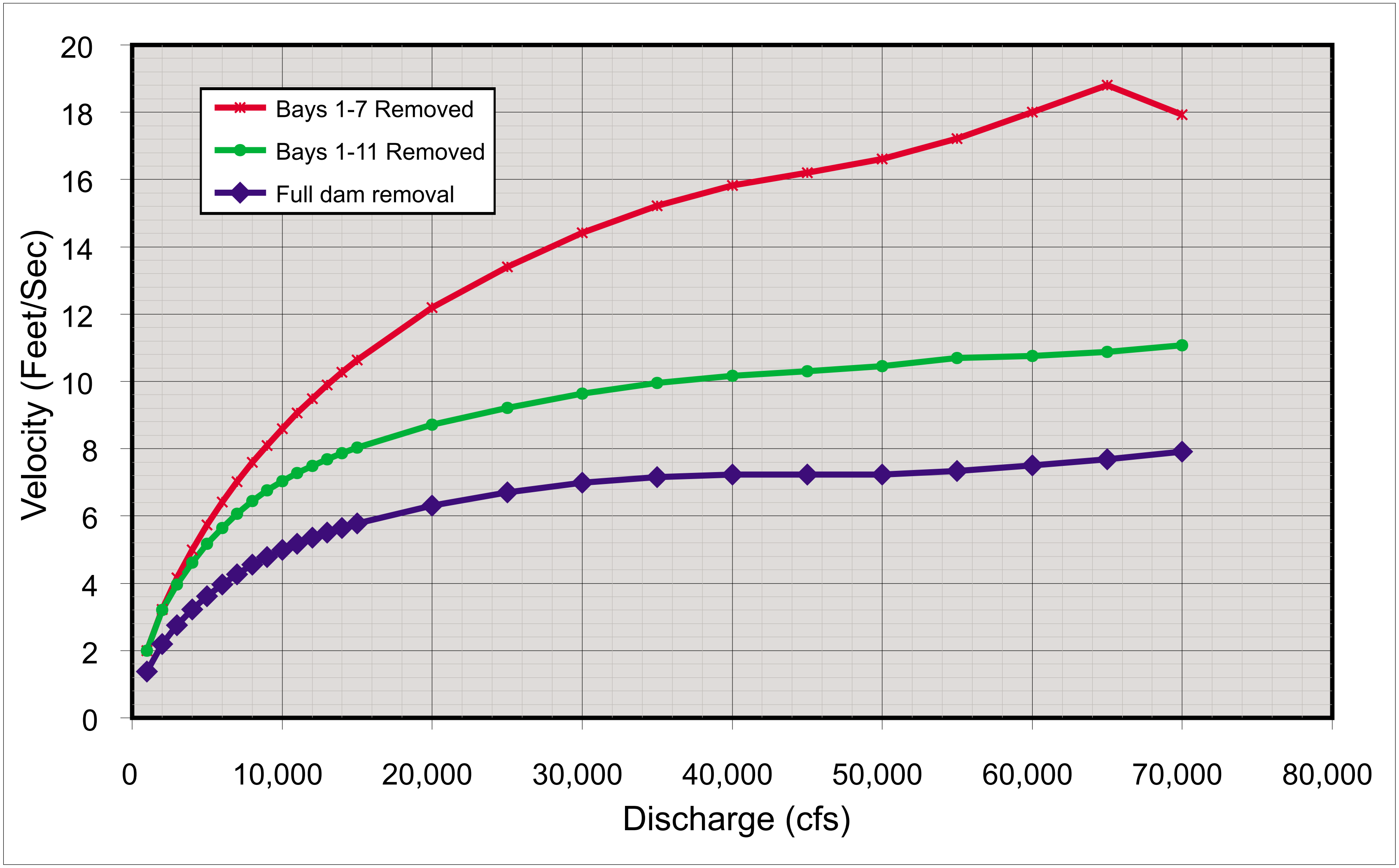

Figure 24. - This plot shows the predicted velocities at the dam site for a series of discharges for three possible dam removal options. The three options estimated were a dam removal of only bays 1-7 (in order from river right), removal of bays 1-11 (including the existing radial gates in bays 10 and 11), and removal of the entire structure.

Figure 25. - Looking downstream from Savage Rapids Dam at the proposed location of the two pumping plants which would supply water for the Grants Pass Irrigation District. One plant would be constructed on each side of the river.

Figure 26a (left) and 26b (right. - Looking at two views of the intake structure for the city of Grants Pass. The structure is located 5 miles downstream from Savage Rapids Dam on river right (looking downstream).

Irrigation Pumping Plants.—If the dam were removed during the irrigation season and the reservoir sediment were allowed to erode downstream, sediment concentrations (weight or volume of sediment transported by a stream in a unit of time) in the river channel (downstream from the dam) would be higher than normal. Because the new pumping plants would be located just downstream from the dam, there is concern that sediment would deposit around the fish screens, at the pump intake, and in the intake channels between the river and pumping plants. If coarse sediment (sands and gravels) entered the pumping plant, it could damage the pumps, through abrasion, and potentially deposit along the irrigation canals. Fine sediment (silt and clay) would not damage the pumps or deposit in the canals. The best way to eliminate or minimize these potential impacts is to prevent coarse sediment from depositing around the fish screens or entering the pumping plants. This would be accomplished by locating the pumping plants along the river channel where the river velocities are relatively high and parallel to the fish screens. A low-elevation submerged training wall could be constructed in the channel to divert coarse sediments, which are transported as bed load, away from the fish screens. Temporary dredge pumps could also be employed to remove sediment from the fish screens and pumps, if necessary.

If the reservoir sediment is allowed to erode during the nonirrigation season, it would not impact the pumps or the irrigation canals because they would not be in operation. Some sediment may deposit around the fish screens or intake channel, but that sediment could be removed prior to the beginning of the next irrigation season.

After the initial flushing of the reservoir sediment, additional sediment would erode only during high-flow periods that would most likely occur during the nonirrigation season, when the pumping plants would not be in operation. During the irrigation season, riverflows and natural sediment loads would tend to be low. In fact, very little coarse sediment would be transported during the low-flow (irrigation) season. There-fore, sediment impacts on the pumping plants would be minimal after the initial flushing of reservoir sediment has occurred following dam removal.

City Water Treatment Plant Intake Structures.—As mentioned above, sediment concentrations would be greatest if the reservoir sediments are first allowed to erode and be transported downstream during the irrigation season, when riverflows tend to be low. As sediment is transported downstream by riverflows, some sediment would deposit in river pools and eddies (especially during low flows), and peak concentrations would reduce in the downstream direction. Because the Grants Pass city water treatment plant is located 5 miles downstream from the dam, and there are several deep pools in this reach, sediment concentrations would be less at the treatment plant than at the irrigation pumping plants.

In general, getting suspended fine sediment (silt and clay) to settle out of water diverted from the river can sometimes be a difficult task for water treatment plants, especially if the concentrations are high. However, the percentage of fine sediment trapped behind

Savage Rapids Dam is very low (2 percent), so it should not pose a significant problem for the city water treatment plant. Coarse sediment would rapidly settle in the treat-ment plant, but large settling volumes would require additional dredging and disposal, and this would lead to increased labor costs. The reservoir sediment is predominantly sand (71 percent), and the volume of sand entering the treatment plant during the initial flushing of reservoir sediment would likely increase. In general, gravel-sized sediment would be too coarse to enter the treatment plant.

The amount of sand deposition within the treatment plant resulting from dam removal is difficult to predict with certainty. There are no measurements of sand transport by the Rogue River in the vicinity of the treatment plant. Also, the concentration of sand entering the treatment plant, relative to the sand concentration in the river, is not known. However, it is known that, under existing conditions, the amount of sand that enters the water treatment plant is generally between 5 to 15 yds^3 per year (G.A. Geer, City of Grants Pass, written communication, September 1, 2000), and nearly all of that volume enters during high-flow periods. Most of the sand in the existing riverbed is covered by gravel. Because it takes a fairly high flow to transport gravel, sand remains trapped at low flows, and the concentrations of sand transported by the river are near zero. However, when riverflows are high enough to transport the gravel on the surface of the riverbed, the sand transport rates dramatically increase and continue to increase exponentially with additional increases in riverflow.

During the removal of Savage Rapids Dam, the reservoir sediments would begin to erode, even at low flows, in response to the higher river velocities through the former reservoir area. Sand and gravel-sized sediments would be transported downstream as a long wave, but this wave would tend to diminish because sediment particles would temporarily deposit in river pools during periods of low flow. The river pools would progressively fill (in the downstream direction) to their sediment storage capacity, resulting in a significant portion of the reservoir sediments being temporarily stored in these river pools. The sand and gravel that is transported past the river pools would eventually reach the intake structure, and sand concentrations in the river would be temporarily high. The concentrations of sand in the river would reduce as the peak of the sand wave passed the intake structure during the low-flow period. Sand concentrations would remain low until riverflows were high enough to transport the sand that would be temporarily stored in the river pools. During high riverflows, sand concentrations would be temporarily very high, but the river velocities near the intake structure would be very large relative to the velocities entering the treatment plant. This would tend to limit the concentrations of sand entering the treatment plant, thus reducing potential settling volumes.

The concentrations of sand being transported by the river vary with depth and with location across the channel. Sand concentrations are much greater near the riverbed than near the water surface and tend to be greater along the outside of river bends than along the inside of bends. The intake structure for the city water treatment plant is located on the outside of a river bend and is relatively deep in the water. However, intake structures are normally designed to minimize (to the extent possible) the entrainment of coarse sediment. For computational purposes, the concentration of sand entering the treatment plant was assumed to be equal to the mean concentration in the river. Sand transport computations for the river indicate that riverflows have to exceed 21,000 ft^3/s before gravel and sand can be transported by the river and sand concentrations are high enough to enter the treatment plant. The computed relationship between sand transport and riverflow (figure 14) was applied to the historical flow records to predict the sand concentration of the river and the concentration entering the treatment plant under existing conditions. Because this relationship does not account for the fact that the riverbed sand is covered by gravel, computed sand transport rates were set at zero when the riverflows were less than 21,000 ft^3/s. This procedure yielded a mean annual sand deposition rate in the treatment plant of 10 yds^3 per year, which matches the deposition rate experienced by the city.

Sediment model results for high-water years following dam removal indicate that 80 yds^3 of sand could deposit in the treatment plant within the first year following dam removal. Peak rates of sand deposition could exceed 10 yds^3 per day for a few days and exceed 30 yds^3 over a 1-week period (figure 27). Actual sand deposition volumes may be much less than the model predictions. Based on the assumed hydrology, sand deposition volumes would decrease to 20 yds^3 during the second year following dam removal. After that, deposition volumes would be nearly the same as under existing conditions. Sand deposition rates in the treatment plant would be less if dam removal were followed by low-water years, but the duration of impacts would be extended to several years.

High rates of sand deposition in the treatment plant could cause rapid wear on the pumps and complicate the method of removing sand from the plant's three sedimentation basins. From the perspective of the city water treatment plant, it would be best to release sediment from the reservoir during the period November through March. This would allow for large portions of the sediment to be quickly transported past the treatment plant during high-flow periods. During these months, the water treatment plant is operated at a slower pumping rate and for fewer hours per day (G.A. Geer, City of Grants Pass, written communication, September 1, 2000). The combination of a slower pumping rate and fewer hours of daily operation would lessen the impact of both fine and coarse sediment on the pumps and sedimentation basins.

There is concern that excessive deposition of coarse sediments in the vicinity of the water treatment plant could plug the intake structure. If this were to occur, a dredge would have to be employed to remove the coarse sediments. As a preventative measure, a submerged guide wall could be constructed in the channel that would force riverflows of high sediment concentration near the bed to flow past the intake structure. Surface flows of lower sediment concentration would flow over the wall and tend to flush the area around the intake structure.

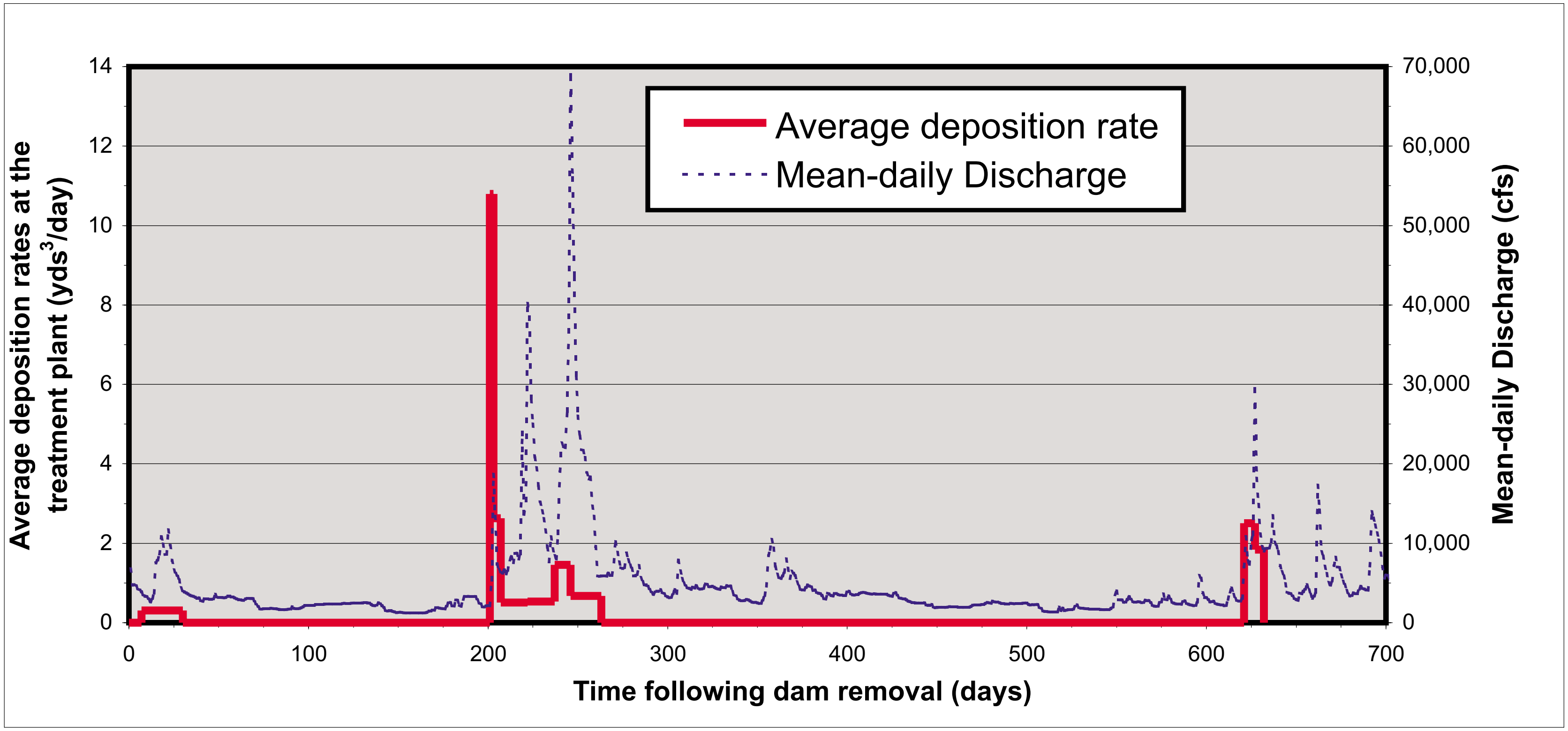

Figure 27. - Estimated deposition of sand at Grants Pass city water treatment plant following dam removal based on an assumed hydrology.

All the sediment-related impacts at the city water treatment plant can be handled, but at additional cost. These additional operating costs are difficult to estimate without knowing the future hydrology and the details of the dam removal plan but could be measured through a monitoring program. The results of this study, relative to the potential impact of sediment transport and deposition, would have to be addressed in future analyses detailing when and how the dam would be removed. Mitigation of adverse impacts that could occur at the Grants Pass city water treatment plant, or anywhere else, could be explored as part of the final design process.

Sediment Monitoring Recommendations.—This study identifies the potential sediment impacts if Savage Rapids Dam is removed. If a dam removal plan is imple-mented, the following recommendations for data collection would provide necessary information for monitoring the actual sediment impacts during and following dam removal:

- Detailed mapping of the eight deep river pools
- Sampling bed material of the eight deep river pools
- Continued measuring of discharge at the USGS gauging station
- Measuring bed load and suspended-sediment concentrations at the USGS gauging station at Grants Pass
- Continuous measuring of turbidity during and after dam removal at three locations: (1) the highway bridge at the town of Rogue River, (2) immediately downstream from Savage Rapids Dam, and (3) at the Grants Pass city water treatment plant river intake

Conclusions

This appendix describes what would happen to the sediment trapped behind Savage Rapids Dam if the dam were removed and the impacts to the river channel through the reservoir and downstream. Since the construction of Savage Rapids Dam, sediment has been trapped in Savage Rapids Reservoir. Nearly all this sediment has deposited in the ½-mile reach of the permanent reservoir pool just upstream from the dam. The sediment storage of the permanent reservoir pool is at full capacity, and likely became full within a few years after the dam was built. The volume of sediment that is trapped within the reservoir is 200,000 yds^3 (see Appendix A). This volume is roughly equivalent to two years of average annual sediment load for the Rogue River at Grants Pass, Oregon. Nearly 98 percent of sediment trapped with the reservoir is sand and gravel.

Because the reservoir contains all the sediment it can hold, sediment entering the reservoir from upstream passes through the reservoir and is transported to the downstream river reach. Both upstream and downstream from the reservoir, the river-bed surface is composed primarily of bedrock, boulders, gravel, and sand. The sand and gravel is transported primarily during winter floods and the spring snowmelt. Gravel-sized sediment is transported along the river bed (as bedload). Sand-sized sediment can be transported either as bed load or in suspension (suspended load). The reservoir is drawn down to the ½-mile-long permanent reservoir pool during the nonirrigation season to avoid flooding along the reservoir margins. During the nonirrigation season, river (rather than reservoir) conditions exist upstream from the permanent pool. During periods of high flow, velocities and turbulence increase, and the natural sediment loads of the river are transported through this reach. This is why the pools in the temporary reservoir reach have not filled with sediment.

Gravel and sand-sized sediment that is transported through the reservoir can deposit in downstream pools during low-flow periods. This coarse sediment is subsequently eroded and transported further downstream during floods. This cycle of erosion and deposition was documented at a USGS gauging station that is located in a river pool about 5 miles downstream from the dam. About 6 feet of erosion occurred along the channel bottom during a winter storm. The channel was gradually filled back in as sediment deposited during the low-flow period during the following year. The Applegate River, 12 ½ miles downstream of the dam, is the next significant contributor of sediment and water to the Rogue River. Downstream from the confluence with the Applegate River, the Rogue River passes through Hellgate Canyon, a steep, high- velocity, turbulent reach (average slope of 0.0024) that has high sediment transport capacity.

The Hec-6t (Thomas, 1996) sediment transport model was used to predict the rate at which the reservoir sediment would erode from the reservoir and the location and magnitude of deposition that might result downstream from the dam. This model was applied to the 2 ½-mile reach of reservoir and the 12 ½-mile reach of river downstream from the dam. At this time, a specific dam removal plan has not been determined. Therefore, model simulations were performed for the period immediately following dam removal. The river flows that would occur after dam removal are unknown; therefore, historic flow measurements since 1977 were used to simulate future conditions. Lost Creek Reservoir, built in 1977, regulates floods for a portion of the upstream watershed. This flood control regulation was assumed to continue in the future. Four different hydrologic scenarios were modeled based on flows measured by the USGS gaging station at Grant Pass, Oregon. The largest flood modeled was the flood that occurred in January 1997. It had a mean daily flow of 69,000 ft^3/s. Two scenarios assumed the dam would be removed in May, at the beginning of the irrigation season, and a series of either high-magnitude flow years or of low-magnitude flow years would follow the removal. The other two scenarios assumed the dam would be removed in November, at the start of the winter flood season, and either high-flow years or low-flow years would follow removal of the dam.

Savage Rapids Reservoir is only 2 to 3 times wider than the river channel. During dam removal, most of the reservoir sediment trapped behind the dam would be eroded by the river. Small amounts of sediment could remain along the margins of the lower reservoir. As the permanent reservoir pool is lowered (during dam removal), the area of the reservoir would begin to revert to river condition. This would cause an increase in flow velocity and turbulence through the reservoir area, especially in the area just upstream from the dam site. This increase in velocity and turbulence would cause the river flows to erode the reservoir sediment through headcut processes. Erosion would begin near the dam site and progressively move upstream through the reservoir sediments. This process of headcut erosion would continue until a stable slope is reached upstream from the dam site. Initially, sediment concentrations downstream from the dam would significantly increase for a short time. After the initial erosion, sediment concentrations would return to near natural levels during low-flow periods. Sediment concentrations would again increase during the first flood following dam removal. These increased sediment concentrations would gradually decline toward natural levels with each subsequent flood. Between floods, sediment concentrations would be relatively low.

Model results indicate that nearly all the 200,000 yds^3 of sediment would be eroded from the reservoir following removal of the dam. This sediment would be transported past the confluence with the Applegate River within a 1- to 10–year period, depending on the frequency and magnitude of high flows following dam removal. The 1-year period would require an extremely wet year with several high peaks following dam removal, and the 10-year period would result if several dry years with very few or no high peaks occurred following dam removal. Maximum river pool deposition in the reach between the dam and the Applegate River would range from 1 to 8 feet. The amount of deposition in downstream river pools would vary by location and time as sediment is gradually reworked downstream during floods.

After the reservoir sediment is eroded and transported past the confluence with the Applegate River, it would reach Hellgate Canyon and continue on downstream. If flood magnitudes following dam removal are high and they occur frequently, the reservoir sediment would reach the ocean within a few years. If the flood magnitudes are low or occur infrequently, the reservoir sediment would reach the ocean over a much longer period of time. Under either scenario, sediment concentration and transport rates would be relatively low and near natural levels in between floods.

Before construction of the dam, a riffle existed at the dam site, and a pool was immediately upstream from the riffle. After removal of the dam, the water surface elevation in the ½ mile reach upstream from the dam would be lowered to near the predam elevation and a riffle and pool would return. The water surface elevation in the upstream 2 miles of the reservoir would look very similar to the way it looks now during the nonirrigation season when the reservoir is drawn down.

Complete removal of the dam may not be necessary to restore river flow conditions through the dam site. There are 17 bays at the dam site. The river bed is composed of bedrock on the south (left) side (south of dam bay number 11). If the right side of the dam (bay numbers 1 through 11) were removed, model results indicate that mean flow velocities would not exceed 10 ft/s at flows up to 30,000 ft^3/s. Existing velocities in Pierce Riffle, approximately 1 mile downstream from the dam, do not typically exceed 8 ft/s.

Two pumping plants would be constructed (one on each side of the river) immediately downstream from the existing dam site to enable the Grants Pass Irrigation District to continue to deliver water to its members after dam removal. Sediment impacts from dam removal on these two pumping plants and the City of Grants Pass water treatment plant (located 5 miles downstream) were addressed. There is a potential for deposition of coarse sediment in the vicinity of the intake structures to these pumping plants and the city water treatment plant. If this were to occur, a dredge would have to be employed to remove the coarse sediment. However, these facilities could be designed and operated to minimize the amount of sediment deposition and the associated impacts.

If the reservoir sediment is allowed to erode during the nonirrigation season, it would not impact the irrigation pumps or the canals because they would not be in operation. Some sediment may deposit around the fish screens or intake channel, but that sediment could be removed before beginning the next irrigation season. The city water treatment plant operates year round. However, the city water treatment plant is located 5 miles downstream from the dam, and there are several deep pools in this reach which would trap sand and gravel-sized sediment. Therefore, sediment concentrations would be less at the treatment plant than at the irrigation pumping plants.

High rates of sand deposition in the city water treatment plant could cause rapid wear on the pumps and complicate the method of removing sand from the plant's three sedimentation basins. Under existing conditions, the amount of sand that enters the water treatment plant is generally between 5 and 15 yds^3 per year (G.A. Geer, City of Grants Pass, written communication, September 1, 2000), and nearly all of that volume enters during high-flow periods. Sediment model results for high-water years following dam removal indicate that 80 yd^3 of sand could deposit in the treatment plant within the first year following dam removal. Peak rates of sand deposition could exceed 10 yd^3 per day for a few days and exceed 30 yd^3 over a 1-week period (figure 27). Actual sand deposition volumes may be much less than the model predictions. Based on the assumed hydrology, sand deposition volumes would decrease to 20 yd^3 during the second year following dam removal. After that, deposition volumes would be nearly the same as under existing conditions. Sand deposition rates in the treatment plant would be less if dam removal were followed by low-water years, but the duration of impacts would be extended to several years.

From the perspective of the city water treatment plant, it would be best to release sediment from the reservoir during the period November through March. This would allow for large portions of the sediment to be quickly transported past the treatment plant during high-flow periods. During these months, the water treatment plant is operated at a slower pumping rate and for fewer hours per day (G.A. Geer, City of Grants Pass, written communication, September 1, 2000). The combination of a slower pumping rate and fewer hours of daily operation would lessen the impact of both fine and coarse sediment on the pumps and sedimentation basins.

All the sediment-related impacts at the pumping plant and the city water treatment plant could be handled, but at additional cost. These additional operating costs are difficult to estimate before dam removal without knowing the future hydrology and the details of the dam removal plan. Sediment impacts could be measured through a monitoring program during dam removal to document the impacts. The results of this study, relative to the potential impact of sediment transport and deposition, would have to be addressed in future analyses detailing when and how the dam would be removed.

The authors recommend that a monitoring program be implemented if the dam is removed. The monitoring would provide necessary information for evaluating the sediment impacts to the river channel and downstream infrastructure.

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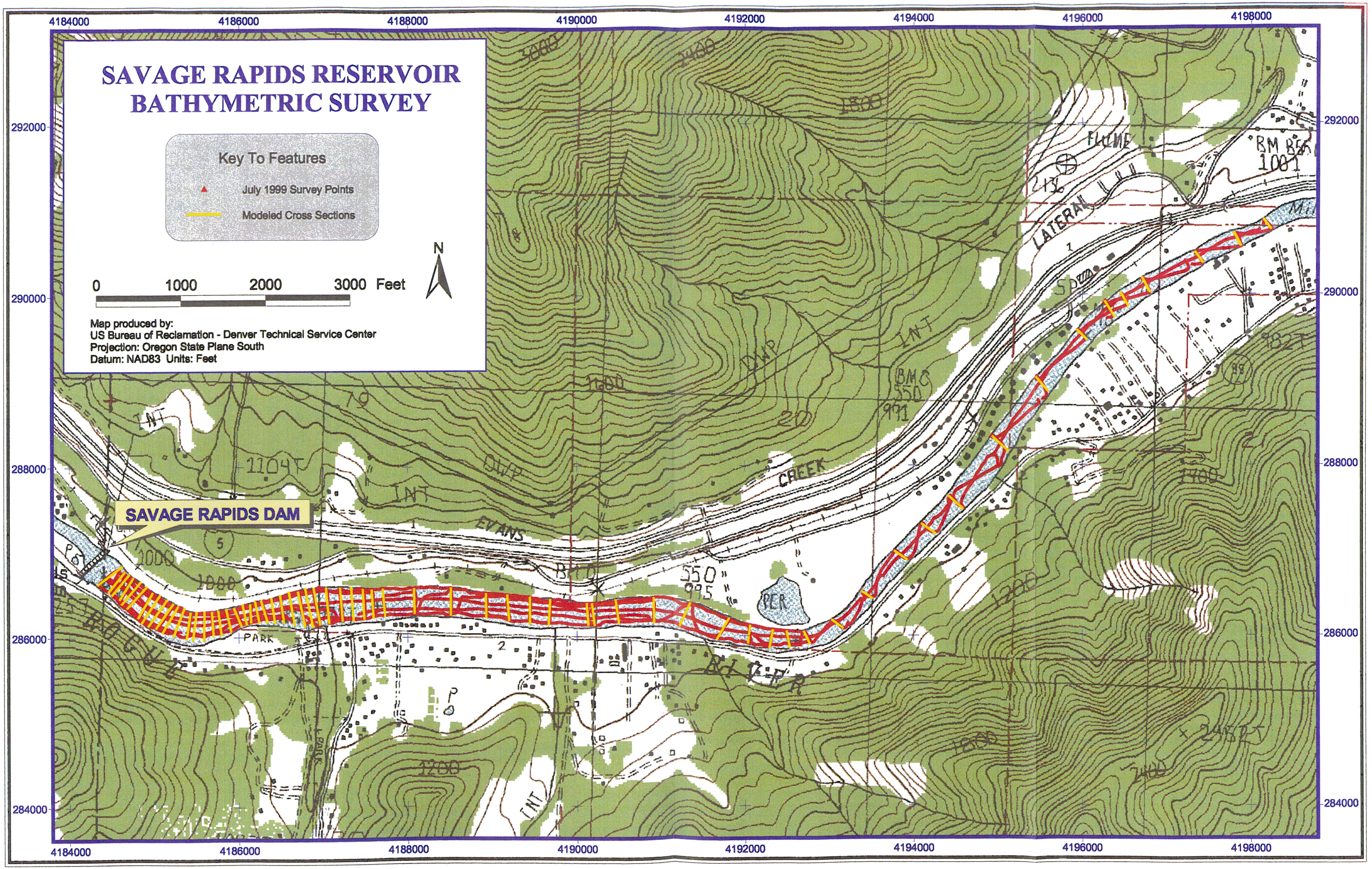
Attachment A

BATHYMETRIC SURVEY DATA OF SAVAGE RAPIDS
RESERVOIR AND CROSS SECTION LOCATIONS



SAVAGE RAPIDS RESERVOIR
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July 1999 Survey Points
Modeled Cross Sections
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US Bureau of Reclamation - Denver Technical Service Center
Projection: Oregon State Plane South
Datum: NAD83 Units: Feet
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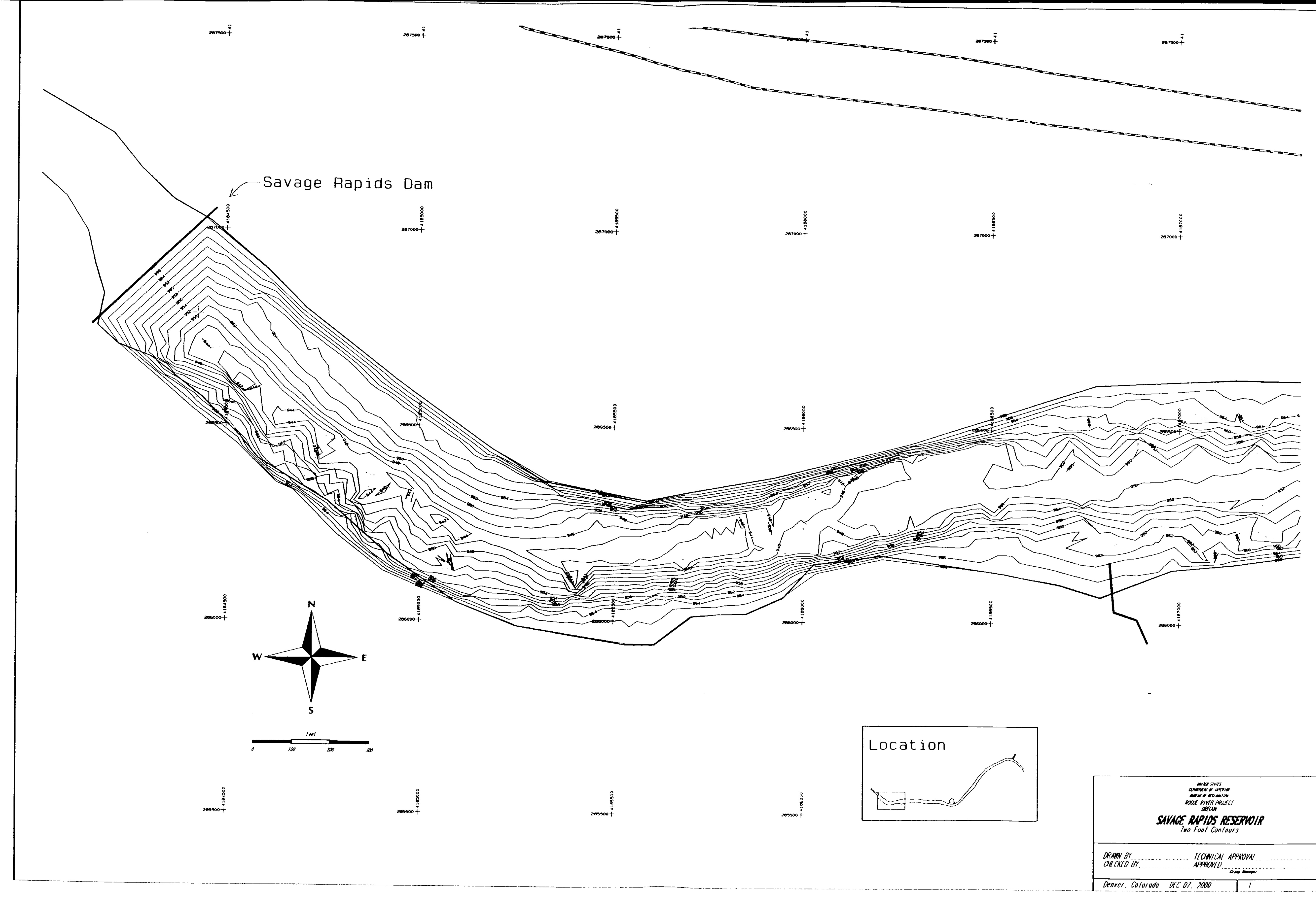
Attachment B

2-FOOT CONTOUR MAP OF
SAVAGE RAPIDS RESERVOIR



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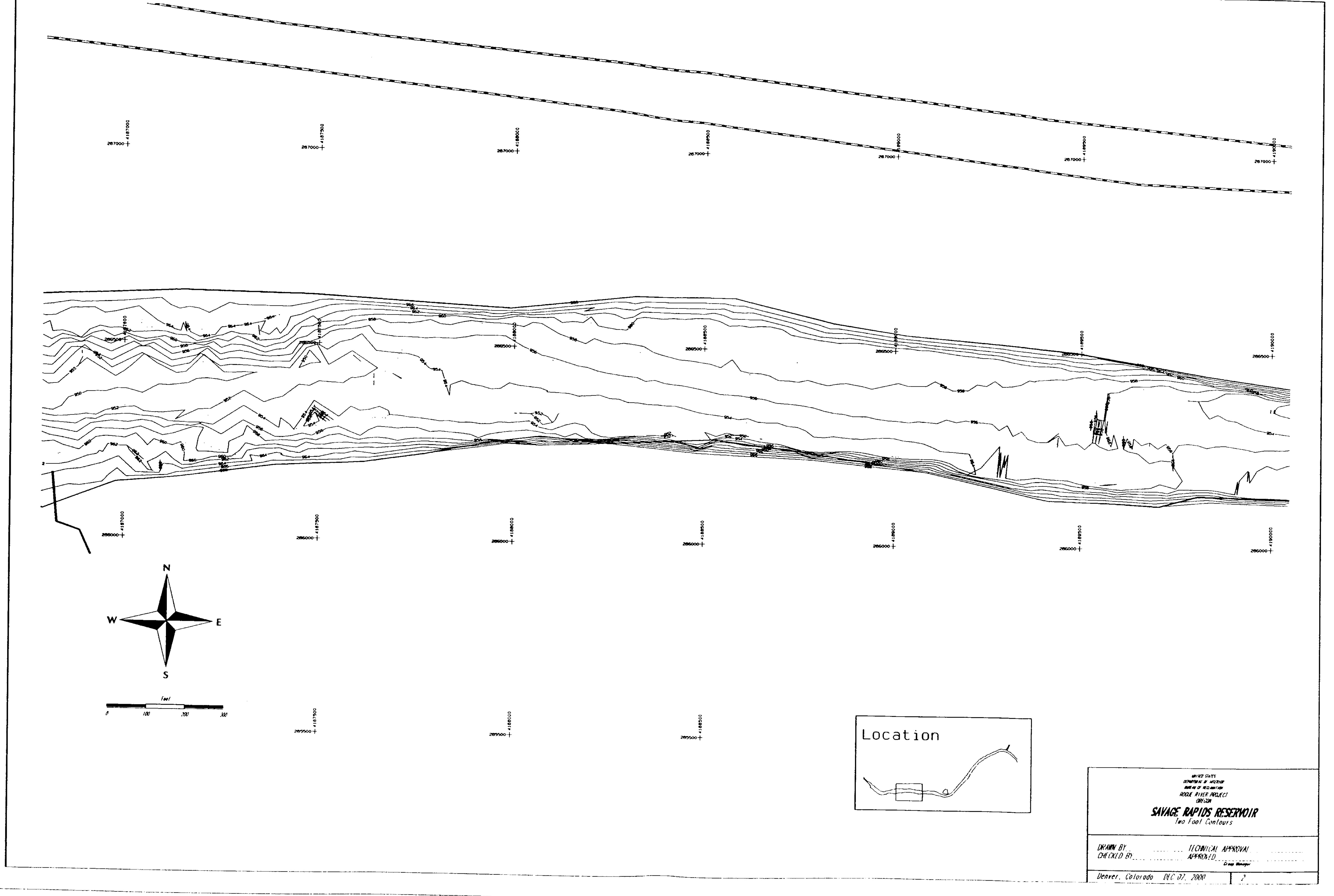
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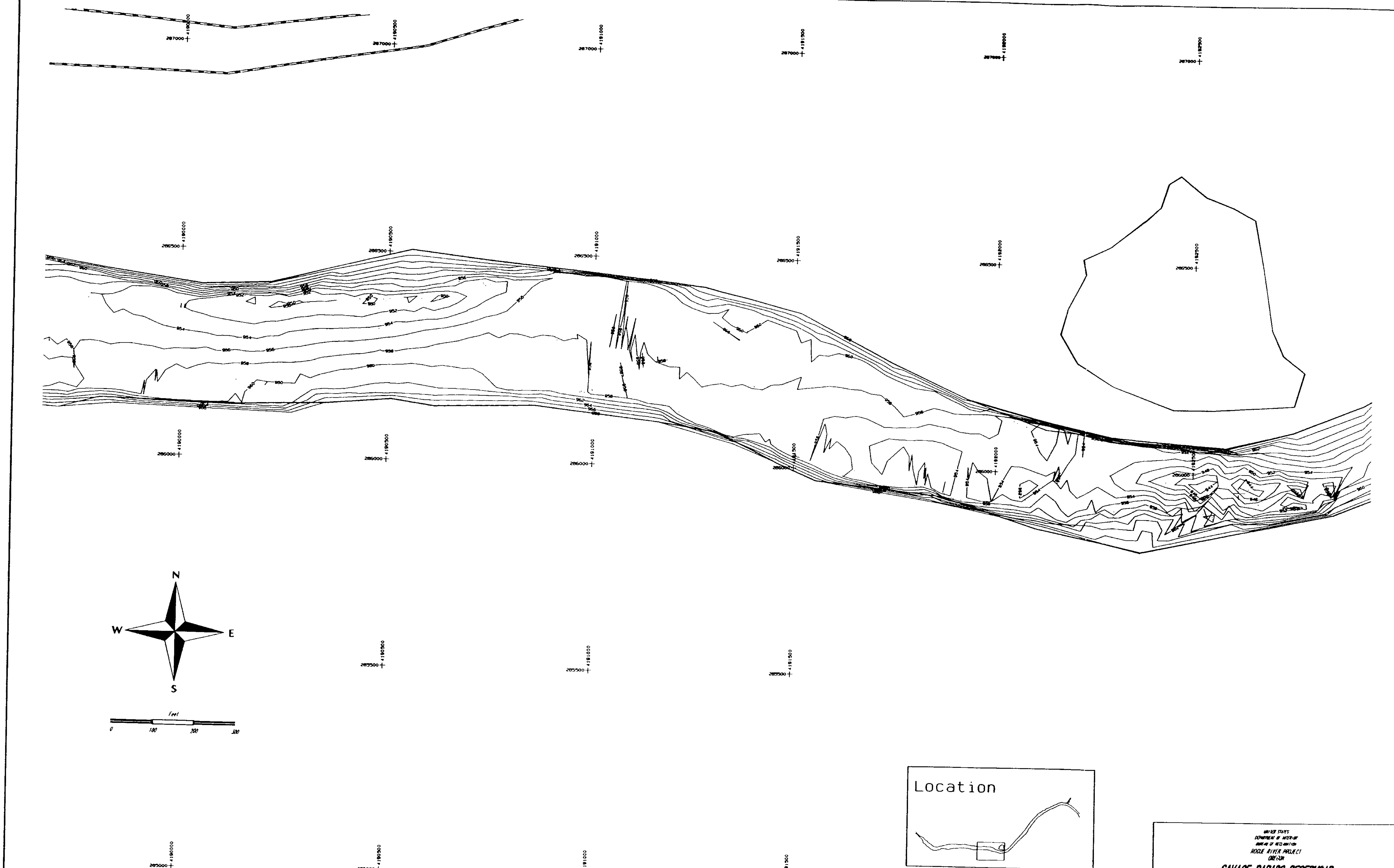

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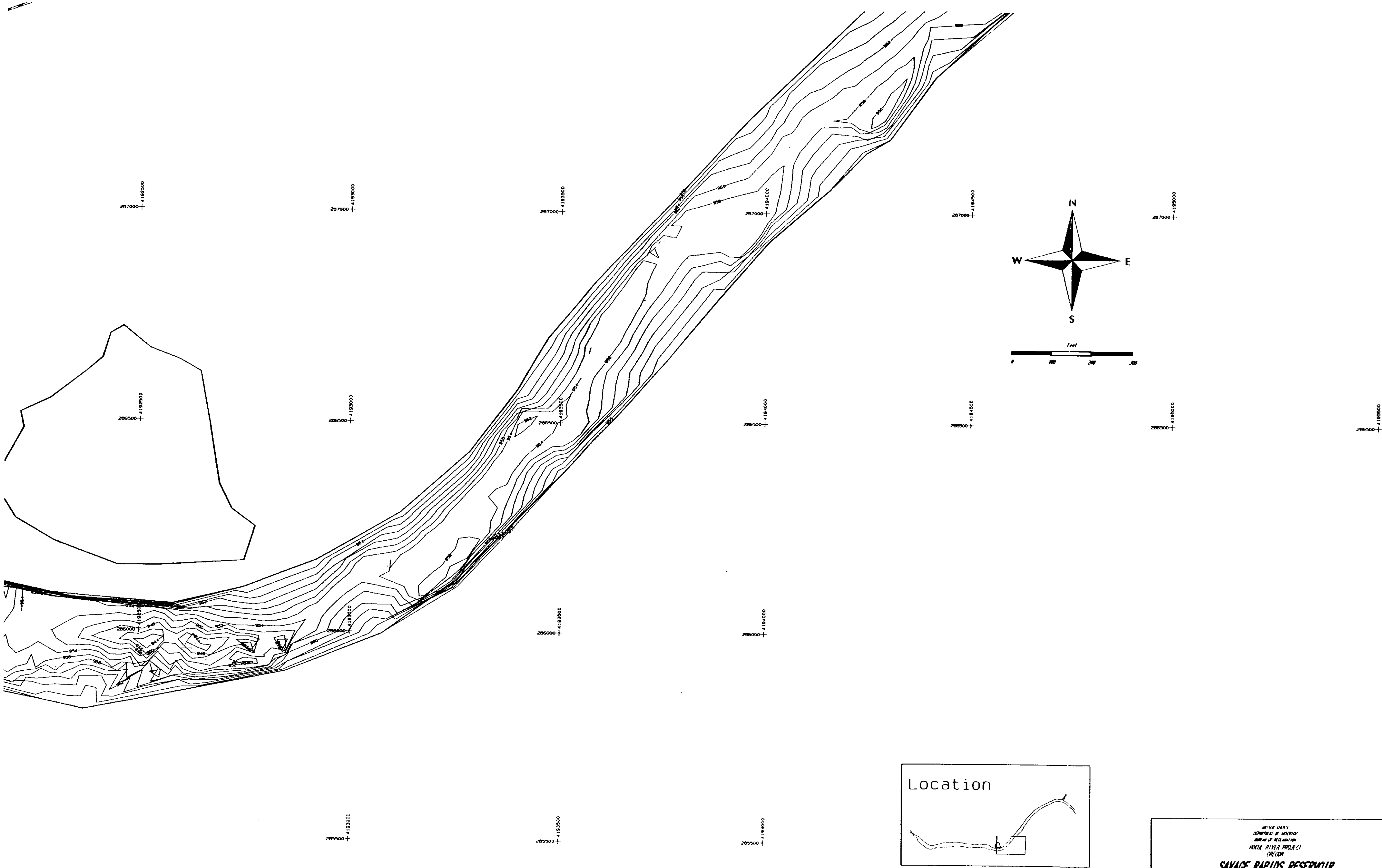

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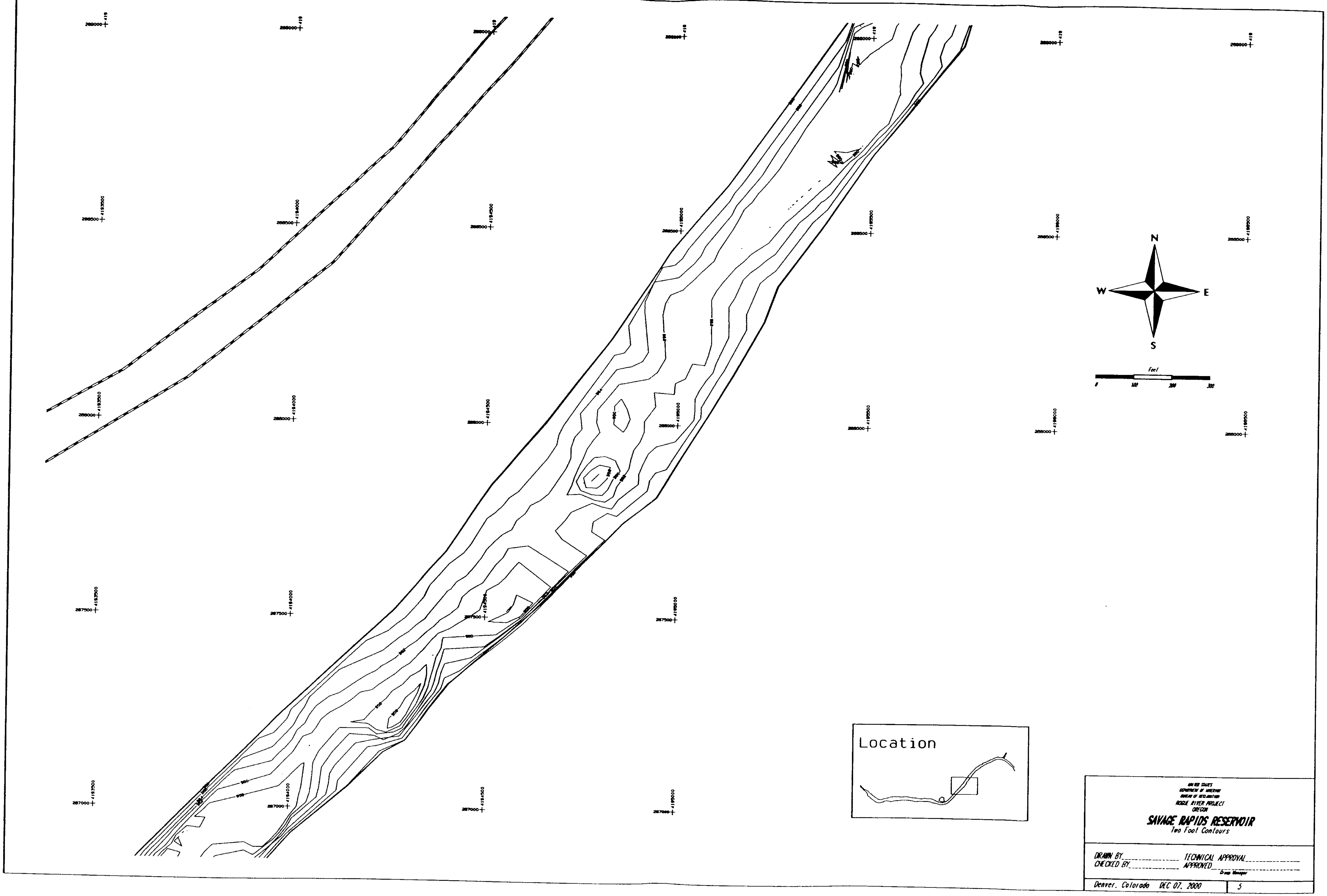
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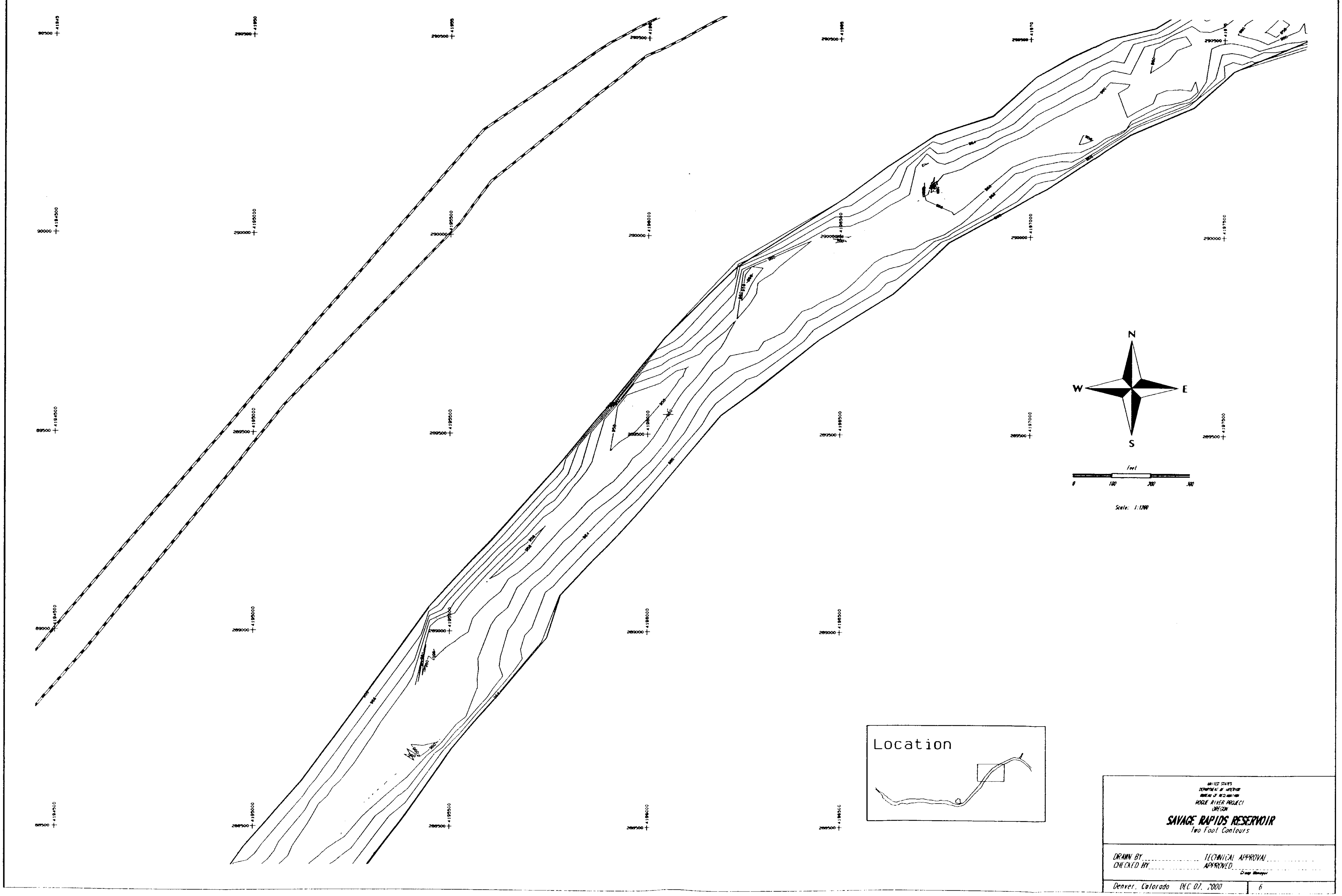
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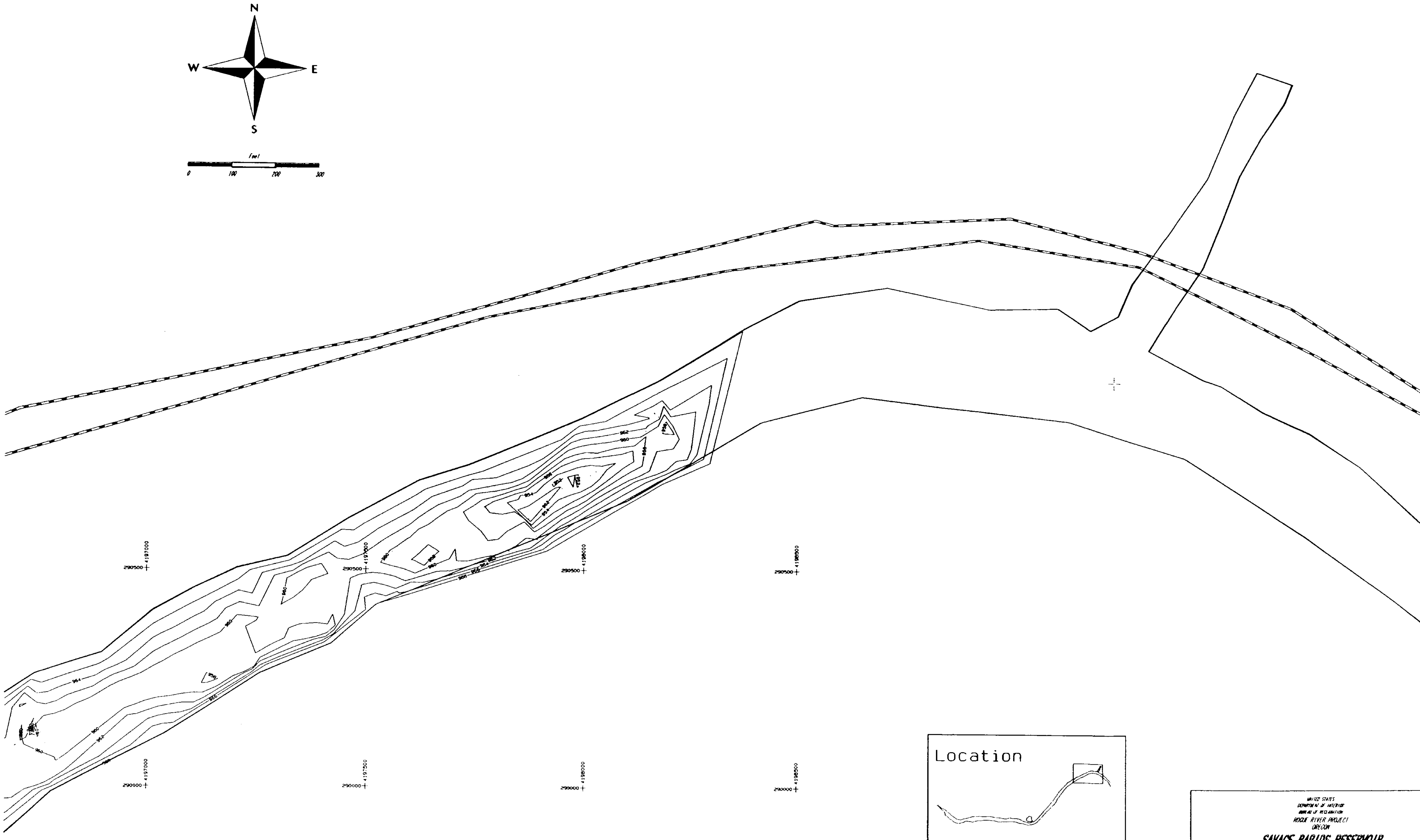

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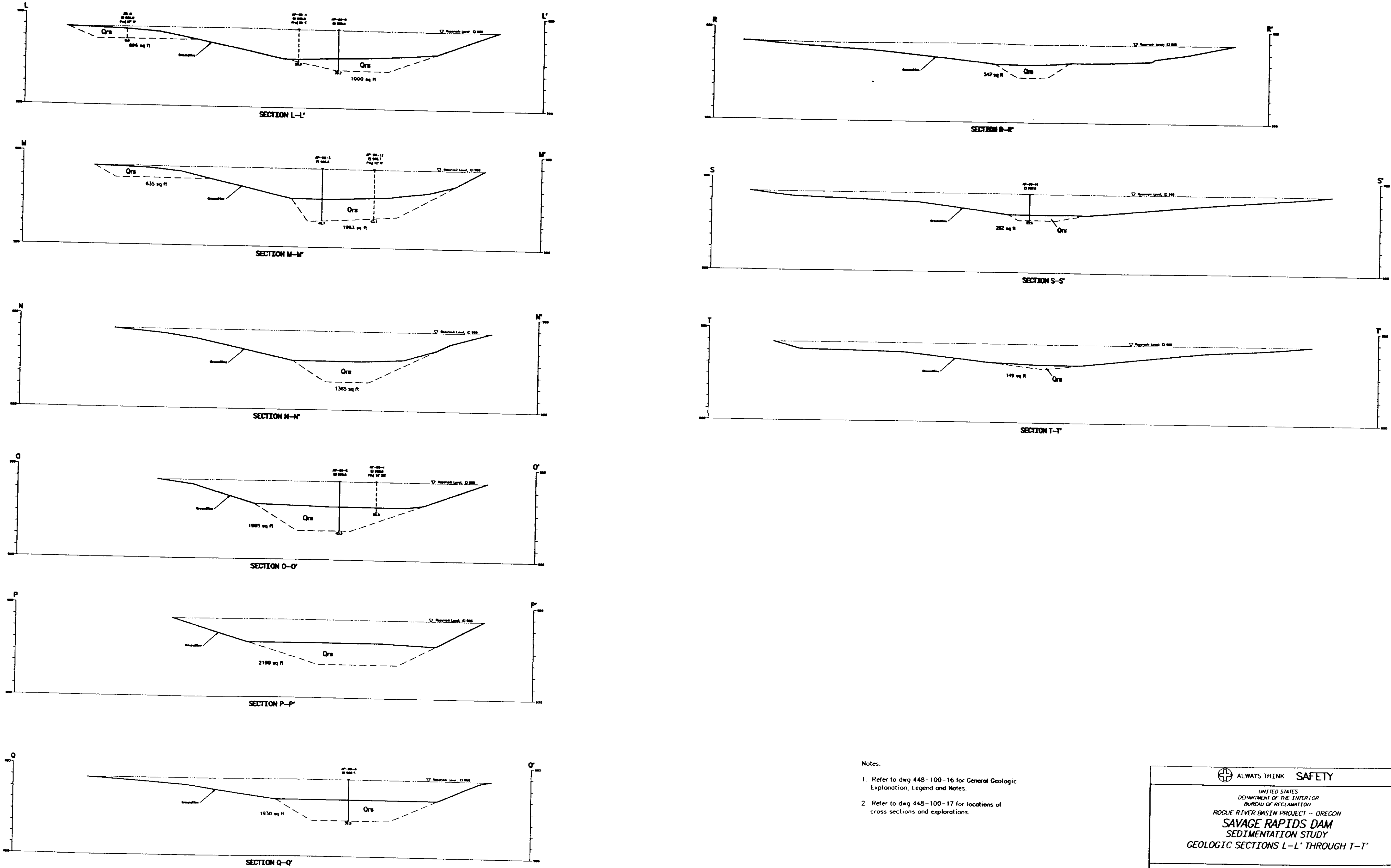

Notes:

1. Refer to dwg 448-100-16 for General Geologic Explanation, Legend and Notes.
2. Refer to dwg 448-100-17 for locations of cross sections and explorations.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
ROGUE RIVER BASIN PROJECT – OREGON

SAVAGE RAPIDS DAM
SEDIMENTATION STUDY
GEOLOGIC SECTIONS L–L' THROUGH T–T'

GEOLOGY R. LINK
DRAWN T. ENGLAND TECH. APPROVAL
CHECKED APPROVED
PROGRAM MANAGER

CADD SYSTEM ACAD v14	CADD FILENAME	DATE PLOTTED 4-11-00
BOISE, IDAHO	NOVEMBER 1999 SHEET 1 OF 1	448–100–19

Attachment C

Hydraulic Parameters from Calibration Model Runs

Attachment C for Appendix B:

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
			RIVER DISCHARGE: 3,866 cfs			
Upstream End of Survey	110.72	957.0	969.2	12.2	3	130
	110.64	952.0	969.2	17.2	2	190
	110.54	958.0	969.1	11.1	2	180
	110.41	960.0	969.0	9.0	2	210
	110.35	960.0	968.9	8.9	2	200
	110.31	956.0	968.9	12.9	2	240
	110.22	956.0	968.8	12.8	2	180
	110.08	959.0	968.7	9.7	2	230
	109.92	961.0	968.6	7.6	2	280
	109.76	956.0	968.4	12.4	2	240
	109.67	955.0	968.4	13.4	2	220
	109.58	957.0	968.3	11.3	2	200
	109.47	951.0	968.3	17.3	2	160
	109.38	951.0	968.3	17.3	1	180
	109.31	944.0	968.3	24.3	1	160
	109.27	943.0	968.3	25.3	1	180
	109.24	951.0	968.3	17.3	1	200
	109.19	953.0	968.2	15.2	1	230
	109.14	953.0	968.2	15.2	1	290
	109.04	957.0	968.2	11.2	1	320
	108.96	956.0	968.2	12.2	1	310
	108.87	949.0	968.2	19.2	1	290
	108.82	950.0	968.2	18.2	1	280
	108.81	950.0	968.2	18.2	1	280
	108.73	955.0	968.2	13.2	1	320
	108.68	955.0	968.2	13.2	1	330
	108.63	953.0	968.2	15.2	1	320
	108.58	952.0	968.1	16.1	1	300
	108.50	952.0	968.1	16.1	1	340
	108.42	952.0	968.1	16.1	1	310
	108.35	952.0	968.1	16.1	1	340
	108.32	951.0	968.1	17.1	1	350
	108.28	950.0	968.1	18.1	1	410
	108.25	949.0	968.1	19.1	1	370
	108.20	948.0	968.1	20.1	1	410
	108.17	949.0	968.1	19.1	1	440
	108.14	950.0	968.1	18.1	1	484
	108.10	950.0	968.1	18.1	1	524
	108.06	950.0	968.1	18.1	1	443
	108.02	950.0	968.1	18.1	1	351
	107.98	946.0	968.1	22.1	1	271
	107.94	946.0	968.1	22.1	1	287

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
			RIVER DISCHARGE: 3,866 cfs			
	107.91	942.0	968.1	26.1	1	328
	107.88	942.0	968.1	26.1	1	340
	107.85	942.0	968.1	26.1	1	376
	107.83	942.0	968.1	26.1	1	378
	107.81	946.0	968.1	22.1	1	379
	107.79	946.0	968.1	22.1	1	396
	107.77	942.0	968.1	26.1	1	413
	107.74	944.0	968.1	24.1	1	413
	107.71	944.0	968.1	24.1	1	391
	107.69	944.0	968.1	24.1	1	389
	107.66	942.0	968.1	26.1	1	386
	107.64	943.0	968.1	25.1	1	398
	107.62	941.0	968.1	27.1	1	400
	107.62	940.0	968.1	28.1	0	437
Savage Rapids Dam	107.60	958.3	964.7	6.4	14	44
	107.59	933.0	939.9	6.9	3	225
	107.58	932.5	939.7	7.2	4	224
	107.55	935.4	938.8	3.4	7	167
	107.51	935.0	938.4	3.4	4	266
	107.46	934.4	937.9	3.5	4	265
	107.41	933.9	937.3	3.4	4	263
	107.36	933.3	936.8	3.5	4	263
	107.32	932.9	936.4	3.5	4	262
	107.27	932.3	935.8	3.5	4	261
	107.22	931.8	935.3	3.5	4	260
	107.17	931.2	934.7	3.5	4	259
	107.13	930.8	934.3	3.5	4	258
	107.08	930.2	933.8	3.6	4	258
	107.03	929.7	933.3	3.6	4	257
	106.98	929.1	932.9	3.8	4	257
	106.94	928.7	932.6	3.9	4	258
	106.89	928.1	932.3	4.2	4	258
	106.84	927.6	932.0	4.4	3	259
	106.80	927.2	931.8	4.6	3	260
	106.75	926.6	931.7	5.1	3	261
	106.70	926.1	931.6	5.5	3	262
	106.65	925.5	930.5	5.0	7	111
	106.63	925.3	928.8	3.5	11	107
	106.50	921.2	927.3	6.1	2	260
	106.49	921.0	927.3	6.2	2	260
	106.46	921.4	925.9	4.5	9	182
	106.41	916.3	925.8	9.5	4	135
	106.30	915.4	925.7	10.3	3	142
	106.26	916.3	925.6	9.3	3	140

RIVER DISCHARGE: 3,866 cfs

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
	106.23	911.1	924.6	13.5	8	75
	106.20	906.0	925.0	19.0	4	108
	106.18	910.8	923.7	13.0	9	67
	106.04	894.2	924.5	30.3	1	172
	105.94	904.2	924.4	20.2	2	165
	105.89	907.9	924.3	16.4	3	163
	105.83	919.0	924.0	5.1	4	231
	105.80	920.0	923.0	3.0	7	266
	105.74	915.2	919.6	4.4	8	202
	105.70	914.0	916.7	2.7	9	161
	105.66	901.5	915.9	14.4	4	141
	105.62	894.7	915.9	21.2	3	142
	105.60	887.6	915.9	28.4	1	199
	105.58	884.1	915.9	31.9	1	187
	105.56	888.2	915.9	27.7	1	192
	105.54	893.1	915.9	22.9	2	215
	105.51	905.5	915.8	10.3	3	179
	105.48	907.3	915.7	8.4	3	161
	105.45	910.0	913.8	3.8	11	102
	105.37	877.2	912.2	35.0	1	205
	105.32	898.7	912.1	13.4	3	163
	105.28	906.0	911.5	5.5	6	151
	105.23	905.0	910.9	5.9	5	237
	105.19	900.6	910.8	10.2	4	134
	105.16	901.6	910.6	9.0	5	138
	105.13	903.8	909.8	6.0	7	112
	105.10	904.0	909.0	5.0	8	123
	105.07	901.4	908.9	7.5	5	123
	105.04	898.7	908.8	10.1	4	142
	105.00	893.0	908.8	15.9	3	170
	104.96	894.4	908.7	14.3	3	163
	104.94	900.7	908.7	8.0	3	212
	104.91	903.7	908.3	4.6	5	185
	104.84	900.0	908.2	8.1	3	194
	104.74	899.4	907.8	8.4	4	167
	104.69	898.2	907.8	9.6	2	217
	104.59	897.2	907.5	10.4	4	194
	104.52	898.7	907.3	8.6	4	181
	104.44	897.6	907.3	9.7	2	221
	104.39	902.1	906.8	4.7	5	227
	104.36	903.1	905.2	2.1	8	231
	104.33	897.9	903.3	5.4	7	177
	104.30	894.0	903.5	9.5	3	205
	104.20	894.8	903.1	8.4	3	203

RIVER DISCHARGE: 3,866 cfs

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
	104.16	893.7	903.1	9.4	3	212
	104.11	894.9	903.0	8.1	3	209
	104.04	895.3	902.9	7.6	3	196
	103.91	893.9	902.5	8.6	3	210
	103.84	892.7	902.3	9.6	3	187
	103.80	894.6	901.9	7.3	5	177
	103.79	890.7	902.0	11.3	3	174
	103.78	893.1	901.9	8.8	4	189
	103.77	892.7	901.9	9.2	4	195
	103.74	894.2	901.4	7.3	5	184
	103.71	896.5	900.1	3.6	8	164
	103.70	894.0	900.4	6.4	4	179
	103.69	891.6	900.5	8.9	3	179
	103.67	889.1	900.5	11.4	3	169
	103.64	891.2	900.3	9.2	3	188
	103.56	890.9	900.3	9.4	2	217
	103.52	890.8	900.3	9.5	3	217
	103.47	891.8	900.2	8.3	3	216
	103.45	892.0	900.1	8.1	3	216
	103.39	893.0	899.9	6.9	3	214
	103.34	893.0	899.5	6.5	5	213
	103.29	892.0	898.7	6.7	5	201
	103.24	895.0	897.5	2.5	6	261
	103.19	890.5	897.6	7.1	2	250
	103.14	893.0	897.2	4.2	5	223
	103.08	887.2	897.3	10.2	2	246
	103.07	884.6	897.3	12.7	2	252
	103.06	875.3	897.3	22.1	1	242
	103.02	888.2	897.3	9.1	2	251
	102.97	890.4	897.2	6.7	3	254
	102.93	891.8	897.0	5.2	3	261
	102.88	892.0	896.5	4.5	5	262
	102.77	891.4	895.9	4.4	3	290
	102.68	890.9	894.8	3.9	5	258
	102.60	888.4	894.2	5.9	4	234
	102.51	885.2	894.1	8.9	3	242
	102.44	886.3	893.9	7.6	3	223
	102.36	887.5	893.7	6.2	3	229
	102.28	890.1	892.2	2.1	8	237
	102.17	881.0	888.8	7.8	3	182
	102.06	866.5	888.9	22.4	1	256
	102.04	882.4	888.6	6.3	4	265
	102.03	880.4	888.7	8.3	2	299
	101.85	881.1	888.4	7.3	2	313

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
			RIVER DISCHARGE: 3,866 cfs			
	101.77	880.6	888.2	7.7	2	338
	101.72	879.8	888.2	8.4	2	341
	101.72	879.7	888.2	8.5	2	332
	101.72	879.6	888.2	8.6	2	332
	101.71	879.6	888.2	8.6	2	342
	101.70	879.7	888.2	8.5	2	341
	101.67	880.0	888.0	8.1	3	201
	101.64	879.9	888.0	8.2	2	255
	101.63	879.9	888.0	8.1	2	255
	101.61	879.9	888.0	8.1	2	254
	101.60	879.9	887.9	8.1	3	255
	101.60	879.8	887.9	8.2	2	292
	101.58	879.6	887.9	8.4	2	282
	101.53	881.8	887.7	5.9	3	289
	101.43	883.0	887.3	4.3	3	333
	101.40	881.9	886.1	4.2	8	271
	101.32	880.3	884.1	3.8	4	279
	101.28	877.9	884.1	6.3	2	327
	101.20	871.7	884.1	12.3	2	261
	101.13	875.4	883.7	8.3	4	198
	101.06	878.0	881.7	3.7	8	243
	101.05	875.6	881.2	5.6	5	161
	101.04	874.2	881.2	7.0	4	152
	101.02	872.8	881.2	8.4	4	144
	101.01	871.4	881.2	9.8	3	172
	100.98	866.0	881.2	15.2	2	166
	100.96	872.0	881.1	9.0	3	165
	100.91	871.9	880.9	9.0	3	164
	100.89	873.5	880.6	7.1	5	131
	100.88	875.0	880.3	5.3	6	153
	100.86	872.2	880.3	8.2	4	146
	100.84	867.4	880.4	13.0	3	157
	100.78	873.0	880.0	7.0	4	148
	100.73	875.0	879.2	4.2	6	274
	100.69	874.5	878.7	4.2	4	251
	100.65	874.0	878.1	4.0	5	219
	100.61	871.6	877.6	6.0	4	195
	100.56	869.2	877.5	8.4	3	204
	100.45	869.0	877.3	8.3	3	205
	100.44	865.4	877.3	11.9	2	212
	100.43	870.4	877.2	6.8	3	246
	100.37	868.8	877.1	8.3	2	260
	100.30	870.0	876.6	6.6	5	139
	100.27	871.5	876.4	4.9	5	188

RIVER DISCHARGE: 3,866 cfs

Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
	100.24	871.5	876.2	4.6	4	208
	100.23	871.3	875.5	4.2	7	179
	100.22	870.6	875.3	4.8	6	172
	100.21	869.9	875.2	5.4	6	169
	100.20	869.1	875.2	6.0	5	167
	100.19	868.4	875.1	6.7	5	165
	100.18	867.7	875.1	7.4	4	164
	100.17	867.0	875.1	8.1	4	162
	100.10	862.4	874.9	12.5	4	128
	100.02	864.0	874.8	10.8	3	166
	99.94	865.6	874.7	9.1	3	194
	99.82	866.1	874.5	8.5	3	209
	99.79	866.1	874.4	8.3	3	205
	99.73	867.6	874.2	6.6	3	196
	99.64	867.5	873.9	6.5	3	224
	99.55	868.1	873.2	5.2	5	172
	99.42	867.0	872.8	5.8	3	240
	99.31	866.9	872.0	5.1	5	193
	99.20	864.7	871.0	6.3	4	211
	99.07	864.1	870.0	5.9	4	216
	98.96	862.5	869.5	7.0	3	205
	98.91	861.8	869.2	7.3	4	162
	98.84	851.1	869.3	18.2	1	247
	98.82	860.5	869.2	8.7	3	234
	98.78	856.8	869.1	12.3	3	138
	98.76	858.3	869.1	10.8	3	169
	98.65	858.7	869.0	10.3	2	237
	98.60	860.9	868.9	8.0	3	212
	98.54	862.8	868.5	5.7	4	188
	98.48	861.7	868.2	6.5	4	191
	98.41	862.6	866.5	4.0	8	252
	98.37	861.7	865.3	3.6	5	257
	98.33	860.5	865.1	4.6	3	300
	98.26	857.9	864.8	7.0	3	253
	98.20	858.4	864.5	6.0	4	219
	98.15	855.2	864.3	9.1	3	173
	98.11	852.7	864.3	11.7	2	218
	98.07	853.3	864.3	11.0	2	211
	98.04	853.8	864.2	10.4	2	206
	97.98	854.8	864.1	9.3	3	195
	97.92	855.8	864.1	8.3	2	299
	97.84	858.3	863.8	5.5	4	248
	97.76	858.5	863.1	4.6	4	233
	97.69	858.0	862.2	4.2	5	226

			RIVER DISCHARGE: 3,866 cfs			
Description	Cross Section River Mile	Thalweg (ft)	Water Surface (ft)	Maximum Depth (ft)	Average Velocity (ft/s)	Wetted Width (ft)
	97.62	857.1	861.3	4.2	5	212
	97.54	856.0	860.9	4.9	3	302
	97.46	855.0	860.7	5.6	3	318
	97.33	853.2	860.2	7.0	3	246
	97.26	852.3	859.9	7.6	4	190
	97.17	851.1	859.8	8.7	2	216
	97.08	849.9	859.8	9.9	2	238
	96.98	848.7	859.7	11.0	2	277
	96.89	847.4	859.6	12.2	2	324
	96.80	846.2	859.6	13.4	1	377
	96.70	847.8	859.6	11.8	2	366
	96.61	849.4	859.5	10.1	2	349
	96.52	851.0	859.4	8.4	2	328
	96.43	852.6	859.2	6.6	3	293
	96.33	852.7	858.9	6.2	3	315
	96.24	852.8	858.6	5.8	3	343
	96.15	852.9	858.2	5.3	3	385
	96.05	853.0	857.5	4.5	3	449
	95.96	852.4	856.8	4.4	3	504
	95.91	852.0	856.5	4.5	3	505
	95.87	851.8	856.1	4.3	4	260
	95.84	851.6	855.7	4.1	4	256
	95.80	851.3	855.4	4.1	4	262
	95.75	850.7	854.9	4.2	4	265
Downstream End of Model	95.63	849.5	851.9	2.4	8	221

Attachment D

PRELIMINARY SEDIMENT MODEL RESULTS

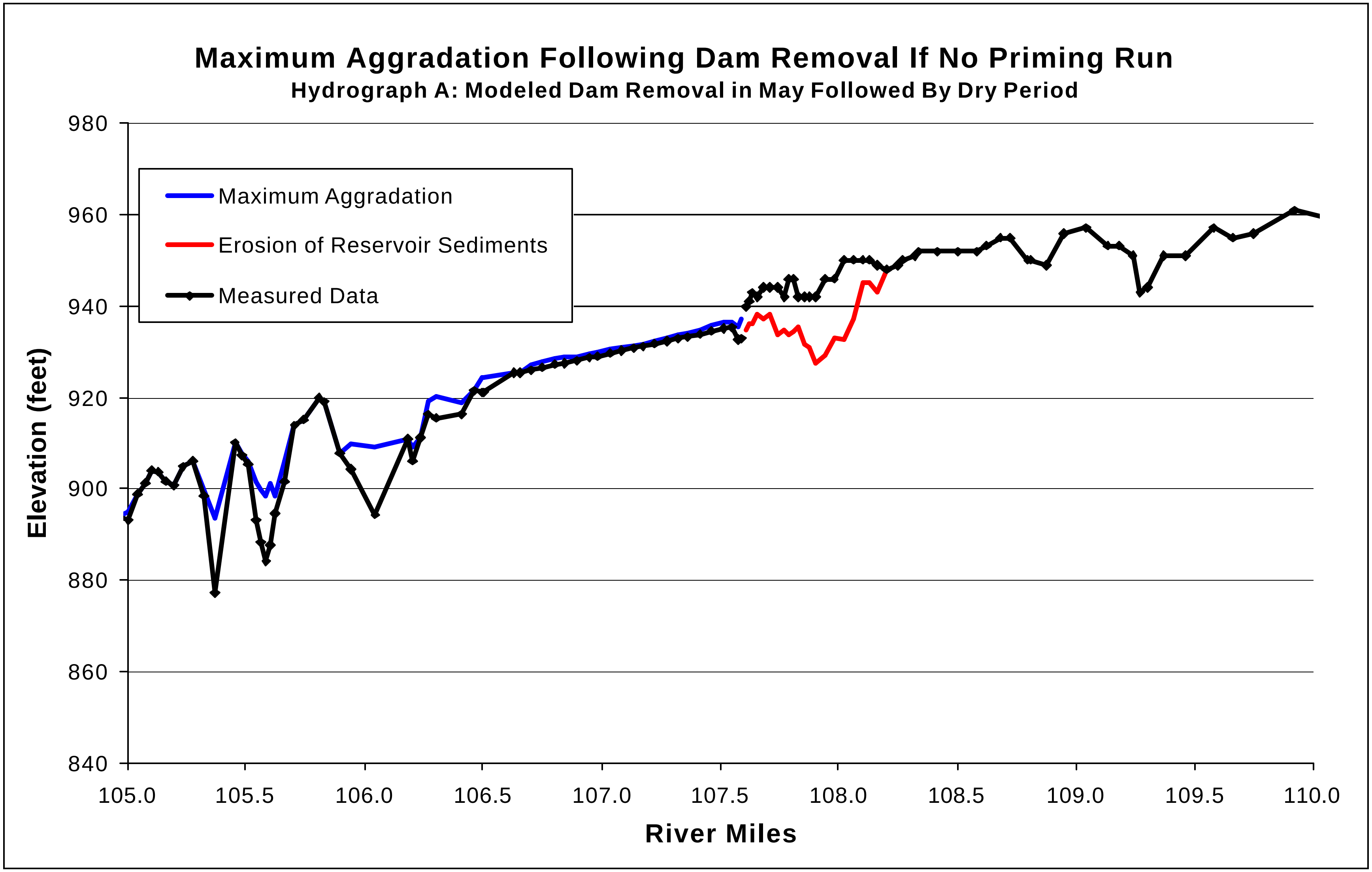


Figure D-1.—Longitudinal profile plot was made of model results for channel bottom, erosion of reservoir sediments, and maximum aggradation following the dam removal for the first 5 miles downstream from the dam. The dam removal was initially modeled to occur in May, followed by a dry period (few peak flows). Initial model results showed large amounts of deposition in deep river pools downstream from the dam. However, these results were unlikely because sediment that currently passes through Savage Rapids Reservoir during peak flows would have filled these river pools long ago.

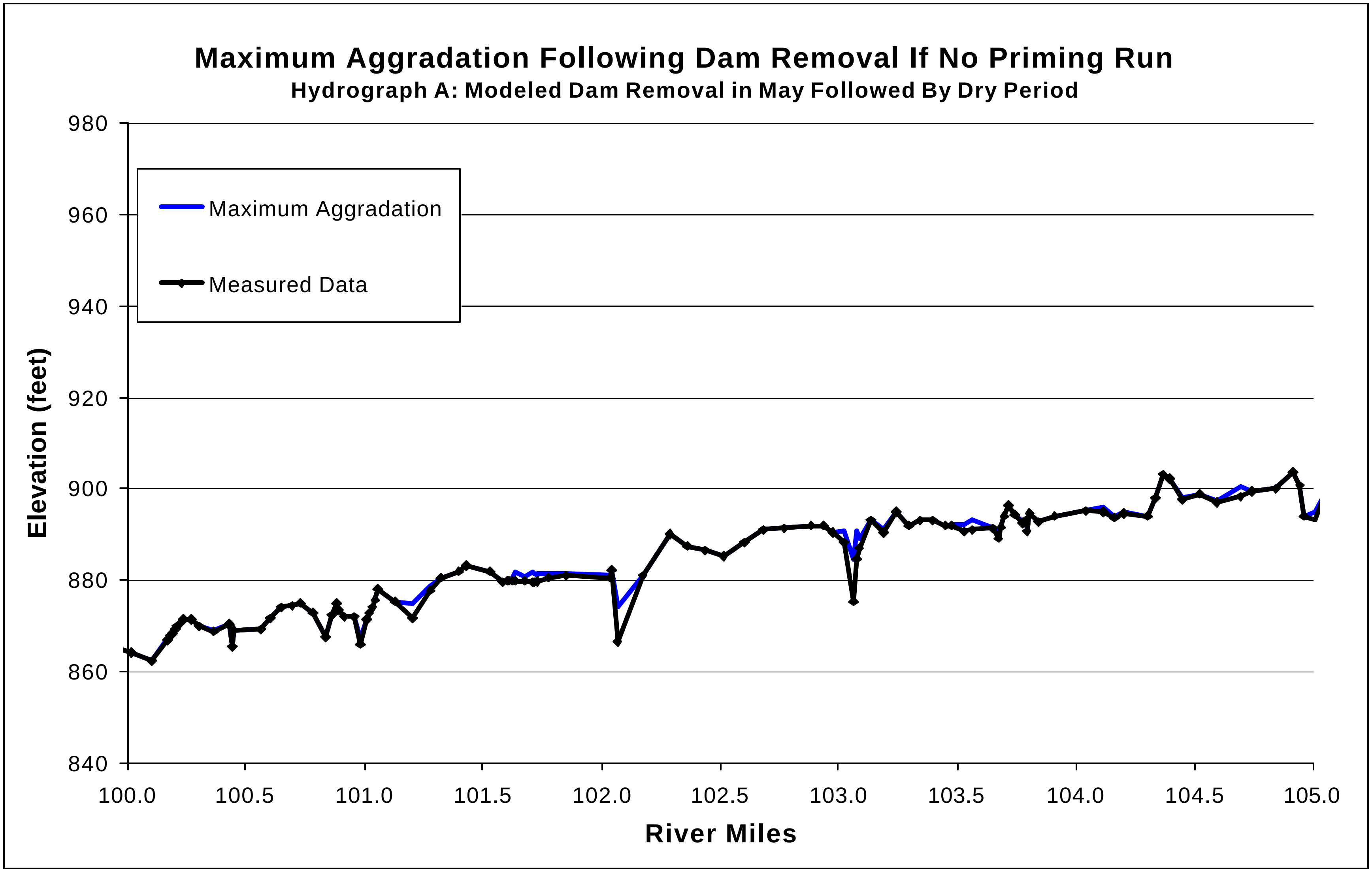


Figure D-2.—A longitudinal profile plot made of model results for channel bottom, erosion of reservoir sediments, and maximum aggradation for river miles 100 to 105 (5 to 10 miles downstream from the dam).

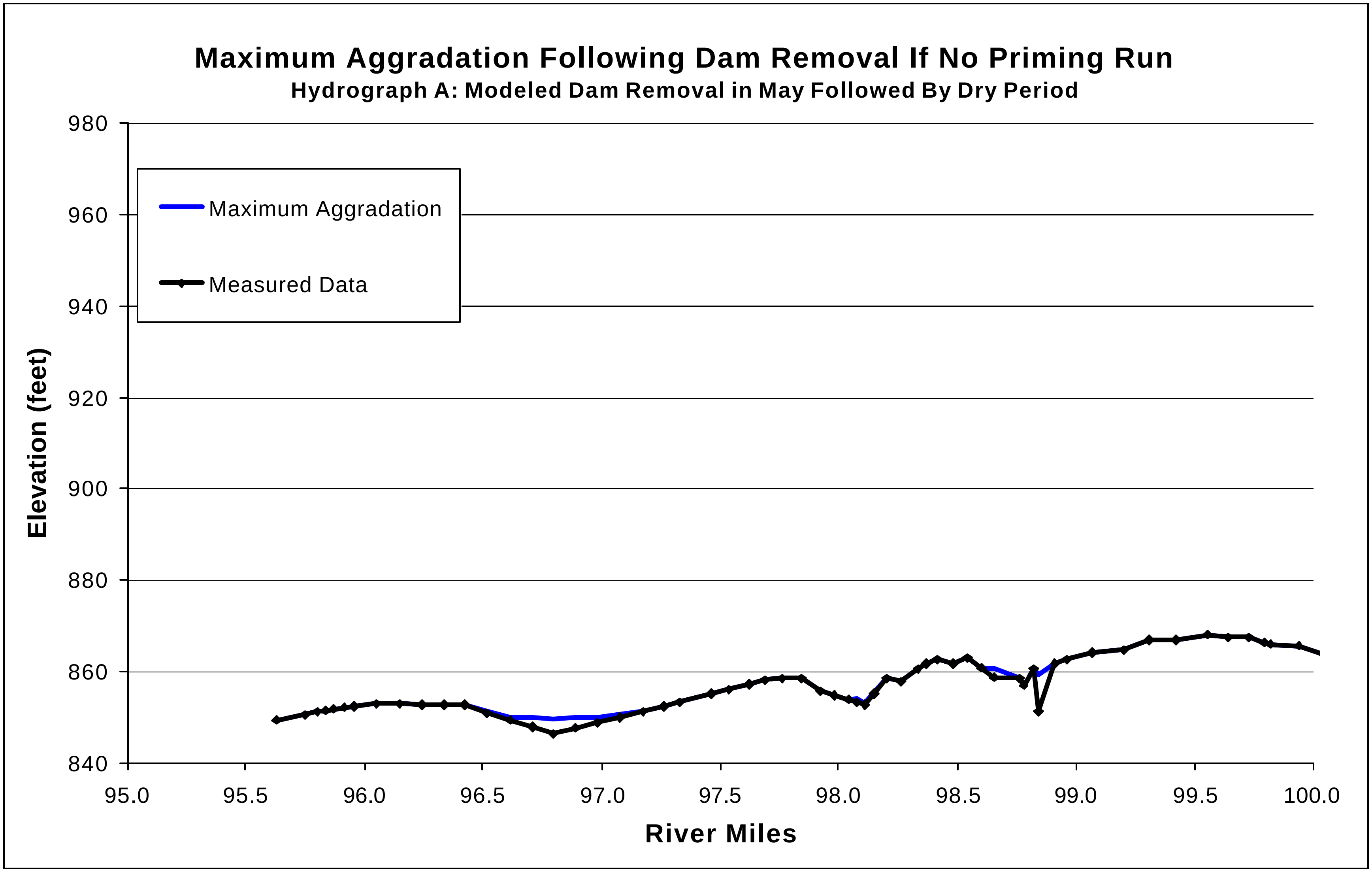


Figure D-3.—A longitudinal profile plot made of model results for channel bottom, erosion of reservoir sediments, and maximum aggradation for river miles 95 to 100 (10 to 15 miles downstream from the dam).

Attachment E

SEDIMENT PRIMING RUN RESULTS

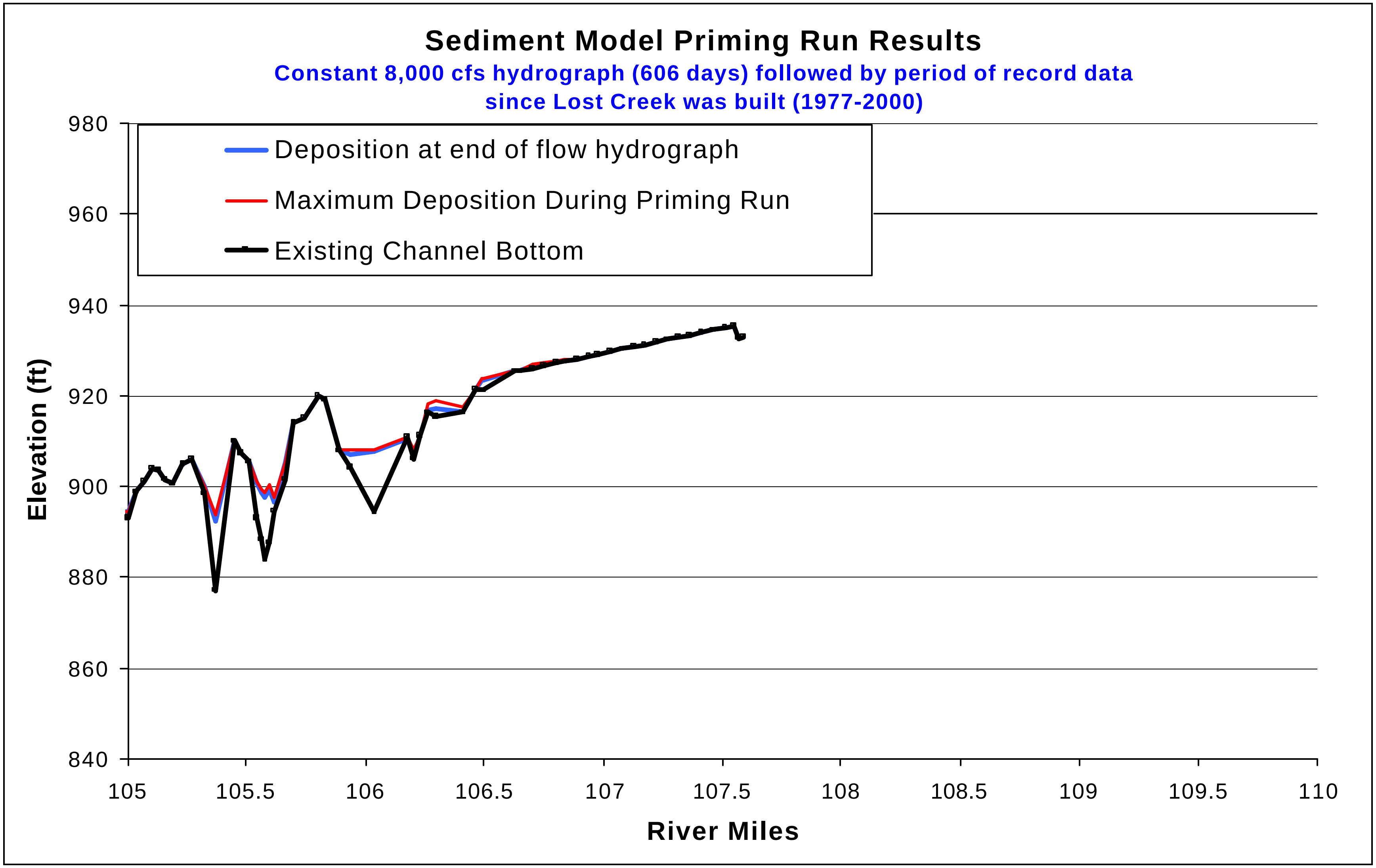


Figure E-1.—Results for sediment model priming run for first 5 miles downstream from Savage Rapids Dam. Model priming was necessary to stabilize the model for natural conditions (estimated incoming sediment load) and to enable modeling of the net change from removing the dam and allowing reservoir sediments to erode and be transported downstream.

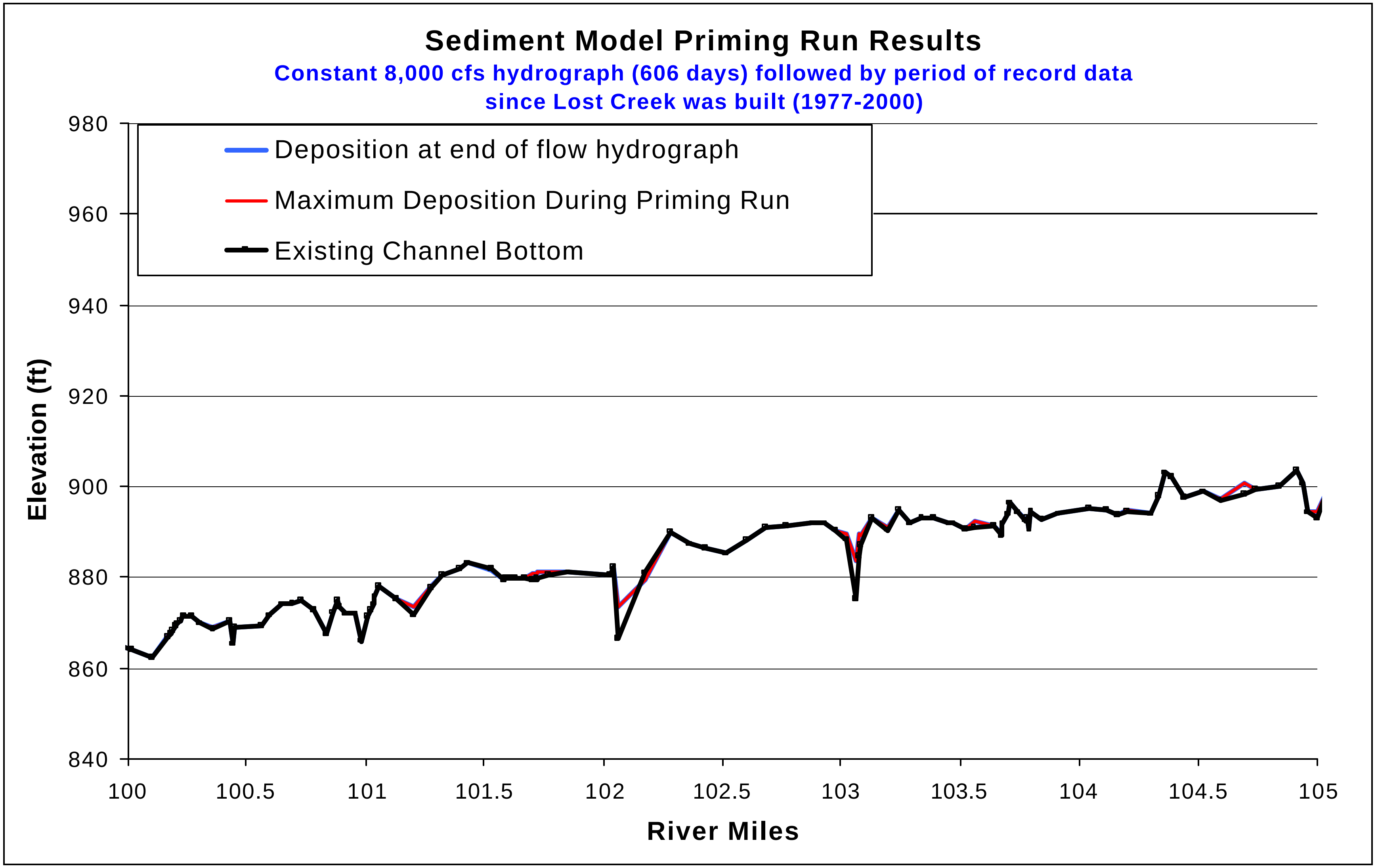


Figure E-2.—Results for sediment model priming run for the second 5 miles downstream from Savage Rapids Dam. Model priming was necessary to stabilize the model for natural conditions (estimated incoming sediment load) and to enable modeling of the net change from removing the dam and allowing reservoir sediments to erode and be transported downstream.

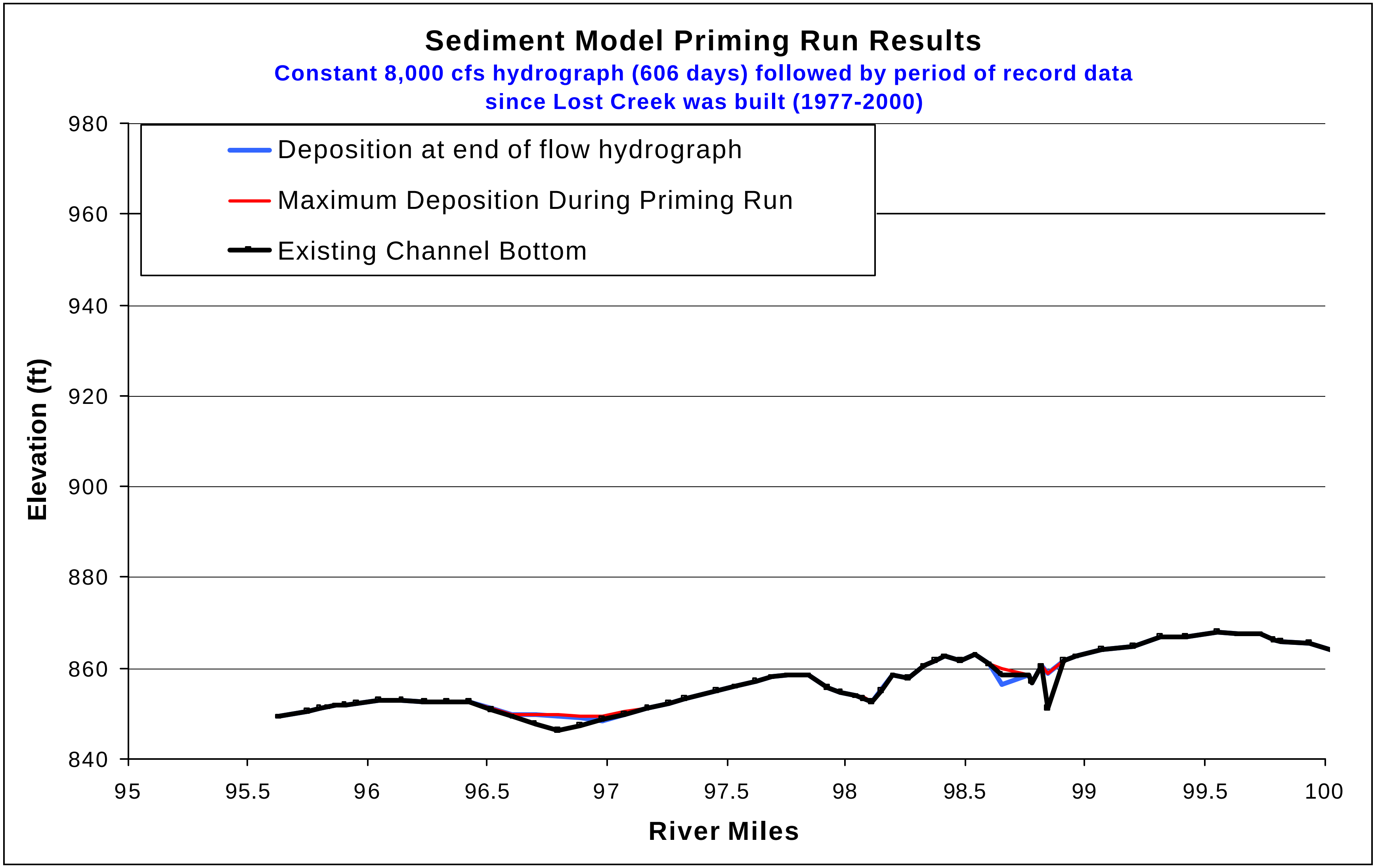


Figure E-3.—Results for sediment model priming run for the 5 miles directly upstream from the confluence with the Applegate River. Model priming was necessary to stabilize the model for natural conditions (estimated incoming sediment load) and to enable modeling of the net change from removing the dam and allowing reservoir sediments to erode and be transported downstream.

Attachment F

SERIES OF PLOTS ILLUSTRATING SEDIMENT TRANSPORT DOWNSTREAM FROM THE DAM SITE FOLLOWING DAM REMOVAL

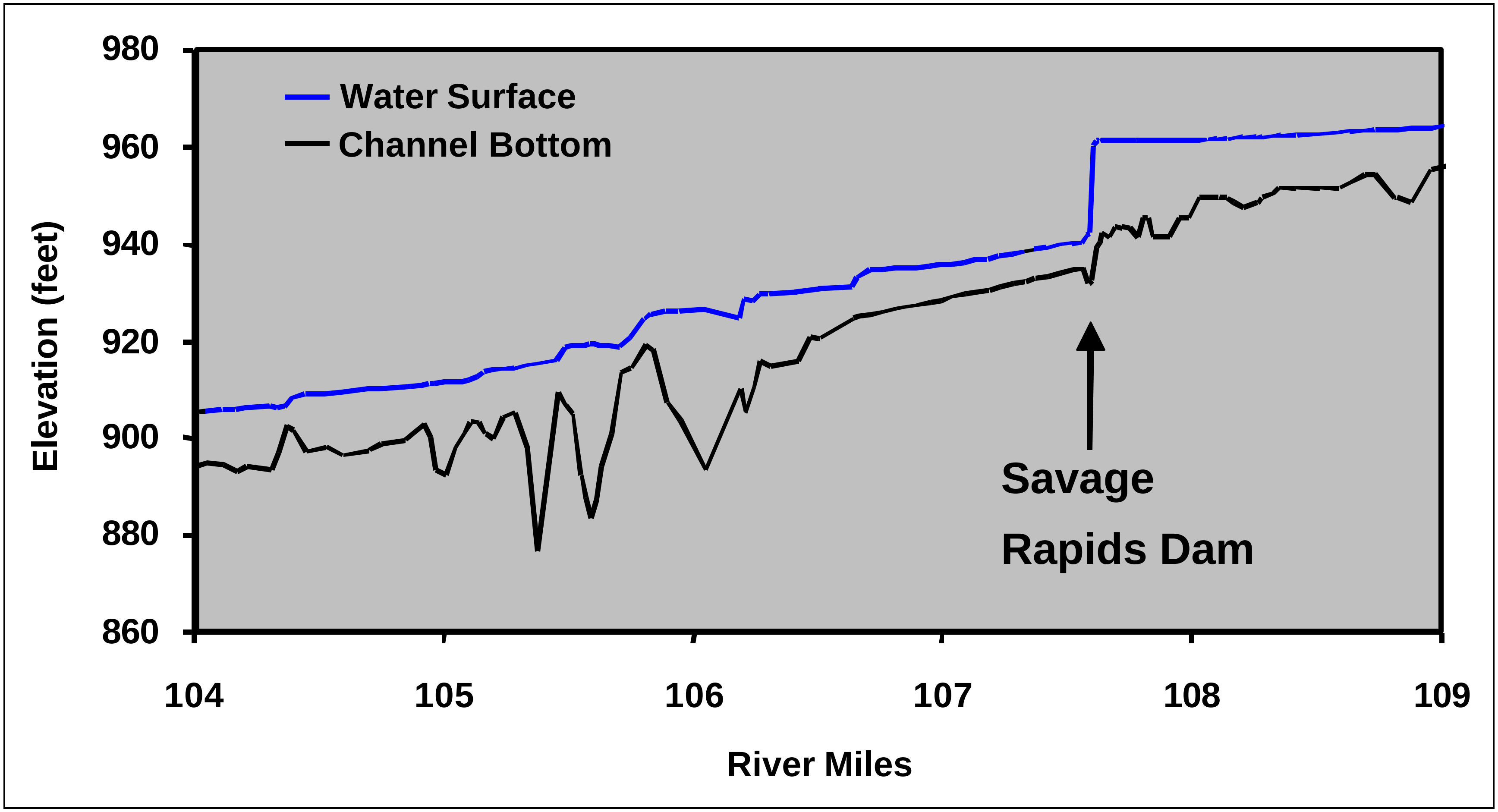
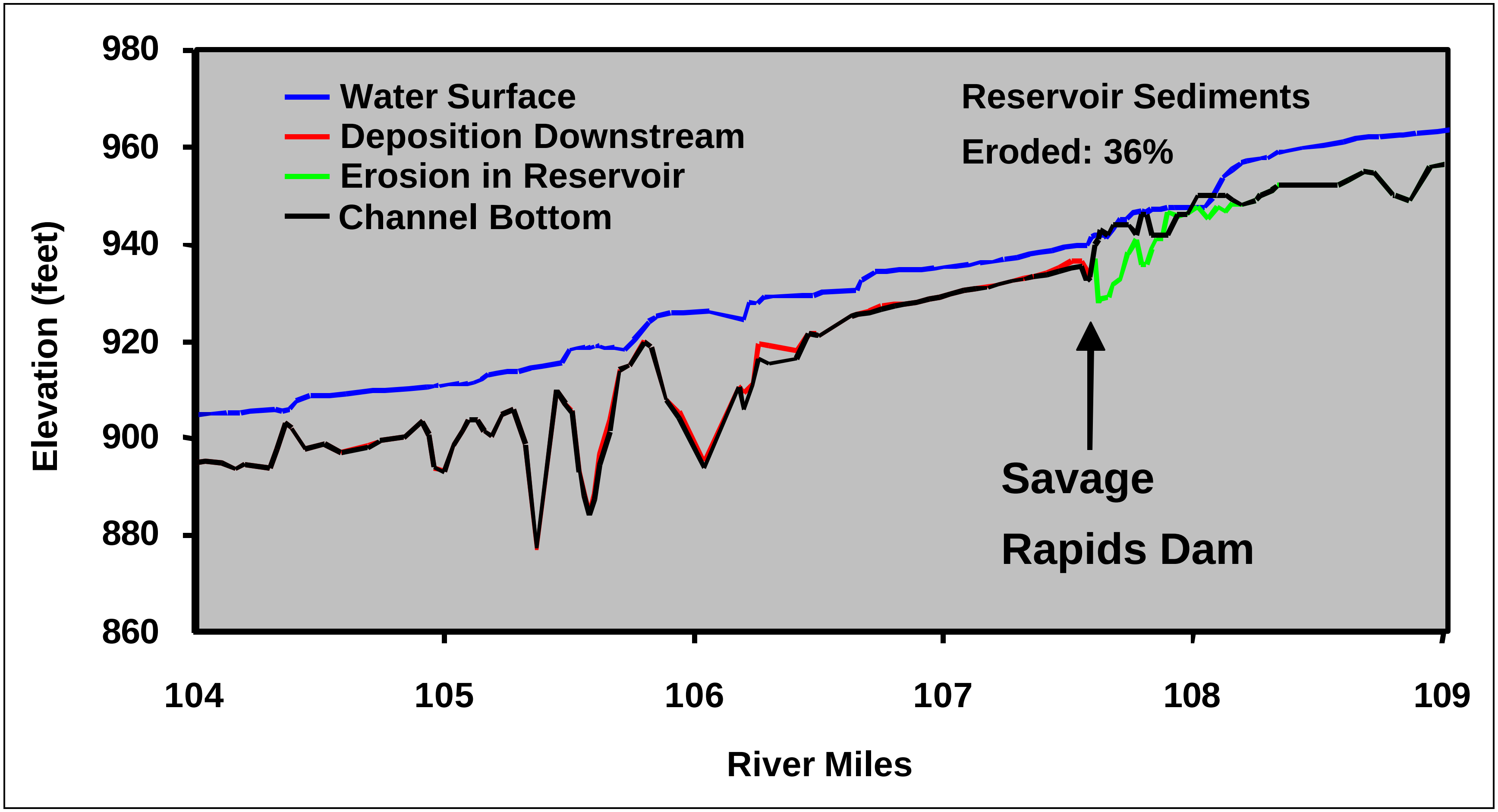


Figure F-1.—An animator was developed of the following slides that represents the model results for erosion of reservoir sediment and subsequent deposition downstream following the removal of Savage Rapids Dam.



Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 36%
Savage
Rapids Dam
980
960
940
920
900
880
860
Elevation (feet)
104
105
106
107
108
109
River Miles

Figure F-2

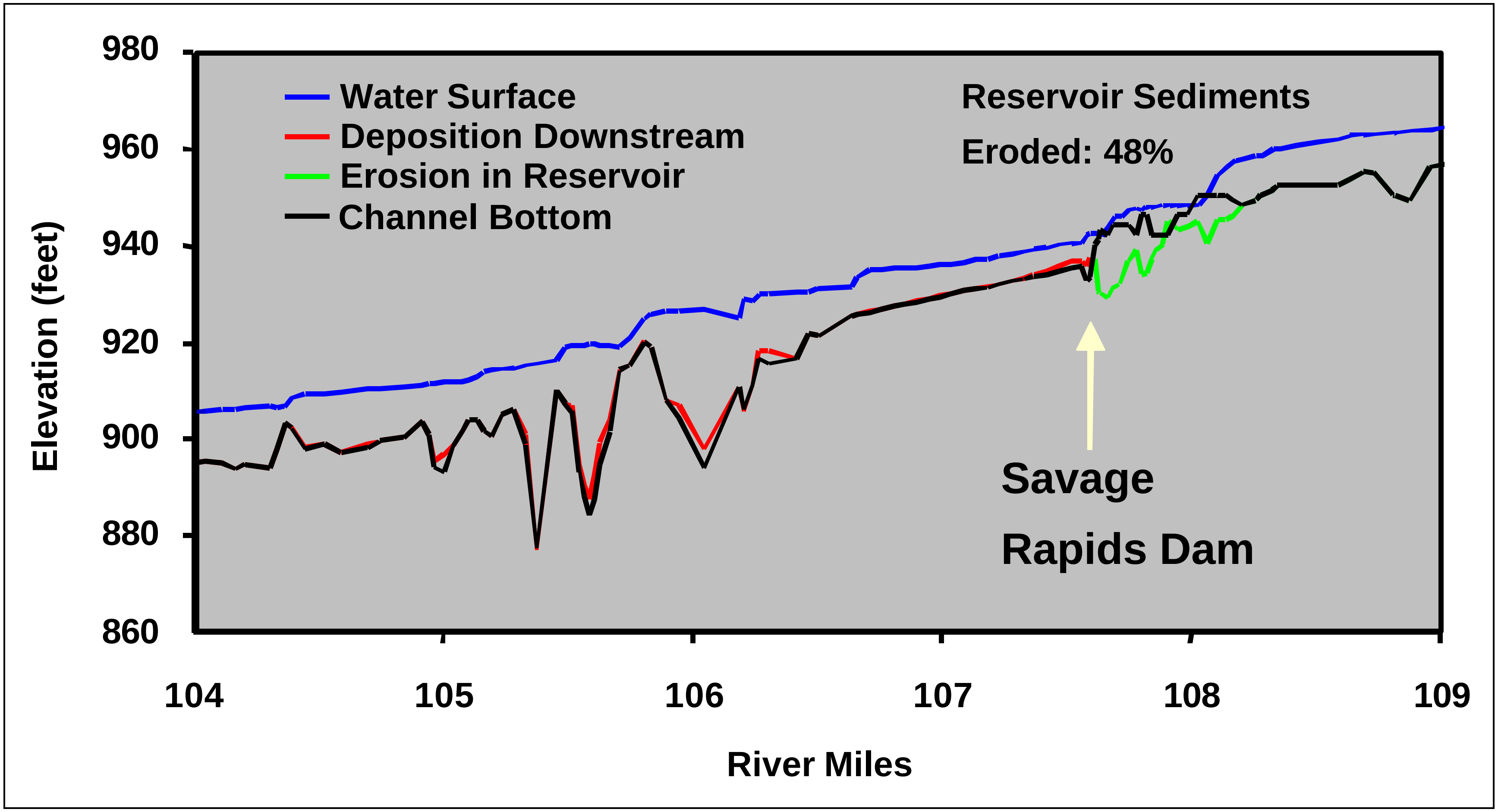
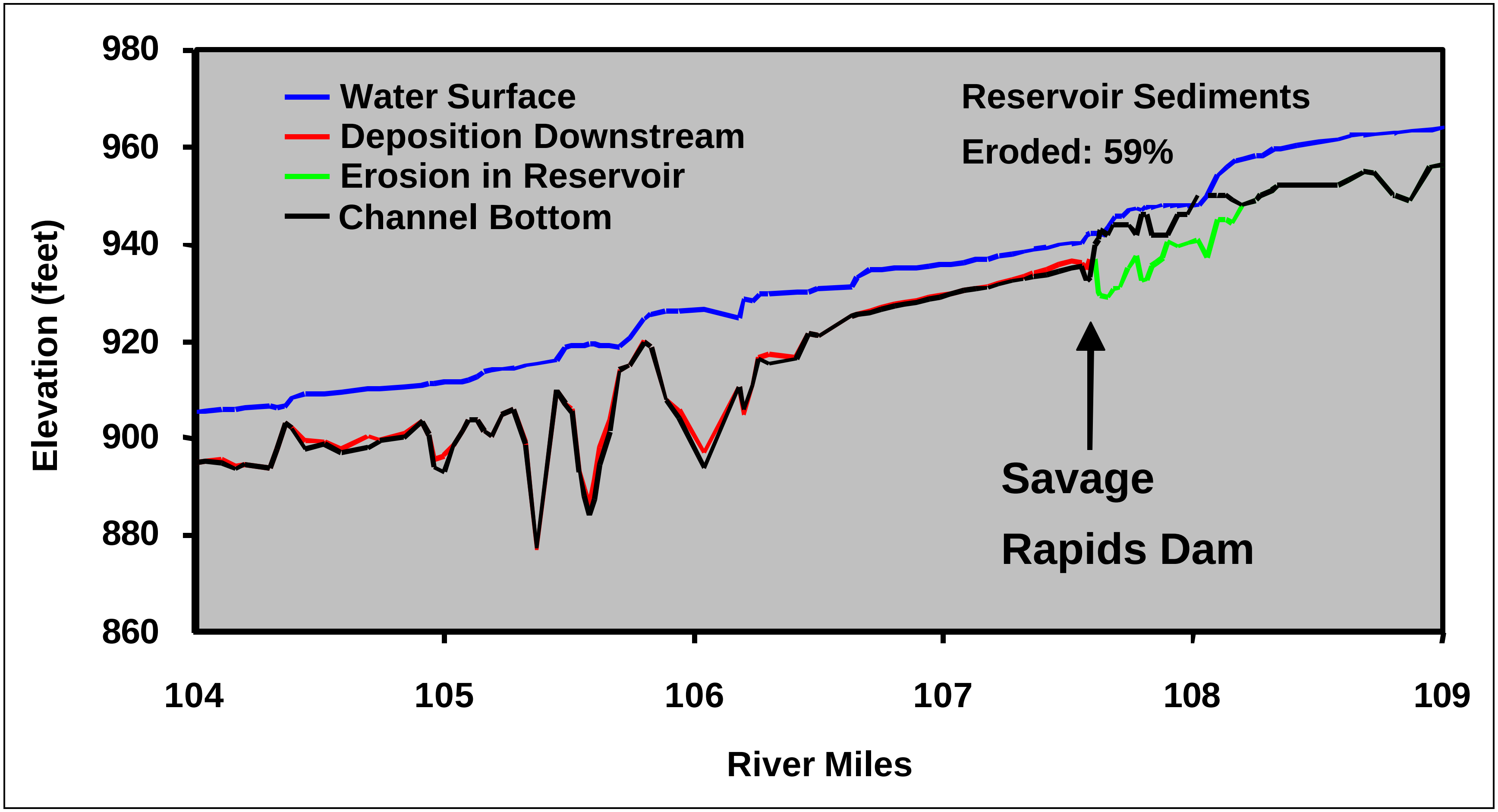

980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 48%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-3



980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 59%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-4

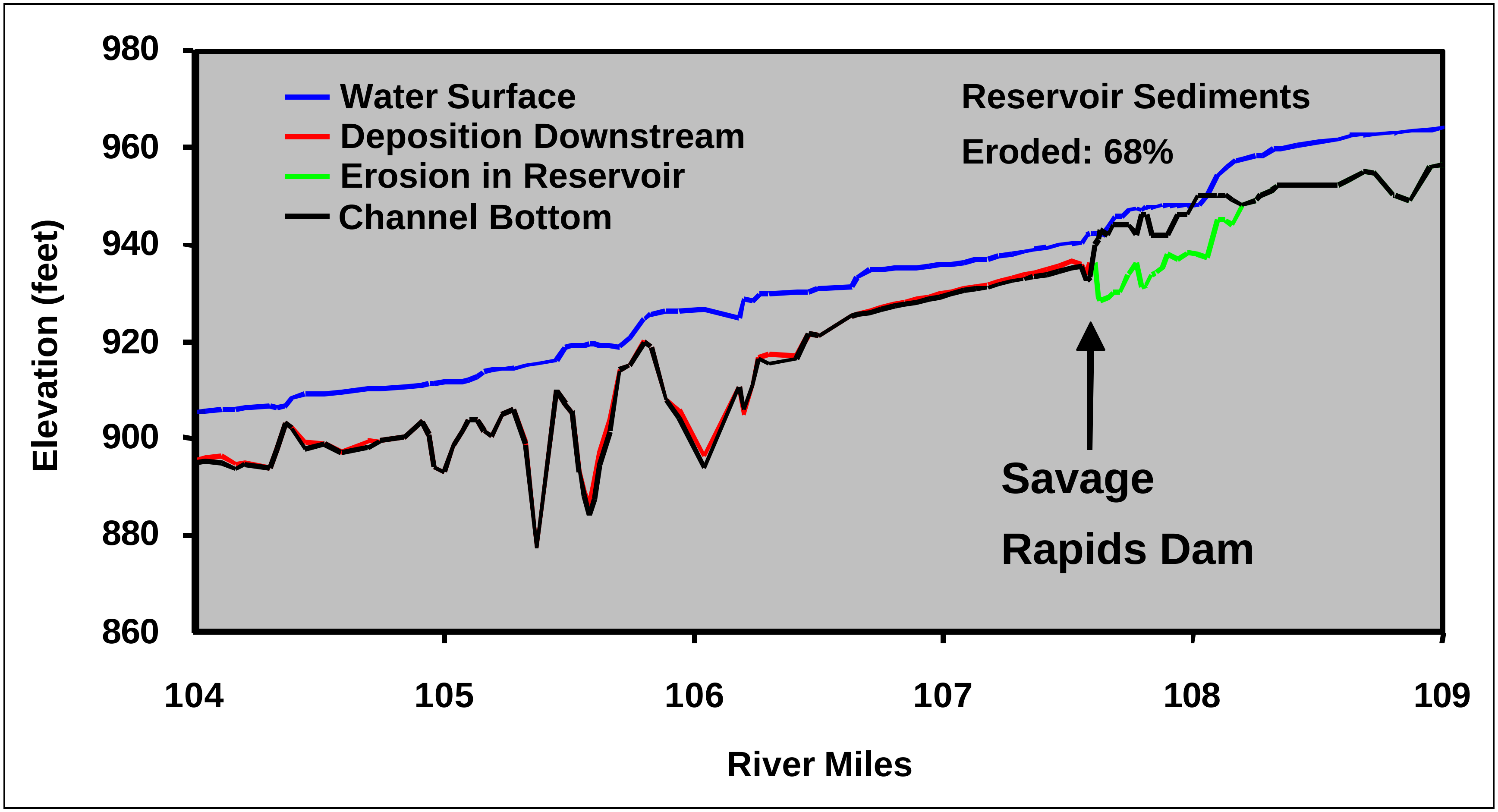

Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 68%
Savage
Rapids Dam
980
960
940
920
900
880
860
Elevation (feet)
104
105
106
107
108
109
River Miles

Figure F-5

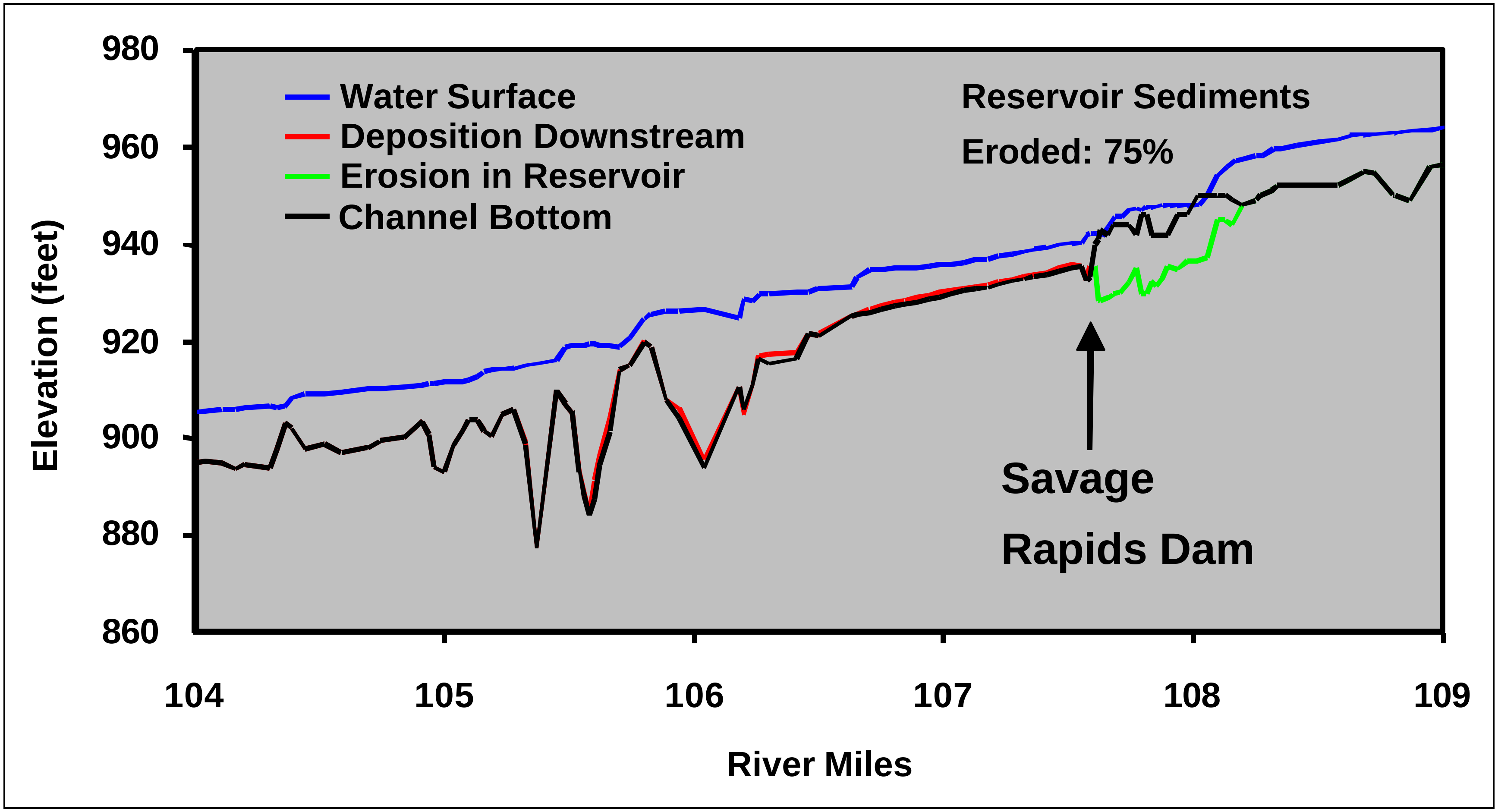

980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 75%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-6

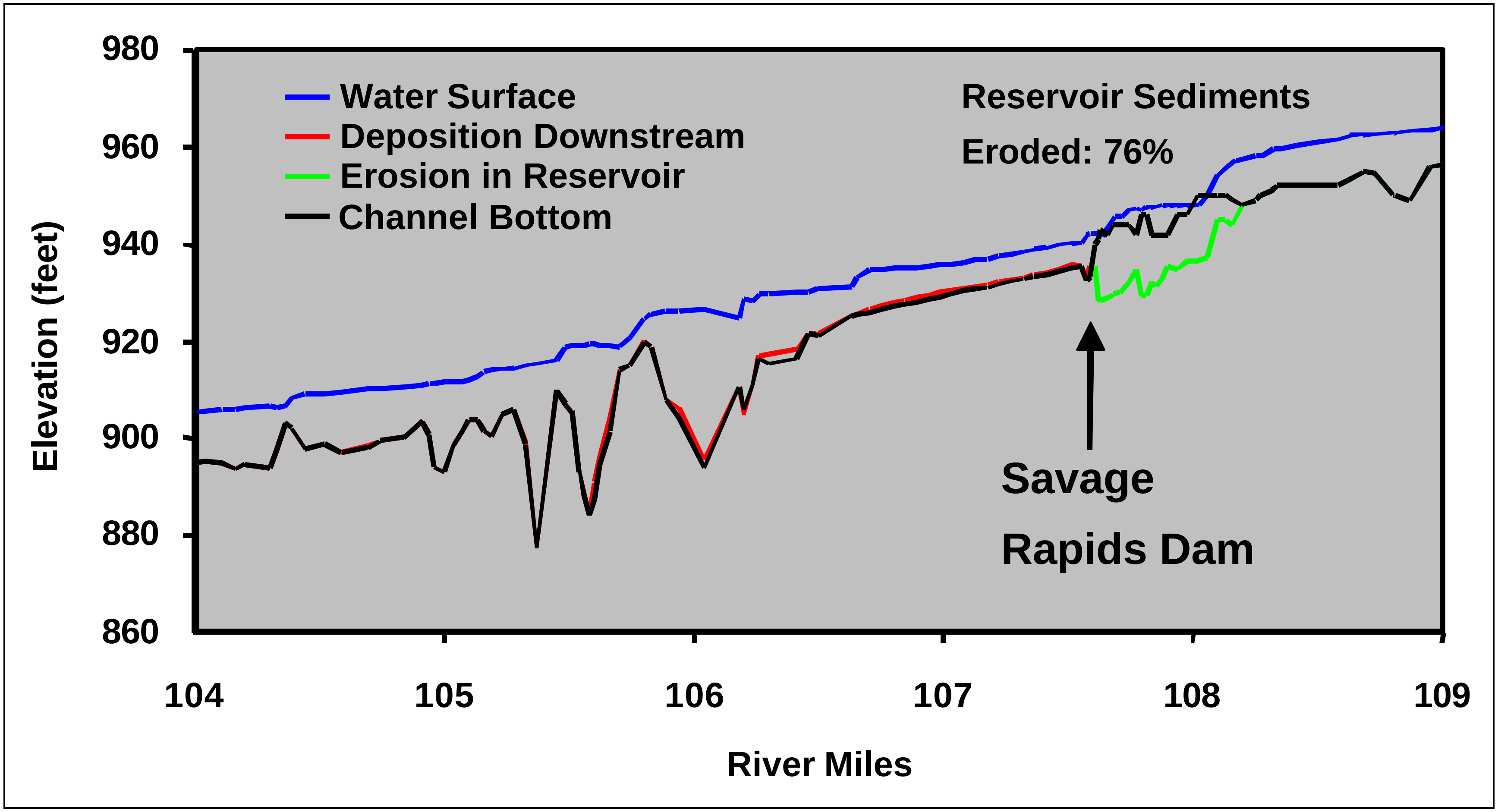
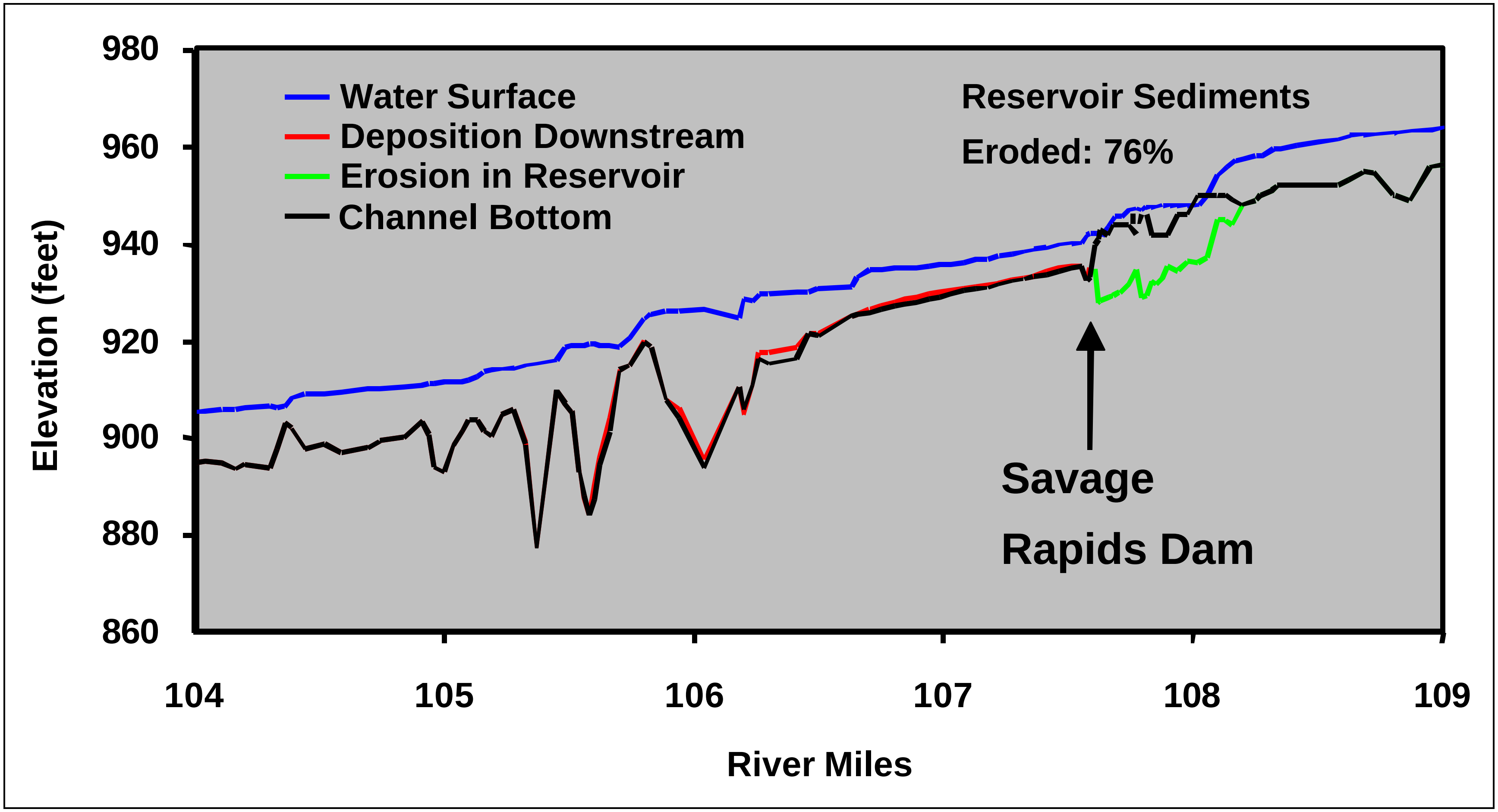
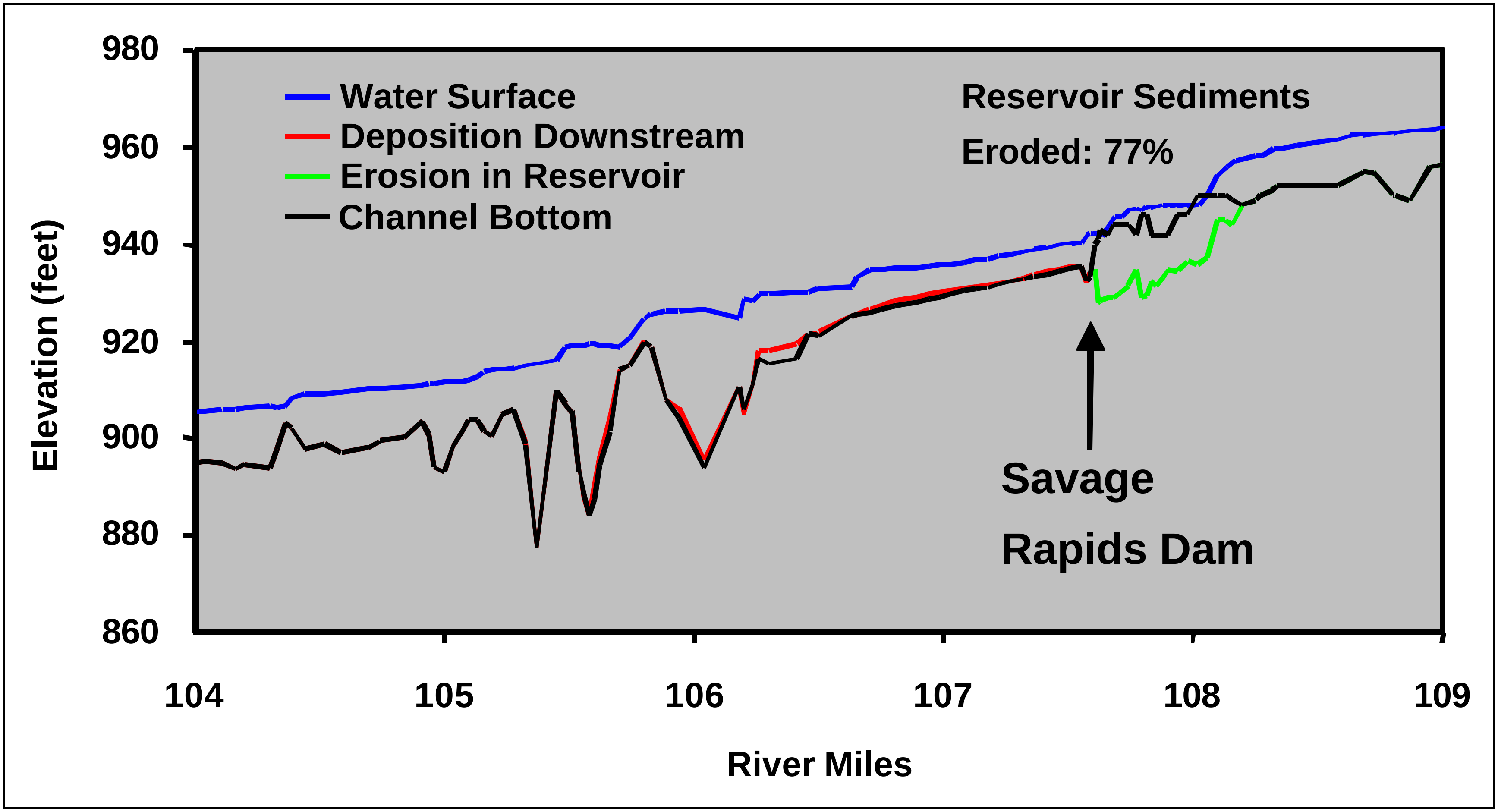

Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 76%
Savage
Rapids Dam
Elevation (feet)
980
960
940
920
900
880
860
104
105
106
107
108
109
River Miles

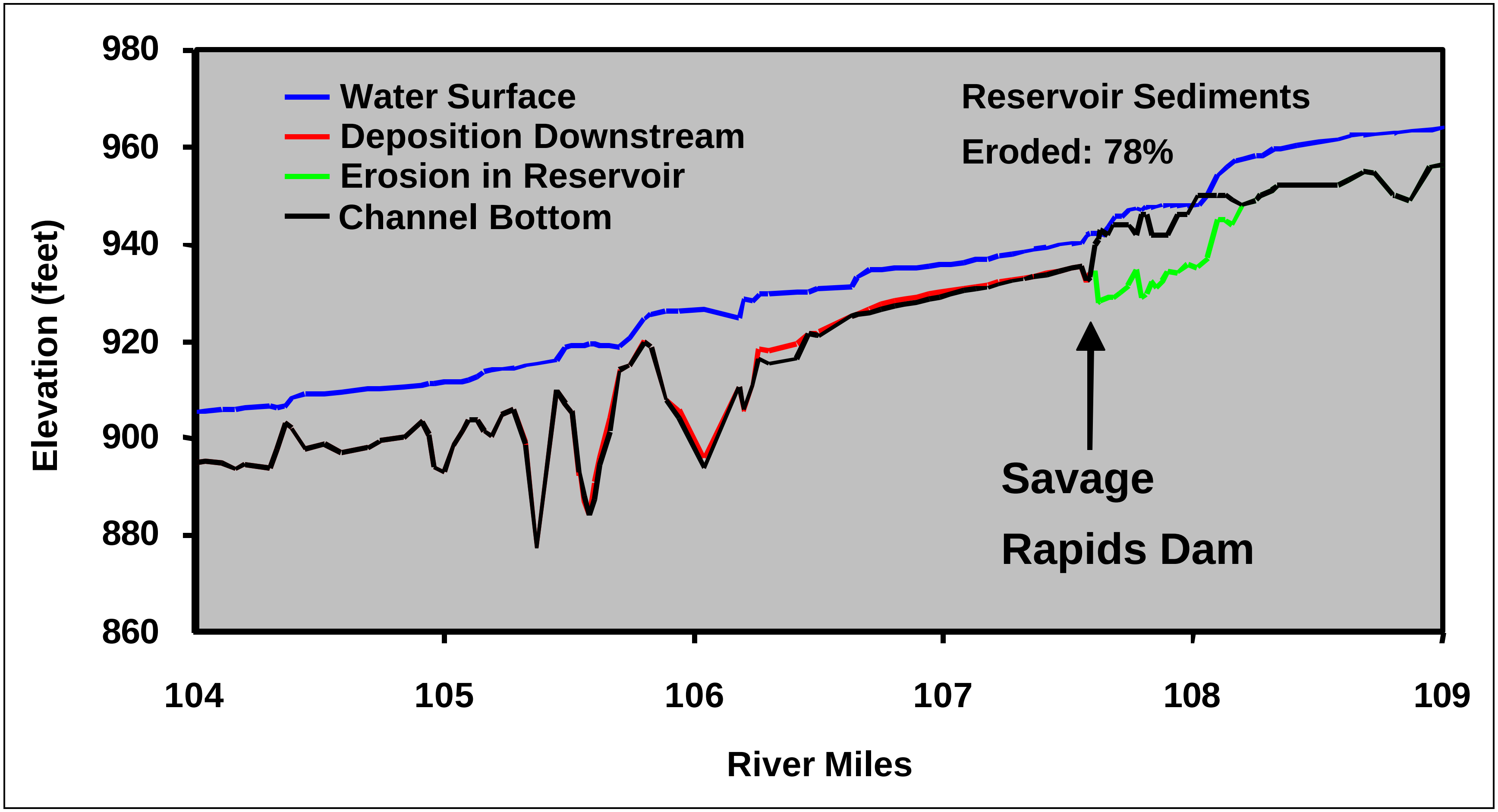
Figure F-7


980
960
940
920
900
880
860
Elevation (feet)
104
105
106
107
108
109
River Miles
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 76%
Savage
Rapids Dam
Figure F-8



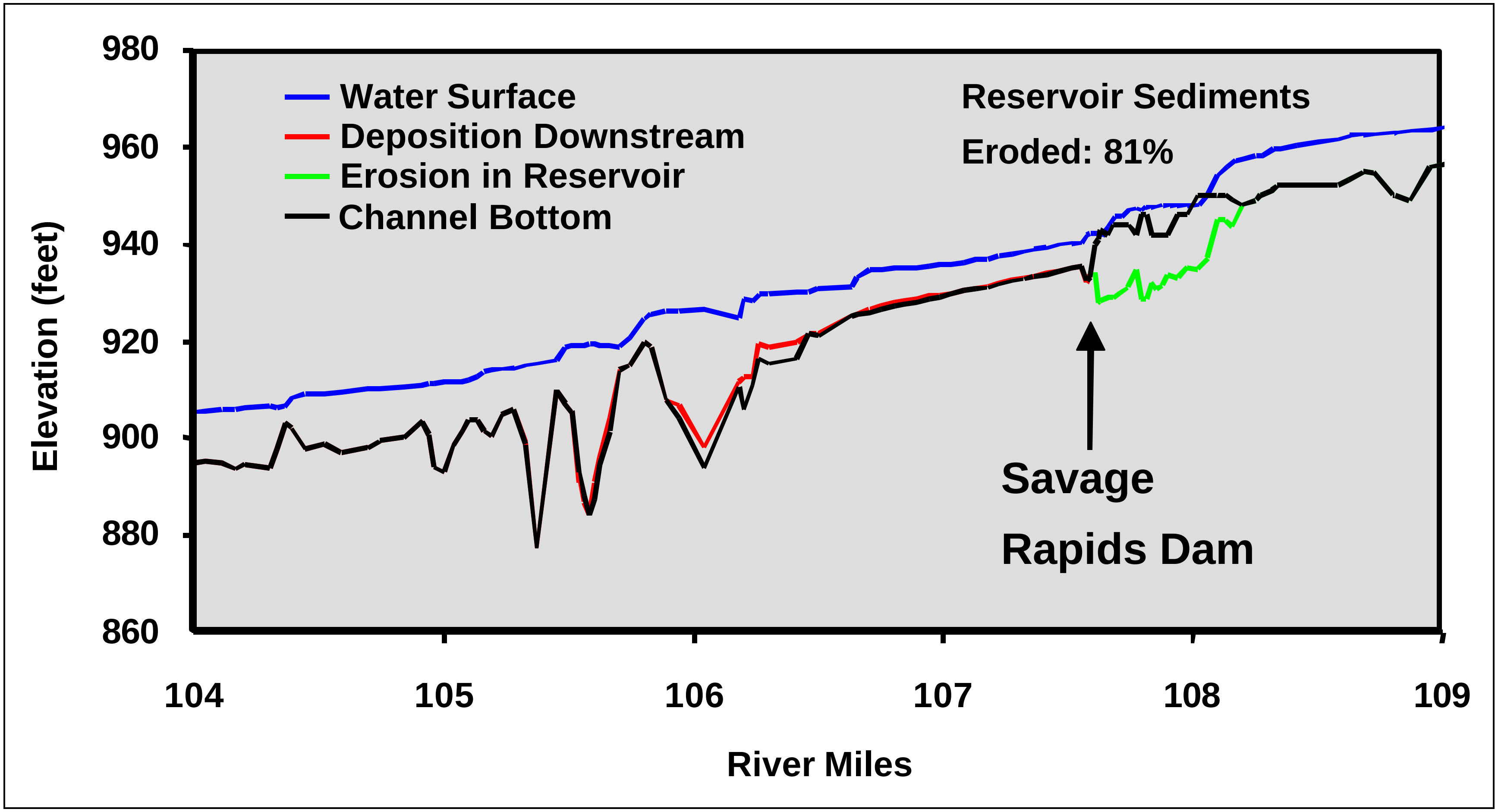
980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 77%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-9



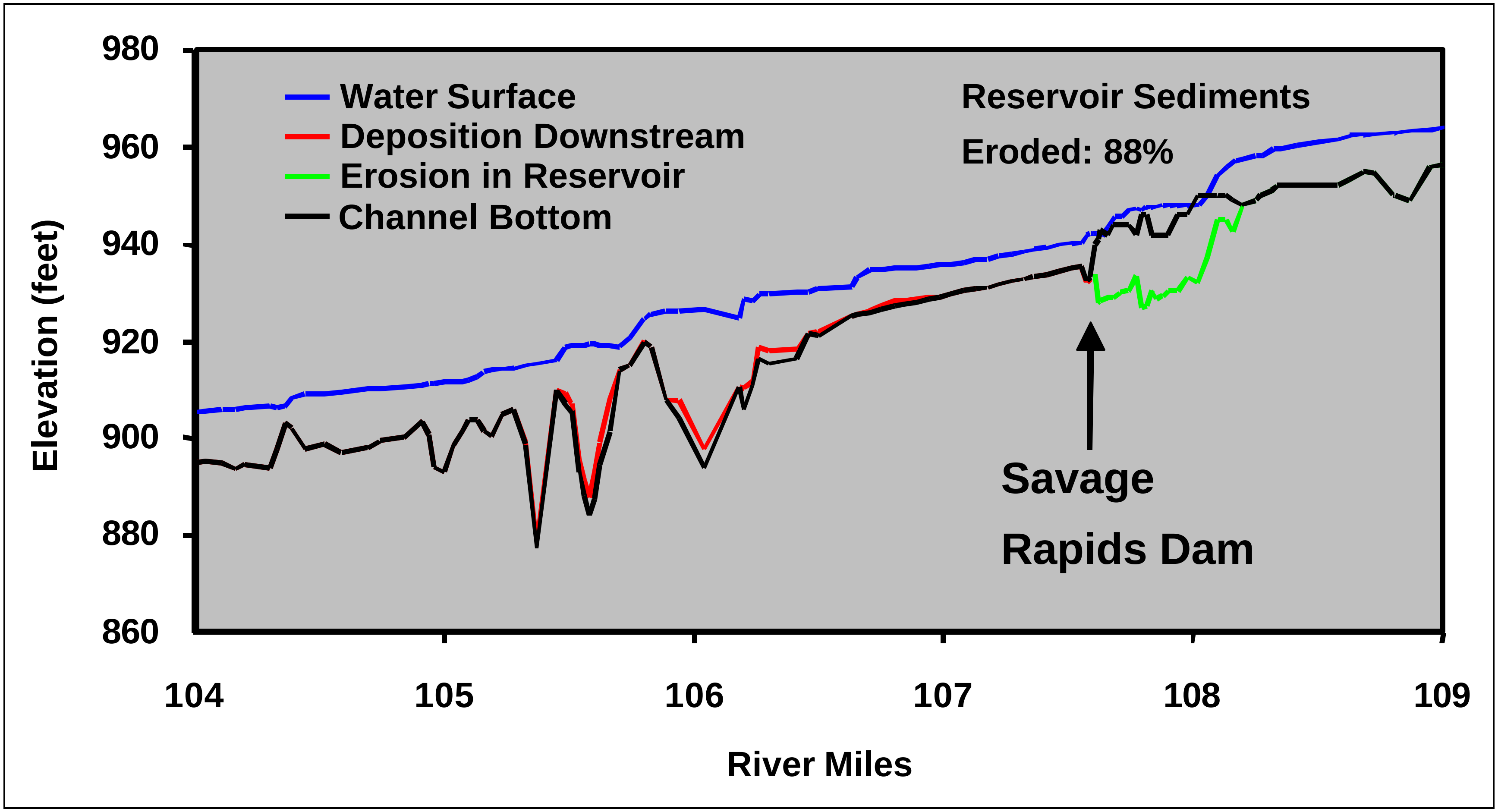
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 78%
Savage
Rapids Dam
Elevation (feet)
980
960
940
920
900
880
860
104
105
106
107
108
109
River Miles

Figure F-10



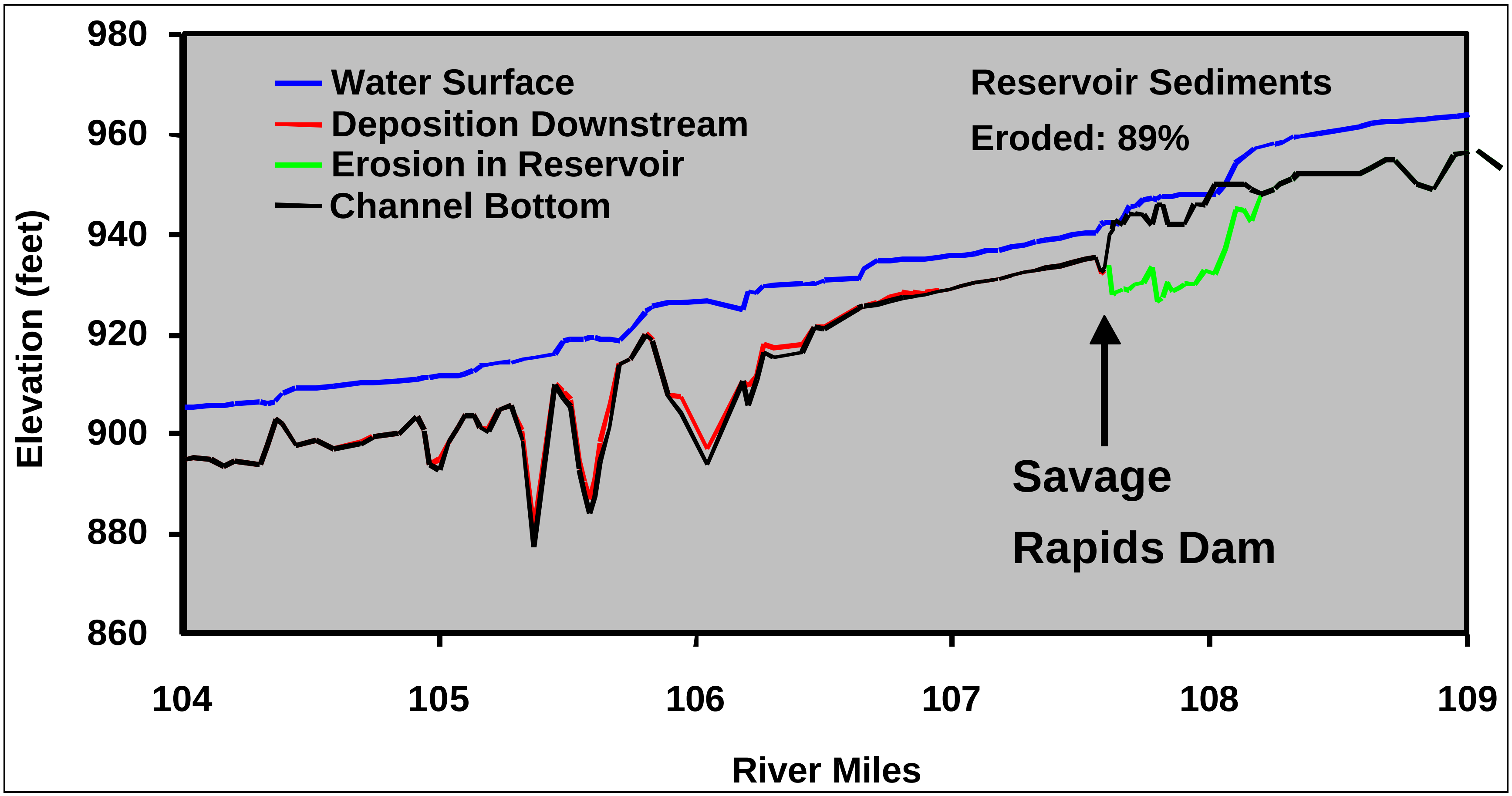
980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 81%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-11



980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 88%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-12



980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 89%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-13

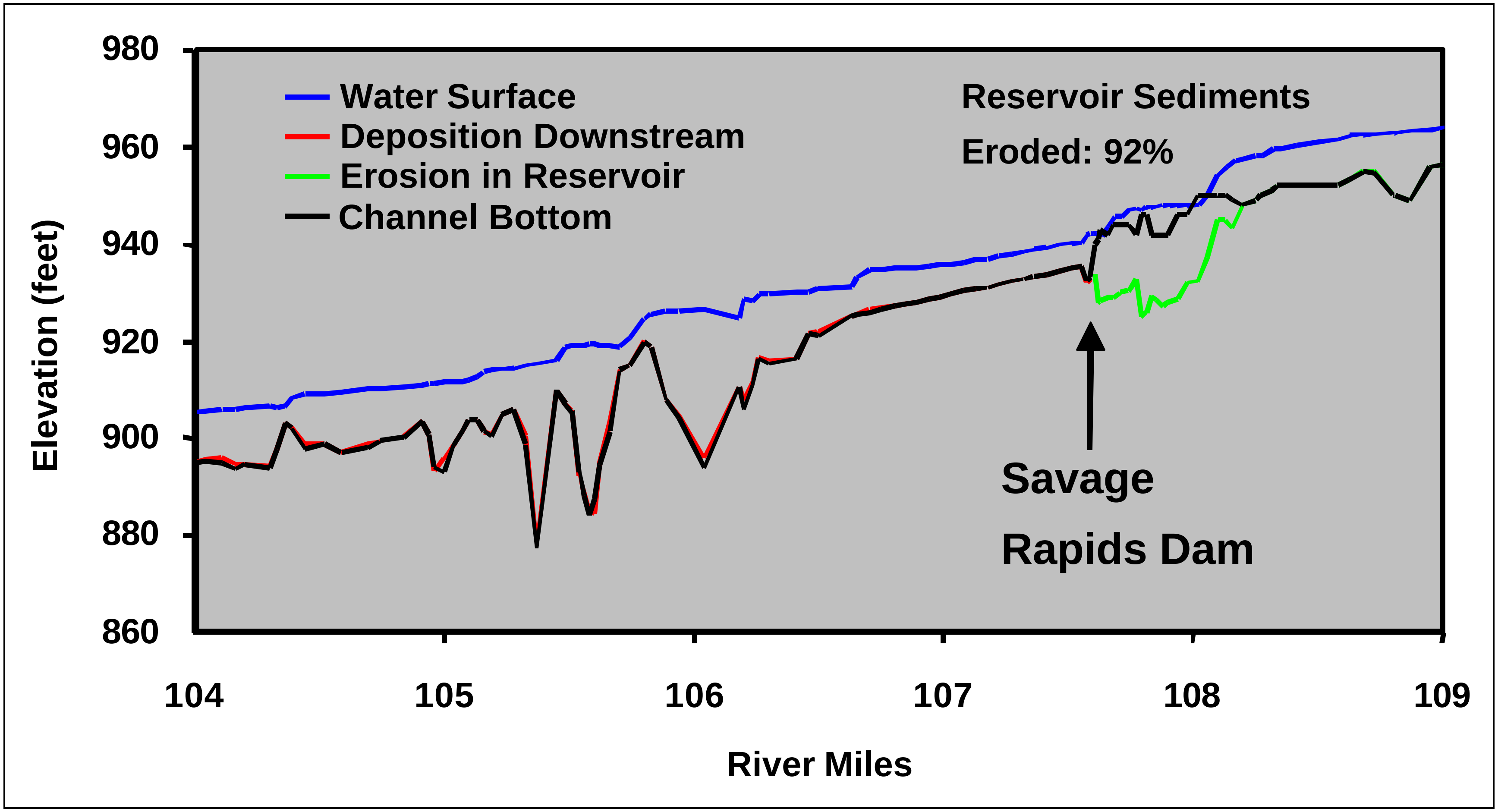

980
960
940
920
900
880
860
Elevation (feet)
Water Surface
Deposition Downstream
Erosion in Reservoir
Channel Bottom
Reservoir Sediments
Eroded: 92%
Savage
Rapids Dam
104
105
106
107
108
109
River Miles

Figure F-14

Appendix C

WATER AND SEDIMENT QUALITY CONSIDERATION RELATED TO THE POTENTIAL SAVAGE RAPIDS DAM REMOVAL

by James Yahnke
Hydrologist

U.S. Bureau of Reclamation
Technical Service Center
Denver, Colorado

CONTENTS – APPENDIX C

Page

Tables

Table *Page*

Figures

Figure *Page*

Figures (continued)

Figure *Page*

Water and Sediment Quality Considerations Related to the Potential Savage Rapids Dam Removal

Background

McLaren/Hart (1998) conducted a sediment assessment on samples collected from the exposed area on the margins of Savage Rapids Reservoir. These sample sites are subjected to wetting and drying. Samples from the deeper parts of the reservoir may be different from those on the margins of the reservoir. Sediments below the deeper waters would be inundated longer (or permanently) and would be expected to be more organic. Historically, sediments that accumulate near the dam during the irrigation season are flushed from the reservoir when the stoplogs are removed after the season ends. Consequently, few of the recent sediments are likely to remain in the reservoir.

The marginal sediments average about 600 parts per million (ppm) total organic carbon (TOC). The marginal sediments would also be expected to be oxidized. Sediments from the deeper parts of the reservoir may be oxidized near the sediment/water interface but would be expected to be chemically reduced within a few inches of that surface. The effect of the reduced sediments on water quality could be different from the effect of the marginal oxidized sediments sampled in the McLaren/Hart (1998) assessment.

The McLaren/Hart (1998) assessment analyzed the total concentration of elements in the sediment samples using methods developed by the Environmental Protection Agency (EPA) to evaluate the biological availability of potential contaminants in solid wastes. These were compared against effect levels from the literature, where available, and background concentrations for western soils when effect levels were not available.

There are 3 years of water quality data collected from 1953 through 1956. These years may not be representative of existing conditions, but they do encompass a period during the historic operation of Savage Rapids Dam, including the period in which federally financed repairs were being undertaken. The data are summarized in table 1. The data indicate that the water in the Rogue River was well within any drinking water standard (maximum contaminant level [MCL] or secondary maximum contaminant level [SMCL]), with the exception of the SMCL for color. It should be noted that MCLs and SMCLs apply to treated water; after coagulation and filtration, the color could meet its SMCL. The distinction between MCLs and SMCLs is that MCLs are related to health concerns, and SMCLs apply to aesthetics (e.g., taste and odor).

McLaren/Hart (1998) analyzed the marginal sediments for volatile and semivolatile organic compounds (VOCs and SVOCs). Neither VOCs and SVOCs were found in measurable concentrations in any of the samples. There is no indication of a source of either type of compound upstream from the reservoir, and none should be expected to be found.

Table 1.—Summary of water quality data for the Rogue River at Grants Pass between January 1953 and September 1956

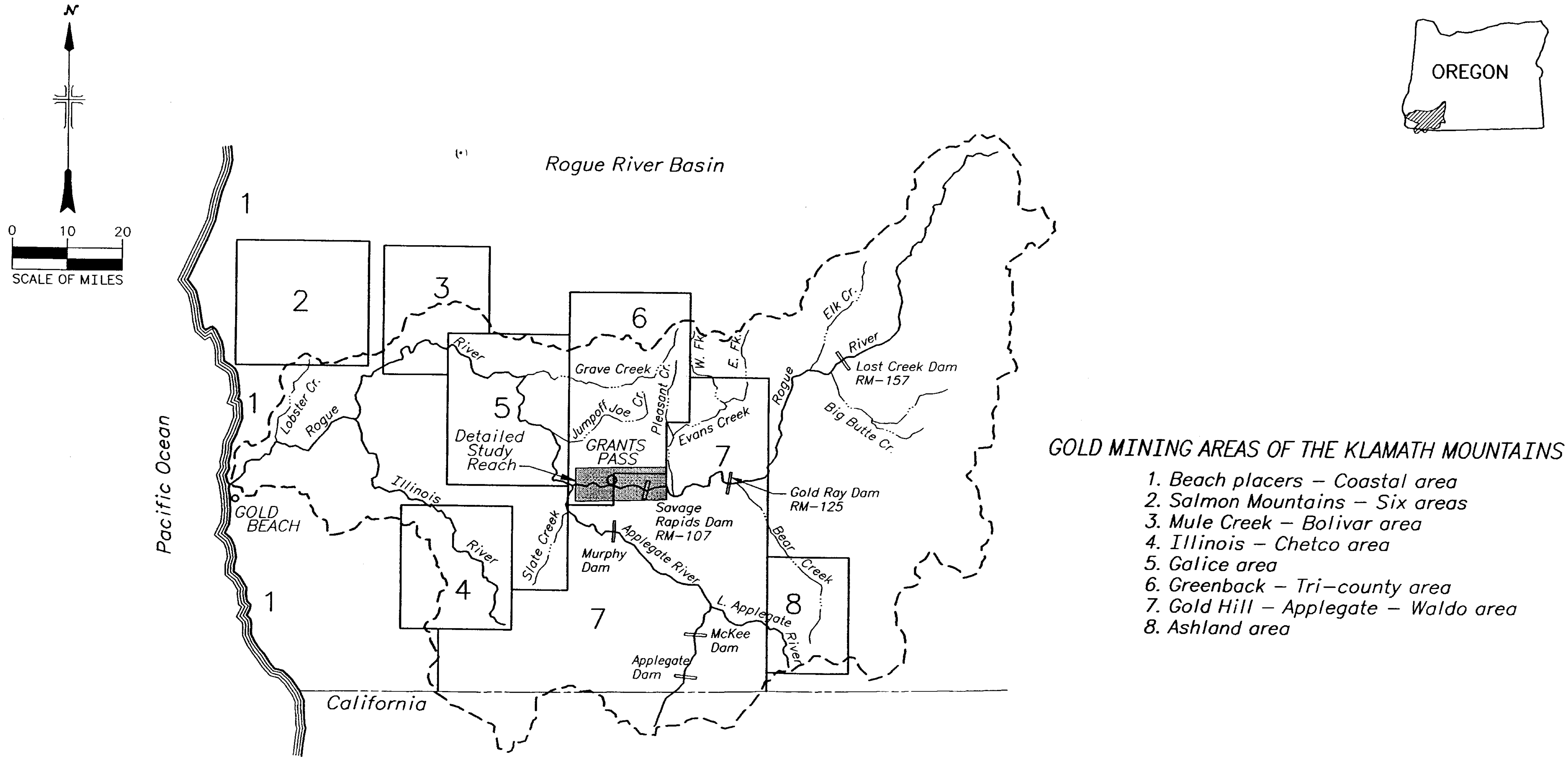
	Q, daily (ft^3/s)[1]	Ca, dissolved (mg/L)[2]	Mg, dissolved (mg/L)	Na, dissolved (mg/L)	K, dissolved (mg/L)
Minimum	885	5.6	0.5	3.3	1.0
Median	3,171	8.3	3.0	5.0	1.5
Maximum	27,300	26	5.0	9.1	2.8
No. of observations	127	127	127	127	53

	HCO_3 (mg/L)	SO_4, total (mg/L)	Cl, dissolved (mg/L)	Spec. cond. (µmho/cm at 25 EC)[3]	TDS ROE (180 EC) (mg/L)
Minimum	34	1.0	1.0	62	53
Median	49	2.1	2.2	90	78
Maximum	98	10	3.8	190	136
SMCL[4]	—	250	250	—	500
No. of observations	127	127	127	127	127

	pH	Fe, total (µg/L)[5]	Color (platinum-cobalt units)	F, dissolved (mg/L)	Total NO_3 (mg/L)
Minimum	6.6	< 10	< 1	< 0.1	< 0.1
Median	7.1	70	10	0.2	0.6
Maximum	8.1	290	60	0.6	3.0
MCL[6]/SMCL	6.5-8.5	300	15	2.0	45.0
No. of observations	125	58	55	58	127

[1] Cubic feet per second.
[2] Milligrams per liter.
[3] Micromhos per centimeter at 25 EC.
[4] Secondary maximum contaminant level = 2E drinking water standard.
[5] Micrograms per liter.
[6] Maximum contaminant level (only NO_3 is an MCL) = 1E drinking water standard.

McLaren/Hart (1998) analyzed the marginal sediments for a variety of metals and metalloids. Most were present in measurable concentrations, but none was above an uncontaminated background concentration. The inorganic contaminants were analyzed because of concerns over the possible contamination of the sediments from the remains of historic mining activities in the upper Rogue River basin. Brooks and Ramp (1968) summarize historic mining in southwestern Oregon and present a list of the mines in two mining areas in the Rogue River basin along with the predominant mineralization in each (figure 1). The hydrologic basin in which each mining area is located is also



Adapted from Brooks and Ramp, 1968.

Figure 1

noted. This information can be used to characterize the potential water quality of runoff and the chemical composition of sediment in that runoff entering the river from the mining areas.

There are two mining areas in southwestern Oregon, both of which are partially within the Rogue River basin. These include the Klamath Mountains and western Cascades mining areas. The Klamath Mountains mining area is divided into 10 subareas. Eight of these subareas are wholly or partially within the Rogue River basin, but only three of them are upstream from Savage Rapids Dam. The three that are upstream from the dam are the Greenback-Tri-County area, which is primarily located in the Evans Creek Basin; the Gold Hill-Applegate-Waldo area, which includes the Applegate River Basin down-stream from the dam, numerous mines east of the town of Rogue River, and the lower end of Bear Creek; and the Ashland area, which is located in the upper Bear Creek Basin, south of Medford. Within the western Cascades area, there are five delineated subareas. There are two mines that are not included within any of the subareas. These two mines are in the headwater areas of the Rogue Basin and will not be considered further.

The Greenback-Tri-County area, as described by Brooks and Ramp (1968), extends from Grants Pass northeastward to include a group of mines which lie in northeastern Josephine County and along the adjacent margins of Douglas and Jackson Counties, where the three counties join. The mining area incorporates parts of the Grants Pass, Greenback, Riddle, and Gold Hill mining districts. The specific mines described by Brooks and Ramp (1968) are in the Grave Creek and Jumpoff Joe Creek Basins, to the west of Grants Pass, but the mineralogy of the area should be similar throughout and would be expected to typify that to the east of Savage Rapids Dam.

The usual ore mineral assemblage of the Greenback-Tri-County area includes native gold, pyrite (iron sulfide = FeS_2), chalcopyrite (copper-iron sulfide = Cu,FeS_2), and arsenopyrite (FeAsS), which is the principal ore material in some of the richer deposits. Occasional galena (lead sulfide = PbS) and sphalerite (zinc sulfide = ZnS) are also noted among the ore minerals. Brooks and Ramp (1968) do note that mineralization in the eastern part of the area contains some copper and significant zinc. If the sediments in Savage Rapids Reservoir have a significant component derived from mine waste, the above metals could be used as indicators.

Ore was concentrated mostly with stamp mills and cyanide. The use of amalgamation plates is also noted. The use of amalgamation plates raises the possibility of mercury releases. In addition, there were several mercury mines in the basin, and production continued to the time of World War II (Brooks, 1963). The primary mercury ore in the basin was cinnabar (HgS), with minute globules of native quicksilver locally occurring with it (Brooks, 1963). Bowen (1969) showed measurable mercury in the sediments of tributaries to the Rogue River.

The Gold Hill-Applegate-Waldo area is a broad region covering 900 square miles in western Jackson and southeastern Josephine Counties (Brooks and Ramp, 1968). Ore minerals include gold, pyrite, chalcopyrite, some galena, pyrrhotite (an iron sulfide = Fe_7S_8-FeS), and occasional sphalerite (Brooks and Ramp, 1968.). Rich, near-surface pocket deposits were also noted; these were associated with sooty iron and manganese oxides. The Sylvanite Mine, near Gold Hill, located a deposit of scheelite (calcium tungstate = $CaWO_4$) associated with the gold ore. Because of this, tungsten may also be an indicator of mine runoff.

Most of the mines, other than placer mines, ceased working by 1940. This would mean that any materials discharged during active mining would be relatively deep in the reservoir sediment or not present at all. There were numerous placer dredging operations upstream from Savage Rapids Dam. The placer operations were located in the main stem of the river and on the lower reaches of many of its larger tributaries. These operated through the 1940s, although several continued into the 1950s and 1960s. Dredging causes sedimentation in the river. However, the sediment had already been in the river and was only relocated. The river gravels that are stirred up during placer mining should be considered either nontoxic or of very low toxicity. Any toxics that could be leached in toxic concentrations should be long gone by the time the particles are trapped in the reservoir.

There were also several large hydraulic operations in the basin (Brooks and Ramp, 1968). Hydraulic mining would contribute more sediment than placer operations, but the sediment quality would be about the same as the placers.

Rationale for Sampling

On the basis of the above, either very low concentrations or no measurable organic contaminants would be expected to be found in the sediments. Heavy metals could be expected to be found in the sediments. Metals from active mining would be buried deeper in the sediments than recent mine drainage. The most common method of mining during the later stages of mining in the basin was hydraulic mining of placer deposits. These deposits would contribute metals that would show up in a total analysis but should be very low in an extract. Because of this potential difference with depth in the sediments, subsamples of selected core samples have been analyzed. The subsamples have been from near the surface of the sediments and near the deepest part of the core column. At a minimum, the analyzed metals in any samples will include copper, iron, lead, manganese, mercury, and zinc. The metalloid, arsenic, has also been included in the minimum list of analytes since arsenopyrite seems to be a relatively common ore in the basin. Cadmium, along with mercury and lead, is one of the "big three" heavy metal poisons (Manahan, 1989). Cadmium occurs as a constituent in lead and zinc ores (Manahan, 1989) (i.e., galena and sphalerite, respectively). Because of its potential toxicity and the occurrence of these lead and zinc minerals in the upper basin, cadmium has also been included in the minimum list of analytes.

McLaren/Hart (1998) analyzed the sediments for a wide variety of inorganic elements and characteristics and for a broad suite of organic contaminants. Since the main goal of the followup sampling was to look for evidence of mining contamination, the analysis only included elements associated with hard-rock mining. No analyses for organic contaminants were performed on the samples. Aside from this, the samples were handled and analyzed in the same manner as in the McLaren/Hart (1998) assessment.

Methods

An overview of the sample sites for contaminant analysis is presented in table 2. The samples were taken from two of the drill holes used in the volumetric study. There were surface samples from each of the holes. The deeper samples were taken from an individual hole. This was felt to be a depositional area within the reservoir at the time it was impounded. The rationale for selecting the sites is presented in the attached field report on the sampling (Attachment A).

Table 2.—Description of sample locations

Drill hole	Depth of water over sediments	Interval depths (feet)		Feet below sediment surface	Hole location
		Surface	Bottom		
AP-99-11	17.5	17.7	19.7	0.2	Across from boat ramp at Savage Rapids Park
AP-99-12	26.1	26.9	28.9	0.8	Between the park and the large gravel bar on the north side of the reservoir
		35.7	37.7	9.6	
		41.1	43.1	15.0	

All analyses were performed using EPA methods (EPA, 1986). The sediments were digested using Method 3051, the microwave modification of Method 3050. The digests were analyzed for the metals, cadmium (Cd), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), and zinc (Zn), by Inductively Coupled Plasma emission spectroscopy (ICP/ES)-Method 6010. Mercury (Hg) was analyzed by Method 7471 (cold vapor atomic fluorescence). Arsenic was initially analyzed by ICP/ES, but because of the high detection limit (14 milligrams per kilogram [mg/kg] = ppm dry weight), it was rerun by graphite furnace atomic absorption (Method 7060A). There was low spike recovery in the initial determination, so arsenic was determined by the method of standard additions (Method 7000 [sec. 8.7]). Total organic carbon was determined with a carbon analyzer (Method 9060).

There were some difficulties encountered during sample collection (detailed in Attachment A). One of the sample bottles was broken in transit. The broken bottle contained the surface sample for drill hole AP99-12. The results for that sample will be used with some caution because of a potential for contamination. Because the sample was contained in a newly purchased cooler, and the chances for significant contamination were considered low, the sample was analyzed like the others.

Contaminants in Deep Sediments

The results of the chemical analysis of the samples are shown in table 3. There was no detectable cadmium in any of the samples, and measurable mercury was present in only one sample. The measurable mercury occurred in the sample from the broken bottle; the mercury may be the result of slight contamination. The remaining elements, with the exception of manganese, are not much different from the other samples from the same drill hole that were not broken. The manganese is somewhat higher than the other samples from the same drill hole but not greatly higher than the surface sample from the other drill hole. The more upstream surface sample had somewhat higher copper, lead, and zinc than any of the layers of the downstream sample. One oddity in the data in table 3 concerns the layers from AP-99-12. The minimum concentrations of arsenic, iron, manganese, lead, and zinc occur in the middle layer. If there were some long-term trend, the minimum would be expected to be at the top or the bottom. On the other hand, the maximum manganese and mercury are in the surface layer, while the maximum arsenic, copper, iron, and zinc are in the lowest layer. These latter results would be consistent with historic mining as the source of the maxima. The most significant source for those elements with the maximum concentration near the surface would reflect the effects of more recent development in the drainage basin.

Table 3.—Savage Rapids Dam deep sediment samples – total metals (mg/kg) during October 1999

	AP-99-11	AP-99-12				
Element	17.7-19.7'	26.9-28.9'	35.7-37.7'	41.1-43.1'	McLaren/Hart maximum	1999 detection limit
Arsenic	2.19	2.52	2.09	2.61	6.1	0.20
Cadmium	ND[1]	ND	ND	ND	1.5	0.80
Copper	106	35.8	40.2	54.3	956	0.80
Iron	11,200	10,300	8,340	13,200	—	0.80
Lead	18.7	9.3	8.6	13.8	16.0	6.00
Manganese	231	296	119	194	—	0.80
Mercury	ND	0.022	ND	ND	0.114	0.011
Zinc	38.5	25.9	22.7	32.9	46.2	0.80

[1] Not detected at listed detection limit.

The Bureau of Reclamation's (Reclamation) Plan of Study indicated that the results would be compared to those of McLaren/Hart's previous sediment analysis. The minimum concentrations for most elements in both sets of chemical data are the detection limits. Because the detection limits were different between the two data sets, only the maximum concentrations are compared. This is accomplished in table 3 using only the McLaren/Hart maximum concentrations for the elements analyzed in the 1999 deep sediment samples. As can be seen in table 3, the Reclamation samples are within the range of the McLaren/Hart data, with one exception, the lead concentration in the sample from the upstream drill hole (AP-99-11). The maximum lead concentration in the McLaren/Hart data set was 16 mg/kg, while the maximum in the Reclamation deep-water sediment samples was 18.7 mg/kg.

Table 4 shows the results of various other analyses that were run on the Savage Rapids deep sediment samples. The pH of the sediments was essentially neutral. There was little moisture in some of the sediments, but two of the samples were near the usual value of 25 percent. The organic matter content was low, and the TOC was within the range of the McLaren/Hart data. One interesting result is that the sample with the highest percent organic matter did not have any measurable TOC. This seemed contradictory, and a followup investigation of the samples was undertaken. The result appears to be a reflection of the analytical procedure and the particle sizes of the organic matter. The organic matter samples consisted of 10-20 grams of sediment, while the TOC samples consisted of only 0.2 gram of sample. The organic matter was mostly small, woody particles that were nevertheless too large for the TOC samples. This is consistent with the McLaren/Hart (1998) results, where woody particles were reported in some of the cores. Consequently, if none of the particles happened to be included in the TOC sample, the result was an undetectable concentration of TOC. The minimum TOC in the McLaren/Hart samples was also < 0.001 percent.

Table 4.—Miscellaneous measurements in Savage Rapids sediments

Drill hole number and depth interval	pH	Percent moisture	Percent organic matter	TOC (%)
AP-99-11: 17.7-19.7'	6.7	3.0	1.1	< 0.001
AP-99-12: 26.9-28.9'	7.4	29.3	0.8	0.089
AP-99-12: 35.7-37.7'	7.4	24.5	0.7	0.272
AP-99-12: 41.1-43.1'	7.3	10.7	0.8	< 0.001
McLaren/Hart maximum				0.375

As was done by McLaren/Hart, the analytical results are to be compared to various sediment quality criteria. McLaren/Hart compared their results to the ER-L (effects range low), ER-M (effects range median), TEL (threshold effects level), and PEL (probable effects level) concentrations developed by Long et al. (1995) and MacDonald et al. (1996), respectively. The McLaren/Hart results were also compared to LAET (lowest adverse effects threshold),

developed for the Puget Sound cleanup; these are numerically the same as the Dredged Material Evaluation Framework (Corps of Engineers [Corp] et al., 1998) screening level guidelines, which will be used here.
These effects and screening levels are summarized in table 5.

Table 5.—ER-L and ER-M guideline values for trace metals (ppm, dry weight) and percent incidence of biological effects in concentration ranges defined by the two values

Chemical	ER-L[1]	ER-M[2]	TEL[3]	PEL[4]	Screening level[5]
Arsenic	8.2	70	7.24	41.6	57
Cadmium	1.2	9.6	0.68	4.21	5.1
Copper	34	270	18.7	108	390
Lead	46.7	218	30.2	112	450
Mercury	0.15	0.71	0.13	0.7	0.41
Zinc	150	410	124	271	410

[1] ER-L, effects range low (Long et al., 1995).
[2] ER-M, effects range median (Long et al., 1995).
[3] TEL, threshold effect level (MacDonald et al., 1996).
[4] PEL, probable effects level (MacDonald et al., 1996).
[5] Corps et al. (1998) screening level; also LAET, lowest apparent effects threshold used in McLaren/Hart (1998).

Copper was the only element in the deep sediment samples that exceeded any of the guideline levels shown in table 5. All the copper results exceeded the ER-L and the TEL concentrations shown (compare tables 3 and 5). Concentrations of the other elements were well below their respective guideline criteria shown in table 5, although the maximum copper concentration (106 ppm [table 3]) approached its PEL (table 5). None of the samples from the deeper sediments had concentrations of any of the elements that approached the Dredged Material Evaluation Framework screening levels (compare tables 3 and 5). Based on this, these results for the deep sediment samples are within the Tier IIB screening level guidelines.

The McLaren/Hart (1998) results also showed samples that exceeded some of the more conservative guidelines, in particular the TEL concentrations. Of the 50 samples collected by McLaren/Hart (1998), 10 each exceeded the TELs for cadmium and copper, 15 exceeded the TEL for nickel, and 1 exceeded the TEL for chromium. As the effects thresholds become less conservative, the number of samples that exceed the guidelines decreases. There are two cadmium, three copper, and seven nickel samples that exceed their respective ER-L concentrations. One sample each exceeded the PEL for copper and nickel, while only the maximum copper result (956 ppm) exceeded the ER–M and LAET.

This same copper result also exceeds the DMEF screening level. The second highest copper concentration in the McLaren/Hart (1998) data set was 104 ppm, which is very near the maximum from the deeper sediment samples. From a statistical perspective, the maximum copper concentration in the McLaren/Hart (1998) data set appears to be an outlier.

A second purpose behind the additional sampling effort was to evaluate the potential for mining contamination in the sediments. Mining can contribute to sediment contamination either through erosion of solids from spoil piles or by the release of mine drainage that contributes metals precipitated from solution. Mine-contaminated sediments would be enriched in iron relative to normal background concentrations. Pais and Jones (1997) give a normal background concentration for soils, the principal source of sediments, as 38,000 ppm and a normal background for the lithosphere as 41,000 ppm. The iron concentrations in the Savage Rapids deeper sediments ranged from 8,340 to 13,200 ppm. These concentrations are well below the background concentrations noted above. Iron in stream sediment downstream from sources of mine-drainage contamination are more likely to be very high; for example, concentrations of iron in the Upper Arkansas River basin of Colorado range from 4 (approximate background) to 29 percent (Church et al., 1994) (i.e., 40,000 to 290,000 ppm). The iron concentrations from Savage Rapids Reservoir are around ¼ background.

In the case of the Arkansas River, lead and zinc turned out to be the better indicators of mine-waste associated contamination. Lead and zinc concentrations in the sediments were over 500 and 1,500 ppm, respectively, in the vicinity of contamination. The concentrations decreased steadily downstream to concentrations of 37 and 180 ppm in reservoir sediments 150 miles downstream (Church et al., 1994.). These latter concentrations are still much greater than those observed in Savage Rapids Reservoir, where the maximum lead was 18.7 ppm, and the maximum zinc was 38.5 ppm. Background lead in the lithosphere is given as 14 ppm by Pais and Jones (1997); this value is bracketed by the lead data from the deeper sediments from Savage Rapids (i.e., 8.6 to 18.7 ppm). On the other hand, the background concentration for zinc is given as 80 ppm (Pais and Jones, 1997), which is more than twice as large as any of the results from sediments from Savage Rapids.

In summary, samples collected from the deeper sediments in Savage Rapids Reservoir in 1999 showed analytical results that were within the range of samples collected from the edges of the reservoir in 1998. With the exception of the maximum copper concentration in samples collected during 1998, all results are below the Dredged Material Evaluation Framework (Corps et al., 1998) screening levels and seem to meet the criteria for open water disposal. Based on a comparison of sediments contaminated by mine drainage and a set representative of background concentrations of the elements that were sampled, the Savage Rapids sediments are much like the background in some cases and much below an average for the background in others. Based on this result, it has been concluded that the sediments are not contaminated with mine wastes.

McLaren/Hart (1998) analyzed the Savage Rapids samples for 21 organochlorine pesticides and 64 SVOCs. Of the list of analytes, benzoic acid was detected in one sample out of a total of five; the concentration in the sample did not exceed the available benchmark (an LAET of 650 micrograms per kilogram). Because there were no detections in 50 samples for 85 other organic analytes, the single value was considered a statistical outlier (McLaren/Hart, 1998.). The LAET benchmarks are essentially the same as the Corps et al. (1998) screening levels. (There are a few of the organic compounds that have an LAET benchmark that have no SL.) The comparison made to the set of LAET benchmarks is equivalent to a comparison to SLs. Since any organic contaminants were considered just as likely to occur in more recent sediment as in older sediment, Reclamation felt the McLaren/Hart (1998) study was adequate, and none of the deep sediment samples was analyzed for organics.

Water Quality

There are two aspects to potential water quality effects related to the removal of the dam. One is related to the potential leaching of contaminants from the sediments; the other is related to the sediments themselves. Based on the sediment chemistry presented earlier, the release of contaminants from the sediments will probably not significantly affect water quality in the river downstream from the dam.

There is a relationship between water quality and flow in most rivers of the western United States. In terms of total dissolved solids (TDS), this takes the form of an inverse relationship. This is because higher flows increasingly dilute saline base flows. However, this is not true of the Rogue River. Scattergrams of TDS plotted against flow for the period January 1953 through September 1956 are shown in figure 2. The upper plot (figure 2A) shows all the TDS data. The best fit line (regression line) was based on a log transformation of the flow data and untransformed TDS data. In most cases in the western United States, the regression would be based on a log transformation of both variables. The best fit regression line in figure 2A (i.e., the line designated pred.) is a constant 77 milligrams per liter (mg/L) TDS across the range of flow from 885 to over 15,000 cubic feet per second [ft^3/s]). The regression is not statistically significant. The TDS data in figure 2A include one outlier.

The point well above the others on the plot is a TDS of 136 mg/L, which is well above the next highest value. The usual procedure in statistics is to delete outliers and redo the procedure. This is done in figure 2B. With the outlier deleted, the best fit line shows a slight downward slope; however, the decrease is only from a maximum of 78 mg/L to a minimum of 75 mg/L. Once again, the regression is not statistically significant.

The use of iron as an indicator of possible mining pollution was mentioned earlier. At the time the TDS data were collected, iron data were also collected but only in 1953 and

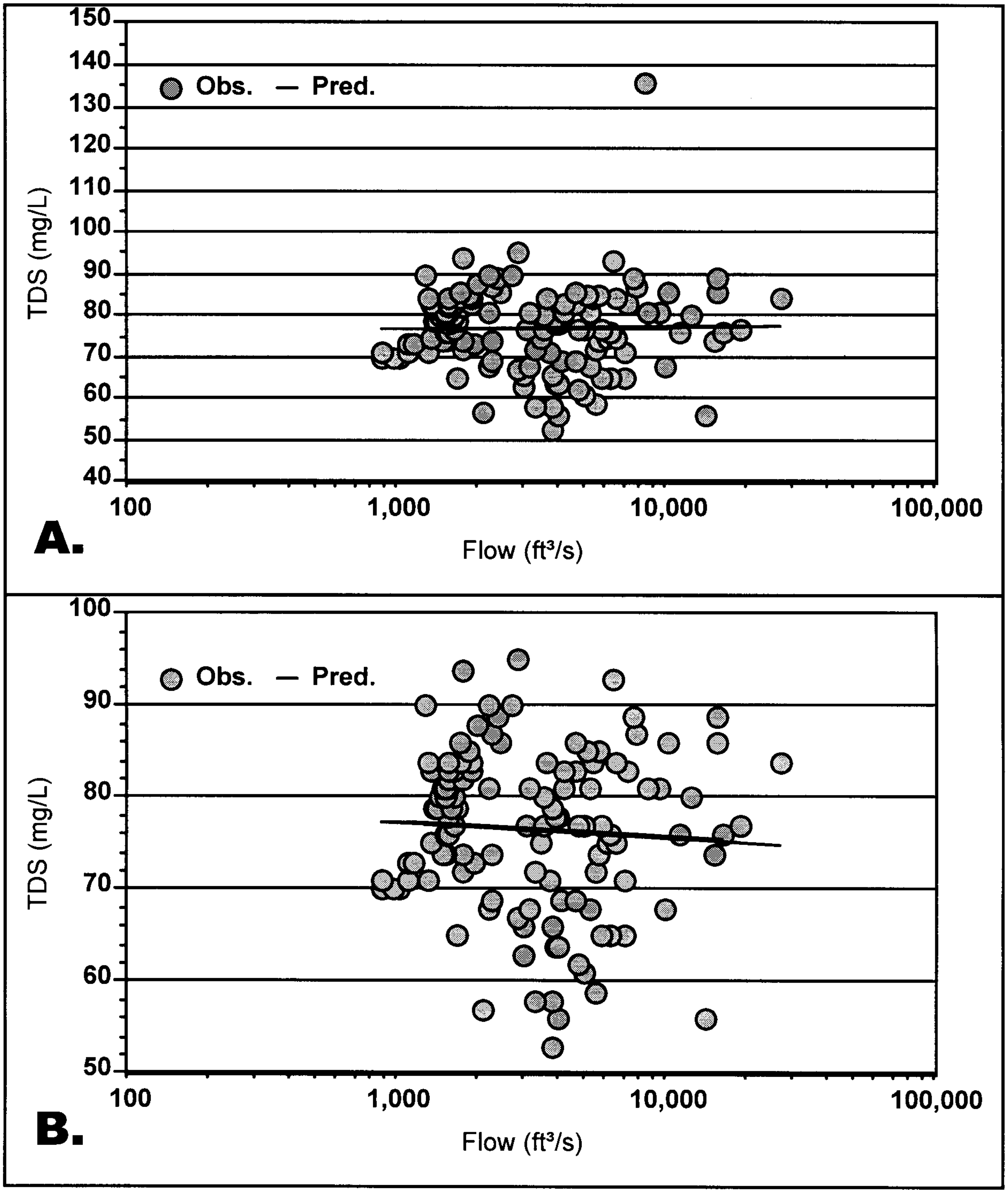


Figure 2.—TDS-flow relationships for the Rogue River at Grants Pass (1953-56).

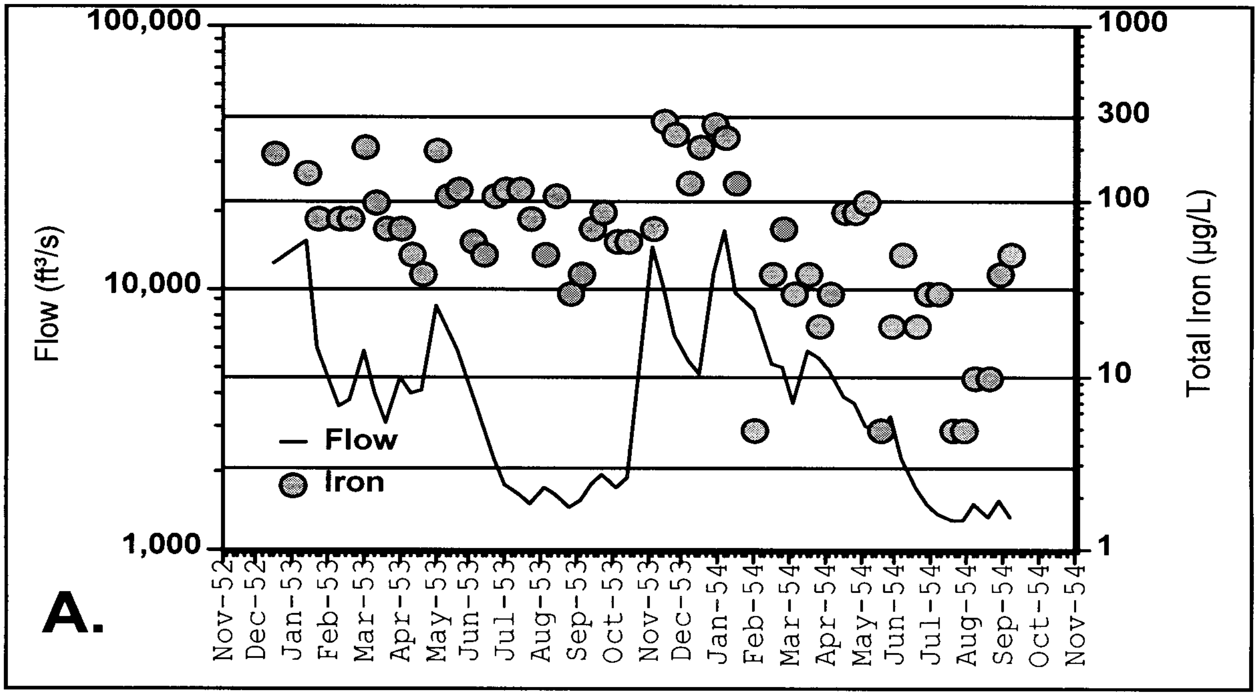
1954. The iron data, along with the flow data, are plotted as a time series in figure 3A. There is also a grid line on the iron axis that a shows a drinking water SMCL of 300 micrograms per liter (µg/L). The SMCL applies to treated water and is not exceeded by any of the iron samples. The maximum total iron in the 2 years of samples was 290 µg/L. This indicates that iron, at the time, was relatively low.

Figure 3B shows a scattergram of total iron data plotted against flow. Both are on logarithmic axes. The "best fit" line is also plotted on the scattergram. The relationship, unlike the one for TDS, is statistically significant; it is also positive (i.e., as flow increases, total iron increases). This indicates that most of the iron is in suspended form and that the source is erosive. This does not mean that mining is not the source, but it indicates that if it is the source, iron is being eroded off the sites. Given the low maximum concentration of iron, the source cannot be particularly significant.

The City of Grants Pass Water Treatment Plant has monitored certain aspects of the water quality of the Rogue River since the 1930s. Data from 1940 to the present are available in electronic format. Those data were provided to Reclamation. The monitoring data are summarized in table 6. Instead of flow, the monitoring data files included a water level measurement. The flow data substituted in table 6 were downloaded from the U.S. Geological Survey National Water Information System (NWIS) web site. The flow data encompass the period January 1, 1940, through September 1998. The city’s water quality data encompass the period from January 1, 1940, through April 30, 1999. The initial date in the NWIS data file was set to 1940 to be comparable to the water quality data.

The turbidity data are of most interest to this study. However, turbidity measurement technology has changed since the monitoring period began. Prior to the routine use of the Nephelometric method, the standard method for measuring turbidity was the Jackson candle turbidimeter (Brown et al., 1970). The lowest turbidity that could be measured directly was 25 Jackson Turbidity Units (JTU) (Brown et al., 1970). The Nephelometric method measures turbidity in Nephelometric Turbidity Units (NTU), which are equal to the JTU at a turbidity of 40; however, differences may occur across a range of turbidity owing to fundamental differences in optical systems. This may account for the large differences between the earlier data and the more recent data (table 6, figure 4). Alternatively, there is also a strong relationship between turbidity and flow (figure 5), i.e., $r = 0.593$, $n = 21,340$. A plot of the flow data similar to the one for turbidity in figure 6 shows that flow has also varied over the 60-year monitoring period. Based on a comparison of the turbidity and flow data in figures 4 and 6, respectively, the differences in turbidity during the monitoring period appear to be due to a combination of the effects of the change in technology and the influence of a difference in hydrologic conditions over the period.

The data presented earlier for TDS and iron were collected in the 1950s. Figure 6 indicates that the 1950s were much above the other decades in terms of flow. A



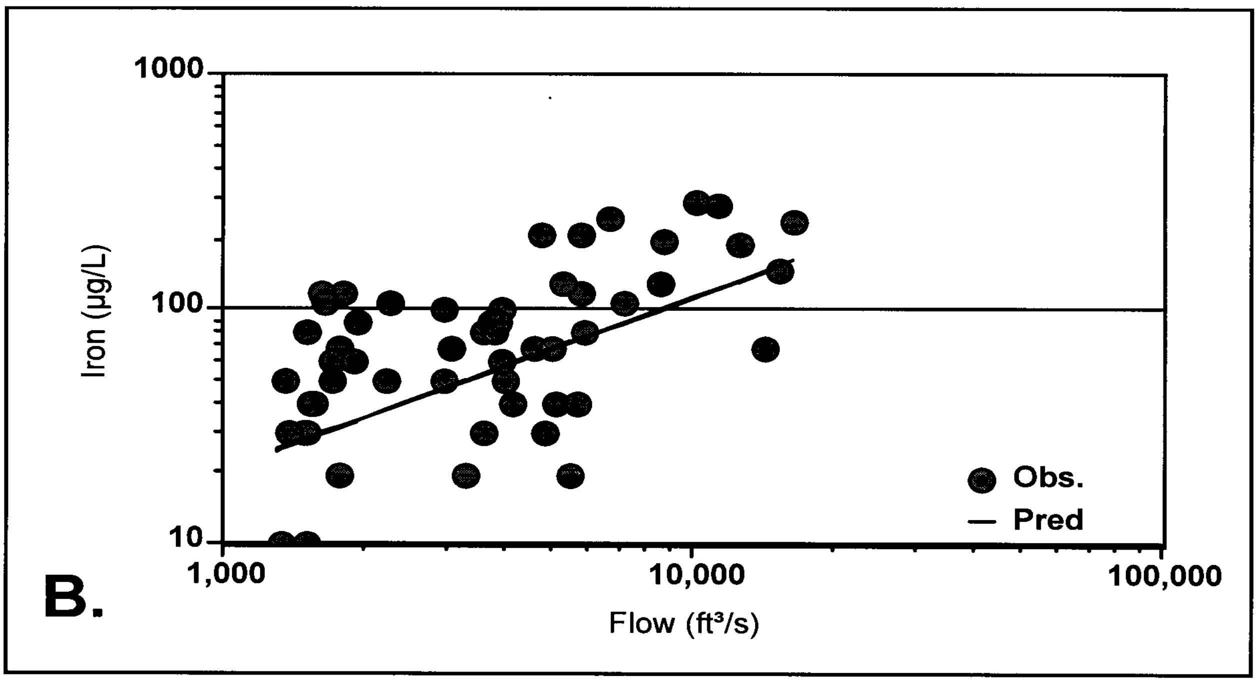


Figure 3.—(A) Time series of flow and total iron in the Rogue River at Grants Pass; (B) Scattergram of iron on flow in the Rogue River at Grants Pass in 1953-54.

Table 6.—Summary of water quality and flow data for the Rogue River at Grants Pass

		Flow (ft^3/s)	Temperature (° Fahrenheit)	Precip. (inches)	Turbidity (JTU)	pH
All data	Minimum	606	32	0	< 1	5.3
	Median	2,310	51	0	11	7.3
	Maximum	124,000	78	19	4250	9.1
	No. of cases	21,458	21,505	18,017	21,478	21,319
1940s	Minimum	637	29.2		3	6.8
	Median	2,080	50		20	7.4
	Maximum	53,700	74		1,100	8.6
	No. of cases	3,653	3,635	0	3,645	3,639
1950s	Minimum	862	32	0	7	6.4
	Median	2,795	50	0	25	7.4
	Maximum	107,000	74	5.27	2,200	8.4
	No. of cases	3,652	3,636	3,652	3,624	3,627
1960s	Minimum	606	32	0	2	5.3
	Median	2,280	50	0	20	7.4
	Maximum	124,000	78	10.2	4,250	9.1
	No. of cases	3,653	3,653	3,653	3,652	3,645
1970s	Minimum	710	32	0	1	6.1
	Median	2,330	51	0	6	7.3
	Maximum	85,800	74	3.35	380	7.7
	No. of cases	3,652	3,651	3,652	3,649	3,565
1980s	Minimum	906	32	0	< 1	6.0
	Median	2,330	52	0	3	7.2
	Maximum	50,400	70	19	200	8.3
	No. of cases	3,653	3,597	3,653	3,577	3,518
1990s	Minimum	744	32	0	< 1	6.7
	Median	2,250	52	0	2	7.4
	Maximum	69,000	74	9	1,093	8.2
	No. of cases	3,195	3,333	3,407	3,331	3,325

A statistical comparison (Fisher's Least Significant Difference Test) indicates that the flows during the 1950s were significantly higher than in any of the other decades shown. Since there was no TDS-flow relationship under those conditions, there should be none under any conditions within the larger flow range available. Alternatively, because of the relationship between iron and flow in the 1950s, concentrations of iron that are much higher than the concentration for the 1950s are not likely. The fact that iron should be no higher than con-centrations of iron in the 1950s would also indicate that if there was no great effect due to mine wastes based on the 1950s data, there would probably be none under conditions that would be encountered over a broader period of time.

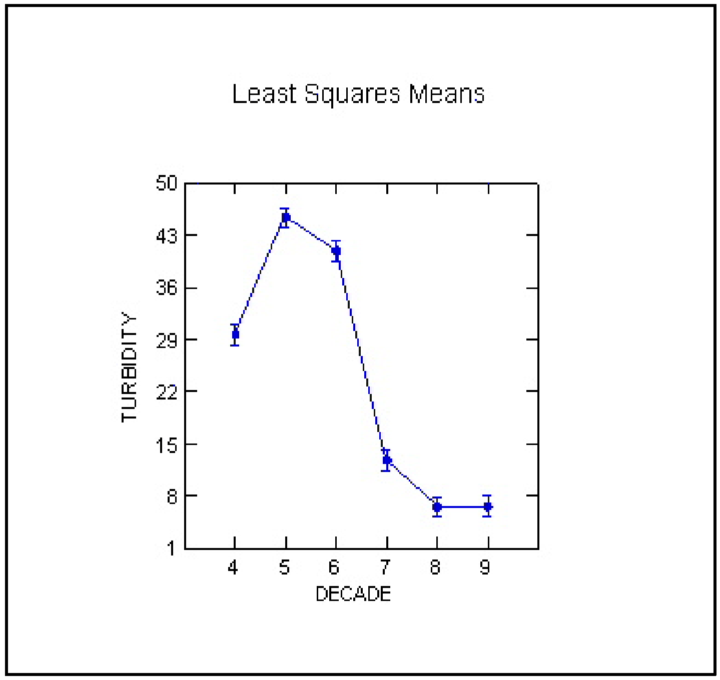


Figure 4.—Mean turbidity and confidence interval in each decade from 1940 through 1999.

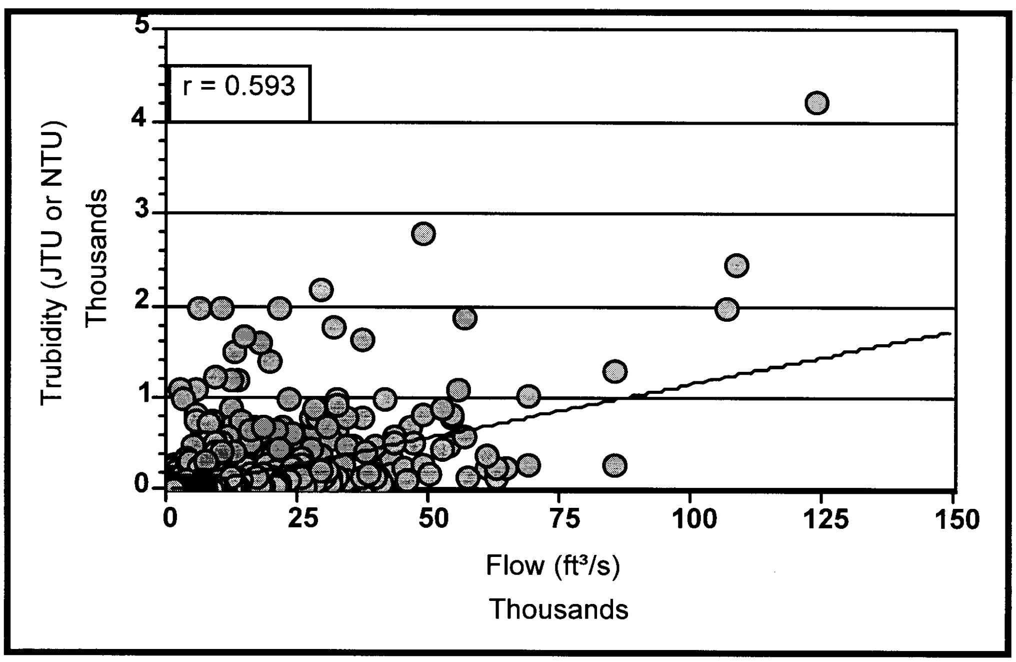


Figure 5.—Relationship between turbidity and flow in the Rogue River at Grants Pass.

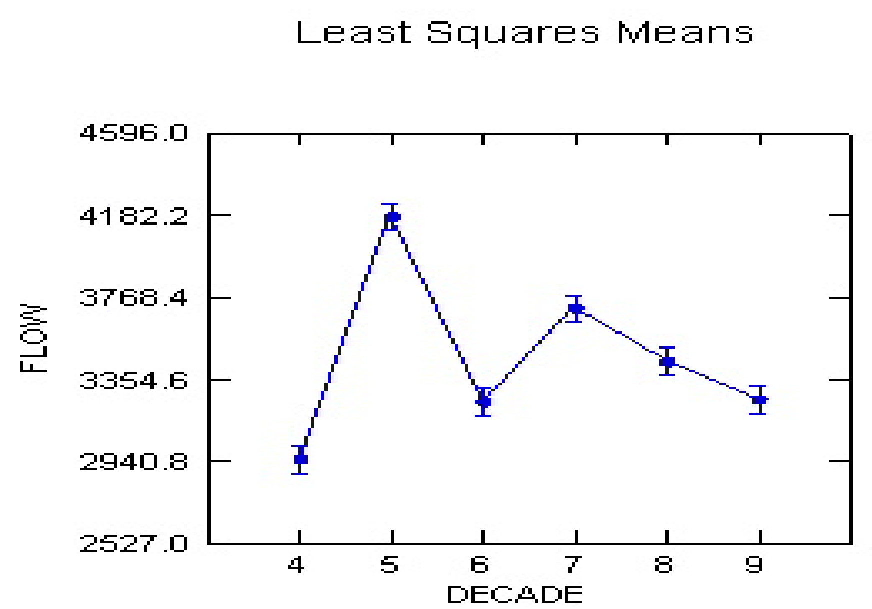


Figure 6.—Mean flow and confidence interval for each decade from 1940 through 1998.

Turbidity is only indirectly related to suspended solids, although it is, by definition, the reduction in light due to the presence of such particles. Suspended solids may consist of clay or silt, finely divided organic matter, plankton, or other suspended microscopic organisms. Attempts to correlate turbidity with the weight concentration of suspended matter are impractical because the size, shape, and refractive index of the particulate matter are important optically but bear little relationship to the concentration or specific gravity of the suspended matter. Nevertheless, turbidity is important in water treat-ment. The drinking water standard for turbidity is 1 NTU. Also, turbidity can be measured rapidly and easily. As can be seen from table 6, the turbidity of the raw water has been very high in the past (> 4,000 JTU), although the more recent data do not approach that maximum from the 1960s. The assessment from Appendix B based on the sediment data indicates that suspended solids would increase for at least the first year if the dam is removed, and the increase may extend as long as 10 years.

The suspended solids available for erosion would consist primarily of coarser particles. The fines that would have the greatest effect on turbidity constitute less than 2 percent of the sediment in the reservoir. The effect on turbidity will reflect the rate of the erosion of the fines. If initial erosion of sediment consists mostly of finer particles, the effect would be to increase the turbidity for a short period of time. If the erosion of fines is slow and regular, then the increase in turbidity would be comparatively small but would extend for the duration of the erosion period. As has been noted above, the rate of erosion would depend greatly on the sequence of flows following the removal of the dam.

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Attachment A

From: Richard Link
To: Fahy, Juli; Yahnke, James
Date: Thu, Oct 7, 1999 9:02 AM
Subject: Savage Rapids - Heavy Metals Samples

Dear Jim and Juli,

I sent five samples to Juli yesterday for the heavy metals testing portion of the Savage Rapids sedimentation study. They are going via Federal Express and you should receive the cooler today. I thought I would write up a brief summary of field testing procedures and site conditions so that we are all on the same page.

Before we left for the field, Jim and I discussed our goals and decided to try to obtain two samples from about two holes (i.e., four total samples). One sample would be collected from the surface of the lakebed and then a second sample would be collected from the base of the reservoir sediments just above the pre-dam riverbed. In practice, collection of the first sample at the top of the reservoir sediments/lakebed proved to be very difficult in the extreme due to the generally low density of the material and we had no recovery of this sample in 10 of 12 holes. I have shipped the two samples we did recover, but the one from AP-99-11 is very coarse grained with high concentrations of gravel. This hole is the most upstream of the 12 and is located across from the boat launch at Savage Rapids Park. The other 3 samples come from AP-99-12 which is located between the park and the large gravel bar on the north side of the reservoir. This area appears to be a pre-dam topographic low in an old pool area and the holes drilled in this pool terminated at depths ranging from 10 to 12 feet lower than the base elevation of the dam. If heavy metals are present at Savage Rapids, I would think they would be concentrated in this upstream pool area, so the samples from AP-99-12 are probably the most important.

We were set up to sample with a 2.75-inch I.D. split-tube, stainless steel barrel. Previous sampling in the other holes had shown us that we could not retrieve samples without the use of a basket catcher and plastic Saran wrap placed behind the catcher to act as a baffle. Use of flapper valves had been totally ineffective. We had a teflon-coated basket for use with the stainless barrel, but initial testing with the barrel had no recovery and it was evident that the fingers of the basket were too widely spaced to retain the sample inside the barrel. I called Jim and reported this problem. We did have a larger, non-stainless barrel on hand which we were using to obtain samples for standard properties testing that had a much better basket system with numerous, closely spaced fingers. We were getting good recovery with that barrel, although we were getting the best results when spraying the inside of the barrel with PAM (a cooking agent used to keep food from sticking to frying pans, etc.). **Jim and I decided to proceed with the non-stainless barrel in order to get the samples.** Jim requested that I thoroughly decontaminate the non-stainless barrel and then retain a sample of the wash water to establish any background contaminant levels.

I completed the decontamination of the barrel using a gallon of de-ionized water obtained from our USBR water quality lab in Boise mixed with about 1.25 fluid ounces of Liqui-Nox detergent. The barrel was then rinsed in a spray of de-ionized water. A sample of this wash water is included in the cooler for testing. This decontamination procedure was used for all the samples submitted for testing, except one which is described below. Initial attempts with the sampler in AP-99-9 and -10 continued to have no recovery despite use of the finer fingers and the Saran wrap. In the last two holes, I decided to resort to spraying the interior of the barrel with PAM and had good recovery in all four sample intervals. **You should be aware that there is potential for PAM to be present in these samples**, but I do not think there should be any impact to the heavy metals as PAM is a house-hold cooking ingredient.

Drill hole AP-99-12 was located adjacent to previous hole AP-99-3 which had been drilled to a depth of 45.7 feet earlier in the study (this is the deepest hole we drilled at Savage Rapids). I anticipated similar depths for AP-99-12 and decided to alternate between heavy metals and standard properties testing in that hole with samples spaced about 3 to 4 feet apart. We obtained an excellent sample from the surface of the lakebed (26.9-28.9') and also collected an additional heavy metals sample from 35.7-37.7'. I had anticipated that we would be able to collect one more heavy metals sample at about 45 feet, but the hole attained refusal after a standard properties sample was collected from 41.1-43.1'. Although the barrel had not been decontaminated prior to that last sample interval, I decided to go ahead and split it and send part in for heavy metals testing as this sample was located in a critical location immediately above the pre-dam river channel. **This last interval (41.1-43.1') is the only sample sent to you that did not go through the decontamination process.**

I hope this helps alert you to the irregularities we experienced in the testing. The bulk of the samples consist of sand particles. The sample from 35.7-37.7' was taken from a layer of silty sand at the top of the interval and contains the highest fines concentration in any of the samples we obtained at Savage Rapids (my field estimate is about 35% nonplastic fines).

Give me a call if you have any further questions or comments.

Dick

Appendix D

HYDROLOGY

by Ken Bullard
Hydrologist

U.S. Bureau of Reclamation
Technical Service Center
Denver, Colorado

Contents – Appendix D

Tables

Figures

HYDROLOGY

The Bureau of Reclamation has been asked to perform studies related to the potential removal of Savage Rapids Dam, on the Rogue River upstream from Grants Pass, Oregon. Among the many significant concerns with this project is the disposition of sediment accumulated behind the structure. This report provides hydrologic flow data for use in the proposed sediment models for this project.

Flow Frequency Data

Lost Creek Dam and Reservoir were completed by the Corps of Engineers (Corps) on the Rogue River in 1977. Lost Creek Dam controls the upper 686 square miles of the Rogue River watershed. This large flood control reservoir can have a dramatic impact on flood peaks in the downstream areas, including the Savage Rapids Dam and Grants Pass, Oregon, areas. Flood peaks in Grants Pass typically occur from November through March, with most occurring in December and January. The Rogue River has five gauging stations on the main stem, which record peak and daily discharges between Lost Creek Dam and Agness, Oregon. There are no significant river diversions below Lost Creek Dam that affect flood peaks during the winter. Peak flow and daily flow values for the Rogue River were available from the U.S. Geological Survey (USGS) water data web site, http://waterdata.usgs.gov/nwis-w/OR/

The Corps, Portland District Office, was contacted [1] and asked for information about regulated flows on the Rogue River. That office has provided estimated regulated frequency curves for three locations on the Rogue River. Regulated flow frequency curves attempt to predict what the flow at a specific point in the river will be, given a flood of some specific return period and the estimated flood peak reduction due to the upstream flood control dam. For the Rogue River, the Corps has provided estimated unregulated and regulated flow frequency curves for the main stem of the Rogue River at the Lost Creek Dam, Dodge Bridge, Raygold, and Grants Pass gauge site locations.

The regulated peak flow frequency curves supplied by the Corps were prepared in 1991, with peak flow data available through 1989. Since the preparation of these curves, the largest flood since Lost Creek Dam began regulation occurred in January 1997. The regulated peak flow curves should be redone and updated with the more recent data; however, they are considered adequate for the purposes of this study. These curves will provide a consistent set of flows for each of the gauge sites to estimate the reaches of the Rogue River most likely to experience sediment deposition following the removal of Savage Rapids Dam. This is accomplished in a preliminary sense through the use of the stream power plot developed as part of this study. Additional, more detailed studies will depict the potential sediment deposition at various locations in the river by using the daily flow hydrographs developed as part of this study.

Table 1 (at the end of this appendix) lists the regulated discharges for various return periods at four of the gauging stations located downstream from Lost Creek Dam. These discharges were taken from the regulated flow frequency curves supplied by the Corps and by a simple application of the log-Pearson III statistical technique to the Rogue River peak flows at Agness for the regulated years 1977 through 1998. Flows at Agness are considered to be far enough downstream and to have enough uncontrolled drainage area that any peak flow regulation effects of Lost Creek Dam are minimal. Also listed in table 1 are the drainage area and gauge datum elevation for each gauge location and the locations of other large tributaries. Included in table 1 is a list of river miles associated with each gauge site and each tributary. These gauge characteristics come from the available USGS water supply paper [2].

Figure 1 (at the end of this appendix) displays the gauge datum elevation plotted with river miles for five stations. Figure 2 displays the computed 2-, 5-, 10-, 25-, 50-, and 100-year discharges for the four gauges farthest downstream in this river. The Mcleod gauge data were not included in this graph since the computed values for the various return periods at Mcleod did not follow the pattern established by the more down-stream gauges. The Mcleod gauge data for this analysis showed a positive skew value, due largely to the influence of Lost Creek Dam, only 3 miles upstream. All other gauges show negative skew values, indicating the influence of Lost Creek Dam is not as great on the distribution of flood peak values farther downstream. The other downstream gauges also have the influence of many more unregulated tributary flows. The Mcleod gauge is too far upstream to have any impact on the sediment modeling farther down-stream near Savage Rapids Dam and the Grants Pass gauge site. The Mcleod gauge data, except for drainage area, elevation, and river mile, were not used in any other computation in this report.

Figure 2 displays the discharges for the five return periods, plotted as a function of drainage area at the gauge sites. This plot provides a smooth family of curves and provides some good visual confirmation of the validity of the calculated return period flows for the four gauge stations farthest downstream. This figure is not particularly useful for any location on the main stem of the Rogue River since river miles and the locations of the tributaries are not indicated.

Figure 3 is a plot of the various return period discharges as a function of river mile. This plot also shows the Corps regulated peak flood frequency for the three gauges farthest upstream. Again, the downstream gauges appear to show a nice family of curves for all return periods. The Corps curves show a strong influence by the Lost Creek Dam regulation. This figure also shows the relative difference in magnitude between the Corps regulated peak flow curves and the analysis of the last 21 years of regulated flows below Lost Creek Dam. Possible reasons for these differences were discussed earlier in this report. The location of the tributaries is needed on this plot to make it useful in determining a flow for a given return period for a specific location on the Rogue River.

Figure 4 is a plot of drainage area versus river mile for all locations on the Rogue River, including the location of the tributary inflows. Data for this graph were calculated by computing the change in drainage area for each gauge location and then subtracting any major tributary drainage area in the reach. The difference in drainage areas, less the tributary area, was divided by the difference in river miles for the known gauge site locations. This rate of change of drainage area was applied for all river miles between the two sites. At the location of the major tributaries, the area of the tributary is added to the plot. This is reflected by the jumps in drainage area at the tributary locations on the plot.

Figure 5 is a plot of the discharge for various return periods as a function of river mile. Data for this plot were created similarly to the plot for drainage area versus river mile. Unit discharges for drainage areas at the gauge sites were computed. The unit discharge was multiplied by the drainage areas for each river mile location determined in the previous calculation, and the plot of discharge versus river mile, with appropriate jumps at the tributary locations, was created. Table 1 provides details related to the calculation of values on this plot.

Figure 6 is a plot of total stream power (discharge times slope) versus river mile of the stream for the four gauge sites where elevation and discharge data are known. The slope used in the calculations for this plot was calculated by digitizing the water surface profile of the river from USGS quadrangle maps.

Daily Flow Hydrographs

In addition to peak flows, hydrographs representing the following four conditions were requested.

Daily flow hydrograph conditions for Savage Rapids Dam Sediment Evaluation Study
1 – High winter flows and high summer flows
2 – High winter flows and low summer flows
3 – Low winter flows and high summer flows
4 – Low winter flows and low summer flows

Daily data for the Grants Pass gauging station was retrieved for the regulated flow years 1977 through 1998 from the USGS water data web site, http://waterdata.usgs.gov/nwis-w/OR/

The yearly data were divided into seasons. The winter season was considered to be November 1 through May 31 each year, and the summer season was considered to be July 1 through September 30 each year. The months of June and October were considered to be transition months and not considered as part of either season. Computations were made to determine the maximum 120-day flow values in each season of each year. These values were then ranked. The highest value indicated the highest year for each season, and the lowest value indicated the lowest year for each season. For the years 1977 through 1998, the highest winter season was 1997, the highest summer season was 1984, and both the lowest winter and lowest summer were in 1992. This information was verified by a simple visual inspection of the daily values plot available from the web site.

To create the high-winter/high-summer hydrograph, the 1997 data for the months of December 1 through May 31 were used, and the summer values for the year 1984 from June 1 through November 30 were combined in a single hydrograph. The low-winter and high-summer values were October 1 through May 31, 1992, and June 1 through September 30, 1984, respectively. High-winter and low-summer values were December 1 through May 31, 1997, and June 1 through September 30, respectively. The low-winter/low-summer hydrograph was the entire water year of 1992. These dates for the conditions selected were determined in such a way as to make the hydrographs appear reasonable and still maintain the conditions used to describe each hydrograph. Figures 7, 8, and 9 display these hydrographs. Table 2 displays the ordinates for these hydrographs.

Acknowledgments

This report was prepared by Kenneth L. Bullard, Hydraulic Engineer, Flood Hydrology Group, Bureau of Reclamation, Technical Service Center, Denver, Colorado. Peer review was provided by Tim Randle, Hydraulic Engineer, River Sedimentation and Hydraulics Group, Bureau of Reclamation, Technical Service Center, Denver, Colorado.

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1. Personal communication, June 21, 1999, Mr. Ron Mason, Hydraulic Engineer, Portland District, U. S. Army Corps of Engineers, Portland, Oregon.

2. U.S. Geological Survey, March 31, 1999, *Water Resources Data for Oregon, Water Year 1998*. Water Data Report OR-98-1.

Table 1
Rogue River - Savage Rapids Dam Removal and Sedimentation Study
Stream Flow and Gauge Statistics Summary

2 Year Return Period

			Corps of Engineers Regulated Flows				Slopes calculated from digitized water surface profile on USGS Quadrangle Maps			
Location	River Mile	Elevation (ft)	DA	Q	Q/DA	Mile Q	distance (ft)	elev diff (ft)	slope (ft/ft)	disch*slope
McLeod	154.0	1489.08	686.00	NA	NA	NA	NA	NA	NA	NA
	151.9		958.18			15221				
Elk Creek	151.9		1087.18			17270				
Dodge Bridge	138.6	1271.99	1215.00	19300	15.88	19300	81312	217.09	0.00267	51.53
	126.8		1721.11			27339				
Bear Creek	126.8		2010.11			25457				
Raygold	125.8	1121.78	2053.00	26000	12.66	26000	67584	150.21	0.00222	57.79
Grants Pass	101.8	884.28	2459.00	37500	15.25	37500	126720	237.50	0.00187	70.28
	94.6		2537.09			38691				
Applegate River	94.6		3235.09			49335				
Agness	29.7	113.81	3939.00	53644	13.62	53644	380688	770.47	0.00202	108.57

5 Year Return Period

			Corps of Engineers Regulated Flows				Slopes calculated from digitized water surface profile on USGS Quadrangle Maps			
Location	River Mile	Elevation (ft)	DA	Q	Q/DA	Mile Q	distance (ft)	elev diff (ft)	slope (ft/ft)	disch*slope
McLeod	154.0	1489.08	686.00	NA	NA	NA	NA	NA	NA	NA
	151.9		958.18			16009.1				
Elk Creek	151.9		1087.18			18164.4				
Dodge Bridge	138.6	1271.99	1215.00	20300	16.71	20300.0	81312	217.09	0.00267	54.20
	126.8		1721.11			28756.0				
Bear Creek	126.8		2010.11			36814.5				
Raygold	125.8	1121.78	2053.00	37600	18.31	37600.0	67584	150.21	0.00222	83.57
Grants Pass	101.8	884.28	2459.00	58600	23.83	58600.0	126720	237.50	0.00187	109.83
	94.6		2537.09			60461.0				
Applegate River	94.6		3235.09			77094.9				
Agness	29.7	113.81	3939.00	100723	25.57	100723.0	380688	770.47	0.00202	203.85

10-Year Return Period

			Corps of Engineers Regulated Flows				Slopes calculated from digitized water surface profile on USGS Quadrangle Maps			
Location	River Mile	Elevation (ft)	DA	Q	Q/DA	Mile Q	distance (ft)	elev diff (ft)	slope (ft/ft)	disch*slope
McLeod	154.0	1489.08	686.00	NA	NA	NA	NA	NA	NA	NA
	151.9		958.18			17586				
Elk Creek	151.9		1087.18			19954				
Dodge Bridge	138.6	1271.99	1215.00	22300	18.35	22300	81312	217.09	0.00267	59.54
	126.8		1721.11			31589				
Bear Creek	126.8		2010.11			43570				
Raygold	125.8	1121.78	2053.00	44500	21.68	44500	67584	150.21	0.00222	98.90
Grants Pass	101.8	884.28	2459.00	73300	29.81	73300	126720	237.50	0.00187	137.38
	94.6		2537.09			75628				
Applegate River	94.6		3235.09			96434				
Agness	29.7	113.81	3939.00	138496	35.16	138496	380688	770.47	0.00202	280.30

25-year Return Period										
			-------- Corps of Engineers Regulated Flows --------				Slopes calculated from digitized water surface profile on USGS Quadrangle Maps			
Location	River Mile	Elevation (ft)	DA	Q	Q/DA	Mile Q	distance (ft)	elev diff (ft)	slope (ft/ft)	disch*slope
McLeod	154.0	1489.08	686.00	NA	NA	NA	NA	NA	NA	NA
	151.9		958.18			21293				
Elk Creek	151.9		1087.18			24160				
Dodge Bridge	138.6	1271.99	1215.00	27000	22.22	27000	81312	217.09	0.00267	72.09
	126.8		1721.11			38247				
Bear Creek	126.8		2010.11			56788				
Raygold	125.8	1121.78	2053.00	58000	28.25	58000	67584	150.21	0.00222	128.91
Grants Pass	101.8	884.28	2459.00	97400	39.61	97400	126720	237.50	0.00187	182.55
	94.6		2537.09			100493				
Applegate River	94.6		3235.09			128141				
Agness	29.7	113.81	3939.00	192936	48.98	192936	380688	770.47	0.00202	390.48

Table 1 (cont)
Rogue River - Savage Rapids Dam Removal and Sedimentation Study
Stream Flow and Gauge Statistics Summary

50-Year Return Period										
			-------- Corps of Engineers Regulated Flows --------				Slopes calculated from digitized water surface profile on USGS Quadrangle Maps			
Location	River Mile	Elevation (ft)	DA	Q	Q/DA	Mile Q	distance (ft)	elev diff (ft)	slope (ft/ft)	disch*slope
McLeod	154.0	1489.08	686.00	NA	NA	NA	NA	NA	NA	NA
	151.9		958.18			27839				
Elk Creek	151.9		1087.18			31586				
Dodge Bridge	138.6	1271.99	1215.00	35300	29.05	35300	81312	217.09	0.00267	94.25
	126.8		1721.11			50004				
Bear Creek	126.8		2010.11			73041				
Raygold	125.8	1121.78	2053.00	74600	36.34	74600	67584	150.21	0.00222	165.80
Grants Pass	101.8	884.28	2459.00	121500	49.41	121500	126720	237.50	0.00187	227.72
	94.6		2537.09			125359				
Applegate River	94.6		3235.09			159847				
Agness	29.7	113.81	3939.00	237966	60.41	237966	380688	770.47	0.00202	481.62

100-Year Return Period										
			-------- Corps of Engineers Regulated Flows --------				Slopes calculated from digitized water surface profile on USGS Quadrangle Maps			
Location	River Mile	Elevation (ft)	DA	Q	Q/DA	Mile Q	distance (ft)	elev diff (ft)	slope (ft/ft)	disch*slope
McLeod	154.0	1489.08	686.00	NA	NA	NA	NA	NA	NA	NA
	151.9		958.18			35409				
Elk Creek	151.9		1087.18			40177				
Dodge Bridge	138.6	1271.99	1215.00	44900	36.95	44900	81312	217.09	0.00267	119.88
	126.8		1721.11			63603				
Bear Creek	126.8		2010.11			95953				
Raygold	125.8	1121.78	2053.00	98000	47.74	98000	67584	150.21	0.00222	217.81
Grants Pass	101.8	884.28	2459.00	151500	61.61	151500	126720	237.50	0.00187	283.94
	94.6		2537.09			156311				
Applegate River	94.6		3235.09			199315				
Agness	29.7	113.81	3939.00	286544	72.75	286544	380688	770.47	0.00202	579.93

Table 2
Savage Rapids Dam Removal and Sedimentation Study Hydrographs

Date	Day	High Winter High Summer	High Winter Low Summer	Low Winter igh Summer	Low Winter Low Summer
1-Oct	1	2350	1010	1010	1010
2-Oct	2	2300	1020	1020	1020
3-Oct	3	2260	1040	1040	1040
4-Oct	4	2250	1050	1050	1050
5-Oct	5	2240	1060	1060	1060
6-Oct	6	2160	1070	1070	1070
7-Oct	7	2150	1060	1060	1060
8-Oct	8	2160	1050	1050	1050
9-Oct	9	2220	1060	1060	1060
10-Oct	10	2260	1090	1090	1090
11-Oct	11	2240	1120	1120	1120
12-Oct	12	2210	1120	1120	1120
13-Oct	13	2210	1130	1130	1130
14-Oct	14	2180	1130	1130	1130
15-Oct	15	2160	1140	1140	1140
16-Oct	16	2180	1140	1140	1140
17-Oct	17	2320	1140	1140	1140
18-Oct	18	2310	1170	1170	1170
19-Oct	19	2310	1120	1120	1120
20-Oct	20	2310	1110	1110	1110
21-Oct	21	2290	1400	1400	1400
22-Oct	22	2320	1550	1550	1550
23-Oct	23	2450	1250	1250	1250
24-Oct	24	2420	1270	1270	1270
25-Oct	25	2350	1330	1330	1330
26-Oct	26	2340	1310	1310	1310
27-Oct	27	2330	1260	1260	1260
28-Oct	28	2340	1150	1150	1150
29-Oct	29	2330	1170	1170	1170
30-Oct	30	2340	1190	1190	1190
31-Oct	31	2440	1150	1150	1150
1-Nov	32	2570	1130	1130	1130
2-Nov	33	2770	1120	1120	1120
3-Nov	34	2770	1110	1110	1110
4-Nov	35	2860	1110	1110	1110
5-Nov	36	3060	1110	1110	1110
6-Nov	37	3420	1100	1100	1100
7-Nov	38	3760	1090	1090	1090
8-Nov	39	3340	1110	1110	1110
9-Nov	40	3250	1140	1140	1140
10-Nov	41	3340	1130	1130	1130
11-Nov	42	3610	1130	1130	1130
12-Nov	43	3720	1130	1130	1130
13-Nov	44	5440	1160	1160	1160
14-Nov	45	5890	1210	1210	1210
15-Nov	46	4490	1200	1200	1200
16-Nov	47	3870	1140	1140	1140
17-Nov	48	5870	1500	1500	1500
18-Nov	49	5310	2280	2280	2280
19-Nov	50	5850	1780	1780	1780
20-Nov	51	7450	1570	1570	1570
21-Nov	52	6180	1870	1870	1870
22-Nov	53	5290	1590	1590	1590
23-Nov	54	6150	1430	1430	1430
24-Nov	55	11200	1410	1410	1410
25-Nov	56	9040	1600	1600	1600
26-Nov	57	6570	1750	1750	1750
27-Nov	58	5520	2490	2490	2490
28-Nov	59	5030	2980	2980	2980
29-Nov	60	4700	2630	2630	2630
30-Nov	61	3920	5960	2530	2530

Table 2 (cont)
Savage Rapids Dam Removal and Sedimentation Study Hydrographs

Date	Day	High Winter High Summer	High Winter Low Summer	Low Winter igh Summer	Low Winter Low Summer
1-Dec	62	8750	8750	2430	2430
2-Dec	63	8740	8740	2410	2410
3-Dec	64	7990	7990	2380	2380
4-Dec	65	8660	8660	2320	2320
5-Dec	66	24000	24000	2250	2250
6-Dec	67	13600	13600	2630	2630
7-Dec	68	15300	15300	6390	6390
8-Dec	69	40200	40200	4510	4510
9-Dec	70	38500	38500	3670	3670
10-Dec	71	28100	28100	3310	3310
11-Dec	72	25000	25000	2860	2860
12-Dec	73	20800	20800	2490	2490
13-Dec	74	19500	19500	2370	2370
14-Dec	75	17200	17200	2210	2210
15-Dec	76	15200	15200	1960	1960
16-Dec	77	14100	14100	1870	1870
17-Dec	78	13100	13100	1820	1820
18-Dec	79	11700	11700	1950	1950
19-Dec	80	9460	9460	2580	2580
20-Dec	81	7650	7650	2350	2350
21-Dec	82	10800	10800	2060	2060
22-Dec	83	9330	9330	1980	1980
23-Dec	84	8440	8440	1940	1940
24-Dec	85	7970	7970	1870	1870
25-Dec	86	11200	11200	1810	1810
26-Dec	87	19000	19000	1770	1770
27-Dec	88	22600	22600	1730	1730
28-Dec	89	22200	22200	1720	1720
29-Dec	90	22000	22000	1670	1670
30-Dec	91	26600	26600	1650	1650
31-Dec	92	38400	38400	1600	1600
1-Jan	93	69000	69000	1580	1580
2-Jan	94	56000	56000	1520	1520
3-Jan	95	43500	43500	1510	1510
4-Jan	96	31000	31000	1590	1590
5-Jan	97	26000	26000	1750	1750
6-Jan	98	23500	23500	1720	1720
7-Jan	99	21800	21800	1740	1740
8-Jan	100	21700	21700	1710	1710
9-Jan	101	20800	20800	1650	1650
10-Jan	102	18900	18900	1640	1640
11-Jan	103	18100	18100	1690	1690
12-Jan	104	18300	18300	1730	1730
13-Jan	105	14700	14700	1630	1630
14-Jan	106	13400	13400	1580	1580
15-Jan	107	9600	9600	1550	1550
16-Jan	108	5930	5930	1540	1540
17-Jan	109	5840	5840	1650	1650
18-Jan	110	5880	5880	1720	1720
19-Jan	111	5850	5850	1640	1640
20-Jan	112	5850	5850	1580	1580
21-Jan	113	5870	5870	1530	1530
22-Jan	114	6220	6220	1480	1480
23-Jan	115	5960	5960	1370	1370
24-Jan	116	5960	5960	1290	1290
25-Jan	117	7630	7630	1310	1310
26-Jan	118	10200	10200	1310	1310
27-Jan	119	8880	8880	1320	1320
28-Jan	120	7670	7670	1470	1470
29-Jan	121	6950	6950	1800	1800
30-Jan	122	6800	6800	1670	1670
31-Jan	123	6960	6960	1570	1570

Table 2 (cont)
Savage Rapids Dam Removal and Sedimentation Study Hydrographs

Date	Day	High Winter High Summer	High Winter Low Summer	Low Winter igh Summer	Low Winter Low Summer
1-Feb	124	8740	8740	1650	1650
2-Feb	125	7960	7960	1720	1720
3-Feb	126	7250	7250	1610	1610
4-Feb	127	6870	6870	1510	1510
5-Feb	128	5930	5930	1470	1470
6-Feb	129	5920	5920	1400	1400
7-Feb	130	6060	6060	1370	1370
8-Feb	131	7220	7220	1340	1340
9-Feb	132	5640	5640	1320	1320
10-Feb	133	5200	5200	1300	1300
11-Feb	134	4730	4730	1280	1280
12-Feb	135	4750	4750	1240	1240
13-Feb	136	4560	4560	1250	1250
14-Feb	137	4180	4180	1270	1270
15-Feb	138	3770	3770	1410	1410
16-Feb	139	3580	3580	1420	1420
17-Feb	140	3840	3840	1490	1490
18-Feb	141	3980	3980	1490	1490
19-Feb	142	3920	3920	1520	1520
20-Feb	143	4100	4100	1820	1820
21-Feb	144	3830	3830	2400	2400
22-Feb	145	3630	3630	3120	3120
23-Feb	146	3420	3420	2620	2620
24-Feb	147	3260	3260	2200	2200
25-Feb	148	3130	3130	1960	1960
26-Feb	149	3200	3200	1780	1780
27-Feb	150	3650	3650	1630	1630
28-Feb	151	4130	4130	1530	1530
1-Mar	152	3660	3660	1470	1470
2-Mar	153	7880	7880	1380	1380
3-Mar	154	6540	6540	1250	1250
4-Mar	155	5570	5570	1200	1200
5-Mar	156	5010	5010	1180	1180
6-Mar	157	4610	4610	1220	1220
7-Mar	158	4400	4400	1230	1230
8-Mar	159	4310	4310	1190	1190
9-Mar	160	4220	4220	1170	1170
10-Mar	161	4500	4500	1130	1130
11-Mar	162	4390	4390	1110	1110
12-Mar	163	4600	4600	1090	1090
13-Mar	164	4380	4380	1060	1060
14-Mar	165	4220	4220	1040	1040
15-Mar	166	4250	4250	1040	1040
16-Mar	167	4330	4330	1050	1050
17-Mar	168	4930	4930	1070	1070
18-Mar	169	4790	4790	1100	1100
19-Mar	170	4530	4530	1100	1100
20-Mar	171	4540	4540	1060	1060
21-Mar	172	4630	4630	1040	1040
22-Mar	173	4470	4470	1010	1010
23-Mar	174	4340	4340	1020	1020
24-Mar	175	4240	4240	1040	1040
25-Mar	176	4200	4200	1030	1030
26-Mar	177	4460	4460	1000	1000
27-Mar	178	4410	4410	1050	1050
28-Mar	179	4420	4420	1050	1050
29-Mar	180	4670	4670	1020	1020
30-Mar	181	4590	4590	1030	1030
31-Mar	182	4600	4600	1050	1050

Table 2 (cont)
Savage Rapids Dam Removal and Sedimentation Study Hydrographs

Date	Day	High Winter High Summer	High Winter Low Summer	Low Winter igh Summer	Low Winter Low Summer
1-Apr	183	3970	3970	1070	1070
2-Apr	184	3530	3530	1070	1070
3-Apr	185	3330	3330	997	997
4-Apr	186	3040	3040	979	979
5-Apr	187	2830	2830	941	941
6-Apr	188	2750	2750	953	953
7-Apr	189	2760	2760	994	994
8-Apr	190	2790	2790	1040	1040
9-Apr	191	2940	2940	975	975
10-Apr	192	2870	2870	1040	1040
11-Apr	193	2760	2760	1160	1160
12-Apr	194	2580	2580	998	998
13-Apr	195	2520	2520	1590	1590
14-Apr	196	2560	2560	1260	1260
15-Apr	197	2500	2500	1420	1420
16-Apr	198	2430	2430	1380	1380
17-Apr	199	2460	2460	1400	1400
18-Apr	200	2810	2810	1840	1840
19-Apr	201	3430	3430	2140	2140
20-Apr	202	4570	4570	2010	2010
21-Apr	203	8390	8390	1830	1830
22-Apr	204	9200	9200	1700	1700
23-Apr	205	10500	10500	1580	1580
24-Apr	206	9390	9390	1490	1490
25-Apr	207	7060	7060	1440	1440
26-Apr	208	6070	6070	1420	1420
27-Apr	209	5700	5700	1310	1310
28-Apr	210	5560	5560	1310	1310
29-Apr	211	5860	5860	1310	1310
30-Apr	212	6310	6310	1110	1110
1-May	213	8050	8050	1180	1180
2-May	214	6870	6870	1560	1560
3-May	215	5540	5540	1610	1610
4-May	216	6470	6470	1740	1740
5-May	217	6210	6210	1760	1760
6-May	218	5940	5940	1700	1700
7-May	219	5170	5170	1540	1540
8-May	220	4620	4620	1570	1570
9-May	221	4210	4210	1550	1550
10-May	222	4130	4130	1550	1550
11-May	223	4120	4120	1580	1580
12-May	224	4440	4440	1560	1560
13-May	225	4690	4690	1520	1520
14-May	226	4610	4610	1490	1490
15-May	227	4490	4490	1450	1450
16-May	228	4040	4040	1410	1410
17-May	229	4080	4080	1740	1740
18-May	230	3840	3840	2010	2010
19-May	231	3700	3700	2070	2070
20-May	232	3620	3620	2180	2180
21-May	233	3430	3430	2540	2540
22-May	234	3020	3020	2190	2190
23-May	235	2940	2940	2110	2110
24-May	236	3750	3750	2250	2250
25-May	237	3610	3610	2320	2320
26-May	238	3400	3400	2240	2240
27-May	239	3370	3370	2180	2180
28-May	240	3640	3640	2110	2110
29-May	241	3720	3720	2080	2080
30-May	242	3530	3530	2040	2040
31-May	243	3440	3440	1990	1990

Table 2 (cont)
Savage Rapids Dam Removal and Sedimentation Study Hydrographs

Date	Day	High Winter High Summer	High Winter Low Summer	Low Winter igh Summer	Low Winter Low Summer
1-Jun	244	3335	1940	3335	1940
2-Jun	245	4680	2110	4680	2110
3-Jun	246	4220	2000	4220	2000
4-Jun	247	4070	2000	4070	2000
5-Jun	248	4360	2040	4360	2040
6-Jun	249	6560	1920	6560	1920
7-Jun	250	6510	1830	6510	1830
8-Jun	251	7530	1810	7530	1810
9-Jun	252	8600	1730	8600	1730
10-Jun	253	6480	1750	6480	1750
11-Jun	254	5740	1750	5740	1750
12-Jun	255	5160	1630	5160	1630
13-Jun	256	4730	1520	4730	1520
14-Jun	257	4520	1620	4520	1620
15-Jun	258	4400	1670	4400	1670
16-Jun	259	4230	1650	4230	1650
17-Jun	260	4200	1580	4200	1580
18-Jun	261	4170	1520	4170	1520
19-Jun	262	4120	1400	4120	1400
20-Jun	263	4070	1230	4070	1230
21-Jun	264	3980	1240	3980	1240
22-Jun	265	3890	1220	3890	1220
23-Jun	266	3810	1190	3810	1190
24-Jun	267	3470	1140	3470	1140
25-Jun	268	3070	1130	3070	1130
26-Jun	269	3030	1160	3030	1160
27-Jun	270	2930	1210	2930	1210
28-Jun	271	2930	1210	2930	1210
29-Jun	272	3360	1220	3360	1220
30-Jun	273	3360	1510	3360	1510
1-Jul	274	3390	1480	3390	1480
2-Jul	275	3290	1590	3290	1590
3-Jul	276	3060	1210	3060	1210
4-Jul	277	3140	1140	3140	1140
5-Jul	278	3110	1150	3110	1150
6-Jul	279	3110	1190	3110	1190
7-Jul	280	3080	1270	3080	1270
8-Jul	281	3090	1160	3090	1160
9-Jul	282	3080	1080	3080	1080
10-Jul	283	3100	990	3100	990
11-Jul	284	3060	1000	3060	1000
12-Jul	285	3020	998	3020	998
13-Jul	286	3020	995	3020	995
14-Jul	287	3030	992	3030	992
15-Jul	288	3050	991	3050	991
16-Jul	289	3040	986	3040	986
17-Jul	290	3030	980	3030	980
18-Jul	291	3010	976	3010	976
19-Jul	292	2990	995	2990	995
20-Jul	293	3010	990	3010	990
21-Jul	294	3130	976	3130	976
22-Jul	295	3170	1040	3170	1040
23-Jul	296	3230	1020	3230	1020
24-Jul	297	3210	1040	3210	1040
25-Jul	298	3220	1020	3220	1020
26-Jul	299	3220	1010	3220	1010
27-Jul	300	3220	1010	3220	1010
28-Jul	301	3210	1000	3210	1000
29-Jul	302	3230	1000	3230	1000
30-Jul	303	3270	1010	3270	1010
31-Jul	304	3270	1000	3270	1000

Table 2 (cont)
Savage Rapids Dam Removal and Sedimentation Study Hydrographs

Date	Day	High Winter High Summer	High Winter Low Summer	Low Winter igh Summer	Low Winter Low Summer
1-Aug	305	3250	1010	3250	1010
2-Aug	306	3330	1000	3330	1000
3-Aug	307	3340	1010	3340	1010
4-Aug	308	3320	1010	3320	1010
5-Aug	309	3310	1010	3310	1010
6-Aug	310	3330	1000	3330	1000
7-Aug	311	3300	1010	3300	1010
8-Aug	312	3280	1020	3280	1020
9-Aug	313	3220	1050	3220	1050
10-Aug	314	3210	1030	3210	1030
11-Aug	315	3190	1020	3190	1020
12-Aug	316	3210	1090	3210	1090
13-Aug	317	3230	1360	3230	1360
14-Aug	318	3280	1500	3280	1500
15-Aug	319	3260	2240	3260	2240
16-Aug	320	3220	2270	3220	2270
17-Aug	321	3010	2280	3010	2280
18-Aug	322	3030	2200	3030	2200
19-Aug	323	2980	2160	2980	2160
20-Aug	324	3020	2210	3020	2210
21-Aug	325	3040	2210	3040	2210
22-Aug	326	2820	2240	2820	2240
23-Aug	327	2800	2270	2800	2270
24-Aug	328	2820	2270	2820	2270
25-Aug	329	2820	2270	2820	2270
26-Aug	330	2810	2260	2810	2260
27-Aug	331	2830	2260	2830	2260
28-Aug	332	2800	2270	2800	2270
29-Aug	333	2770	2230	2770	2230
30-Aug	334	2800	2250	2800	2250
31-Aug	335	2860	2180	2860	2180
1-Sep	336	3240	2140	3240	2140
2-Sep	337	3180	2120	3180	2120
3-Sep	338	3100	1930	3100	1930
4-Sep	339	3050	1940	3050	1940
5-Sep	340	3000	1970	3000	1970
6-Sep	341	2980	1950	2980	1950
7-Sep	342	2950	1930	2950	1930
8-Sep	343	2850	1940	2850	1940
9-Sep	344	2840	1920	2840	1920
10-Sep	345	2820	1920	2820	1920
11-Sep	346	2790	1870	2790	1870
12-Sep	347	2610	1770	2610	1770
13-Sep	348	2630	1580	2630	1580
14-Sep	349	2630	1380	2630	1380
15-Sep	350	2400	1430	2400	1430
16-Sep	351	2420	1450	2420	1450
17-Sep	352	2260	1430	2260	1430
18-Sep	353	2190	1430	2190	1430
19-Sep	354	2030	1430	2030	1430
20-Sep	355	2000	1400	2000	1400
21-Sep	356	2090	1410	2090	1410
22-Sep	357	2180	1400	2180	1400
23-Sep	358	1920	1290	1920	1290
24-Sep	359	1850	1060	1850	1060
25-Sep	360	1830	1020	1830	1020
26-Sep	361	1620	1020	1620	1020
27-Sep	362	1570	1030	1570	1030
28-Sep	363	1580	1010	1580	1010
29-Sep	364	1570	1010	1570	1010
30-Sep	365	1590	998	1590	998

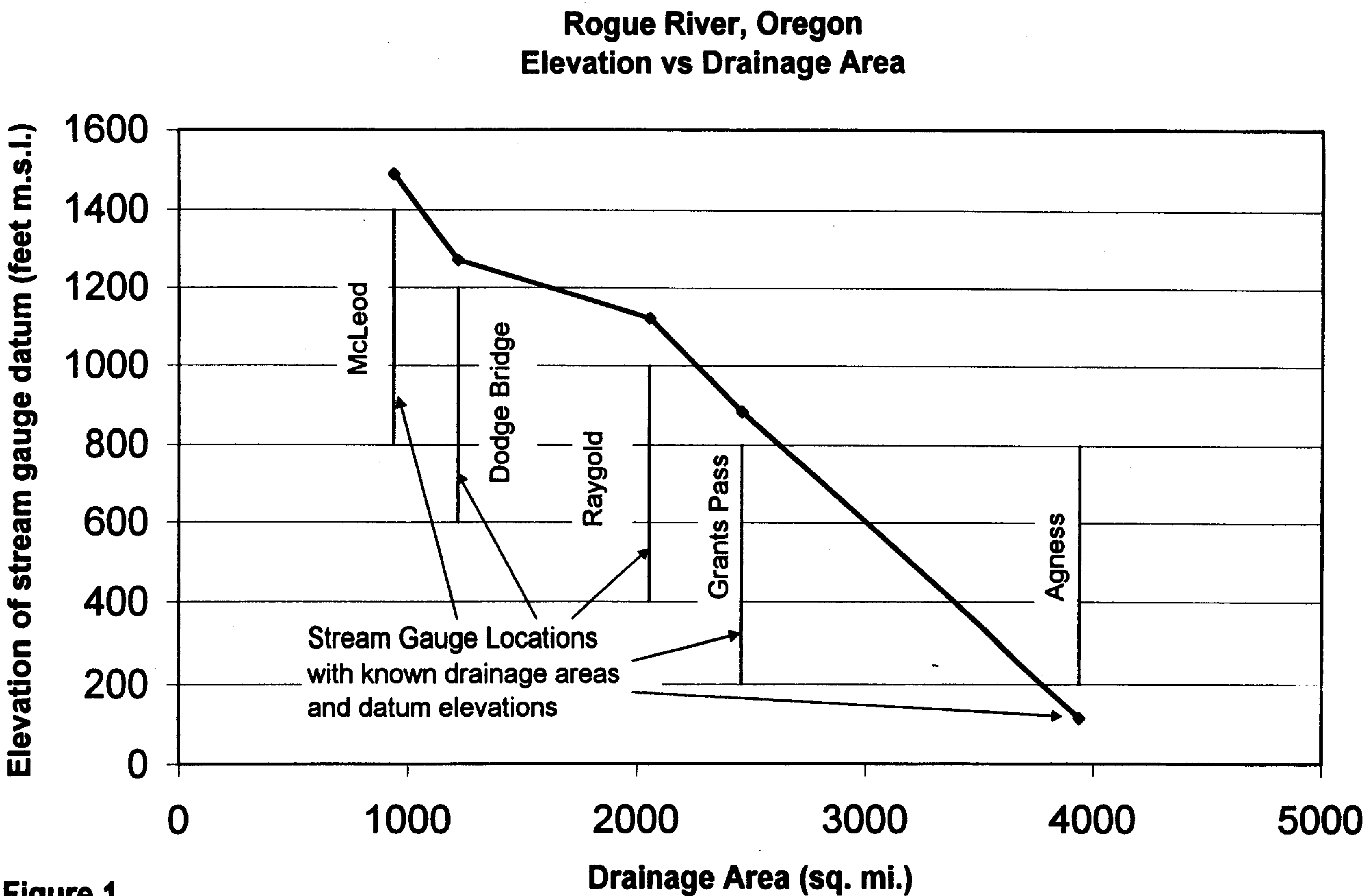
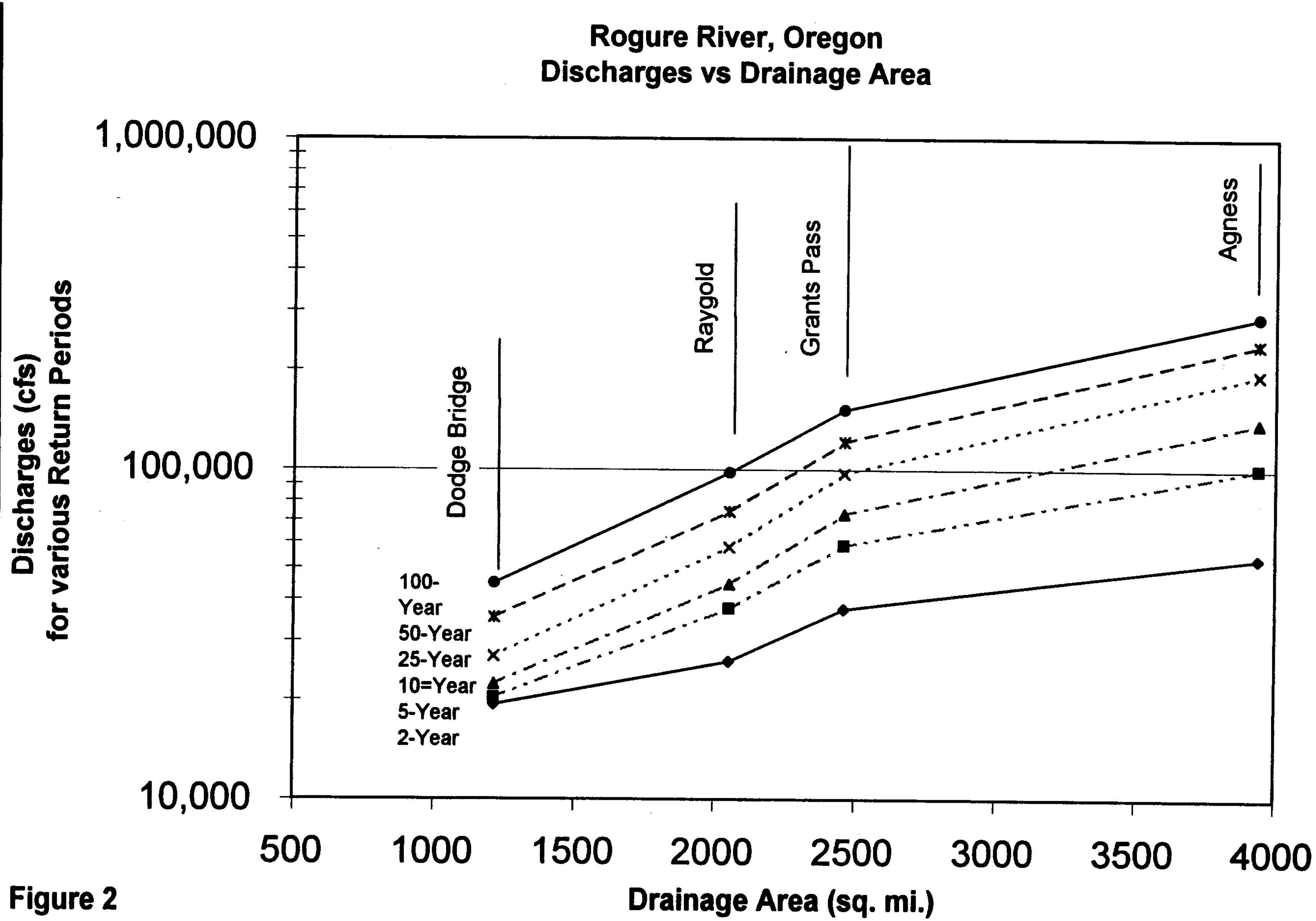

Rogue River, Oregon
Elevation vs Drainage Area
Elevation of stream gauge datum (feet m.s.l.)
1600
1400
1200
1000
800
600
400
200
0
McLeod
Dodge Bridge
Raygold
Grants Pass
Agness
Stream Gauge Locations
with known drainage areas
and datum elevations
0
1000
2000
3000
4000
5000
Drainage Area (sq. mi.)

Figure 1



Rogure River, Oregon
Discharges vs Drainage Area
Discharges (cfs)
for various Return Periods
1,000,000
100,000
10,000
Dodge Bridge
Raygold
Grants Pass
Agness
100-
Year
50-Year
25-Year
10=Year
5-Year
2-Year
500
1000
1500
2000
2500
3000
3500
4000
Drainage Area (sq. mi.)

Figure 2

Discharges vs River Mile

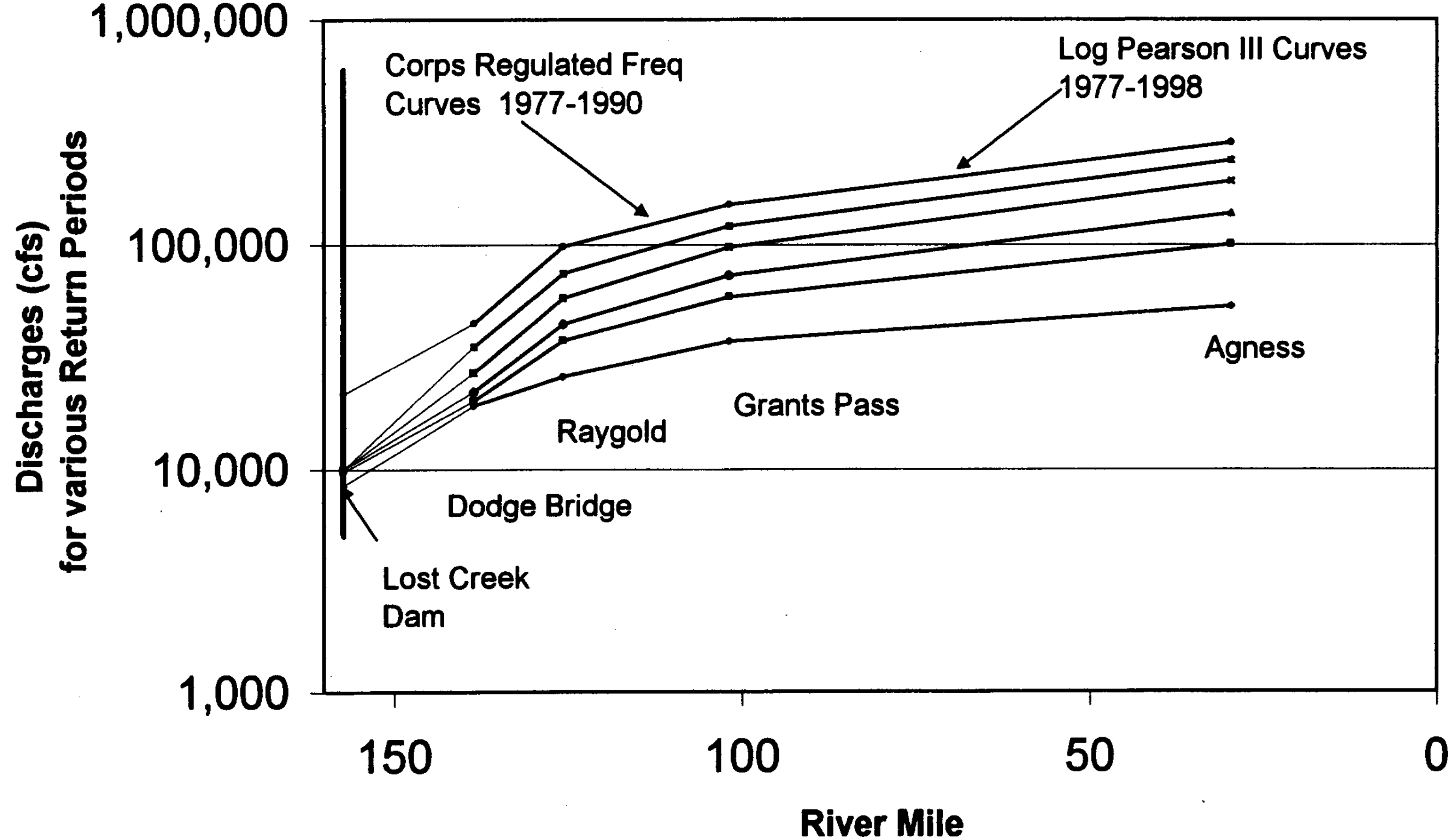


Figure 3

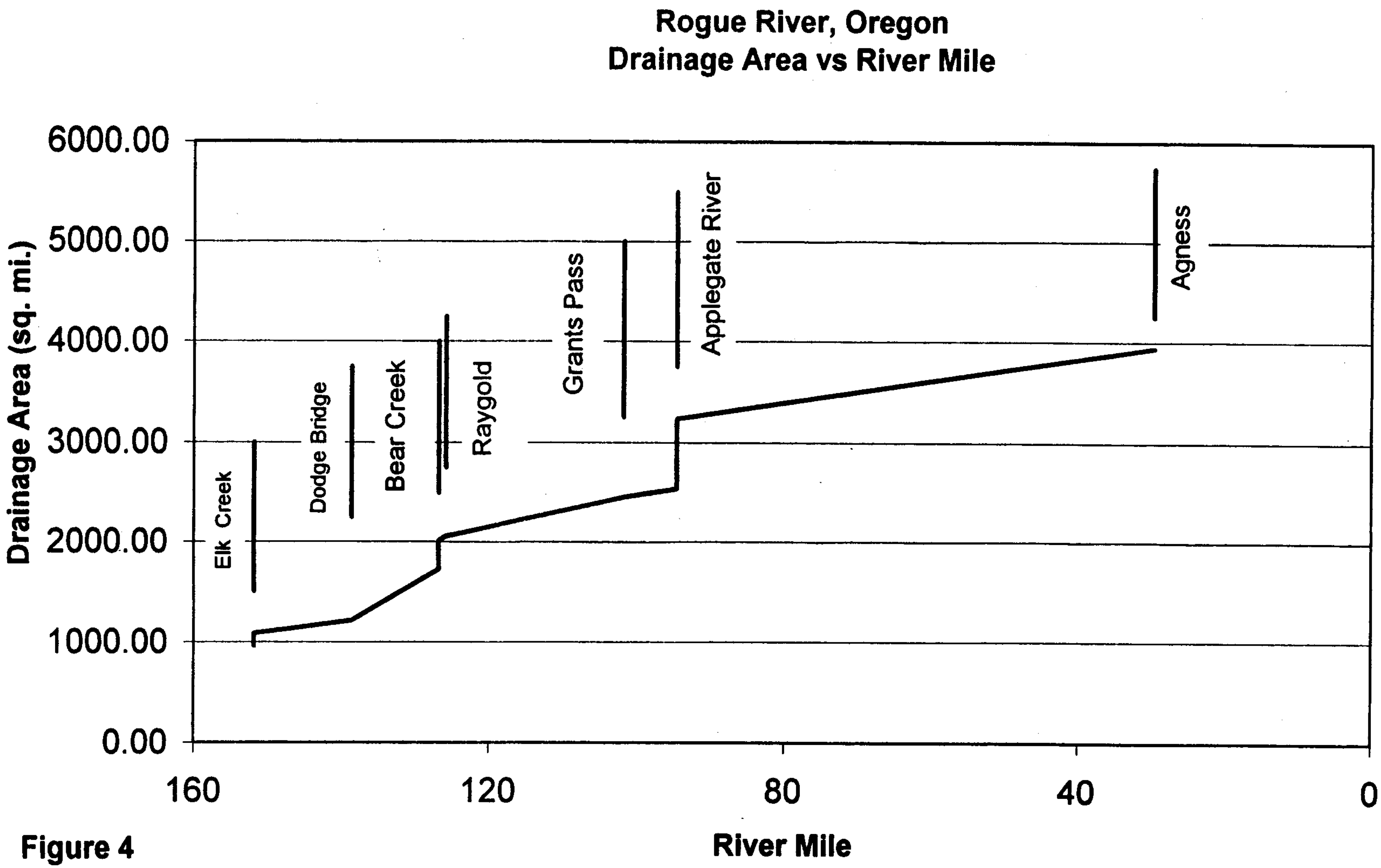

Rogue River, Oregon
Drainage Area vs River Mile
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
Drainage Area (sq. mi.)
160
120
80
40
0
River Mile
Elk Creek
Dodge Bridge
Bear Creek
Raygold
Grants Pass
Applegate River
Agness

Figure 4

Rogue River, Oregon
Retrun Period Discharges vs River Mile

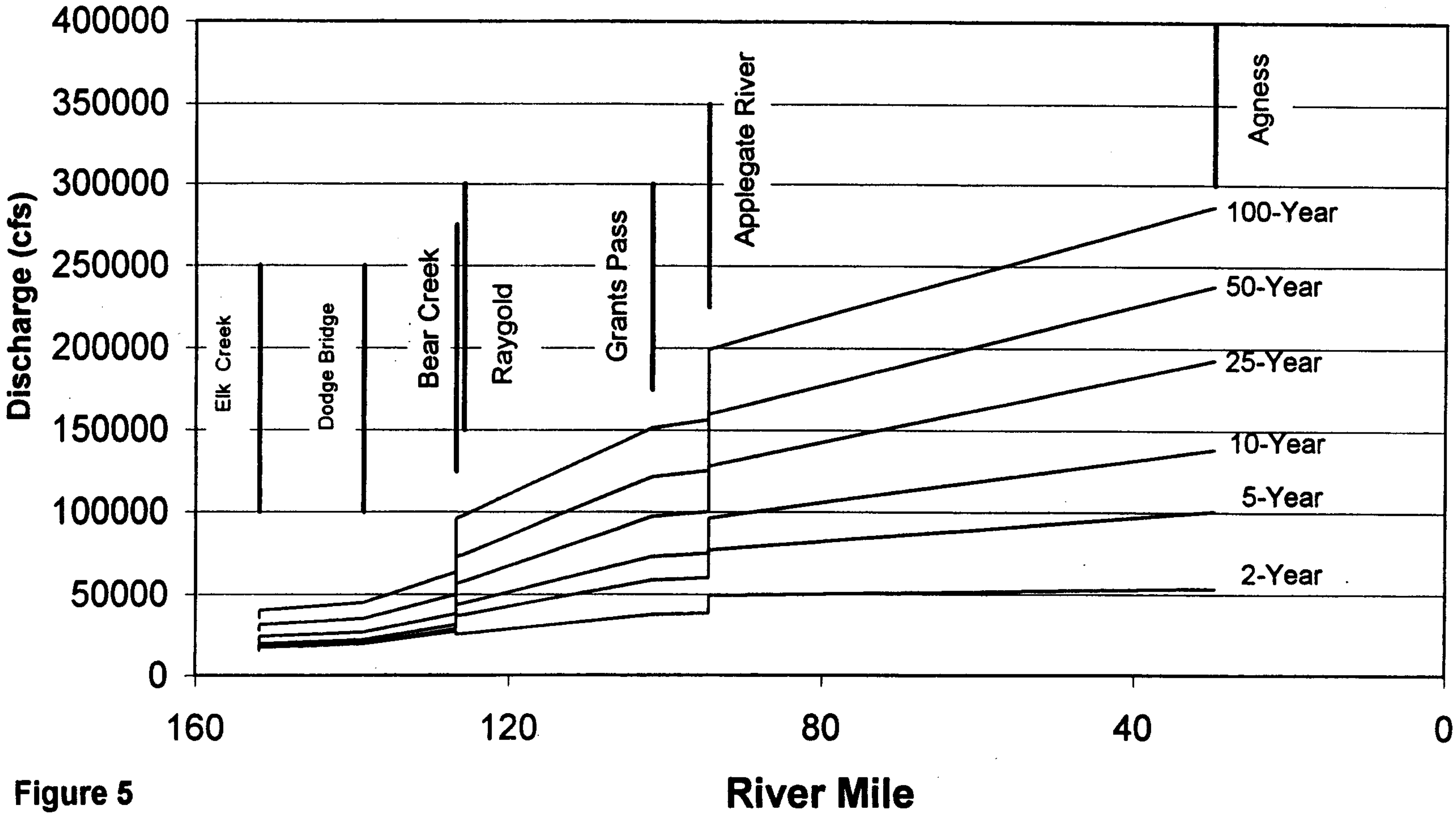
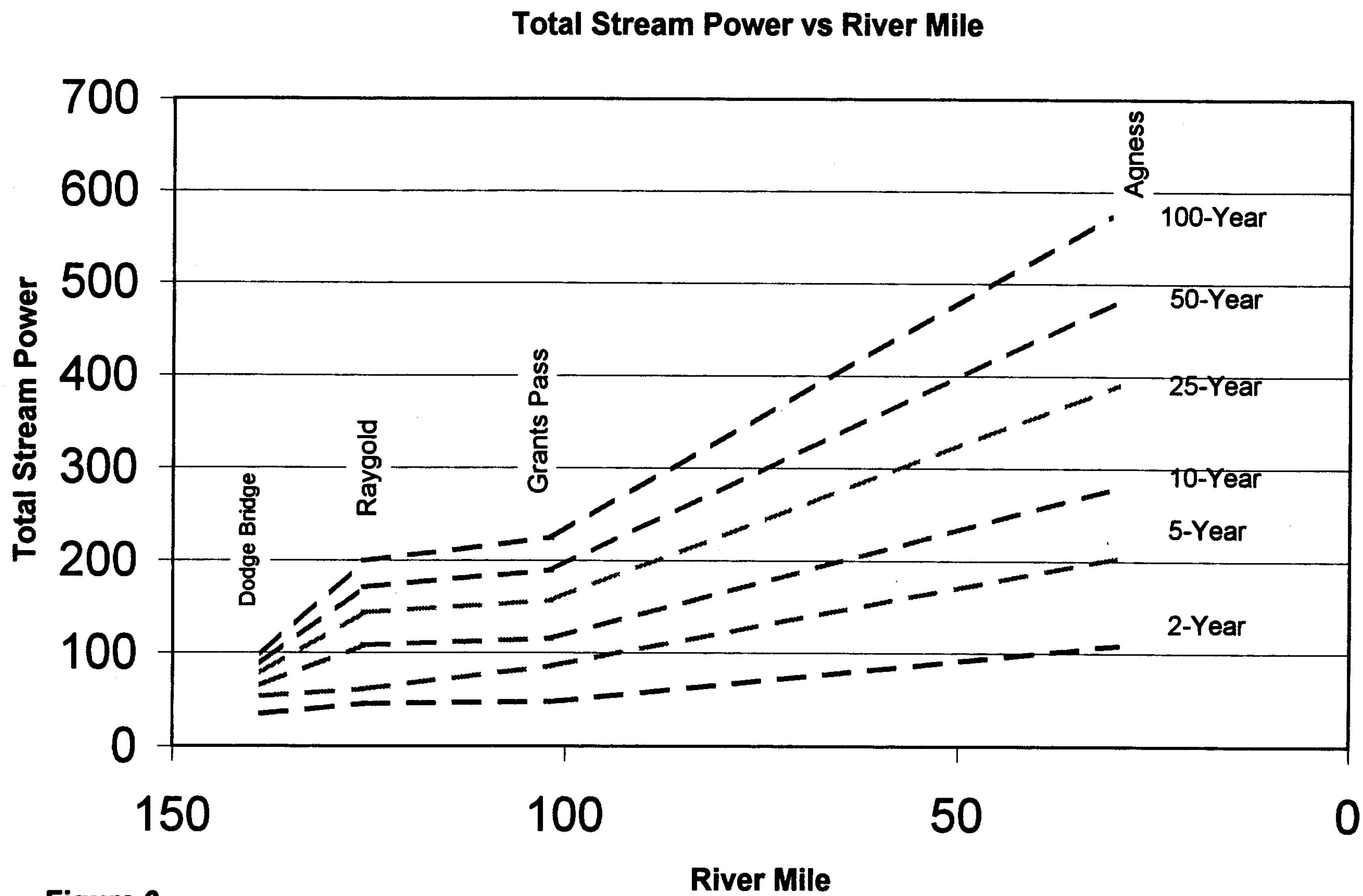


Figure 5



Total Stream Power vs River Mile
Total Stream Power
700
600
500
400
300
200
100
0
150
100
50
0
River Mile
Dodge Bridge
Raygold
Grants Pass
Agness
100-Year
50-Year
25-Year
10-Year
5-Year
2-Year

Figure 6

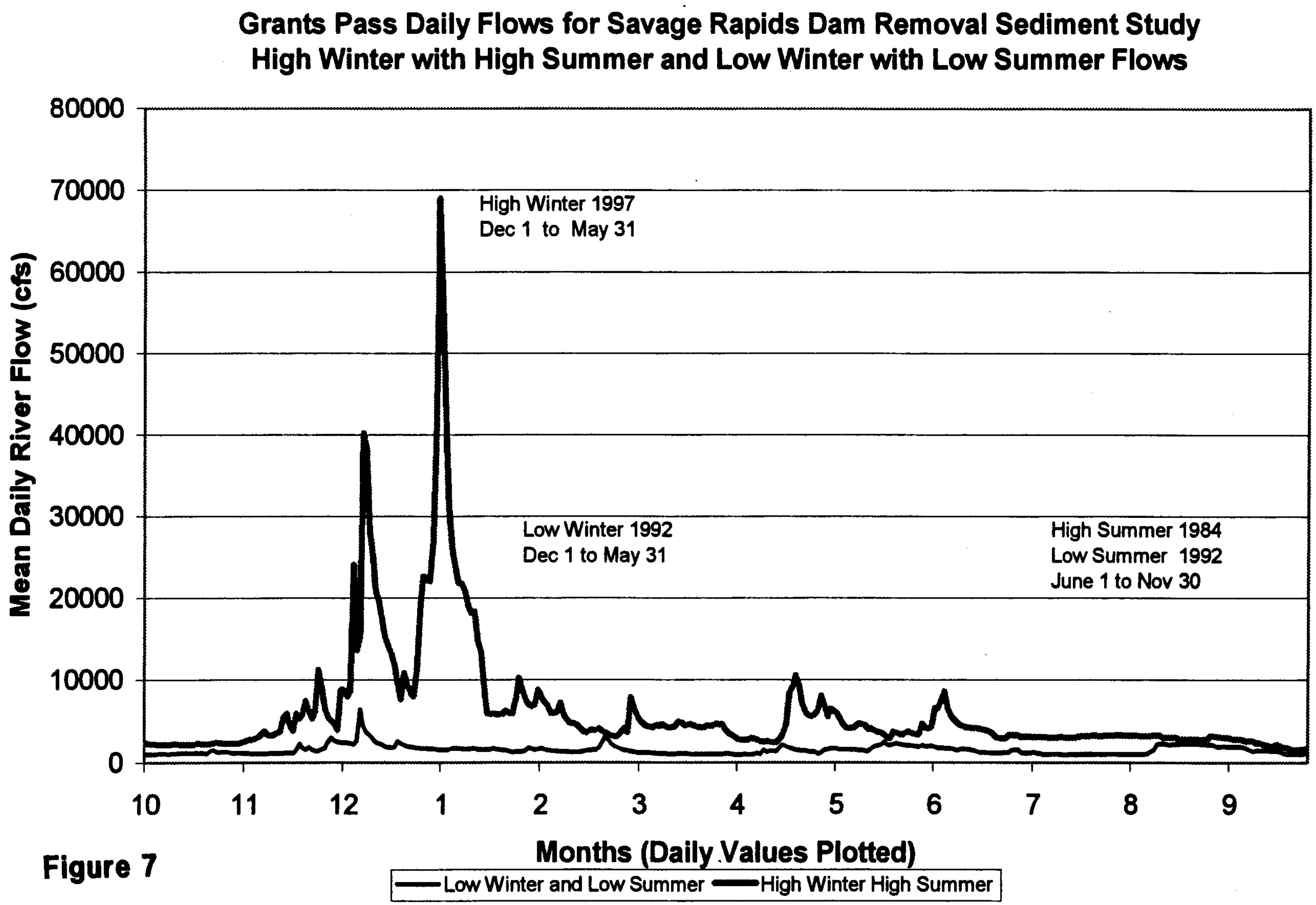

Grants Pass Daily Flows for Savage Rapids Dam Removal Sediment Study
High Winter with High Summer and Low Winter with Low Summer Flows
Mean Daily River Flow (cfs)
80000
70000
60000
50000
40000
30000
20000
10000
0
High Winter 1997
Dec 1 to May 31
Low Winter 1992
Dec 1 to May 31
High Summer 1984
Low Summer 1992
June 1 to Nov 30
10
11
12
1
2
3
4
5
6
7
8
9
Months (Daily Values Plotted)
Low Winter and Low Summer
High Winter High Summer

Figure 7

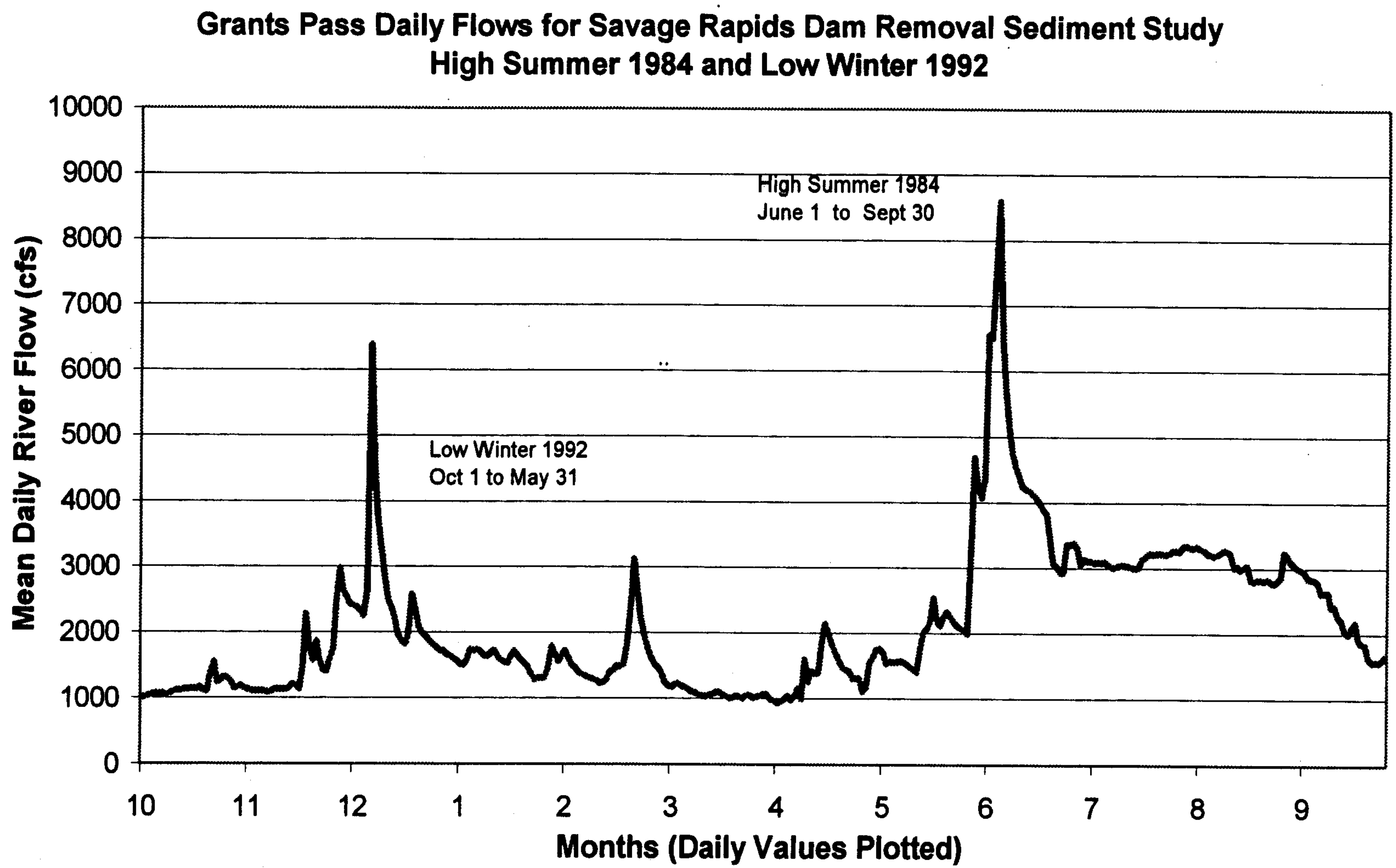

Grants Pass Daily Flows for Savage Rapids Dam Removal Sediment Study
High Summer 1984 and Low Winter 1992
Mean Daily River Flow (cfs)
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
High Summer 1984
June 1 to Sept 30
Low Winter 1992
Oct 1 to May 31
10
11
12
1
2
3
4
5
6
7
8
9
Months (Daily Values Plotted)

Figure 8

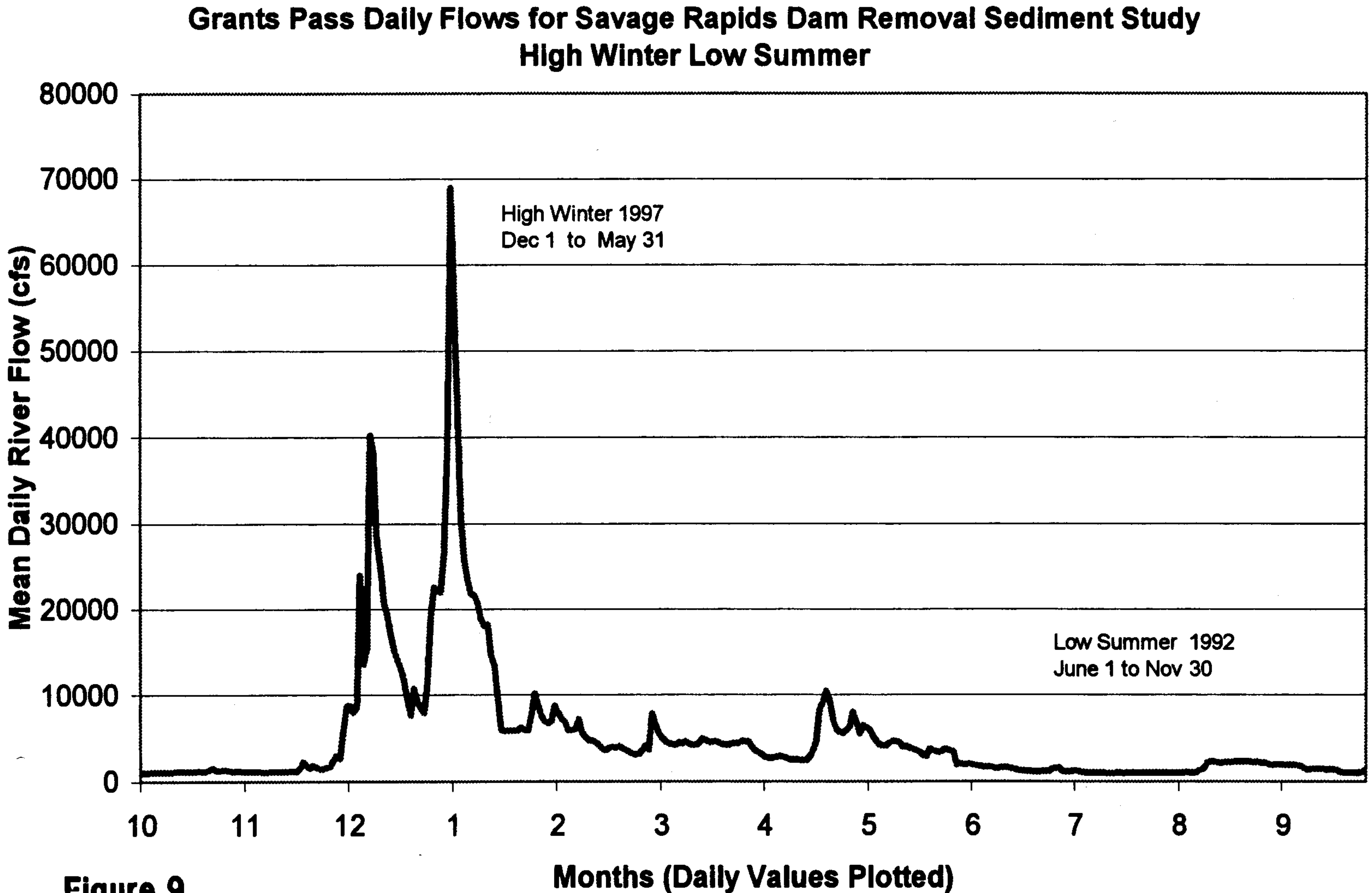

Grants Pass Daily Flows for Savage Rapids Dam Removal Sediment Study
High Winter Low Summer
Mean Daily River Flow (cfs)
80000
70000
60000
50000
40000
30000
20000
10000
0
High Winter 1997
Dec 1 to May 31
Low Summer 1992
June 1 to Nov 30
10
11
12
1
2
3
4
5
6
7
8
9
Months (Daily Values Plotted)

Figure 9