US Army Corps
of Engineers®
Walla Walla District

United States
Environmental Protection Agency
Region 10

DREDGED MATERIAL MANAGEMENT PLAN AND ENVIRONMENTAL IMPACT STATEMENT

McNary Reservoir and Lower Snake River Reservoirs

APPENDIX A
Hydrologic Analysis

DRAFT
October 2001

FINAL
July 2002

FINAL DREDGED MATERIAL MANAGEMENT PLAN AND ENVIRONMENTAL IMPACT STATEMENT
McNary Reservoir and Lower Snake River Reservoirs

JULY 2002

ERRATA SHEET
FOR
APPENDIX A - HYDROLOGIC ANALYSIS

This appendix has not been substantially changed from the draft and will not be reprinted. Please make the following changes to the draft appendix and consider the draft appendix with corrections as the final appendix.

Front cover:
Apply the attached label (FINAL, July 2002) on the front cover to the right of the draft date.

Footnotes throughout the appendix:
Change all footnote references from "Draft DMMP/EIS, October 2001" to "Final DMMP/EIS, July 2002."

Section 4.0, Page A-4
Last sentence should read:
The DMMP study tasks were: (1) to review and update the sediment monitoring program; (2) prepare a summary of existing data on sediment sources and deposition patterns within the study area; (3) update flood frequencies, flow durations, and long-term sediment deposition predictions; (4) re-evaluate, re-calibrate, and re-run the Corps, Hydrologic Engineering Center's (HEC) sediment model HEC-6; (5) evaluate sediment transport in the confluence area of the Snake and Clearwater Rivers utilizing a two-dimensional sediment transport model; (6) re-evaluate dredging requirements for in-water dredged-material placement; and (7) evaluate sediment transport under drawdown conditions below the normal high inflow drawdown of elevation 724 at the dam.

Section 9.0, Page A-6
4th sentence of first paragraph should read:
This mountainous area is included within the Northern Rocky Mountain Province. Overall extremes of elevation are 4,196 m (13,766 feet) above msl at Grand Teton Mountain in Wyoming to approximately 91.4 m (300 feet) above msl at the Snake River's confluence with the Columbia River.

Section 14.0, Page A-7
2nd and 3rd sentences of first paragraph should read:
The major storage projects located immediately upstream of Lower Granite Dam are Dworshak Dam on the North Fork of the Clearwater River and Brownlee Dam on the Snake River's main stem. At present, the Lower Granite Project impounds the majority of sediments which are

contributed to the Snake River and Clearwater River from upstream portions of the Snake River basin which are not tributary to either the Dworshak or Brownlee projects.

Page A-8, 2nd paragraph
First sentence of second paragraph should read:
At present on the Columbia River, Priest Rapids Dam which is the next upstream project from the Snake River and Columbia River confluence as well as other upstream projects impound the majority of the sediments presently being transported into them.

Section 21.0 Risk-Based Backwater Analyses
Page A-17, 1st paragraph
Add at the end of the first paragraph:
The average flow contribution into Lower Granite Reservoir is approximately 64% from the Snake River and 36% from the Clearwater River. Flow contributions for each of the three specific frequency sites are shown in Table A-2 using this 64%-36% distribution. As an example, Lower Granite inflows for the 1% event varies from 320,000 cfs, to 334,200 cfs, and to 354,110 cfs depending on which location is used as the controlling or 1% event location. The magnitude of the event typically decreases as the areal distribution increases; thus, all three numbers are correct but just represent different locations where the event is centered.

Page A-20, 1st paragraph
Last sentence should read:
During the SPF[3], [11,894 cms (420,000 cfs)], the reservoir must be drawn down to elevation 220.7 m msl (724.0 feet msl) at the forebay of the Dam to maintain the desired confluence elevation.

Plates
Title of Plate 5 should be: Snake River in Lower Granite Reservoir Sedimentation Ranges
Title of Plate 6 should be: Clearwater River in Lower Granite Reservoir Sedimentation Ranges
Title of Plate 7 should be: Columbia River in McNary Reservoir Sedimentation Ranges

*** * * END OF CHANGES * * ***

DREDGED MATERIAL MANAGEMENT PLAN
AND ENVIRONMENTAL IMPACT STATEMENT

McNARY RESERVOIR AND LOWER SNAKE RIVER RESERVOIRS

APPENDIX A

HYDROLOGIC ANALYSIS

U.S. Army Corps of Engineers
Walla Walla District Hydrology Section
201 N. 3rd Avenue
Walla Walla, WA 99362

October 2001

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

TABLE OF CONTENTS (CONTINUED)

LIST OF PLATES (CONTINUED)

Plate

ENGLISH TO METRIC CONVERSIONS

To Convert From	To	Multiply
Length Conversions:		
Inches	Millimeters	25.5
Feet	Meters	0.3048
Miles	Kilometers	1.6093
Area Conversions:		
Acres	Hectares	0.4047
Acres	Square Meters	4047
Square Miles	Square Kilometers	2.590
Volume Conversions:		
Gallons	Cubic Meters	0.003785
Cubic Yards	Cubic Meters	0.7646
Acre-Feet	Hectare-Meters	0.1234
Acre-Feet	Cubic Meters	1234
Other Conversions:		
Feet/Mile	Meters/Kilometer	0.1894
Tons	Kilograms	907.2
Tons/Square Mile	Kilograms/Square Km	350.2703
Cubic Feet/Second (cfs)	Cubic Meters/Second (cms)	0.02832
Degrees Fahrenheit (°F)	Degrees Celsius (°C)	(°F - 32) x (5/9)

1.0 INTRODUCTION

This Hydrologic Analysis Appendix was prepared in support of a study to evaluate the dredged material disposal requirements for the navigable waterways within the boundaries of the United States Army Corps of Engineers (Corps), Walla Walla District. This appendix provides an overview of the hydrologic information as it corresponds to the Mid-Columbia and Lower Snake River Sediment Management Areas. The reaches analyzed in this appendix, include the reservoir upstream of McNary Dam on the Columbia River and those upstream of the four lower Snake River dams (these dams are also generally referred to as "projects"). The four lower Snake River projects are located on the Snake River between the downstream population centers of the Tri-Cities, Washington (Pasco, Kennewick, and Richland) and the upstream population centers of Lewiston, Idaho, and Clarkston, Washington. Refer to the two Project Location Maps, plates 1 and 2, for locations of these geographic features as well as for other locations given in this report. Plate 1 is a map of the Columbia River Basin within the continental United States and plate 2 is a map of the lower Snake River project areas. The working draft of Engineering Circular (EC) 1165-2-200, entitled *Policy - Dredged Material Management Plans*, states that Dredged Material Management Plans will be prepared for all Federal navigation projects including systems of inland waterway projects for which:

> "existing dredged material disposal sites, including existing confined disposal facilities, are expected to reach capacity, or to no longer be available sometime in the next 10 years, or existing and projected navigation usage of the project indicates that continued maintenance of the project, or of any substantial increment thereof, may not be warranted."

2.0 BACKGROUND

The Columbia River and Snake River inland navigation waterway provides slack water navigation from the mouth of the Columbia River near Astoria, Oregon, upstream to port facilities on the Snake and Clearwater Rivers at Lewiston, Idaho, and Clarkston, Washington. This is a distance of approximately 748 kilometers (km) (465 miles) as measured along the Columbia, Snake, and Clearwater River centerlines. The distance along the Columbia River is approximately 523 km (325 miles) from its mouth at the Pacific Ocean upstream to the Tri-Cities, Washington. The distance along the Snake and Clearwater Rivers is approximately 225 km (140 miles) from the Tri-Cities area upstream to the Port of Lewiston, Idaho. The four lock and dam projects on the Columbia River, in upstream order, are Bonneville, The Dalles, John Day, and McNary. The four lock and dam projects on the Snake River, in upstream order, are Ice Harbor, Lower Monumental, Little Goose, and Lower Granite. These eight projects create a continuous navigable waterway having a minimum depth of 4.3 meters (m) (14 feet), which provides the State of Idaho barge traffic access to the Pacific Ocean via the Port of Lewiston.

Lower Granite Dam is located at Snake River Kilometer (Rkm) 173.0 [River Mile (RM) 107.5] and is the most upstream of the eight projects previously mentioned. Its sediment contributing drainage area is relatively large as compared to the other three lower Snake River projects and the McNary Project, and includes the entire Salmon River drainage, the Imnaha and Grande

Ronde Rivers, the main stem of the Clearwater River, and the local Snake River drainage between the Hells Canyon complex and Lower Granite. Lower Granite Reservoir serves as a sediment trap for most of the material carried by each of its inflowing tributaries. The quantity of sediment that collects in the Lower Granite Reservoir far exceeds the quantities observed in each of the other lower Snake River reservoirs and in the McNary Reservoir. Therefore, previous sediment studies have been primarily focused on that reservoir. These studies have included hydrologic and sediment surveys, coordination with many interested parties to determine a methodology to evaluate the biological impacts of dredging, three interim dredging events to create in-water test sites for biological testing, and 5 years of field testing and data collection associated with the beneficial use tests.

The situation at the upstream end of Lower Granite Reservoir is further complicated by the location of the cities of Lewiston and Clarkston. The Lower Granite Project includes a backwater levee system that was installed in lieu of relocating the business district of Lewiston. This levee system was not designed for the purpose of providing flood control to the city of Lewiston. Rather, it can be thought of as an upstream non-overflow extension of the dam which was designed to allow Lower Granite Reservoir to be maintained at the normal operating pool elevation of 224.9 m (738 feet) above mean sea level (msl) and yet still protect Lewiston from inundation during a Standard Project Flood (SPF) event. The Lewiston Levee System was designed to provide a minimum freeboard of 1.5 m (5 feet) during the SPF event, which is 11,894 cms (420,000 cfs) on the Snake River downstream of its confluence with the Clearwater River, 8,354 cms (295,000 cfs) upstream of this confluence, and 4,248 cms (150,000 cfs) on the Clearwater River upstream of the Snake River confluence.

The Tucannon River and the Palouse River are tributaries to the reservoir created upstream of Lower Monumental Dam. The Columbia River drainage basin downstream of Priest Rapids Dam, the Yakima River, and the Walla Walla River are all tributaries to the reservoir created upstream of McNary Dam on the Columbia River. These tributaries provide the majority of sediment inflow although it is recognized that all local drainage areas are capable of producing sediment inflows due to their fine nature.

Plates 1 and 2, the Project Location Maps, collectively show the locations of these geographic features and table A-1 presents drainage areas for the major tributaries to the respective projects.

Table A-1. Snake River Basin Drainage Area and Stream Gauge Summary.

Location	USGS[1] Station Number	Drainage Area (Square Km /Square Miles[2])
Snake River at Hells Canyon Dam	13290450	189,847 / 73,300
Imnaha River at Imnaha, Oregon	13292000	1,600 / 622
Imnaha River at Snake River	None	1,813 / 700 (E)[3]
Salmon River at Whitebird, Idaho	13317000	35,094 / 13,550
Salmon River at Snake River	None	36,519 / 14,100 (E)
Grande Ronde River at Troy, Oregon	13333000	8,482 / 3,275
Grande Ronde River at Snake River	None	10,541 / 4,070 (E)
Snake River near Anatone, Washington	13334300	240,766 / 92,960
Snake River at Clearwater River	None	242,165 / 93,500 (E)
N. Fork Clearwater River at Dworshak Dam	None	6,320 / 2,440
Clearwater River at Spalding, Idaho	13342500	24,216 / 9,350
Clearwater River at Snake River	None	24,968 / 9,640 (E)
Snake River at Lower Granite Dam	None	267,288 / 103,200 (E)
Tucannon River near Starbuck, Washington	13344500	1,116 / 431
Tucannon River at Snake River	None	1,424 / 550 (E)
Palouse River at Hooper, Washington	13351000	6,475 / 2,500
Palouse River at Snake River	None	6,734 / 2,600 (E)
Snake River at Columbia River	None	281,533 / 108,700 (E)
Columbia River below Priest Rapids Dam	12472800	248,640 / 96,000
Yakima River at Kiona, Washington	12510500	14,543 / 5,615
Yakima River at Columbia River	None	15,022 / 5,800 (E)
Columbia River at Snake River	None	266,770 / 103,000 (E)
Walla Walla River near Touchet, Washington	14018500	4,292 / 1,657
Walla Walla River at Columbia River	None	5,662 / 1,800 (E)
Columbia River at McNary Dam	14019200	554,260 / 214,000

Notes:
1. USGS is acronym for United States Geological Survey.
2. One square mile equals 2.590 square km.
3. (E) indicates that drainage area is estimated.

3.0 PROJECT AUTHORIZATION

McNary Project and the four lower Snake River projects were authorized by the River and Harbors Act of 1945 (reference 44). The applicable portions of the act read as follows:

> "Columbia River, Oregon and Washington: The construction of the Umatilla Dam for purposes of navigation, power development, and irrigation in accordance with the plan submitted in House Document 704, Seventy-fifth Congress; Provided, that surplus electric energy generated at said dam shall be delivered to

the Secretary of the Interior for disposition in accordance with existing laws relating to the disposition of power at Bonneville Dam…"

"Snake River, Oregon, Washington, and Idaho: The construction of such dams as are necessary, and open channel improvement for the purposes of providing slackwater navigation and irrigation in accordance with the plan submitted in House Document Numbered 704, Seventy-fifth Congress, with such modifications as do not change the requirement to provide slackwater navigation as the Secretary of War may find advisable after consultation with the Secretary of the Interior and such other agencies as may be concerned: Provided, that surplus electric energy generated at the dams authorized in this item shall be delivered to the Secretary of the Interior for disposition in accordance with existing laws relating to the disposition of power at Bonneville Dam…"

4.0 DREDGED MATERIAL MANAGEMENT PLAN STUDY SCOPE

Hydrologic studies relating to the Dredged Material Management Plan (DMMP) were concerned with two major tasks. These tasks were: (1) the determination of that portion of the present and future dredging requirements which become necessary as a result of channel aggradation; and (2) the identification of hydraulically acceptable in-water disposal sites and an evaluation of the effects of disposal of dredged material within the reservoir or in areas subject to erosion. Although the DMMP was created for a 20-year focus period, the consideration of a time period extending through the year 2074, which is the year when the most recently constructed dam (Lower Granite Dam) reaches the end of its 100-year economic life, was also required with respect to the determination of dredging and dredged material disposal requirements. The study was geographically limited to McNary, Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Reservoirs. The sources of sediment inflow were identified as well as the processes or conditions that result in deposition at particular locations. The locations and volumes of dredged material were determined. Proposed in-water disposal sites were located in areas that were hydraulically compatible with navigation, flood control, and other project operation parameters.

The DMMP study tasks were: (1) to review and update the sediment monitoring program; (2) prepare a summary of existing data on sediment sources and deposition patterns within the study area; (3) update flood frequencies, flow durations, and long-term sediment deposition predictions; (4) re-evaluate, re-calibrate, and re-run the Corps, Hydrologic Engineering Center's (HEC) sediment model HEC-6; (5) evaluate sediment transport in the confluence area of the Snake and Clearwater Rivers utilizing a two-dimensional sediment transport model; (6) re-evaluate dredging requirements for in-water dredged-material placement; and (7) evaluate sediment transport under drawdown conditions.

5.0 SNAKE RIVER BASIN DESCRIPTION

The Snake River basin has a total drainage area of approximately 281,533 square km (108,700 square miles) upstream of its confluence with the Columbia River near Pasco, Washington. Approximately 5 percent of the Snake River's total drainage area is located downstream of its confluence with the Clearwater River at Lewiston, Idaho, and this region is relatively arid as compared to the Snake River's upstream drainage areas. Therefore, only a relatively small amount of runoff occurs along the lower Snake River downstream of the Clearwater River confluence and is contributed primarily from the Tucannon and Palouse Rivers, which both empty into the Snake River between Lower Monumental and Little Goose Dams. Most of Idaho and lesser amounts of Oregon, Washington, Wyoming, Nevada, and Utah, are within the Snake River basin. The greatest overall dimensions of the basin are approximately 724 km (450 miles) in both the north-south and east-west directions, measured as a straight-line distance.

6.0 COLUMBIA RIVER BASIN DESCRIPTION

The Columbia River has a total drainage area of approximately 554,260 square km (214,000 square miles) measured at McNary Dam. McNary Dam is located at Columbia Rkm 469.9 (RM 292), approximately 51.5 river km (32 river miles) downstream of the Columbia River's confluence with the Snake River. Refer to plate 2 for the location of McNary Dam. The Columbia River's total drainage at its mouth is approximately 670,810 square km (259,000 square miles). The Columbia River's drainage area upstream of the Snake River confluence is approximately 266,770 square km (103,000 square miles). Thus at the confluence of the Snake and Columbia Rivers, both rivers have approximately the same drainage area with the Snake River's drainage area being slightly larger than the Columbia's at this location. The Snake River comprises approximately 42 percent of the Columbia River's total drainage area.

7.0 SNAKE RIVER STREAM DESCRIPTION

The Snake River is 1,735 km (1,078 miles) long and is the largest tributary of the Columbia River. It originates high in the Yellowstone National Park area of western Wyoming and traverses the southern part of Idaho in a broad arc running from east to west. It then flows almost due north, forming part of the boundary between Idaho, Oregon, and Washington. Near Lewiston, Idaho, it turns abruptly to the west and joins the Columbia River near Pasco, Washington. Total fall of the Snake River from its source near Two Ocean Plateau, Wyoming, to its confluence with the Columbia River is approximately 2,896 m (9,500 feet), for an average slope of approximately 1.7 m per km (8.8 feet per mile) computed over its entire length. Between Lewiston and Pasco, the lower Snake River falls approximately 122 m (400 feet) vertically in a distance of approximately 225 km (140 miles), yielding an average slope of approximately 0.54 m per km (3 feet per mile) along this reach.

8.0 EXISTING SNAKE RIVER BASIN WATER RESOURCES PROJECTS

The numerous artificial reservoirs and partially controlled lakes in the Snake River Basin have a substantial effect on the flow characteristics of the lower Snake River. Total usable storage in these upstream lakes and reservoirs is approximately 1,184,185 hectare-meters (9,600,000 acre-feet). Dworshak Reservoir has the greatest usable storage capacity with approximately 246,705 hectare-meters (2,000,000 acre-feet). It is followed with respect to usable capacity by American Falls Reservoir with approximately 209,699 hectare-meters (1,700,000 acre-feet), Palisades Reservoir with approximately 148,270 hectare-meters (1,202,000 acre-feet), Brownlee Reservoir with approximately 120,886 hectare-meters (980,000 acre-feet), and the Boise River Reservoir system with approximately 120,145 hectare-meters (974,000 acre-feet) combined storage within the Lucky Peak, Arrowrock, and Anderson Ranch Reservoirs.

9.0 SNAKE RIVER BASIN GEOGRAPHY AND GEOLOGY

Several complex systems of mountain ranges, with intervening valleys and plains, lie within the Snake River Basin. Much of the southern part of the basin is included within the Columbia Plateau Province, a semiarid expanse formed by successive flows of basaltic lava. To the north of this plateau is a rugged area of mountain ridges and troughs, with deeply incised stream channels. This mountainous area in included within the Northern Rocky Mountain Province. Overall extremes of elevation are 4,196 m (13,766 feet) above msl at Grand Teton Mountain in Wyoming to approximately 91.4 m (300 feet) above msl at the Snake River's confluence with the Columbia River. The basin mean elevation is approximately 1,585 m (5,200 feet) above msl. Fenneman (reference 7) as well as other geography and geology texts listed in the Bibliography and List of References should be consulted for a more in-depth discussion of the Snake River Basin's geography and geology.

The Snake River flows across a major physiographic region of the Pacific Northwest known as the Snake River Plateau and along the southern portion of the Columbia Plateau. The Snake River Plateau extends from southwestern Oregon across southern Idaho and includes parts of Nevada and Utah. The Columbia Plateau extends south from the upper curve of the Columbia River to the Blue Mountains, west to the Cascades, and east above the Snake River, just east of the Washington-Idaho state line. These two regions are comprised mainly of lava flows covered with soil. In areas where the Snake River has cut canyons, the dark basalt rock is a primary surface feature. Many of the soils of the Snake River Plateau are light and highly erodable with low rainfall limiting the ability of vegetative cover to reestablish, once removed. This results in heavy sediment loads in the river, especially during the spring runoff season.

10.0 SNAKE RIVER BASIN CLIMATE

Generally, the climate of the Snake River Basin is transitional between the maritime regimen west of the Cascade Mountain Range and the continental type climate of the northern Great Plains. Both maritime and continental air masses affect the basin but since it is located in the zone of prevailing westerly flow, the maritime air masses predominate. The Rocky Mountains, located to the north and east, provide some protection against outbreaks of cold arctic air from Canada, but such incursions do occur occasionally in the winter season, particularly over the eastern part of the Snake River Basin. Because of the irregular topography and large differences in elevation and exposure, there are pronounced differences of local climates within the basin.

11.0 SNAKE RIVER BASIN AIR TEMPERATURES

Air temperatures within the Snake River Basin are controlled by elevation and distance from the Pacific Ocean, as well as by individual air masses and the season of the year. An important aspect of basin temperature to the regulation of water resources project lies in the effect of temperature and solar radiation on snowmelt. The shape, timing, and peak discharge of the spring snowmelt runoff of the lower Snake River are determined to a considerable degree by the sequence of spring season basin temperatures. In addition, temperatures in the region have a pronounced effect on electric power demand and, therefore, on generation at hydroelectric projects which serve the area.

Normal summer maximum temperatures for most climatological stations are between 26.7 and 32.2 °C (80 and 90 °F) and normal winter minimums are between -17.8 and -6.7 °C (0 and 20 °F). Extreme recorded temperatures are -54.4 °C (-66 °F) at West Yellowstone, Montana, which is located immediately outside the upper Snake River basin boundary, and 47.8 °C (118 °F) at Ice Harbor Dam, Washington, and at Orofino, Idaho. Average frost-free periods in agricultural areas vary with location from about 50 to 200 days, and some small high elevation areas experience frost every month of the year.

12.0 SNAKE RIVER BASIN PRECIPITATION

The normal annual precipitation over the Snake River Basin ranges from less than 203 millimeters (mm) (8 inches) in the vicinity of Ice Harbor Dam and in portions of the plains of southern Idaho to an estimated maximum of 1,778 mm (70 inches) in the Bitterroot Mountains. The normal annual precipitation averaged over the entire basin is estimated to be approximately 508 mm (20 inches). Much of the winter precipitation is in the form of snow, a factor of great hydrologic importance. Snow course data are used for forecasting runoff volumes from major basins within the Snake River Basin.

13.0 SNAKE RIVER DISCHARGE CHARACTERISTICS

Plate 3 presents the Snake River Summary Hydrographs for inflows into Lower Granite Reservoir. Plate 4 presents the Annual Peak Discharge Frequency Curves for the Snake River at Lower Granite Dam. Inflows into the Snake River between the Clearwater River and the Columbia River are minor when compared to the total Snake River discharge at Lower Granite Reservoir. Therefore, these summary hydrographs and peak discharge frequency curves may also be considered to be representative of the entire lower Snake River between the Clearwater and Columbia Rivers. The average annual runoff from the Snake River Basin is approximately 152.4 mm (6.0 inches) of moisture.

14.0 COLUMBIA AND SNAKE RIVER BASIN SEDIMENTATION

The four lower Snake River projects, as well as other dam and reservoir projects within the Snake River basin, impound the majority of sediments transported into them by tributary streams. The major storage projects located immediately upstream of Lower Granite Dam are Dworshak Dam on the North Fork of the Clearwater River and Hells Canyon Dam on the Snake River's main stem. At present, the Lower Granite Project impounds the majority of sediments which are contributed to the Snake River and Clearwater River from upstream portions of the Snake River basin which are not tributary to either the Dworshak or Hells Canyon projects. This includes sediment inflows from the Lochsa River, the South Fork of the Clearwater River, and the Potlatch River, which are tributaries to the Clearwater River, and the Imnaha River, the Salmon River, and the Grande Ronde River, which are tributaries to the Snake River downstream of Hells Canyon Dam. Two major tributaries to the Snake River which enter the Snake between

Lower Granite Dam and the Snake River's confluence with the Columbia River are the Tucannon River and the Palouse River, which both are tributary to the Lower Monumental Project on the Snake River.

At present on the Columbia River, Priest Rapids Dam which is the next upstream project from the Snake River and Columbia River confluence as well as other upstream storage projects impound the majority of the sediments presently being transported into them. The Yakima River and Walla Walla River are the two major tributaries, in addition to the Snake River, to the McNary Project.

Sediment transport by streams within the Walla Walla River Basin was studied by B.E. Mapes of the USGS from July 1962 through June 1965. Results of this work are documented in reference 41. During this period average annual sediment yields in the basin were found to range from approximately 147,114 kilograms per square km (420 tons per square mile) in the mountainous areas of the drainage basin to more than 1,401,081 kilograms per square km (4,000 tons per square mile) in the extensively cultivated northern and central parts of the basin which are drained by the Touchet River and Dry Creek. The Touchet River and Dry Creek were found to transport approximately 80 percent of the total sediment load discharged from the Walla Walla River basin. During the July 1962 through June 1965 study period, two runoff events resulting from rain and snowmelt on partially frozen ground produced 76 percent of the suspended sediment discharged from the basin during the study period. Depending upon location within the drainage basin, bedload transport was estimated to be approximately 2 through 12 percent as much as the suspended load.

15.0 PRIOR SNAKE RIVER SEDIMENTATION STUDIES AND REPORTS

The following reports specifically address hydrologic and sedimentation studies previously accomplished within Lower Granite Project. They contain much background information, which is not repeated within the present DMMP report, and should be consulted for obtaining this background information as desired.

- Lower Granite Lock and Dam, Design Memorandum Number 1, Hydrology, December 1963 (reference 19).

- Lower Granite Lock and Dam, Design Memorandum Number 39, Lake Sedimentation Ranges, May 1975 (reference 21).

- Lower Granite Sedimentation Study, Preliminary Evaluation and Progress Report, December 1992 (reference 22).

- Sedimentation Study, Interim Report, Lower Granite Project, Snake River, Washington and Idaho, February 1984 (reference 23).

- *Sediment Transport in the Snake and Clearwater Rivers in the Vicinity of Lewiston, Idaho*, USGS Open File Report 80-690, August 1980 (reference 42).

16.0 SNAKE RIVER BASIN SOIL CHARACTERISTICS

Soil characteristics within the Snake River Basin vary considerably by geographic location, making it extremely difficult to apply site-specific information basin wide. For this reason, several of the Snake River's sub-basins having published information available will be briefly discussed. Paul E. Packer states in his paper, *Status of Research on Watershed Protection Requirements for Granitic Mountain Soils in Southwestern Idaho,* (reference 10), that "the mountain lands that constitute the upper drainage basins of the Boise, Payette, and Salmon Rivers in south-central Idaho have long presented a difficult watershed management problem." The soil in these basins is generally highly erodable, loose granitic soil which is highly vulnerable to displacement by raindrop impact and to erosion by overland flow, particularly during high intensity rainstorms. F. G. Renner, is his report "Conditions Influencing Erosion on the Boise Watershed," (reference 12) noted the following relationships:

- Erosion was found to vary directly with the degree to which the plant cover had been depleted and the soil surface disturbed.

- Erosion was found to vary directly with the steepness of slope, increasing up to about 35 percent gradient. On steeper slopes, other factors interfered with the evaluation of this relationship.

It is expected that these relationships may also apply to the Salmon River watershed.

In direct contrast to the coarse granitic soils of the Salmon, Payette, and Boise River basins, much of the central Palouse region in Idaho and Washington is covered chiefly by thick loess deposits that are highly erodible. Loess is a fine-grained windblown deposit of late Pliocene, Pleistocene, and Holocene age and is the most important source of sediment in the Palouse River basin. One factor responsible for the mechanical shaping of the loess hills, besides normal surface runoff and wind action, is the buildup of large banks of snow on the north and east faces of the hills. As these snowbanks melt, excess runoff causes deeper erosion of the soil on the north and east slopes. This is especially true in the Colfax-Pullman-Moscow area. In the easternmost part of the Palouse River basin, local relief is high, the loess cover is thin, and precipitation is relatively heavy. In the westernmost part of the Palouse River basin are scablands which lack an integrated drainage system and have little local relief. Lakes are numerous and signify the lack of integrated drainage. Interchannel areas in the scabland are locally characterized by remnant mantles of loess.

Sediment transport in the Palouse River basin is highly dependent on climatic activity. During a 4-year study period extending from July 1961 through June 1965, 81 percent of the total 4-year suspended sediment load occurred during the storm periods of February 3 through 9,1963; December 22 through 27, 1964; and January 27 through February 4, 1965. Reference 40 documents the results of these studies. The single storm of February 3 through 9 of 1963 accounted for approximately 50 percent of the total suspended load. This study determined that the average annual sediment discharge of the Palouse River at its mouth was approximately 1,433,376,000 kilograms (1,580,000 tons) per year and that the average annual sediment yield was approximately 168,129 kilograms per square km (480 tons per square mile). However, the sediment yield ranged from 1,751 kilograms per square km (5 tons per square mile) in the western part of the Palouse River basin to 735,568 kilograms per square km (2,100 tons per square mile) in the central part of the basin having the loess hills. Sediment yield in the eastern part of the basin ranged from 161,124 kilograms per square km (460 tons per square mile) to more than 350,270 kilograms per square km (1,000 tons per square mile).

The Tucannon River basin is similar to the Palouse River basin in that the headwaters areas are rugged volcanic highlands and the downstream portions are characterized by extensive loess deposits. Its sedimentation activity should somewhat qualitatively resemble that of the Palouse River basin.

17.0 PRIOR SNAKE RIVER BASIN SEDIMENTATION STUDIES

Verle C. Kaiser has made long-term studies starting in the mid-1930s of the annual erosion rates on standards plots throughout Whitman County, Washington. His observations are among the very few sustained and systematic records of erosional processes in the general region. He concluded that:

- Sediment delivery to the active channels is small relative to the amount of detached soil, with the difference deposited at the base of slopes and in swales.

- Soil loss and sediment delivery are not in simple relation to rainfall or runoff but depend to a great degree on antecedent ground temperature and moisture conditions as well as on effective rainfall intensity.

His data also suggests that erosion rates may range through cycles of 10 to 15 years, which complicates the definition of "average" or "normal" rates of soil loss and sediment yields. His work is documented in reference 8, and the above descriptions of his studies were from page 13 of the U.S. Department of Agriculture, Soil Conservation Service's report, *Sediment Transport, Water Quality, and Changing Bed Conditions, Tucannon River, Southeastern Washington*, (reference 31).

McCool and Papendick (reference 9) also discuss the variability of sediment yields in Palouse type watersheds. They noted that daily, seasonal, or annual variability in yields is very large in the small-grained dryland regions of the Pacific Northwest. Individual runoff events can account for more than half of the annual sediment yield. Sediment transport during a given year or a single large storm can be as large as the total of 4 or 5 other years. They recommended that intensive sampling during storms should be the basis of any field program. They concluded that "sampling programs based on weekly samples, even at stations with excellent streamflow records, can give extremely misleading results and sampling programs of only 1 or 2 years duration can also give extremely misleading results." McCool has also found that the distribution of frozen ground is a dominant factor in soil loss during individual storms (this description from reference 31, pages 14-15).

From 1972 through 1979, the USGS gathered both suspended load and bedload information on the Snake and Clearwater Rivers, in response to recognized needs for this inflowing sediment information. The results of this data gathering effort are documented in reference 42.

Suspended sediment and bedload transport was monitored within the Tucannon River drainage basin from October 1979 through September 1980. Other than the studies accomplished on the Snake and Clearwater Rivers from 1972 through 1979, no bedload transport monitoring had been attempted in southeastern Washington prior to the Tucannon River monitoring. Reference 31 documents the Tucannon River studies and should be consulted for more in-depth information on them.

The Walla Walla District, Corps of Engineers, developed a one-dimensional sediment model of Lower Granite Reservoir, utilizing the HEC-6 model, as a tool to assist in reviewing the adequacy of the Lower Granite Project as related to sedimentation effects on navigation and flood control. The results of this study were documented in *Sedimentation Study, Interim Report, Lower Granite Project, Snake River, Washington and Idaho*, published in February 1984 (reference 23). Further refinement of this initial work continued and in December 1992, another draft preliminary report was published which documented studies done as of that date (reference 22). The Walla Walla District also performed sedimentation studies in McNary Reservoir as part of the Tri-Cities levees studies. Results of these studies are documented in reference 24, published in May 1992. A USGS study entitled, *Sediment Transport by Streams in the Walla Walla River Basin, Washington and Oregon July 1962-June 1965*, was published in 1969 (reference 41).

18.0 SEDIMENTATION MONITORING

Sedimentation ranges have been established on the Snake and Clearwater Rivers in and immediately upstream of Lower Granite Reservoir as well as on Asotin Creek, which discharges into the Snake River at the upper end of Lower Granite Reservoir near the town of Asotin, Washington. The sedimentation ranges were established to monitor sediment deposition over time within Lower Granite Reservoir in order to provide a basis for determining the effects of this sedimentation activity. Plates 5 and 6 present the locations of these sediment ranges.

For monitoring the amount and pattern of sediment deposition in McNary Reservoir, 28 sedimentation ranges have been established beginning at Columbia Rkm 472.3 (RM 293.5) and extending upstream to Columbia Rkm 553.6 (RM 344.0). There are also 23 sedimentation ranges on the lower reaches of the Walla Walla River and 11 on the lower reaches of the Yakima River regularly monitored by the Corps of Engineers. Sedimentation ranges have not been officially established on the Snake River downstream of Ice Harbor Dam, although some sediment surveys have been accomplished downstream of Ice Harbor Dam. Plates 7 through 13 present the locations of the sediment ranges within McNary Reservoir, on the Walla Walla River, and on the Yakima River.

Data from the sedimentation range surveys is used to calibrate a one-dimensional sediment deposition model and to update reservoir flow models. These computer models are used in determining water surface profiles for flood control purposes and to study the effects of various reservoir projects.

19.0 CURRENT SEDIMENT MODEL DEVELOPMENTS

A one-dimensional sediment model of Lower Granite Reservoir, based on the HEC's numerical model "Scour and Deposition in Rivers and Reservoirs," (HEC-6) (reference 15) has been under development since the early 1980s. Results of this modeling effort is documented in two reports, *Sedimentation Study, Interim Report, Lower Granite Project, Snake River, Washington and Idaho*, dated February 1984 (reference 23) and *Lower Granite Sedimentation Study-Preliminary Evaluation and Progress Report*, (reference 22) dated December 1992. These two reports should be consulted for further background information on these studies.

As part of the current DMMP modeling studies, the existing HEC-6 model of Lower Granite Reservoir was extended downstream to McNary Dam on the Columbia River. This was accomplished utilizing existing geometric information available from existing data sets developed for utilization in the HEC's numerical model "Water Surface Profiles" (HEC-2) (reference 14). The applicable sediment information required for the development of the sediment model was approximated utilizing available information contained either in the Lower Granite sediment model or readily available from published reports. No new data collection was accomplished in the development of the current model that extended from Lower Granite Reservoir downstream to McNary Dam.

The cursory modeling accomplished with the current extended sediment model reinforced intuitive beliefs that the immediate primary focus of dredging efforts should be made in Lower Granite Reservoir. Since it is the most upstream of the four lower Snake River projects it is the first project to receive the sediment inflow of the Clearwater and Snake Rivers. Therefore, the bulk of this inflowing sediment which is able to readily settle out does so in Lower Granite Reservoir.

Little Goose Reservoir has no large tributaries of note that carry large inflowing sediment loads into its pool. Some localized dredging has been accomplished for navigation purposes in Little Goose Reservoir.

Lower Monumental Reservoir receives the inflowing sediment load of the Tucannon and Palouse Rivers and has experienced minor localized sedimentation problems. Ice Harbor Reservoir has no large tributaries of note that carry large inflowing sediment loads into its pool. Its local climate is very arid and only occasionally produces large runoff events.

McNary Reservoir receives the inflowing sediment load from the Yakima and Walla Walla Rivers. The majority of the inflowing sediment load of the Columbia River's main stem is captured by upstream projects such as Priest Rapids and Grand Coulee. Localized sedimentation problems have been noted at the Columbia River's confluences with the Yakima and Walla Walla Rivers.

Because the sedimentation problems in Lower Granite Reservoir are the most severe, it will be the primary quantitative focus of this DMMP's report, and the remaining areas will be given qualitative analyses as required.

20.0 DREDGING ALTERNATIVES

Four alternative dredging plans were evaluated for Lower Granite Reservoir:

A. Alternative 1: Navigation Maintenance Dredging. Navigation dredging only to provide required depths of navigation channel in Lower Granite Reservoir. Assuming a required depth of 4.3 m (14 feet) plus a 0.6 m (2 foot) depth of overdredging below the minimum operating pool elevation of 223.4 m (733 feet) above msl, this alternative results in a bottom template[1] elevation of 218.5 m (717 feet) above msl.

B. Alternative 2: Dredge 300,000 Cubic Yards (cy) Per Year. Dredge 229,380 cubic meters (m^3) (300,000 cy) per year from 2001 through 2074 to achieve a combination of dredged template development and maintenance dredging.

C. Alternative 3: Dredge 1,000,000 cy Per Year. Dredge 764,600 m3 (1,000,000 cy) per year from 2001 through 2074 to achieve a combination of dredged template development and maintenance dredging.

D. Alternative 4: Dredge 2,000,000 cy Per Year. Dredge 1,529,200 m3 (2,000,000 cy) per year from 2001 through 2074 to achieve a combination of dredged template development and maintenance dredging.

For navigation dredging only, a template 76.2 m (250 feet) wide having a bottom elevation of 218.5 m (717 feet) msl was assumed. It provided the width and depth required for navigation purposes. For the analysis of the other three options, two dredging templates were assumed. A smaller one was utilized for both the 229,380 cubic meter (300,000 cubic yard) and 764,600 cubic meter (1,000,000 cy) dredging scenarios and a larger one for the 1,529,200 cubic meter (2,000,000 cy) dredging scenario.

The four dredging alternative plans are further described as follows:

A. Alternative 1: Navigation Maintenance Dredging.

(1) Dredging areas. The only areas upstream of Lower Granite Dam which required dredging for navigation only were located on the Clearwater River between the Snake

[1] Template: Extent of the area required to be free from underwater hazards or obstructions for purposes of navigation, recreation, and irrigation intake. If material has been deposited within the template, it would require removal, usually by dredging. In the case of the navigation channel, the extent would be defined by the depth, bottom width, and side slopes of the channel as well as advance maintenance measures and allowable overdepth if specified. In the case of a boat landing or irrigation intake, the extent may be defined by the construction plans for the area. In the case of flow conveyance dredging, the defined template may extend outside the limits of the navigation channel and, in some cases, down into original riverbed material.

River confluence and the Port of Lewiston, located between Clearwater Rkms 0.00 to 2.67 (RMs 0.00 and 1.66). An initial dredging of approximately 63,462 m3 (83,000 cy) was required during the first 10 years to develop and maintain the design navigation template. For the remainder of the project life (to year 2074), approximately 1,529 to 3,823 m3 (2,000 to 5,000 cy) of maintenance dredging of the desired template was required annually.

(2) Dredging template design. The assumed navigation dredging template was 76.2 m (250 feet) wide, with all dredging done above elevation 218.5 m (717 feet) above msl, which is 4.9 m (16 feet) below the minimum authorized pool elevation of 223.4 m (733 feet) msl. The dredging template was assumed to be located at the deepest parts of the river channel so as to minimize the amount of navigation dredging required to maintain the required navigation channel depths. The channel was assumed to provide port access only, and no localized dredging within port areas was accounted for in the analysis. Since the location of the assumed dredged template for navigation was specifically chosen so as to minimize dredging requirements and also since no nearshore dredging within port areas was assumed, the volumes computed for this report for the navigation dredging only alternative are generally less than volumes actually dredged during previous dredging work in the Lewiston-Clarkston area.

(3) Disposal site areas. All material was assumed to be disposed downstream of Centennial Island located near Snake Rkm 193.86 (RM 120.46), under the In-Water Disposal Option. Disposal could be initiated at the downstream end of this area and then proceed upstream from Lower Granite Dam towards Centennial Island. The entire channel below elevation 204.2 m (670 feet) msl was assumed to be available to be utilized for material disposal as required. The final fill template for the entire disposal area was a level horizontal surface at 204.2 m (670 feet) msl. The total initially available disposal volume, based on 1997 survey information, was 91,134,433 m3 (119,192,300 cy). This disposal site was adequate to contain all materials dredged under this option, and no in-water disposal in Little Goose Pool was required. For the Upland Disposal Alternative, no specific disposal area was assumed, but the assumption was made that all dredged material would be permanently removed from the Snake and Clearwater Rivers.

(4) Material types. Approximately 27,526 m3 (36,000 cy) of material dredged from the initial template would be original bed materials, likely composed of gravels and cobbles. All subsequently dredged material would likely be inflowing sediments deposited in Clearwater River, between the Snake River confluence and Rkm 2.67 (RM 1.66), a mixture of sands, gravels, and cobbles carried by inflowing waters as suspended and bedloads.

B. Alternative 2: Dredge 300,000 cy Per Year.

(1) Dredging areas. The Snake River dredging areas were assumed to extend from the Port of Wilma near Snake Rkm 215.6 (RM 134) upstream to the State Highway 12 bridge located upstream of the confluence of the Snake and Clearwater Rivers, near Snake Rkm 224.5 (RM 139.5). The Clearwater River dredging areas were assumed to extend from the Snake River confluence upstream to the Port of Lewiston, from Clearwater Rkm 0.00 (RM 0.00) to Clearwater Rkm 2.67 (RM 1.66).

(2) Dredging template design. The Snake River's dredging template varied in width from 91.4 m (300 feet) near the Port of Wilma to 518.2 m (1,700 feet) in the confluence area. The average dredging width on the Snake River was 228.6 m (750 feet). The average depth of dredging on the Snake River was approximately 3 m (10 feet) below the 1997 ground surface. The Clearwater's dredging template varied in width from 91.4 m (300 feet) near the Camas Prairie Railroad (CPRR) bridge crossing to 304.8 m (1,000 feet) in the Port of Lewiston turning basin. The average width was 228.6 m (750 feet). The average depth of dredging was approximately 1.5 m (5 feet) below the 1997 ground surface.

(3) Disposal site areas. All material was assumed to be disposed downstream of Centennial Island located near Snake Rkm 193.86 (RM 120.46), under the In-Water Disposal Option. Disposal could be initiated at the downstream end of this area and then proceed upstream from Lower Granite Dam towards Centennial Island. The entire channel below elevation 204.2 m (670 feet) msl was assumed to be available to be utilized for material disposal as required. The final fill template for the entire disposal area was a level horizontal surface at 204.2 m (670 feet) msl. The total available disposal volume was 91,134,433 m3 (119,192,300 cy), based on 1997 survey information. This disposal site was adequate to contain all materials dredged under this option, with no in-water disposal required within Little Goose Pool. For the Upland Disposal Alternative, no specific disposal area was assumed, but the assumption was made that all dredged material would be permanently removed from the Snake and Clearwater Rivers.

(4) Material types. Approximately 4,325,189 m3 (5,656,800 cy) of material dredged on the Snake River would be original bed material and would generally be gravels and cobbles. Approximately 411,508 m3 (538,200 cy) of material on the Clearwater River would be original bed material generally composed of gravels and cobbles. Approximately 17,669,906 m3 (23,110,000 cy) of material would be dredged between years 2001-2074 under this option.

C. Alternative 3: Dredge 1,000,000 cy Per Year.

(1) Dredging areas. The Snake River dredging areas were assumed to extend from the Port of Wilma near Snake Rkm 215.6 (RM 134) upstream to the State Highway 12 bridge upstream of the confluence of the Snake and Clearwater Rivers located near Snake Rkm 224.5 (RM 139.5). The Clearwater River dredging areas were assumed to extend from the Snake River confluence upstream to the Port of Lewiston, from Clearwater Rkm 0.00 (RM 0.00) to Clearwater Rkm 2.67 (RM 1.66).

(2) Dredging template design. The dredging template for this option was identical to that for dredging 229,380 m3 (300,000 cy) per year. The Snake River's dredging template varied in width from 91.4 m (300 feet) near the Port of Wilma to 518.2 m (1,700 feet) in the confluence area. The average width on the Snake River was 228.6 m (750 feet). The average depth of dredging on the Snake River was approximately 3 m (10 feet). The Clearwater's dredging template varied in width from 91.4 m (300 feet) near the CPRR bridge crossing to 304.8 m (1,000 feet) in the Port of Lewiston turning basin. The average width was 228.6 m (750 feet). The average depth of dredging was 1.5 m (5 feet) below the 1997 ground surface.

(3) Disposal site areas. All material was assumed to be disposed downstream of Centennial Island located near Snake Rkm 193.86 (RM 120.46), under the In-Water Disposal Option. Disposal could be initiated at the downstream end of this area and then proceed upstream from Lower Granite Dam towards Centennial Island. The entire channel below elevation 204.2 m (670 feet) msl was assumed to be available to be utilized for material disposal as required. The final fill template for the entire disposal area was a level horizontal surface at 204.2 m (670 feet) msl. The total available disposal volume was 91,134,433 m3 (119,192,300 cy) based on 1997 survey information. This disposal site was adequate to contain all materials dredged under this option, and no in-water disposal was required within Little Goose Pool. For the Upland Disposal Alternative, no specific disposal area was assumed, but the assumption was made that all dredged material would be permanently removed from the Snake and Clearwater Rivers.

(4) Material types. Approximately 4,325,189 m3 (5,656,800 cy) of material dredged on the Snake River would be original bed material and be gravels and cobbles. Approximately 411,508 m3 (538,200 cy) of material on the Clearwater River would be original bed material composed of gravels and cobbles. Approximately 24,351,210 m3 (31,848,300 cy) of material would be dredged between years 2001-2074 under this option.

D. Alternative 4: Dredge 2,000,000 cy Per Year.

(1) Dredging areas. The Snake River dredging areas were assumed to extend from the vicinity of Silcott Island near Snake Rkm 210.8 (RM 131) upstream to the State Highway 12 bridge upstream of the confluence of the Snake and Clearwater Rivers, located near Snake Rkm 224.5 (RM 139.5). The Clearwater River dredging areas were assumed to extend from the Snake River confluence upstream to the Port of Lewiston, from Clearwater Rkm 0.00 (RM 0.00) to Clearwater Rkm 2.67 (RM 1.66). It was identical to the dredging template utilized on the Clearwater River for the 229,380 and 764,600 m3 (300,000 and 1,000,000 cy) per year options.

(2) Dredging template design. The Snake River's dredging template varied in width from 182.9 m (600 feet) near Silcott Island to 518.2 m (1,700 feet) in the confluence area. The average width on the Snake River was 289.6 m (950 feet). The average depth of dredging on the Snake River was approximately 6.1 m (20 feet). The Clearwater's dredging template varied in width from 91.4 m (300 feet) near the CPRR bridge crossing to 304.8 m (1,000 feet) in the Port of Lewiston turning basin. The average width was 228.6 m (750 feet). The average depth of dredging was 1.5 m (5 feet).

(3) Disposal site areas. All material was assumed to be disposed downstream of Centennial Island located near Snake Rkm 193.86 (RM 120.46), under the In-Water Disposal Option. Disposal could be initiated at the downstream end of this area and then proceed upstream from Lower Granite Dam towards Centennial Island. The entire channel below elevation 204.2 m (670 feet) msl was assumed to be available to be utilized for material disposal as required. The final fill template for the entire disposal area was a level horizontal surface at 204.2 m (670 feet) msl. The total available disposal volume was 91,134,433 m3 (119,192,300 cy) based on 1997 survey information. This disposal site was adequate to contain all materials dredged under this option, and no in-water disposal was required within Little Goose Pool. For

the Upland Disposal Alternative, no specific disposal area was assumed, but the assumption was made that all dredged material would be permanently removed from the Snake and Clearwater Rivers.

(4) Material types. Approximately 18,356,899 m3 (24,008,500 cy) of material dredged on the Snake River would be original bed material composed of gravels and cobbles. Approximately 411,508 m3 (538,200 cy) of material on the Clearwater River would be original bed material composed of gravels and cobbles. Approximately 58,724,338 m3 (76,804,000 cy) of material would be dredged between years 2001-2074 under this option.

21.0 RISK-BASED BACKWATER ANALYSES

The Risk-Based analyses for Lower Granite Reservoir required the utilization of eight specific frequency floods, these being the 2-, 5-, 10-, 25-, 50-, 100-, 250-, and 500-year floods. Flood flow frequency information has previously been developed at three sites in the vicinity of Lower Granite Reservoir. These sites are the Clearwater River at the Spalding gauge site (USGS Station Number 13342500) located at Clearwater Rkm 18.7 (RM 11.6), the Snake River at the Anatone gauge site (USGS Station Number 13334300) located at Snake Rkm 269.1 (RM 167.2), and the Snake River at Lower Granite Dam, located at Snake Rkm 172.9 (RM 107.43). This flood flow frequency information as well as flow split information for the Snake and Clearwater Rivers at their confluence was utilized in the development of the required flood magnitudes. Three flow combinations were assumed, based on the specific frequency floods occurring (1) on the Snake River downstream of its confluence with the Clearwater River; (2) on the Snake River upstream of this confluence; and (3) on the Clearwater River upstream of this confluence. Discharges on each river, for each of these three combinations are as follows in table A-2, given both in cms and cfs.

Table A-2. Computed River Discharge Combinations.

(1) Snake River Downstream of Clearwater Confluence Controlling			
Flood Recurrence Interval	Snake River Downstream (cms / cfs)	Snake River Upstream (cms / cfs)	Clearwater River Upstream (cms / cfs)
2-Year	4,672.8 / 165,000	2,833.6 / 100,055	1,839.2 / 64,945
5-Year	6,145.4 / 217,000	3,815.8 / 134,740	2,329.6 / 82,260
10-Year	6,938.4 / 245,000	4,344.7 / 153,415	2,593.7 / 91,585
25-Year	7,646.4 / 270,000	4,816.9 / 170,090	2,829.5 / 99,910
50-Year	8,496.0 / 300,000	5,383.6 / 190,100	3,112.4 / 109,900
100-Year	9,062.4 / 320,000	5,761.4 / 203,440	3,301.0 / 116,560
250-Year	9,628.8 / 340,000	6,139.2 / 216,780	3,489.6 / 123,220
500-Year	10,053.6 / 355,000	6,422.6 / 226,785	3,631.0 / 128,215
(2) Snake River Upstream of Clearwater Confluence Controlling			
Flood Recurrence Interval	Snake River Downstream (cms / cfs)	Snake River Upstream (cms / cfs)	Clearwater River Upstream (cms / cfs)
2-Year	4,808.0 / 169,775	2,923.8 / 103,240	1,879.0 / 66,350
5-Year	6,408.2 / 226,280	3,991.1 / 140,930	2,417.1 / 85,350
10-Year	7,376.8 / 260,480	4,637.1 / 163,740	2,739.7 / 96,740
25-Year	8,508.3 / 300,435	5,391.8 / 190,390	3,116.5 / 110,045
50-Year	9,290.8 / 328,065	5,913.8 / 208,820	3,377.0 / 119,245
100-Year	10,028.4 / 354,110	6,405.7 / 226,190	3,622.7 / 127,920
250-Year	11,026.5 / 389,355	7,071.5 / 249,700	3,955.0 / 139,655
500-Year	11,609.9 / 409,955	7,460.6 / 263,440	4,149.3 / 146,515
(3) Clearwater River Upstream of Clearwater Confluence Controlling			
Flood Recurrence Interval	Snake River Downstream (cms / cfs)	Snake River Upstream (cms / cfs)	Clearwater River Upstream (cms / cfs)
2-Year	4,528.7 / 159,910	2,737.4 / 96,660	1,791.2 / 63,250
5-Year	5,998.2 / 211,800	3,717.6 / 131,270	2,280.6 / 80,530
10-Year	6,897.9 / 243,570	4,317.7 / 152,460	2,580.2 / 91,110
25-Year	7,994.2 / 282,280	5,048.9 / 178,280	2,945.3 / 104,000
50-Year	8,732.5 / 308,350	5,541.4 / 195,670	3,191.1 / 112,680
100-Year	9,464.5 / 334,200	6,029.6 / 212,910	3,434.9 / 121,290
250-Year	10,290.4 / 363,360	6,580.4 / 232,360	3,709.9 / 131,000
500-Year	11,097.5 / 391,860	7,118.8 / 251,370	3,978.7 / 140,490

These three flow combinations were utilized to compute backwater profiles utilizing the HEC-2 model, "Water Surface Profiles," for these 15 conditions:

1. Initial conditions at Year 0 (2001).
2. Navigation Dredging at Year 20 (2021).
3. Navigation Dredging at end of project life (2074).
4. Dredge 229,380 m3 (300,000 cy) per year, with upland disposal, at Year 20 (2021).

5. Dredge 229,380 m3 (300,000 cy) per year, with upland disposal, at end of project life (2074).
6. Dredge 229,380 m3 (300,000 cy) per year, with in-water disposal, at Year 20 (2021).
7. Dredge 229,380 m3 (300,000 cy) per year, with in-water disposal, at end of project life (2074).
8. Dredge 764,600 m3 (1,000,000 cy) per year, with upland disposal, at Year 20 (2021).
9. Dredge 764,600 m3 (1,000,000 cy) per year, with upland disposal, at end of project life (2074).
10. Dredge 764,600 m3 (1,000,000 cy) per year, with in-water disposal, at Year 20 (2021).
11. Dredge 764,600 m3 (1,000,000 cy) per year, with in-water disposal, at end of project life (2074).
12. Dredge 1,529,200 m3 (2,000,000 cy) per year, with upland disposal, at Year 20 (2021).
13. Dredge 1,529,200 m3 (2,000,000 cy) per year, with upland disposal, at end of project life (2074).
14. Dredge 1,529,200 m3 (2,000,000 cy) per year, with in-water disposal, at Year 20 (2021).
15. Dredge 1,529,200 m3 (2,000,000 cy) per year, with in-water disposal, at end of project life (2074).

This computational process resulted in 45 sets of results to enter into the HEC Flood Damage Analysis (HEC-FDA) computer program. The 45 sets of data were derived from computing backwater profiles using each of the 15 different dredging conditions processed with each of the 3 sets of flow data. The numerical model HEC-2 (reference 14) was used to compute backwater profiles.

22.0 LEWISTON LEVEE OVERTOPPING/FAILURE ANALYSIS

At the time of initial design of the Lewiston Levee System, another dam was expected to be constructed upstream of Asotin, Washington. If it had been constructed, this project, named Asotin Dam, would have trapped the majority of the migrating sediments on the Snake River. However, this dam was subsequently de-authorized, which then shifted the location of any required maintenance dredging caused by inflowing Snake River sediments from Asotin Dam's pool downstream to the Lower Granite Project. Much of the inflowing sediment carried annually by spring freshets on the Snake and Clearwater Rivers settles in upper Lower Granite Reservoir, where the fast-flowing rivers meet the slack water from the dam. Coarser sediments settle first, filling in the natural channel in the vicinity of Lewiston and Clarkston. Finer sediments remain entrained in the streamflow longer and progressively settle out when the velocity of water diminishes to the point where it will no longer transport particles of a particular size. Without regular maintenance, the continuous inflow of sediment would raise the river invert and reduce the protection provided by the levees. Sedimentation also fills in the navigation channels to the Ports of Lewiston and Clarkston.

A. Methods of analysis. To predict potential flood damages under different dredging options, several mathematical models were constructed using the HEC program "Water Surface Profiles," commonly known as HEC-2 (reference 14). The HEC-2 is a standard step model using river cross section geometry and Manning's equation of energy loss to predict water surface profiles in steady flow channels where the starting water surface elevation is known. In this case, the starting water surface elevation is the operating pool at Lower Granite Dam, operated as necessary to maintain a constant water surface elevation of 224.9 m (738.0 feet) [2] at the confluence of the Snake and Clearwater Rivers, at Snake Rkm 224.2 (RM 139.3). Maintaining this constant elevation at the confluence is standard operating procedure for Lower Granite Project. During the SPF,[3] [11,894 cms (420,000 cfs)], the reservoir must be drawn down to elevation 220.7 m msl (724.0 feet msl) to maintain the desired elevation.

Manning's equation requires an estimate of energy loss that contains a component that is proportional to channel roughness. In the Snake and Clearwater Rivers, the natural channel bottom is very smooth compared to water depth and width. Manning's n was estimated to be 0.030[4] near Lewiston.

The Snake and Clearwater Rivers have been surveyed repeatedly since 1974 to monitor sediment buildup, but overbank flooding was never considered. Although USGS Quadrangles are available, they have insufficient detail to accurately map floodplain limits so a field survey was conducted. A contract was given to obtain 2-foot contours of lower portions of Lewiston and Clarkston near the Snake and Clearwater Rivers. Another contract acquired new depth soundings along the previously surveyed cross section lines across the Snake and Clearwater Rivers. The cross sections were then extended into the floodplain by interpolating elevations and distances from the new contour maps. Therefore, the elevations at hundreds of locations were field surveyed to create a topographic map with 61-centimeter (2-feet) contours[5] in the areas likely to be flooded. The new overbank contours were then combined with new depth soundings to create a new HEC-2 backwater model.

B. Stream Discharges. The drainage area of the Snake River upstream of the Clearwater River is much larger than that of the Clearwater River, but both rivers experience peak discharges in late May and early June.

Discharge and frequency on the two rivers are computed independently. A 17-year history of peak discharges on the Snake River below Lewiston from 1972 to 1988 were plotted against simultaneous flows on the Clearwater River at Spalding, Idaho. A regression line, hinged on the distribution of SPF,[6] was visually fitted to define the following typical distributions of flow:

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[2] All elevations are given in meters (feet) above msl referenced to National Geodetic Vertical Datum 1929.
[3] The SPF is the worst combination of meteorological events considered "reasonably characteristic of the area." Its derivation was presented in *Lower Granite Lock and Dam, Design Memorandum No. 1, Hydrology*, Corps, 1963 (reference 19).
[4] Manning's n value is non-dimensional and therefore independent of U.S. and Standard International units.
[5] Contour maps are accurate to one-half of the contour interval unless noted otherwise.
[6] Standard Project Flood, Corps, 1963.

$$Q_C = 0.333\, Q_{SL} + 10$$
$$Q_{SU} = Q_{SL} - Q_C$$

Where:

Q_C = Flow on Clearwater River at Spalding (1,000 cfs)
Q_{SL} = Flow on Snake River below Lewiston (1,000 cfs)
Q_{SU} = Flow on Snake River above Lewiston (1,000 cfs)

Flood frequencies were then computed separately for the Snake River below Lewiston, the Snake River above Lewiston, and the Clearwater River. During a 1-percent chance flood on the Clearwater River, it is possible to predict concurrent flows in the Snake River above and below the city of Lewiston and vice versa. To find the worst case flooding scenario at Lewiston, it was necessary to compute flooding at specific frequencies on each of the three component rivers separately.

C. Sedimentation. To predict flooding with and without maintenance, several versions of the model were created using different sedimentation and maintenance options based upon data gathered by the USGS from 1972 to 1979 (reference 42). They found that bedload in the Clearwater River ranged from about 45,000 metric tons (50,000 short tons) per year in 1972 and 1974 to about 900 metric tons per year in the drought years of 1973 and 1977. Suspended sediment load at the same location ranged from about 900,000 metric tons per year in 1974 to about 45,000 metric tons per year in 1977. Snake River bedload ranged from about 182,000 metric tons per year for 1972 and 1974 to about 9,000 metric tons per year in 1973 and too low to measure in 1977. Suspended sediment ranged from 4,500,000 metric tons per year in 1974 to 45,000 metric tons per year in 1977.

Alternative 1 assumed a fully dredged 76-meter wide by 4.3-meter (250 feet by 14 feet) deep navigation channel up to Clearwater Rkm 2.67 (RM 1.66) on the Clearwater River, which approximates the existing condition. Alternatives 2, 3, and 4 assumed river-wide removal of 229,400, 764,600, and 1,529,200 m3 (300,000, 1,000,000, 2,000,000 cy) of sediment annually. None was a direct continuation of the present situation, which includes navigation dredging on an as-needed basis and occasional dredging for flood control to prevent loss of levee capacity. To evaluate the long-term tendencies of the rivers, models were created for two time frames: 1999, representing the present, and 2074, representing the end of amortization of costs and benefits for Lower Granite Dam in the original feasibility analysis.

D. Levees. For each of these options, models attempted to show flooding conditions with and without effective levees. Three types of levees were considered: natural floodplain (levees in place but completely ineffective), present condition (levees heights limited to current elevation), and raised levees.

The wind wave portion of the design freeboard was determined by a method in *John Day Design Memorandum, Number 7, Supplement 2* (reference 18). The wave heights expected to be exceeded by 25 waves per year on average are given (reference 20) as:

Clearwater Rkm	Effective Fetch (Meters)	Wave Height (Centimeters)
1.0	970	85
3.2	320	52
Snake Rkm		
224.5	1,130	67
226.0	1,130	70

The wave height and sediment accumulations were added together to arrive at the design freeboard of 1.5 m (5 feet).

E. Results of analysis. As previously shown in the Discharge–Frequency tables, the specific-frequency floods that produce the highest discharges (and, correspondingly, the highest water surfaces) at Lewiston occur on the Snake River above Lewiston. Computations based on a 0.4 percent chance flood on the Snake River above the confluence yield discharges of 3,955 cms (139,655 cfs) on the Clearwater River (which has a frequency of slightly over 0.2 percent) and 11,026 cms (389,355 cfs) on the Snake River below the confluence (which has a frequency of less than 0.2 percent).

The highest water surface occurs with 75 years of sedimentation and raised levees. The starting water surface at the confluence is the same in all three runs. The levees have little impact on the first 2 km. Only as the backwater effect proceeds upstream does the presence of levees cause the flood profile to rise. The SPF will overtop both levees near Rkm 4.5 and at the confluence. Although the model overflow at the confluence will be deeper, the actual overflow at Clearwater Rkm 4.5 will be more significant. The river will overtop the levees at the confluence first and flood low-lying areas. Then, the upstream levees will likely breach, erode to ground level, and allow flow overland behind the levee to join the flood already in progress. Velocities in the overbank will not be fast but may be very damaging.

The 1-percent chance flood will overtop the lower 500 m of the right bank and lower 1.3 km of the left bank. It also comes near enough at Memorial Bridge and at Clearwater Rkm 4.2 to be considered a likely breach. The lowest point on the right bank has a crest elevation approximately equal to the 1.2-percent chance flood with no allowance for freeboard. The left bank will be just crested by a 1.9-percent chance flood. Assuming a scant 50 to 60 centimeters of freeboard, both levees will contain floods up to about 4-percent chance of exceedence. The design freeboard was 1.5 m (5 feet) above SPF. At that level, the maximum capacity has about 7-percent chance of exceedence.

23.0 TWO-DIMENSIONAL FLOW MODELING OF SNAKE AND CLEARWATER RIVERS CONFLUENCE

The original study plan for the DMMP included provision for performing a two-dimensional model analysis of sediment transport in the vicinity of the confluence of the Snake and

Clearwater Rivers. The objective of this portion of the study was to determine if a two-dimensional analysis could improve the mathematical simulation of sediment transport in this area, particularly during a major flood event such as the SPF or during a major drawdown of the Lower Granite Reservoir's pool. Difficulties had been experienced during previous attempts to calibrate one-dimensional HEC-6 sedimentation models in this particular reach of the reservoir.

Using an Acoustic Doppler Current Profiler, detailed velocity and geometric data was collected in the spring of 1998, and preliminary velocity profile maps were developed for use in calibrating the hydraulic portion of the two-dimensional sediment model. The Surface Water Modeling System software was installed in the Walla Walla District's Hydrology Branch, and a preliminary finite-element grid of the study area within Lower Granite Reservoir was developed. However, due to scheduling priorities, it became evident that the entire DMMP would be delayed by attempting to complete the two-dimensional analysis in time for its inclusion in the present study. It was also felt that the probability of significantly improving the results of the study by utilizing the two-dimensional analysis was relatively small, and that the available resources could be better utilized by focusing upon more critical areas of the study.

Even though the two-dimensional sediment transport model of the confluence area was not used in the DMMP study, it is felt that this model would serve as a valuable tool for use in understanding the complex sediment and hydraulic interactions found in this area, and that it should be completed as manpower and funding become available in the future.

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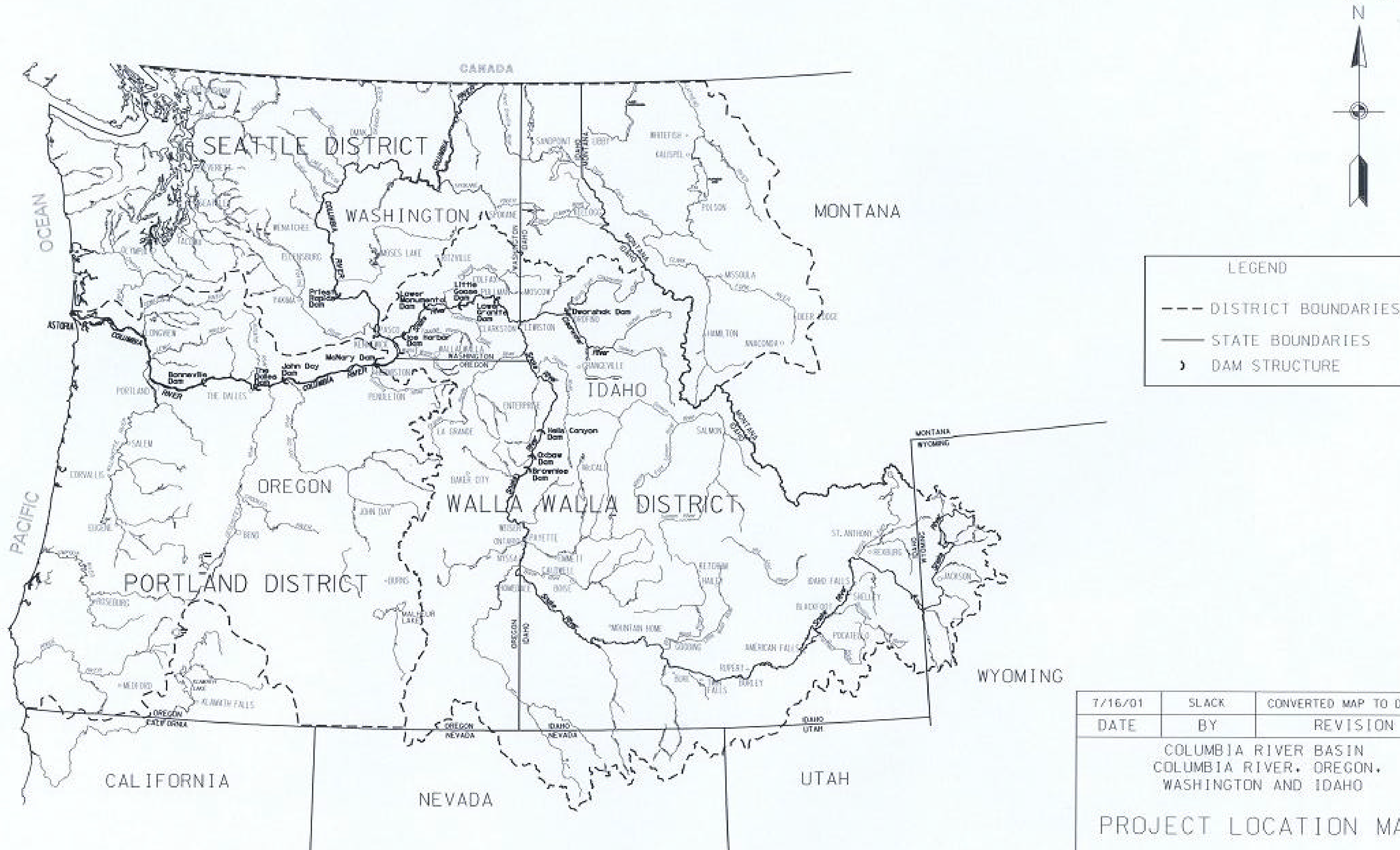
PLATES



7/16/01	SLACK	CONVERTED MAP TO DIGITAL
DATE	BY	REVISION

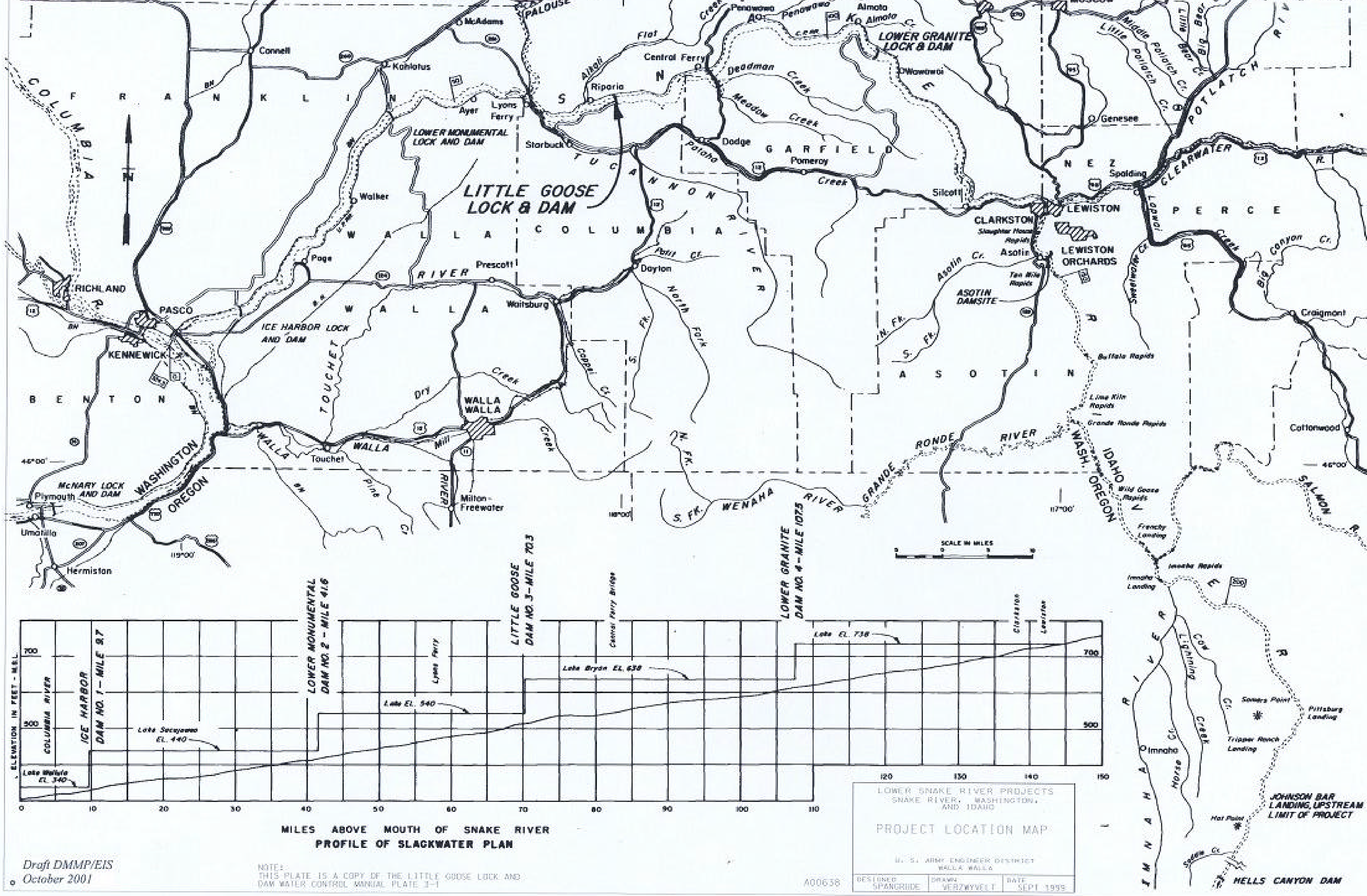
COLUMBIA RIVER BASIN
COLUMBIA RIVER, OREGON,
WASHINGTON AND IDAHO

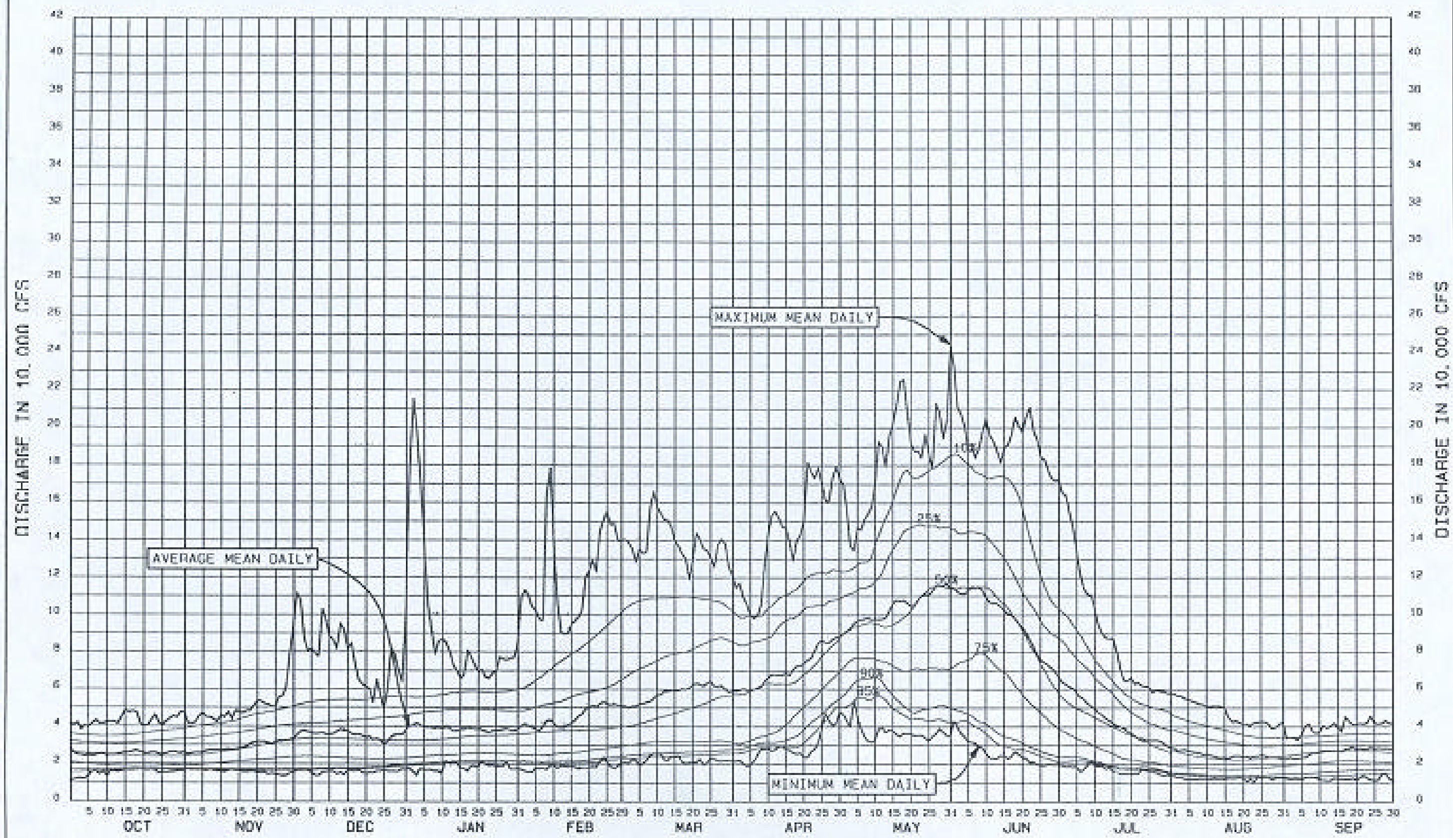
PROJECT LOCATION MAP

U.S. ARMY ENGINEER DISTRICT
WALLA WALLA - HYDROLOGY SECTION

DESIGNED	DRAWN	DATE
SPANGRUDE	VERZWYVELT	SEPT 1999

A00637


LITTLE GOOSE LOCK & DAM
LOWER GRANITE LOCK & DAM
LOWER MONUMENTAL LOCK AND DAM
ICE HARBOR LOCK AND DAM
McNARY LOCK AND DAM
ASOTIN DAMSITE
PASCO
KENNEWICK
RICHLAND
CLARKSTON
LEWISTON
LEWISTON ORCHARDS
PULLMAN
MOSCOW
WALLA WALLA
WASHINGTON
OREGON
IDAHO
HELLS CANYON DAM
JOHNSON BAR LANDING, UPSTREAM LIMIT OF PROJECT
SCALE IN MILES
MILES ABOVE MOUTH OF SNAKE RIVER
PROFILE OF SLACKWATER PLAN
ELEVATION IN FEET - M.S.L.
ICE HARBOR DAM NO. 1 - MILE 9.7
LOWER MONUMENTAL DAM NO. 2 - MILE 41.6
LITTLE GOOSE DAM NO. 3 - MILE 70.3
LOWER GRANITE DAM NO. 4 - MILE 107.5
Lake Wallula EL. 340
Lake Sacajawea EL. 440
Lake EL. 540
Lake Bryan EL. 638
Lake EL. 738
LOWER SNAKE RIVER PROJECTS
SNAKE RIVER, WASHINGTON, AND IDAHO
PROJECT LOCATION MAP
U. S. ARMY ENGINEER DISTRICT
WALLA WALLA
DESIGNED SPANGRUDE
DRAWN VERZWYVELT
DATE SEPT 1999
A00638
NOTE:
THIS PLATE IS A COPY OF THE LITTLE GOOSE LOCK AND DAM WATER CONTROL MANUAL PLATE 3-1



NOTES:

1. SUMMARY HYDROGRAPHS PLOTTED FROM CORPS OF ENGINEERS MEAN DAILY INFLOW DATA FOR LOWER GRANITE DAM.
2. PERIOD OF RECORD IS OCT 1975 THROUGH SEP 1998
3. DRAINAGE AREA IS 103,500 SQUARE MILES.
4. EXCEEDENCE LINES REPRESENT THE PERCENTAGE OF TIME THE FLOW IS EQUALLED OR EXCEEDED ON THAT PARTICULAR DAY.

SNAKE RIVER, WA

LOWER GRANITE INFLOW

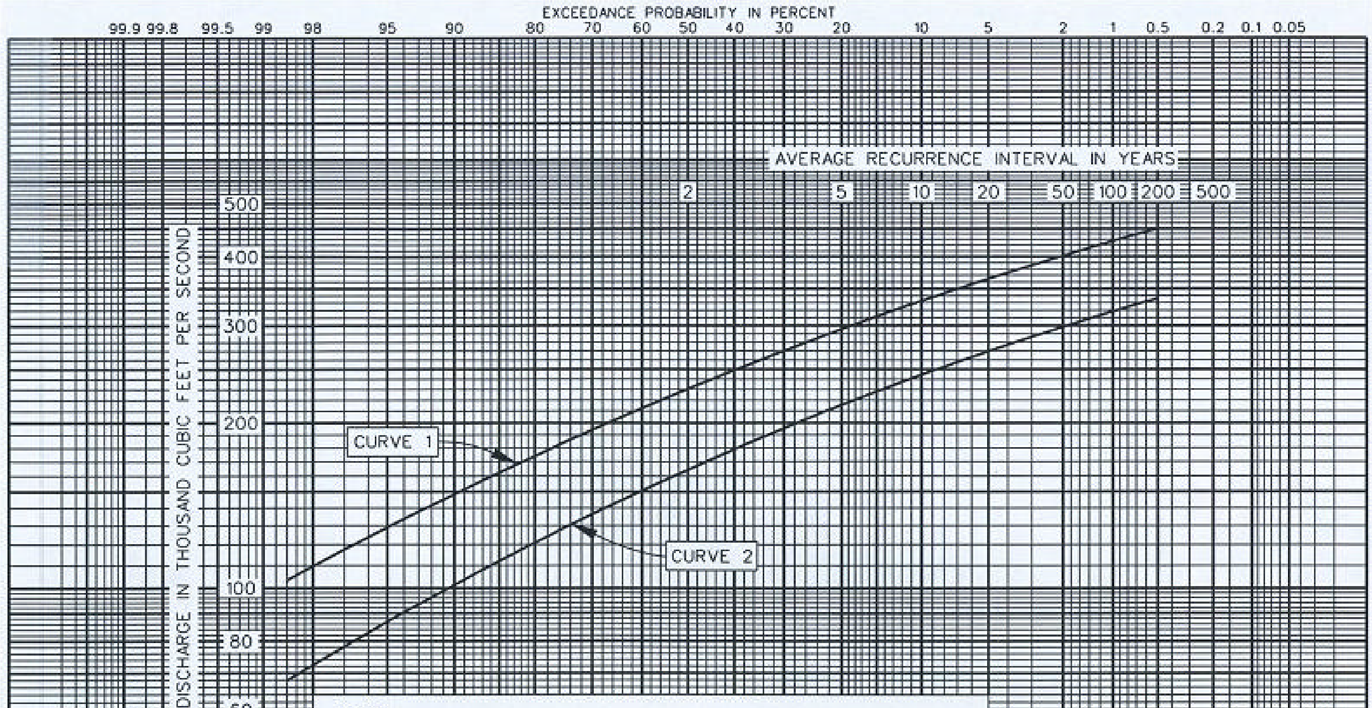
SUMMARY HYDROGRAPHS

U.S. ARMY ENGINEER DISTRICT

WALLA WALLA - HYDROLOGY BRANCH

MAXSON SEPTEMBER 1999

PLATE 3



NOTES:

1. Drainage area equals 103,200 square miles.

2. This is a preliminary graph subject to revision.

3. Curve 1 represents natural discharges and is based on the 1894-1975 station record adjusted for irrigation depletions and storage and extended by correlation with the 1858-1975 Columbia River at The Dalles station record. It includes an expected probability adjustment. The station and adopted skew is -0.5. Natural discharges for the 1894-1975 period of record are plotted based on their ranking within the extended record. The median plotting position method was utilized.

4. Curve 2 represents regulated discharges and is based on the 1975 level of storage development and the 1985 level on irrigation depletions. Regulated discharges are from regulation studies for 1894, 1929 through 1958, and in addition the regulated observed discharges for the high runoff years of 1972 and 1974. The plotting positions for the regulated event years are for the natural frequency curve. Curve 2 is a graphical fit of the regulated data.

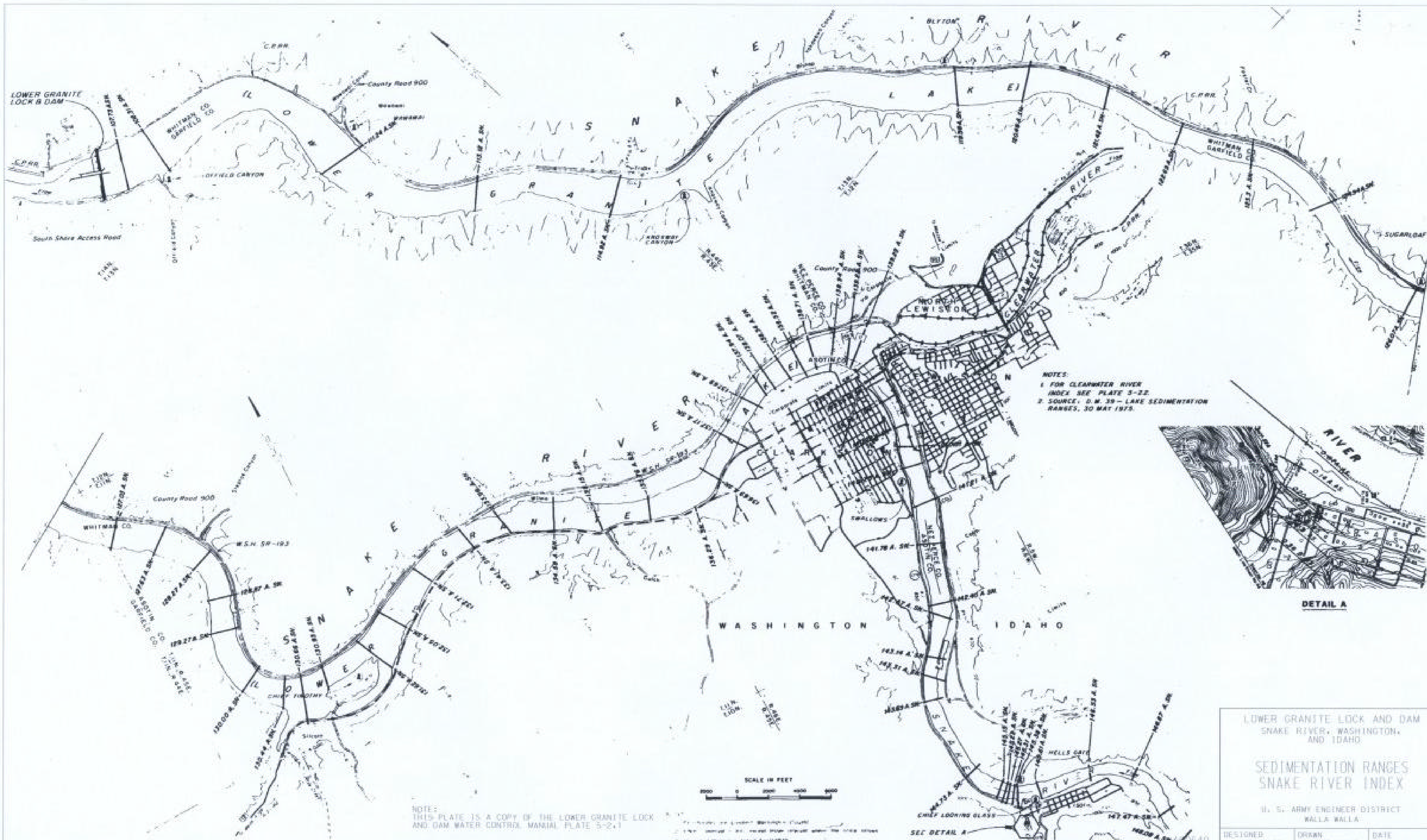
5. Curves were redrawn from copy of Plate 9-1, Water Control Manual for Lower Granite Lock and Dam, done by NPDEN-WM-HES dated May, 1978.

SNAKE RIVER BASIN
SNAKE RIVER AT LOWER GRANITE DAM

ANNUAL PEAK DISCHARGE FREQUENCY CURVES

U. S. ARMY ENGINEER DISTRICT
WALLA WALLA - HYDROLOGY BRANCH

DESIGNED	DRAWN	DATE
NPD	SCHUSTER	AUGUST 1992



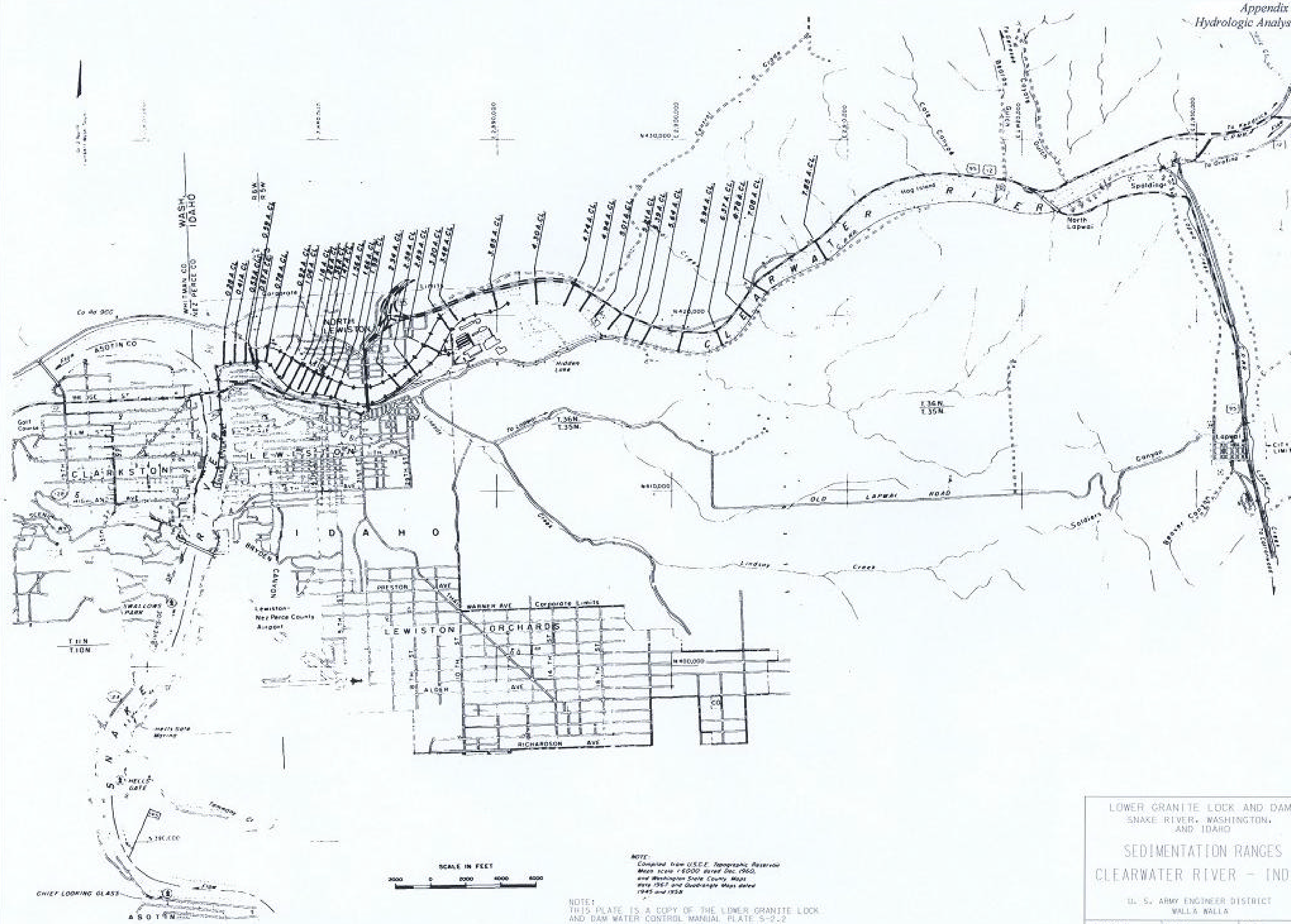
NOTE:
THIS PLATE IS A COPY OF THE LOWER GRANITE LOCK AND DAM WATER CONTROL MANUAL PLATE 5-2.1

LOWER GRANITE LOCK AND DAM
SNAKE RIVER, WASHINGTON, AND IDAHO

SEDIMENTATION RANGES
SNAKE RIVER INDEX

U. S. ARMY ENGINEER DISTRICT
WALLA WALLA

DESIGNED	DRAWN	DATE
SPANGRUDE	VERZWYVELT	SEPTEMBER 1999



NOTE:
Compiled from U.S.C.E. Topographic Reservoir Maps scale 1:6000 dated Dec. 1960, and Washington State County Maps date 1957 and Quadrangle Maps dated 1945 and 1958.

NOTE:
THIS PLATE IS A COPY OF THE LOWER GRANITE LOCK AND DAM WATER CONTROL MANUAL PLATE 5-2.2

LOWER GRANITE LOCK AND DAM
SNAKE RIVER, WASHINGTON, AND IDAHO

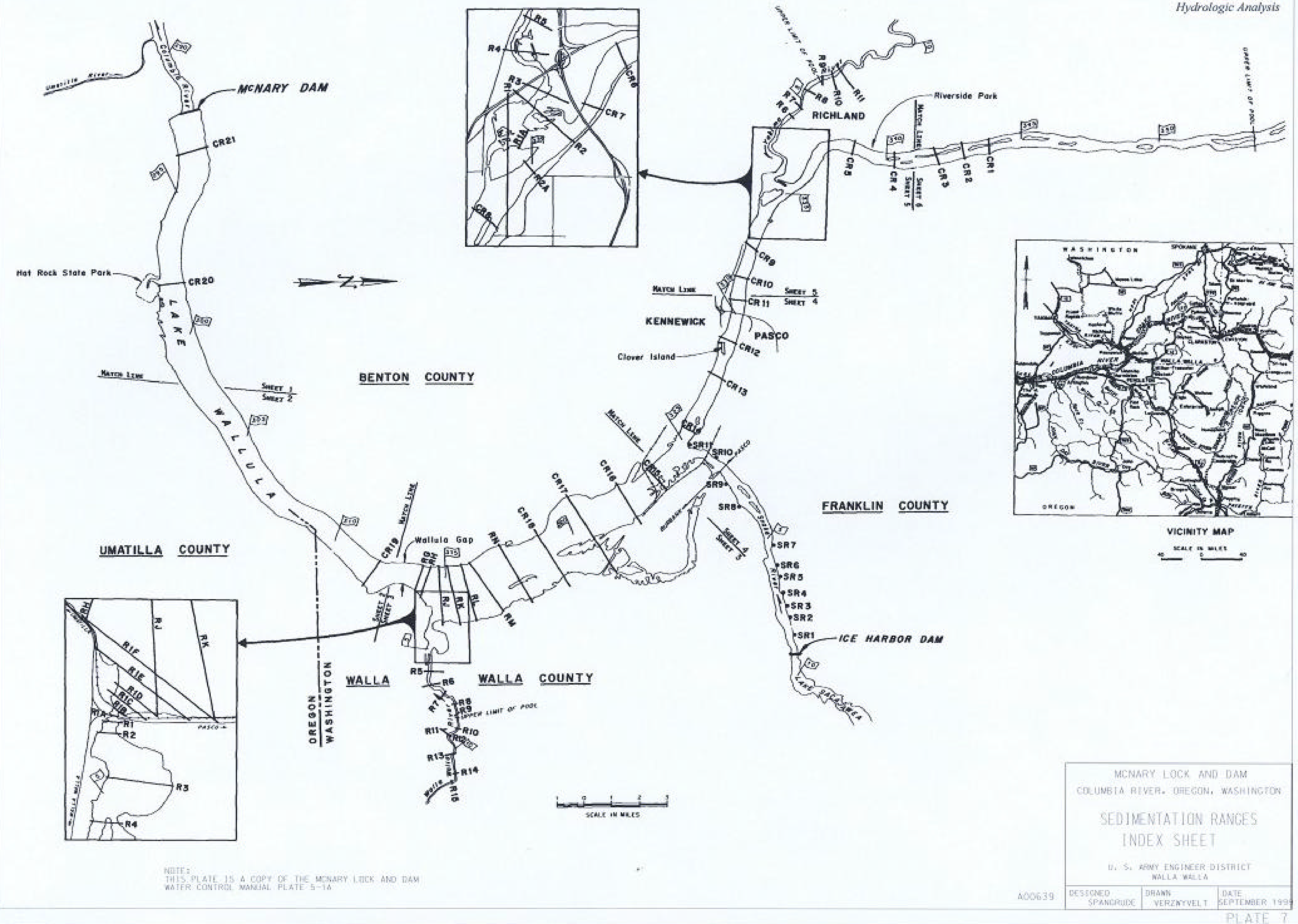
SEDIMENTATION RANGES
CLEARWATER RIVER - INDEX

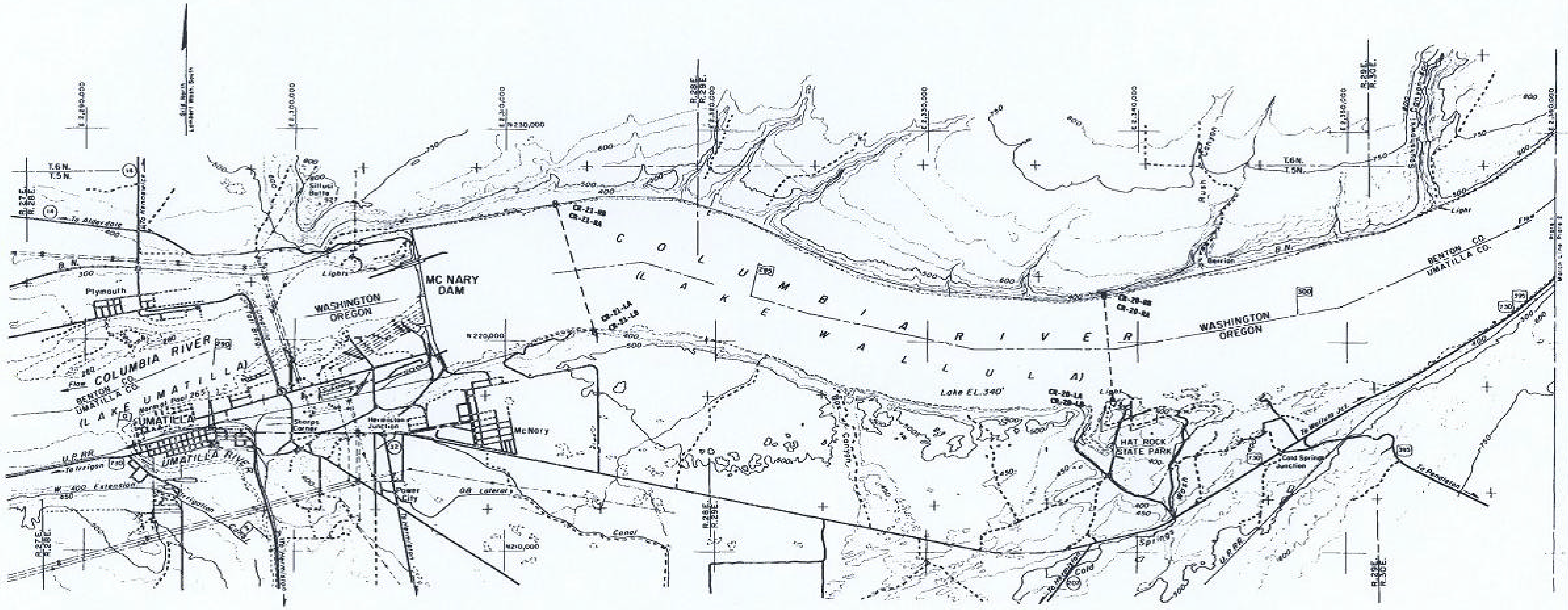
U. S. ARMY ENGINEER DISTRICT
WALLA WALLA

DESIGNED	DRAWN	DATE
SPANGRUDE	VERZWYVELT	SEPTEMBER 1999

A00641

PLATE 6


McNARY DAM
Hat Rock State Park
LAKE WALLULA
BENTON COUNTY
UMATILLA COUNTY
WALLA WALLA COUNTY
FRANKLIN COUNTY
OREGON
WASHINGTON
Wallula Gap
KENNEWICK
PASCO
RICHLAND
Clover Island
Riverside Park
ICE HARBOR DAM
UPPER LIMIT OF POOL
MATCH LINE
VICINITY MAP
SCALE IN MILES
MCNARY LOCK AND DAM
COLUMBIA RIVER, OREGON, WASHINGTON
SEDIMENTATION RANGES
INDEX SHEET
U. S. ARMY ENGINEER DISTRICT
WALLA WALLA
DESIGNED SPANGRUDE
DRAWN VERZNYVELT
DATE SEPTEMBER 1999
A00639
PLATE 7
NOTE:
THIS PLATE IS A COPY OF THE MCNARY LOCK AND DAM
WATER CONTROL MANUAL PLATE 5-1A



McNary Sedimentation Ranges

Monument Designation	River Miles	Elevation
[illegible]	[illegible]	[illegible]

NOTE:
THIS PLATE IS A COPY OF THE MCNARY LOCK AND DAM WATER CONTROL MANUAL PLATE 5-1, SHEET 1 OF 6

SCALE IN FEET
2000 0 2000 4000 6000

NOTE.
Basic Topography compiled from Quadrangle Maps 1:24,000 dated 1964 & 1962.
Contour Interval 50'.
Coordinates are Lambert Washington South.

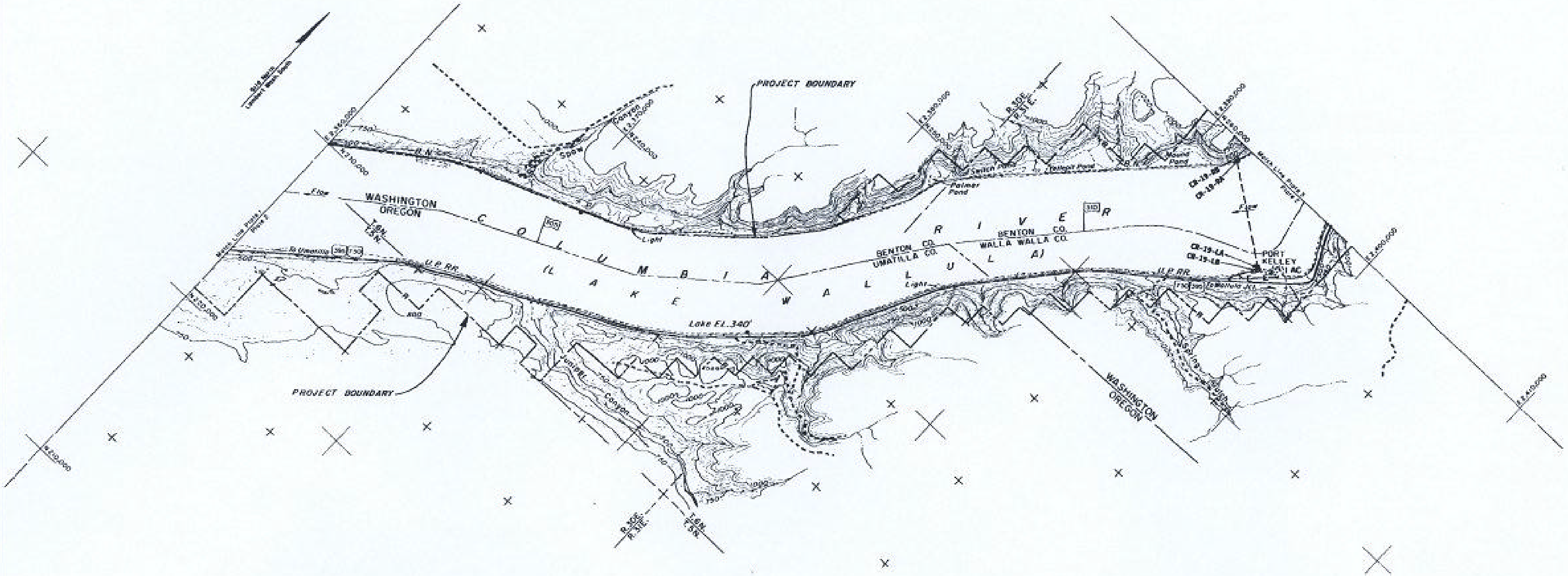
MCNARY LOCK AND DAM
COLUMBIA RIVER, OREGON, WASHINGTON

LAND USE ALLOCATION PLAN
SEDIMENTATION RANGES

U. S. ARMY ENGINEER DISTRICT
WALLA WALLA

A00631

DESIGNED	DRAWN	DATE
SPANGRUDE	VERZWYVELT	SEPTEMBER 1999



McNary Sedimentation Ranges

Monument Designation	River Miles	Elevation
CR19	311.93	341.16

SCALE IN FEET
2000 0 2000 4000 6000

NOTE:
THIS PLATE IS A COPY OF THE MCNARY LOCK AND DAM WATER CONTROL MANUAL PLATE 5-1, SHEET 2 OF 6

NOTE:
Basic Topography compiled from Quadrangle Maps 1:24,000 dated 1964 & 1962.
Contour Interval 50'.
Coordinates are Lambert Washington South.

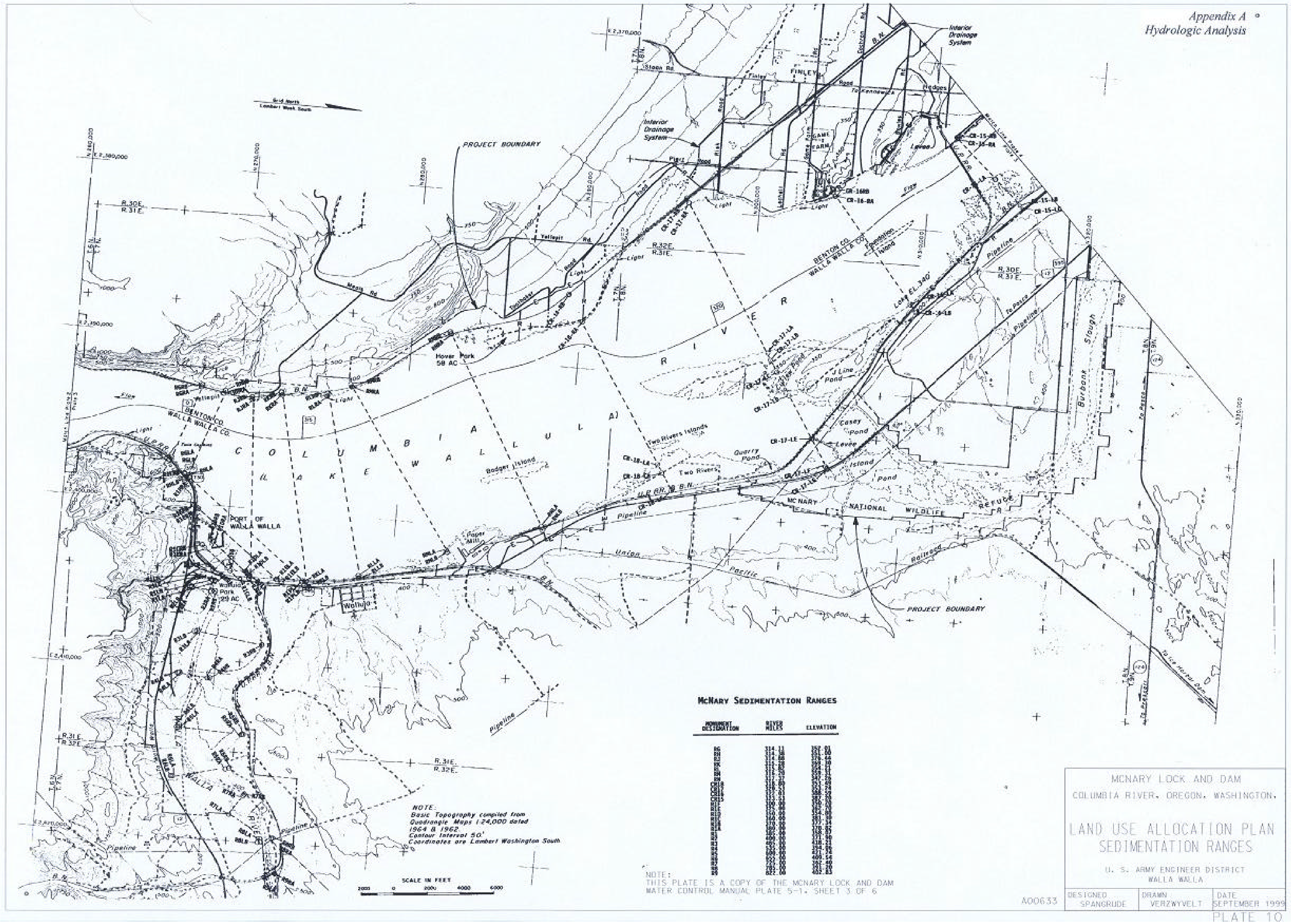
A00632

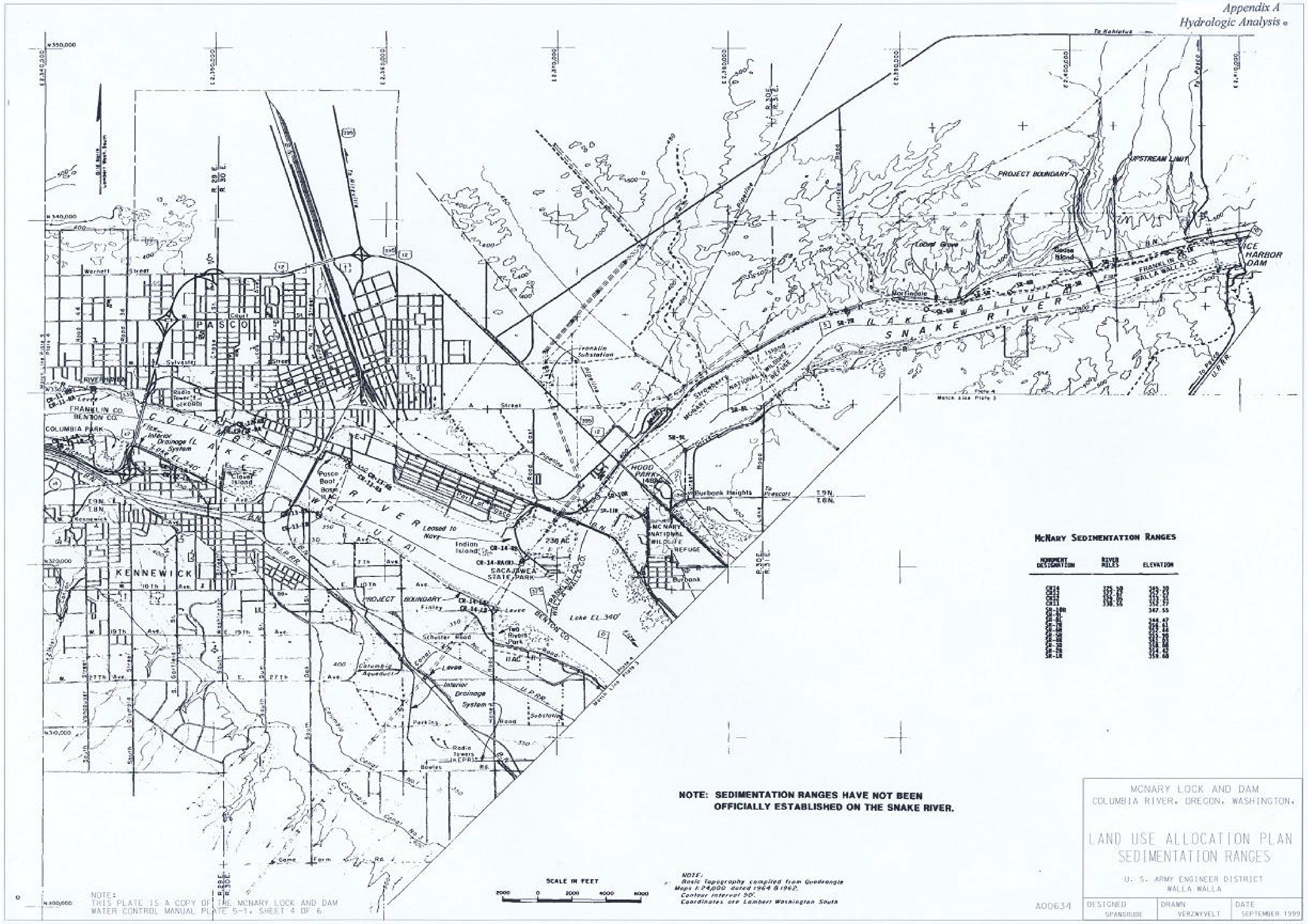
MCNARY LOCK AND DAM
COLUMBIA RIVER, OREGON, WASHINGTON

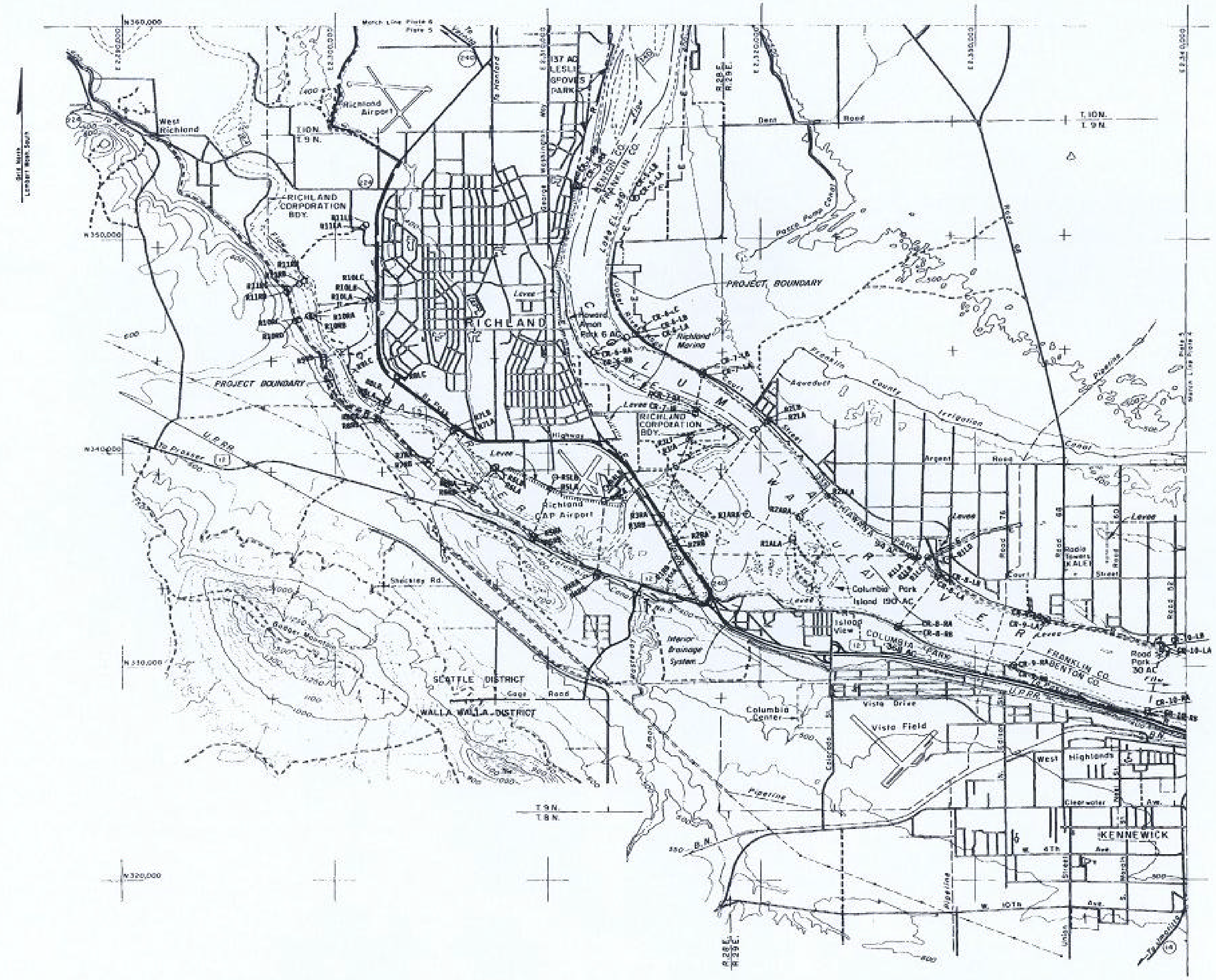
LAND USE ALLOCATION PLAN
SEDIMENTATION RANGES

U. S. ARMY ENGINEER DISTRICT
WALLA WALLA

DESIGNED	DRAWN	DATE
SPANGRUDE	VERZWYVELT	SEPTEMBER 1999


PROJECT BOUNDARY
COLUMBIA RIVER
LAKE WALLULA
Two Rivers Islands
Badger Island
Hover Park 58 AC
PORT OF WALLA WALLA
Wallula Park 29 AC
Wallula
FINLEY
GAME FARM
Burbank Slough
McNARY NATIONAL WILDLIFE REFUGE
Casey Pond
Quarry Pond
J Line Pond
Two Rivers
BENTON CO.
WALLA WALLA CO.
Union Pacific Railroad
Pipeline
Interior Drainage System
Paper Mill
WALLA WALLA RIVER
McNARY SEDIMENTATION RANGES
MONUMENT DESIGNATION
RIVER MILES
ELEVATION
NOTE:
Basic Topography compiled from Quadrangle Maps 1:24,000 dated 1964 & 1962.
Contour Interval 50'
Coordinates are Lambert Washington South
SCALE IN FEET
NOTE:
THIS PLATE IS A COPY OF THE MCNARY LOCK AND DAM WATER CONTROL MANUAL PLATE 5-1, SHEET 3 OF 6
A00633
MCNARY LOCK AND DAM
COLUMBIA RIVER, OREGON, WASHINGTON.
LAND USE ALLOCATION PLAN
SEDIMENTATION RANGES
U. S. ARMY ENGINEER DISTRICT
WALLA WALLA
DESIGNED SPANGRUDE
DRAWN VERZWYVELT
DATE SEPTEMBER 1999
PLATE 10


ICE HARBOR DAM
UPSTREAM LIMIT
PROJECT BOUNDARY
SNAKE RIVER
(LAKE WALLULA)
FRANKLIN CO.
WALLA WALLA CO.
PASCO
KENNEWICK
COLUMBIA RIVER
HOOD PARK
Burbank Heights
MC NARY NATIONAL WILDLIFE REFUGE
SACAJAWEA STATE PARK
Two Rivers Park
Lake EL.340'
McNary Sedimentation Ranges
MONUMENT DESIGNATION
RIVER MILES
ELEVATION
NOTE: SEDIMENTATION RANGES HAVE NOT BEEN OFFICIALLY ESTABLISHED ON THE SNAKE RIVER.
SCALE IN FEET
2000 0 2000 4000 6000
NOTE:
Basic topography compiled from Quadrangle Maps 1:24,000 dated 1964 & 1962.
Contour interval 50'.
Coordinates are Lambert Washington South
NOTE:
THIS PLATE IS A COPY OF THE MCNARY LOCK AND DAM WATER CONTROL MANUAL PLATE 5-1, SHEET 4 OF 6
MCNARY LOCK AND DAM
COLUMBIA RIVER, OREGON, WASHINGTON.
LAND USE ALLOCATION PLAN
SEDIMENTATION RANGES
U. S. ARMY ENGINEER DISTRICT
WALLA WALLA
A00634
DESIGNED SPANGRUDE
DRAWN VERZWYVELT
DATE SEPTEMBER 1999
PLATE 11



McNARY SEDIMENTATION RANGES

MONUMENT DESIGNATION	RIVER MILES	ELEVATION
[illegible]	[illegible]	[illegible]

NOTE:
THIS PLATE IS A COPY OF THE MCNARY LOCK AND DAM WATER CONTROL MANUAL PLATE 5-1, SHEET 5 OF 6

SCALE IN FEET
2000 0 2000 4000 6000

NOTE:
Basic topography compiled from Quadrangle Maps 1:24,000 dated 1964 & 1962.
Contour interval 50'.
Coordinates are Lambert Washington South.

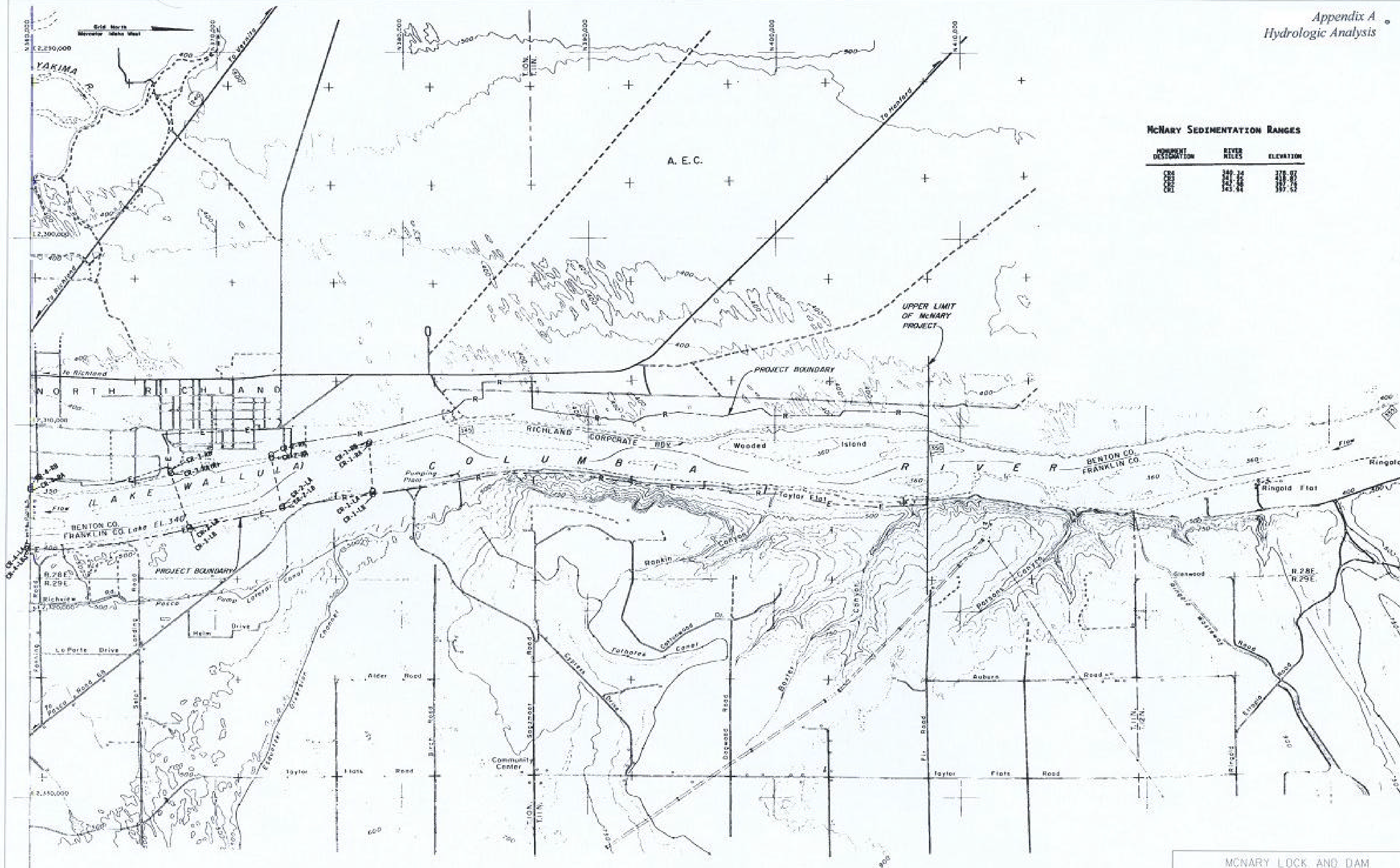
A00635

MCNARY LOCK AND DAM
COLUMBIA RIVER, OREGON, WASHINGTON.

LAND USE ALLOCATION PLAN
SEDIMENTATION RANGES

U. S. ARMY ENGINEER DISTRICT
WALLA WALLA

DESIGNED	DRAWN	DATE
SPANGRUDE	VERZWYVELT	SEPTEMBER 1999



McNary Sedimentation Ranges

Monument Designation	River Miles	Elevation
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

NOTE:
THIS PLATE IS A COPY OF THE MCNARY LOCK AND DAM WATER CONTROL MANUAL PLATE 5-1, SHEET 6 OF 6

NOTE:
Basic Topography compiled from Quadrangle Maps 1:24,000 dated 1964 & 1962.
Contour interval 50'.
Coordinates are Lambert Washington South.

MCNARY LOCK AND DAM
COLUMBIA RIVER, OREGON, WASHINGTON.

LAND USE ALLOCATION PLAN
SEDIMENTATION RANGES

U. S. ARMY ENGINEER DISTRICT
WALLA WALLA

A00636

DESIGNED	DRAWN	DATE
SPANGRUDE	VERZWYVELT	SEPTEMBER 1995

PLATE 13