US Army Corps of Engineers®

U.S. Army Corps of Engineers
Walla Walla District

Lower Snake River Programmatic Sediment Management Plan, Final Environmental Impact Statement

Appendix B - Investigation of Sediment Source and Yield, Management, and Restoration Opportunities Within the Lower Snake River Basin

August 2014

Investigation of Sediment Source and Yield, Management, and Restoration Opportunities Within the Lower Snake River Basin

Prepared by
Tetra Tech EC, Inc.

April 2006

Submitted to
Walla Walla District
U.S. Army Corps of Engineers

Delivery Order No. 7
Contract W912EF-05-D-0002

CONTENTS

TABLES

FIGURES

CHARTS

ACRONYMS

AWQMAP	Agricultural Water Quality Management Area Plan
BLM	USDI Bureau of Land Management
BMPs	Best Management Practices
BPA	Bonneville Power Administration
CCRP	Continuous Conservation Reserve Program
cfs	cubic feet per second
Corps	U.S. Army Corps of Engineers
CREP	Conservation Reserve Enhancement Program
CRITFC	Columbia River Inter-Tribal Fish Commission
CRP	Conservation Reserve Program
CWA	Clean Water Act (Federal)
EA	Environmental Assessment
EDT	Ecosystem Diagnosis and Treatment
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
EQIP	Environmental Quality Incentives Program
ESA	Endangered Species Act of 1973
Forest Service	USDA Forest Service
FOTG	NRCS Field Office Technical Guides
FSA	Food Security Act of 1985
GIS	Geographic Information System
HB	House Bill
HCC	Hells Canyon Complex
HUC	Hydrologic Unit Code
IAC	Interagency Committee
ICBEMP	Interior Columbia Basin Ecosystem Management Project
IDAPA	Idaho Administrative Procedures Act
IDEQ	Idaho Department of Environmental Quality
INFISH	Inland Native Fish Strategy (similar to PACFISH, but for non-anadromous fish)
IPC	Idaho Power Company
ISCC	Idaho Soil Conservation Commission
mg/l	milligrams per liter
MUSLE	Modified Universal Soil Loss Equation

MMBF	Million Board Feet
NAWQA	National Aquatic Water Quality Assessment
NMFS	National Marine Fisheries Service
NPPC	Northwest Power and Conservation Council (formerly Northwest Power Planning Council)
NRCS	US Natural Resource Conservation Service
NTU	Nephelometric Turbidity Unit
ODEQ	Oregon Department of Environmental Quality
OWEB	Oregon Watershed Enhancement Board
PACFISH	Decision Notice for the Interim Strategies for Managing Anadromous Fish-Producing Watersheds in Eastern Washington, Eastern Oregon, Idaho, and Portions of California to protect salmon within that habitat
PCSRF	Pacific Coastal Salmon Recovery Fund
PIBO	PACFISH/INFISH Biological Opinion
PL	Public Law
RHCAs	Riparian Habitat Conservation Areas
RM	River Mile
RMOs	Riparian Management Objectives
RMZ	Riparian Management Zones
PSMP	Programmatic Sediment Management Plan
RUSLE	Revised Universal Soil Loss Equation
SCS	USDA Soil Conservation Service
SPZ	Stream Protection Zone
SRFB	Salmon Recovery Funding Board
SWCA	NRCS Soil and Water Conservation Assistance Program
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USBWPTT	Upper Salmon Basin Watershed Project Technical Team
USDA	U.S. Department of Agriculture
USDI	U.S. Department of Interior
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USLE	Universal Soil Loss Equation
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WDOE	Washington Department of Ecology
WEPP	Water Erosion Prediction Project

WHIP	Wildlife Habitat Incentives Program
WQMP	Water Quality Management Plan
WRIA	Water Resource Inventory Area
WRP	Wetlands Reserve Program
WSU	Washington State University
WVIC	Wallowa Valley Improvement Canal
WAC	Washington Administrative Code

1. INTRODUCTION

1.1 BACKGROUND

Since construction of its first dam on the lower Snake River, the U.S. Army Corps of Engineers (Corps) has recognized that sediment management would be an ongoing maintenance issue within the reservoirs. Historically, the Corps has used dredging as the primary means of managing sediment that deposited in areas that interfere with man's use of the river. Most of these maintenance dredging actions have been conducted on a case-by-case basis without a long-term look at more effective ways of managing sediment. The Corps has now determined it would be more effective to evaluate sediment management within the lower Snake River on a watershed scale, and evaluate the potential for reducing sediment input, rather than focusing only on the reservoirs themselves. Although the Corps does not have the authority to manage land outside of the reservoir project boundaries, the Corps can identify and evaluate management strategies that could be implemented on non-Corps property.

The Corps has decided to develop a Programmatic Sediment Management Plan (PSMP) that will address sediment management within the four lower Snake River reservoirs and that portion of McNary reservoir contained within the lower Snake River. The plan will identify and evaluate ways the Corps can manage sediment within these reservoirs and examine the sediment input (sources) on a programmatic basis in the near-term, mid-term, and long-term. The intent of the PSMP is to identify ways to reduce the amount of sediment entering the reservoirs, identify how to manage the sediment once it enters the reservoirs, and identify possible changes to structures or operations to reduce maintenance and associated impacts while still providing for authorized project purposes, including navigation. The Corps intends to prepare an Environmental Impact Statement (EIS) for this plan and issued a Notice of Intent to prepare an EIS in the fall of 2005.

A variety of sediment management measures, which could be used individually or in combination, are under consideration by the Corps. Measures identified for evaluation in the Corps' Notice of Intent include:

Sediment Reduction Measures

Structural Sediment Reduction Measures

- Aquatic ecosystem restoration projects under current authorities (Section 206 Water Resources Development Act of 1996 and Section 1135 of the Water Resources Development Act of 1986)
- Shoreline vegetated filter strips
- Streambank erosion control

- Upstream sediment traps
- Improved logging road placement and design

Non-Structural Sediment Reduction Measures

- U.S. Natural Resource Conservation Service (NRCS) conservation programs
- Land use planning
- Public education
- Watershed planning
- Forest management practices
- Timber harvest planning

Sediment Management Measures

In-water systems to control sediment deposition

- Agitation to prevent settling
- Bendway weirs
- Dikes and dike fields
- Air curtains to prevent settling of material at specific locations

Sediment Removal and Management

- Agitation to re-suspend sediment
- Dredging to remove sediment
- Beneficial use of dredged material
- In-water disposal of dredged material
- Upland disposal of dredged material

System Management Measures

Modify Navigation System Infrastructure

- Relocate affected commercial navigation, recreational boating, and water intake facilities
- Build sediment retention dams upstream of Lower Granite Reservoir and/or in tributaries

Modify Reservoir Operations

- Raise pool levels to increase water depth
- Modify flows to flush sediment
- Draw down Lower Granite Reservoir to add flow conveyance capacity
- Provide flow conveyance at the confluence of the Snake and Clearwater Rivers

1.2 SCOPE AND OBJECTIVES

This report documents the first step in the effort towards evaluating management strategies on a watershed scale. Its purpose is to serve as an information base for subsequent analyses and planning efforts. It summarizes the results of an extensive investigation of available information sources related to sediment in the Lower Snake River Basin. The investigation covered generalized mapping of land ownership/stewardship responsibilities, identifying and documenting sediment management practices, identifying and documenting sediment data, and the collection and organization of geographic information system (GIS) data layers that are relevant to sediment within the basin. Specific objectives were to:

1. determine and pictorially document, through mapping, generalized land ownership/stewardship responsibilities within each basin;
2. determine and document any sediment management practices currently implemented by individual owner/steward by watershed;
3. determine and document any published or unpublished sediment data previously gathered within each watershed; and
4. collect and organize GIS data layers that have a potential effect on the contribution of sediment into the Lower Snake River and document in a summary report.

Although not part of the original objectives, the majority of the published and many unpublished documents were collected in electronic format. All electronic documents, indexes, and GIS layers were provided to the Corps on an external hard drive. Ten copies of the final report were also delivered.

1.3 STUDY AREA

The Lower Snake River Basin study area includes the Snake River Basin below Hells Canyon Dam to its confluence with the Columbia River [Hydrologic Unit Code (HUC) 1706]. The study area does not include areas upstream of Hells Canyon Dam, because the dam blocks any appreciable sediment transport from upstream areas. Also, because sediment transport from the North Fork Clearwater watershed is blocked by Dworshak Dam, this watershed is excluded from the current study area, leaving a study area of almost 33,000 square miles in size.

The study area is divided into five geographic areas. These are displayed in Figure 1 and include:

- Salmon River Subbasin
- Clearwater River Subbasin (exclusive of the North Fork Clearwater)
- Snake River Basin between Hells Canyon Dam and Clearwater River
- Grande Ronde Subbasin
- Lower Snake River Basin between Clearwater River and Mouth

Within each geographic area, information is summarized by 4th-field HUC or Cataloguing Unit. There are 26, 4th-field HUCs in the study area and they are referred to as watersheds in this report. Table 1 presents the area (in square miles), the percent of the study area, and number of 4th-field HUC watersheds in each geographic area.

Table 1. Size, Percent, and Number of 4th-Field HUC Watersheds within each Geographic Area making up the Study Area

Geographic Area	Number of 4th-Field HUC Watersheds	Area (Square Miles)	Percent of Study Area
Salmon Subbasin	10	13,994	43
Clearwater Subbasin (excluding North Fork)	6	6,907	21
Lower Snake River Basin – Hells Canyon Dam to Clearwater	3	2,104	6
Grande Ronde Subbasin	3	4,101	13
Lower Snake River Basin – Clearwater to Columbia	4	5,471	17
Total	**26**	**32,576**	**100%**

1.4 REPORT ORGANIZATION

Following this Introduction, Section 2.0 of this report provides a description of the methods used in the investigation. Section 3.0 describes the general land cover, ownership and stewardship of the basin along with a general description of sediment management practices associated with each owner type. Section 4.0 has two parts. The first part (Section 4.1) describes the overview studies on hydrologic and riparian disturbance and on erosion, mass wasting, and sedimentation, which are reported in two subsections of each geographic area discussion. The second part (Section 4.2) gives a broad overview of the sediment yield across the study area. Sections 5, 6, 7, 8, and 9 cover the five geographic areas and represent the main body of the report. As noted above, information is summarized by watershed (at the 4th-field HUC level) within each geographic area. Each of the sections is divided into five subsections. The first subsection describes “The Setting” of each geographic study area. As such, it summarizes the geography, topography, hydrology, land cover, land ownership, and land use of each geographic area. Next, is an overview of sediment trends and historic changes. These first two subsections attempt to establish the background or framework for the current situation in each geographic study area. The third subsection is called Sediment Sources and Yield, and summarizes general information on sediment production and transport issues within each watershed. The fourth subsection describes Management Practices and Restoration Projects within the geographic area and the final subsection provides preliminary highlights relative to sediment reduction opportunities within each geographic area. Section 10 presents preliminary recommendations for further study. Section 11 provides the references cited in this report.

The first three appendices (Appendices A, B, and C) also represent an important part of the documentation for this investigation. These appendices present abbreviated versions of the databases that represent the raw information and information sources identified in this investigation. Appendix A presents the References Database, Appendix B presents the GIS Layer Database, and Appendix C presents the Contact/Information Source Database.

The actual databases are in Excel spreadsheets, which accompany this report. The file names are as follows:

- References_Database_04-10-06.xls
- GIS_Layer_Database_04-10-06.xls
- Contact-Source_Database_04-10-06.xls

Appendix D presents an overview of studies on the transport and accumulation of sediment at the confluence of the Clearwater and Snake Rivers in the Lewiston-Clarkston area. Appendix E identifies the sources for information on the many dams and stream flow gauging (discharge monitoring) sites located within the three-state study area. This information will be important to consider in conducting subsequent phases of this sediment investigation.

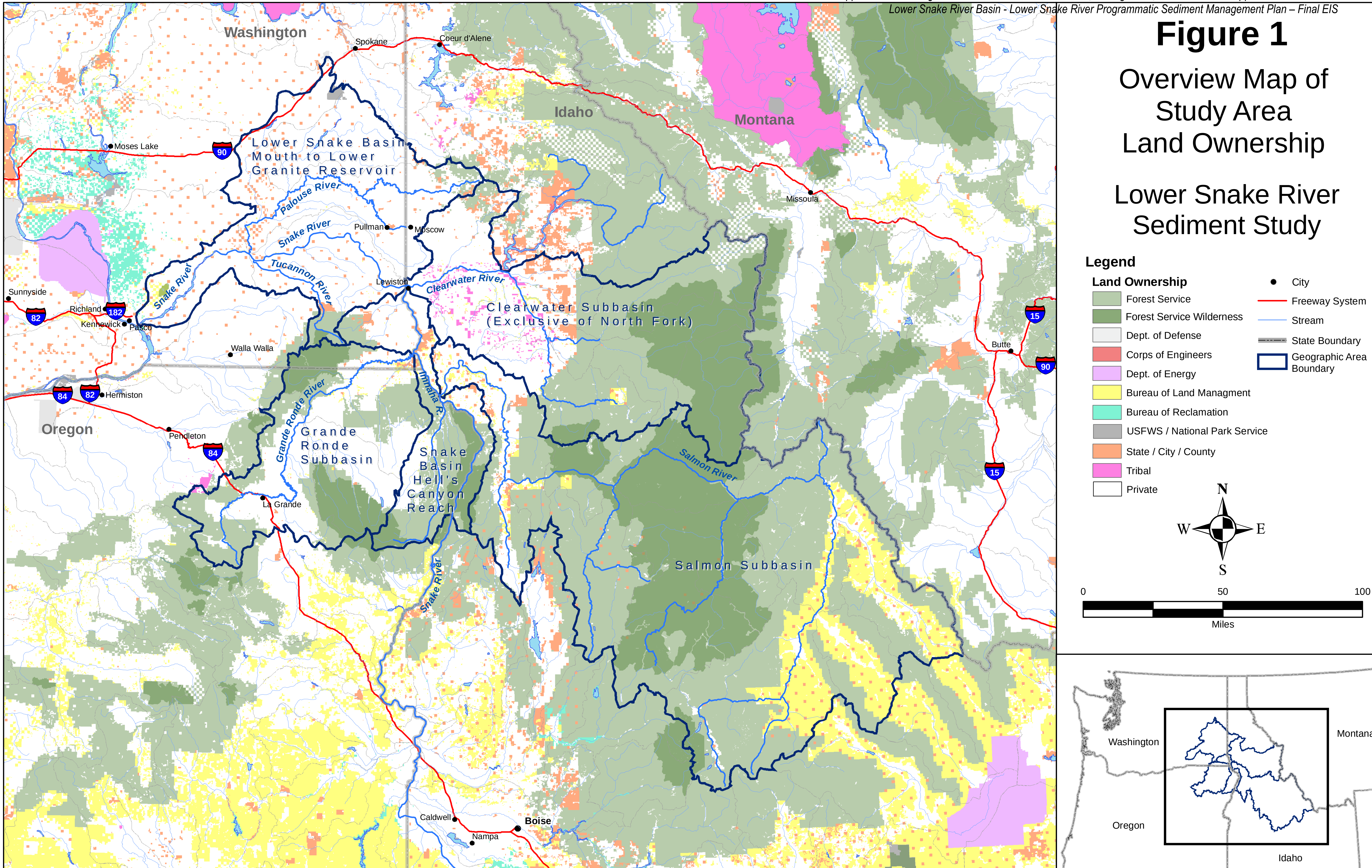


Figure 1
Overview Map of
Study Area
Land Ownership
Lower Snake River
Sediment Study
Legend
Land Ownership
Forest Service
Forest Service Wilderness
Dept. of Defense
Corps of Engineers
Dept. of Energy
Bureau of Land Managment
Bureau of Reclamation
USFWS / National Park Service
State / City / County
Tribal
Private
City
Freeway System
Stream
State Boundary
Geographic Area Boundary
N
W
E
S
0
50
100
Miles
Washington
Idaho
Montana
Oregon
Lower Snake Basin
Mouth to Lower
Granite Reservoir
Clearwater Subbasin
(Exclusive of North Fork)
Grande
Ronde
Subbasin
Snake
Basin
Hell's
Canyon
Reach
Salmon Subbasin
Palouse River
Snake River
Tucannon River
Clearwater River
Grande Ronde River
Imnaha R.
Salmon River
Spokane
Coeur d'Alene
Moses Lake
Pullman
Moscow
Lewiston
Sunnyside
Richland
Kennewick
Pasco
Walla Walla
Hermiston
Pendleton
La Grande
Missoula
Butte
Caldwell
Boise
Nampa
90
182
82
84
15
Washington
Montana
Oregon
Idaho

2. METHODS

The primary efforts of this investigation involved the identification, collection, and documentation of references and GIS layers related to sediment in the Lower Snake River Basin. The work was conducted by a number of specialists simultaneously, so it was important that efforts be documented and shared among specialists, and that consistent procedures were followed. Therefore, the first step was the development of a study plan including procedures.

The next step was to search for, identify, and collect relevant information. This search was conducted by contacting relevant agencies and other professions and searching agency and other relevant Web sites to identify and collect available information. Relevant GIS layers were sought at the same time. Lists of potential relevant sources and potential topics to search for were identified prior to initiating the searches. All electronic documents collected were stored on a hard drive. Hard copy documents were stored in project files.

All sources investigated and information collected were documented in three spreadsheet databases. These include the following:

- References Database
- GIS Layer Database
- Contact/Information Source Database

A master spreadsheet for each database was maintained on a server. Each specialist working on the project worked on their own copy of each spreadsheet, and then added the new records to the master spreadsheets at the end of each day. The master spreadsheets were regularly backed up.

References Database

The purpose of this database is to document the information that was collected, including a reference number, the lead agency or organization that published or sponsored the reference, the complete bibliographic entry, the electronic file name or Web site where the document is located, a description of the document, a description of the sediment information in the document, notes, a relevance rating for each document, the author of the entry, and the 4th-field HUCs that are covered. All relevant references were recorded in the database. As a result, the database contains more than 500 references.

Appendix A contains an abbreviated version of the database. The entire database is in an Excel file that accompanies this report (References_Database_04-10-06.xls).

GIS Layer Database

The purpose of this database is to document the information that is contained in the GIS data layers collected, including a layer number, the lead agency or organization that published or distributed the layer, the title or subject of the layer, a description of the layer, the source of the layer (individual or Web site it was obtained from), the file name(s), the metadata file name, notes, the author of the entry, and the 4th-field HUCs that are covered. Specialists collected all potentially relevant GIS layers they could identify. The database contains over 150 GIS layers.

Appendix B contains an abbreviated version of the database. The entire database is in an Excel file that accompanies this report (GIS_Layer_Database_04-10-06.xls).

Contact/Information Source Database

The purpose of this database is to document who was contacted for information and which Web sites represent sources for information. The fields include: the agency or organization; the name, position, and phone number of individuals contacted; the Web site link for Web sites that represent sources of information; the date of contact (if a personal contact), the author of the entry, notes from the conversation or describing the Web site, and other notes. The database includes over 150 contacts and/or Web sites.

Appendix C contains an abbreviated version of the database. The entire database is in an Excel file that accompanies this report (Contact-Source_Database_04-10-06.xls).

3. GENERAL LAND COVER, OWNERSHIP, AND MANAGEMENT

3.1 LAND COVER

The study area is dominated by forest cover types in the higher elevations of the southeastern two-thirds of the study area (Table 2, Chart 1, and Figure 2). Overall, forest types make up 62 percent of the study area and agricultural/urban types make up 23 percent. The Salmon, Clearwater, and Grande Ronde geographic areas have at least 70 percent in forest types, while the Lower Snake River Basin – Hells Canyon Dam to Clearwater is 47 percent in forest types, and the Lower Snake River Basin – Clearwater to Columbia is less than 10 percent in forest types. The Salmon and the Clearwater geographic areas have the greatest percentage in mid and late-seral forests.

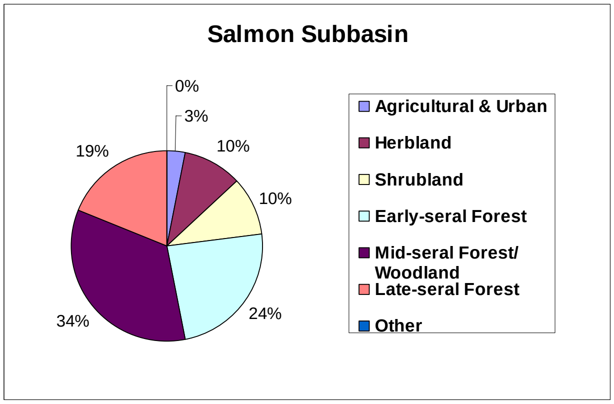
Agricultural/urban types dominate in the lower elevations of the northwestern one-third of the study area. The Lower Snake River Basin – Clearwater to Columbia has 79 percent in agricultural/urban types, while the Salmon geographic area has only 3 percent. The Clearwater, Lower Snake – Hells Canyon Dam to Clearwater, and the Grande Ronde areas are intermediate with 24, 22, and 17 percent, respectively.

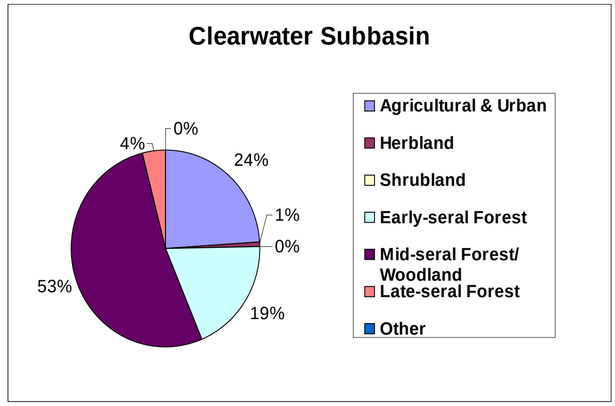
Table 2. General Land Cover by Geographic Area within the Lower Snake River Basin (percent of each geographic area and percent of total area)

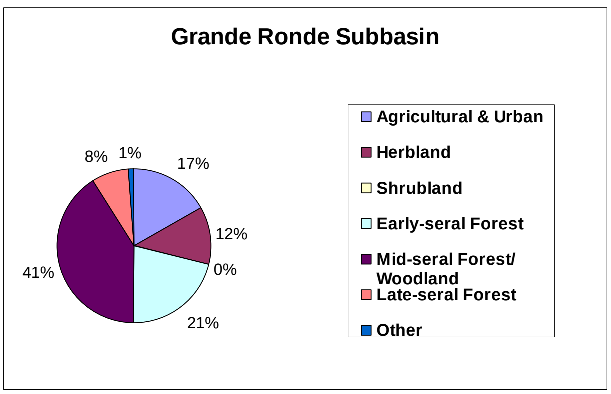
Geographic Area Name	Agricultural and Urban	Herbland	Shrubland	Early-seral Forest	Mid-seral Forest/ Woodland	Late-seral Forest	Other[1/]
Salmon Subbasin	3%	10%	10%	24%	34%	19%	0%
Clearwater Subbasin (excluding North Fork)	24%	1%	0%	19%	53%	4%	0%
Lower Snake River Basin – Hells Canyon Dam to Clearwater	22%	28%	2%	28%	13%	6%	1%
Grande Ronde Subbasin	17%	12%	0%	21%	41%	8%	1%
Lower Snake River Basin – Clearwater to Columbia	79%	4%	8%	1%	7%	0%	1%
Total Study Area	**23%**	**8%**	**6%**	**19%**	**33%**	**10%**	**1%**

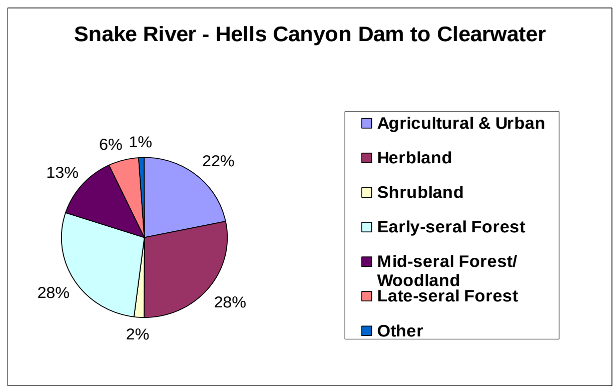
[1/] Riparian, Alpine, Water, Rock, Barren
Source: Interior Columbia Basin Ecosystem Management Project GIS layers

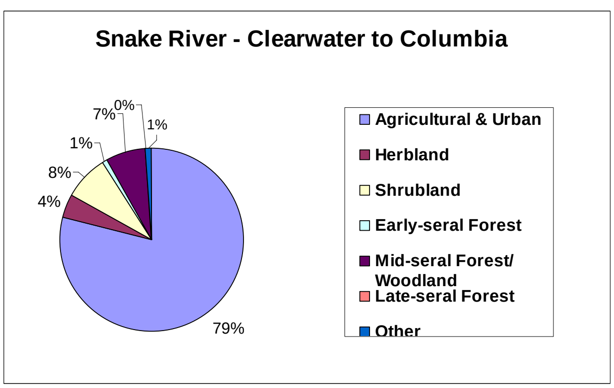
Chart 1. General Land Cover by Geographic Area within the Lower Snake River Basin (percent of each geographic area and percent of total area)

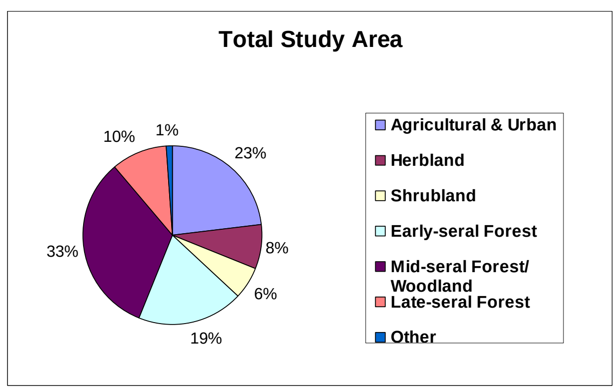












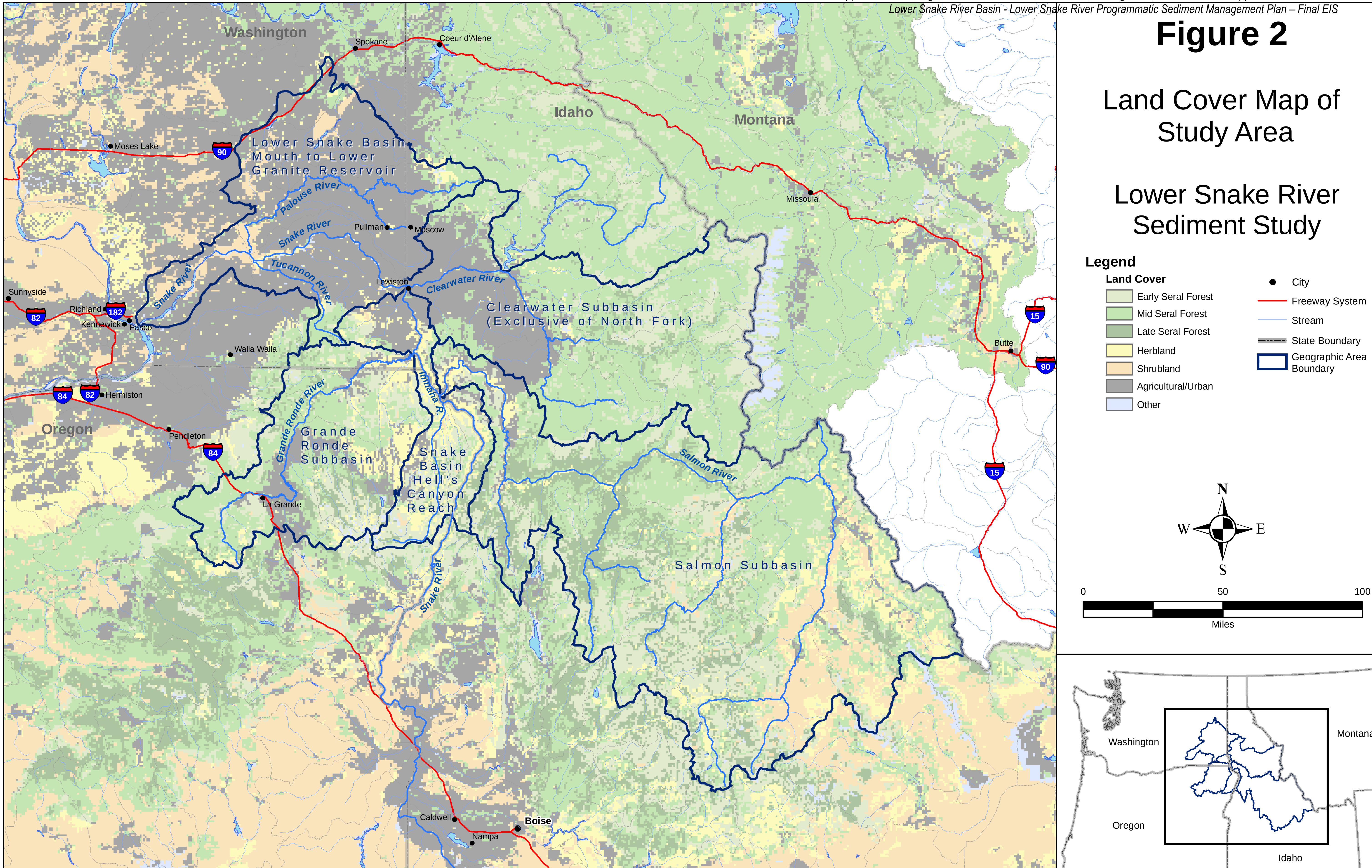


Figure 2

Land Cover Map of Study Area

Lower Snake River Sediment Study

P:\...nake_River_Sediment\maps\vegetation.mxd

3.2 LAND OWNERSHIP

The USDA Forest Service (Forest Service) manages approximately 56 percent of the lands in the study area. Combined with the USDI Bureau of Land Management (BLM), the two agencies manage over 60 percent of study area lands (Table 3, Chart 2, and Figure 1). The individual geographic areas vary considerably in the proportion of their lands managed by these Federal agencies, ranging from less than 5 percent of the Snake River Basin downstream of the Clearwater to 90 percent of the lands in the Salmon subbasin.

Of note is the large amount of land managed by the Forest Service (primarily) and BLM that is in designated wilderness within the study area (21 percent of all lands).

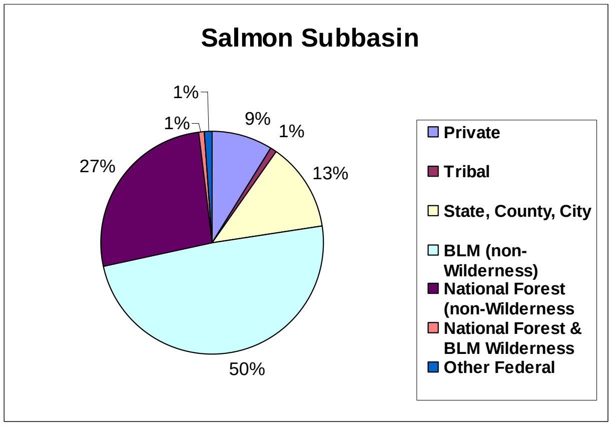
The second largest category is private ownership, which represents 35 percent of the study area, and ranges from 9 percent of the Salmon subbasin to 92 percent of the Snake River Basin downstream of the Clearwater. Minor portions of the study area are owned by the states, counties, and cities (2 percent), tribes (<1 percent), and other Federal agencies (<1 percent). The other Federal agency lands consist mostly of lands managed by the Corps and U.S. Fish and Wildlife Service (USFWS).

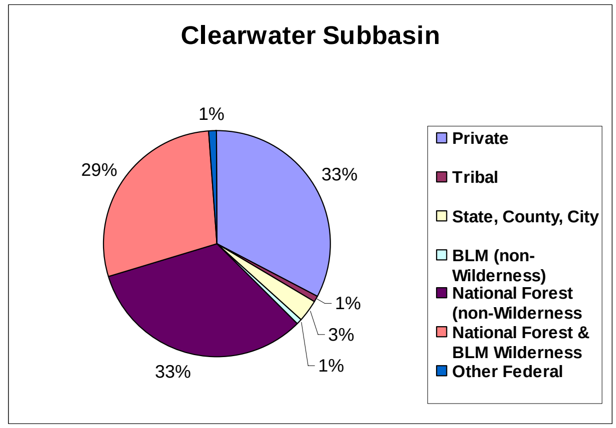
Table 3. Land Ownership by Geographic Area within the Lower Snake River Basin (percent of each geographic area and percent of total area)

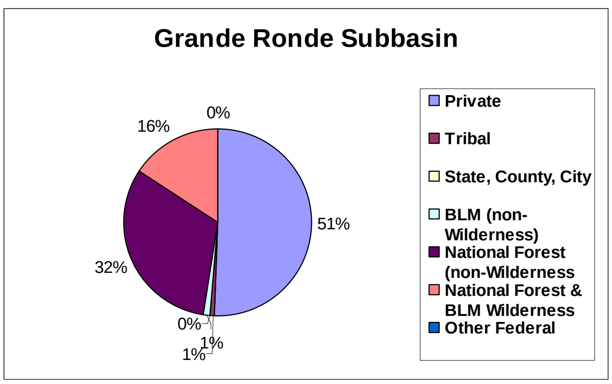
Geographic Area Name	Private	Tribal	State, County, and City	BLM (non-Wilderness)	National Forest (non-Wilderness)	National Forest and BLM Wilderness[1/]	Other Federal
Salmon Subbasin	9%	0%	1%	13%	50%	27%	<1%
Clearwater Subbasin (excluding North Fork)	33%	1%	3%	1%	33%	29%	<1%
Lower Snake River Basin – Hells Canyon Dam to Clearwater	40%	0%	3%	1%	38%	18%	0%
Grande Ronde Subbasin	51%	<1%	0%	1%	32%	16%	0%
Lower Snake River Basin – Clearwater to Columbia	92%	0%	3%	<1%	3%	1%	<1%
Total Study Area	**35%**	**<1%**	**2%**	**6%**	**35%**	**21%**	**<1%**

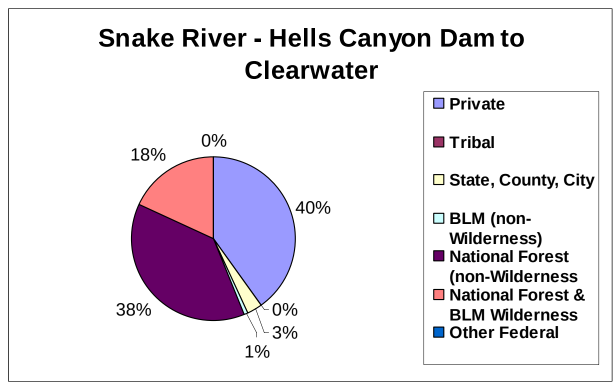
[1/] The vast majority of the wilderness acres are on National Forest System lands; only 6,000 acres (Juniper Dunes) are under BLM management in the Snake River Basin – Clearwater to Columbia geographic area.

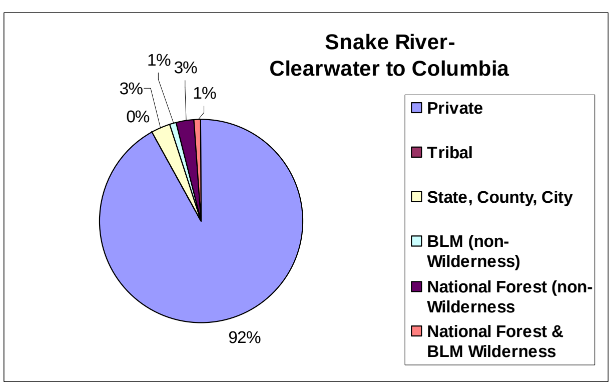
Chart 2. Land Ownership by Geographic Area within the Lower Snake River Basin (percent of each geographic area and percent of total area)

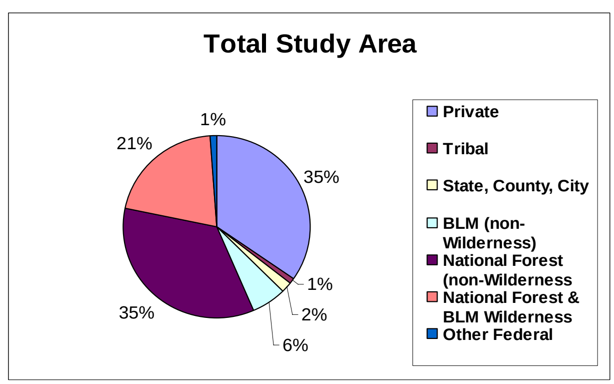












3.3 LAND MANAGEMENT

Sediment management practices within the Lower Snake River Basin vary with the landowner and the management plan they implement. This section provides a general overview of management practices related to sediment for the major Federal, state, and other landowners in the study area.

3.3.1 Federal Land Management

As noted in Section 3.1, the Forest Service and BLM are the primary Federal land managers in the study area. National Forest System lands are managed under Land and Resource Management Plans (or Forest Plans), which guide all natural resource management activities, establish Forest-wide multiple use goals and objectives, and establish standards and guidelines for National Forest management. BLM lands are managed under similar plans called Resource Management Plans.

These Federal lands can be broadly divided into those lands inside designated wilderness and those outside of wilderness. Wilderness makes up 21 percent of the study area (Table 3). However, the proportion of each geographic area made up of wilderness varies considerably, ranging from 1 percent of the Snake River Basin downstream of the Clearwater to 29 percent of the Clearwater subbasin (excluding the North Fork). Management of lands designated as wilderness is extremely restrictive. In general, wilderness is managed to maintain a natural state, within which only natural disturbance events are allowed to proceed. Therefore, human-caused ground-disturbing activities are not allowed (including sediment management or restoration activities).

About 41 percent of study area lands are managed by the Forest Service and BLM outside of wilderness. These lands are allocated to a variety of management prescriptions and are managed under a range of standards and guidelines. However, substantial consistency in riparian standards and guidelines was added to all Forest Service and BLM-managed lands in the Columbia River Basin because of plan amendments adopted in the mid-1990s. These amendments were adopted as interim management strategies with the objective of producing a consistent level of additional protection to riparian areas and improvements in water quality. They are referred to as PACFISH (USDA Forest Service and USDI BLM 1994) and INFISH (Inland Native Fish Strategy, Forest Service 1995). PACFISH guidelines are used in anadromous fish areas east of the Cascade Crest. INFISH guidelines are used for protection of habitat and populations of resident fishes outside of anadromous fish habitat. PACFISH (anadromous fish habitat) and INFISH (non-anadromous) established Riparian Goals and Riparian Management Objectives (RMOs). Riparian Goals were written to maintain or restore water quality, stream channel integrity, instream flows to support healthy habitats, natural timing and variability of the water table elevation in meadows and wetlands, diversity of plants, riparian vegetation, and appropriate habitats. The RMOs (objectives) for stream channel conditions provide criteria to measure attainment of goals of healthy, functioning watershed, riparian areas, and fish habitats. Included are objectives for habitat features such as pool frequency, water temperature, large woody debris, and bank stability, bank angle.

Riparian Habitat Conservation Areas (RHCAs) were established adjacent to all stream courses and adjacent waters to provide areas where management activities are limited in order to protect the stream habitat. RHCA widths range from 50 feet on intermittent streams to 300 feet on fish-bearing streams. Altogether, four categories of RHCAs are defined: fish-bearing streams; permanently flowing non-fish bearing streams; ponds, lakes, and wetlands greater than 1 acre; and intermittent streams, wetlands less than 1 acre, landslides, and landslide-prone areas. Project and site-specific standards and guidelines are listed in PACFISH and INFISH that apply to all RHCAs and projects and activities outside RHCAs that would degrade the riparian area. The standards and guidelines modify timber harvest, grazing, recreation and other activities. They include the following: timber harvest is prohibited with a few exceptions; new road building is to be minimized in RCHAs and roads that are already present are to be managed to reach RMOs; grazing is to be adjusted or eliminated to prevent impacts inconsistent with attaining RMOs. Deviation from the defined RHCA definitions and standards and guidelines requires project-specific consultation with the National Marine Fisheries Service (NMFS) and USFWS. The details for the goals, RMOs, RHCA definitions, and the standards and guidelines are in Appendix C under Alternative 4 of the Environmental Assessment portion of PACFISH (USDA Forest Service and USDI BLM 1995). For INFISH, the details for the RMOs and RHCAs are in Appendix E under Alternative D of the Environmental Assessment portion of INFISH (USDA Forest Service 1995).

PACFISH and INFISH provide management direction on Federal lands until the individual Forest Plans and Resource Management Plans are revised to provide the same habitat protection (USDA Forest Service and USDI BLM 1995; USDA Forest Service 1995).

In addition to riparian standards and guidelines, each Forest Plan and Resource Management Plan identifies Best Management Practices (BMPs) and other measures to follow that relate to limiting sediment delivery to streams. These practices and measures relate to timber harvest, road construction, grazing, and other potentially ground-disturbing activities.

3.3.2 State, County, and City Land Management

The study area includes substantial areas within Washington, Oregon, and Idaho. The management of state lands naturally varies by state; however, the majority of state lands in all three states are managed for fish and wildlife habitat, grazing, and/or forest management. All three states have a State Forest Practices Act, which guides logging, road-building and other activities on state forest lands. Guidelines are intended to protect fish-bearing streams and limit sediment delivery. Washington's Forest Practices Rules are the most protective. County and city lands make up a very small proportion of study area lands.

3.3.3 Tribal Land Management

The only tribe that manages a significant acreage of lands within the study area is the Nez Perce Tribe. The Tribe has a number of departments and divisions responsible for protecting, enhancing, and restoring tribal resources both on the reservation and within the Tribe's treaty territory. Reservation lands are managed for fish and wildlife, agriculture and grazing, forestry, and other activities.

3.3.4 Private Land Management

Private lands within the study area are managed for a variety of uses. The dominant uses include agriculture, grazing, and forestry. A myriad of state and local laws affect the management of private lands, but not substantially. The State Forest Practices Acts may be the most restrictive in terms of limiting activities that affect sediment on a large scale. Numerous Federal, state, and local programs assist in the conservation and restoration of private lands. These are discussed in Section 3.4

3.4 CONSERVATION AND RESTORATION PROGRAMS AND LEGISLATION

A wide variety of Federal, state, and local programs are being implemented across the study area that affect sediment and are designed to protect, conserve, or restore fish or wildlife habitats or water quality. These programs often apply to all ownerships, but participation is voluntary for private ownerships. This section presents an overview of the major programs that affect sediment. Table 4 provides an overview of the major regulations or programs that involve sediment input to streams in the study area. In addition to these, there are many other specific regulations and laws that are implemented at the state, county, and local levels. Examples would include BMPs for road construction and maintenance, zoning ordinances, shoreline management restrictions, and others.

Table 4. Major Federal, State, and Other Programs and Legislation affecting Sediment Production and Control

Regulation/Program	Administering Agency	Description/Notes
Clean Water Act (CWA) – State Water Quality Standards	Washington Department of Ecology (WDOE), Oregon Department of Environmental Quality (ODEQ), Idaho Department of Environmental Quality (IDEQ)	States establish water quality standards that define the goals and limits for all waters within their jurisdictions. In establishing water quality standards, states must take three major, interrelated actions. They must 1) designate uses; 2) establish water quality criteria; and 3) develop and implement antidegradation policies and procedures. U.S. Environmental Protection Agency (EPA) oversees the states' administration of the Clean Water Act.
Clean Water Act - Section 303(d)	WDOE, ODEQ, and IDEQ	States identify polluted water bodies and set priorities for clean up. The "impaired waters" list is referred to as the 303(d) listed streams. States must develop a watershed restoration action plan, called a Total Maximum Daily Load (TMDL) Plan, for 303(d) listed waters. After plans are developed, implementation and monitoring must begin.
Clean Water Act - Section 404	U.S. Army Corps of Engineers (Corps)	Protect aquatic life and water resources; requires a permit when locating a structure, excavating, or discharging dredged or fill material in waters of the United States.
Section 10 – Rivers and Harbors Act of 1899	Corps	Protect aquatic life and water resources; requires a permit when locating a structure, excavating, or discharging dredged or fill material in waters of the United States.
Bonneville Project Act of 1937, as amended	Bonneville Power Administration (BPA)	Has mitigation responsibility for fish and wildlife restoration under the Fish and Wildlife Program of the Northwest Power and Conservation Council (NPPC). Provides planning, regulatory compliance, and oversight for fish and wildlife mitigation efforts in the Columbia River Basin that are developed under the NPPC's Fish and Wildlife Program.
Federal Power Act of 1930, as amended	Federal Energy Regulatory Commission (FERC)	Includes multiple permits, agreements, and other requirements under the license.
Endangered Species Act of 1973, as amended (ESA)	National Marine Fisheries Service (Anadromous Fish)/U.S. Fish and Wildlife Service (Wildlife and resident fish)	Protect, mitigate, and enhance listed species from actions that may result in harm or death to the species.
Fish and Wildlife Coordination Act of 1936, as amended	National Marine Fisheries Service (Anadromous Fish)/U.S. Fish and Wildlife Service (Wildlife and Resident Fish)	Coordinate and provide consultation with lead entities on the review of proposed Federal projects and their potential effect on anadromous fish species.

Table 4 (continued). Major Federal, State, and Other Programs and Legislation Affecting Sediment Production and Control

Regulation/Program	Administering Agency	Description/Notes
Magnuson-Stevens Fishery Conservation and Management Act (Essential Fish Habitat) of 1976, as amended and re-authorized	National Marine Fisheries Service	Review and provide opinions on activities that may affect Essential Fish Habitat, as defined by the Magnuson-Stevens Act.
Multiple USDA Programs	USDA Natural Resource Conservation Service and Farm Service Agency Programs	Many different programs (often voluntary) that preserve or restore croplands, wetlands, water quality, and fish and wildlife habitats through BMPs, reserves, incentives, and funding. Includes multiple authorizations (see Table 5).
Forest Practices Act of 1971 (Oregon)	Oregon State Department of Forestry	Governs forest practices on all non-Federal lands.
Forest Practices Act of 1974 (Washington)	Washington Department of Natural Resource	Governs forest practices on all non-Federal lands.
Forest Practices Act of 1974 (Idaho)	Idaho Department of Lands	Governs forest practices on all non-Federal lands.
Multiple State and Local Programs and Permits	Multiple Agencies	Examples include: • Hydraulic Project Approval (Washington) • Shoreline Substantial Development, Conditional Use, Variance Permit or Exemption – Local Government • Local Planning Certification (Oregon) • Floodplain Management Permit and/or Critical Areas Ordinances – review by Local Government • Section 401 (Clean Water Act) Water Quality Certification – from WDOE, IDEQ, or ODEQ • Washington Aquatic Resources Use Authorization Notification (if project is on, crosses, or impacts the bedlands, tidelands, or shorelands of a navigable river)
Sovereign Nation Status	Native American Tribes – Nez Perce Tribe has the largest land-holding in the study area.	Provides management authority for lands within reservation lands.

3.4.1 Bonneville Power Administration and the Northwest Power and Conservation Council Programs

The Northwest Power and Conservation Council (NPCC) was directed by the Northwest Power Act of 1980 to develop a program – the Columbia River Basin Fish and Wildlife Program – to protect, mitigate, and enhance fish and wildlife communities and populations affected by the Federal Columbia River hydropower system. The NPCC was also directed to make annual funding recommendations to the Bonneville Power Administration (BPA) for projects to implement the program. Subbasin plans have been developed to help guide the review, selection, and funding of projects that implement the NPCC's Columbia River Basin Fish and Wildlife Program. As of 2005, all 40 subbasin plans have been approved for the Columbia River basin. The eight subbasin plans that cover the study area include the following:

- Salmon Subbasin Plan
- Clearwater Subbasin Plan
- Snake Hells Canyon Subbasin Plan
- Imnaha Subbasin Plan
- Grande Ronde Subbasin Plan
- Palouse Subbasin Plan
- Tucannon Subbasin Plan
- Lower Snake Subbasin Plan

Habitat improvement and watershed project expenditures through the program since 1982 have totaled more than $450 million for the entire Columbia River basin. These projects are varied, but many have a direct influence on sediment. Examples of these include revegetation and/or fencing of riparian areas, land purchase or easements to protect fish and wildlife habitats, and recontouring or reconstruction of stream banks and channels.

Funds are distributed to a wide variety of entities such as Federal, state, and local agencies, Native American Tribes, and others. The following Web sites provide examples of recent projects (2001 through 2004) that have received funding in the Blue Mountain Province, Columbia Plateau Province, and Mountain Snake Province:

http://www.cbfwa.org/FWProgram/Reports/FY2004/Chapter03BlueMountain.pdf

http://www.cbfwa.org/FWProgram/Reports/FY2004/Chapter07ColumbiaPlateau.pdf

http://www.cbfwa.org/FWProgram/Reports/FY2004/Chapter12MountainSnake.pdf

The 542 projects currently under review for FY2007 – 2009 funding are listed on the following Web site:

http://www.nwcouncil.org/fw/budget/2007/Default.asp

This site includes summary reports by province, province prioritization, the review guidance document, reviews by state, a mainstem/systemwide review, and a general process schedule.

3.4.2 USDA Natural Resource Conservation Service and Farm Service Agency Programs

Within the USDA, the NRCS and the Farm Service Agency oversee the implementation of conservation programs to help solve natural resource concerns on private agricultural and forestry lands (Table 5). The NRCS administers the Environmental Quality Incentives Program (EQIP), which was established in the 1996 Farm Bill and provides a voluntary conservation program for farmers and ranchers who face serious threats to soil, water, and related natural resources. The Conservation Reserve Program (CRP) and the Continuous Conservation Reserve Program (CCRP) are protection programs implemented on croplands and riparian areas, respectively. These two programs are managed by the Farm Service Agency with technical assistance provided by the NRCS. The Conservation Reserve Enhancement Program (CREP) helps to establish forested riparian buffers. The NRCS assists landowners to develop farm conservation plans and provides engineering and other support for habitat protection and restoration [Public Law (PL) 566]. Other NRCS programs include River Basin Studies, Forestry Incentive Program, Wildlife Habitat Incentives Program (WHIP), and the Wetlands Reserve Program (WRP). A summary of the major NRCS and Farm Service Agency programs that affect sediment production or related issues is provided in Table 5.

3.4.3 U.S. Environmental Protection Agency Programs

The U.S. Environmental Protection Agency (EPA) is responsible for implementing and administering the Clean Water Act (CWA), which requires enforcement of water quality standards by states. These standards are separated into point and nonpoint source water pollution, with point sources requiring permitting under the CWA. This segregation means that most farming, ranching, and forestry practices are considered nonpoint sources and thus do not require permitting by EPA. A TMDL, or total maximum daily load, is a tool for implementing water quality standards where impairment of beneficial uses exists. TMDL assessments must be completed on 303(d) listed streams. The EPA provides funding through Section 319 of the CWA for TMDL implementation projects. The Washington Department of Ecology (WDOE), Oregon Department of Environmental Quality (ODEQ), and the Idaho Department of Environmental Quality (IDEQ) administer the programs in the respective states.

Table 5. Major NRCS and Farm Service Agency Programs that Involve Sediment or Related Issues

Program	Purpose	Additional information
Conservation Reserve Program (CRP)	Remove highly erodible land from agricultural production and planting cover crops to increase wildlife habitat	Voluntary program for private landowners involving a 10-year contract and installation and annual payments
Continuous Conservation Reserve Program (CCRP)	Restore riparian habitat and improve water quality	Voluntary program for private landowners involving a 10-15 year contract and installation and annual payments
Conservation Reserve Enhancement Program (CREP)	Protect and restore agricultural land and riparian habitat by removing land from production	Voluntary program for private landowners involving a 10-15 year contract, rent, incentive and maintenance payments, and cost-sharing for installation
Wildlife Habitat Incentives Program (WHIP)	Restore and enhance fish and wildlife habitat on private lands	Voluntary program for private landowners; includes both financial and technical assistance from NRCS
Wetland Reserve Program (WRP)	Restore, create, protect, and enhance wetlands	Voluntary program for private landowners, who may participate in restoration cost-sharing or establish conservation easements on their land
Environmental Quality Incentives Program (EQIP)	Address soil, water, and related natural resource concerns on private lands in an environmentally beneficial and cost-effective manner	Voluntary program targeting farmers and ranchers; technical and financial assistance provided by NRCS, esp. for implementing land management practices such as nutrient management, pest management, and grazing land management
The Public Law 566 Small Watershed Program (PL 566)	Improve watershed conditions	Local organizations can seek funding from NRCS and other Federal, state, and local funds

Source: *Lower Snake Mainstem Subbasin Plan* (Pomeroy Conservation District 2004)

3.4.4 U.S. Army Corps of Engineers

Environmental restoration is one of the missions of the Corps. Following completion of a feasibility study and design of the project, the Corps will share 65 to 75 percent of the cost of project construction. Section 1135 of the Water Resources Development Act provides the Corps the authority to modify existing Corps projects to restore habitat. Section 206 of the Act permits the Corps to restore degraded aquatic ecosystems, regardless of the presence of a Corps project.

3.4.5 National Marine Fisheries Service

The NMFS administers the Pacific Coastal Salmon Recovery Fund (PCSRF). This fund was established in 2000 to provide grants to the states and tribes to assist state, tribal and local salmon conservation and recovery efforts. The PCSRF was requested by the governors of the states of Washington, Oregon, California and Alaska in response to listings of West Coast salmon and steelhead populations under the Endangered Species Act of 1973 (ESA). The fund supplements existing state, tribal, and local programs to foster development of Federal-state-tribal-local partnerships in salmon and steelhead recovery and conservation. Throughout the Pacific Northwest, Alaska, and California, there are hundreds of habitat restoration projects that have been funded. The following website provides further information on the PCSRF and projects funded through this organization:

http://webapps.nwfsc.noaa.gov/servlet/page?_pageid=784&_dad=portal30&_schema=PORTAL30

The PCSRF provides these funds to other organizations. Most prominent in the study area are the:

- Washington State Interagency Committee (IAC) Salmon Recovery Funding Board (SRFB) – see website:

  http://www.iac.wa.gov/maps/presentation/map.asp?ScreenWidth=1024&MapType=2a&Cmd=INIT&AreaType=County&Area=ALL

- Oregon Watershed Enhancement Board (OWEB) – see website:

  http://www.oregon.gov/OWEB/docs/pubs/BiennialReport1_2003-2005.pdf

- Idaho Office of Species Conservation – see website:

  http://osc.idaho.gov/strategic_plan.html

4. GENERAL SEDIMENT SOURCE AND YIELD INFORMATION

This section has two parts. The first part (Section 4.1) describes the studies that are reported in each geographic area discussion under two different subsections. The second part (Section 4.2) gives a broad overview of the sediment yield across the study area.

4.1 OVERVIEW STUDIES ON HYDROLOGIC AND RIPARIAN DISTURBANCE, EROSION, MASS WASTING, AND SEDIMENTATION

A number of studies have developed ratings and other results across the entire Columbia River Basin or larger areas. These studies are useful because they give perspective and permit relative comparisons to be made among geographic areas and among watersheds within geographic areas. The ratings and other results are presented for each geographic area in Sections 5 through 9 under subsections titled: *Overview of Sediment Trends and Historic Change* and *Overview Studies on Erosion, Mass Wasting, and Sedimentation*. This section presents a description of these overview studies.

ICBEMP Ratings for Overall Level of Hydrologic and Riparian Disturbance

The Interior Columbia Basin Ecosystem Management Project (ICBEMP) conducted by the Forest Service and the BLM (Quigley and Arbelbide 1997) developed many ratings for each watershed in the Columbia Basin relative to other watersheds. In the *Overview of Sediment Trends and Historic Change* subsections of Sections 5 through 9, three ratings are given for the overall level of hydrologic and riparian disturbance within each watershed. These ratings are described as follows:

- Relative Hydrologic Disturbance Rating of Forest Environments: This rating was based on four impact variables – surface mining, dams, cropland conversion, and roads. Each 6th-field HUC was assigned to an impacted or non-impacted class for each of the four impact variables and the percent of impacted 6th-field HUCs within each 4th-field HUC watershed was calculated by impact variable type. The four impact variable percent values for each watershed were then converted to cumulative frequency distributions and a generalized description of hydrologic disturbance was developed by summing all four impact variable values for forest land within each 4th-field HUC. These cumulative frequency values were converted to three hydrologic disturbance class ratings: low = 0 to 33 percent, moderate = 34 to 66 percent, and high = greater than 66 percent.

- Relative Hydrologic Disturbance Rating of Rangeland Environments: This rating is exactly the same as the one described above for forest environments, except this one covers rangeland habitats.

- Relative Riparian Disturbance Rating of Rangeland Environments: This rating was based on estimated riparian disturbance levels based on information concerning the sensitivity of streambanks to grazing and the sensitivity of stream channel function to the maintenance of riparian vegetation. In this approach, the resiliency of riparian areas to grazing was used to infer probable riparian area disturbance given the fact that many riparian areas in the Columbia Basin have experienced historically high grazing pressure which often still persists today. Accordingly, areas with low relative grazing resiliency were considered to potentially have high riparian disturbance while areas with relatively high grazing resiliency were considered to potentially have lower riparian disturbance. Cumulative frequency distributions were calculated for the combined streambank sensitivity and riparian vegetation sensitivity scores of each rangeland 6th-field HUC which were then averaged by watershed (4th-field HUC). Stratification into classes was done the same way as for the Hydrologic Disturbance Ratings described above.

ICBEMP Ratings for Soil Erosion, Mass Failure, and Sediment Hazard from Nonpoint Sources

The ICBEMP also developed various soil erosion, mass failure, and sediment hazard ratings for nonpoint sources for each watershed, relative to all Columbia Basin watersheds (Quigley and Arbelbide 1997). In the *Overview Studies on Erosion, Mass Wasting, and Sedimentation* subsections of Sections 5 through 9, seven ratings are given for each watershed. These ratings were developed following general procedures described in EPA (1980) with required modification to facilitate use of general erosion/sediment process models at broader spatial scales (Quigley and Arbelbide 1997).

In all cases, the ratings were converted to a cumulative frequency distribution percentile, which expressed the percent of other watersheds within the Columbia Basin that had the same or smaller value for the interpretation. Maps were then produced with each watershed assigned to one of four classes based on their cumulative frequency numbers as follows: low (0-25), low to moderate (26-50), moderate to high (51-75), and high (76-100). The ratings are described below:

- Surface Soil Erosion Hazard: This rating was developed using an approach similar to the EPAs Modified Universal Soil Loss Equation (MUSLE). In this model (EPA 1980), surface soil erosion in tons per acre per year was estimated based on slope/length, soil erodibility, rainfall intensity, and vegetation management (cover). The version of the model based on existing vegetation cover was used in this report.
- Earth Flow Hazard: This rating used similar parameters and approaches to those identified in surface soil erosion hazard analysis (above); however, parameter weights

were adjusted to follow suggested procedures (EPA 1980). Specific parameters used were slope, probable soil texture and permeability, and average annual precipitation.

- Debris Avalanche Hazard: This rating used similar parameters and approaches to those identified in surface soil erosion hazard analysis (above); however, parameter weights were adjusted to follow suggested procedures (EPA 1980). Specific parameters used were slope and average annual precipitation.
- Sediment Delivery Potential: This rating was calculated by: 1) overlaying the 1:100,000 scale hydrography map onto each watershed delineation and calculating drainage density, 2) calculating the average slope of each delineation with 90-meter DEM data, and 3) multiplying drainage density by the average slope of each delineation to obtain its initial sediment delivery index.
- Sediment Delivery Hazard: This rating was developed by multiplying the relative sediment delivery potential scores by the average surface soil erosion hazard value for a watershed.
- Road Erosion Hazard: This rating was calculated for each watershed based on groupings of lithology and their relative erosion rates following road construction.
- Road Sediment Delivery Hazard: This rating was developed by multiplying the relative sediment delivery potential scores by the average road erosion hazard value for a watershed.

NMFS Draft Erosion Rate Model Outputs

NMFS (Baker et al. 2005) has developed two draft models for estimating increases in erosion rates relative to historical rates in the Interior Columbia Basin, to assist in the assessment of the level of salmonid population impact from excessive fine-sediment deposition. The first model predicts change in surface erosion rates in historically non-forested areas based on slope, soil erosivity, and land use factors. The second model predicts change in erosion rates due to mass wasting and surface erosion from roads and clear cuts in currently forested areas. In historically non-forested areas, a simplified variant of the Revised Universal Soil Loss Equation (RUSLE) was developed for estimating the impact of land use on erosion rates (Renard et al. 1996). In historically forested areas, a second empirical model was developed to account for mass wasting based on a simple classification of hillslope angle and land use classification. Both models are designed to produce erosion rate indices that are estimates of how much erosion has increased over natural levels.

U.S. Geological Survey Landslide Hazard Mapping

The U.S. Geological Survey (USGS) developed a landslide overview map (Radbruch-Hall et al. 1982). This map delineates areas where large numbers of landslides have occurred and areas that are susceptible to landsliding in the conterminous United States. It was developed by evaluating the geologic map of the United States and classifying the geologic units according to high, medium, or low landslide incidence (number) and high, medium, or low susceptibility to landsliding.

NRCS Cropland Erosion Maps

A NRCS analysis of cropland for 1997 in the conterminous United States, referred to as the 1997 Natural Resources Inventory (NRCS 2000) provides a number of maps related to cropland erosion. One is called "Excessive Erosion on Cropland, 1997." This map is a dot density map showing acres where excessive erosion from wind and water is occurring on cropland. It shows the acres of highly erodible land eroding excessively and the acres of non-highly erodible land eroding excessively, in 5,000 acre units. Excessive erosion is defined as erosion greater than the tolerable rate (the maximum rate of annual soil erosion that will permit crop productivity to be sustained economically and indefinitely). Highly erodible land is defined as land where the erodibility index is greater than or equal to 8. The Universal Soil Loss Equation (USLE) is used to calculate water erosion and the Average Annual Wind Erosion Equation is used to calculate wind erosion.

4.2 OVERVIEW OF SEDIMENT DELIVERY TO THE SNAKE RESERVOIRS

The delivery of sediment to Lower Granite and the other three Lower Snake River reservoirs is an extremely complex interaction of numerous processes and physical conditions. Because of the size of the area, there is a high level of spatial and temporal variability among sources. Assembling the information in this report, including the supporting GIS product, is an important first step in developing the information and analyses necessary to evaluate the feasibility of sediment management activities in reducing the need for dredging on the Lower Snake. This section provides some general information concerning the magnitude and distribution of sediment sources based on information in the literature. An overview of the studies on transport and accumulation of sediment at the confluence of the Clearwater and Snake Rivers in the Lewiston-Clarkston area is presented in Appendix D.

The study area is divided into five geographic areas. Based on Table 1, the sediment contributing drainage area associated with each area is:

Salmon Subbasin	13,994 square miles
Clearwater Subbasin (excluding North Fork)	6,907 square miles
Lower Snake River Basin – Hells Canyon Dam to Mouth of Clearwater	2,104 square miles
Grande Ronde Subbasin	4,101 square miles
Lower Snake River Basin – Clearwater River to Mouth	5,471 square miles
TOTAL	**32,576 square miles**

These areas represent sediment "contributing" portions of the watershed. Therefore, areas upstream of major dams such as Dworshak on the North Fork of the Clearwater and Hells Canyon Dam on the Snake were excluded. The entire drainage area of the Snake River above Ice Harbor Dam is 108,800 square miles. Based on these numbers, there are 75,750 square miles of drainage area that is considered to not contribute sediment because it is trapped in large dams. The vast majority of the noncontributing area, 73,300 square miles, is on the Snake River above Hells Canyon. This area represents nearly 70 percent of the entire Snake River Basin.

Of the contributing area, the Salmon, Clearwater and Grande Ronde Rivers and the remaining portions of the Snake River below Hells Canyon Dam and above the confluence with the Clearwater, total 27,106 square miles and represent 83 percent of the sediment-contributing area.

4.2.1 USGS Studies

A study of the sediment load from this area was conducted from 1972 through 1979 by the USGS (Jones and Seitz 1980). In this study, the USGS measured both suspended and bedload on the Snake River near Anatone, Washington and on the Clearwater at Spalding, Idaho. Rating curves were developed from the measurements and daily sediment loads calculated based on application of the sediment rating curves. Table 6 provides a summary of the results of the USGS study. The Snake River near Anatone, Washington includes the Salmon, Grande Ronde and all but the lower 25 miles of the remaining Snake River drainage area between Hells Canyon Dam and the Clearwater confluence. The Clearwater gage is about 10 miles upstream of the Snake River confluence. Therefore, the sum of the sediment loads at these two gages closely represents the total sediment load delivered to Lower Granite Reservoir from the Snake River above Lewiston.

Though this is a limited period of record, some inferences about sediment delivery to Lower Granite Reservoir can be made from this information. First, the majority of the material delivered is suspended load. It comprises approximately 95 percent of the total load on the average. The Snake River delivers more sediment than the Clearwater River with an average ratio of nearly four times or 80 percent of the sediment from the Snake and 20 percent from the Clearwater. Though this ratio varies from year to year, the dominance of the Snake River is apparent in all but the extreme drought year of 1977 when both systems delivered negligible sediment (less than 3 percent of the average for the period). This also points out the high variability in the annual delivery of sediment. Looking at the four highest years of 1972, 1974, 1975 and 1976, they represent nearly 90 percent of the sediment delivered during the 9-year period, though they represent less than half the time period. The highest year, 1974, is responsible for delivering 37 percent of the sediment accounted for over the 9 years of the study, or slightly over three times the average annual load.

Table 6. Summary of Sediment Transport in Millions of Tons per Year on the Snake and Clearwater Rivers near Lewiston, Idaho

Year	Snake near Anatone, WA			Clearwater at Spalding, ID			Combined		
	Susp	Bed	Total	Susp	Bed	Total	Susp	Bed	Total
1972	2.85	0.19	3.04	0.92	0.04	0.96	3.77	0.23	4.00
1973	0.24	0.01	0.25	0.03	0.00	0.03	0.27	0.01	0.28
1974	5.29	0.23	5.52	1.28	0.05	1.33	6.57	0.28	6.85
1975	2.10	0.15	2.25	0.45	0.03	0.48	2.55	0.18	2.73
1976	2.18	0.15	2.33	0.42	0.03	0.45	2.60	0.18	2.78
1977	0.03	0.00	0.03	0.03	0.00	0.03	0.06	0.00	0.06
1978	0.97	0.09	1.06	0.26	0.01	0.27	1.23	0.10	1.33
1979	0.42	0.03	0.45	0.20	0.01	0.21	0.62	0.04	0.66
Total	14.08	0.85	14.93	3.59	0.17	3.76	17.67	1.02	18.69
Average	**1.76**	**0.11**	**1.87**	**0.45**	**0.02**	**0.47**	**2.21**	**0.13**	**2.34**

Source: Modified from Jones and Seitz (1980)

The size distribution of sediment transported was provided for both bedload and suspended load. However, no attempt was made to identify the overall breakdown of sediment sizes transported over the 9-year study period. As a general representation of sediment sizes transported, the study discusses this information for 1979. In 1979 on the Snake River, 92 percent of the suspended sediment was finer than sand (silts and clays) at the beginning of runoff and about 67 percent by the end of runoff. For the Clearwater River, 98 percent of the suspended load was finer than sand at the beginning of runoff and 37 percent by the end of runoff. The bedload transport was also highly variable in terms of size fractions, sometimes exhibiting the majority of transport in the finer sand range and at other times the majority is in the coarse gravel and small cobble range. During some periods, a bimodal distribution was observed with significant transport in both these ranges.

Sediment transport information similar to that presented in the Jones and Seitz report (1980) is not available at many other points in the system. This type of information would greatly help in identifying areas of high sediment production. Only limited numbers of discrete suspended sediment measurements are available at Anatone (see: USGS 13334300 or Anatone at http://waterdata.usgs.gov/nwis/qwdata?).

Review of current and historic USGS suspended sediment measurement station data (Hydrosphere 2005) revealed only two other stations with reported daily suspended sediment discharge measurements. (Note: The Jones and Seitz 1980 study data does not show up in the daily discharge database). The two stations within the study area are located on the Tucannon River near Starbuck, Washington (record from 1961 to 1970) and the Palouse River at Hooper, Washington (record from 1961 to 1970).

An additional nine stations with daily suspended sediment data (Hydrosphere 2005) were found within the Snake River Basin, but are outside of the study area. Six are located on the North Fork of the Teton River (record from 1977 to 1978 which was the period after failure of Teton Dam in 1976); one on Bully Creek near Vale, Oregon (record from 1958 to 1962); and one on the Powder River near Baker City, Oregon (1960 to 1961). These eight stations are all within the portion of the Snake River basin above Hells Canyon and within the non-contributing area for sediment. The ninth station is on the North Fork of the Clearwater at Ahsahka, Idaho (1966 to 1968). This station is just below Dworshak Dam and was used to monitor the North Fork prior to construction of the dam.

The average annual sediment yield from the 431 square miles of the Tucannon near Starbuck, Washington over the period of 1961 to 1970 was 0.66 million tons per year. For the period from 1962 to 1970, the average annual sediment yield from the 2,500 square mile drainage for Palouse near Hooper, Washington was 1.0 million tons per year. These values are extremely high and represent sediment yields on the same order as the entire watersheds upstream of Lower Granite Reservoir. Further investigation of the hydrology during this period needs to be conducted since the reported annual sediment yields vary by two orders of magnitude over the period of record. This high yield may be partially the result of extreme runoff years. However, the data do indicate the high sediment production potential of the Palouse farmlands.

4.2.2 USDA Soil Conservation Service Basin -Wide Studies

The USDA Soil Conservation Service (SCS), now the NRCS, has conducted studies that estimate sediment delivery throughout the basin. The study that provided an estimate for the largest portion of the basin was associated with an effort to estimate the reduction in erosion and sediment delivery from implementation of the Food Security Act of 1985[1] (FSA) above Lower Granite (Reckendorf et al. 1988; Reckendorf et al. 1989). The sediment load to Lower Granite was estimated at the time of the study as 2.9 million tons/year (Note: the report provides conflicting estimates depending on which table is used – Table 1 or Table 2. The numbers quoted in this section were taken from Table 2). The estimate was comprised of 0.9 million tons/year from the Salmon, 1.2 million tons/year from the Clearwater and 0.8 million tons/year from the Snake below the Salmon, primarily the Grande Ronde. This estimate differs from the USGS in the much higher percentage of sediment from the Clearwater in the SCS study, 20 percent in the USGS versus 41 percent in the SCS. Additionally, the total is 2.9 million tons/year as opposed to 2.3 million tons/year by the

[1] The Food Security Act of 1985, as amended in 1990 and 1996, includes several provisions for the conservation of wetlands on agricultural lands and promotes wildlife habitat and water quality. It also has provisions for highly erodible lands (i.e., commodities produced on these types of lands are ineligible for certain Federal subsidies available to farmers). In addition, the Act provides for the establishment of conservation reserves, conservation set-asides, and conservation easement programs on existing farmlands (see Table 5).

USGS. The SCS study predicted nearly a 40 percent reduction in the delivery of sediment to Lower Granite under various alternative implementation scenarios for the programs in the FSA. The study addressed sediment reduction from dryland farm areas, since these were the same areas that the FSA would address.

Reduction estimates were determined for the non-irrigated farmland. The area with the highest potential for reduction was the area tributary to the Clearwater below the North Fork confluence (Middle Fork, South Fork, and Clearwater watersheds), with a reduction of 0.9 million tons per year from a 1.2 million tons per year level. The vast majority of this estimated reduction was in the Clearwater watershed. The next highest reduction was on Asotin Creek with sediment delivery dropping from 0.20 million tons per year to 0.04 million tons per year. A significant reduction in sediment delivery was also predicted for the Grande Ronde (Upper and Lower Grande Ronde and the Wallowa watersheds) with a decline in annual sediment delivery from 0.17 million tons per year to 0.04 million tons per year.

4.2.3 Preliminary Summary Observations

Based on the limited review of the sediment transport data and sediment yield estimates that cover the entire or most of the basin, several important observations have been made. First, there is limited “hard” sediment transport data to determine sediment yields from small or medium-scale areas within the basin. The Jones and Seitz (1980) study covers the majority of the sediment contributing area above Lower Granite. There are also some data available to directly characterize the sediment yield from the Palouse and Tucannon Rivers. These data show that these two relatively small portions of the watershed (about 10 percent) may contribute on the same order of sediment as the combined portions of the Clearwater and Snake above the USGS gages in the 1980 study.

The SCS studies (Reckendorf et al. 1989, Reckendorf et al. 1989) of the sediment yield to the Snake River tend to substantiate this characteristic of the watershed since it showed very high sediment yields from the dryland farm areas on the Palouse. Based on this preliminary assessment, the main area to target for sediment reduction may be the agricultural areas. The SCS study indicated that participation in the 1985 FSA by farmers in this region could reduce sediment yield to the Lower Snake River reservoirs by nearly 40 percent. However, it should be noted that 20 years have passed since the 1985 Food Security Act, so it is possible that many of the reductions its implementation may have already been realized. It could be of very high value in evaluating strategies for reduction of sediment yield to collect current data to determine if there has been a substantial reduction in sediment yield, as well as evaluate to the level that the various programs in the 1985 FSA have been implemented.

In general, recent data on major sediment sources and yields in the Snake River basin are limited. Coupled with this limited amount of information is the rapid expansion of habitat restoration (e.g., riparian plantings, stream stabilization), BMPs for agriculture and forestry, more stringent water quality requirements, and other activities that would tend to reduce sediment input to streams.

A number of data gaps would need to be filled in order to fully determine sediment sources and yields in the study area. These data would need to be recent and extended over a number of years to identify changes in sediment input that occur due to management activities (e.g., habitat restoration, changes in forestry and agriculture practices, or implementation of BMPs) and large-scale natural events (e.g., major floods or landslides). Coupled with this need for additional data is the need to identify very specific locations (either point or non-point sources), the amount and types (e.g., size, shape, type of material) of sediment being input, and transport times. All of these data gaps imply more detailed analysis is needed (e.g., field, laboratory, and office evaluations) to more firmly identify alternatives for reducing sediment transport to the Lower Granite and the other lower Snake reservoirs. Some of this information about specific sites might be developed through an intensive review of watershed and subbasin plans that address specific characteristics of stream reaches.

5. SALMON RIVER SUBBASIN

5.1 THE SETTING

5.1.1 Geography and Topography

The Salmon River subbasin covers approximately 13,984 square miles or almost 17 percent of the land of Idaho (Figure 3). It consists of 10 major watersheds with approximately 1,900 named streams. Table 7 shows the size of each of the watersheds (unique cataloguing units or 4th-field HUCs). Most of the subbasin is a mosaic of mountains and deeply cut valleys. Elevation within the subbasin ranges from 12,661 feet at the summit of Mount Borah down to 684 feet at the mouth of the Salmon River. The southeastern portion of the subbasin includes the high alpine of the Lost River and Lemhi ranges and the western portion encompasses the northern Seven Devils Mountains and the southern fringe of the Palouse Prairie region (NPCC 2004).

Key geologic features within the subbasin are the Idaho Batholith, Challis volcanics, and the Quaternary alluvial deposits of the Pahsimeroi and Lemhi valleys. Soils derived from these parent materials are typically highly erodible. Stream erosion has played the predominant role in shaping the physical features, creating relatively narrow, V-shaped valleys and steep valley side slopes. Large-scale, glacially derived features have contributed areas with broad U-shaped valleys and more localized glacial evidence (pothole lakes and cirques in the upper areas) at higher elevation features. The eastern Upper Salmon, Pahsimeroi, and Lemhi watersheds are an exception to this description. In the sub-parallel block fault ridges of the Lost River and Lemhi ranges give rise to high mountain peaks above broad, gentle valleys. The combination of the erodible soils, steep topography, and climatic stresses gives rise to significant base surface erosion, slumping, and debris avalanche hazards (NPCC 2004).

5.1.2 Hydrology

The western portion of the Salmon subbasin is Pacific maritime-influenced with most precipitation occurring as snow during the mild or cool winters and early springs. The easternmost portion of the subbasin (primarily the Lemhi, Pahsimeroi, and Upper Salmon) has typically one-half the precipitation of that received in the west of the subbasin due to the rain shadow effect of the mountains. The winters in the east are relatively dry and precipitation frequently occurs in the early summer. During winter, extended durations of cold can cause water bodies to freeze with the potential of flooding or severe bank damage as the ice breaks from the banks. Diverse snowmelt patterns may cause significant runoff events. Additionally, rain on snow events can occur in the spring and contribute to increased stream flow (NPCC 2004).

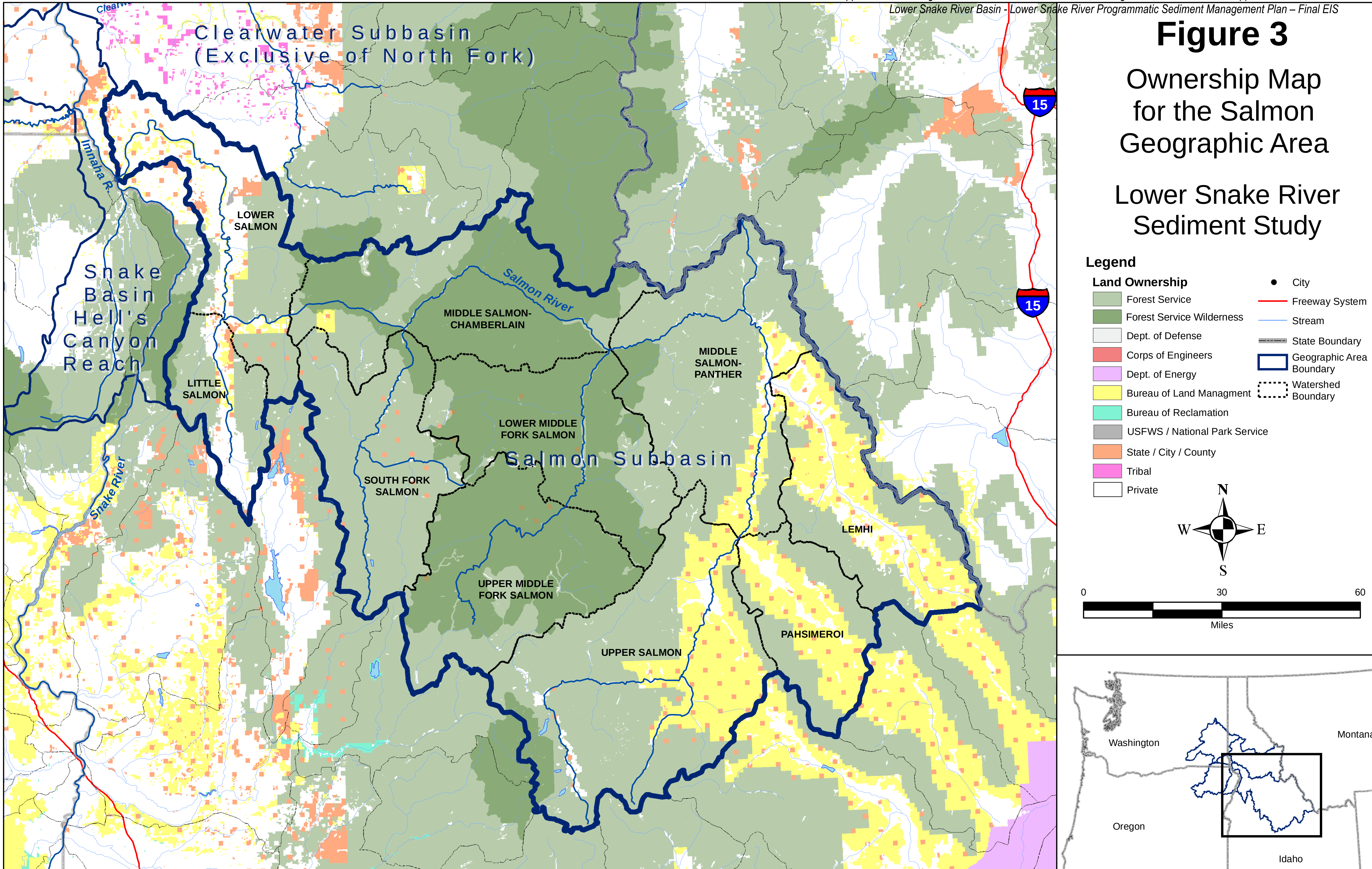


Figure 3
Ownership Map for the Salmon Geographic Area
Lower Snake River Sediment Study
Legend
Land Ownership
Forest Service
Forest Service Wilderness
Dept. of Defense
Corps of Engineers
Dept. of Energy
Bureau of Land Managment
Bureau of Reclamation
USFWS / National Park Service
State / City / County
Tribal
Private
City
Freeway System
Stream
State Boundary
Geographic Area Boundary
Watershed Boundary
N
W
E
S
0
30
60
Miles
Clearwater Subbasin (Exclusive of North Fork)
Snake Basin Hell's Canyon Reach
Salmon Subbasin
Salmon River
Snake River
Imnaha R.
LOWER SALMON
LITTLE SALMON
MIDDLE SALMON-CHAMBERLAIN
MIDDLE SALMON-PANTHER
LOWER MIDDLE FORK SALMON
SOUTH FORK SALMON
UPPER MIDDLE FORK SALMON
UPPER SALMON
LEMHI
PAHSIMEROI
15
Caldwell
Washington
Montana
Oregon
Idaho

Table 7. Size and Cataloging Unit Number for Watersheds within the Salmon Subbasin

Watershed Name	Cataloging Unit Number	Area (Square Miles)	Percent of Study Area
Upper Salmon	17060201	2,429	17%
Pahsimeroi	17060202	841	6%
Middle Salmon-Panther	17060203	1,809	13%
Lemhi	17060204	1,249	9%
Upper Middle Fork Salmon	17060205	1,501	11%
Lower Middle Fork Salmon	17060206	1,378	10%
Middle Salmon-Chamberlain	17060207	1,689	12%
South Fork Salmon	17060208	1,311	9%
Lower Salmon	17060209	1,208	9%
Little Salmon	17060210	579	4%
Total Subbasin		**13,994**	**100%**

Source: Interior Columbia Basin Ecosystem Management Project GIS layers

The Salmon River flows 410 miles north and west through central Idaho, from its headwaters in Beaverhead, Salmon River, Lemhi, Lost River, Sawtooth, and smaller mountain ranges to its confluence with the Snake River in lower Hells Canyon. The Salmon River derives its flow from several primary tributaries including the Lemhi, Pahsimeroi, Middle Fork Salmon, South Fork Salmon, and Little Salmon Rivers. Records indicate that peak flows generally occur in May and June from snowmelt.

There are places in the basin with unique hydrologic factors that affects sediments in the streams. The Pahsimeroi and Lemhi watersheds contain few tributaries that contribute significant surface water to the mainstems and then primarily during high water years. Irrigation diversions combined with large natural percolation losses as the streams flow through alluvial deposits prevent the tributaries from contributing significant water flow. Most tributaries move underground while crossing alluvial deposits and appear as many springs as they move to the mainstems. The mainstem Pahsimeroi also flows beneath the surface for a five-mile section in the lower watershed. The result is that activity on the Federal lands in the upper watershed areas has little effect on the lower river water quality.

The waters percolate through the gravels during subsurface flow and thus, sedimentation problems are minimized [Idaho Soil Conservation Commission (ISCC) 1995].

In the mainstem Salmon in the Middle Salmon-Panther watershed, flooding of the Salmon River occurs frequently in the Deadwater area (approximately 4,000 feet long) between the North Fork Salmon River and Dump Creek. At the end of the Deadwater area, Dump Creek has created a large alluvial fan that pinches the Salmon River against the opposite bank. The fan at Dump Creek has been exacerbated in the last 100 years due to mining and logging, but existed before the area was settled. The Deadwater area resembles a long, narrow lake with slow currents and a flat bottom that freezes over completely in most winters and may include ice jams.

5.1.3 Land Cover

Forest (dry ponderosa pine/Douglas fir and mesic mixed conifer) occupies the greatest amount of area in the subbasin (70 percent or higher of cover in all but the Lemhi, Pahsimeroi, Upper Salmon and Lower Salmon watersheds). In the eastern watersheds – the Lemhi, Pahsimeroi, and Upper Salmon – shrub and grassland habitats are important, ranging from about 39 to 49 percent of cover. The Lower Salmon watershed has the greatest percentage of agricultural and urban types. Riparian and herbaceous wetlands are scarce, but distributed in all the watersheds and concentrated along the streams. The greatest density of wetlands is in the Lower Salmon and western portion of the Middle Salmon-Chamberlain watersheds. Table 8 shows general vegetation by watershed in the Salmon subbasin.

5.1.4 Land Ownership

National Forest System lands account for approximately 77 percent and BLM accounts for 13 percent of the total Salmon subbasin, leaving only 9 percent of the land as private (Table 9). The National Forest is concentrated in the middle portion and the BLM is primarily concentrated in the upper (eastern) portion of the watershed. Four of the central watersheds (South Fork Salmon, Middle Salmon-Chamberlain, Lower and Upper Middle Forks) are 99 percent National Forest. Three of those watersheds are almost entirely protected wilderness and the fourth, South Fork Salmon, has large roadless and unroaded areas. Two stream segments are federally designated as Wild, Scenic or Recreational Rivers: 125 miles of the Salmon River (from the mouth of the North fork Salmon to Long Tom Bar) and the entire Middle Fork Salmon (104 miles). Additionally, the larger water bodies within the South Fork Salmon subwatershed (e.g., South Fork Salmon, East Fork of the South Fork Salmon, Johnson Creek, and the Secesh River) are designated as Special Resource Waters by Idaho State. Special Resource Waters are specific segments or bodies of water recognized as “needing intensive protection to preserve outstanding or unique characteristics or to maintain current beneficial uses” [Idaho State Regulations: Idaho Administrative Procedures Act (IDAPA) 58.01.02.002.96].

Table 8. General Land Cover Percent by Watershed (Cataloging Unit) within the Salmon Subbasin (percent of total watershed area)

Watershed Name	Agricultural and Urban	Herbland	Shrubland	Early-seral Forest	Mid-seral Forest/ Woodland	Late-seral Forest	Other1\
Upper Salmon	<1%	13%	26%	30%	15%	15%	<1%
Pahsimeroi	2%	14%	35%	12%	23%	11%	2%
Middle Salmon-Panther	1%	11%	11%	11%	60%	5%	-
Lemhi	6%	31%	13%	7%	35%	7%	1%
Upper Middle Fork Salmon	-	4%	3%	50%	22%	22%	-
Lower Middle Fork Salmon	-	4%	7%	27%	41%	20%	<1%
Middle Salmon-Chamberlain	-	3%	<1%	19%	51%	27%	<1%
South Fork Salmon	-	1%	<1%	27%	35%	37%	<1%
Lower Salmon	19%	12%	<1%	16%	34%	19%	<1%
Little Salmon	6%	1%	<1%	36%	16%	40%	<1%
Total Subbasin	**3%**	**10%**	**10%**	**24%**	**34%**	**19%**	**<1%**

1\ Riparian, Alpine, Water, Rock, Barren

Source: Interior Columbia Basin Ecosystem Management Project GIS layers

Table 9. Land Ownership by Watershed (Cataloging Unit) within the Salmon Subbasin (percent of total watershed area)

Watershed Name	Private	State / County/ City	Forest Service (non-Wilderness)	Forest Service Wilderness	BLM (non-Wilderness)
Upper Salmon	4%	2%	65%	4%	25%
Pahsimeroi	9%	2%	45%	-	44%
Middle Salmon-Panther	4%	<1%	80%	5%	11%
Lemhi	18%	3%	40%	-	40%
Upper Middle Fork Salmon	<1%	-	23%	77%[2\]	-
Lower Middle Fork Salmon	<1%	<1%	19%	80%[3\]	-
Middle Salmon-Chamberlain	<1%	<1%	30%	69%	1%
South Fork Salmon	<1%	<1%	90%	8%[4\]	0%
Lower Salmon	48%	5%	41%[1\]	1%	6%
Little Salmon	31%	3%	58%	4%	3%
Total Subbasin	**9%**	**1%**	**50%**	**27%**	**13%**

1\ Includes 1,977 National Park Service acres (<1% watershed).
2\ Includes 1977 acres managed by BLM and 366 privately owned acres in Frank Church River of No Return Wilderness.
3\ Includes 1,328 acres managed by BLM and 322 privately owned acres in Frank Church River of No Return Wilderness.
4\ Includes 625 acres managed by Idaho State.
Source: Interior Columbia Basin Ecosystem Management Project GIS layers

Private land is concentrated in the valley bottoms of the upper and lower portions of the Salmon subbasin. Only three subwatersheds are greater than 10 percent private land with the Lower Salmon, Little Salmon and Lemhi watersheds at 50, 32 and 18 percent private land. Private landowners also control management of the majority of land in the river bottom of the Pahsimeroi and Upper Salmon (NPCC 2004, ISCC 1995). Table 9 summarizes land ownership by watershed within the Salmon subbasin.

5.1.5 Land Use

Historically, cattle ranching, logging, and mining have played important economic roles in the subbasin economy. Ninety percent of the Salmon subbasin is in Federal management and 27 percent of the subbasin is in designated wilderness. Approximately one-third of the National Forest is actively managed for timber or rangeland and much of BLM land is managed for rangeland for a total of approximately 40 percent of the Federal land.

Ranching and agriculture for cattle feed are important activities, especially in the eastern and western subbasin. Grazing on Federal lands is an important part of the livestock operations. It provides allotments for use through the summer months where the regulations and location of the pastures reduce degradation of the streams compared to that on private land (NPCC 2004).

Native American tribes traditionally fished and hunted within the Salmon subbasin. The Nez Perce Tribe has the right to fish in traditional and accustomed sites in the Salmon subbasin through the Treaty of 1855. The Shoshone-Bannock Tribes have the right to fish on unoccupied Federal lands through the 1868 Fort Bridger Treaty. The extent of the Shoshone-Paiute Tribes' fishing right is unresolved pending research and evaluation (NPCC 2004).

The Salmon River subbasin includes portions of eight counties and is sparsely populated, with the largest communities within the subbasin being Salmon (population approximately 3,122) and Challis (population 909). On average, road densities appear low in this subbasin with 58 percent of the area being unroaded. However, they are quite variable. The subbasins range from over 75 percent unroaded (Upper Salmon, Lower Middle Fork Salmon and Middle Salmon-Chamberlain) to 75 percent moderate to high density of roads (Lower Salmon). Road density by watershed is listed in Table 10.

Table 10. Road Density by Watershed (Cataloging Unit) within the Salmon Subbasin (percent of total watershed area with specified road density)

Watershed Name	Road Miles per Square Mile					
	0 – 0.02	0.02-0.1	0.1-0.7	0.7-1.7	1.7-4.7	>4.7
Upper Salmon	67%	8%	8%	9%	7%	<1%
Pahsimeroi	52%	4%	17%	11%	16%	<1%
Middle Salmon-Panther	39%	12%	4%	33%	10%	2%
Lemhi	41%	9%	13%	19%	18%	<1%
Upper Middle Fork Salmon	90%	2%	4%	2%	2%	<1%
Lower Middle Fork Salmon	93%	3%	1%	2%	<1%	<1%
Middle Salmon-Chamberlain	76%	3%	2%	9%	10%	<1%
South Fork Salmon	55%	14%	7%	14%	8%	1%
Lower Salmon	9%	5%	9%	41%	28%	7%
Little Salmon	20%	10%	4%	31%	29%	7%
TOTAL SUBBASIN	58%	7%	6%	16%	11%	2%

Source: Map 3.28, Volume II, in Quigley and Arbelbide (1997). Data used to form these classes was statistically extrapolated from sampled 6th-field HUC road data.

5.2 OVERVIEW OF SEDIMENT TRENDS AND HISTORIC CHANGES RELATIVE TO SEDIMENT

In the central watershed, the protected status of the land (wilderness, roadless, protected streams) has resulted in little change in that part of the watershed. Since the mid 1800s, there has been grazing, logging, and mining on Federal, tribal, and private lands in the rest of the watershed. While timber activities and wood products continue to be important in some areas, it has declined for several reasons including sustainability issues, market issues, and environmental standards. Mining activities have also declined during the last century and the late 1990s has seen a further decline in Custer and Lemhi counties, the most important to mining. There has been an overall increase in farming, although the number of irrigated acres has changed little in the last 30 years. Grazing activity has not changed substantially over the last 40 years. Recreation and tourism, primarily in the summer, are also important to the region and with the increases in the population of surrounding areas, this is growing (NPCC 2004).

Timber harvest in the 1950's and 1960's was most active in the South Fork Salmon River. Between 1958 and 1965, a series of intense storms and rain-on-snow events created numerous landslides and slumps triggered by logging and road construction, inundating the river and some of its tributaries with heavy sediment load. The rain-on-snow events in the winter and spring of 1965 caused over 100 landslides, the majority of which were related to roads. Concerns over sedimentation and fish habitat resulted in the stopping of land-disturbing activities in the upper South Fork Salmon River drainage in 1965. In 1974, floods in the East Fork of the South Fork Salmon River drainage carried heavy loads of sediment and in 1996-97, a high magnitude flood and sediment delivery event occurred that was estimated to have a 20-year return period. While timber activity is not currently widespread in the South Fork Salmon River watershed, it is the roads built during past harvest activities that are an important source of sediment (IDEQ 2002). Since the 1965 events, the Forest Service initiated a watershed restoration program.

Table 11 presents some ratings, developed by the Interior Columbia Basin Ecosystem Management Project (Quigley and Arbelbide 1997), which can be used as overall indices of the relative level of disturbance in each watershed within the geographic area. The measures relate to the degree of hydrologic disturbance in forest and rangeland environments (based on the level of surface mining, dams, cropland conversion, and roads) and the degree of riparian disturbance in rangeland environments (based on the sensitivity of streambanks to grazing and the sensitivity of stream channel function to the maintenance of riparian vegetation).

Based on these ratings, some broad generalizations can be made. The overall level of disturbance is low in the subbasin. While the riparian disturbance rating in the Lemhi, Little Salmon and Lower Salmon is low, the Middle Fork, South Fork, and Clearwater watersheds are generally rated to have a moderate to high level of disturbance, depending on the category.

Table 11. Hydrologic Disturbance Rating of Forest and Rangeland Environments and Riparian Disturbance Rating of Rangeland Environments Relative to the Entire Columbia Basin by Watershed (4th-field HUC) within the Salmon River Subbasin

Watershed Name	Hydrologic Disturbance Rating of Forest Environments	Hydrologic Disturbance Rating of Rangeland Environments	Riparian Disturbance Rating of Rangeland Environments
Upper Salmon	Low	Low	Low
Pahsimeroi	Low	Low	Low
Middle Salmon-Panther	Low	Low	Low
Lemhi	Mod	High	Low
Upper Middle Fork Salmon	Low	unclassified	unclassified
Lower Middle Fork Salmon	Low	Low	Low
Middle Salmon-Chamberlain	Low	Low	Low
South Fork Salmon	Low	Low	Low
Lower Salmon	High	Low	Mod
Little Salmon	Mod	Low	Mod

Source: Maps 2.34, 2.35, and 2.36, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

5.3 SEDIMENT SOURCES AND YIELD

5.3.1 Overview Studies on Erosion, Mass Wasting, and Sedimentation

In this section, ratings and other results from a number of overview studies that were conducted across the entire Columbia River basin or over larger areas are presented for perspective and comparison purposes. The methods behind these studies are summarized briefly below and in more detail in Section 4.1.

The Interior Columbia Basin Ecosystem Management Project, conducted by the Forest Service and the BLM (Quigley and Arbelbide 1997) developed various soil erosion, mass failure, and sediment hazard ratings for nonpoint sources for each watershed, relative to all Columbia Basin watersheds. The key ratings are shown for the Salmon subbasin, in Tables 12 and 13.

Table 12. Soil Erosion, Mass Failure, and Sedimentation Measures Relative to the Entire Columbia Basin by Watershed (Cataloging Unit) within the Salmon Subbasin

Watershed Name	Surface Soil Erosion Hazard	Earth Flow Hazard	Debris Avalanche Hazard	Sediment Delivery Potential	Sediment Delivery Hazard
Upper Salmon	Low - Mod	Mod - High	High	High	Low - Mod
Pahsimeroi	High	Low - Mod	Low – Mod	Low - Mod	Low - Mod
Middle Salmon-Panther	Mod - High	Mod - High	High	Mod - High	Mod - High
Lemhi	High	Low - Mod	Low – Mod	High	Mod - High
Upper Middle Fork Salmon	Low	Mod - High	High	High	Low - Mod
Lower Middle Fork Salmon	Mod - High	Mod - High	High	High	Mod - High
Middle Salmon-Chamberlain	Mod - High	Mod - High	High	High	Mod - High
South Fork Salmon	Low	Mod - High	High	High	Low - Mod
Lower Salmon	High	Mod - High	High	High	High
Little Salmon	Mod - High	Mod - High	High	High	High

Source: Maps 2.10, 2.11, 2.12, 2.13, and 2.15, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

Table 13. Road Erosion Hazard and Road Sediment Delivery Hazard Relative to the Entire Columbia Basin by Watershed (Cataloging Unit) within the Salmon Subbasin

Watershed Name	Road Erosion Hazard	Road Sediment Delivery Hazard
Upper Salmon	Mod - High	High
Pahsimeroi	Mod - High	Low - Mod
Middle Salmon-Panther	Low	Mod - High
Lemhi	Mod - High	Mod - High
Upper Middle Fork Salmon	High	High
Lower Middle Fork Salmon	Mod - High	High
Middle Salmon-Chamberlain	Mod - High	High
South Fork Salmon	High	High
Lower Salmon	Low - Mod	High
Little Salmon	Low - Mod	High

Source: Maps 2.16 and 2.17, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

NMFS (Baker et al. 2005) has developed a draft model for estimating increases in erosion rates relative to historical rates. Based on this study, erosion rates in most of the Salmon subbasin are predicted to be very close to historical rates (1 to 1.5 times). There are four exceptions. Erosion rates range up to 3 times the historical rate in the forested areas of the South Fork Salmon and the Middle Salmon – Panther watersheds. It ranges up to 3 times the historical rate in the forested areas of the Little Salmon and generally is 1.5 to 3 times historical values in the Lower Salmon with areas up to 6 times.

The USGS developed a landslide overview map (Radbruch-Hall et al. 1982). This map delineates areas where large numbers of landslides have occurred and areas which are susceptible to landsliding in the conterminous United States. Within the Salmon subbasin, extensive areas are mapped with a moderate or high incidence of past landslides and a moderate or high susceptibility to future landslides. These areas occur in all watersheds, but especially the upper watersheds in the eastern half of the subbasin.

A NRCS analysis of cropland for 1997 in the conterminous United States found that the Salmon River subbasin had few areas with highly erodible cropland or areas of cropland with excess erosion (NRCS 2000). The only areas were on the northern edge of the Lower Salmon watershed (NRCS 2000).

5.3.2 Subbasin Studies

303(d) Water Quality

The 1998 list of Section 303(d) water quality impaired water bodies included 89 water bodies in the Salmon River subbasin. Of those segments, 88 were listed for sediment concerns. The list included 10 to 25 percent of the waters within the South Fork Salmon and Lower Salmon watersheds, 5 to 10 percent of the waters in the Little Salmon, Pahsimeroi, Middle Salmon–Panther, Lemhi, and Middle Salmon–Chamberlain watersheds, and less than 5 percent of the Upper Salmon, Upper Middle Fork Salmon, and Lower Middle Fork Salmon watersheds (NPCC 2004). It is the state's responsibility to assess the streams and develop TMDLs for waters which do not comply with water quality standards or waters where beneficial uses are not supported due to a pollutant.

The general surface water criteria for sediment used by IDEQ in its assessments are from Idaho State Administrative Rules, Water Quality Standards and Wastewater Treatment Requirements (IDAPA 58.01.02.200.08). The State Rules read as follows: Sediment shall not exceed quantities specified in Section 250, or, in the absence of specific sediment criteria, quantities which impair designated beneficial uses. Section 250 of IDAPA specifies concentrations for individual pollutants that are based on categories of water and individual beneficial uses. For cold waters where aquatic life is the beneficial use, the guidelines specify turbidity less than 50 NTU (nephelometric turbidity units) (instantaneous) or 25 NTU

(10 day average) greater than background. Further, IDAPA 58.01.02.070 specifies that "where natural background conditions from natural surface or ground water sources exceed any applicable water quality criteria…that background level shall become the applicable site-specific water quality criteria". Much of the water quality monitoring data from various sources includes monitoring the total suspended solids (TSS) or bedload which are rarely collected concurrently. Therefore, IDEQ often uses surrogate measures for determining sediments including turbidity, TSS data, cobble embeddedness, and/or streambank stability.

Assessments of many of the 303(d) listed streams have been completed since 1998 and while TMDLs have been developed for some of the streams, several streams have been found to support beneficial uses and have been recommended for delisting. In the Upper Salmon River watershed, only Challis Creek was recommended for remaining on the Section 303(d) list and its TMDL identified a sediment target of reducing the component of subsurface fine sediment less than 6.35 mm to below 28 percent. A target of 80 percent stream bank stability to reduce erosion was thought to be effective in reaching that subsurface fine sediment goal (IDEQ 2003). The Pahsimeroi River watershed assessment recommended that only the mainstem Pahsimeroi River remain on the 303(d) list. Bank erosion along the river itself was thought to be contributing excess sediment as the lack of hydrologic connections likely prevented tributaries from contributing sediment to the river. The state water quality monitoring data in 2000 (see Beneficial Use Reconnaissance Program described in Section 5.4) showed stretches of the Pahsimeroi that included 35 to 45 percent fines and bank stability as low as 31 and 43 percent (IDEQ 2001). In the Lemhi watershed, 8 tributaries remained on the 303(d) list for sediments and TMDLs were developed. Streambank erosion and road erosion were considered to be the most important sources of sediment to the tributaries (IDEQ 1999). In these three upper watersheds (Pahsimeroi, Lemhi, and Upper Salmon), stream bank erosion due to cattle management and resulting lack of stream bank stability is considered a very significant source of sediment (ISCC 1995).

In the Little Salmon watershed assessment for water quality, no streams were recommended for remaining on the 303(d) list. Suspended sediments were sampled in the lower Little Salmon in 2004 by the Department of Agriculture for water quality assessment. There were no major peak concentrations and the overall suspended sediment concentrations averaged 2 to 4 milligrams per liter (mg/l) and never exceeded 9 mg/l. It was noted in the report that due to the nature of the sampling schedule (every 2 weeks) sediment runoff events may have been missed. Highway 95, built in 1938 and realigned in 1964, has resulted in channel, riparian, and floodplain encroachment, including channel constriction. Coarse sediment was transported during the 1997 flood and remains in the channel and side channel. Therefore, the Little Salmon River below Round Valley Creek was recommended by IDEQ for listing for habitat alteration, not sediment. The changes in channel length and width over time are being studied to help quantify the slope and sediment transport (IDEQ 2005).

In the Middle Salmon-Panther and Middle Salmon – Chamberlain subwatershed assessments for water quality, no streams were recommended for remaining on the 303(d) list for sediments. Dump Creek, a significant source of sediments over time, was recommended for removal from the 303(d) list because the conditions are being addressed by the Salmon-Challis National Forest with appropriate standards and practices and conditions are improving. The drainage has been assessed over a number of years and the general conclusion is that slumping of the canyon will continue until it reaches an equilibrium condition (IDEQ 2001). It was noted in the Middle Salmon – Chamberlain assessment that erodible soils, fire history, and periodic intense climatic events have resulted in substantial natural erosion and delivery of sediment to the Salmon River. Large increases in natural sediment generally are associated with early spring rains and later with higher flows from snowmelt runoff. In most years, suspended sediment ranged from 2 mg/l to 65 mg/l, except in May when it ranged from 6 mg/l to 503 mg/l. The Middle Salmon River generally has levels below 25 mg/l suspended sediment but can significantly increase during climactic events (Shumar 2002).

The South Fork subwatershed analysis by IDEQ recommended that only the mainstem of the South Fork Salmon remain on the list. Review of the biological and sediment data and sediment affecting aquatic habitat indicates that the habitat conditions within the watershed are improving and in the process of re-establishing historical conditions. While the data used in the subwatershed assessment suggests that the watershed has attained the cobble embeddedness targets set in the 1991 TMDL, it has not attained the target for percent depth fines. After the TMDL for sediments was developed in 1991, the Forest Service initiated projects to meet the objectives and many are underway (listed in IDEQ 2002). The recommendation in the more recent assessment was to focus additional efforts on road management activities (IDEQ 2002).

There has been considerable sediment monitoring data for the South Fork Salmon, beginning after the large sediment depositions in the mid 1960’s. Nelson and Burns (2004) reported free matrix counts, embeddedness measurements, surface fines estimates, core sampling, and photography for 1983 to 2003. The IDEQ South Fork Salmon Subbasin Assessment Addendum reports percent depth fines (8 sites) and cobble embeddedness (4 sites) for 1993 to 2001. The routine monitoring of the South Fork Salmon by the Forest Service started after the large landslide depositions in 1965. The monitoring reports include interstitial, surface sediment and intergravel conditions at several sites (varies by year) from 1966 to 2003.

The Middle Fork (Upper and Lower) do not have a completed assessment to review the 1998 303(d) listing. Less than 5 percent of these two watersheds are on the 1998 303(d) list and the majority of the watersheds are federally protected wilderness. While these watersheds have been monitored by the Forest Service, USGS, and IDEQ, most is not available and there is very little summary data in reports that can be referenced.

Adjudication Studies

A sediment analysis project was done for 20 sites in the Salmon subbasin by the Boise Aquatic Sciences Lab of the Rocky Mountain Research Station, Forest Service, to support the Snake River Adjudication Proceedings. In the Salmon subbasin, there were nineteen studies done in seven watersheds. The analyses includes channel profile and cross-section, geometry, discharge, channel material, sediment transport, and in some cases bedload transport rate versus discharge for selected size classes, and transport distance of painted rocks. The data not summarized below are in site summaries available on line at:

http://www.fs.fed.us/rm/boise/teams/soils/Bat%20WWW/index.htm.

The undated summaries with separate data spreadsheets have been referenced in the project document index with Forest Service, Rocky Mountain Research Station, and the stream name.

Lemhi River Watershed

- Hawley Creek, tributary to Eighteenmile Creek in the upper part of the Lemhi River watershed, about 0.7 miles upstream from the National Forest boundary - Streamflow and sediment data were collected from 1990 to 1996 and other information was collected for the study (pebble counts and stream reach survey). Stream discharges ranged from 9.83 cubic feet per second (cfs) to 94.6 cfs, bedload transport ranged from 0.00704 to 2.89 tons per day, and suspended transport ranged from 0.016 to 47.3 tons per day. Over the range of measured discharges, suspended transport accounts for approximately two to three fold difference at the lowest discharge and over a six fold difference at the highest discharge more than the bedload transport (USDA Forest Service undated).

Upper Salmon

- Herd Creek, tributary of the East Fork of the Salmon River, about 1.6 miles upstream of the confluence with the East Fork Salmon River - The stream is on land managed by the Bureau of Land Management. Streamflow, sediment data, pebble counts, painted rock transport, and stream reach survey were collected in 1994 and 1995. Stream discharges ranged from 10.2 cfs to 287 cfs, bedload transport ranged from 0.000964 to 60.2 tons per day, and suspended transport ranged from 0.265 to 218 tons per day. Over the range of measured discharges, suspended transport accounted for four to over five fold greater transport rate than the bedload transport rate (USDA Forest Service undated).

- Fourth of July Creek, tributary of the Salmon River, 2.9 miles east of Highway 75 - The stream is on Forest Service land. Streamflow and sediment data were collected from 1994 to 1997 and other information was collected for the study (pebble counts, stream reach survey, painted rock transport). Stream discharges ranged from 5.46 cfs to 137 cfs, bedload transport ranged from 0.00034 to 10.4 tons per day, and suspended transport ranged from 0.0952 to 71.7 tons per day. Over the range of measured discharges, suspended transport accounts for the majority of the material in transport with approximately an order of magnitude greater suspended transport at the lowest discharges and about three times as much at the highest discharges (USDA Forest Service undated).

- Salmon River, Yankee Fork, near Clayton, ID) - The stream is on Forest Service land. Sediment, pebble counts, reach survey, and core samples were taken in 1999 and 2000; streamflow records were available from 1922 to 1991. Sediment transport measurements spanned a range of stream discharges from 1,360 cfs to 5,070 cfs, bedload transport ranged from 0.111 to 328 tons per day, and suspended transport ranged from 17.0 to 4,730 tons per day. Over the range of measured discharges, suspended transport accounted for the majority of the material in transport by approximately and order of magnitude (USDA Forest Service undated).

- Salmon River near Obsidian, ID - The stream is on Forest Service land. Streamflow, sediment data and other information was collected for the study (pebble counts and core samples) were collected in 1999. Sediment transport measurements spanned a range of stream discharges from 264 cfs to 739 cfs, bedload transport ranged from 0.764 to 128 tons per day, and suspended transport ranged from 9.33 to 210 tons per day. Suspended transport accounts for the majority of the material in transport by approximately an order of magnitude greater at the lower range of measured discharges and about a two to three fold difference at the higher range of measured discharges (USDA Forest Service undated).

- Squaw Creek, two miles upstream from its mouth at the Salmon River - The stream is on Forest Service land. Streamflow and sediment data were collected from 1990 to 1996 and other information was collected for study (pebble counts, stream reach survey, and substrate surface material). Sediment transport measurements spanned a range of stream discharges from 0.76 cfs to 53.6 cfs, bedload transport ranged from 0.00833 to 12.1 tons per day, and suspended transport ranged from 0.00177 to 20.4 tons per day. At discharges near and larger than bankfull, suspended and bedload transport account for about equal proportions of the total sediment load. At lower discharges, suspended transport accounts for the majority of the material in transport (USDA Forest Service undated).

- Valley Creek, just upstream of its mouth at the Salmon River - The stream is on Forest Service land. Streamflow and sediment data were collected in 1994, 1995, and 1997. Other information collected for study was pebble counts, stream reach survey, substrate surface material, and core samples. Sediment transport measurements spanned a range of stream discharges from 139 cfs to 1,420 cfs, bedload transport ranged from 0.0077 to 89.8 tons per day, and suspended transport ranged from 1.08 to 223 tons per day. At discharges less than about 500 cfs, suspended transport accounts for the majority of the material in transport and at higher discharge bedload accounts for the majority of material in transport (USDA Forest Service undated).

- Thompson Creek is a tributary of the Salmon River near Clayton, ID - Streamflow and sediment data were collected in 1994 and 1995. Other information collected for study was pebble counts, stream reach survey, painted rock transport, and core samples. Sediment transport measurements spanned a range of stream discharges from 8.15 cfs to 124 cfs bedload transport ranged from 0.000627 to 22.0 tons/day, and suspended transport ranged from 0.154 to 63.7 tons/day. Over the range of measured discharges, suspended transport accounted for the majority of the material in transport by approximately an order of magnitude at the lowest discharges and about three times as much at the highest (USDA Forest Service undated).

Other Data

While there are many separate sediment or related studies of individual streams in the subbasin, there are few monitoring data sources that are consistent across space and time. PACFISH/INFISH Biological Opinion (PIBO) Effectiveness Monitoring Program was initiated to determine whether PACFISH/INFISH management practices are effective in maintaining or improving the riparian conditions and to evaluate the effect of land management activities. Sampling, started in 2001 followed by a second sampling rotation beginning in 2006, will provide data to describe changes in conditions. Sampling sites were selected because they were thought to be the most likely location to show integrated effects from upstream management actions. There are several sites in each subwatershed in the Salmon River subbasin where both physical and biological monitoring are done. The monitoring protocols and other information are available on line at:

http://www.fs.fed.us/biology/fishecology/emp/

and the data can be accessed on:

http://svinetfc2.fs.fed.us/pibo/

There is also on-line data for the Salmon River subbasins that is consistently collected in Idaho. There is the USGS monitoring data on http://id.water.usgs.gov/public/wq/index.html and the IDEQ data on:

http://mapserver.deq.state.id.us/Website/deqwaters/viewer.htm.

Both of these sites provide the data from individual site visits for streams monitored in Idaho.

5.4 MANAGEMENT PRACTICES AND RESTORATION PROJECTS

As noted earlier, approximately 90 percent of the Salmon subbasin is federally owned (Forest Service and BLM). The BLM land and about one-third of the National Forest System land is actively managed leaving about 45 percent of the subbasin without potential for sediment production related to timber harvest or road construction and little potential to reduce sediment because it is naturally occurring from nonpoint sources.

The land managed by the Forest Service or BLM is managed under Forest Plans and Resource Management Plans (see Section 3.3.1) including Forest strategies and priorities. The Forests and BLM have adopted the more restrictive guidance set forth in interagency agreements (commonly known as PACFISH and INFISH) that specify Interim RMOs to maintain or restore properly functioning watersheds, riparian areas, and associated fish habitats. The interagency agreements were intended to be interim guidance until the forests each revised their plans. The Boise, Sawtooth, and Payette National Forests revised their plans jointly but did not substantively decrease the stream protection. The Nez Perce National Forest is jointly revising its plans with the Clearwater National Forest and they are not expected to substantively change stream protection. The Salmon-Challis National Forest has not revised their plans and is still guided by PACFISH and INFISH.

The Idaho Forest Practices Act and its amendments constitute minimum standards for forest practices on forest lands in Idaho; the Act primarily affects forest practices on state and private lands, because Forest Service and BLM forest practices are more restrictive. It establishes Stream Protection Zones (SPZs) around streams and limits practices within those SPZs. Skidding logs in or through streams is prohibited but there is no prohibition against slash burning within SPZs. Harvest practices must retain at least 75 percent of existing stream shade and leave trees are designated by number, distance from stream, stream width, and tree diameter. Class I streams (including lakes and streams used for domestic water supply and/or are important for spawning, rearing or migration of fish) have a designated SPZ of the area encompassed by a slope distance of 75 feet on each side of ordinary high water marks. The Class II SPZ for streams that contribute flow to Class I streams is the area encompassed by a slope distance of 30 feet on each side of the ordinary high water mark. Streams that do not contribute flow to Class I streams have minimum SPZs of 5 feet.

BMPs have been published in the Idaho Agricultural Pollution Abatement Plan (Resource Planning Ltd. 2003) for agriculture (including grazing), but are largely voluntary at this time. Improvements are generally implemented with willing landowners through the efforts of several agencies (e.g., soil and water conservation districts, Idaho Department of Fish and Game, Idaho Department of Water Resources), Nez Perce Tribe, and non-for-profit groups. The Clearwater Subbasin Management Plan (Ecovista 2003) includes general prioritization for watershed improvements to guide habitat improvement efforts on publicly and privately owned lands.

The IDEQ routinely monitors surface water quality using its Beneficial Use Reconnaissance Program (BURP). BURP is a monitoring program that combines biological monitoring and habitat assessment to determine the quality of Idaho's waters. The field manuals for standardized data collection and annual work plans are published on the IDEQ web site at:

> http://www.deq.state.id.us/water/data_reports/surface_water/monitoring/publications.cfm#burp

The Salmon Subbasin Management Plan, (Ecovista 2004), contracted by the Nez Perce and Shoshone-Bannock Tribes, prioritizes watersheds for priority actions. It identifies four priorities that do not directly address sediment; however, some actions resulting would affect sediments. The priorities are: 4) Travel management and access in all watersheds; 3) Minimize grazing impacts in Lemhi, Little Salmon, Lower Salmon, Upper Salmon, Pahsimeroi, and Middle Salmon-Panther; 2) Restore natural disturbance regimes in the Lower Salmon, Lemhi, Upper Salmon, Middle Salmon-Panther, and Pahsimeroi watersheds; and 1) Target prevention and reduction of exotic invasive plant species in the Middle Salmon-Chamberlain, Lower Middle Fork and Upper Middle Fork watersheds. The plan does not give more specific actions plans.

A summary list of restoration/habitat improvement projects in the Salmon River watershed is listed in Appendix 4 of the Salmon Subbasin Management Plan (Ecovista 2004). Most of the projects are recent (since 1990) but it does include projects started earlier. There are 97 pages with over 525 projects listed that occur in all watersheds. The list shows that many agencies and organizations are involved as funding sponsors and as principal implementing agency (Federal, state, local agencies, not-for-profit, and volunteer organizations are represented). Additional lists of pollution control projects that were or are being implemented in the watersheds are in the IDEQ Assessment and TMDL reports.

Upper Salmon Basin Watershed Project, formerly the Model Watershed Group, was initiated by the NPPC in 1992 to improve Chinook salmon and steelhead habitat in the Lemhi, Pahsimeroi, and East Fork of the Salmon River. It was changed to the Upper Salmon Basin Watershed Project in 2001 to include the North Fork and Yankee Fork Salmon Rivers, as well as the mainstem of the Salmon River from the mouth of the Middle Fork upstream to its headwaters, for habitat restoration watersheds. The Model Watershed Plan (ISCC 1995) was developed as part of the NPPC's Columbia River Basin Fish and Wildlife Program and is used to help direct BPA funding of projects. The plan was locally organized and involved the major resource manager and government agencies. It specifies habitat goals that include reducing the sediment levels within spawning gravels. It includes a prioritized list of streams within watersheds to guide fish screening and habitat improvement efforts on privately owned lands throughout the Upper Salmon Basin. The plan specifies the following highest priority actions that would affect sediment:

- Enhance and protect the riparian corridor along 3 miles of Herd Creek.
- Stabilize 10,000 feet of streambank in Herd Creek where the stream has widened.
- Maintain and enhance the riparian corridor along 17 miles of critical fish habitat in the reach from the river's mouth to Hooper Lane.
- Enhance 10 miles of riparian corridor in the Patterson-Big Springs reach through selective planting of trees and shrubs.
- Improve 12 irrigation diversions to provide stable diversion points and reduce erosion (Pahsimeroi mouth to Hooper Lane).
- Maintain and enhance the riparian corridor along the upper 10 miles of the Hayden Creek-to-Leadore reach.
- Stabilize streambanks in the 10-mile section from the bridge near Leadore to the Eightmile Creek confluence.

In 2005, the Upper Salmon Basin Watershed Project Technical Team (USBWPTT), which is comprised of professional technical experts and fisheries biologists from regional state, Federal, tribal agencies, and other groups, developed a prioritization process for the Upper Salmon Basin Watershed Project Area because the current demand for conservation funding assistance to landowners was greater than the available resources. While it is intended to address fish conservation needs, high sediment levels and lack of streamside vegetation are listed as two of the key limiting factors in the watershed analysis and would be issues that would be funded. The document provides the scores used to prioritize each steam and is intended to be used by funding agencies to set priorities (USBWPTT 2005).

5.5 SUMMARY OF PRELIMINARY CONCLUSIONS

Based on this review of available information, a few preliminary conclusions can be made regarding opportunities for sediment reduction. It appears that the most promising watersheds for reduction efforts would include the Lower Salmon, South Fork Salmon, and the Little Salmon in the lower portion of the subbasin and the Lemhi and Pahsimeroi watersheds in the upper subbasin. In these watersheds, it appears that primarily forest management and grazing land uses should be the focus of additional efforts at sediment control. Restoration of degraded riparian areas, streambank erosion projects, and preventing road failures and road erosion appear to be the projects with the highest potential for success.

6. CLEARWATER RIVER SUBBASIN

6.1 THE SETTING

6.1.1 Geography and Topography

The Clearwater River subbasin is located primarily in north-central Idaho (less than 1 square mile occurs in Washington). It is bracketed by the Salmon River basin to the south and St. Joe River basin to the north. The Clearwater River drains approximately 9,353 square miles, with 6,907 in the study area. The Upper and Lower North Fork Clearwater watersheds are not in the study area because they lie above the Dworshak Dam, which effectively traps the vast majority of sediment from these watersheds. The Clearwater River originates in the Bitterroot Mountains at the Idaho/Montana border and flows to the Snake River at the Washington–Idaho border at the town of Lewiston, Idaho. Table 14 shows the size of each of the six watersheds (4th-field HUCs) in the project geographic area and their locations are shown in Figure 4.

Table 14. Size and Cataloging Unit Number for Watersheds within the Clearwater River Subbasin (does not include the Upper and Lower North Fork Watersheds)

Watershed Name	Cataloging Unit Number	Area (Square Miles)	Percent of Study Area
Upper Selway	17060301	986	14
Lower Selway	17060302	1,022	15
Lochsa	17060303	1,173	17
Middle Fork Clearwater	17060304	221	3
South Fork Clearwater	17060305	1,175	17
Clearwater	17060306	2,328	34
Total	**--**	**6,907**	**100%**

Note: The Upper North Fork Clearwater Watershed includes 1,295 sq. mi. and the Lower North Fork Clearwater Watershed includes 1,151 sq. mi.
Source: Interior Columbia Basin Ecosystem Management Project GIS layers

From west to east, the basin is characterized by plateaus and foothills, divided by breaklands, and further east by the Selway-Bitterroot mountain range that forms the Idaho/Montana border. The breaklands lie mostly in the central portion of the basin, closely bordering the mainstem and most tributaries. The slope gradients in the breaklands average between 60 to 80 percent and contribute to sediment transport efficiency. The mountains in much of the basin include glaciated areas.

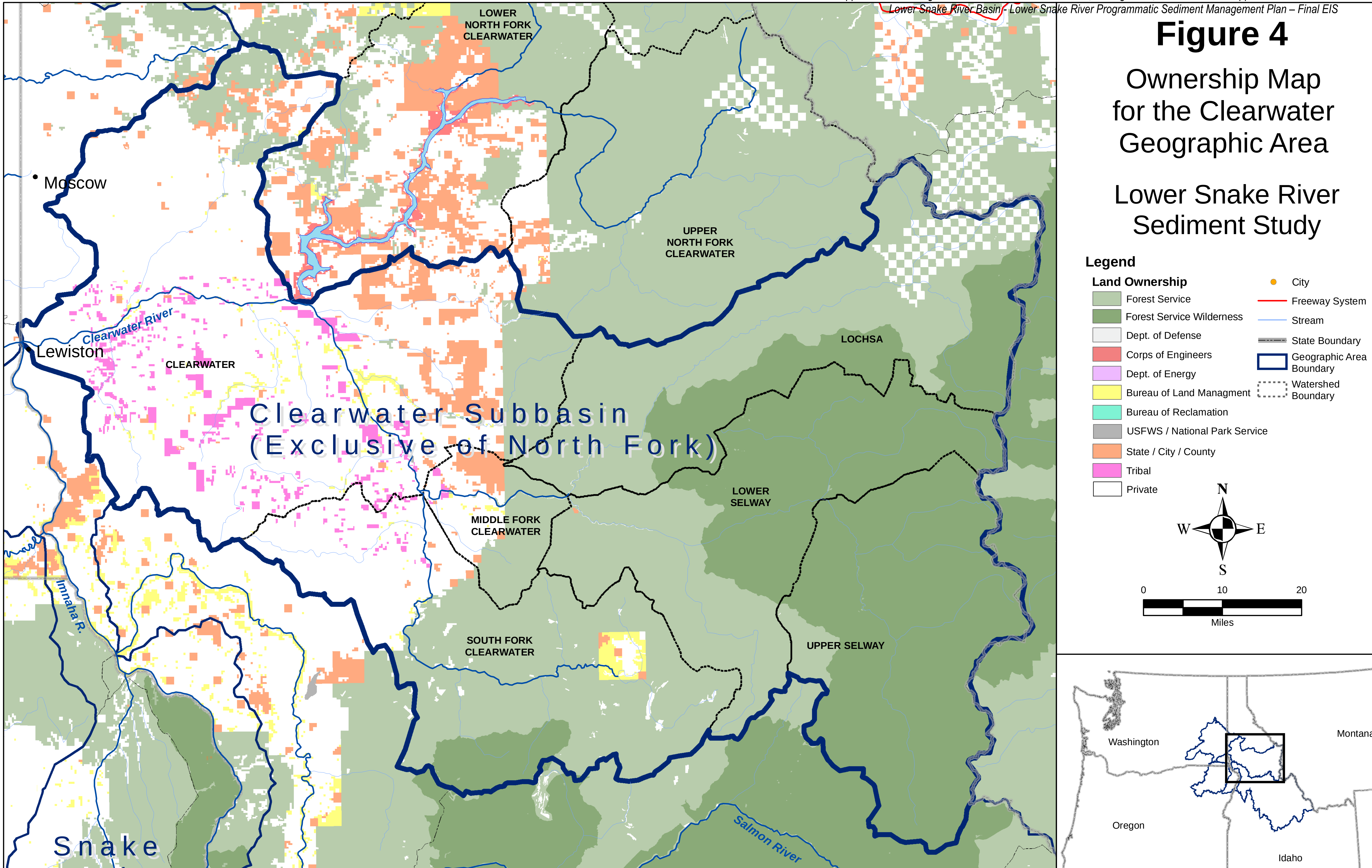


Figure 4
Ownership Map for the Clearwater Geographic Area
Lower Snake River Sediment Study
Legend
Land Ownership
Forest Service
Forest Service Wilderness
Dept. of Defense
Corps of Engineers
Dept. of Energy
Bureau of Land Managment
Bureau of Reclamation
USFWS / National Park Service
State / City / County
Tribal
Private
City
Freeway System
Stream
State Boundary
Geographic Area Boundary
Watershed Boundary
N
W
E
S
0
10
20
Miles
Washington
Montana
Oregon
Idaho
LOWER NORTH FORK CLEARWATER
UPPER NORTH FORK CLEARWATER
LOCHSA
CLEARWATER
Clearwater Subbasin (Exclusive of North Fork)
LOWER SELWAY
MIDDLE FORK CLEARWATER
SOUTH FORK CLEARWATER
UPPER SELWAY
Moscow
Lewiston
Clearwater River
Imnaha R.
Salmon River
Snake
P:\proj..._River_Sediment\maps\salmon_ownership.mxd

Marine sediments followed by volcanic activity and uplift and extension with a major cycle of folding and faulting were important parts of the geologic history in this subbasin. Granite and schist are widespread throughout most watersheds and form the dominant parent materials, occurring on almost two-thirds of the subbasin. Granitics, common throughout the subbasin and more dominant in the east, have variable erodiblity influenced by weathering. Schists, widespread throughout north and south-central portions of the subbasin, are highly erodibile and are considered to represent among the least stable of all geologic materials in the subbasin. Basalt is an important parent material in the eastern third of the subbasin and the Palouse and Camas Prairie regions of the lower (western) portion of the subbasin, is covered by windblown loess. The ash loess cap was laid down to depths of 4–5 meters and has been largely eroded away on steeper and/or burned slopes. This deep, silt-sized material is easily transported through processes of erosion (Ecovista et al. 2003).

6.1.2 Hydrology

The Clearwater subbasin is influenced by warm, moist maritime air masses similar to other parts of the Lower Snake River basin. The southern and eastern high elevations experience drier and colder weather typical of the northern Rocky Mountains. Most precipitation occurs in the fall, winter, and spring, and is predominantly snow at the higher elevations. The subbasin can experience rain-on-snow events from November through March.

The mainstem Clearwater River contributes approximately one-third of the flow of the Snake River. The Clearwater derives its flow from four primary tributaries (North and South Forks of the Clearwater, Lochsa and Selway Rivers). The Selway and Lochsa Rivers both originate at the Idaho–Montana border along the Selway-Bitterroot divide and flow west to their junction at Lowell, Idaho. The confluence of the Lochsa and Selway form the Middle Fork of the Clearwater. The South Fork flows west and north to join the Middle Fork where it becomes known as the mainstem. From there it flows west to the Snake. Records indicate that peak flows generally occur in May and June from snowmelt (Ecovista et al. 2003).

Dworshak Dam, constructed in 1972, is located 2 miles above the mouth of the North Fork Clearwater River and regulates the flow to the Clearwater. It is the only major water regulating facility in the watershed. Because the dam stores water in a reservoir and effectively stores sediment, the North Fork is not included in the study area. There are 70 smaller dams in the Clearwater watershed, concentrated in the lower part of the watershed area. Surface water use is permitted in all subwatersheds, but is most common in the lower Clearwater, Lolo/Middle Fork, and South Fork areas. While there are 53 gauging stations in the Clearwater watershed, only 12 of the stations are currently active (Ecovista et al. 2003).

6.1.3 Land Cover

Coniferous forests make up approximately 70 percent of the vegetation and are concentrated in the mountainous eastern two-thirds of the subbasin. Cropland and pastureland makes up approximately 18 percent of the vegetation and is located largely in the western portion. Shrublands and herbaceous areas, primarily within forest lands, make up about 10 percent. Table 15 summarizes the extent of general land cover types within the subbasin, by 4th-field watershed.

Table 15. General Land Cover Percent by Watershed (4th-field HUC) within the Clearwater River Subbasin (percent of total watershed area)[1/]

Watershed Name	Agricultural and Urban	Herbland	Shrubland	Early-seral Forest	Mid-seral Forest/ Woodland	Late-seral Forest	Other[2/]
Upper Selway	-	-	<1%	33%	62%	4%	<1%
Lower Selway	-	-	-	32%	55%	12%	<1%
Lochsa	-	-	-	35%	57%	7%	1%
Middle Fork Clearwater	18%	6%	-	10%	58%	5%	2%
South Fork Clearwater	23%	<1%	-	10%	66%	1%	<1%
Clearwater	57%	2%	-	3%	38%	<1%	<1%
Total Basin[1\]	**24%**	**1%**	**<1%**	**19%**	**53%**	**4%**	**<1%**

[1/] Does not include the Upper and Lower North Fork Clearwater watersheds
[2/] Riparian, Alpine, Water, Rock, Barren
Source: Interior Columbia Basin Ecosystem Management Project GIS layers

6.1.4 Land Ownership

The majority of the geographic area is federally owned with 62 percent of the land in the Clearwater and Nez Perce National Forests and an additional 1 percent under BLM management. Approximately 3 percent is owned by the State of Idaho, 1 percent by the Nez Perce Tribe, and the remaining 33 percent is privately owned. Most of the forested land is on National Forest System lands, but the state of Idaho, Potlatch Corporation, and Plum Creek Timber Company also own large forested areas. The western third of the watershed is mostly in private ownerships, especially timber companies, small timber landowners, farming and ranching families, and companies. Nez Perce Tribal lands are located primarily in the western half of the watershed within the current boundaries of the Nez Perce Reservation. The Nez Perce lands consist of both Fee lands owned and managed by the Nez Perce Tribe and properties placed in trust status with the Bureau of Indian Affairs. Tribal members also have land use rights in other areas.

Table 16 summarizes land ownership by watershed within the Clearwater subbasin and Figure 4 shows its spatial distribution. The Upper Selway, Lower Selway, and Lochsa watersheds are almost entirely under Forest Service management. The South Fork and the Middle Fork watersheds are 71 and 51 percent under Federal management (including BLM), respectively. In contrast, the Clearwater watershed is mostly in private ownership and only has 10 percent under Forest Service management.

Table 16. Land Ownership by Watershed (4th-field HUC) within the Clearwater River Subbasin (percent of total watershed area)[1/]

Watershed Name	Private	Tribal	State	National Forest (non-Wilderness)	National Forest Wilderness	BLM
Upper Selway	-	-	-	5%	95%	-
Lower Selway	<1%	-	-	42%	58%	-
Lochsa	5%	-	-	64%	31%	-
Middle Fork Clearwater	36%	<1%	11%	51%	0%	<1%
South Fork Clearwater	28%	<1%	<1%	60%	9%	2%
Clearwater	79%	4%	7%	10%	-	<1%[2/]
Total Basin[1\]	**33%**	**1%**	**3%**	**33%**	**29%**	**1%**

[1/] Does not include the Upper and Lower North Fork Clearwater watersheds.
[2/] Includes 66 acres of lands managed by the Corps.
Source: Interior Columbia Basin Ecosystem Management Project GIS layers

6.1.5 Land Use

Approximately 29 percent of the Clearwater subbasin (not including the North Fork) is in designated wilderness and an additional 16 percent is designated in some other highly protected status, mostly inventoried roadless areas, but also including federally designated Wild and Scenic Rivers. The Selway-Bitterroot Wilderness encompasses portions of the Upper and Lower Selway and Lochsa watersheds. The Gospel Hump Wilderness extends into the southern edge of the South Fork watershed. The Upper Selway, Upper North Fork, Lochsa, and Lower Selway each have at least 75 percent of their land in protected areas (Ecovista et al. 2003). There are also 54 miles of Wild River and 131 miles of Recreational River (Federal Wild and Scenic River classifications) in the Clearwater watershed, which were federally designated in 1968. Protected areas include the Lochsa River from the Powell Ranger Station and the Selway River from its origin, both downstream to Lowell where they meet and form the Middle Fork Clearwater. The Middle Fork Clearwater is designated from its origin at Lowell downstream to Kooskia, Idaho.

Agriculture (primarily wheat and barley) and grazing dominate the western part of the watershed, with grazing extending into the National Forests. Historically, the Forest Service was the largest producer of timber, but in 1996, harvest began to be dominated by private companies and individuals. Plum Creek Timber Company operates within the Upper North Fork with some landholdings in the Lochsa watershed, the Potlatch Corporation operates primarily in the Lower North Fork and Lolo/Middle Fork areas, and the Nez Perce Tribe is active on tribally managed lands primarily within the Lower Clearwater and South Fork Clearwater areas. Mining has historically occurred throughout the entire watershed, but has been most dense in the South Fork drainage. Its current importance is greatly reduced.

Roads on the plateau in the southwestern part of the watershed include rural roads and farm access roads. The highest road densities are in the center of the subbasin due to logging roads, where they typically range from 3 to 5 miles/square mile. Due to their protected status, there are very few existing roads and a low potential for road development in the eastern part of the watershed (Table 17).

Table 17. Road Density Predicted Classes by Watershed (4th-field HUC) within the Clearwater River Subbasin (percent of total watershed area)

Watershed Name	Road Miles per Square Mile					
	0 – 0.02	0.02-0.1	0.1-0.7	0.7-1.7	1.7-4.7	>4.7
Upper Selway	95%	3%	<1%	<1%	<1%	-
Lower Selway	60%	4%	1%	13%	22%	<1%
Lochsa	46%	2%	2%	18%	29%	3%
Middle Fork Clearwater	3%	2%	7%	33%	48%	6%
South Fork Clearwater	10%	1%	8%	33%	43%	5%
Clearwater	1%	<1%	26%	44%	24%	5%
Total Basin	**32%**	**2%**	**11%**	**26%**	**25%**	**3%**

Source: Map 3.28, Volume II, in Quigley and Arbelbide (1997). Data used to form these classes was statistically extrapolated from sampled 6th-field HUC road data.

6.2 OVERVIEW OF SEDIMENT TRENDS AND HISTORIC CHANGE

Since the mid-1800s, there has been grazing, logging, and mining on Federal, tribal, and private lands in this subbasin. The first significant commercial logging began in the Clearwater in the 1880s, but it did not start on a large scale until 1927. Logging on the national forests was minimal prior to WWII: the largest annual cut on the Clearwater National Forest prior to 1946 was 18 million board feet (MMBF). After the war, the annual cut increased dramatically and was at or above 100 MMBF from 1959 until the 1990s when it began to decline. Much of the reduction in timber harvest on Federal land has been due to restrictions related to fish and wildlife and lack of resolution on the management of remaining roadless areas.

The South Fork Clearwater drainage has a complex mining history that included periods of intense placer, dredge, and hydraulic mining. Currently, mining claims are distributed throughout the Clearwater watersheds, with the lowest number of occurrences in the Selway watersheds (where the majority of the land is in wilderness). Ecological hazard ratings for mines (delineated by the Interior Columbia Basin Ecosystem Management Project) indicate that most of mines in the Clearwater River subbasin have a rating of relatively low environmental risk. However, there are mines with relatively high ecological hazard ratings in the South Fork and in the Orofino Creek drainages (Ecovista et al. 2003).

Table 18 presents some ratings, developed by the Interior Columbia Basin Ecosystem Management Project (Quigley and Arbelbide 1997), which can be used as overall indices of the relative level of disturbance in each watershed within the geographic area. The measures relate to the degree of hydrologic disturbance in forest and rangeland environments (based on the level of surface mining, dams, cropland conversion, and roads) and the degree of riparian disturbance in rangeland environments (based on the sensitivity of streambanks to grazing and the sensitivity of stream channel function to the maintenance of riparian vegetation).

Based on these ratings, some broad generalizations can be made. The overall level of disturbance is low in the Upper and Lower Selway and the Lochsa watersheds. In contrast, the Middle Fork, South Fork, and Clearwater watersheds are generally rated to have a moderate to high level of disturbance, depending on the category.

Table 18. Hydrologic Disturbance Rating of Forest and Rangeland Environments and Riparian Disturbance Rating of Rangeland Environments Relative to the Entire Columbia Basin by Watershed (4th-field HUC) within the Clearwater River Subbasin

Watershed Name	Hydrologic Disturbance Rating of Forest Environments	Hydrologic Disturbance Rating of Rangeland Environments	Riparian Disturbance Rating of Rangeland Environments
Upper Selway	Low	Low	Low
Lower Selway	Low	Low	Low
Lochsa	Low	Unclassified	Unclassified
Middle Fork Clearwater	High	High	Low
South Fork Clearwater	Moderate	Moderate	High
Clearwater	High	High	Moderate

Source: Maps 2.34, 2.35, and 2.36, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

6.3 SEDIMENT SOURCES AND YIELD

6.3.1 Overview Studies on Erosion, Mass Wasting, and Sedimentation

In this section, ratings and other results from a number of overview studies that were conducted across the entire Columbia River basin or over larger areas are presented for perspective and comparison purposes. The methods behind these studies are summarized briefly below and in more detail in Section 4.1.

The Interior Columbia Basin Ecosystem Management Project conducted by the Forest Service and the BLM (Quigley and Arbelbide 1997) developed various soil erosion, mass failure, and sediment hazard ratings for nonpoint sources for each watershed, relative to all Columbia Basin watersheds. The key ratings are shown for the Clearwater subbasin in Tables 19 and 20.

Table 19. Soil Erosion, Mass Failure, and Sedimentation Measures Relative to the Entire Columbia Basin by Watershed (4th-field HUC) within the Clearwater River Subbasin

Watershed Name	Surface Soil Erosion Hazard	Earth Flow Hazard	Debris Avalanche Hazard	Sediment Delivery Potential	Sediment Delivery Hazard
Upper Selway	Low - Mod	Mod - High	High	High	Mod - High
Lower Selway	Low - Mod	High	High	High	Mod - High
Lochsa	Low - Mod	High	High	High	Mod - High
Middle Fork Clearwater	High	High	High	High	High
South Fork Clearwater	Mod - High	Mod - High	High	Mod - High	High
Clearwater	High	High	High	Mod - High	High

Source: Maps 2.10, 2.11, 2.12, 2.13, and 2.15, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

Table 20. Road Erosion Hazard and Road Sediment Delivery Hazard Relative to the Entire Columbia Basin by Watershed (4th-field HUC) within the Clearwater River Subbasin

Watershed Name	Road Erosion Hazard	Road Sediment Delivery Hazard
Upper Selway	High	High
Lower Selway	Mod - High	High
Lochsa	High	High
Middle Fork Clearwater	Low	Mod - High
South Fork Clearwater	Low	Mod - High
Clearwater	Mod - High	Mod - High

Source: Maps 2.16 and 2.17, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

NMFS (Baker et al. 2005) has developed two draft models for estimating increases in erosion rates relative to natural levels. Based on this study, erosion rates in the Upper and Lower Selway and Lochsa watersheds have not changed much and are 1 to 1.5 times historical rates. The Middle Fork Clearwater watershed was modeled to have increased erosion rates of 1.5 to 3 times the historical rate. The South Fork Clearwater and the Clearwater watersheds have erosion rates up to 10 times the historic rate or greater. In both cases the higher values are primarily in agricultural areas of the lower watersheds. In the South Fork Clearwater, the upper watershed, including the wilderness, has shown little change and is close to 1 times the historical rate.

The USGS developed a landslide overview map (Radbruch-Hall et al. 1982). This map delineates areas where large numbers of landslides have occurred and areas which are susceptible to landsliding in the conterminous United States. Within the Clearwater subbasin, localized areas with a moderate incidence of past landslides and high susceptibility to future landslides were identified in the lower portion of the Lochsa watershed, the Lower Selway watershed, and in the upper Clearwater watershed.

A NRCS analysis of cropland for 1997 in the conterminous United States found that the Clearwater River watershed and the lowermost portion of the South Fork watershed have areas of highly erodible cropland and areas of non-highly erodible cropland (NRCS 2000). Both categories of croplands had areas with excess erosion above the tolerable soil erosion rate (NRCS 2000).

6.3.2 Subbasin Studies

In the Clearwater Subbasin Assessment (Ecovista et al. 2003), two types of sedimentation were modeled, mass wasting and surface erosion hazard. A model developed by University of Idaho and Potlatch Corporation was used for projecting mass wasting potential and combined with another model developed by the Washington State University (WSU) Center for Environmental Education to provide input regarding the likelihood that the sediment from mass wasting would enter the streams. The results showed that the subbasin has high erosion hazard due to its steep slopes and unstable parent materials (such as schist). This hazard, combined with storm events and older roads or bare ground, were found to favor mass wasting in the central and eastern portions of the subbasin. The mobilized sediment was considered to be most likely conveyed to stream channels in the Lower and Upper Selway, in the lower Lochsa, in the South Fork Clearwater River, and in the North Fork Clearwater above Dworshak Reservoir (Ecovista et al. 2003).

A second modeling exercise looked at surface erosion hazard data for the watershed. When vegetation cover is considered, potential sedimentation ratings were highest in the lower Clearwater, Lolo/Middle Fork and Lower North Fork areas, and lowest in the South Fork and Lochsa areas. Surface erosion within the Clearwater watershed is considered to be highest in the agricultural areas in the western portions of the watershed. The erosion in the agricultural areas is largely determined by agricultural practices and programs run by NRCS have recently improved some of the worst erosion on these lands (Ecovista et al. 2003).

Forest management activities have been shown to increase the number of landslides. An analysis of the 1995–1996 landslides, due to rain-on-snow events, estimated that approximately 71 percent of the sediment that reached the streams was from natural landslides and 29 percent was caused by roads and timber activities (IDEQ 2000).

In a study conducted by the University of Idaho, the RUSLE was applied to estimate erosion due to sheet and rill erosion in non-forested areas and the Water Erosion Prediction Project (WEPP) model was used to estimate erosion and delivery of sediment from road surfaces. In this analysis, roads were assumed graveled with a non-eroding ditch; therefore, road erosion and sediment delivery may be somewhat underestimated. The results of the analysis of agriculturally dominated areas in the Clearwater subbasin showed that erosion from roads accounted for less than 1 percent of the total estimated erosion, and sheet and rill erosion from agricultural fields accounted for the rest. Likewise, sediment delivery showed that roads accounted for 1 percent of the total estimated sediment delivery and sheet and rill erosion from agricultural fields accounted for 99 percent (Boll et al., 2002).

A study was conducted at WSU for the IDEQ to estimate ephemeral gully and stream channel erosion in the Potlatch River watershed. Aerial survey techniques and analysis of seasonal high resolution aerial images was used. Approximately 1,250 miles of ephemeral and stream channels were estimated to exist in the six primary agricultural subbasins of the lower Potlatch River watershed (Big Bear, Cedar, little Bear, Little Potlatch, Middle Potlatch, and Pine basins). Ephemeral gully erosion was estimated at less than 0.5 tons per acre in

2003-2004. A channel sediment study found that channel sediment is a small fraction of the reported annual land surface erosion in the basin. The two estimates of channel sediment provided a high geomorphic estimate of 0.21 tons per acre per year and a low channel survey-based estimate of 0.06 tons per acre per year. Erosion in ephemeral gullies in western part of the study area was noted to be caused mostly by rain after spring tillage (Teasdale and Barber 2005).

The 1998 list of Section 303(d) water quality limited stream segments included approximately 540 miles of stream within the Clearwater watershed (not including the North Fork). Approximately 70 percent of the miles are in the Lower Clearwater, 19 percent in the Middle Fork Clearwater, and 9 percent are in the South Fork Clearwater. The Upper and Lower Selway and Lochsa watersheds, with a high portion of wilderness or inventoried roadless area, had a limited number of stream miles listed as water quality limited in the 1998.

Several assessments of the listed streams have been completed since 1998 and while TMDLs have been developed for some of the streams, several have been found to support beneficial uses and have been recommended for delisting. The South Fork Clearwater TMDL Assessment (not including Cottonwood Creek) projected sediment loadings from agricultural and grazing areas of approximately 10-30 times natural background in the lower watershed while sediment from forested areas was projected to be no greater than twice natural background. Seven of the ten stream segments were recommended for delisting (IDEQ 2000 and 2003). Cottonwood Creek, which was analyzed separately, remained on the 303(d) list, and TMDLs were developed for sediments and other pollutants (IDEQ and Nez Perce Tribe 2000). Several segments in the portion of the Lower Clearwater, Jim Ford Creek area, have remained on the 303(d) list and TMDLs have been developed (IDEQ and Nez Perce Tribe 2000). In the Lochsa River and Selway watersheds, streams segments that were listed for sediment were recommended for delisting. The management practices implemented on publicly owned land are expected to improve water quality and the current level of sedimentation is not considered to have impaired beneficial use of the area (Bugosh 1999, 2000).

Most of the TMDL analyses have general information regarding the source of sediments to the streams. In the Selway, sediment loading to waters was more specifically estimated to be 25 percent from roads, 4 percent from timber harvest areas, and 71 percent from natural landslides (Bugosh 2000).

Adjudication Studies

While there are many separate sediment or related studies of individual streams in the basin, there are few monitoring data sources that are consistent across space and time. A sediment analysis project was done for Idaho streams by the Boise Aquatic Sciences Lab of the Forest

Service Rocky Mountain Research Station (USDA Forest Service 2005) to support the Snake River Adjudication Proceedings. In the Clearwater River Basin, there were seven studies done in four watersheds. While there is some variability in the data available or collected, all sites included sediment transport at various stream discharges. The analyses also include other measurements such as channel profile and cross section, geometry, channel material, bedload transport rate versus discharge for selected size classes, and transport distance of painted rocks. The data not summarized below is in site summaries available on line at:

http://www.fs.fed.us/rm/boise/teams/soils/Bat%20WWW/index.htm

The undated summaries with separate data spreadsheets have been referenced in the project document index with Forest Service, Rocky Mountain Research Station, and the stream name.

Lochsa Watershed

- Lochsa River, about one mile from its confluence with the Selway – The stream is on National Forest. Sediment transport measurements were made during water years 1994 through 1997. Additional information collected at this site includes a survey of the stream reach, pebble counts and core samples. The measurements spanned a range of stream discharges from 3,910 to 26,800 cfs; bedload transport ranged from 0.0800 to 346 tons/day; and suspended transport ranged from 14.7 to 37,100 tons/day. Suspended transport accounted for the majority of the material in transport over the range of measured discharges by between one and two orders of magnitude (USDA Forest Service undated).

Selway Watershed

- Selway River near Lowell, ID - The stream is on National Forest. Streamflow and sediment data were available from 1994 to 1997 and other information was collected for the study (pebble counts, stream reach survey, core samples). Stream discharges ranged from 4,760 cfs to 37,700 cfs; bedload transport ranged from 0.1 to 368 tons/day; and suspended transport ranged from 16.6 to 64,300 tons/day. Over the range of measured discharges, suspended transport accounted for the majority of the material in transport by an order of magnitude (USDA Forest Service undated).

South Fork Clearwater Watershed

- Johns Creek at its confluence with the South Fork Clearwater River – The stream originates in the Gospel Hump Wilderness and is managed by the Forest Service. Streamflow and sediment data were available from 1986 to 1995 and other information was collected for the study (pebble counts, stream reach survey and core samples). Stream discharge ranged from 21.1 cfs to 1,210 cfs; bedload transport ranged from 0.0007 to 23.5 tons/day; and suspended sediment transport ranged from

0.109 to 2,213 tons/day. Over the range of measured discharges, suspended sediment accounted for the majority of the sediment transport with rates exceeding bedload transport by over an order of magnitude (USDA Forest Service undated).

- Main Fork Red River at its confluence with the South Fork Red River – The stream is on National Forest. Streamflow and sediment data were available from 1986 to 1999 and other information was collected for the study (painted rock movement and large bedload during high snowmelt flows, pebble counts, stream reach survey, and core samples). Stream discharges ranged from 9.88 cfs to 646 cfs; bedload transport ranged from 0.0 to 23.6 tons/day; and suspended sediment transport ranged from 0.02 to 194 tons/day. At the lowest discharge measure, suspended transport was about seven times that of bedload and at the highest measured discharge, it is about 1.5 times (USDA Forest Service undated).
- South Fork Red River at the confluences with the Main Fork Red River - The stream is on National Forest. Streamflow and sediment data were available from 1986 to 1999 and other information collected for the study was the same as for Main Fork Red River. Stream discharges ranged from 5.93 cfs to 458 cfs; bedload transport ranged from 0.0 to 22.4 tons/day; and suspended sediment transport ranged from 0.01 to 119 tons/day. Over the range of measured discharges, suspended transport accounted for the majority of the material in transport with approximately a four to six -fold difference in the rates (USDA Forest Service undated).
- Trapper Creek about 0.8 miles upstream of its confluences with the South Fork of Red River. The stream is on National Forest. Streamflow and sediment data were available from 1986 to 1997 and other information was collected for the study (pebble counts, stream reach survey, core samples). Stream discharges ranged from 1.69 cfs to 135 cfs; bedload transport ranged from 0.0005 to 15.1 tons/day; and suspended sediment transport ranged from 0.0045 to 27.8 tons/day. Over the range of measured discharges, suspended transport accounted for the majority of the material in transport, especially at lower discharges (USDA Forest Service undated).

Middle Fork Clearwater Watershed

- Lolo Creek, tributary to the Middle Fork Clearwater River, at Forest Service boundary near Greer, Idaho. The stream is on National Forest. Streamflow and sediment data were available from 1982 to 1997 and other information was collected for the study (pebble counts, stream reach survey, core samples). Stream discharges ranged from 26.8 cfs to 809 cfs; bedload transport ranged from 0.0110 to 14.1 tons/day; and suspended transport ranged from 0.03 to 58.4 tons/day. Over the range of measured discharges, suspended transport accounted for the majority of the material in transport (USDA Forest Service undated).

Three draft work plans were written for the Snake River Basin Adjudication: Cottonwood Creek in the lower part of the South Fork Clearwater Watershed; Lapwai Creek in the lower part of the Clearwater Watershed (11 miles east of Lewiston); and Lawyer Creek in the Clearwater Watershed, just below the confluence of the Middle Fork Clearwater and South Fork Clearwater. All three are largely on private land.

In the draft Cottonwood Creek work plans written for the Adjudication, it was found that sediment levels are an issue. Riparian tree and shrub removal, field plowing and channelization have modified most streams on agricultural land. This has resulted in channel erosion, channel destabilization, and sediment deposition. As the tributary streams flow from the prairie via the breaklands to the confluence of the South Fork Clearwater River, erosion of channels is common due to steeper gradients and altered upstream conditions. As these streams get closer to the valley floor, their gradients drop considerably, causing deposition of bedload sediment. This has resulted in aggraded channels. Analyses showed that to meet the total suspended TMDL at the mouth of Cottonwood Creek, the suspended sediment load needs to be reduced 60 percent during the period of January through May. Similarly, Red Rock needs a 64 percent reduction. Bedload modeling indicated that to stabilize the streambed at bankfull discharge, the streambed stability needs to be increased by approximately 46 percent (ISCC 2005a).

In the Lapwai and Lawyer Work Plans (ISCC 2005b, c) sediment was determined to need reduction for similar reasons as in Cottonwood Creek, particularly for cropland as it is the source of approximately 99 percent of the sediment over background levels.

Other Sediment Data

The PIBO Effectiveness Monitoring Program was initiated to determine whether PACFISH/INFISH management practices are effective in maintaining or improving the riparian conditions and to evaluate the effect of land management activities. Sampling started in 2001 and the second sampling rotation will begin in 2006 to provide data to describe changes in conditions. The sites were selected because they were thought to be the most likely locations that would show integrated effects from upstream management actions. There are several sites in each of the watersheds in the Clearwater River Basin where both physical and biological monitoring are done. The monitoring protocols and other information are available on line at:

http://www.fs.fed.us/biology/fishecology/emp/

and the data can be accessed on:

http://svinetfc2.fs.fed.us/pibo/.

There are also on-line data collected in the Clearwater River watersheds that are consistently collected in Idaho. There are USGS monitoring data on http://waterdata.usgs.gov/nwis and the IDEQ data collected for the 303(d) listing evaluations on:

http://mapserver.deq.state.id.us/Website/deqwaters/viewer.htm.

Both of these sites provide the data from individual site visits for streams monitored in Idaho.

6.4 MANAGEMENT PRACTICES AND RESTORATION PROJECTS

As noted in Section 5.1.5, approximately 45 percent of the Clearwater subbasin (not including the North Fork) is designated as having some degree of protected status; 29 percent of the subbasin is in designated wilderness. Management in these areas has virtually no potential to create sediment problems or to reduce sediment production from natural problem areas.

Overall, 63 percent of the subbasin is managed by the Forest Service or BLM under Forest Plans and Resource Management Plans (see Section 3.2.1). The Clearwater and Nez Perce National Forests are jointly revising their management plans, including customizing, but they are not expected to substantively change the protection provided by PACFISH and INFISH.

As noted in Section 5.1.4, the Upper Selway, Lower Selway, and Lochsa watersheds are almost entirely under National Forest management, the South Fork and the Middle Fork watersheds are 71 and 51 percent under Federal management (including BLM), respectively, and the Clearwater watershed is mostly in private ownership and only has 10 percent under National Forest management.

As a result of past landslides, the Forest Service has worked on identifying roads with high failure risks and either abandoning or obliterating them. They have also worked with the Nez Perce Tribe to obliterate old, unused roads and roads that are in danger of failing and damaging streams (Bugosh 1999).

The Idaho Forest Practices Act and its amendments constitute minimum standards for forest practices on forest lands in Idaho; the Act primarily affects forest practices on state and private lands, because Forest Service and BLM forest practices are more restrictive. It establishes SPZs around streams and limits practices within those SPZs. Skidding logs in or through streams is prohibited, but there is no prohibition against slash burning within SPZs. Harvest practices must retain at least 75 percent of existing stream shade and leave trees are designated by number, distance from stream, stream width, and tree diameter. Class I streams (including lakes and streams used for domestic water supply and/or are important for spawning, rearing or migration of fish) have a designated SPZ of the area encompassed by a slope distance of 75 feet on each side of ordinary high water marks. The Class II SPZ for streams that contribute flow to Class I streams is the area encompassed by a slope distance of

30 feet on each side of the ordinary high water mark. Streams that do not contribute flow to Class I streams have minimum SPZs of 5 feet.

BMPs have been published in the Idaho Agricultural Pollution Abatement Plan (Resource Planning Ltd. 2003) for agriculture (including grazing), but they are largely voluntary at this time. Improvements are generally implemented with willing landowners through the efforts of several agencies (e.g., soil and water conservation districts, Idaho Department of Fish and Game, Idaho Department of Water Resources), Nez Perce Tribe, and non-for-profit groups. The Clearwater Subbasin Management Plan (Ecovista 2003) includes general prioritization for watershed improvements to guide habitat improvement efforts on publicly and privately owned lands.

The Clearwater River Focus Program was created in late 1996 under the NPPC's Columbia River Basin Fish and Wildlife Program. The purpose of the program is to coordinate efforts to restore habitats in the Clearwater River watershed to meet the goals of the Council's fish and wildlife program. The ISCC and the Nez Perce Tribal Watershed Division co-coordinate the program. They have conducted restoration projects on private, state, Federal, and tribal lands. Major funding is BPA-approved through the NPPC. Other partners include the Forest Service, NRCS, soil conservation districts, private landowners, Idaho Department of Fish and Game, and the BLM. The projects funded include riparian fencing, riparian planting, road obliteration, culvert replacement, bank stabilization, sediment basins, off-site watering, and other.

The Clearwater Focus Program convened the Policy Advisory Committee, including the Nez Perce Tribe, and developed the Clearwater Subbasin Plan. The plan was developed as part of the NPPC's Columbia River Basin Fish and Wildlife Program and is used to help direct BPA funding of projects. The plan was locally organized and involved the major resource manager and government agencies. The planning included developing an assessment of the watershed to provide the background information to support the recommendations, an inventory of the management, existing resources, and ongoing work in the watershed, and a management plan with a vision for the Clearwater watershed, biological objectives, and strategies for reaching management goals (Clearwater Focus Program 2005).

In the Clearwater Assessment, sedimentation is cited as a primary limiting factor for the federally listed fish species in all assessment units, although it's most widespread in the Lolo/Middle Fork area and also problematic in most of the Lower Clearwater and South Fork areas. Sediment abatement activities in the watershed include road decommissioning, riparian fencing, implementing forestry BMPs, and implementing agricultural BMPs. While effectiveness of the programs is monitored in some cases, additional efforts are needed to understand the effectiveness (Ecovista et al. 2003). Appendix B to the Clearwater Inventory is a compilation of individual ongoing projects or programs that are related to habitat restoration and/or research, monitoring, and evaluation projects that address the management plan strategies and objectives (Objective S is to reduce sediments). The objective for each project (over 700 listed) is shown. Approximately one-third of the projects directly address the strategy to reduce sediments and many others would also indirectly affect sediments (Ecovista 2003).

6.5 SUMMARY OF PRELIMINARY CONCLUSIONS

Based on this review of available information, a few preliminary conclusions can be made regarding opportunities for sediment reduction. It appears that the most promising watersheds for reduction efforts would include the Clearwater, South Fork Clearwater, and Middle Fork Clearwater watersheds. In these watersheds, it appears that both agricultural lands and forest management land uses could be the focus of additional efforts at sediment control. Restoration of degraded riparian areas, projects to limit field erosion and delivery to streams in agricultural/grazing areas, and preventing road failures and minimizing road erosion in forest management areas appear to be the projects with the highest potential for success.

A large proportion of Federal lands, which dominate the Upper Selway, Lower Selway, and Lochsa watersheds, is in highly protected status, such as wilderness. Other Federal lands are managed under protective standards and guidelines. Although there appear to be several areas identified where natural landslides are a key factor, it is unlikely that much can be done to address these at the source.

7. SNAKE RIVER BASIN HELLS CANYON REACH – GEOGRAPHIC AREA

7.1 THE SETTING

7.1.1 Geography and Topography

The Snake River Hells Canyon Reach geographic area includes all drainages upstream of the mouth of the Clearwater River and downstream of Hells Canyon Dam, exclusive of the Salmon and Grande Ronde subbasins (Figure 5). It includes three 4th-field HUCs (referred to as watersheds) covering portions of Idaho, Oregon, and Washington and is 2,104 square miles in size (Table 21). Although the geographic area does not extend upstream of Hells Canyon Dam, flows in the Snake River within the geographic area include flows from the large drainage basin of more than 70,000 square miles upstream of Hells Canyon Dam (including most of southern Idaho and portions of Oregon, Washington, Wyoming, Nevada, and Utah).

Table 21. Size and Cataloging Unit Number for Watersheds within the Snake River Basin Hells Canyon Reach Geographic Area

Watershed Name	Cataloging Unit Number	Area (Square Miles)	Percent of Study Area
Hells Canyon	17060101	538	26
Imnaha	17060102	857	41
Lower Snake - Asotin	17060103	708	34
Total	**--**	**2,104**	**100%**

Source: Interior Columbia Basin Ecosystem Management Project GIS layers

The Snake River generally flows in a northerly direction in the reach from Hells Canyon Dam to the mouth of the Clearwater River. In this reach, it forms either the border between Oregon and Idaho (southerly portion) or the border between Washington and Idaho (northerly portion). Major tributaries to this reach are the Imnaha River (which enters the Snake from the west side near the downstream end of the lower Hells Canyon watershed), the Salmon River (which enters the Snake from the east side at the lowest end of the Hells Canyon watershed), the Grande Ronde River (which enters the Snake from the west side in the middle of the Lower Snake-Asotin watershed), and Asotin Creek (which enters the Snake from the west side near the downstream end of the Lower Snake-Asotin watershed) (Figure 5). In addition, there are other smaller tributaries located throughout this reach that flow directly into the mainstem Snake River.

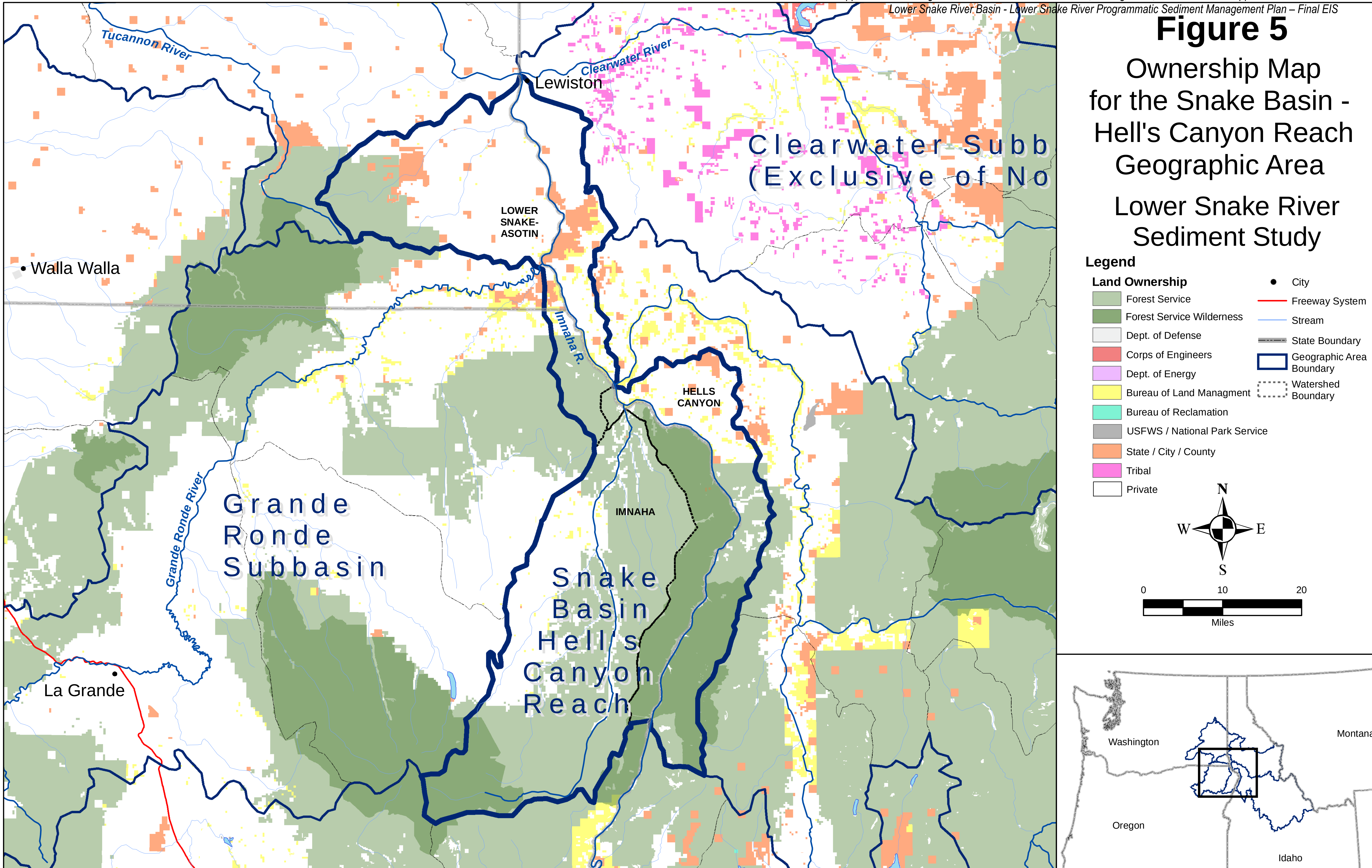


Figure 5

Ownership Map for the Snake Basin - Hell's Canyon Reach Geographic Area

Lower Snake River Sediment Study

The mainstem Snake River within the Hells Canyon watershed flows through a narrow, steep-sided, V-shaped canyon averaging 5,500 ft. deep that is entrenched in erosion-resistant basalt and metamorphic rock. The main formative agent for Hells Canyon was the "catastrophic flood of water from Lake Bonneville" that occurred approximately 14,500 years ago. Peak flood flows during this event have been estimated to be about 20 million cfs [Idaho Power Company (IPC) 2003]. Since the Bonneville Flood, the Hells Canyon section of the Snake River is considered to be highly stable.

The Imnaha River flows in a generally northerly direction, paralleling the Snake River (Figure 5). The primary tributaries (Big and Little Sheep creeks) originate in the Wallowa Mountains in Oregon.

Asotin Creek originates in the Blue Mountains of Oregon and flows in a generally northeasterly then easterly direction to its confluence with the Snake River in Washington State. Key tributaries to the mainstem of Asotin Creek include George Creek, Pintler Creek, Charley Creek, North and South Forks of Asotin Creek, and Lick Creek (tributary to the North Fork).

Because of the geographic division of many of the studies, the following breakdown of areas is used in most of the discussions that follow, rather than the 4th-field HUC watershed breakdown:

- Mainstem Snake River and Local Tributaries in the Reach from Hells Canyon Dam downstream to mouth of the Clearwater River (exclusive of the Imnaha, Salmon, and Grande Ronde Rivers, and Asotin Creek)
- Imnaha River Subbasin
- Asotin Creek Subbasin

7.1.2 Hydrology

The climate in this region is influenced by predominantly westerly winds from the Pacific Ocean and the Cascade Mountains. The region is generally characterized as temperate continental and dry. Most precipitation occurs during short intense summer storms and longer, milder winter storms. During the summer period, the area is influenced by marine air that moves into the area from the Pacific Ocean. In the winter, the area is influenced y Arctic air masses that spill over the Rockies. Local weather patterns may also be affected by the Wallowa Mountains and the Blue Mountains to the west of the Snake River.

A large portion of the streamflow in this area originates from snowpack or large rain-on-snow events that historically have resulted in major flooding. For example, major floods that caused substantial damage to private property and riverine habitat occurred in this region in December 1964, January 1965, January 1974, December 1996, and January 1997 (Kuttle

2002). In contrast, flows from areas upstream of Hells Canyon Dam, are controlled by numerous water control structures (e.g., dams or diversions for hydropower, irrigation, municipal and industrial uses, recreation, and other off-channel uses). As a result, the runoff pattern from upstream is highly regulated.

7.1.3 Land Cover

In general, this region was originally covered with prairie and canyon grasslands and shrub-steppe vegetation at low to mid-elevations. Forest became more prominent as elevation increased and in proximity to either the Wallowa or Blue Mountains (Kuttle 2002). Table 22 describes the present-day vegetation and land cover/use in this reach.

Higher elevations tend to be forested or geologically "young" areas, whereas the lower elevations are mainly used for agriculture (i.e., cropland or livestock production). An exception to this is the low elevations within Hells Canyon, which are non-agricultural and typically grasslands. The higher elevations of Hells Canyon watershed are mostly forested.

The Imnaha watershed higher elevations are also mostly forested, but the watershed also contains many grasslands and some agricultural areas. The Lower Snake-Asotin watershed is characterized by grasslands and agricultural lands at lower elevations and evergreen forests at higher elevations (Asotin County Conservation District 2004).

Table 22. General Land Cover Percent by Watershed within the Snake River Basin Hells Canyon Reach Geographic Area (percent of total watershed area)

Watershed Name	Agricultural and Urban	Herbland	Shrubland	Early-seral Forest	Mid-seral Forest/ Woodland	Late-seral Forest	Other[1/]
Hells Canyon	9%	30%	3%	28%	17%	13%	0%
Imnaha	10%	30%	3%	41%	10%	5%	2%
Lower Snake – Asotin	47%	26%	2%	13%	12%	0%	0%
Total	**22%**	**28%**	**2%**	**28%**	**13%**	**6%**	**1%**

[1/] Riparian, Alpine, Water, Rock, Barren
Source: Interior Columbia Basin Ecosystem Management Project GIS layers

7.1.4 Land Ownership

Table 23 presents the land ownership for each watershed in the geographic area. As can be seen, the majority of the geographic area is managed by the Forest Service, with a limited acreage by the BLM. The Hells Canyon and Imnaha watersheds are each over 70 percent in Federal ownership. Private lands dominate the Lower Snake-Asotin watershed, but Federal ownership covers 25 percent and Idaho and Washington state lands cover 8 percent combined.

Table 23. Land Ownership by Watershed within the Snake River Basin Hells Canyon Reach Geographic Area (percent of total watershed area)

Watershed Name	Private	Tribal	State	National Forest (non-Wilderness)	National Forest Wilderness	BLM
Hells Canyon	23%	-	2%	21%	52%	1%
Imnaha	28%	-	-	60%	11%	<1%
Lower Snake – Asotin	66%	-	8%	23%	-	2%
Total Basin[1\]	**40%**	**0%**	**3%**	**38%**	**18%**	**1%**

Source: Interior Columbia Basin Ecosystem Management Project GIS layers

7.1.5 Land Use

Approximately 18 percent of the geographic area is in designated wilderness. The wildernesses include the Hells Canyon Wilderness, primarily in the Hells Canyon watershed, and the Eagle Cap Wilderness in the Imnaha watershed. In addition, a large portion of the lands are managed as Federal Wild and Scenic Rivers, and National Recreation Areas. Private ownerships are largely dedicated to croplands or grazing.

Road densities are very low in the Hells Canyon watershed, slightly higher in the Imnaha watershed, and moderate in the Lower Snake-Asotin watershed, where the majority of the roads are rural roads and farm access roads (Table 24). Over 70 percent of the Hells Canyon watershed has road densities less than 0.1 mile/square mile. This density class represents 55 percent for the Imnaha watershed, but only 20 percent of the Lower Snake-Asotin watershed.

Table 24. Road Density Predicted Classes by Watershed within the Snake River Basin Hells Canyon Reach Geographic Area (percent of total watershed area).

Watershed Name	Road Miles per Square Mile					
	0 – 0.02	0.02-0.1	0.1-0.7	0.7-1.7	1.7-4.7	>4.7
Hells Canyon	70%	2%	5%	17%	5%	1%
Imnaha	51%	4%	7%	22%	14%	2%
Lower Snake – Asotin	15%	5%	27%	37%	11%	5%
Total Basin	**44%**	**4%**	**13%**	**26%**	**11%**	**3%**

Source: Map 3.28, Volume II, in Quigley and Arbelbide (1997). Data used to form these classes was statistically extrapolated from sampled 6th-field HUC road data.

7.2 OVERVIEW OF SEDIMENT TRENDS AND HISTORIC CHANGE

Table 25 presents some ratings developed by Interior Columbia Basin Ecosystem Management Project (Quigley and Arbelbide 1997), which can be used as overall indices of the relative level of disturbance in each watershed within the geographic area. The measures relate to the degree of hydrologic disturbance in forest and rangeland environments (based on the level of surface mining, dams, cropland conversion, and roads) and the degree of riparian disturbance in rangeland environments (based on the sensitivity of streambanks to grazing and the sensitivity of stream channel function to the maintenance of riparian vegetation).

Based on these ratings, some broad generalizations can be made. The overall level of disturbance is low to moderate in the Hells Canyon and Imnaha watersheds, depending on the category. In contrast, the Lower Snake-Asotin watershed has a moderate to high disturbance rating, depending on the category.

Table 25. Hydrologic Disturbance Rating of Forest and Rangeland Environments and Riparian Disturbance Rating of Rangeland Environments Relative to the Entire Columbia Basin by Watershed (4th-field HUC) within the Snake River Basin Hells Canyon Reach Geographic Area

Watershed Name	Hydrologic Disturbance Rating of Forest Environments	Hydrologic Disturbance Rating of Rangeland Environments	Riparian Disturbance Rating of Rangeland Environments
Hells Canyon	Moderate	Low	Moderate
Imnaha	Low	Low	Moderate
Lower Snake – Asotin	High	High	Moderate

Source: Maps 2.34, 2.35, and 2.36, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

Snake River Upstream of Hells Canyon Dam

The Snake River upstream of the Hells Canyon Dam includes lands in Idaho, Oregon, and small portions of Wyoming, Nevada, and Utah. In support of its application for a new Federal Energy Regulatory Commission license for the Hells Canyon Complex (HCC – this includes the Hells Canyon Dam at river mile [RM] 247.6, Oxbow Dam at RM 272.5, and Brownlee Dam at RM 284.9), IPC reviewed the history and current status of sediment transport from upstream areas into the reach downstream of Hells Canyon Dam (to the confluence with the Salmon River). The information in the application provides a detailed accounting of the investigations and findings of the study (IPC 2003).

The following briefly summarizes IPC's (2003) findings regarding trends and historic change:

- Beginning in the early 1800s, major sources of sediment in this area (from anthropogenic [human] activities) included trapping, mining, forest management, fires, and agricultural development. During the 1900s, further growth (particularly in agriculture) continued to add to this sediment load (IPC 2003).
- Numerous reservoirs have been constructed on the mainstem Snake River and along its tributaries since the early 1900s. For example, there are 13 major facilities on the mainstem Snake River between Jackson Dam in Wyoming and the HCC. These are used to store water for irrigation, flood control, hydropower, or some combination of the three. IPC also indicates that there are an additional 35 facilities (each with at least 5,000 acre-feet of storage capacity) located along the Snake River tributaries upstream of Brownlee Reservoir (IPC 2003).
- Primary sources of sediment occur in the upper parts of watersheds and particularly in the Idaho Batholith area (Boise River and Payette River watersheds). Sediment input to the lower Snake River from these areas has been largely cut off by the reservoirs (IPC 2003).
- The HCC essentially prevents all sediments in the Snake River upstream of the HCC (sand size and larger) from traveling to areas downstream. This conclusion by IPC is based on evaluation of sources upstream of Brownlee Reservoir and tributaries to the reservoirs of the HCC (IPC 2003).

Based on the above conclusions, the input of any sediment from areas upstream of Hells Canyon Dam is essentially negligible and this trend is expected to continue. The only exception might be fine sediment that can remain in suspension during higher flows.

Snake River Downstream of Hells Canyon Dam

Hells Canyon has steep continuous slopes that, in some areas, extend over a mile in elevation from the river to the crest of the canyon. Information on erosion characteristics and processes of soils in the canyon is limited. Soils in the area have been identified as potentially highly erodible. However, surface erosion processes are not common because of the protective cover of grassland and shrub-steppe vegetation as well as forest canopies on many north-facing side slopes (Ecovista 2004b). Historical human disturbances in the canyon affecting sediment have been relatively limited. The main erosion processes taking place in the canyon are various forms of mass wasting, with rock and debris flows being most prevalent (Ecovista 2004b).

Imnaha Subbasin

The primary source of sediment in the basin is roads, mainly along the mainstem Imnaha (Ecovista 2004a). Additional sediment sources include livestock grazing, rural home sites, pasture creation, and other activities that have modified soil and vegetation characteristics. The upper watershed has high sedimentation rates because of the instability of the barren granite mountain peaks. Debris flows and other processes of mass wasting, which are commonly triggered by thunderstorms or rain-on-snow events, are primary sources of sediment input to downstream areas (BLM 1993).

The Forest Service has closed, decommissioned, relocated, and restricted access on several roads or road segments to decrease sedimentation. For example, in 1990 and 1991, 6.4 miles of road were closed, 3 miles were obliterated, and 26 acres of roadbed were seeded (USDA Forest Service 1998). In addition, a 5-mile section of USFS Road 3900 was relocated or reconstructed. Other measures include seasonal road use restrictions and increased road maintenance. These measures will reduce sediment inputs in the future.

The Imnaha Subbasin Plan (Ecovista 2004a) provides information about historic changes and trends in grazing activities. In the 1800s and early 1900s, there was intense competition for grass in the Imnaha River Subbasin. This reached a peak in the 1930s when most riparian areas lost their native grasses and woody vegetation. This resulted in excessive erosion of soils into stream channels during spring runoff or following summer storm events (Wallowa County and Nez Perce Tribe 1993).

Due to concern about the deteriorated stream conditions, local groups, with the assistance of the Forest Service collaborated in reducing grazing in the basin. Improvement has occurred, mainly by passage of private and Federal land regulations in 1994, and again in 1997, that set forth certain rules governing land use activities and developments that are designed to stabilize the watershed and reduce sediment inputs (Ecovista 2004a).

Fires have also contributed to increased sheet and rill erosion in the Imnaha River basin. These are unpredictable events that may occur in the future. Areas affected may take several decades to recover, with highest sediment inputs occurring soon as the fire and decreasing as vegetation returns and streams stabilize.

Agriculture and timber harvest are identified as other additional sediment sources in this subbasin. Increased regulatory constraints for these activities (e.g., establishment of stream buffers along streams and BMPs for agriculture) should reduce sediment inputs in the future. The Subbasin Plan identifies the Wallowa Valley Improvement Canal (WVIC) between RM 31.9 and RM 33.7 on Big Sheep Creek as a contributor to changes in sediment availability and transport capacity due to decreased flows.

Present-day conditions in the Imnaha River subbasin are generally good relative to other subbasins in the Columbia River Basin (Ecovista 2004a). Reasons for this include the high percentage of the basin that is protected under management of the Forest Service and the general improvement in habitat conditions over the past 20 to 30 years resulting from better land management practices and reduced levels of road construction, logging, and grazing.

Asotin Subbasin

This summary is based on the key findings of the Asotin Subbasin Plan (Asotin County Conservation District 2004) that address sediment sources and transport in the Asotin subbasin. Historically, Asotin Creek had a less severe gradient, a meandering flow pattern, and well developed floodplain connections. In contrast, much of Asotin Creek and its tributaries have been straightened, diked, or relocated. Farming, timber harvesting, and urbanization have changed the runoff patterns in the Asotin Creek subbasin. Other contributors to these conditions include modification of the riparian zone, including tree removal, road building, grazing, soil compaction, and flood control projects or stream channel straightening. Major flooding events (e.g., in 1997) have substantially altered the riparian vegetation. Stream channel instability in the Asotin Creek subbasin includes channel widening, downcutting, vertical cut banks, and excessive gully development. Livestock grazing in the Asotin Creek subbasin is a major land use, starting in the early 1800s. The Forest Service implemented regulations on its lands in 1929 with the Asotin Allotment, which was followed by the Peola-Pomeroy allotment in 1939.

The Subbasin Plan characterized the current trends in habitat in the Asotin subbasin as improving. The primary reason cited for this improvement is the implementation efforts of the Asotin Creek Model Watershed Plan. Additional improvement should occur as a result of the subbasin planning efforts.

7.3 SEDIMENT SOURCES AND YIELD

7.3.1 Overview Studies of Erosion and Mass Wasting Hazards

In this section, ratings and other results from a number of overview studies that were conducted across the entire Columbia River basin or over larger areas are presented for perspective and comparison purposes. The methods behind these studies are summarized briefly below and in more detail in Section 4.1.

The Interior Columbia Basin Ecosystem Management Project conducted by the Forest Service and the BLM (Quigley and Arbelbide 1997) developed various soil erosion, mass failure, and sediment hazard ratings for nonpoint sources for each watershed, relative to all Columbia Basin watersheds. The key ratings are shown for the Snake River Basin – Hells Canyon Reach geographic area in Tables 26 and 27.

Table 26. Soil Erosion, Mass Failure, and Sedimentation Measures Relative to the Entire Columbia Basin by Watershed (4th-field HUC) within the Snake River Basin Hells Canyon Reach Geographic Area .

Watershed Name	Surface Soil Erosion Hazard	Earth Flow Hazard	Debris Avalanche Hazard	Sediment Delivery Potential	Sediment Delivery Hazard
Hells Canyon	High	Mod - High	High	High	High
Imnaha	High	Mod - High	High	High	High
Lower Snake – Asotin	High	Low - Mod	Low - Mod	High	High

Source: Maps 2.10, 2.11, 2.12, 2.13, and 2.15, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

Table 27. Road Erosion Hazard and Road Sediment Delivery Hazard Relative to the Entire Columbia Basin by Watershed (4th-field HUC) within the Snake River Basin Hells Canyon Reach Geographic Area

Watershed Name	Road Erosion Hazard	Road Sediment Delivery Hazard
Hells Canyon	Low	High
Imnaha	Low	Mod - High
Lower Snake – Asotin	Mod - High	High

Source: Maps 2.16 and 2.17, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

NMFS (Baker et al. 2005) has developed two draft models for estimating increases in erosion rates relative to natural levels. Based on this study, erosion rates in the Hells Canyon watershed are mostly in the range of 1 to 2 times historical rates, except in the small northern portion that is mostly private lands where erosion rates are estimated at 2 to 3 times historical rates. Erosion rates for the Imnaha watershed are also mostly estimated at 1 to 2 times historical; however, the western edge of private lands is estimated at mostly in the range of 3 to 8 times historical. The Lower Snake-Asotin watershed is the most variable, with rates ranging from 1 to 2 times historical in a few small subwatersheds to 7 to 9 times historical in several low elevation agricultural areas.

The USGS developed a landslide overview map (Radbruch-Hall et al. 1982). This map delineates areas where large numbers of landslides have occurred and areas which are susceptible to landsliding in the conterminous United States. Within the geographic area, there are no areas mapped as having a moderate or high incidence of past landslides or susceptibility to future landslides, except for an area that barely enters the Hells Canyon watershed along its far eastern edge.

A NRCS analysis of cropland for 1997 in the conterminous United States found that the geographic area had no areas of highly erodible cropland and no areas of highly erodible or non-highly erodible cropland with excessive erosion above the tolerable soil erosion rate, except for some areas in the lower elevations of the Lower Snake-Asotin watershed (NRCS 2000).

7.3.2 Specific Studies within the Geographic Area

Upstream of Hells Canyon Dam

The IPC studies of this reach evaluated potential sediment inputs from upstream of the Brownlee Reservoir and potential inputs from tributaries to the HCC reservoirs. IPC concluded that the heavily armored streambed (both above and below the HCC) demonstrates that the sediments stored in the bed are generally not available for transport or geomorphic processes. Findings by IPC (2003) include:

- HCC prevents essentially all of the sand size and larger sediment in the Snake River upstream of the HCC from traveling to the Hells Canyon reach of the Snake River.
- More than 96 percent of the material trapped in Brownlee Reservoir is fine sand (or smaller) and therefore, smaller than the majority of material found in the sandbars in Hells Canyon.
- Brownlee Reservoir has trapped about 62,000 acre-feet of sediment (estimated); an average of 1,550 acre-feet per year during the 40-year period between when Brownlee Dam was closed in 1958 and a bathymetric survey was completed in 1998. [To put this volume in perspective, this converts to nearly 2.4 million tons per year, assuming a unit weight of deposited sediments of 70 lbs per cubic foot, which is slightly higher than the 2.3 million tons/year measured in the USGS study for the Snake and Clearwater above Lewiston (Jones and Seitz 1980)].

Snake River Downstream of Hells Canyon Dam

Ecovista (2004b) prepared a subbasin assessment for the Snake Hells Canyon subbasin, which included an assessment of multiple attributes such as land use and cover, water quality, human disturbances, and limiting factors to production of anadromous salmonids. This subbasin plan was used extensively in describing the sediment characteristics for this area.

A large portion of the lands adjacent to the Snake River between Hells Canyon Dam and the confluence with the Salmon River is managed by the Forest Service, either as a designated Wild and Scenic River, Hells Canyon National Recreation Area, Hells Canyon Wilderness, or as general National Forest System lands (Figure 5). Overall, it is anticipated that sediment management practices under these designations will result in sediment inputs to the Snake River reach downstream of HCC at either present or lower levels.

As previously indicated, information on sediment sources or transport in the Hells Canyon reach is very limited (Ecovista 2004b). The most extensive work was conducted by IPC for its application for a new Federal Energy Regulatory Commission license (IPC 2003). In its application, IPC reported on studies that evaluated sediment inputs to the reach of the Snake River downstream from HCC from sources other than those upstream of Hells Canyon Dam. This included an evaluation of potential sediment input from tributaries, sandbars, hill slopes/terraces, and gravel bars/bedload.

The following summarizes IPC's findings for each of these areas. It also includes studies conducted by other sources, as noted.

Local Tributaries Upstream of Salmon River Confluence

Nearly all "fish-bearing" tributaries to the Snake River in the Hells Canyon National Recreation Area have high water quality, with good streamside cover and little streambank instability (Ecovista 2004b). IPC evaluated the sediment load from 17 tributaries (not including the Salmon or Imnaha Rivers) in a study area from Hells Canyon Dam downstream to near the confluence with the Clearwater River. Fifteen of these tributaries are upstream of the Salmon River because IPC felt that the Salmon River provides significant amounts of sediment, which mask any potential effects of sediment from sources upstream of this major tributary. Two other tributaries studied (Cook Creek and Cherry Creek) are immediately downstream of the confluence with the Salmon River.

In general, IPC described the 17 tributaries as having "steep slopes, relatively small drainage areas, and limited groundcover". With these conditions, IPC indicated "sediment conditions would be expected to be high". Four of these tributaries (Deep Creek, Getta Creek, Wolf Creek, and Divide Creek are listed under Section 303(d) for sediment. The TMDLs for these listings were due for completion by December 31, 2005.

For the tributaries evaluated, IPC did not identify specific sources of sediment or trends. IPC did, however, develop estimates of sediment input from each of the 17 tributaries. These estimates were based on field sampling and modeling results.

IPC (2003) determined that the two largest relative sources of sediment were Granite Creek and Sheep Creek, which are near the upper end of the study area. However, habitat conditions in these tributaries are less limited than in other tributaries because they originate in wilderness areas (Ecovista 2004b).

The studies by IPC (2003) made the following conclusions about input from the tributaries:

- The tributaries between the HCC and the Salmon River (not including the Imnaha River drainage) account for an average sediment yield of 8.60 million tons per year. The same calculations for sand and spawning-size gravels, respectively, are 1.44 and 4.14 million tons per year. (Note: This number does not agree well with the monitoring performed by the USGS (1980) which indicated that the sediment load for this reach, including the Salmon and Grande Ronde, was 1.76 million tons per year.).
- Tributaries in Hells Canyon not affected by HCC can supply sediment in the size range useful for maintaining sediment-related features such as sandbars and spawning sites in Hells Canyon.
- From visual observations, it appears that these tributaries have supplied sediment to the Snake River in Hells Canyon in recent years under current hydrologic conditions.
- The sediment is supplied directly from the tributaries during peak-flow events that occur on relatively short (geologically) time scales (tens to hundreds of years).

Local Tributaries Downstream of Salmon River Confluence

Tributaries downstream of the confluence of the Snake and Salmon Rivers have been described as degraded by road construction, timber harvest, development in riparian areas and floodplains, agriculture, livestock grazing, mining, recreation, and water uses. As a result, these lands have reduced water quality and elevated levels of sediment (Ecovista 2004b).

The Asotin Subbasin Plan (Asotin County Conservation District 2004) primarily addresses the Asotin Creek watershed. However, it also includes two creeks that flow directly into the Snake River downstream of the Salmon River. These are Tenmile and Couse Creeks. The Asotin Subbasin Plan indicates that little technical information is available for either creek.

The Limiting Factors Analysis report prepared by Kuttle (2002) indicated that sediment load and habitat diversity were problems in the Tenmile Creek watershed. This may improve in the future, however, because most of this stream is included the CREP. The Subbasin Plan recommends that when the stream buffer portion of this program is completed, efforts should be focused on upland areas to further reduce sediment to Tenmile Creek.

Couse Creek is “thought” to be limited by sediment loads and lack of habitat diversity (Kuttle 2002), but little technical information is available. Crouse Creek is not a priority in the Asotin Subbasin planning process, but is recommended for future consideration. However, one specific project implemented by the Asotin County Conservation District, landowners, and the NRCS involved fencing of over 8 miles of stream to restore riparian buffers. The project was funded by the CREP, BPA, and WDOE (WDOE 2005).

There are also small drainages on the east side of the Snake River that the IDEQ includes in its designation of the "Asotin – Lower Snake River Subbasin". One of these drainages is Tammany Creek. It is currently listed under Section 303(d) for excessive sediment. A TMDL has been developed for this drainage (IDEQ 2001). This TMDL is noteworthy because the Tammany Creek drainage likely represents several similar small local drainages in the lower elevations of the Asotin and nearby subbasins.

Following is a brief overview of the Tammany Creek drainage and the TMDL actions.

Watershed Description: Tammany Creek originates in the farmlands southeast of Lewiston and flows in a predominantly northwesterly direction to where it joins the Snake River. The creek is approximately 13 miles long and includes intermittent and perennial channels. The watershed is approximately 35 square miles and is predominantly agricultural land including both cultivated crop and livestock range uses (IDEQ 2001). The stream channel varies from well-developed floodplains to highly entrenched channels. The IDEQ indicates that the highly entrenched channels are particularly difficult problems for the control of instream sediment loading.

Sediment Sources: Sediment sources within the Tammany Creek watershed are sheet and rill erosion from crop and grazing lands, pasture land surface runoff, unpaved roadway runoff, rural development activities, animal feeding operations, wildlife stream bank damage, and direct stream bank erosion. The primary sediment sources have been identified as sheet and rill erosion, surface runoff from rural developments and stream bank erosion. The sediment sources are considered non-point sources (IDEQ 2001).

Through a combination of field surveys, water quality data analysis, and modeling of hydrologic and erosion processes, it was determined that sediment loading in Tammany Creek is above background levels by almost 3,000 tons per year and that this excess occurs from December through June during periods of higher flows. Mean monthly flows range from 0.48 cfs in August to 2.50 cfs in April. Therefore, even though this is a very small stream, it does contribute to the overall sediment input to the Snake River.

Management Plans: Sediment reductions need to occur in Tammany Creek to meet Idaho State Water Quality Standards and the requirements of the TMDL. The TMDL planning process is under development for inclusion in an existing PL-566 watershed project. This existing project is being implemented by the NRCS and the Nez Perce Soil and Water Conservation District. The project will be monitored by the Idaho Association of Soil Conservation Districts. The Association will be monitoring the effectiveness of BMPs implemented as part of the PL-566 project and the TMDL. The Association will report information generated to the watershed advisory group. The IDEQ also has reporting and monitoring responsibilities through the Idaho's reporting requirements under Sections 305(b) and 303(d) of the Federal CWA.

Conclusions and Recommendations: Although Tammany Creek is a very small drainage, it does carry sediment loads that are discharged into the Snake River very near the Lewiston area. These inputs are from non-point sources of discharge that are being dispersed across the drainage. An implementation plan has been initiated and will include BMPs and other aspects of the existing PL-566 project.

The inclusion of Tammany Creek and similar small drainages in this evaluation is likely very important because of the dispersed and cumulative effects that this drainage represents. It is also important to note that a TMDL has been developed and an implementation plan initiated for reducing sediment loads. Over time, if this plan succeeds, sediment reductions should occur. The Corps should track the implementation planning process and any monitoring and evaluation studies that may occur as a result of this process.

Sandbars, Hillslopes/Terraces, and Gravel Bar/Bedload Movement:

IPC evaluated non-tributary sediment input from sources within Hells Canyon downstream of Hells Canyon Dam (e.g., hillslopes/terraces and gravel bar/bedload movement) and the deposition or erosion of sandbars and banks during the period of 1997 to 2000 (IPC 2003).

Using X-ray diffraction, field studies, sediment transport modeling, and other approaches, IPC (2003) found that:

- Course sediment and spawning gravels in the streambed are of local origin and were not transported from upper parts of the basin.
- The heavily armored bed below HCC demonstrates that the sediments stored in the bed are generally not available for transport or geomorphic process.
- Transport mechanisms of the mainstem river upstream of the HCC are insufficient to mobilize and transport material such as that found in the riverbed of the Hells Canyon reach.
- River banks in Hells Canyon are very stable, with only 2 percent showing evidence of erosion.
- Terraces along the canyon are generally stable for the large majority of flows but may become unstable when subjected to rapid drawdown of water surface elevations following major flood events.
- Sandbars respond in size and shape to varying flows and sediment loads in the river. Each sandbar in the study reach experiences erosion. Possible reasons suggested for erosion of the sandbars were jet boats (and their associated effects of wave action and jet pumps) and foot traffic associated with landing of boats. Overall, however, the number of sandbars in the Hells Canyon Reach has been relatively stable from 1973 to 1997.

Imnaha Subbasin

The Imnaha Subbasin Plan (Ecovista 2004a) provides key information about sediment sources and transport in the Imnaha River subbasin. The Plan provides extensive details on natural resource attributes (e.g., soils, elevations, erosion) and land use (e.g., National Forest, cattle allotments, streams, hydrology). This document and its supplements were the primary sources of general information about this area.

The Imnaha Subbasin Plan (Ecovista 2004a) describes the general features of the subbasin as:

- The narrow river terraces along the banks of the Imnaha River and its major tributaries are primarily formed from alluvial deposits. The sources of these deposits are river rock from upstream, colluvial basalt from the canyon side slopes, and Mazama ash (volcanic source) and windblown silt mixed in with the soils that formed on the river terraces. The terraces are located in the central part of the Imnaha River and lower Big and Little Sheep creeks. The main channels in these areas have some ability to meander through the unconsolidated sediment. About 84 percent of the riverbanks in the subbasin, including these terraces, are stable due mainly to vegetation and course sediment (Ecovista 1994a).
- The primary source of sediment in the basin is roads, mainly along the mainstem Imnaha. Additional sediment sources include livestock grazing, rural home sites, pasture creation, and other activities that have modified soil and vegetation characteristics.
- The upper watershed has higher sedimentation rates because of the instability of the barren granite mountain peaks. Debris flows and other processes of mass wasting, which are commonly triggered by thunderstorms or rain-on-snow events, are primary sources of sediment input to downstream areas (Ecovista 2004a).

The Imnaha Subbasin Plan (Ecovista 2004a) identifies naturally occurring unstable barren granite mountain peaks in the upper portion of the subbasin as being high sediment sources. These are natural processes that may or may not continue into the future. They are exacerbated by thunderstorms or rain-on-snow events that trigger debris flows or other forms of mass wasting. Similarly, bank erosion is accelerated by these same events. One of the largest single sediment input events in recent years was from landslides in the wilderness areas of the headwaters during the 1997 flood.

The Subbasin Plan characterized Big Sheep and Little Sheep creeks, two major tributaries in the Imnaha River Basin, as “geomorphologically young systems with active erosion in the oversteepened headwalls of the Wallowa Mountains.” Snow avalanches and debris flows occur frequently contributing sediment and large woody material to downstream reaches (Ecovista 2004a). These natural processes are likely to continue.

The Subbasin Plan indicates “roads represent the primary source of sediment in the subbasin, and specifically within the mainstem Imnaha.” The large flood event in 1997 caused considerable disruption of the road infrastructure, which resulted in the needed for major repairs and reconstruction. Repair work emphasized the need to “fortify” the structures to protect against similar future flood events. This has resulted in “detrimental” changes to the channel morphology and hydraulics in some areas.

A number of isolated sediment studies have been conducted in the Imnaha River Basin. The Imnaha Subbasin Plan indicates that fine sediment problems are localized. The Plan attributes this to the stability of the system, which is characterized by non-erodible Columbia River basalt, metamorphosed volcanic rock, coarse alluvium, and hydrophilic ash that overlies upland areas. The Forest Service (Ecovista 2004a) found that forest fires and timber harvest accelerated sheet and rill erosion in the Big Sheep Creek watershed.

The Forest Service has also documented other incidents of sediment input into the Imnaha River (Ecovista 2004a). These incidents include streambank erosion, gully erosion, road development and grazing. The 1997 flood event and a thunderstorm in August 1992 both resulted in landslides in the Imnaha subbasin. The Forest Service believes that this material will move in “pulses” through the subbasin until stabilized by large woody debris, riparian vegetation, or channel processes that bring the materials in to equilibrium with stream flows. The Subbasin Plan indicates that many of the headwater tributaries have high gradients and, combined with effects from land use activities, these areas produce a very flashy flow regime that is often capable of mobilizing bedload.

As part of the subbasin planning process, an Ecosystem Diagnosis and Treatment (EDT) analysis was conducted (Mobrand Biometrics 2006). This process evaluates existing information and knowledge of local biologists to determine the current state of a watershed and helps to prioritize areas for protection or restoration of fish habitat. The results of this analysis are presented in the Subbasin Plan. The Subbasin Plan identifies a need to develop a subbasin-wide database to facilitate monitoring and evaluation of sedimentation trends.

Asotin Subbasin

The Asotin Subbasin Plan (Asotin County Conservation District 2004) provides key information about sediment sources and transport in the Asotin River subbasin. The plan and its supplements were primary sources of information for this section because the information is relatively recent and provides a good perspective on sediment in the basin.

Key findings in the Asotin Subbasin Plan that address sediment sources and transport include the following:

- The Asotin Creek Basin consists of basaltic rocks that are overlain by highly erodible fine-grained loess soils. The underlying bedrock in the basin is tilted slightly to the north and east which results in streams that are cut down and form very steep and generally narrow, V-shaped canyons (Asotin County Conservation District 2004).
- Historically, Asotin Creek had a less severe gradient, a meandering flow pattern, and well developed floodplain connections. In contrast, much of Asotin Creek and its tributaries have been straightened, diked, or relocated (Asotin County Conservation District 2004).
- Farming, timber harvesting, and urbanization have changed the runoff patterns in the Asotin Creek Basin. Other contributors to these conditions include modification of the riparian zone, including tree removal, road building, grazing, soil compaction, and flood control projects or stream channel straightening (Asotin County Conservation District 2004).
- Major flooding events (e.g., in 1997) have substantially altered the riparian vegetation (Asotin County Conservation District 2004).
- Stream channel instability in the Asotin Creek Basin includes channel widening, downcutting, vertical cut banks, and excessive gully development (Asotin County Conservation District 2004).
- Livestock grazing in the Asotin Creek Basin was a major land use, starting in the early 1800s. The Forest Service implemented regulations on its lands in 1929 with the Asotin Allotment, which was followed by the Peola-Pomeroy allotment in 1939 (Asotin County Conservation District 2004).

As part of the subbasin planning process, an EDT analysis was conducted. This process evaluates existing information and knowledge of local biologists to determine the current state of a watershed and helps to prioritize areas for protection or restoration. The results of this analysis are presented in the Subbasin Plan.

7.4 MANAGEMENT PRACTICES AND RESTORATION

Upstream of Hells Canyon Dam

Although there are dozens of plans and regulatory processes (e.g., Federal, state, local, and private) to reduce sediment input in areas upstream of the HCC, the trapping efficiency of the HCC reservoirs and other water resource projects upstream is high, and therefore, sediment input from areas upstream of Hells Canyon Dam is considered negligible.

Snake River Downstream of Hells Canyon Dam

Practices

Under the Wild and Scenic River, National Recreation Area, and Wilderness designations, little or no development would be anticipated and sediment levels would likely remain at current or lower levels. For management of National Forest lands, the trend is to reduce sediment inputs to water bodies through updated standards and guidelines, Land and Resource Management Plans, and other regulatory mechanisms that specifically address sediment issues associated with timber harvest, road management (including construction measures and road decommissioning), and riparian habitat protection/management.

On private lands in the northern portion of this reach (on the Idaho side of the river), most of the land use in this area is agriculture (Figure 2). A large number of agencies, Tribes, and citizen groups are addressing sediment input problems, mainly in relation to loss of productive soil and potential impacts on aquatic habitat and fish species listed under the ESA. Examples include the Asotin County Conservation District, NRCS, WSU Cooperative Extension and others (Kuttle 2002). In addition, soil erosion issues are addressed under the Federal CWA, Farm Security and Rural Investment Act of 2002, Water Resources Development Act, and others.

BMPs have been published in the Idaho Agricultural Pollution Abatement Plan for agricultural practices (including grazing). However, these are largely voluntary at this time. Improvements are generally implemented with willing landowners through the efforts of several agencies (e.g., NRCS, soil and water conservation districts, Idaho Department of Fish and Game, Idaho Department of Water Resources, Nez Perce Tribe, and not-for-profit groups).

Examples of BMPs that are being implemented include no-till/direct seeding, installation of terraces, sediment basins, vegetated filter strips, and enrollment of acreage in the CRP. This voluntary program is directed at conversion of annual cropland to perennial grass stands for wildlife habitat benefits – which, in turn, stabilizes soils and reduces sediment input to streams.

Other measures include improving riparian buffers through approaches such as fencing to exclude livestock, planting degraded areas, and development of alternate livestock watering areas. Instream measures include placement of large rocks and large woody debris, which tend to restrict movement of sediments.

Funding for many of the habitat improvement projects is derived from the BPA. Under this funding, the organization that implements a particular project needs to follow BMPs developed by the BPA and other Federal, state, or local permitting requirements (BPA 1997). Additional funding sources can include the Salmon Recovery Funding Board in Washington

State, the OWEB in Oregon State, the EPA, and the Corps (e.g., projects under the Water Resource Development Act).

Projects

No specific projects to restore or reduce sediment were identified in IPC's license application. However, tentative plans for reducing sediment input via road management BMP has been proposed for the HCC relicensing for areas within the project boundary. In addition, IPC found that about 6 acres of shoreline have eroded along the Snake River below Hells Canyon Dam over the past 30 years. IPC attributes this to a number of potential causes including its operations and to other activities such as boat-driven waves, camping, trails, dispersed recreation, livestock grazing, and road or other construction or maintenance activities under the action of Federal agencies, public interest groups, or private landowners.

Outside of its own operations, IPC has indicated that it has little management authority to implement enhancement or restoration plans because most of these activities fall under the jurisdiction of the Forest Service, which manages the majority of the downstream lands along this reach. The lands managed by the Forest Service are primarily in the categories of wilderness, Wild and Scenic River, or National Recreation Area where minimal or no development would likely occur.

In areas downstream of the confluence with the Salmon River, a large number of projects have been implemented or are planned for private or public lands. These include projects funded for habitat restoration, BMPs for croplands, better road management, and other potential measures to decrease the current levels of sediment input to the Snake River. Most of these are tiered to programs directed at either restoration or enhancement of habitat for species listed under the ESA, soil conservation, or regulations promulgated under the Federal CWA.

Imnaha Subbasin

Practices

More than half of the Imnaha River basin is managed by the Forest Service (particularly in the eastern half of the upper basin) as multiple use forest lands or as wilderness. As such, these lands would be managed under a no development scenario (wilderness) or under Forest Service standards and guidelines, which are designed to maintain or improve existing conditions (e.g., decrease sediment input). Therefore, there is likely to be decreases in sediment input from these lands in the future.

Other portions of the Imnaha River basin are in private ownership. A wide variety of regulatory processes (e.g., TMDL, shoreline management, subbasin plans, and others) and voluntary programs (e.g., CREP) are designed to decrease sediment loading, particularly from croplands or grazing, on private lands. In addition, habitat restoration or protection measures have been implemented (mainly for salmon recovery in relation to the ESA) or will be implemented by various groups such as BPA, the Salmon Resource Recovery Board, the OWEB, and public or private groups. It is anticipated that this trend to stabilize habitat through these various groups, agencies, or Tribes will continue into the future, thus further decreasing sediment inputs.

Projects

The Subbasin Plan indicates that there are "currently, and have been historically, numerous enhancement/restoration efforts designed to improve instream habitat diversity throughout various portions of the Imnaha subbasin." It is likely that many of these would contribute to stream stability and thus, reduce sediment inputs. For example, livestock exclosures and woody debris reintroductions by the Forest Service have improved gravel accrual rates in the mainstem Imnaha River (Ecovista 2004a).

Specific strategies that are directly related or indirectly related to promoting decreased sediment inputs in the Imnaha River Basin are outlined in the Subbasin Plan. Already numerous habitat improvement projects have been constructed or management plans implemented. Future funding, however, is an unknown. Specific strategies include:

- Maintain currently functioning wetlands and restoration of degraded wetlands
- Maintain currently functioning riparian areas and restore degraded riparian areas
- Reduce the impact of the transportation system on wildlife and fish populations and habitats
- Restore the composition, structure, and density of forests to within the historic range of variability
- Restore non-functional riparian zones, maintain/protect functional riparian zones, ameliorate grazing impacts, restore natural floodplain processes, restore channel form
- In problem areas, reduce sedimentation impacts to aquatic focal species
- Reduce the risk of catastrophic fire

The Subbasin Plan also prioritizes many of these measures in specific areas throughout the Imnaha River Basin. In addition, specific areas in the Imnaha River basin have been designated in the Subbasin Plan for protection, protection and restoration, and restoration.

Asotin Subbasin

Practices

The Subbasin Plan identifies (in specific reaches of Asotin Creek), the causes of habitat deterioration, assumptions considered, hypotheses for testing, and assumptions. It also identifies priority protection area strategies.

In addition to these plans, the Asotin Creek Subbasin Plan also has established a management plan that is directed at enhancement of aquatic and terrestrial habitat over the next 10 to 15 years. The plan is to be implemented by landowners, conservation districts, agencies, tribes, and others. The plan is voluntary, and will be implemented, to the extent possible, by BPA funds or other available funding sources.

Projects

The Asotin Subbasin Plan indicates that multiple projects to improve or protect aquatic and terrestrial habitats have been implemented by Federal, state, tribal, and local entities. For example, the Plan indicates that, since 1996, a total of 581 fish habitat-related projects have been implemented (through May 2004). Most of these projects directly or indirectly affect sedimentation. They include various activities such as:

- Instream habitat construction
- Direct seeding
- Establishment of permanent grasses/pastures/haylands
- Sediment basin construction/maintenance
- Upland multi-purpose pond construction
- Terrace construction
- Reforestation/tree planting
- Spring development
- Erosion control (critical area planting, grassed waterways, conservation cover)
- Pipeline installation
- Water gaps and windbreaks
- Riparian fencing and tree planting

7.5 SUMMARY OF PRELIMINARY CONCLUSIONS

Upstream of Hells Canyon Dam

Inputs of sediment to the Snake River from areas upstream of Hells Canyon Dam are likely negligible, based on the studies by IPC, the number of major water resource facilities (primarily dams), and increasing regulatory requirements focused on decreasing sediment inputs. Therefore, it is recommended that no priority be initially assigned to this potential source of sediments and that no further considerations be made for evaluations of sediment inputs from upstream of HCC, unless current conditions (e.g., regulatory constraints, continued operation of the HCC and other water resource facilities) change significantly.

Snake River Downstream of Hells Canyon Dam

The Forest Service manages the majority of lands in the upstream half of this reach. Sediment input does occur from tributaries and estimates of the volumes of sediment have been made by IPC (2003). Other potential contributors are likely small (e.g., erosion of stream banks and sandbars, movement of bedload, and hillslope erosion) because this reach has been generally characterized as stable (due to regulated flows, arid climate, and minimal upslope activities on federally managed lands such as the Wild and Scenic River, National Recreation Area, and Wilderness Areas). Overall, unless a catastrophic hillslope failure or other similar unanticipated event occurs (e.g., major flood), the sediment input to the Snake River from sources in this reach is likely small. In addition, the future trend would be expected to remain at existing levels or somewhat lower due to upslope management practices (particularly by the Forest Service) that would tend to decrease inputs (e.g., through increase road management activities).

The IPC information concerning sediment input from the 17 tributaries appears to be of interest in considering the overall sediment sources and transport within the Snake River upstream of its confluence with the Clearwater River (IPC 2003). In addition, one of the tributaries (Divide Creek) involves land ownership that is primarily private. IPC's information on the 17 tributaries can be evaluated for its potential for incorporation into the overall study. Also, the TMDL for Tammany Creek should be useful for evaluating small local drainages in the lower portion of the Snake River reach between Hells Canyon Dam and the confluence with the Clearwater River.

For other areas on private lands, a number of funding mechanisms and habitat restoration/soil conservation/water quality programs are designed to improve stability within these watersheds, thus providing a reduction in sediment input.

Imnaha Subbasin

As indicated in the Subbasin Plan, the Imnaha River basin is in generally good condition compared to other subbasins in the Columbia River basin. Conditions have improved over historic levels as a result of increased emphasis (particularly on the National Forest System lands) on improving habitat (both terrestrial and aquatic), which provides a trend to increased stability and less sediment input to the system. However, catastrophic events such as the 1997 flood cannot be predicted, and thus, conditions could change.

Overall, with the generally good conditions in the Imnaha River subbasin and the specific strategies in place to further stabilize the subbasin, sediment inputs should decrease in the future. With a large portion of the subbasin managed as National Forest and with updated approaches for managing these lands to improve or protect aquatic resources (e.g., road decommissioning, protection of riparian areas, etc.), this should enhance the overall basin efforts.

With the subbasin planning process well underway, opportunities for the Corps might include participation on some projects that specifically address major sediment issues or possible joint funding for these types of projects.

Asotin Subbasin

Overall, the specific strategies in place to further stabilize the Asotin Creek Subbasin, sediment inputs should decrease in the future. The upper portion of the subbasin is managed as National Forest and with updated approaches for managing these lands to improve or protect aquatic resources (e.g., road decommissioning, protection of riparian areas, etc.). This should enhance the overall basin efforts. In addition, processes are in place to reduce sediment inputs from agricultural lands. However, the agricultural areas in the lower portion of this subbasin including adjacent areas along the Snake River, likely produce a considerable amount of sediment input to the Snake River.

With the subbasin planning process well underway, opportunities for the Corps might include participation on some projects that specifically address major sediment issues or possible joint funding for these types of projects.

8. GRANDE RONDE RIVER SUBBASIN

8.1 THE SETTING

8.1.1 Geography and Topography

The Grande Ronde River subbasin comprises 4,130 square miles with the majority of the subbasin in northeastern Oregon and a small portion in southeastern Washington (Figure 6). It consists of three 4th-field (HUC) watersheds, the Upper Grande Ronde, Wallowa, and Lower Grande Ronde (Table 28.). The basin consists largely of rugged mountains and includes portions of the Blue Mountains in the west and northwest and the Wallowa Mountains in the southeast. Peaks in the Blue Mountains reach elevations of 7,700 feet and those in the Wallowas reach nearly 10,000 feet. The Grande Ronde and Wallowa Rivers flow through major valleys at relatively high elevations. The Grande Ronde valley is relatively flat valley at elevations between 2,600 and 2,800 feet and the Wallowa valley is steeper and lies at elevations between 2,800 and 4,700 feet. The Grande Ronde flows into the Snake River about 20 miles upstream of the town of Asotin, Washington (Grande Ronde Model Watershed Program 2004).

Table 28. Size and Cataloging Unit Number for Watersheds within the Grande Ronde River Basin

Watershed Name	Cataloging Unit Number	Area (Square Miles)	Percent of Study Area
Upper Grande Ronde	17060104	1,650	40%
Wallowa	17060105	950	23%
Lower Grande Ronde	17060106	1,530	37%
Total Grande Ronde River Basin		**4,130**	**100%**

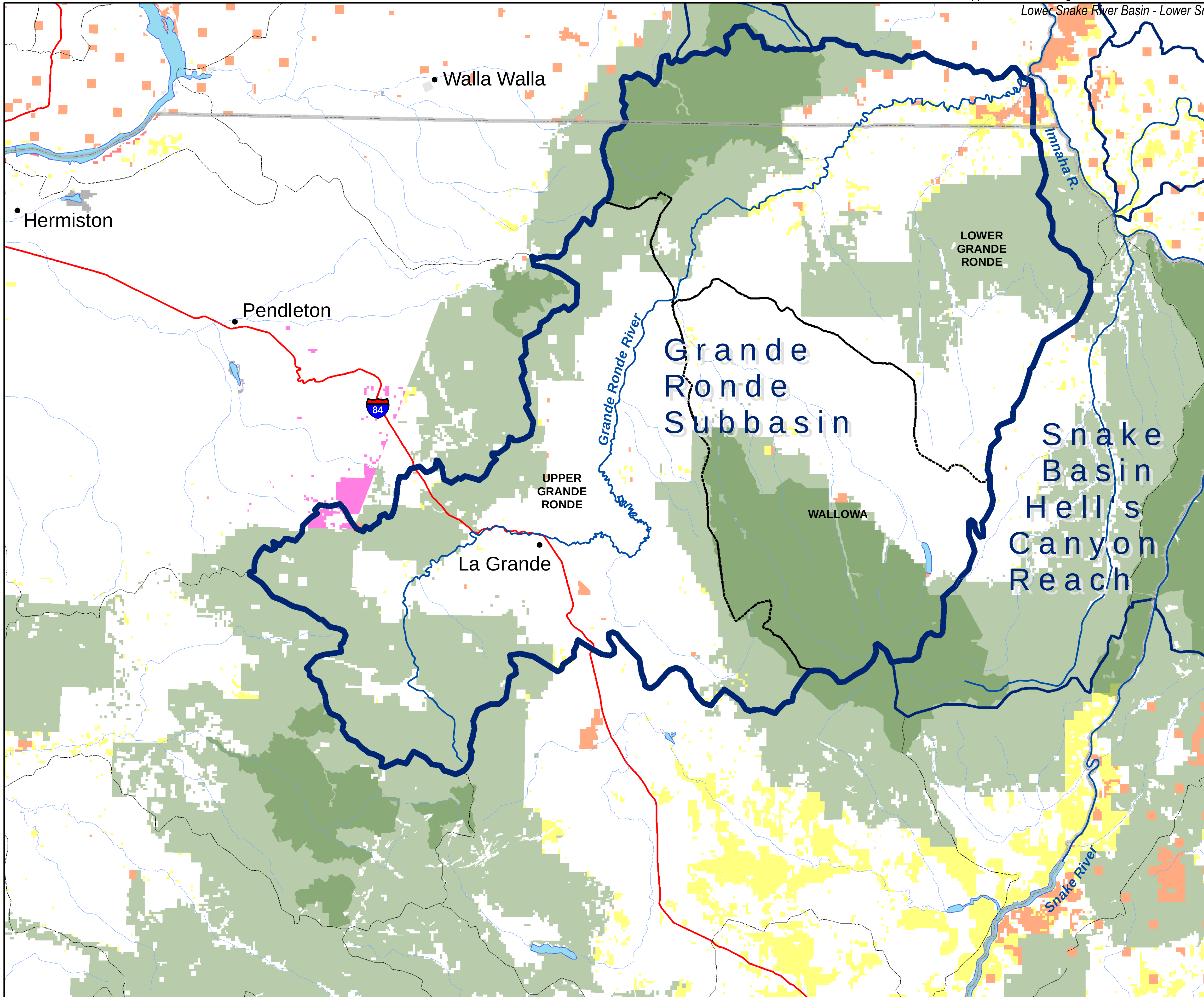
Source: Interior Columbia Basin Ecosystem Management Project GIS layers

The Grande Ronde subbasin has a complex geologic history. Rocks of the Columbia River Basalt Group dominate the surface geology of the area. Rocks older than the Columbia River Basalts occur only in the headwaters areas of the Grande Ronde River, the Wallowa River, and Catherine Creek. These rocks consist of granitic intrusives and older volcanics with associated sedimentary deposits. The structural geology of the area is also complex and many faults cut the bedrock formations. These faults follow a general northwest-southeast trend. The presence of hot springs and regional, deep ground water flow systems indicate ongoing tectonic activity (Grande Ronde Model Watershed Program 2004). Soils in the Grande Ronde River subbasin are highly variable and may range from those on thin, rocky, low-productivity ridgetop scablands to those in deep ash accumulations on very productive sites.

Figure 6

Ownership Map for the Grande Ronde Geographic Area

Lower Snake River Sediment Study



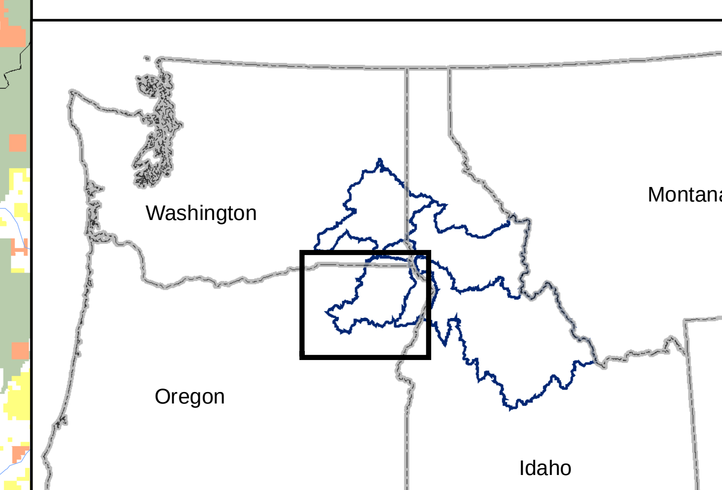
Legend

Land Ownership
- Forest Service
- Forest Service Wilderness
- Dept. of Defense
- Corps of Engineers
- Dept. of Energy
- Bureau of Land Managment
- Bureau of Reclamation
- USFWS / National Park Service
- State / City / County
- Tribal
- Private

- City
- Freeway System
- Stream
- State Boundary
- Geographic Area Boundary
- Watershed Boundary

N W E S

0 10 20
Miles



8.1.2 Hydrology

The climate of the Grande Ronde River Basin is variable as a result of the high relief of the Blue and Wallowa Mountains. However, winters are generally cold and moist and summers are warm and dry. Average annual precipitation increases from 14 inches on the valley floor to over 60 inches in some mountain areas.

The major streams that flow into the Grande Ronde include Catherine and Joseph creeks and the Wallowa and Wenaha Rivers. Catherine Creek and the Wallowa River originate in the Eagle Cap Wilderness and the Wenaha River originates in the Wenaha-Tucannon Wilderness. The Grande Ronde and its tributaries are snowmelt runoff streams. Peak runoff occurs in spring, generally from April through June, from melting snowpack and spring rains, and low flows occur in late summer. The Wallowa River flows into Wallowa Lake, which is the only large lake in the study area. Although it is a natural lake, a dam was constructed at its outlet and its storage is used primarily for irrigation. The majority of its drainage basin is in the Eagle Cap Wilderness. There are also a number of small impoundments in the subbasin.

8.1.3 Land Cover

At one time grasslands, dominated much of the Grande Ronde subbasin. However, plowing, burning, irrigating, grazing, and mowing have converted many of these lands to agricultural cover types. Remnant strips of the native grassland steppe still exist within farming areas, but these are generally confined to areas inappropriate for farming (Grande Ronde Model Watershed Program 2004). Currently, grasslands cover about 12 percent of the subbasin overall, ranging from 21 percent in the Lower Grande Ronde to 4 percent in the Upper Grande Ronde watershed (Table 29). Agricultural and urban types occupy 17 percent of the subbasin, ranging from 22 percent in the Upper Grande Ronde to 11 percent in the Lower Grande Ronde watershed.

As elevation increases, scrub-shrub vegetation occurs and coniferous forests eventually dominate. Forest types cover about 70 percent of the entire subbasin. Diverse wetland communities also occur throughout the subbasin. Table 29 summarizes the extent of general land cover types within the subbasin, by 4th-field watershed.

Table 29. General Land Cover by Watershed within the Grande Ronde River Basin (percent of total watershed area)

Watershed Name	Agricultural and Urban	Herbland	Shrubland	Early-seral Forest	Mid-seral Forest/ Woodland	Late-seral Forest	Other[1/]
Upper Grande Ronde	22%	4%	<1%	16%	52%	6%	<1%
Wallowa	17%	14%	<1%	23%	24%	18%	3%
Lower Grande Ronde	11%	21%	<1%	25%	39%	4%	<1%
Total Grande Ronde Subbasin	**17%**	**12%**	**<1%**	**21%**	**41%**	**8%**	**1%**

[1/] Riparian, Alpine, Water, Rock, Barren
Source: Interior Columbia Basin Ecosystem Management Project GIS layers

8.1.4 Land Ownership

The Forest Service is the largest single land manager in the Grande Ronde basin, managing 47 percent (Table 30). Wallowa-Whitman and the Umatilla National Forest lands make up a similar percentage of all three watersheds ranging from 46 to 49 percent. The BLM manages a small amount of land in the Lower Grande Ronde and scattered parcels in the other watersheds, totaling 1 percent of the subbasin overall. The states of Oregon and Washington also manage lands in the Lower Grande Ronde, and the state of Oregon also manages limited parcels in the other watersheds. State ownership within the subbasin also totals approximately 1 percent. Privately owned lands occur extensively at lower elevations along stream valleys and on the valley floors, especially along the Grande Ronde and Wallowa valleys and along portions of the Joseph Creek headwaters and within higher elevation meadows of the Upper Grande Ronde. Private ownerships comprise just over half of the entire subbasin and make up 47 to 53 percent of each watershed.

Table 30. Land Ownership by Watershed within the Grande Ronde River Basin (percent of total watershed area)

Watershed Name	Private	Tribal	State	National Forest (non-Wilderness)	National Forest Wilderness	BLM
Upper Grande Ronde	53%	<1%	<1%	45%	1%	<1%
Wallowa	53%	0%	<1%	4%	43%	<1%
Lower Grande Ronde	47%	0%	1%	33%	16%	2%
Total Grande Ronde Subbasin	**51%**	**<1%**	**1%**	**31%**	**16%**	**1%**

Source: Interior Columbia Basin Ecosystem Management Project GIS layers

8.1.5 Land Use

Approximately 16 percent of subbasin lands are in designated wilderness. The Wallowa watershed, in particular, has 43 percent of its area in the Eagle Cap Wilderness. The Wenaha-Tucannon Wilderness makes up 16 percent of the Lower Grande Ronde and both wildernesses combine to make up 1 percent of the Upper Grande Ronde. The remaining National Forest System lands are managed for multiple uses, especially timber production, livestock grazing, and recreation. Although the Grande Ronde Subbasin contains extensive private lands, it is sparsely populated. Primary uses of private land are for cropland, range management, and timber management. Major crops include wheat, hay and forage, grass and legume seeds, peppermint, potatoes, and specialty crops.

Road densities are moderate to high throughout the majority of the subbasin (63 percent); however, they are absent to very low in the wilderness and adjacent areas (22 percent) (Table 31). Lowest overall densities are in the Wallowa watershed and the highest are in the Upper Grande Ronde.

Table 31. Road Density Predicted Classes by Watershed within the Grande Ronde Subbasin (percent of total watershed area).

Watershed Name	Road Miles per Square Mile					
	0 – 0.02	0.02-0.1	0.1-0.7	0.7-1.7	1.7-4.7	>4.7
Upper Grande Ronde	3%	1%	13%	24%	45%	13%
Wallowa	43%	<1%	2%	31%	21%	2%
Lower Grande Ronde	23%	3%	6%	27%	35%	6%
Total Subbasin	**20%**	**2%**	**8%**	**27%**	**36%**	**8%**

Source: Map 3.28, Volume II, in Quigley and Arbelbide (1997). Data used to form these classes was statistically extrapolated from sampled 6th-field HUC road data.

8.2 OVERVIEW OF SEDIMENT TRENDS AND HISTORIC CHANGE

Historic changes in the Grande Ronde Subbasin that affect sediment are primarily related to road construction, agriculture, timber harvest, and grazing. Extensive roading has been conducted along streams in the subbasin. Overgrazing of riparian zones, conversion of grasslands to agricultural uses, water diversions, and timber harvest have occurred in many areas. Gold dredging has occurred in the upper Grande Ronde above Starkey (McIntosh et al. 1994). All of these changes have contributed to sediment production and transport to streams.

Table 32 presents some ratings developed by Interior Columbia Basin Ecosystem Management Project (Quigley and Arbelbide 1997), which can be used as overall indices of the relative level of disturbance in each watershed within the geographic area. The measures relate to the degree of hydrologic disturbance in forest and rangeland environments (based on the level of surface mining, dams, cropland conversion, and roads) and the degree of riparian disturbance in rangeland environments (based on the sensitivity of streambanks to grazing and the sensitivity of stream channel function to the maintenance of riparian vegetation).

Based on these ratings, some broad generalizations can be made. The overall level of disturbance is high in the Upper Grande Ronde watershed for all categories. For the Wallowa and Lower Grande Ronde, the level of hydrologic disturbance in forest environments is high, but the levels of hydrologic and riparian disturbance in rangeland environments are moderate.

Table 32. Hydrologic Disturbance Rating of Forest and Rangeland Environments and Riparian Disturbance Rating of Rangeland Environments Relative to the Entire Columbia Basin by Watershed (4th-field HUC) within the Grande Ronde Geographic Area

Watershed Name	Hydrologic Disturbance Rating of Forest Environments	Hydrologic Disturbance Rating of Rangeland Environments	Riparian Disturbance Rating of Rangeland Environments
Upper Grande Ronde	High	High	High
Wallowa	High	Moderate	Moderate
Lower Grande Ronde	High	Moderate	Moderate

Source: Maps 2.34, 2.35, and 2.36, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

8.3 SEDIMENT SOURCES AND YIELD

8.3.1 Overview Studies of Erosion and Mass Wasting Hazards

In this section, ratings and other results from a number of overview studies that were conducted across the entire Columbia River basin or over larger areas are presented for perspective and comparison purposes. The methods behind these studies are summarized briefly below and in more detail in Section 4.1.

The Interior Columbia Basin Ecosystem Management Project conducted by the Forest Service and the BLM (Quigley and Arbelbide 1997) developed various soil erosion, mass failure, and sediment hazard ratings for nonpoint sources for each watershed, relative to all Columbia Basin watersheds. The key ratings are shown for the Grande Ronde Subbasin, in Tables 33 and 34.

Table 33. Soil Erosion, Mass Failure, and Sedimentation Measures Relative to the Entire Columbia Basin by Watershed (Cataloging Unit) within the Grande Ronde River Basin

Watershed Name	Surface Soil Erosion Hazard	Earth Flow Hazard	Debris Avalanche Hazard	Sediment Delivery Potential	Sediment Delivery Hazard
Upper Grande Ronde	High	Mod - High	High	Mod - High	High
Wallowa	High	High	High	Mod - High	High
Lower Grande Ronde	High	High	High	Mod - High	High

Source: Maps 2.10, 2.11, 2.12, 2.13, and 2.15, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

Table 34. Road Erosion Hazard and Road Sediment Delivery Hazard Relative to the Entire Columbia Basin by Watershed (Cataloging Unit) within the Grande Ronde River Basin

Watershed Name	Road Erosion Hazard	Road Sediment Delivery Hazard
Upper Grande Ronde	Low to Moderate	Moderate to High
Wallowa	Moderate to High	High
Lower Grande Ronde	Low	Moderate to High

Source: Maps 2.16 and 2.17, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

NMFS (Baker et al. 2005) has developed two draft models for estimating increases in erosion rates relative to natural levels. Based on this study, erosion rates in the Upper Grande Ronde watershed are 1 to 4 times historical rates, 1 to 5 times in the Wallowa watershed, and 1 to 6 times in the Lower Grande Ronde.

The USGS developed a landslide overview map (Radbruch-Hall et al. 1982). This map delineates areas where large numbers of landslides have occurred and areas which are susceptible to landsliding in the conterminous United States. Within the geographic area, there is an area along the Washington-Oregon border within the Lower Grande Ronde watershed (primarily in the Wenaha drainage) that is mapped as having a high incidence of past landslides and susceptibility to future landslides. This area is largely on National Forest System lands and mostly in the Wenaha-Tucannon Wilderness. In addition, there is another area along the boundary of the Upper and Lower Grande Ronde watersheds that is mapped similarly.

A NRCS analysis of cropland for 1997 in the conterminous United States found that the subbasin had some areas of highly erodible cropland with excessive erosion above the tolerable soil erosion rate (NRCS 2000). These areas were primarily in the Upper Grande Ronde and Wallowa watersheds.

8.3.2 Specific Studies within the Geographic Area

The ODEQ has identified many streams in the Grande Ronde Subbasin as water quality limited (or 303(d) listed) for at least one of a number of water quality parameters of concern. Sedimentation is one of the most widespread parameters and 20 stream segments in the Upper Grande Ronde, 2 in the Lower Grande Ronde, and 4 in the Wallowa watershed are 303(d) listed due to sedimentation.

A TMDL and Water Quality Management Plan (WQMP) and Agricultural Water Quality Management Area Plan (AWQMAP) have been developed for the Upper Grande Ronde River watershed (ODEQ 2000) and are in development for the lower Grande Ronde (in Oregon) and Wallowa watersheds. The WQMP prioritized 11 geographic areas within the

Upper Grande Ronde watershed for treatment (Grande Ronde Water Quality Committee 2000). The priorities assigned for treatment of sediment are presented in Table 35.

Table 35. Geographic Priority Areas for Treatment of Sediment in the Upper Grande Ronde Watershed

Watershed	Priority
Lookingglass	Low
Lower Grande Ronde	Low
Willow/Philips	High
Indian/Clark	Medium[1/]
Catherine Creek	High
Beaver	Medium
GRR Valley	High
Ladd Creek	High
Upper Grande Ronde	High
Meadow Creek	High
Spring/Five Pts.	Medium

[1/]Clark Creek probably should be "high" for sediment but the watershed as a whole is medium.
Source: Grande Ronde Water Quality Committee 2000

The WQMP noted that the three parameters commonly listed throughout the subbasin (i.e., sediment, habitat modification, and temperature) can all be improved through management decisions that would lead to improving vegetation conditions. Thus, practices that improve vegetative conditions are high priorities for improving water quality in the subbasin. In general, solutions that involve stabilizing slopes and stream banks, narrowing and deepening channels (decreasing width to depth ratio), and increasing shade by restoring woody vegetation in areas where it has been removed (primarily in riparian areas) will lead to improvement in habitat, sediment loss and temperature. Reducing sediment from roads, or intercepting it before it reaches a stream, is also an approach with large potential benefits (Grande Ronde Water Quality Committee 2000).

Many assessment studies have been conducted in the Upper Grande Ronde Subbasin (Bach 1995; Clearwater BioStudies 1993; Diebel 1997; Hemstrom et al. 2002; Mobrand Biometrics 1997; ODEQ 1997; NRCS/USDA Forest Service/Union County Soil and Water Conservation District 1997; USDA Forest Service 1999; BLM 1993;). Detailed discussions of the abundant water quality monitoring data available in the subbasin can be found in the following two documents: Grande Ronde River Basin Water Quality Technical Assessment – Temperature (ODEQ, May 1998) and Grande Ronde River Basin Water Quality Technical Assessment (Overview of Water Quality Conditions) (ODEQ, May 1998).

8.4 MANAGEMENT PRACTICES AND RESTORATION

Sediment management within the Grande Ronde Subbasin is tied to a mixture of plans, policies, and regulations and depends on the landowner. Areas with the highest protection status and which have a management plan that maintains a natural state are the two wildernesses managed by the Forest Service – the Eagle Cap, which is mostly in the Wallowa watershed and the Wenaha-Tucannon, which is mostly in the Lower Grande Ronde watershed. The Eagle Cap and Wenaha-Tucannon are 361,000 acres and 177,000 acres in size, respectively, including some lands outside the subbasin. Combined, these two wildernesses represent 16 percent of the subbasin (Table 30).

A moderately high protection status is also afforded a number of riverine corridors that are designated as Federal Wild and Scenic Rivers and are managed by the Forest Service within the National Forests of the subbasin and by the BLM outside the Forests. These include the Oregon portion of the lower Grande Ronde River and portions of Joseph Creek and the Wenaha River in the Lower Grande Ronde watershed, and portions of the Lostine and Minam Rivers in the Wallowa watershed.

The Forest Service is the single largest land manager in the subbasin, managing 47 percent of the subbasin (including wilderness). The Wallowa-Whitman and Umatilla National Forest Plans were approved in 1990 and are under revision.

The BLM manages only 1 percent of the subbasin. A Resource Management Plan for the BLM's Baker Resource Area was approved in 1989; a revision is scheduled to begin in 2006.

The Forest Service Forest Plans and BLM Resource Management Plan in the subbasin were amended in the mid-1990s to provide additional protection of riparian areas and improve water quality because of PACFISH and INFISH. PACFISH and INFISH will provide management direction on Federal lands until Forest Plans and Resource Management Plans are revised within the next several years.

Other lands with a relatively high degree of protection status include nearly 20,000 acres of wildlife areas managed by the Washington and Oregon Departments of Fish and Wildlife and 15,000 acres of land called the Precious Lands area of the Nez Perce Tribe. These lands are mostly within the Lower Grande Ronde watershed.

The Grande Ronde Model Watershed Program was designated in 1992 by the NPPC to be the model watershed for Oregon to coordinate restoration work in the Grande Ronde Subbasin. The Program was entrusted by the BPA to oversee the planning and implementation of new projects using BPA funds. Grande Ronde Model Watershed Program oversight has provided consistency in project implementation in the Grande Ronde Subbasin.

On private agricultural lands, the USDA's Farm Service Agency and NRCS administer many farm programs which have been used extensively in the subbasin to reduce agricultural impacts to riparian areas and water quality. The CRP, which puts sensitive croplands under permanent vegetative cover, the CREP, which helps establish forested riparian buffers, and the WRP, which helps protect and enhance privately owned wetlands, are three of the most used programs.

The Oregon Department of Forestry enforces the Oregon Forest Practices Act regulating commercial timber production and harvest on state and private lands in Oregon. The Oregon Forest Practices contains guidelines to protect fish-bearing streams during logging and other forest management activities, which address stream buffers, riparian management, and road maintenance. Similarly, the Washington Department of Natural Resources (WDNR) enforces the Washington Forest Practices Act, which guides and restricts logging and other forest management activities on state and private lands in Washington. Although these regulations are more restrictive than Oregon's, they only affect limited lands in the Lower Grande Ronde watershed.

Over 400 on-the-ground restoration projects were accomplished in the Grande Ronde Subbasin in the last decade (Grande Ronde Model Watershed Program 2004). Many of these were implemented through the Grande Ronde Model Watershed Program using BPA fish and wildlife mitigation funds. Others were done by agencies without the assistance of BPA. These projects are identified in Grande Ronde Model Watershed Program (2004).

Based on the results of the EDT model (Mobrand Biometrics 2006), the Grande Ronde Model Watershed Program (2004) summarized the additional opportunities for fish habitat restoration by watershed, within the entire Grande Ronde Subbasin. The following items identify some of the important observations they made relative to sediment.

Lower Grande Ronde Watershed (4th-field HUC) (Grande Ronde Model Watershed Program 2004)

- Wenaha – this watershed is almost entirely within the Wenaha-Tucannon Wilderness and has had few impacts and it is likely that conditions will remain stable
- Lower Grande Ronde
- Lower Grande Ronde Tributaries 1 geographic area – mostly private lands, almost all tributaries have roads along the streams, and the area has been identified as having sediment impacts in almost all tributaries and as a priority for restoration
- Wildcat Creek geographic area – sediment inputs from grazing and roads are key factors

- Courtney Creek geographic area – minimizing sediment impacts from roads and grazing should be priority actions in this area
- Mud Creek geographic area – minimizing sediment impacts from roads and grazing should be priority actions in this area
- Lower Grande Ronde Tributaries 2 geographic area – some sediment impacts
- Grossman Creek geographic area – minimizing sediment impacts from roads and grazing should be priority actions in this area
- Joseph Creek – overall, this is one of the most heavily roaded watersheds in the Grande Ronde Subbasin; private ranching and grazing are the dominant land uses and many observed impacts can be tied to these activities
- Lower Chesnimius geographic area – mostly private lands with extensive areas of grazing and ranching
- Lower Joseph – sediment impacts in this area are likely from activities upstream
- Upper Joseph – reaches are relatively low gradient, passing through a mix of National Forest System lands and private lands; there are some large ranches with extensive grazing
- Swamp Creek – mix of National Forest System and private lands with extensive grazing
- Crow Creek geographic area – significant sediment impacts have been observed in Crow Creek; this is one of the best areas for restoration
- Upper Chesnimius geographic area – this is one of the most heavily roaded portions of the Grande Ronde Subbasin
- Cottonwood Creek – lands managed by Forest Service, BLM, and private owners
- Joseph Creek Tributaries geographic area – almost entirely on National Forest System lands
- Main Grande Ronde geographic area – river is in relatively confined canyon with a parallel road

Wallowa Watershed (4th-field HUC) (Grande Ronde Model Watershed Program 2004)

- Wallowa River
- Lower Wallowa River – sediment impacts are likely the result of upstream activities

- Lower Wallowa Tributaries – identifying and minimizing sediment inputs from stream adjacent roads should be a priority action
- Mid Wallowa River – a road and railroad parallel most of the reach
- Deer and Sage Creeks – roads parallel the entire lengths
- Mid Wallowa Tributaries geographic area – Water Canyon has a road the entire length and minimizing sediment should be a priority action
- Rock Creek geographic area – maintain and enhance riparian conditions to decrease sediment impacts
- Lower and Upper Bear Creek geographic areas – private lands, irrigation diversions, upper reaches are in wilderness
- Lower Whiskey Creek – farming, grazing, upper portion flows through private timber and grazing lands with a high density of roads
- Lower Lostine geographic area – irrigated agriculture, grazing, residential, and water diversions
- Upper Lostine geographic area – a road follows most of the stream
- Upper Wallowa River – towns of Enterprise and Joseph and many irrigation diversions
- Wallowa Lake Dam and Upper Alder Slope Diversions – significant barriers
- Spring Creek and Upper Wallowa Tributaries – roads and grazing, but area is a low priority for restoration or protection
- Lower and Upper Hurricane Creeks – rural residential, irrigation diversions, farming, and wilderness in the upper reaches
- Prairie Creek geographic area – Prairie Creek has a high sediment load, water is transferred to the creek from ditches
- Wallowa Lake – major impoundment
- Minam River – upper reaches are entirely within the Eagle Cap Wilderness, only the lowest portion is in private ownership, where roads follow the creek bottoms

Upper Grande Ronde Watershed (4th-field HUC) (Grande Ronde Model Watershed Program 2004)

- Lookingglass Creek – one of the most pristine non-wilderness watersheds in the Grande Ronde River basin, but much of the Lower Lookingglass is private timber

- Catherine Creek/Middle Grande Ronde
- Middle Grande Ronde and Tributaries, Phillips and Indian Creeks – ranching, grazing, and roads
- Willow Creek – ranching and farming
- Catherine Creek – EDT rated the middle Catherine Creek area as an overwhelming priority for restoration
- Ladd Creek – extensively modified wetlands for agriculture and roading
- SF and NF Catherine Creek areas – Forest Service road up the South Fork, North Fork Buck Creek, and other roads in the drainage; some tributaries are unroaded
- Upper Grande Ronde – many reaches rated as a priority, but none rated as a high priority; portions of the upper Grande Ronde River above Starkey have been impacted by gold dredging

In their Management Plan for the subbasin, the Grande Ronde Model Watershed Program (2004) identified the following list of strategies for controlling sediment in the watershed:

- Identify sediment sources
- Close, obliterate or relocate sediment-producing roads
- Improve drainage, install culverts, surface, on open sediment producing roads
- Manage grazing in riparian areas following grazing plans designed to improve riparian condition; could include exclusion, partial season use, development of off-site water, herding
- Reestablish riparian vegetation by planting trees, shrubs, sedges (native species preferred)
- Stabilize active erosion sites, where appropriate, through integrated use of wood structures (limited use of rock if necessary) and vegetation reestablishment
- Where appropriate and feasible, relocate channelized stream reaches to historic locations
- Promote interaction of stream channels and floodplains by removing, where feasible and appropriate) channel confinement structures (roads, dikes)
- Encourage landowner participation in riparian management incentive programs (e.g., CREP, WRP, EQIP)
- Promote/implement minimum tillage practices

- Promote/implement development of grazing plans to improve upland vegetative condition
- Implement an integrated noxious weed management program including survey, prevention practices, education, treatment and revegetation
- Create/construct wetlands and filter strips for livestock feedlots and irrigation return flows

8.5 SUMMARY OF PRELIMINARY CONCLUSIONS

In general, primary opportunities for sediment-related restoration efforts appear to be in the Upper Grande Ronde watershed. However, opportunities exist in the lower reaches of the Wallowa watershed and in some locations in the Lower Grande Ronde (e.g., Upper Chesnimius and Crow Creek drainages). Primary methods may include road obliteration or other road management measures for sediment producing roads, fencing or restoration of riparian vegetation where sediment production has been identified as a problem, relocation of channelized stream reaches, creation of wetlands or filter strips for drainage from agricultural areas, and other measures.

9. LOWER SNAKE RIVER BASIN – MOUTH TO LOWER GRANITE RESERVOIR

9.1 THE SETTING

9.1.1 Geography and Topography

The Lower Snake River Basin geographic area is located in the southeast corner of Washington and includes areas in western Idaho (Figure 7). It is defined as the area downstream of the mouth of the Clearwater River to its confluence with the Columbia River and includes four 4th-field watersheds (Table 36.). North of the Snake River is the Palouse and Rock Creek watersheds. South of the Snake River is the Tucannon watershed, which includes Alpowa Creek upstream of Lower Granite Dam, and the Tucannon River, Deadman, Panawawa, and Alkali Flat Creeks downstream of Lower Granite Dam. The fourth watershed is the Lower Snake, which lies downstream of the confluence with the Palouse.

Table 36. Size and Cataloging Unit Number for Watersheds within the Lower Snake River Subbasin

Watershed Name	Cataloging Unit Number	Area (Square Miles)	Percent of Study Area
Palouse	17060108	2,350	43%
Rock	17060109	957	17%
Subtotal Palouse and Rock		**3,308**	**38%**
Tucannon	17060107	1,463	27%
Lower Snake	17060110	700	13%
Total Subbasin		**8,779**	**100%**

Source: Interior Columbia Basin Ecosystem Management Project GIS layers

Rock Creek flows into the Palouse River, which flows to the Snake River. Due to the size of Rock Creek watershed, it has been recognized with a separate Cataloging Unit Number. However, it is a peninsula of land in the northern portion of the Palouse watershed and it has basically the same setting and issues. Therefore, it is included in this discussion as part of the Palouse. The Palouse River originates in the Palouse Mountain Range in western Idaho, flows west through the rolling farm land where it is joined by Rock Creek and then south to the Snake River at the Whitman-Franklin County line downstream of the Little Goose Dam.

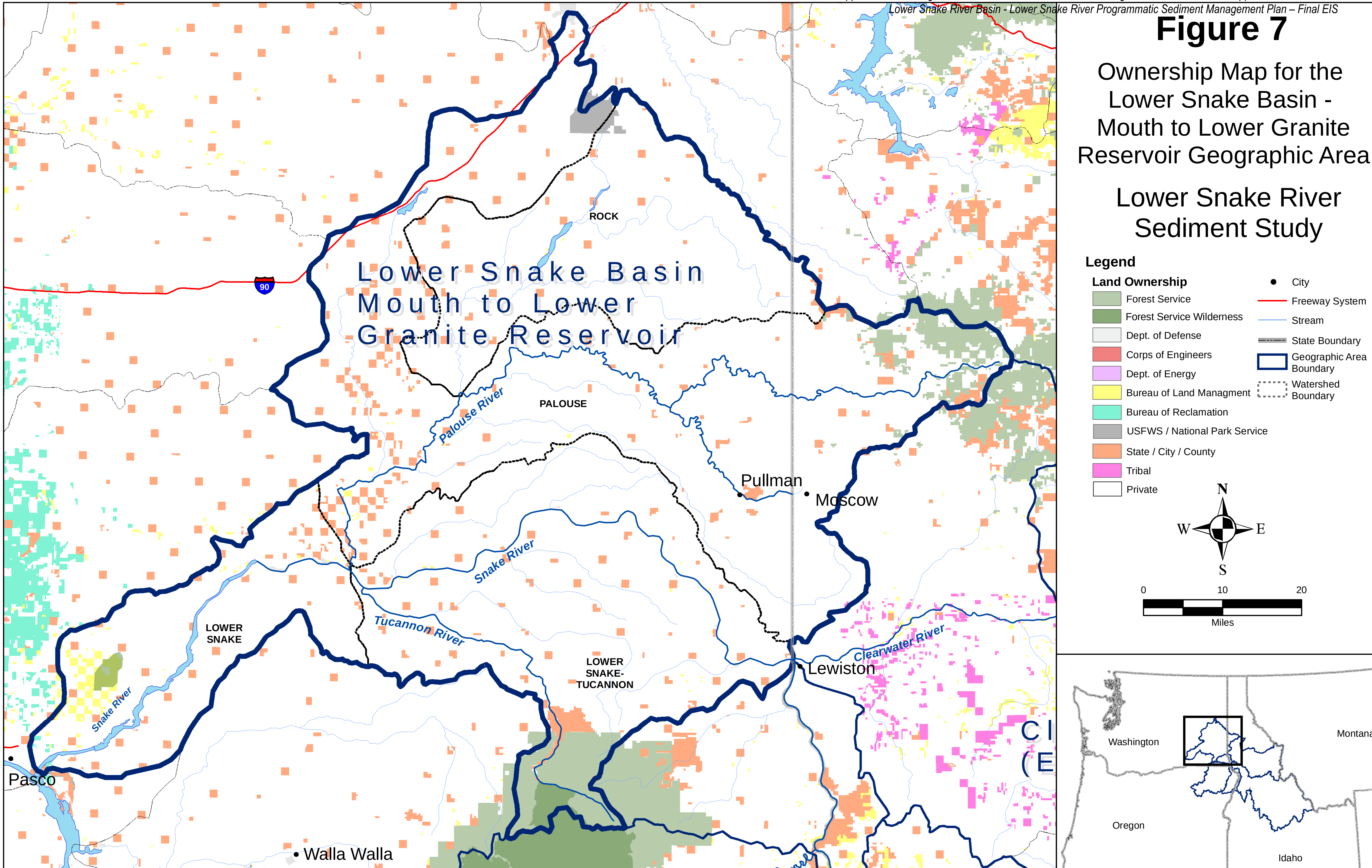


Figure 7
Ownership Map for the Lower Snake Basin - Mouth to Lower Granite Reservoir Geographic Area
Lower Snake River Sediment Study
Legend
Land Ownership
Forest Service
Forest Service Wilderness
Dept. of Defense
Corps of Engineers
Dept. of Energy
Bureau of Land Managment
Bureau of Reclamation
USFWS / National Park Service
State / City / County
Tribal
Private
City
Freeway System
Stream
State Boundary
Geographic Area Boundary
Watershed Boundary
N
W
E
S
0
10
20
Miles
Lower Snake Basin Mouth to Lower Granite Reservoir
ROCK
PALOUSE
LOWER SNAKE
LOWER SNAKE-TUCANNON
Palouse River
Snake River
Tucannon River
Clearwater River
90
Pullman
Moscow
Lewiston
Pasco
Walla Walla
Washington
Montana
Oregon
Idaho

Approximately 88 percent of the watershed is in eastern Washington and the remaining 12 percent is in western Idaho.

The rest of the Lower Snake River geographic area is within Washington. The Tucannon River, Deadman, and Alpowa Creeks originate in the Blue Mountains to the south. Alpowa Creek flows east and the others flow north and west to the Snake River. Other smaller tributaries to the Snake, Alkali Flat and Penawawa Creeks, originate north of the Snake in the hills between the Snake and Palouse Rivers, and flow east and south to the Snake.

Much of the Lower Snake River geographic area, north of the Blue Mountains and east of the Palouse Mountains, is characterized by dune-like ridges, deep wind-blown loess soils, and low gradient, often intermittent streams. Generally, the hills have gently sloping south and west facing slopes with short, steep north and east slopes and relief averaging 100 to 200 feet. The western portion of the basin in the Palouse region is in the channeled scablands where most of the loess that blanketed the basalt has been scoured away by a series of floods originating from Glacial Lake Missoula. The land surface in the scablands is characterized by "scabs" of basalt bedrock, loess islands, and sand and gravel flood deposits. Relief in the scablands, like the Palouse hills, averages 100 to 200 feet (Gilmore 2004).

There are two areas with different physical description. The eastern Palouse is in forested mountains of Idaho where elevation ranges to 5,330 feet and relief can be over 1,000 feet and the valleys are filled with alluvial deposits (Gilmore 2004). The southern Tucannon, in the Blue Mountains where elevations range to 6,400 feet, is characterized by long slopes intersected by steep canyons. The Tucannon watershed includes a major fault system, Hite Fault, which has been the locus of many historic earthquakes, is still active, and thought to be the cause of elevated ground water temperatures. It is approximately 85 miles in length and crosses both the Tucannon River and Pataha Creek at right angles (Columbia Conservation District 2004).

9.1.2 Hydrology

The climate is semi-arid with average annual precipitation ranging from as low as 5 inches in the western part of the Lower Snake River subbasin up to about 50 inches in the Palouse Mountains to the east and 40 inches in the Blue Mountains to the south. Snow normally comprises 60 to 70 percent of the total annual precipitation in the mountainous areas. Precipitation is mostly concentrated in the winter months (Kuttle 2002, Gilmore 2004).

There are five major tributaries to the Palouse River: the South Fork Palouse River, the North Fork Palouse River, Union Flat Creek, Rock Creek, and Cow Creek. There are many other intermittent or ephemeral streams and more than 40 lakes in the watershed. Many of the lakes are large water filled depressions with basalt bottoms and no outlet. Flows in the Palouse River and its tributaries vary seasonally, with high flows generally in early spring and low flows in late summer. The Palouse River and its tributaries have no major man-made impoundments. The Palouse River plunges over the 182-foot Palouse Falls approximately six miles up from its confluence with the Snake River. The falls act as a natural barrier for salmon and other migrating fish (Gilmore 2004).

The Tucannon Watershed is dominated by the Tucannon River. The river has two major drainages: the Pataha (36 percent of the watershed) and the mainstem Tucannon. Precipitation and ground water are the water sources for the Tucannon River and associated tributaries. Virtually all of the base flow in the Tucannon watershed comes from ground water discharge. Low flows are during late summer and peak flows are May/June when severe runoff events can lead to sediment problems in Pataha Creek and lower Tucannon River (Columbia Conservation District 2004). Average late summer flows are about 29 percent of the average spring flows [Water Resource Inventory Area (WRIA) 35]. The reservoir created by the Lower Monumental Dam, which is 20 miles downstream on the Snake River, has resulted in the lower two miles of the Tucannon River becoming a marshland (Middle Snake Watershed Planning Unit 2005).

The mainstem Snake River flows in a generally westerly direction to its confluence with the Columbia River. In addition to the Palouse and Tucannon Rivers, there are a number of smaller tributaries: the Alpowa, Deadman, and Meadow Creeks south of the river and Alkali Flat Creek, Penawawa Creek, Almota Creek, Wawawai Creek and Steptoe Canyon Creek north of the river. There are also a number of gulches (New York, Dry, and Fields gulches) or canyons (e.g., Walker Canyon). The Corps operates four major dams on the Snake River in this reach that provide power generation, water for irrigation, navigation, and recreation.

9.1.3 Land Cover

The Palouse region was historically covered with forest in the eastern mountains, grassland with scattered shrubs in the central area of rolling hills, and shrub-steppe and grassland in the eastern third (Kaiser 1975, Gilmore 2004). It is now highly altered with approximately 81 percent of the land being farmed for grain crops or developed. The Palouse grasslands are considered one of the most endangered ecosystems in the United States with less than one percent estimated to remain in a natural state. They cover less than two percent of the Palouse/Rock watersheds (Gilmore 2004).

Cultivated fields also dominate the Tucannon watershed with confer forest only in the Blue Mountains in the south. Areas of grassland and shrubland are concentrated along the larger streams. The Lower Snake Watershed is also predominantly agriculture but includes larger areas that remain shrub-steppe with some ponderosa pine and small wetland areas (Pomeroy Conservation District 2004). Table 37 summarizes the extent of general land cover types within the river basin, by 4th-field watershed.

Table 37. General Land Cover Percent by Watershed (4th-field HUC) within the Lower Snake River Basin Geographic Area (percent of total watershed area)

Watershed Name	Agricultural and Urban	Herbland	Shrubland	Early-seral Forest	Mid-seral Forest/ Woodland	Late-seral Forest	Other[1/]
Palouse	79%	4%	6%	<1%	11%	-	<1%
Rock	87%	1%	10%	<1%	2%	-	<1%
Subtotal Palouse and Rock	81%	3%	7%	<1%	8%	-	<1%
Tucannon	81%	4%	2%	2%	8%	<1%	1%
Lower Snake	65%	4%	26%	<1%	2%	-	2%
Total Subbasin	**79%**	**4%**	**8%**	**<1%**	**7%**	**<1%**	**<1%**

1\ Riparian, Alpine, Water, Rock, Barren

Source: Interior Columbia Basin Ecosystem Management Project GIS layers

9.1.4 Land Ownership

Private land ownership dominates the Lower Snake River subbasin, accounting for 92 percent of the land (Table 38). There are two large areas of concentrated National Forest System lands: approximately 48,200 acres in the Palouse Mountains managed by the Clearwater National Forest and 77,800 acres in the southern Tucannon managed by the Umatilla National Forest (of which 18 percent is wilderness). The only other large government-owned tract of land is 18,300 acres of BLM land in the Lower Snake, of which approximately a third is Juniper Dunes Wilderness. The Washington Department of Fish and Wildlife (WDFW) manages Wooten Wildlife Area, approximately 12,000 acres adjacent to the Umatilla National Forest and along the Tucannon River. While the Wooten Wildlife Area is protected to some extent, a salvage logging operation is currently underway after the 2005 School Wildfire (WDFW 2006). Three tribes have areas of interest within the Lower Snake River subbasin area: Nez Perce Tribe, Coeur d’Alene Tribe, and Spokane Tribe.

Table 38. Land Ownership by Watershed (Cataloging Unit) within the Lower Snake River Basin Geographic Area (percent of total watershed area)

Watershed Name	Private	State / County/ City	National Forest (non-Wilderness)	BLM (non-Wilderness)	National Forest and BLM Wilderness	U.S.FWS, DOD, or BOR
Palouse	92%	4%	3%	<1%	-	<1%
Rock	98%	2%	<1%	-	-	<1%
Tucannon	88%	3%	7%	-	2% [1\]	-
Lower Snake	92%	3%	-	3%	1% [2\]	<1%
Total Subbasin[1\]	**92%**	**3%**	**3%**	**<1%**	**<1%**	**<1%**

1\ Wenaha-Tucannon Wilderness, Forest Service managed
2\ Juniper Dunes Wilderness, BLM managed
Source: Interior Columbia Basin Ecosystem Management Project GIS layers

9.1.5 Land Use

Approximately 64 percent of the land in the Palouse and Rock watersheds is used for dryland agriculture (wheat, barley, lentils and peas), dominating the central loess covered rolling hills. An additional 25 percent of the Palouse and Rock watersheds are used for livestock grazing, largely in the channeled scablands in the western portion of the watershed. It is estimated that today, fewer than a third of the farms have livestock. It is common for a producer to graze the animals on bottomlands during the spring, summer and fall months and then move the animals to a winter-feeding operation. An estimated 14 percent of the riparian areas within the watershed are grazed (Gilmore 2004). Timber activities are primarily concentrated in the eastern portion of the watershed. The major urban areas are Pullman, Washington, and Moscow, Idaho, where WSU and the University of Idaho are located, respectively.

In the Tucannon watershed, crops, forest, rangeland, and pasture comprise over 90 percent of the watershed with the remainder being protected (wilderness or managed by WDFW). Most of the non-forested land with slopes of 45 percent or less is under cultivation. The private land is primarily used for grazing and dryland agriculture (36 and 34 percent of the watershed respectively). Of the National Forest land in the watershed, only approximately one-quarter of the acres outside wilderness are considered suitable for harvest (Kuttle 2002).

Overall, road densities are low to moderate in this basin (Table 39). Road densities are high in the northern and eastern most portion of the Palouse watershed, areas with historical timber activities including unsurfaced roads that are more susceptible to erosion. In the areas with wind-blown loess soils, road building has also contributed to sedimentation by concentrating run-off and conveying it through road culverts where it can cut a gully across agriculture fields (Gilmore 2004).

Table 39. Road Density Predicted Classes by Watershed (4th-field HUC) within the Lower Snake River Basin Geographic Area (percent of total watershed area)

Watershed Name	Road Miles per Square Mile					
	0 – 0.02	0.02-0.1	0.1-0.7	0.7-1.7	1.7-4.7	>4.7
Palouse	1%	2%	74%	15%	6%	1%
Rock	<1%	1%	84%	12%	2%	<1%
Tucannon	4%	2%	61%	26%	6%	2%
Lower Snake	6%	3%	64%	24%	1%	2%
Total Subbasin[1\]	**2%**	**2%**	**71%**	**19%**	**5%**	**1%**

Source: Map 3.28, Volume II, in Quigley and Arbelbide (1997). Data used to form these classes was statistically extrapolated from sampled 6th-field HUC road data.

9.2 OVERVIEW OF SEDIMENT TRENDS AND HISTORIC CHANGE

The first inhabitants of this area were Native Americans. They utilized this area for grazing horses in the river bottoms and high meadows. Early activities by European settlers included trapping followed by farming. Dryland production of wheat expanded significantly in the 1870s (Kuttle 2002). Nearly all productive land was settled from 1870 through 1885 with completion of railroad vastly improving the marketing of agricultural products. Agriculture conversions have significantly impacted vegetation including valley bottom grasslands, shrublands, cottonwood dominated riparian areas and brush laden draws. It was estimated that 70 percent of the wetlands within the scablands were drained in the early 1900s for agriculture. Tillage has accelerated erosion and increased sediment loads to streams. The hill tops of the Palouse have lost all or most of their wind-blown loess topsoil through the combined tillage and water action (Kaiser 1975). Tillage often occurs up to the stream edges in many places leaving no buffer between croplands and streams.

The completion of the four major Corps dams between 1961 and 1975 provided better and more reliable navigation to Lewiston-Clarkston, which provided more reliable shipment of numerous products. However, the region, in general, has largely remained rural, with agriculture being the primary land use.

Conversion of floodplains and riparian forest buffers to agricultural fields and residences, and channel modifications including straightening, diking, and bank armoring have dramatically altered the Palouse, the lower portions of the Tucannon River as well as smaller systems such as Alpowa and Deadman Creeks. Logging, conversion of perennial grasslands to annually planted dry cropland, and grazing have led to increased runoff and erosion of fine sediment throughout the region (Kuttle 2002).

Historically, much of the farming consists of winter-spring rotations with clean cultivated summer fallow. Today, when fallow operations are used, chemical fallow instead of mechanical fallow is often implemented to reduce erosion potential. No-till farming is also used to reduce erosion. It includes using specialized equipment to place the fertilizer and seed directly into the previous year's crop residue without performing prior tillage operations. It is not uncommon to see a no-till operation replace conventional practices in one leg of the rotation (Gilmore 2004).

In areas where tillage is used in the highly erodible wind-blown loess soils, there can be the formation of ephemeral gullies when runoff is concentrated and leaves fields with a velocity that cuts a ditch. When gully erosion does occur, sediment delivery is high. This type of erosion is more problematic in conventionally farmed fields and less likely to occur when crop residues remain. While a gully would be groomed between crops, it can re-form. Also, many small, intermittent streams have been ditched, straightened and riparian vegetation removed for conversion to drainage ditches.

Deeper soil sites were mostly converted to agriculture while drier grasslands and canyon grasslands, those with shallower soils, steeper topography, or hotter, drier environments, were more likely to be grazed. Erosion is accelerated in the grazed riparian areas due to stock trails at the water's edge, denuded streambanks and unarmored cattle crossings. The Palouse was more affected by grazing than other types of grassland such as in the Great Plains. Not only was the type of grass in the Palouse not developed under the pressure of close grazing, but the moisture pattern with a summer drought made the grasses vulnerable to late spring or early summer grazing (Gilmore 2004).

Private logging began in the 1880's at low levels. The major boom took off in 1905 with the creation of the Potlatch mill that closed in the early 1980s. Logging activity on National Forest System lands and associated road construction was at its peak in the 1960s and 1970s, and has tapered off considerably (Gilmore 2004).

In the Palouse and Rock watersheds, approximately 85 percent of the riparian areas within the watershed are estimated to be directly effected by human land use (agricultural activities, grazing or urban development). Healthy riparian vegetation is limited, reducing or eliminating a buffer that could prevent the soil erosion from reaching the streams as sedimentation. However, approximately 10 percent of the farmable cropland is estimated to be enrolled in the CRP where farmland is left idle for a period of at least 10 years while being maintained in a permanent cover crop of grass, or a mixture of grass and legumes (Gilmore 2004).

Over time, the streams have undergone change in the flow regime, bed and riparian structure, and water quality. In the Pataha, the changes seem to have occurred in the decades following establishment of the agricultural economy. In the Tucannon drainage, the changes were a combination of land use and extreme floods. The wooded riparian zones were replaced with open zones in the agricultural areas resulting in diminished shade and less stable banks. Many of the changes in the upper half of the watershed occurred during the extreme floods in the 1960's and 1970's and most of the changes in the lower watershed pre-date these events (Covert et al. 1995).

The sinuosity of the Tucannon River decreased by 50 percent and the channel length was decreased between 7 to 20 percent from 1937 to 1975 leading to channel braiding and decreased bank stability (Kuttel 2002 and Hecht 1982).

In recent years, the listing of certain species of salmon and steelhead under the ESA coupled with the loss of soils from farming areas has provided the impetus for stream restoration and stabilization, plus the need to implement better farming techniques that conserve and retain soils. In general, the Palouse hills area has been characterized as one of the "worst" for soil erosion in the United States (USDA Soil Conservation Service et al. 1984). Several conservation districts have taken a lead in soil conservation efforts. As such, sediment inputs to local tributaries could decrease in the future as these techniques become more universal and as habitat (such as riparian zones) is reestablished and stream banks become more stabilized.

Table 40 presents some ratings, developed by the Interior Columbia Basin Ecosystem Management Project (Quigley and Arbelbide 1997), which can be used as overall indices of the relative level of disturbance in each watershed within the geographic area. The measures relate to the degree of hydrologic disturbance in forest and rangeland environments (based on the level of surface mining, dams, cropland conversion, and roads) and the degree of riparian disturbance in rangeland environments (based on the sensitivity of streambanks to grazing and the sensitivity of stream channel function to the maintenance of riparian vegetation).

Based on these ratings, the broad generalization can be made that the overall level of disturbance to the non-forested land is high. The forests were not rated because they make up less than 20 percent of the watersheds.

Table 40. Hydrologic Disturbance Rating of Forest and Rangeland Environments and Riparian Disturbance Rating of Rangeland Environments Relative to the Entire Columbia Basin by Watershed (4th-field HUC) within the Lower Snake River Basin Geographic Area

Watershed Name	Hydrologic Disturbance Rating of Forest Environments	Hydrologic Disturbance Rating of Rangeland Environments	Riparian Disturbance Rating of Rangeland Environments
Palouse	Unclassified	High	High
Rock	Unclassified	High	High
Tucannon	Unclassified	High	High
Lower Snake	Unclassified	High	Mod

1\ watersheds with less than 20 percent forest were not classified.

Source: Maps 2.34, 2.35, and 2.36, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings

9.3 SEDIMENT SOURCES AND YIELD

9.3.1 Overview Studies on Erosion, Mass Wasting, and Sedimentation

In this section, ratings and other results from a number of overview studies that were conducted across the entire Columbia River basin or over larger areas are presented for perspective and comparison purposes. The methods behind these studies are summarized briefly below and in more detail in Section 4.1.

The Interior Columbia Basin Ecosystem Management Project, conducted by the Forest Service and the BLM (Quigley and Arbelbide 1997) developed various soil erosion, mass failure, and sediment hazard ratings for nonpoint sources for each watershed, relative to all Columbia Basin watersheds. The key ratings are shown for the Lower Snake and tributaries basin in Tables 41 and 42.

Table 41. Soil Erosion, Mass Failure, and Sedimentation Measures within the Lower Snake River Basin Geographic Area Relative to the Entire Columbia Basin by Watershed

Watershed Name	Surface Soil Erosion Hazard	Earth Flow Hazard	Debris Avalanche Hazard	Sediment Delivery Potential	Sediment Delivery Hazard
Palouse	High	Low - Mod	Low – Mod	Mod - High	Low - Mod
Rock	High	Low - Mod	Low	Low	Low - Mod
Tucannon	High	Low - Mod	Low – Mod	Low	High
Lower Snake	High	Low - Mod	Low	Low	Low - Mod

Source: Maps 2.10, 2.11, 2.12, 2.13, and 2.15, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

Table 42. Road Erosion Hazard and Road Sediment Delivery Hazard within the Lower Snake River Basin Geographic Area Relative to the Entire Columbia Basin by Watershed

Watershed Name	Road Erosion Hazard	Road Sediment Delivery Hazard
Palouse	High	Low
Rock	High	Low
Tucannon	High	Mod - High
Lower Snake	High	Low

Source: Maps 2.16 and 2.17, Volume I, in Quigley and Arbelbide (1997). See Section 4.1 of this report for a description of the methods behind the ratings.

NMFS (Baker et al. 2005) has developed a model for estimating increases in erosion rates relative to historical, pre-settlement rates. Based on this study, erosion rates in the forested areas of the Palouse and Tucannon watersheds have not changed much and are 1 to 1.5 times historical rates. The erosion rates on non-forested land in the eastern half of the non-forested Palouse, Rock, and Tucannon watersheds ranges from 5 to 10 times that of historical rates. In the western half of those watersheds (including scablands) it ranges from 1.5 to 5 times the historical rate. The Lower Salmon Watershed was estimated to have erosion up to 3 times the historic rate.

The USGS developed a landslide overview map (Radbruch-Hall et al. 1982). This map delineates areas where large numbers of landslides have occurred and areas which are susceptible to landsliding in the conterminous United States. Within the Lower Snake River Basin geographic area, no areas with a moderate to high incidence of past landslides or susceptibility to future landslides were identified.

A NRCS analysis of cropland in the conterminous United States found that the all four watersheds showed extensive areas with excessive erosion on highly erodible lands. The western portion of the Lower Snake River watershed also includes areas of non-highly erodible land, also with excess erosion (NRCS 2000).

9.3.2 Subbasin Studies

A Southeast Washington Cooperative River Basin Study (USDA Soil Conservation Service et al. 1984) investigated sediments and erosion for the Snake River drainage and all tributaries south of the Snake River in Washington State. The study found that soil erosion and sedimentation on cropland is the most serious issue. Average erosion rates on forested land (0.37 tons/acre/year) and rangeland (0.5 tons/acre/year) are notably less than that of cropland (8 tons/acre/year). Of the 10.3 million tons soil eroded per year, the study estimated that 1.7 million tons enters the streams as sediment. Over 90 percent results from sheet and rill erosion on cropland. The erosion rates are highest in areas where mean average precipitation is 15 to 18 inches per year. It is also highest on the top and steeper northeast side of the Palouse type hills created by wind-blown loess, the most erodible parts of these hills. In forested areas, only road and streams have average annual erosion or sediment rates greater than one ton/acre. The result is a very close correlation between road density and sediment yield in forested areas; sediment rate in tons per square mile per year is nine times the road density. Despite that, the largest total yield of erosion in forested areas was from undisturbed areas (USDA Soil Conservation Service et al. 1984).

Sediments are monitored by several agencies at various sites. As part of their long-term Ambient Water Quality Monitoring Program, WDOE has water quality monitoring stations in the watershed and the data are available on-line at:

http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html#4

USGS has water quality and flow measurement stations in each of the watersheds and also has the data available on-line: http://waterdata.usgs.gov/nwis. In addition, the USGS National Aquatic Water Quality Assessment (NAWQA) Program for the Central Columbia Plateau (http://wa.water.usgs.gov/projects/ccyk/summary.htm) provides information and publications regarding sediment, nutrients, and other water quality parameters in the Palouse River. The Pomeroy Ranger District of the Umatilla National Forest has been monitoring water quality and the results are not routinely published. WSU has monitored water quality for conservation districts.

The following discusses the existing information for specific watersheds. While there are similarities among the Palouse, Rock, Tucannon, and Lower Snake watersheds, they have been often studied separately. The tributaries also influence the sediment in different reservoirs due to the location of their confluence with the Snake River. Therefore, this section is divided into a discussion of the tributaries of the four major reservoirs upstream of the Snake River mouth: Lower Granite Reservoir, Little Goose Reservoir (Lake Bryan), Lower Monumental Reservoir (Lake Herbert G. West), and Ice Harbor Reservoir (Lake Sacajawea).

Sediment Sources and Transport into Lower Granite Reservoir

The Snake and Clearwater Rivers upstream of their confluence provide a large amount of sediment to the upstream end of Lower Granite Reservoir. This deposition requires periodic dredging by the Corps to maintain the navigation channel and sufficient freeboard on local levees to prevent flooding. Sediment input and transport to this area are discussed in separate sections. The three main tributaries to Lower Granite Reservoir are Alpowa Creek, Wawawai Creek, and Steptoe Canyon Creek. The following describe information on each of these.

<u>Alpowa Creek</u>

Alpowa Creek originates from springs at the northeast end of the Blue Mountains. The mainstem is the only creek in this watershed that maintains perennial flow (Pomeroy Conservation District 2004). Major sediment transport occurs during rain-on-snow events that contribute to the extensive alluvial fan at the mouth of Alpowa Creek (Kuttle 2002). The *Salmonid Habitat Limiting Factors Water Resource Inventory Areas 33 (Lower) and 35 (Middle) Snake Watersheds, and Lower Six Miles of the Palouse River* (Kuttle 2002) provides a detailed description of habitat conditions in various segments of Alpowa Creek. Key characteristics described that would affect sediment input and transport include riparian habitat conditions, water diversions, streambank condition, substrate embeddedness, large woody debris, and width/depth ratio. Similarly, the *Lower Snake Mainstem Subbasin Plan* (Pomeroy Conservation District 2004) also describes characteristics of the Alpowa Creek watershed.

The Soil Conservation Service (USDA Soil Conservation Service et al. 1984) has indicated that cropland in the Alpowa drainage had some of the highest erosion rates in southeastern Washington. Indications of this are demonstrated by the large alluvial fan at the mouth of Alpowa Creek where it flows into Lower Granite Reservoir (Spangrude 2004). The Soil Conservation Service provided estimates of the erosion and soil loss that occurs in this drainage.

Other information on sediment input and transport in Alpowa Creek is limited to the summary documents by Kuttle (2002), Pomeroy Conservation District (2004), and water quality monitoring reports (Pomeroy Conservation District (2001). In the latter report, TSS have been sampled from 1999 through 2001. The general observation made in this report was that sediment levels were decreasing, likely as a result of implemented conservation practices.

The Corps also monitors sediment deposition in Lower Granite Reservoir at a number of different “ranges” (Corps 2002). The primary reason for gathering this data is to determine deposition rates in relation to the maintenance of the navigation channel.

<u>Steptoe Canyon and Wawawai Creeks</u>

Little information is available on either of these drainages. The Lower Snake Mainstem Subbasin Plan indicates that a “large depositional fan” exists at the mouth of Steptoe Canyon Creek (Pomeroy Conservation District 2004). This would tend to indicate that soil erosion is occurring upstream. In addition, Spangrude (2004) presented a picture of this alluvial deposit in a public meeting in March 2004.

The *Salmonid Habitat Limiting Factors Water Resource Inventory Areas 33 (Lower) and 35 (Middle) Snake Watersheds, and Lower Six Miles of the Palouse River* (Kuttle 2002) provides a detailed description of habitat conditions in various segments of Steptoe and Wawawai creeks. Key characteristics described that would affect sediment input and transport include riparian habitat conditions, water diversions, streambank condition, substrate embeddedness, large woody debris, and width/depth ratio. Kuttle indicates that a major flash flood during late summer 2001 resulted in scoured out portions of the channel and large deposits of gravel in other areas of Steptoe Canyon Creek. Livestock grazing in some areas of Steptoe Canyon Creek has also eroded streambanks. In Wawawai Creek, the streambanks appear more stable (Kuttle 2002).

Sediment Sources and Transport into Little Goose Reservoir (Lake Bryan)

The main tributaries or drainages to the Little Goose Reservoir (Lake Bryan) are Deadman Creek, Almota Creek, Penawawa Creek, New York Gulch, and Dry Gulch.

<u>Deadman Creek</u>

Major sediment transport occurs during rain-on-snow events, which are contributors to the alluvial fan at the mouth of Deadman Creek. Major storms often carry “immense” fine sediment loads in both Meadow and Deadman creeks (Kuttle 2002).

TSS were surveyed by WSU for Pomeroy Conservation District for 2003 to 2005 for sites on Pataha, Deadman and Meadow Creeks. Generally the samples taken were less than 10 mg/l, but at each sample sites there were individual readings with notable individual day spikes. Lower Deadman showed readings of 35 and 4000 mg/l at the two sampling sites and 200 mg/l were the high individual readings at sites on Meadow Creek (WSU 2005).

The *Salmonid Habitat Limiting Factors Water Resource Inventory Areas 33 (Lower) and 35 (Middle) Snake Watersheds, and Lower Six Miles of the Palouse River* (Kuttle 2002) provides a detailed description of habitat conditions in various segments of Deadman Creek. Key characteristics described that would affect sediment input and transport include riparian habitat conditions, water diversions, streambank condition, substrate embeddedness, large woody debris, and width/depth ratio. Similarly, the Lower Snake Mainstem Subbasin Plan (Pomeroy Conservation District 2004) also describes characteristics of the Deadman Creek watershed.

Sediment Sources and Transport into Little Goose Reservoir (Lake Bryan)

<u>Almota Creek, Penawawa Creek, New York Gulch, and Dry Gulch</u>

Very limited information relative to sediment is available on these drainages. The Pomeroy Conservation District (2004) identified roads, channelization, and agricultural land uses next to streams as limiting factors for Almota Creek. Also, Kuttle (2002) describes limiting factors in Almota Creek. However, no information was found on Penawawa Creek, New

York Gulch, or Dry Gulch. Actual measurements of sediment input or transport were not found.

Sediment Sources and Transport into Lower Monumental Reservoir (Lake Herbert G. West)

The main tributaries or drainages to the Lower Monumental Reservoir (Lake Herbert G. West) are the Palouse and Tucannon Rivers, along with smaller drainages including Alkali Flat Creek, and Fields Gulch.

<u>Palouse/Rock Watershed</u>

McCool and Papendick (1975) reported that sediment concentrations in the Palouse area are extremely variable on a daily, seasonal and annual basis. Runoff events of short durations (few days) can account for large percentages of sediment in a year and can even equal 4 to 5 times other years. Sampling programs of just a few years or of low-frequency can be misleading and may explain the wide variation in results of the various reports on sedimentation.

In Idaho, the South Fork Palouse River and several tributaries of the mainstem are on the 303(d) list for sediment. The South Fork of the Palouse River is listed from its headwaters to the Idaho-Washington border for sediment and other pollutants (bacteria, flow alteration, habitat alteration, nutrients, and temperature). Turbidity and TSS were monitored 27 times in one year at four sites. Turbidity averaged between 27 and 34 NTU and TSS averaged between 6 and 37 mg/l at the sites (Clark 2003). Deep, Hanigan, Cold, Flatter, Rock Creeks are tributaries to the mainstem Palouse River in Idaho on the 1998 303(d) list for sediments. The assessment documented by IDEQ in 2005 confirmed that they did not meet Idaho State sediment requirements. The monitored sediment load was determined to be 7,041, 1,452, 662, 1,223, and 148 tons per year in each tributary, respectively. Background sediment load, calculated using the RUSLE model, was determined to be 234, 62, 26, 219 and 12 tons per year, respectively. The resulting percent reductions required by the TMDL, range from 46 to 96 percent. In general, sediment measured adjacent to agricultural lands was higher than adjacent to forest lands in these streams (Henderson 2005). The mainstem of the Palouse was not listed, possibly because it supports beneficial uses.

In the Idaho monitoring report for 303(d) analysis of the South Fork of the Palouse and the tributaries to the mainstem in Idaho, Clark commented that based on visual assessments, TSS rates, and turbidity levels, the South Fork Palouse River, Hatter Creek, Flannigan Creek, Gold Creek, and Deep Creek seem to have the highest rates of bank erosion. Hatter and Flannigan also appear to have more cattle accessing the stream than any other stream in the watershed (Clark 2003).

While several streams in the Palouse/Rock watersheds are on the Washington 303(d) list, none are listed for sediment. Suspended sediments in the Palouse River at Hooper, Washington, were found to have declined from an average of 2.8 tons/acre-foot in 1962 to 1971 to 1.4 tons/acre-foot from 1993 to 1996 (Ebbert 1998).

A Washington State water quality report in 1995 indicated that the water quality in the Palouse is degraded with temperature, fecal coliform and pH frequently exceeding water quality criteria at the mainstem. Sediments and nutrients were noted as being high at all monitoring stations (Pettelier et al. 1995). Water quality is monitored monthly at several stations in the Palouse watershed. The 2003 and 2004 results for turbidity at Hooper, WA (furthest downstream station) ranged from 2 to 70 NTU and for suspended solids ranged from 3 to 66 mg/l.

Boucher (1970) reported the discharge-weighted, mean concentration of suspended sediment in the Palouse at Hooper, Washington from 1961 to 1965 to be 2,970 mg/l and the average annual sediment discharge to the Snake River to be about 1.5 million tons per year. The sediment yield ranged from 5 tons per square mile from the western part of the watershed to 2,100 tons per square mile in the central part and 460 to 1,000 tons per square mile in the eastern part. The high yield in the central part was considered to be the result of low vegetal cover, the wind-blown loess soils, and rapid run-off during winter storms. It was reported that approximately 81 percent of the sediment transport occurred during storm runoff from 1961 to 1965 and the highest concentrations occurred during the winter. Land use was considered to have had the greatest effect on increasing sediment yields. The study showed average annual soil loss in the area to be 14.2 million tons (Boucher 1970).

Erosion is considered to be a serious agriculture sustainability and productivity issue and has been the subject of studies. Erosion in some areas of the Palouse is “enormous” and the Palouse has been called one of the most erosive areas in the United States (Boucher 1970). The United States Department of Agriculture (USDA) estimated the average annual rate of soil erosion in the Palouse from 1939 through 1977 to be 14 tons/acre on cultivated cropland. While not all eroded soils reach the streams, loss of riparian vegetation makes it more likely that it will (Henderson 2005). A Kaiser study (1975) of soil loss due to erosion and its impacts on farming productivity showed that in traditional tillage areas, the Palouse hills eroded unevenly with the steeper north and east sides eroding more than the south and west sides (up to 30 and less than 10 tons per acre respectively).

According to the Palouse Cooperative River Basin Study (SCS 1978), soil loss by water induced erosion within the watershed ranges from moderate (with an average soil loss between 7 to 10 tons per acre per year) across much of the watershed to severe (with an average soil loss of 10 to 13 tons per acre per year). Erosion rates on rangeland and forested areas is considerably lower (up to 1 ton/acre) than that of cropland (20 to 30 tons/acre are common). Erosion is highest in the middle of the watershed.

Erosion and sediment delivery were estimated to be notably lower for pasturelands managed under conventional practices. An estimated 0.9 tons/acre/year erosion can occur on pastureland with a 10 percent sediment delivery ratio for sheet and rill erosion and 0.5 tons/acre/year for ephemeral gully erosion with a 60 percent sediment delivery (Rassmussen et al. 1995).

Tucannon Watershed

While several stream segments in the Tucannon watershed are on the Washington 303(d) list, none are listed for sediment. In a watershed briefing paper published by the WDOE, the water quality in the Tucannon was considered good when compared to the Palouse and Walla Walla systems. However, it was stated that nutrients, sediments and temperatures were high relative to statewide conditions and that while not highly significant, there was an increasing trend noted in suspended sediments (data not included) (Pettelier et al. 1995).

Water quality is monitored monthly by the WDOE at stations in the Pataha and the Tucannon River watershed. The results at Powers, WA (furthest downstream station on the Tucannon River) for 2003 and 2004 ranged from 1 to 32 NTU for turbidity and ranged from 2 to 98 mg/l for suspended solids (WDOE 2006).

Forest Service monitoring, supplemented by WSU, recorded turbidity and suspended solids data in the upper third of the Tucannon watershed. The turbidity data was less than 15 NTU at all stations monitored, except for a peak reading of 101 NTU in the middle reaches. The suspended solids were below the Forest Service-recommended standard of 80 mg/l. The readings were below 35 to 50 mg/l in spring months in the lower reaches of the National Forest to below 10 mg/l in other months and were in the 30 to 55 range all year at the upstream stations. Downstream of the National Forest, in the lower Tucannon, turbidity measurements were below 30 NTU except for a few measurements that ranged to approximately 85 NTU.

WSU and WDOE each have recorded TSS concentration in the Tucannon watershed. The summary of suspended sediments monitoring from 1979 to 2001 at the lowest reach of the river (from Kelly Creek confluence to the mouth) showed an average monthly reading from under 20 to approximately 210 mg/l. The mean monthly TSS recorded by WSU in this reach were generally below that recorded by WDOE and well below the Forest Service recommended standard of 80 mg/l. The mean TSS recorded by WDOE exceeded the recommended standard in 4 out of 12 months (Middle Snake Watershed Planning Unit 2005).

The combined annual sediment yield to streams for the entire Tucannon watershed was determined to be approximately 170,000 tons per year with most severe sedimentation issues in the lower third of the watershed, and noticeable lower severity upstream (Columbia Conservation District 2004).

In the Soil Conservation Service Southeast Washington Study (1984), the Tucannon Watershed was determined to have a high erosion rates on cropland at approximately 7 tons/acre/year compared to the average of 8 tons/acre/year in southeast Washington. While this is below average in the study, it was higher than the erosion for other tributaries to the Snake (the study included Walla Walla subbasin which was about 50 percent higher due to different conditions) (SCS et al. 1984).

A report was prepared for the SCS in 1982 (Hecht et al. 1982) on sediment transport and water quality in the Tucannon watershed. It was noted that a disproportionate amount of the sediment load originates in the lowland portions of this watershed. The portion of sediment that is bedload sediment is normally much smaller in the Tucannon watershed and in southeast Washington than in other areas. The lowest unit yields (0.14 and 0.27 tons per acre) were in the most upstream stations and in the lower watershed the yields ranged up to about 1.4 tons per acre. The total annual yield in 1980 for suspended sediment was estimated at 146,141 tons of sediment at the lowest station (approximately a mile from the Snake River) in a year without an extreme event (Hecht et al. 1982). In the Pataha Creek Watershed Plan, it was noted that in an unpublished SCS report, Pataha River sites had estimated erosion of 649,413 tons per year and total sediment delivery to the Tucannon River of 77,930 tons per year (Pomeroy Conservation District 1998).

Seasonal variations in suspended-sediment concentrations in the Tucannon watershed were described as winter storm runoff, peak snowmelt, and summer cloudbursts. Runoff from the first couple storms of winter often transports significantly larger concentrations of sediment than later events. For a given discharge, snowmelt transport rates are less than transport rates during winter storms. It was noted that the transport rates at flood stage are 10 times or more larger in this region than elsewhere in the United States and that the rate of velocity increase with discharge is among the largest values reported in literature. Less than 10 percent of the sediment yields occur at discharges less than twice the yearly mean (Hecht et al. 1982).

TSS were surveyed by WSU for Pomeroy Conservation District for 2003 to 2005 for sites on Pataha, Deadman and Meadow Creeks. Generally the samples taken were less than 10 mg/l, but at each of the sample sites there were individual readings with notable individual day spikes. Lower Deadman showed readings of 35 and 4,000 mg/l at the two sampling sites. Pataha showed 300, 400 and 700 mg/l at different stations, and 40 and 200 mg/l were the high individual readings at sites on Meadow Creek (WSU 2005).

Alkali Flat Creek and Fields Gulch

Alkali Flat Creek and Fields Gulch were not evaluated by Kuttle (2002). However, this author did provide a few details about Alkali Flat Creek. For example, he indicated that the Soil Conservation Service in 1984 found that sheet and rill erosion of cropland in this watershed carried 79,000 tons of fine sediment per year into the Snake River. In the Soil Conservation Service et al. (1984) study, the rate of erosion for cropland in the Alkali Flat Creek area was reported as below average for the area, 5 tons/acre/year compared to 8 tons/acre/year for watersheds south of the Snake River.

Sediment Sources and Transport into Ice Harbor Reservoir (Lake Sacajawea)

There are only two streams or drainages into Lake Sacajawea. These are Walker Canyon Creek and an unnamed tributary. Neither stream is referenced in Kuttle (2002) or Pomeroy Conservation District (2004). In the Soil Conservation Service et al. (1984) study, the rate of erosion for cropland in the Lower Snake Watershed was reported as below average for the area, 5 tons/acre/year compared to 8 tons/acre/year for watersheds south of the Snake River.

9.4 MANAGEMENT PRACTICES AND RESTORATION PROJECTS

The management practices in Idaho that affect the Idaho portion of the Palouse watershed are described in the Clearwater River subbasin section of this report (Section 6.4).

Washington's nonpoint source pollution control efforts for agriculture focus primarily on voluntary actions of growers and producers. Assistance and incentives from government agencies can be coupled with enforcement to target producers not cooperating with efforts to improve water quality. Local conservation districts, the NRCS, and WSU Cooperative Extension provide technical assistance for implementing BMPs in agriculture as defined in the NRCS field office technical guides (FOTG). Incentives include financial assistance for implementing farm plans and BMPs through the NRCS' EQIP program and reducing erosion and sediment through the lease or purchase of riparian buffer areas through the CREP program. One EQIP wind erosion project in Franklin and Benton Counties pays farmers to increase residue left on their fields. Erosion and sediment problems that are not voluntarily resolved can be directed to WDOE through complaints (Green et al. 2000).

The Washington State standards for turbidity are relative to background turbidity. They are an increase of less than 5 NTU increase for background turbidity of less than or equal to 50 NTU and less than 10 percent increase when the background it greater than 50 NTU [Washington Administrative Code (WAC) 173-201A]. There are no published standards for TSS in Washington State. However, the USFWS (1995, Introduction to Fish Health) suggests the upper limit of continuous exposure for the optimum health of salmonids is 80 mg/l.

The WDFW developed standards for managing and protecting state-owned lands used for agriculture or grazing. These standards are known as House Bill (HB) 1309 Ecosystem Standards for State-Owned Agricultural and Grazing Land. To comply with this bill, the WDNR has integrated a Resource Management Plan in all new or revised agricultural leases. The plan is designed for specific site conditions and generally minimizes land use activities that contribute to the deterioration of the ecosystem (Green et al. 2000).

Forestry in Washington is governed by the Forest Practices Act and regulations related to all aspects of forest practices. A permit from WDNR is required for timber harvest on forestlands in the state. The Forest Practice Rules specify the type and amount of activities that can occur on forest lands. The Rules were revised in 2002 and specify Riparian Management Zones (RMZs) for eastern Washington. The RMZs range from 75 feet to 130 feet from the bank full width of the stream, depending on the class of the stream and the width of the river. In all cases, the core zone is 50 feet. No harvest or construction is allowed in the core zone with few exceptions when necessary. Trees cut for or damaged within the core zone are to be left on site and those cut for road construction to cross a stream can be removed. Outside the core zone, but still within the RMZ, limited activities are allowed and there are requirements for the number of trees to be left to maintain proper functioning of the streams (WDNR 2002).

Improvement and restoration projects are funded and managed by many organizations. The NRCS, in conjunction with locally based conservation districts, also provide technical assistance and education to small timberland owners. There is also the Forestry Incentive Program, administered by the NRCS and WDNR to provide technical assistance on forest production and habitat planning.

NOAA has developed a website with an interactive mapping tool that provides information about restoration projects in the study area (http://www.nwr.noaa.gov/Salmon-Recovery-Planning/PCSRF/). This website provides a broader view of the funding for salmon recovery and encompasses not only the efforts of the Washington IAC salmon recovery efforts, but also the efforts in Oregon and Idaho.

Another funding entity is the BPA, which funds salmon recovery and habitat projects throughout the Columbia River Basin. Information about BPA's fish and wildlife projects is available through Streamnet or the Columbia River Basin Fish and Wildlife Authority at the following respective sites:

http://www.streamnet.org/

http://www.cbfwa.org/fwprogram/maps.cfm

The 2000 to 2002 projects of the Columbia River Inter-Tribal Fish Commission (CRITFC) Tribes (funded by PCSRF), includes some that are in the study area and would affect sediments (CRITFC 2002). The Spirit of the Salmon Plan (CRITFC 1995) lists plans for each watershed to address fish habitat. Many of these projects would reduce sediments because they are designed to stabilize or restore habitats (e.g., streambanks).

In addition, the Corps has recovery or enhancement projects in the Snake River basin that are funded under various plans including the Lower Snake River Compensation Plan (Corps 1975) and its supplement (Corps 1996) which provides terrestrial and aquatic mitigation in response to the development of the Corps' four dams on the lower Snake River, and other funding through sources such as the Water Resources Development Act (particularly Sections 206 and 1135).

Alpowa

There are a wide variety of management approaches and processes for reducing sediment input from Alpowa Creek. These are summarized in the Lower Snake Mainstem Subbasin Plan (Pomeroy Conservation District 2004) and the Southeast Washington Cooperative River Basin Study (USDA Soil Conservation Service et al. 1984). In addition, the IAC's Salmon Recovery Funding Board lists a number of projects on its website that are specifically focused on sediment reduction in Alpowa and other local streams. An example of this is reported by the WDOE (2005) in a joint effort with local landowners, the Pomeroy Conservation District, and the local NRCS office. The project in this example was fencing along 10 miles of the upper Alpowa Creek drainage to exclude livestock coupled with plantings of thousands of native trees and shrubs to help stabilize banks, thus reducing erosion. The CREP, NRCS Soil and Water Conservation Assistance Program (SWCA), and the WDOE Centennial Clean Water Fund provided funding for the project.

Deadman Creek, Steptoe Canyon, Wawawai Creek, Alkali Flat Creek, and Field Gulch

There are a wide variety of management approaches and processes for reducing sediment input from Deadman Creek, Alkali Flat Creek, and Field Gulch. These are summarized in the *Lower Snake Mainstem Subbasin Plan* (Pomeroy Conservation District 2004). For example, the Pomeroy Conservation District has implemented conservation practices to reduce erosion from upland croplands. This broad-based program [funded through the Interagency Committee (IAC) Salmon Recovery Funding Board (SRFB)] includes practices such as changing crop rotations, reducing conventional summer fallow programs, and conversion from conventional tillage to direct seeding (IAC 2005).

Palouse

Loss of soils in farming areas has been the primary subject of research and impetus for implementing better farming techniques that conserve and retain soils. All but the lowest 6 miles of the mainstem are blocked from access by salmonids. The conservation districts have taken a lead in soil conservation efforts and stream restoration and stabilization. As such, sediment inputs to local tributaries may decrease in the future as improved farming techniques become more universal and as riparian zones are reestablished and stabilize stream banks.

A USDA funded study (USDA Cooperative State Research, Education, and Extension Services 2004) is being implemented in Paradise Creek in the eastern Palouse watershed to understand the effectiveness of conservation practices at the watershed scale. The study is funded through 2007 and is intended to provide an understanding of sediment transport and cumulative effects.

Tucannon

Recommendations in the Limiting Factors report for WRIA 35 include improving riparian vegetation and reducing erosion. Specifically, the erosion reduction suggests implementing no-till/direct seed farming methods on as many acres as possible (Kuttle 2002).

The critical limiting factor to salmonid fish production in the Tucannon watershed was determined to be maximum water temperature. Other factors included: riparian function, LWD, hatchery fish outplants, anthropogenic confinement, fish pathogens, harassment/poaching, embeddedness, salmon carcasses, and pools (Kuttle 2002). Most restoration efforts have the potential to decrease sediment inputs to the stream. There are a variety of ongoing restoration activities in the state of Washington that are implemented in the Tucannon Watershed.

Since 1996, a total of 684 projects were implemented in the Tucannon watershed to improve fish habitat. Of those, 34 percent specified a general focus of sediments. Another 8, 9 and 6 percent were for channel stability, temperature, and riparian function, respectively and likely positively affected sediment (Columbia Conservation District 2004).

9.5 SUMMARY OF PRELIMINARY CONCLUSIONS

Based on this review of available information, a few preliminary conclusions can be made regarding opportunities for sediment reduction. It appears that the most promising watersheds for reduction efforts would include the Palouse, Rock, and Tucannon. In these watersheds, it appears that agricultural and grazing areas have the greatest potential for improvements. Restoration of degraded riparian areas, projects to limit field erosion and delivery to streams in agricultural/grazing areas, and preventing road failures and minimizing road erosion appear to be the projects with the highest potential for success. Most of these opportunities are on private lands.

10. PRELIMINARY RECOMMENDATIONS FOR FURTHER STUDY

This section presents preliminary recommendations representing various options for further study, based on the initial information and data gathering efforts. These options can be conducted sequentially or in groups and will depend on available funding levels.

Options for Further Study

Conduct a screening effort using the references and GIS information gathered in the initial effort to identify the following:

- Watersheds and subwatershed with highest sediment production.
- Identify whether production is likely from natural sources or is the result of land use and other human factors.
- From this information, make an initial prioritization of watersheds/ subwatersheds to investigate further (this does not mean medium and lower priority watershed will not be investigated, but that resources can initially be targeted to the highest priority watersheds assuming that resources (staff and funding) are limited.

Further organize and evaluate the many widely dispersed and often short-term sediment transport measurements that have been conducted by various parties throughout the watershed to determine additional information that is available to support identification of sediment delivery from the various watershed and subwatersheds

- USGS 1980 study (Jones and Seitz 1980).
- USGS daily suspended sediment measurements.
- PACFISH/INFISH Biological Opinion Monitoring (PIBO).
- State Water Quality monitoring programs.
- Suspended and bedload sediment measurements from the Snake River Basin Adjudication effort.
- Project-specific measurements from the Forest Service and other agencies that are available only on file in local offices.
- Assess the applicability of the measurements and use this to help identify needs for the sediment transport monitoring program.

Conduct a multi-year sediment transport monitoring program similar to the USGS 1972 to 1979 effort (Jones and Seitz 1980).

- Effort should be concentrated on basins with the highest potential for sediment delivery from a screening effort.
- Bedload sampling, which is expensive and time consuming may not be necessary as the 1980 study showed bedload was a relatively minor portion, averaging about 5 percent, of the total sediment load.
- The effort should be conducted again at both the Anatone, Washington (Snake River) and Spalding, Idaho (Clearwater River). It will be of particular interest to see if the load on the Snake River has lessened compared to the Clearwater. For the 1972 to 1979 period of the previous study, the load on the Snake was approximately 4 times the load on the Clearwater. Recovery of high sediment production areas in the South Fork of the Salmon could possibly have reduced the contribution from the Snake.
- Identify other potential sites to extend the sampling effort to, develop and implement the program at these additional key sites.

Develop an initial sediment budget for the study area to the extent possible with existing information supplemented by field work.

- Utilize reservoir sedimentation information and references such as the USGS 1980 study (Jones and Seitz 1980) to identify the total sediment inflow to the system. For example, sediment transects are completed every 3 years in Lower Granite Reservoir by the Corps (Les Cunningham, Corps, Walla Walla District, personal communication, 2006). The results of these evaluations are filed at the Walla Walla District. In addition, other major documents (see Appendix D) address sediment loading and ranges in the Lower Granite Reservoir (and other lower Snake River reservoirs).
- Utilizing the information gathered to develop a procedure that allocates the sediment production to the various watersheds and subwatersheds based on factors such as soils, geology, topography, cover, land use and mass wasting. Additionally, other sediment transport measurements, if identified, should be used to calibrate and assist in the process.
- Account for non-contributing areas above lakes.
- If practical, the procedure should assign the sediment production to various erosion types such as: sheet and rill erosion, gullying, mass wasting, channel instability (bed and bank erosion) and wind erosion.

- The procedure should also assign the erosion to various land use and land management practice areas.
- Account for instream factors that might delay or limit delivery of upstream sediments.
- This effort will likely require some stratified random sampling of various aspects of the system such as channel instability.

Utilize the results of the sediment budget to reassess priority targets by location and land use and management practices.

- Develop strategies for addressing sediment production and delivery from the target areas.
- Review effectiveness of efforts already underway on these or similar lands.
- Identify administrative authorities to actually fund and implement efforts that will bring about improved conditions.
- Develop additional measures that could be used to address key problems.

Estimate potential for reduction in sediment loading to the Lower Snake Reservoirs from application of the measures.

- Estimate potential sediment reduction from the actions.
- Develop time frame for reduction.
- Determine if there would be a reduction or increase in sediment load to the Lower Snake Reservoirs over time (factors such as already implemented land management and land use practices as well as historic and current restoration efforts).
- Determine difference in future sediment delivery under No Action and Action scenarios.

11. REFERENCES

Asotin County Conservation District. 2004. Asotin Subbasin Plan – May 2004 Version. Prepared for the Northwest Power and Conservation Council. 179 pp plus appendices.

Bach, L. 1995. River basin assessment Upper/Middle Grande Ronde River and Catherine Creek. Oregon Department of Environmental Quality and Oregon Watershed Health Program.

Baker, S., F. Damian, J. Hall, and T. Beechie. 2005. Draft - Modeling erosion rates increases in the Interior Columbia River Basin. Draft Report. NMFS. 42 pages.

Boll, J., E. Brooks, and D. Traeumer. 2002. Hydrologic and Sediment Delivery Analysis of Agriculturally Dominated Watersheds in the Clearwater River Basin. Submitted by Dept. of Biological and Agricultural Engineering, University of Idaho to Idaho Soil Conservation Commission.

Bonneville Power Administration (BPA). 1997. Watershed Management Program Final Environmental Impact Statement DOE/EIS-0265. BPA. Portland Oregon.

Boucher, P. 1970. Sediment Transport by Streams in the Palouse River Basin, Washington and Idaho, July 1961 - June 1965. USDA Geological Survey Water=Supply Paper 1899-C. Washington, DC.

Bugosh, N. 2000. Lower Selway River Subbasin Assessment. Idaho Dept. of Environmental Quality (IDEQ). Lewiston, ID.

Bugosh, N. 1999. Lochsa River Subbasin Assessment. Idaho Dept. of Environmental Quality (IDEQ). Lewiston, ID.

Clark, K. 2003. Tributaries of the Palouse River Monitoring Report 2002 developed for Latah Soil and Water Conservation District, Idaho Soil Conservation Commission, Idaho State Dept. of Agriculture, and Idaho Dept. of Environmental Quality. Technical Results Summary KPC PR-02. Idaho Association of Soil Conservation Districts. Moscow, ID.

Clearwater BioStudies, Inc. 1993. Stream and Riparian Conditions in the Grande Ronde Basin. Final Report.

Clearwater River Focus Program. December 2005 (*Date accessed*). http://www.scc.state.id.us/clwfprogram.htm.

Columbia Conservation District. 2004. Tucannon Subbasin Plan prepared for Northwest Power and Conservation Council. Portland, OR. Available on-line: http://www.nwcouncil.org/fw/subbasinplanning/Tucannon/plan/.

Covert, J., J. Lyerla, and M. Ader. 1995. Initial Watershed Assessment Tucannon River. Washington Dept. of Ecology Open File Report 95-04. Olympia, WA.

Columbia River Intertribal Fish Commission (CRITFC). 1995. The Columbia River Anadromous Fish Restoration Plan of the Nez Perce, Umatilla, Warm Springs and Yakama Tribes. Wy-Kan-Ush-Mi Wa-Kish-Wit.

Columbia River Intertribal Fish Commission (CRITFC). 2002. FY2000 - FY2002 Pacific Coastal Salmon Recovery Fund Projects For The Columbia River Intertribal Fish Commission Tribes. Available on-line: http://www.critfc.org/text/pcsrf/pcsrf.html.

Diebel, K. 1997. Grande Ronde Basin Water Quality Monitoring, Plans for Six Key Watersheds. Union and Wallowa SWCD, Grande Ronde Model Watershed Program, La Grande, Oregon.

Ebbert, J., and R.D. Roe. 1998. Soil Erosion in the Palouse River Basin: Indications of Improvement. USGS Fact Sheet 069-98. USDA Natural Resources Conservation Service. Washington, DC. Available on-line: http://wa.water.usgs.gov/pubs/fs/fs069-

Ecovista, Nez Perce Tribe Wildlife Division, WSU Center for Environmental Education. 2003. Draft Clearwater Subbasin Assessment. Prepared for Nez Perce Tribe Watersheds Division and Idaho Soil Conservation Commission. Boise, ID.

Ecovista. 2003. Draft Clearwater Subbasin Inventory. Contracted by Nez Perce Tribe Watersheds Division. Lapwai, ID.

Ecovista. 2003. Draft Clearwater Subbasin Management Plan. Nez Perce Tribe Watersheds Division. Lapwai, ID.

Ecovista. 2004. Salmon Subbasin Management Plan. For Nez Perce Tribe and Shoshone-Bannock Tribe as part of Northwest Power and Conservation Council's (NPCC) Columbia River Basin Fish and Wildlife Program.

Ecovista. 2004a. Imnaha Subbasin Assessment. Lead entity: Nez Perce Tribe. Planning Team:Wallowa Natural Resource Advisory Committee. Northwest Power and Conservation Council. Portland, OR.

Ecovista. 2004b. Snake Hells Canyon Subbasin Assessment. Lead entity: Nez Perce Tribe, prepared for Northwest Power and Conservation Council. Northwest Power and Conservation Council. Portland, OR.

Gilmore, S. 2004. Final Draft Palouse Subbasin Management Plan. Palouse Rock Lake Conservation District.

Grande Ronde Model Watershed Program. 2004. Grande Ronde Subbasin Plan. Prepared for the Northwest Power and Conservation Council. 494 p.

Green, W., W. Hashim, and D. Roberts. 2000. Washington's Water Quality Management Plan to Control Nonpoint Source Pollution. Washington Dept. of Ecology Publication 99-26. Olympia, WA.

Hecht, B., R. Enkehall, C. Ivor, and P. Baldwin. 1982. Sediment Transport, Water Quality, and Changing Bed Conditions, Tucannon River, Southeastern Washington. USDA Soil Conservation Service. Spokane, WA.

Hemstrom, M., T. Smith, D. Evans, C. Clifton, E. Crowe, and M. Aitken. 2002. Midscale analysis of streamside characteristics in the Upper Grande Ronde Subbasin, northeastern Oregon. USDA Forest Service Pacific Northwest Research Station Research Note PNW-RN-534. 16 pp.

Henderson, R. 2005. Palouse River Tributaries Subbasin Assessment and TMDL. IDEQ (Idaho Dept. of Environmental Quality). Lewiston ID. Available on-line.

Idaho Dept. of Environmental Quality (IDEQ). 1999. Lemhi River Watershed TMDL. Idaho Dept. of Environmental Quality. Boise, ID. December 1999.

Idaho Dept. of Environmental Quality (IDEQ). 2001a. Pahsimeroi River Assessment and TMDLs. Idaho Dept. of Environmental Quality. Boise, ID. December 2001.

Idaho Dept. of Environmental Quality (IDEQ) 2001b. Middle Salmon River-Panther Creek Subbasin Assessment and TMDLs. Idaho Dept. of Environmental Quality. Boise, ID. December 2001.

Idaho Dept. of Environmental Quality (IDEQ). 2002. South Fork Salmon River Subbasin Assessment. Idaho Dept. of Environmental Quality. Boise, ID. May 2002.

Idaho Dept. of Environmental Quality (IDEQ). 2003a. Addendum to the South Fork Salmon River Subbasin Assessment. Idaho Dept. of Environmental Quality. Boise, ID. July 2003.

Idaho Dept. of Environmental Quality (IDEQ). 2003b. Upper Salmon River Subbasin Assessment and TMDLs. Idaho Dept. of Environmental Quality. Boise, ID. January 2003.

Idaho Dept. of Environmental Quality (IDEQ). 2005. Draft Little Salmon River TMDL. Boise Regional Office. Boise, ID.

Idaho Dept. of Environmental Quality (IDEQ). 2001. Tammany Creek Sediment TMDL - Subbasin Assessment and Total Maximum Daily Load Analysis. 57 pages.

Idaho Dept. of Environmental Quality, Nez Perce Tribe and EPA. 2000a. Cottonwood Creek Total Maximum Daily Loads. IDEQ. Lewiston, ID.

Idaho Dept. of Environmental Quality, Nez Perce Tribe and EPA. 2000b. Jim Ford Creek Total Maximum Daily Loads. IDEQ. Lewiston, ID.

IAC (Idaho Administrative Code). 20.02.01 Rules Pertaining to the Idaho Forest Practices Act. Available on line: http://www2.state.id.us/adm/adminrules/rules/idapa20/0201.pdf.

Idaho Power Company (IPC). 2003. New License Application for Hells Canyon FERC Project No. 1971. Submitted to the Federal Energy Regulatory Commission. Application includes technical appendices. July 2003.

Idaho Soil Conservation Commission (ISCC). 1995. Model Watershed Plan; Lehmi, Pahsimeroi and East Fork Salmon River. U.S. Dept. of Energy, BPA. DOE/BP-2772. Portland, OR.

Idaho Soil Conservation Commission (ISCC). 2005a. Draft Cottonwood Creek Watershed Work Plan. Clearwater Focus Program, Subject to SRBA Court Protective Order- DO NOT RELEASE. Idaho Soil Conservation Commission. Boise, ID.

Idaho Soil Conservation Commission (ISCC). 2005b. Draft Lapwai Creek Watershed Work Plan. Clearwater Focus Program, Subject to SRBA Court Protective Order- DO NOT RELEASE. Idaho Soil Conservation Commission. Boise, ID.

Idaho Soil Conservation Commission (ISCC). 2005c. Draft Lawyer Creek Watershed Work Plan. Clearwater Focus Program, Subject to SRBA Court Protective Order- DO NOT RELEASE. Idaho Soil Conservation Commission. Boise, ID.

Jones, M., and H. Seitz. 1980. Sediment transport in the Snake and Clearwater Rivers in the vicinity of Lewiston, Idaho. USGS Water Resources Investigations Open File Report 80-690. Prepared in cooperation with the Corps, Walla Walla District.

Kaiser, V. 1975. Soil Erosion and Wheat Yields in Whitman County, Washington, Northwest Science, v.41, no. 2, p 86-91, 1967.

Kuttle, Jr., M. 2002. Salmonid Habitat Limiting Factors Water Resource Inventory Areas 33 (Lower) and 35 (Middle) Snake Watersheds, and Lower Six Miles of the Palouse River. 197 pages.

McCool, D., and R. Papendick. 1975. Variation of Suspended Sediment Load in the Palouse Region of the Northwest. Paper no. 75-2510. American Society of Agricultural Engineers. St. Joseph, MI.

McIntosh, B., J. Sedell, J. Smith, R. Wissmar, S. Clarke, G. Reeves, and L. Brown. 1994. Management History of Eastside Ecosystems: Changes in Fish Habitat Over 50 Years, 1935-1992. USDA Forest Service, Pacific Northwest Research Station General Technical Report PNW-GTR-321.

Middle Snake Watershed Planning Unit. 2005. Middle Snake River Watershed Level 1 Assessment - WRIA 35. Available on http://www.asotinpud.org/msww/.

Mobrand Biometrics. 1997. Application of the Ecosystem Diagnosis and Treatment (EDT) Method to the Grande Ronde Model Watershed Project.

Mobrand Biometrics, Inc. 2006. EDT Website. http://www.mobrand.com/MBI/edt.html.

Nelson and Burns. 2004. Deposition of Fine Sediment in the Salmon River Watershed, Boise and Payettte National Forests, Idaho. Statistical Summary of Interstitial and Surface Sediment Monitoring, 1983-2003. USDA Forest Service, Payette National Forest.

Northwest Power and Conservation Council (NPCC). 2004. Salmon Subbasin Assessment. NPCC. Portland, OR.

Oregon Department of Environmental Quality (ODEQ). 1997. Water Quality Report – Grande Ronde River.

Oregon Department of Environmental Quality (ODEQ). 1998. Oregon's 1998 Section 303(d) List of Water Quality Limited Waterbodies, Oregon's Criteria for Listing Water bodies and Basin Maps.

Oregon Department of Environmental Quality (ODEQ). 1998. Grande Ronde River Basin Water Quality Technical Assessment – Temperature.

Oregon Department of Environmental Quality (ODEQ). 1998. Grande Ronde River Basin Technical Assessment (Overview of Water Quality Conditions).

Oregon Department of Environmental Quality (ODEQ). 1999. Upper Grande Ronde River Sub-Basin Temperature Total Maximum Daily Load (TMDL).

Oregon Department of Environmental Quality (ODEQ). 2000. Upper Grande Ronde River Sub-Basin Total Maximum Daily Load (TMDL). April 2000.

Pettelier, G., D. Hallock, D. Serdar, R. Garrigues, and Hoyle-Dodson. 1995. Watershed Briefing Paper for the Upper and Lower Snake River Water Quality Management Areas. Washington Dept. of Ecology Publication 95-346. Olympia, WA.

Pomeroy Conservation District Landowner Steering Committee. 1998. Pataha Creek Model Watershed Plan. Pomeroy Conservation District. ID.

Pomeroy Conservation District. 2004. Lower Snake Mainstream Subbasin Plan. Northwest Power and Conservation Council. Portland, OR.

Quigley, T.M., and S.J. Arbelbide, Editors. 1997. An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins, Volumes I-IV. USDA Forest Service, Pacific Northwest Research Station and USDI Bureau of Land Management. General Technical Report PNW-GTR-405.

Radbruch-Hall, D.H., R.B. Colton, W.E. Davies, I. Lucchitta, B.A. Skipp, and D.J. Varnes. 1982. Landslide overview map of the conterminous United States. Geological Survey Professional Paper 1183. U.S. Government Printing Office, Washington, DC. 36 pp.

Reckendorf, F., and P. Pedone. 1989. Erosion and sediment impacts of the 1985 Food Security Act above Lower Granite Reservoir, Idaho, Oregon, and Washington. National Non-point Source Conference 1989, pages 199-136.

Reckendorf, F., P. Pedone, and D. Hoodenpyle. 1988. Erosion reduction impact of the Food Security Act above the Lower Granite Reservoir, Idaho, Oregon, and Washington. July 1988. 24 pages plus tables.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder. 1997. Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE). USDA Agriculture Handbook No. 703, U.S. Government Printing Office, Washington DC. 404 pp.

Resource Planning Ltd. 2003. Agricultural Pollution Abatement Program. For Idaho Dept. of Environmental Quality and Idaho Soil Conservation Commission. Boise, ID.

Shumar, M. 2002. Middle Salmon River-Chamberlain Creek Subbasin assessment and Crooked Creek Total Maximum Daily Load. Idaho Dept. of Environmental Quality (IDEQ). Boise, ID. December 2002.

Spangrude, G. 2004. Navigation Channel Maintenance, Snake and Clearwater Rivers Public Information Meeting In-River Sediment Transport. Available on-line: http://www.nww.usace.army.mil/dmmp/maintenance_dreding/presentation/gene/gne.htm.

Teasdale, G., and M. Barber. 2005. Aerial Assessment of Ephemeral Gully Erosion and Channel Erosion in the Lower Potlatch River Basin Research Report. State of Washington Research Center, University of Washington.

U.S. Army Corps of Engineers (Corps). 1975. Special Report: Lower Snake River Fish and Wildlife Compensation Plan, Lower Snake River, Washington and Idaho. Walla Walla District, Walla Walla, WA.

U.S. Army Corps of Engineers (Corps). 1991. Special Report: Lower Snake River Fish and Wildlife Compensation Plan. Wildlife Habitat Compensation Evaluation for the Lower Snake River Project. U.S. Army Corps of Engineers, Walla Walla District.

U.S. Army Corps of Engineers (Corps). 1996. Interim Report, Supplement to Special Report, Lower Snake River Fish and Wildlife Compensation Plan, Lower Snake River, Washington and Idaho. Walla Walla District, Walla Walla, WA.

USDA Cooperative State Research, Education, and Extension Services. 2004. Investigation of the changes in the Little Bear River Watershed in Response to the Implementation of Best Management Practices. Available at: http://cris.csrees.usda.gov/cgi-bin/starfinder/0?path=fastlink1.txt&id=anon&pass=&searsch=R=9766&format=WEBLINK.

USDA Forest Service (Forest Service) and USDI Bureau of Land Management (BLM). 1995. Decision Notice/Decision Record Finding of No Significant Impact for the Environmental Assessment for the Interim Strategies for Managing Anadromous Fish-producing Watersheds in Eastern Oregon, and Washington, Idaho, and Portions of California. (This document is also known as PACFISH.)

USDA Forest Service (Forest Service). 1995. Inland Native Fish Strategy Environmental Assessment Decision Notice and Finding of No Significant Impact. Intermountain, Pacific, and Northwest Regions. (This document is also known as INFISH.)

USDA Forest Service (Forest Service) and USDI Bureau of Land Management (BLM). 1997. An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great Basins. Volume I. USDA Forest Service, Pacific Northwest Research Station General Technical Report PNW-GTR-405. Portland, OR.

USDA Forest Service (Forest Service) and Bureau of Land Management. 1995a. Decision Notice/Decision Record Finding of No Significant Impact for the Environmental Assessment for the Interim Strategies for Managing Anadromous Fish-producing Watersheds in Eastern Oregon, and Washington, Idaho, and Portions of California.

USDA Forest Service (Forest Service). Undated. Boise Adjudication Team summaries. Rocky Mountain Research Station, Boise Aquatic Sciences Lab, Boise Adjudication Team. On-line at http://www.fs.fed.us/rm/boise/teams/soils/Bat%20WWW/index.htm.

USDA Forest Service (Forest Service). 1995a. Inland Native Fish Strategy Environmental Assessment Decision Notice and Finding of No Significant Impact. Intermountain, Pacific and Northwest Regions.

USDA Forest Service (Forest Service). 1999. Watershed Analysis Catherine Creek – Ladd McAllister. Wallowa-Whitman National Forest, La Grande Ranger Station, La Grande, OR.

USDA Forest Service (Forest Service). 2003a. Record of Decision for the FEIS and Revised Land and Resource Management Plan. Boise National Forest. Boise, ID.

USDA Forest Service (Forest Service). 2003b. Record of Decision for the FEIS and Revised Land and Resource Management Plan. Boise National Forest. Boise, ID. July 2003.

USDA Forest Service (Forest Service) 2003c. Record of Decision for the FEIS and Revised Land and Resource Management Plan. Payette National Forest. McCall, ID. July 2003.

USDA Natural Resource Conservation Service (NRCS), USDA Forest Service (Forest Service), Union Soil and Water Conservation Service. 1997. Grande Ronde River Cooperative River Basin Study. Union County, OR.

USDA Natural Resource Conservation Service (NRCS). 2000. National Resources Inventory (Excessive Erosion on Cropland 1997, Acres of Highly Erodible Cropland 1997, Acres of Non-highly Erodible Cropland 1997). USDA NRCS Resource Assessment Division, Washington, DC. Available on-line: http://www.nrcs.usda.gov/technical/land/meta/m5083.html.

USDA Soil Conservation Service (SCS), Forest Service, Economics, Statistics, and Cooperatives Service. 1978. Palouse Cooperative River Basin Study. 182 pages.

USDA Soil Conservation Service (SCS), Forest Service, and Economic Research Service. 1984. Southeast Washington Cooperative River Basin Study. United States Department of Agriculture.

USDI Bureau of Land Management. (BLM) 1993. Biological evaluation, ESA Section 7 Consultation. Baker Resource Area, Vale District.

U.S. Environmental Protection Agency (EPA). 1980. An approach to water resources evaluation of non-point silvicultural sources: a procedural handbook. EPA-60018-80-012. Environmental Protection Agency, Washington, DC.

Upper Salmon Basin Watershed Project Technical Team (USBWPTT). 2005. The Screening and Habitat Improvement Prioritization for the Upper Salmon (SHIPUSS). Upper Salmon Basin Watershed Project. Salmon, ID.

Upper Salmon Basin Watershed Project. Website accessed 1/15/2006. http://www.modelwatershed.org/Projects.html.

Washington Dept. of Ecology. 2005. Transforming Watersheds Couse Creek - Asotin County. Ecology Publication 05-10-017. Olympia WA.

Washington Department of Ecology (WDOE). 2006. Website accessed January 2006. http://www.ecy.wa.gov/programs/eap/fw_riv/rv_main.html#4.

Washington Dept. of Natural Resources (WDNR). 2002 Washington Forest Practices Rules. Available on line http://www.dnr.wa.gov/forestpractices/rules/.

Washington Department of Fish and Wildlife (WDFW). 2006. William T. Wooten Wildlife Area. Website accessed 1/20/2006. Available on line: http://wdfw.wa.gov/lands/r1woot.htm.

Washington State University (WSU). 2005. Quarterly Report Water Quality Monitoring February 2003 - February 2005. WSU Dept. of Biological Systems and Center for Environmental Education. Pullman, WA.

Lower Snake River Programmatic Sediment Management Plan Environmental Impact Statement

Appendix B

Investigation of Sediment Source and Yield, Management, and Restoration Opportunities Within the Lower Snake River Basin

Appendixes — *available upon request*