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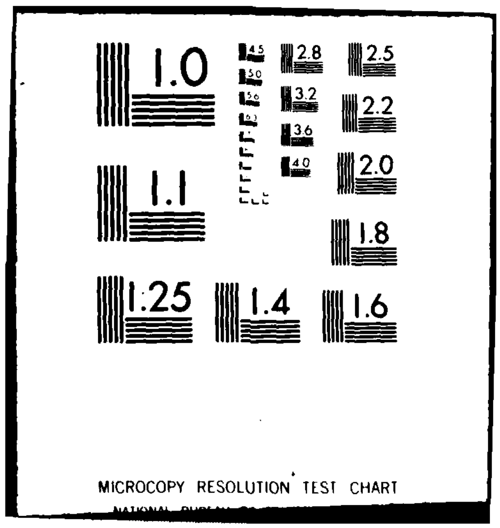
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GRAYS HARBOR AND CHEHALIS RIVER IMPROVEMENTS TO NAVIGATION ENVIRONMENTAL STUDIES

SOURCES OF SEDIMENT TO GRAYS HARBOR ESTUARY

PREPARED BY:

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US Army Corps of Engineers
Seattle District

JANUARY 1982

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Seattle District, U.S. Army Corps of Engineers, is currently conducting studies to ascertain the environmental impacts of widening and deepening the navigation channel in Grays Harbor, Washington. This study is an examination of the origin and amount of sediments filling the navigation channels of Grays Harbor from the Chehalis River basin and the means by which this sediment discharge rate could be reduced. A review of the literature shows that Wynoochee and Satsop River subbasins in the Chehalis River basin are

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) discharging suspended sediment at high rates compared to other similar basins in the Pacific Northwest. The primary land use activity throughout the basin is forestry. The literature on the effects of logging on sediment production shows that suspended sediment discharge levels are 3.4 to 4.9 times higher after logging as compared to the level before logging activities. This increase is primarily due to sediments from logging roads.

Literature on the effectiveness and degree of compliance with the Washington Forestry Practices Act (FPA) is reviewed. Statewide, control of sedimentation is good when compliance is achieved and often poor when it is not. According to studies by the Washington Department of Ecology, the FPA is, statewide, complied with about 80 percent of the time, although in the Wynoochee and Satsop River subbasins, the FPA is probably complied with less frequently. Reduction of the total sediment load from the Chehalis River basin can be accomplished by several methods. Advances in logging road construction technology and increasing logging on previously cut forest lands will also help to stabilize further increases in suspended sediment discharges from the Chehalis River basin.

The degree to which suspended sediment discharges could be reduced and the subsequent savings in dredging costs for the Corps that would result from such a reduction cannot be determined from the available literature.

SOURCES OF SEDIMENT TO

GRAYS HARBOR ESTUARY

By

DAVID M. KEHOE

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SEATTLE DISTRICT
U.S. ARMY CORPS OF ENGINEERS
January 1982

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ABSTRACT

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COVER PHOTOGRAPH: Area of side slope erosion.

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Sources of Sediment to Grays Harbor Estuary

1.0 Background and Purpose of This Report.

1.1 Introduction. The U.S. Army Corps of Engineers has worked within the Chehalis River basin for over a century, involved with projects ranging from the jetties at the mouth of Grays Harbor to evaluation of flood control damsites on the South Fork of the Newaukum River in the Cascade Mountain Range. The first dredging by the Corps of Engineers in the basin occurred in the early 1900's when the Grays Harbor jetties were constructed. Annual maintenance dredging began during the early part of World War II to provide Navy access into the harbor. As larger vessels with deeper drafts became more common in maritime trade, the depth and width of navigation channels were increased to accommodate them. Periodic widening and deepening, as well as yearly maintenance dredging of the sediments continually filling the navigation channels, has been performed by the Corps of Engineers throughout most of this century.

The trend toward larger vessels with deeper drafts has continued in recent times. The Water Resources Committee of the Grays Harbor Regional Planning Commission has identified navigation in Grays Harbor as one of the problems which should receive priority attention in planning from 1970 to 2000. In the committee's words, "Increased traffic is bringing in larger ships, and if the Port of Grays Harbor is to continue as a maritime port, the channel will probably have to be deepened from the present 30 feet. The question is . . . what will be the consequences on the physical and biological environment of Grays Harbor."1/

In July of 1976, the Corps of Engineers, Seattle District, completed an examination of the feasibility of widening and deepening the existing navigation channel in Grays Harbor. The environmental impact statement written as part of this examination led to further environmental studies on the impacts of this project on the Grays Harbor area. The subject addressed by this report, the effects of upstream sediment on Grays Harbor, was selected as one of these studies based upon requests from conservation organizations, the expected quality of information, the degree of project relatedness, and correspondence between Governor Daniel Evans and the District Engineer, Seattle District, Corps of Engineers. In his 22 June 1973 letter to the Seattle District, Governor Evans stated, "Other suggestions to resolve unanswered questions related to dredging in Grays Harbor such as the possibilities of additional upstream flood control measures and soil conservation methods that will reduce sediment transport seem warranted also."

1/Grays Harbor Regional Planning Commission, Water Resources Committee. Water Problems and Priorities Planning for 1970 to 2000. February 1971.

In the 1960's, new laws were passed to reduce the amount of pollution entering the waters of the United States. The initial expenditures by Federal and state governments were directed towards controlling point source pollution problems. By definition, point source or "end of the pipe" pollution originates from discrete or confined places such as pipes, ditches, etc., and are, therefore, easily monitored and controlled. Increasing familiarity with water pollution problems, however, led to the realization that a large part of the water pollution problem was originating at nonpoint sources. "Diffuse" or "nonpoint" sources of pollution are generated from such activities as agriculture, silviculture, construction, and mining. Precipitation events collect and wash pollutants into the surface water system across relatively greater geographic areas and more widely dispersed pathways than do point sources of pollution.

For the entire United States, sediment has been identified as the major nonpoint source pollutant of surface waters (Environmental Protection Agency (EPA), 1973). The major land use activities causing the problem are agriculture and silviculture. Approximately 22 percent of the total land area in the United States is commercial forest land and 42 percent is cropland and grassland (U.S. Department of Agriculture (USDA), Agricultural Research, 1975). Nationwide, sediment from cropland is clearly the major source of sediment pollution (EPA, 1973).

Although forest land contributes signficantly to the problem of sedimentation in the United States, well managed forest land can be very resistant to erosion. Intensive rainfall can often be absorbed without runoff by a forest with good tree cover and a forest floor well covered with duff (decaying twigs, leaves, etc.) (USDA, Agricultural Research, 1975). Severe erosion and sedimentation problems can result from the occurrence of both forest fires and diseases, as well as from alterations brought about in the forest system by some types of tree harvesting practices.

This study is concerned with the degree to which the man-caused sediment load carried by the Chehalis River increases the amount of dredging performed in Grays Harbor by the Corps of Engineers. An evaluation of the natural sediment loads and man's activities in the Chehalis River basin will assist in pointing out areas where excessive soil erosion, sediment discharge, and subsequent dredging may be reduced.

The erosion/sedimentation problem is of concern for the following reasons:

o Sediment deposits can impair navigation and, in severe cases, fish passage.

o Sediment may reduce spawning success for many species of fish. Sediment deposits may also reduce fish food organism abundance in many waters.

o Excessive sedimentation results in a need for more frequent removal of bottom materials from harbors and navigation channels (dredging), causing increased environmental impacts and greater economic costs.

o Deposits of sediment in streams and tributaries or in the beds of channels may restrict the flow of water. Flooding may occur more frequently as a result of this.

o Erosion and sedimentation can cause esthetic problems such as muddy water, undesirable sandbars, etc.

o Increases in sediment loads can affect a body of water through a direct alteration of water quality parameters such as turbidity levels, dissolved oxygen levels, etc.

o Very small sediment particles can bind with pesticides and other chemical pollutants and provide a means of transportation of these contaminants out of the watershed in which they were applied and into bodies of water.

1.2 General Description of Study Area. Grays Harbor (figure 1) is located on the southwest coast of Washington, at the mouth of the Chehalis River. The harbor is classified as a positive estuary (USCOE, 1975), that is, where precipitation plus runoff exceeds evaporation and net surface flow is seaward. The Chehalis River basin (figure 2), which drains approximately 2,170 square miles and contributes 80 percent of the freshwater input to Grays Harbor, is generally low in elevation to the east and south, but rises to about 5,000 feet at the headwaters of the Wynoochee and Satsop River basins to the north.

The bedrock in the basin is deeply weathered in most places and a soil mantle of varying thickness covers most of the area. The amount of annual precipitaton varies widely throughout the basin, ranging from less than 45 inches a year near the city of Chehalis to more than 220 inches a year in the northernmost portions of the Wynoochee River basin. Very little delayed runoff normally occurs because very little precipitation is stored as snow throughout the basin. This causes high riverflow rates in the wetter winter months. In addition, steep slopes exist in much of the northern portions of the basin. Ocean sediments, although beyond the scope of this study, are introduced to the estuary by longshore drift, wind, wave, and tidal action, compounding sediment discharges from the rivers flowing into the estuary. Maintenance dredging in the navigation channel by the Corps of Engineers is responsible for removal of over 1.8 million cubic yards (c.y.) of sediment from the Grays Harbor navigation channel annually (USCOE, 1976).

1.3 Interagency Cooperation. The erosion/sedimentation problem cuts across traditional agency jurisdictional boundaries and interagency cooperation is the key to solving what is considered to be the major pollution problem from nonpoint sources, sedimentation (EPA, 1973). The

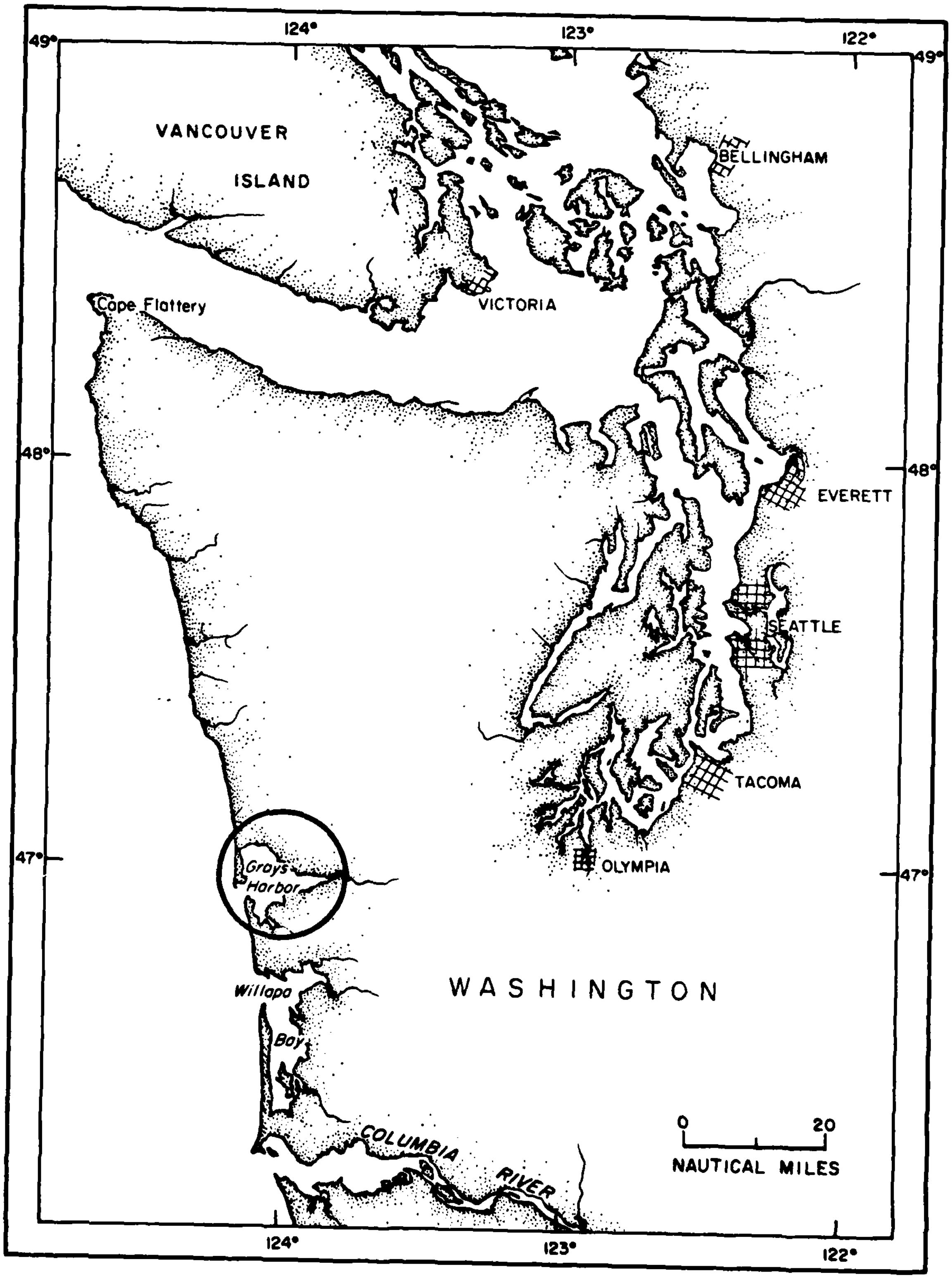

Figure 1 Location of Grays Harbor

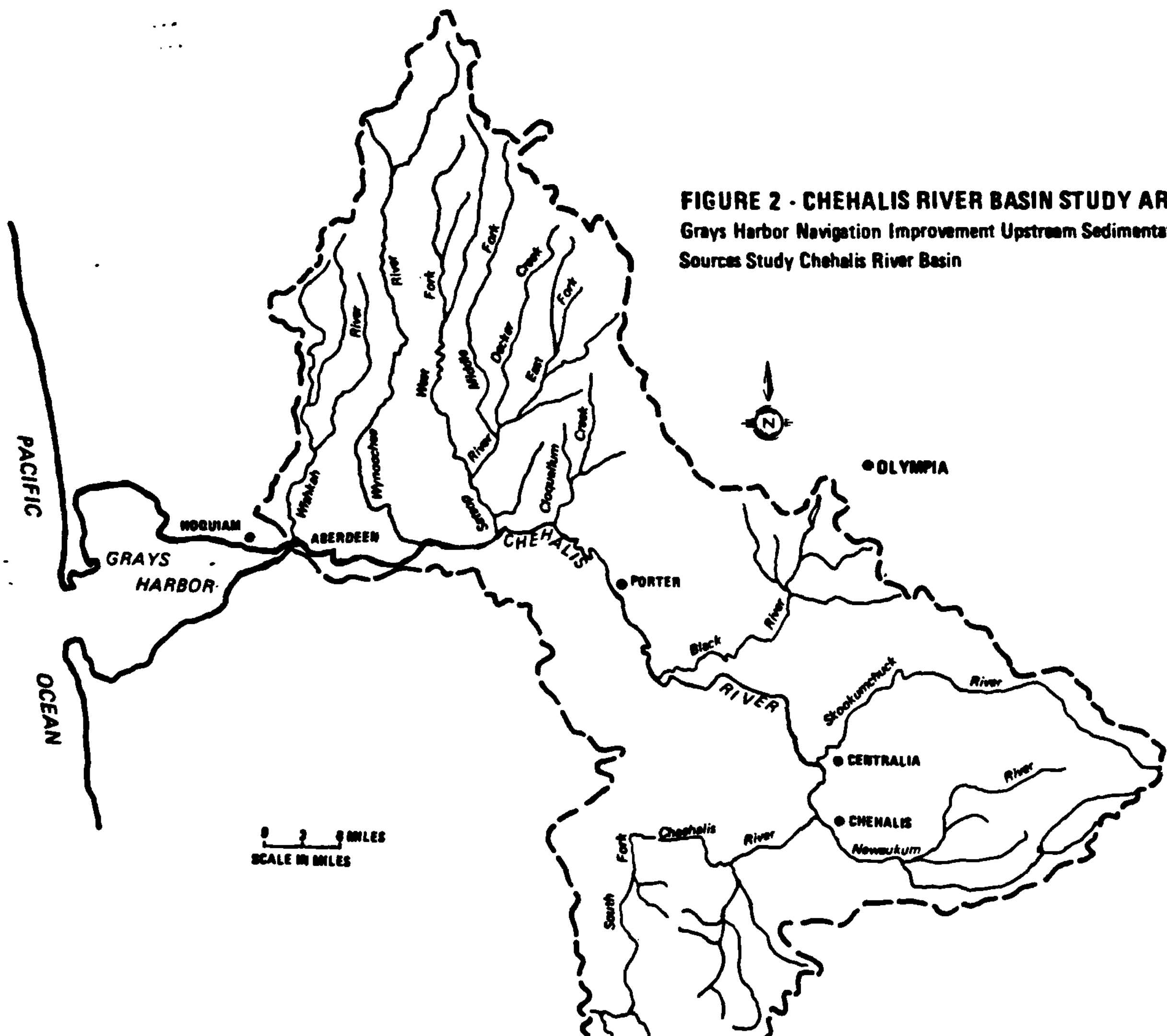

FIGURE 2 - CHEHALIS RIVER BASIN STUDY AREA
Grays Harbor Navigation Improvement Upstream Sedimentation Sources Study Chehalis River Basin

ability of the government agencies involved in addressing the problem of sedimentation in Grays Harbor to work together towards decreasing the amount of material entering the estuary could be a key to effective action. The source and extent of the sedimentation problem, its underlying causes, and the best methods for dealing with it is the subject of this report.

This study will investigate the general erosion/sedimentation problem in the United States, as well as the special problems found in the Chehalis River basin. It will examine man's activities and their influence on the natural system that exists in the basin. The responsibilities and authorities of the government agencies involved in controlling the sedimentation problems will also be discussed.

2.0 Types of Erosion and the Factors Causing Them. Discharge of sediment into the aquatic environment occurs through three major erosional processes: upland or surface erosion, channel or stream erosion, and mass soil movements. Man's activities may accelerate one or more of these processes. However, the occurrence of each separate process is dependent upon a different group of factors, and any given activity may therefore affect one type of erosional process more than the others. A brief definition of each of these erosion processes is presented below, and the factors which influence them are listed.

Surface erosion is the direct result of precipitation striking an exposed soil surface. Soil detachment occurs, and large pore openings in the soil surface become clogged. This reduces the infiltration ability of the soil, and water that would normally be absorbed into the soil surface becomes surface runoff. This overland waterflow further detaches particles of soil, and surface erosion results. The factors playing a part in the amount of surface erosion which occurs include rainfall characteristics (raindrop size, velocity, and rainfall intensity), soil characteristics, topography of the area, and the amount of plant litter and cover present.

Another important source of suspended sediment is from streambank and streambed erosion. In valleys with steep walls, lateral stream channel migration is restricted. But in valleys with large floors that present no definite channel boundaries, the natural path of the river tends to meander or erode over time throughout the valley. Erosion of streambed and streambank material occurs along the outer edges of these curves and meanders, and deposition of material occurs on the inside portion of the curves. The factors playing roles in determining how much channel erosion occurs include the area's rainfall characteristics, riverbed and riverbank soil characteristics, the topography of the area, the hydraulic characteristics of the water flow in the river or stream, the amount of plant litter and cover in and along the stream, burrowing animal activity along the streambanks, and man's activities along the river channel.

Mass soil movement is the downslope movement of a portion of the land surface under the effect of gravity. This may be in the form of landslides, mudflows, or downward creep of an entire hillside. The effect of the mass soil movement on the aquatic environment can vary widely, depending on such factors as the amount of soil moved and the location of the movement in the watershed. Mass soil movements may be a significant type of erosion in areas with very steep slopes, shallow soil layers on a bedrock surface, large amounts of rainfall (resulting in soils with high water content), and soil with physical characteristics that make it naturally unstable and easily displaced.

Sediment discharge from large watersheds is not always correlated with each year's rain and snowmelt. Based upon examination of a limited number of watersheds, major floods were found to cause increases in total sediment concentration in streamflows of 2 to 3.7 times over preflood levels (USDA, Agricultural Research, 1975). However, the magnitude of the contribution of this source of sediment has not been well investigated for most major watersheds, including the Chehalis River basin.

The proportion of the total sediment load contributed from each type of erosion in a river basin varies in different geographic areas. Generally, much of the suspended sediment load (the part of the total sediment load that is carried suspended in the water) comes from surface erosion and mass soil movement. A lesser portion of the suspended sediment load is a result of streambank erosion. The bedload (the part of the total load which is too heavy to be carried in suspension but is instead rolled or bumped along the bottom of the river) originates primarily from the process of channel erosion.

3.0 Review of Agency Authority for Control of Sedimentation.

3.1 Introduction. Legislative authority concerning water quality and erosion control may include policy making, enforcing, and/or funding efforts and may direct these efforts to one or several agencies. A wide spectrum of laws, executive orders, and interagency agreements address the problem of nonpoint pollution from upland areas of the Chehalis River basin. This section briefly reviews the laws applicable to the study area and the role of each agency that has been designated to implement these legislative actions on the Federal, Washington State, and local levels. Table 1 summarizes this information. This section also furnishes the reader with a summary of the legislation that defines each agency's role and responsibilities in the effort to control nonpoint pollution in the Chehalis River basin in table 2. These tables contain the views of the Seattle District, Corps of Engineers, and should not be considered to be a comprehensive listing of all erosion control authorities. An annotated list of the legislation is presented in appendix A for further reference.

3.2 Federal Agencies. The role of the Federal agencies responsible for the control of nonpoint source pollution are briefly reviewed below.

3.2.1 Soil Conservation Service (SCS). As part of the United States Department of Agriculture (USDA), the SCS is responsible for providing advice and recommendations on policies for soil and water conservation, technical assistance to participants in soil and water conservation programs, and soil maps and interpretations to local planning bodies.

3.2.2 Agricultural Stabilization and Conservation Service (ASCS). Another agency in the USDA, the ASCS plays a part in furthering soil conservation and erosion control practices within the agricultural areas of the United States.

3.2.3 United States Forest Service (USFS). This arm of the USDA has three major missions. They are national forest land management, forest land research, and cooperative forestry programs on state and private forest lands.

3.2.4 Environmental Protection Agency. The EPA is primarily concerned with improving the quality of the nation's waters. This interest encompasses both point and nonpoint sources. The EPA relies on many cooperative programs and interagency agreements in the effort to control pollution originating in upland areas.

3.2.5 Farmer's Home Administration (FmHA). As part of the USDA, the FmHA assists in expanding business, industry, and employment, and controlling or abating pollution through water development and soil conservation loans.

TABLE 1

MANAGEMENT FRAMEWORK FOR EROSION/SEDIMENT CONTROL

Function	Agency: Federal				Agency: State				
	EPA	COE	SCS	USGS	WDF	WDG	DNR	WDH	WDE
Problem Identification									
Determination of desired uses for waterbodies					x/*	x/*			x/*
Determination of effects of sedimentation on desired uses	x		x		x/*	x	x	x	x
Monitoring of sediment discharge and sedimentation	x	x	x	x/*	x	x	x	x	x
Problem area identification	x	x			x/*	x	x		x
Implementation of Structural and Physical Solutions									
Instream or lake sediment removal		x/*			x	x	x		
Construction and operation of detention basins		x					x	x/*	
Stabilization of stream channels		x/*							
Development of erosion controls								x/*	
Flood and flow control		x/*							
Management Solutions for Sediment Control									
Regulatory Programs									
Water quality standards									x/*
Shorelines management									x/*
Instream or lake construction control		x/*			x/*	x/*			
Forest practices							x/*		x/*
Informational Programs									
Public education	x/*	x	x/*						x/*
Technical assistance	x/*	x	x/*		x/*	x/*			x/*
Economic Assistance									
Grant monies for instream sediment removal	x								x
Grant monies for sediment control	x								x

x = Existing legislative authority
* = Existing program (specifically for erosion/sediment control).
EPA = U.S. Environmental Protection Agency.
COE = U.S. Army Corps of Engineers
SCS = U.S. Soil Conservation Service.
USGS = U.S. Geological Survey.
WDF = Washington Department of Fisheries.
WDG = Washington Department of Game.
DNR = Washington Department of Natural Resources.
WDH = Washington Department of Highways.
WDE = Washington Department of Ecology.

TABLE 2
LEGAL AUTHORITY OF AGENCIES INVOLVED WITH
EROSION AND SEDIMENT CONTROL

Law*	SCS	ASCS	USFS	EPA	FmHA	BLM	COE	DNR	WDE	WDG/WDF	Conservation Districts	Local Agencies
PL 92-500	x	x	x	x		x			x			
PL 95-217	x	x	x	x		x	x		x			
PL 91-648	x	x	x	x		x	x	x	x	x		
EO 11288	x	x	x	x		x	x					
EO 12088	x	x	x	x		x	x					
EO 11752	x	x	x	x		x	x					
PL 83-566	x				x							
33 USC 408, Sec 14							x					
RECP	x	x	x									
RC&DP	x											
16 USC 851			x									
PL 94-588			x									
16 USC 583			x									
PL 94-579						x						
PL 99							x					
33 USC 401							x					
33 USC 403							x					
33 USC 409							x					
33 USC 540							x					
33 USC 407							x					
33 USC 565							x					
PL 78-526							x					
RCW 76.01-28								x				
WAC 222-10-010								x				
WAC 222-(16-34)								x				
WAC 173-201									x			
RCW 76.09.040									x	x		
RCW 75.20.100										x		
RCW 76.09.200										x		
Coordinate Programs											x	
PL 92-583												x
City and Local Ordinances												x

*A brief description of these laws can be found in appendix A.

x = Existing legislative authority
EPA = U.S. Environmental Protection Agency.
COE = U.S. Army Corps of Engineers
SCS = U.S. Soil Conservation Service.
USGS = U.S. Geological Survey.
ASCS = Agricultural Stabilization and Conservation Service.
WDF = Washington Department of Fisheries.
WDG = Washington Department of Game.
DNR = Washington Department of Natural Resources.
WDH = Washington Department of Highways.
WDE = Washington Department of Ecology.
FmHA = Farmer's Home Administration.

3.2.6 Bureau of Land Management (BLM). The BLM is not directly engaged in water and soil conservation efforts. It is responsible, however, for compliance with many water pollution control laws on the lands it administers.

3.2.7 United States Army Corps of Engineers (COE). The COE is responsible for granting permits for construction work in navigable waters of the United States, as well as for conducting dredging and emergency flood relief programs. They also regulate the discharge of dredged or fill material into waters of the United States, including territorial seas, pursuant to Section 404 of the Clean Water Act of 1977.

3.3 State Agencies. The role of the state agencies responsible for the control of nonpoint source pollution are reviewed below, along with a listing of the legal authorities under which they operate. The regulations set forth under state laws and administered by state agencies are designated as the minimum regulatory standards set forth at the Federal level for soil conservation and water quality plans and policies. Although state legislation is the primary source of state agency authorities, several Federal laws empower state agencies to implement portions of Federal legislation.

3.3.1 Department of Natural Resources (DNR). The DNR is responsible for the management of all state owned lands, as well as for regulatory functions and fire and disease control on private forest land.

3.3.2 Washington Department of Ecology (WDE). The WDE is responsible for planning, management, and regulatory functions applicable to water quality, coastal zone management, and other water resources of the state. It is also responsible for coordination of Federal and state grants for planning and construction in these areas.

3.3.3 Washington Departments of Game (WDG) and Fisheries (WDF). The WDG and WDF are responsible for introducing and reviewing legislation and reviewing and granting permits to insure protection of the resources within their jurisdiction.

3.3.4 Conservation Districts. Conservation districts are geographically divided subgroups of state government organized under state law. Their job is to coordinate soil and water conservation programs within their jurisdiction through memos of understanding with Federal, state, and county departments and agencies. With technical and financial assistance from SCS, and guidance from WDE via their identification of Best Management Practices under authority of Section 208 of the Clean Water Act, programs and practices which mitigate erosion and sedimentation may be implemented by these districts. The conservation districts in Washington are the designated management agencies responsible for implementing the statewide Section 208 water quality management plan for agriculture.

3.3.5 Local Agencies and Programs. City and county governmental groups are also responsible for the control of nonpoint source pollution and erosion. Most of the regulatory controls covering the sedimentation problem are promulgated by the county regional planning commissions. The actions taken by these commissions include the creation of the Shoreline Management Program, written to fulfill the requirements of the Shorelines Management Act of 1971. This county program may be used to regulate the human activities which accelerate erosion. City and county ordinances and building codes may limit the amount and type of construction within erosion hazard areas, and insure protection of natural streamflows and floodways.

4.0 Physical Environment of the Chehalis River Basin.

4.1 Location. The Chehalis River basin drains an area of approximately 2,170 miles in southwestern Washington (figure 2). The headwaters of the Chehalis River are in the Willapa Hills, in the southwesternmost portion of Lewis County. The Chehalis and its tributaries drain major sections of Grays Harbor, Lewis, and Thurston Counties, and limited area in Pacific, Cowlitz, Mason, and Jefferson Counties. As the Chehalis River flows towards Grays Harbor, several major rivers empty into it. Moving downstream, they are: the Newaukum, Skookumchuck, Black, Cloquallum, Satsop, Wynoochee, and the Wishkah Rivers.

4.2 Physical Geography. Three major physiographic regions are drained by the Chehalis River and its tributaries. The Cascade Mountain Range lies in the southwestern portion of the basin, and as the water runoff drains to the northwest, it flows through the Puget-Willamette Lowlands (a broad, relatively flat valley lying between the Cascade and Coast Mountain Ranges). The westernmost portions of the basin lie in the Coast Mountain Range. This range includes drainages to the south in the Willapa Hills and Black Hills, and those portions of the basin to the north in the southernmost flanks of the Olympic Mountains. The Chehalis River then empties into the Pacific Ocean through Grays Harbor. Low elevations prevail throughout most of the basin, with the highest altitudes in the Cascades being about 3,000 feet and the highest in the Coastal Range occurring at the headwaters of the Wynoochee River, about 5,000 feet.

4.3 Climate and Geology. Annual precipitation levels vary widely throughout the basin, ranging from approximately 45 inches per year in the Puget-Willamette Lowlands to as much as 220 inches per year in the very northernmost portions of the basin. The majority of this precipitation falls between October and May, with June through September usually being fairly dry. Temperatures remain mild throughout the summer and winter, generally ranging from a minimum of 38° F to 40° F in January to a maximum of 59° F to 64° F during July. As a result, only a small amount of precipitation is retained in the Cascade and Coast Mountain Ranges as snowpack, and river flow rates in the basin tend to respond rapidly to changes in the amount of rainfall. The areal distribution of mean annual precipitation for the basin is shown in figure 3.

The age of the rocks in the area vary from early Tertiary to Quaternary time. They are mainly marine and nonmarine sedimentary and igneous types. Throughout the basin, this rock has been buried by glacial till and outwash deposits and by recent age alluvium. Much of the bedrock is weathered deeply and a soil mantle of varying thickness has developed. The dense natural vegetation of the region generally protects the soil from surface erosion. However, in some portions of the basin, soil movements supply large quantities of material to the stream channels. In their upper reaches, the Wynoochee and Satsop Rivers and their tributaries, and Cloquallum Creek flow across extensive areas underlain by

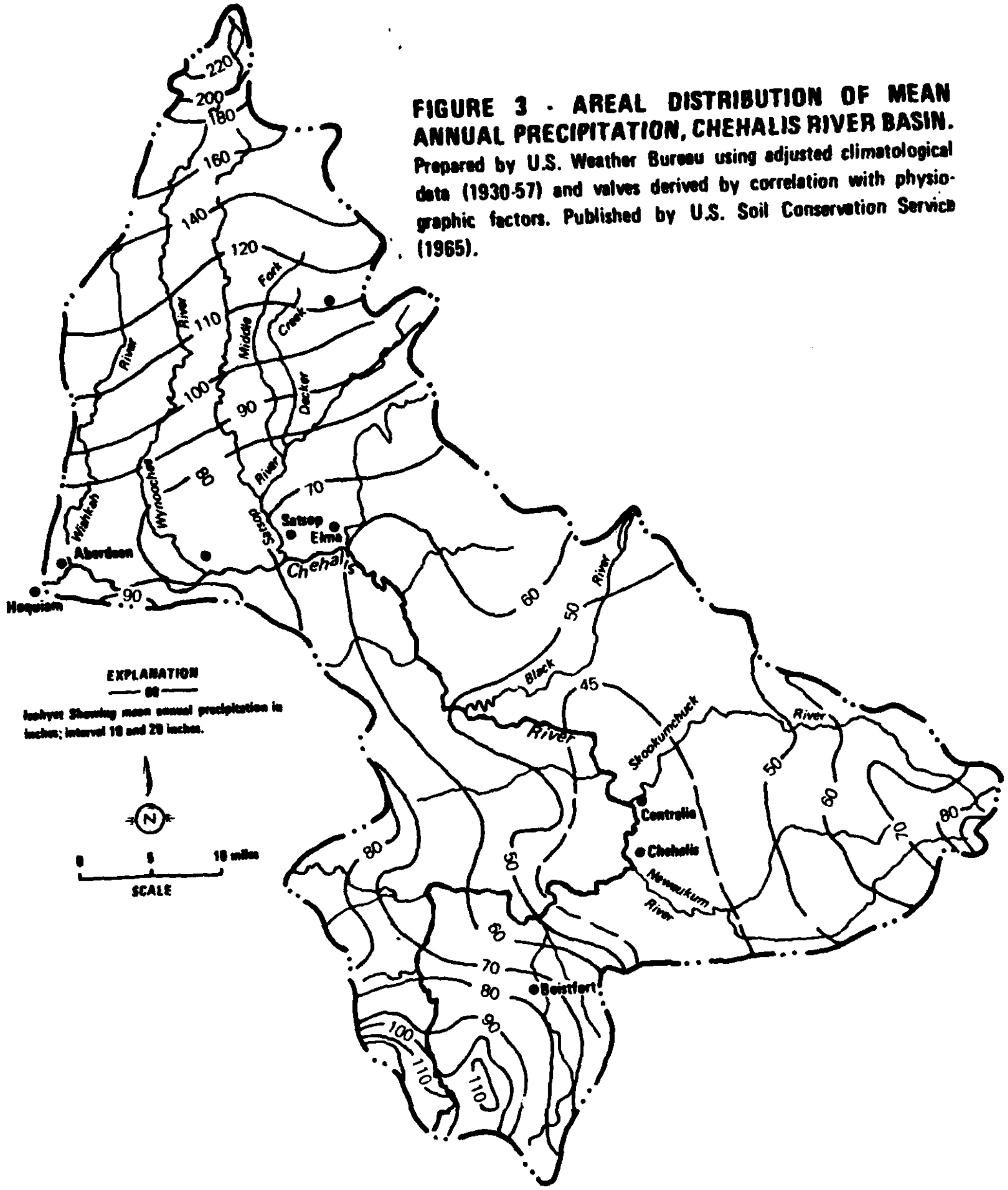

FIGURE 3 - AREAL DISTRIBUTION OF MEAN ANNUAL PRECIPITATION, CHEHALIS RIVER BASIN. Prepared by U.S. Weather Bureau using adjusted climatological data (1930-57) and valves derived by correlation with physiographic factors. Published by U.S. Soil Conservation Service (1965).

unconsolidated debris of glacial origin. This debris has become readily available for erosion and transport by fluvial action (Glancey, 1969).

4.4 Land Use and The Economy. Historically, the forest resources of the area have played a major role in the economic development of the region. The outlook for the future of the basin appears to be tied closely to the possibilities for maintaining or possibly increasing forest products manufacture and export (USCOE, 1981, unpublished data).

Other important economic activities include agriculture, fisheries, food processing, and tourism. Agricultural activities are greatest in the upper or easternmost portion of the basin, near Chehalis and Centralia. Food processing in this area consists primarily of freezing fruits and vegetables. Limited processing of seafood and some manufacturing occurs in the region and is primarily concentrated along the edge of Grays Harbor in Westport, Aberdeen, Cosmopolis, and Hoquiam. A small amount of manufacturing is also concentrated in the Centralia-Chehalis area.

Table 3 presents the land use for the Chehalis River basin in 1969. The acreage for each land use type is indicative of the relative importance of each activity for the region. Commercial forest is the dominant land use, occupying 83.8 percent of the total land area in the basin. Cropland covers only 7.9 percent of the region, and urbanized lands account for 2.4 percent of the entire area.

TABLE 3

PRESENT LAND USE, CHEHALIS RIVER BASIN: 1969[1/]

Land Use	Acres	Percent of Total
Commercial Forest	1,420,092	83.8
Noncommercial Forest	20,573	1.2
Cropland	133,123	7.9
Pasture	31,058	1.8
Rural Nonfarm	8,791	0.5
Urban Lands	40,269	2.4
Barren Lands	5,050	0.2
Other Lands	37,995	2.2
Total Land Area	1,694,951	100.0

1/USDA, SCS, Land and Water Resource Information, Chehalis Subarea, 1974.

The distribution of these land uses within the study area can be seen in figure 4. Agricultural activity and pastures occur mainly in the upper part of the basin, primarily on land bordering the major drainages, in areas of fairly gentle terrain at lower elevations. The two major areas of urbanization both exist at lower elevations, on fairly level land. Commercial forest land covers most of the basin, and is found in both areas of low elevation and gentle terrain, and in areas of higher elevation and steeper slopes in the northernmost portion of the study area.

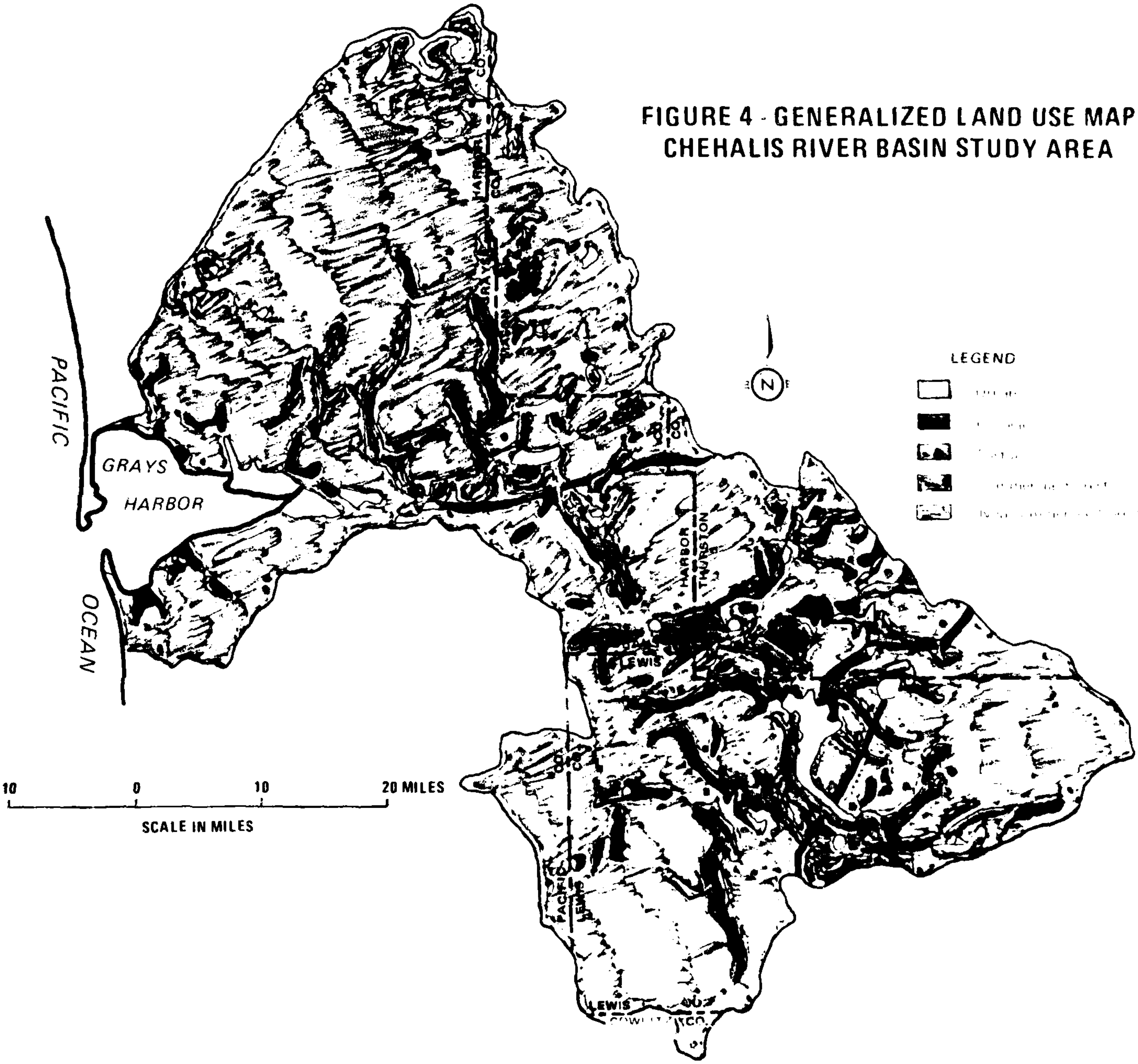

FIGURE 4 - GENERALIZED LAND USE MAP
CHEHALIS RIVER BASIN STUDY AREA

5.0 Review and Analysis of Sediment Discharge in the Chehalis River Basin and its Impact on Grays Harbor

5.1 Introduction. Due to the physical environment of the Chehalis River basin described in the previous chapter, the relative sediment contribution from each of the land uses found in the Chehalis River basin is quite different from the same land uses nationwide. The predominant land cover and use, the economic base, and the climatological, topological, and geological environment of the area all contribute to the unique conditions of erosion and sediment discharge found in the Chehalis River basin.

The potential for erosion is listed by land use in table 4 for the Chehalis River basin (SCS, 1974). The potential for extensive amounts of erosion from commercial forests in the basin is evident.

TABLE 4

POTENTIAL FOR EROSION BY LAND USE, CHEHALIS RIVER BASIN (IN ACRES) (SCS, 1974)

Land Use	None	Slight	Moderate	Severe
Commercial Forest	43,329	173,311	66,252	1,137,200
Noncommercial Forest	2,243	409	289	17,632
Cropland	11,062	82,080	14,882	25,099
Pasture	2,671	20,144	1,943	6,300
Rural Nonfarm	987	3,876	599	3,329
Built-Up Lands (Urban)	8,333	18,212	2,382	11,342
Barren and Other Lands	35,523	1,057	—	4,465
Total	104,148	299,089	86,347	1,205,36[illegible]

Surface erosion and mass soil movements contribute large amounts of material to the total sediment load of the river system. The SCS studied the subjects of erosion and sedimentation in the Chehalis River basin. This study indicated that the majority (76 percent) of the land in the basin would have a severe surface erosion problem if the vegetation were removed by man's activities (USDA, no date). Over 94 percent of this land is commercial forest (primarily due to its location on areas with steeper slopes and higher precipitation levels) and approximately 5 percent is used for agriculture.

Streambank erosion is also a serious problem in many parts of the basin and contributes significantly to the total sediment load of the river system. Approximately 544 miles of streambank in the Chehalis River basin have a moderate erosion problem and 268 miles have a serious problem (SCS, 1974). This is the latest available data which could be found on this subject. The applicability of this information to the current situation is not known.

This chapter will examine the available literature concerning the suspended and bedload sediment contributions of each subbasin in the study area. Literature addressing the degree to which surface erosion, mass soil movement, and channel erosion is contributing to the suspended and bedload sediment yields from each major tributary will also be reviewed. Finally, this chapter will review the existing information on the effects of the suspended and bedload sediments from the Chehalis River on Grays Harbor estuary and the navigation channels within it.

5.2 Review of Suspended Sediment Discharge Yields by Subbasin. This section will present a review of the literature dealing with the amount and source of suspended sediment discharged from the subbasins (a subbasin is an area drained by a major tributary of the Chehalis River) of the Chehalis River basin, as well as the basin as a whole.

The only original work found on this subject was by P. A. Glancey, USGS Water Supply Paper 1798-H, June 1969. His information was obtained by collection of suspended sediment data at 20 streamflow gaging stations and correlation of this data with stream discharge data collected from these stations. The data was collected from 1962 to 1966. Since man's land use activities have generally increased in the basin since this study was performed, the information it contains is still applicable to the basin. According to Glancey (1969), no calculations of bedload were made due to a lack of available, acccurate techniques. Approximately 1,800 square miles of the Chehalis River basin are included in Glancey's study area (83 percent of the total Chehalis River basin area).

The average annual suspended sediment discharge from the area during the period of 1962-1965 was about 540,000 tons. The annual loads ranged from 270,000 to 690,000 tons, or an average of 300 tons/square mile, annually, for the entire basin. Wide variations in sediment discharge levels exist from subbasin to subbasin throughout the study area (table 5). Starting with the most upstream subbasins, suspended sediment discharge quantities will be presented along with subbasin size estimations and general types of land use.

The subbasin lying furthest to the east is the Chehalis River above Porter (see figure 2). This subbasin contains the South Fork Chehalis River, the Newaukum River, the Skookumchuck River, and the Black River drainages. The combined areas equal 1,294 square miles and the land use is primarily woodland, with the balance being cropland and some urban areas. The average annual suspended sediment load of this subbasin is 129,400 tons, or about 100 tons/square mile/year. Contributions of suspended sediments from each drainage in this subbasin are nearly equal. The land area contained within this subbasin is 71 percent of the total basin, yet it contributes only about 24 percent of the total annual suspended sediment load.

TABLE 5

CHEHALIS RIVER BASIN
SUSPENDED SEDIMENT DISCHARGE
LEVELS FROM MAJOR TRIBUTARIES
(IN TONS)(FROM GLANCEY, 1969)

Tributary	Land Area (sq. mi.)	Annual Suspended Sediment Discharge Level (tons/sq. mi./yr)	Total Annual Discharge (tons/yr)
Chehalis River Above Porter	1,294	100	129,400
Cloquallum Creek	65	136	8,840
Satsop River (All Forks)	299	787	235,313
Wynoochee River	155	1,070	165,850
Total	1,813	298	539,403

Cloquallum Creek drains about 65 square miles in the northern portion of the study area. Woodland occupies 83 percent of the basin. This subbasin's permeable glacial outwash stores much of the precipitation in ground water. This tends to even out the flow rates of the subbasin and results in nonflashy (i.e., the riverflow rates are not responsive to precipitation activity) runoff characteristics. The average annual suspended sediment yield of 136 tons/square mile is far below the average for the overall study area.

The Satsop River system contains four major tributaries: the East, Middle, and West Forks Satsop River, and Decker Creek. The entire basin covers 299 square miles. About 90 percent of the basin is forested, cropland covers 3 percent and almost 8 percent is classified as "idle" (rock outcrops, landslide areas, bluffs, and other agriculturally unproductive land). The precipitation range varies greatly throughout the basin but is much higher overall than all of the previously discussed basins. The mean annual suspended sediment discharge of this tributary basin is about 44 percent of the entire study area although it covers only 16 percent of the geographic area. It has an average annual suspended sediment yield of 787 tons/square mile, much greater than any of the previously discussed subbasins.

The Middle and West Fork Satsop River, which yield 1,100 tons/square mile and 1,500 tons/square mile, respectively, are the major suspended sediment contributing tributaries in this subbasin and in the entire study area. Runoff is flashy in the Middle and West Forks, and peak suspended sediment concentrations generally occur coincidentally and in a linear relationship with peak flow rates. About 90 percent of the estimated annual suspended sediment load leaving these subbasins moved through the system in a time period equal to about 6 percent of the year. The topological (rugged terrain) and geological (unconsolidated fluvial and glaciofluvial deposits and deeply weathered sedimentary rocks) environments make the Middle and West Forks Satsop River very susceptible to erosion. Although upland erosion contributes much of the material, substantial channel erosion also occurs in some parts of the basin, and landslides also supply large volumes of material to the fluvial system.

The East Fork Satsop River and Decker Creek have very low suspended sediment yields, with each contributing about 60 tons/square mile annually. Nonflashy runoff characteristics on the East Fork Satsop and Decker Creek, due to smaller variations in topography and lower rainfall levels, minimize channel erosion. Upland erosion (sheet and rill) also occurs less due to dense vegetative cover.

The Wynoochee River subbasin lies in the northernmost part of the study area and covers about 155 square miles, according to Glancey (1969). This drainage area is 74 percent woodland, 3 percent cropland, and 18 percent "idle" (as defined for the Satsop River subbasin). It has the greatest topographic relief (5,000 feet) of any subbasin in the study area and mean precipitation levels range from 75 to 220 inches annually. The geologic environment of the subbasin is very similar to the West and Middle Fork Satsop River, and it shares their flashy runoff characteristics. The Wynoochee River subbasin covers 9 percent of the total study area but contributes 30 percent of the total annual suspended sediment load carried by the Chehalis River system. The mean average yield in this tributary basin is 1,070 tons of suspended sediment/square mile, far above the average for the entire study area of 300 tons/square mile. Much of the sediment yield from the Wynoochee River originates from upland erosion in areas without vegetative cover, and from channel migration and erosion. This data was gathered prior to the construction of the Wynoochee Dam at river mile 51.8. The effect of this structure on sediment being carried by the river downstream has not been studied. Also, the annual rate at which sediment is accumulating behind the dam is not known. It is known that the dam traps virtually all of the total load from the portions of the Wynoochee River upstream of the structure.

The Wishkah River information was not included in Glancey's overall calculations because it is not considered to be a tributary of the Chehalis River. However, some data were gathered from this subbasin which drains an area of 102 square miles and joins the Chehalis in the upper estuary of Grays Harbor. The Wishkah River is 74 percent woodland, 17 percent agriculturally unproductive areas, and 4 percent cropland. It is a subbasin of low topographic relief and contributes about 30,000 tons of suspended sediment annually to Grays Harbor. Its average yield is 290 tons/square mile of suspended sediment.

Additional information on the amount of suspended sediment produced in the Chehalis River basin was found in a report by Norman Associates entitled Grays Harbor Erosion Management Study, published in June 1974. The works of Norman (1974) are largely based on the original work by P. A. Glancey in 1969. However, his studies conducted in 1961 to 1965 were extrapolated to include the time period from 1950 through 1969. The extrapolation methodology was not provided. Additionally, Glancey's unit of measurement, tons, were converted to cubic yards by Norman Associates. The factor used to perform the conversion was not given. However, a useable conversion estimate for the suspended sediments in this area is: 1.4 tons equals 1 c.y. (USCOE, unpublished, 1982). Based on this factor, table 6 shows the average annual suspended sediment load, in tons, for the major tributaries of the Chehalis River for the period 1950 through 1969.

TABLE 6

CHEHALIS RIVER BASIN
AVERAGE ANNUAL SUSPENDED SEDIMENT LOAD,
1950 THROUGH 1969 (IN TONS)
(FROM NORMAN ASSOCIATES, 1974)

Drainage	Average Annual Suspended Sediment Load (Tons)
Wynoochee River	294,000
Satsop River	420,000
Cloquallum Creek	21,000
Chehalis River at Porter	224,000
Total	959,000

Norman Associates' estimate of the average annual suspended sediment load for 1950 through 1969 is 959,000 tons, much higher than Glancey's estimate for 1961 through 1965 of 540,000 tons. Norman Associates' work is based on Glancey's data, but no explanation of this difference in estimates was presented by Norman Associates.

5.3 Proportions of the Suspended Sediment Load Contributed By Each Type of Erosion. Glancey's document did not attempt to precisely address the percent contributions of each type of erosion to the annual suspended sediment load of the Chehalis River basin. However, his observations point out that although channel erosion seems to contribute a large proportion of the annual suspended sediment load to the system, surface erosion and mass soil movements probably contribute a somewhat greater percentage of the annual suspended load. No quantitative analysis was made.

In the Grays Harbor Erosion Management Study by Norman Associates, a precise estimate of the percentage of annual suspended load from each type of erosion is made. Norman Associates states that surface erosion and mass soil movements account for about 85 percent of the suspended sediment load transported by the streams in the Chehalis River basin. Norman Associates also states that channel erosion contributes about 15 percent of the annual suspended sediment load to the system. However, neither methodologies nor references were provided to explain the source of these percentages. Discussions with various agency representatives,1/ however, indicate that surface erosion and mass soil movement may account for a lower percentage of the suspended load in the Chehalis River than stated by Norman Associates, and the channel erosion may account for a higher percentage of the annual suspended sediment load than Norman Associates' estimate.

5.4 Review of Bedload Sediment Discharge Yields By Subbasin. This section will present a literature review and analysis of the amount and source of the bedload sediment discharged from the subbasins of the Chehalis River basin and the basin as a whole.

As stated previously, the work performed by P. A. Glancey did not include calculations of the bedload sediment discharge rates.

Norman Associates, in the Grays Harbor Erosion Management Study, state that bedload sediment calculations for the Chehalis River, just downstream from its confluence with the Wynoochee River, estimated the average annual bedload to be about 43 percent of the suspended sediment load. The source of these calculations and the methodology used to derive them was not given. No information from other sources was available to confirm these calculations, which are shown in table 7 for the subbasins of the Chehalis River basin. Conversion of the calculations by Norman Associates in cubic yards to tons was made using the bedload material conversion factor of 1.5 ton: 1 c.y. (USCOE, unpublished, 1982).

5.5 Proportions of the Bedload Sediment Load Contributed by Each Type of Erosion. The document by P. A. Glancey did not address bedload sediment loads and, therefore, did not examine the source of bedload sediments.

Norman Associates' study states that channel erosion contributes primarily to the bed material moved by the rivers in Grays Harbor. The method used to reach this conclusion, however, was not presented.

1/Grays Harbor Regional Planning Commission; U.S. Forest Service; Personal Communication, 1981.

TABLE 7

CHEHALIS RIVER BASIN
AVERAGE ANNUAL SUSPENDED SEDIMENT LOAD,
1950 THROUGH 1969 (IN TONS)
(FROM NORMAN ASSOCIATES, 1974)

Drainage	Average Annual Suspended Sediment Load (Tons)
Wynoochee River	135,000
Satsop River	195,000
Cloquallum Creek	7,500
Chehalis River at Porter	105,000
Total	442,500

Assuming that the contributions of bedload sediments from surface erosion and mass wasting is small compared to the contribution from channel erosion, identification of areas with severe channel erosion will indicate regions where a large proportion of the bedload sediments are produced.

Two studies have attempted to identify the areas within the Chehalis River basin experiencing severe channel erosion. Norman Associates (1974) assessed the number of miles of river in Grays Harbor County that were "actively" (not defined in the study) eroding. Another study (SCS, no date) examined and identified riverbank erosion that was considered "serious" (not defined in the study) throughout the entire Chehalis basin.

The Norman Associates document identified 107 miles of actively eroding riverbank in Grays Harbor County. It did not examine the entire Chehalis River basin. The SCS study did investigate the entire basin, however, and identified 268 miles of seriously eroding riverbank. The tributaries highlighted by both studies as having the greatest amounts of channel erosion are presented in table 8, but should not be considered to be a complete list of the actively eroding areas.

Table 8 shows that channel erosion is occurring throughout the Chehalis River basin. Several studies (Norman Asociates, 1974; Nelson 1967) point out that channel erosion processes are accelerated further downstream in a fluvial system as riverflow rates become greater and the depth of unconsolidated material generally becomes greater.

In summary, the proportions of bedload sediment load contributed by each type of erosion can not be identified. The actual annual bedload sediment load volume of the Chehalis River basin also can not be determined without further studies.

TABLE 8

CHANNEL EROSION IN THE CHEHALIS RIVER BASIN
(IN MILES)

Tributary	Norman Associates "Actively Eroding" in Grays Harbor County	SCS "Serious" Erosion in Chehalis River Basin
Chehalis River (above Porter)	—	63
Chehalis River (main stem)	28	41
Cloquallum Creek	5	—
Satsop River	11.5	17
Wynoochee	16	28

5.6 The Effects of Sedimentation on Grays Harbor Estuary. Review of suspended and bedload sediment discharge levels from each subbasin in the Chehalis River basin provides useful information for analyzing the extent of the erosion and sediment discharge levels in the upland areas of the Chehalis River basin.

However, we must have an understanding of how the sediment loads of the rivers are being deposited in the estuary to assess their impact on Grays Harbor. Although several studies have addressed the subject of erosion and sediment discharge from the Chehalis River basin, very little work has been done on the fate of this material as it moves into Grays Harbor estuary.

Several factors affect the amount of sediment reaching an estuary. The type of sediment sources, the size and texture of the eroded materials, climate, transport systems, land use, proximity of sediment sources, source size, watershed characteristics, and the nature of the estuarine area all determine what fraction of the land mass removed by gross erosion is delivered to the estuary (EPA, October 1973). Additionally, the estuary/river interface, tidal influences, floccuation by salt water, estuarine currents, and peak riverflow rates all cause variations in how both the suspended sediment load and the bedload of the river are deposited in the estuary.

As outlined in the previous sections, Norman Asociates has estimated the average annual suspended and bedload sediment levels carried by the Chehalis River for 1950 through 1969. This information is shown in table 9.

TABLE 9

AVERAGE ANNUAL SUSPENDED AND BEDLOAD SEDIMENT LEVELS FROM RIVERS IN THE CHEHALIS BASIN (NORMAN ASSOCIATES, 1974)

River Name	Suspended Load (tons/year)	Bedload (tons/year)
Chehalis Basin		
Wynoochee River	294,000	135,000
Satsop River	420,000	195,000
Cloquallum Creek	21,000	7,500
Chehalis at Porter	224,000	105,000
Total	959,000	442,500

Complete explanation of how the above figures were derived were not given by Norman Associates. They estimate that 1,401,500 tons of material is carried annually by the Chehalis River, or approximately 934,500 c.y. of material, with an approximate suspended sediment: bedload sediment ratio of 3:1.

The relative proportions of suspended load and bedload material moving into and occupying the channels being considered for widening and deepening are not known. Studies analyzing grain sizes of 18 Grays Harbor estuary sediment samples by Phipps1/ for the Washington Department of Ecology found that, generally, the sediments become finer grained with increasing amounts of wood fragments from the western edge of the inner harbor to the mouth of the Chehalis River.

The downstream migration of the alluvial bedload sediment material is restricted as it reaches the upper estuary and the river velocities become influenced by tidal water movement, which causes deposition of the bedload. The salinity wedge and density currents also reduce the numbers of larger particles entering the estuary; however, the finer sediments are carried in suspension into the estuary.

According to Norman Associates (1974), within the North Channel area of the estuary, navigation channel and harbor maintenance activities result primarily from the deposition of the suspended sediment material from the Chehalis River.

1/Phipps, James B., Grain Size Analysis of Some Grays Harbor Estuary Sediment Samples, Washington Department of Ecology, Contract No. 75-081, 1975.

However, any bedload sediment that does reach the estuary is confined primarily to the navigation channels, while the lighter suspended sediments are responsible for the shoaling of the shallow areas as well as the navigation channels. Since at least 1.8 million c.y. of sediment is removed annually from the navigation channel alone (see table 10), redistribution of fine sediments within the estuary (especially the shallow areas) must contribute significantly to the annual harbor dredging, although the extent of this contribution is unknown (USCOE, 1976).

Although beyond the scope of this study, the deposition of sediments in the estuary from marine sources should be noted. On the basis of sand mineralogy, three regions of sand deposition can be found in Grays Harbor. According to Phipps (1975), ocean sediments add approximately 2.0 million c.y. annually to the outer harbor area of Grays Harbor estuary (see figure 5). Figure 5 shows the approximate areas of deposition in the estuary.

Maintenance dredging in the navigation channels and other areas of the harbor between 1966 and 1980 can be seen in table 10. The annual total yards dredged has varied between 1.3 and 2.1 million c.y.

TABLE 10

MAINTENANCE DREDGING IN GRAYS HARBOR
FOR THE FISCAL YEARS 1966-1980

Fiscal Year	Hopper Dredge (c.y.)	Pipeline/ Clamshell Dredge (c.y.)	Total (c.y.)
1966	488,415	886,950	1,375,365
1967	836,803	935,294	1,773,097
1968	660,356	1,157,000	1,817,356
1969	891,933	820,893	1,712,826
1970	1,358,386	560,000	1,918,386
1971	1,197,372	853,068	2,050,440
1972	1,069,398	830,316	1,899,714
1973	986,222	1,021,570	2,007,792
1974	963,196	1,145,135	2,108,331
1975	1,039,390	766,878	1,806,268
1976	1,400,000	740,000	2,140,000
1977	987,500	860,000	1,847,500
1978	1,691,500	538,500	2,230,000
1979	1,242,000	—	1,242,000
1980	1,433,700	268,000	1,701,700

SOURCE: U.S. Army Corps of Engineers, unpublished, 1980.

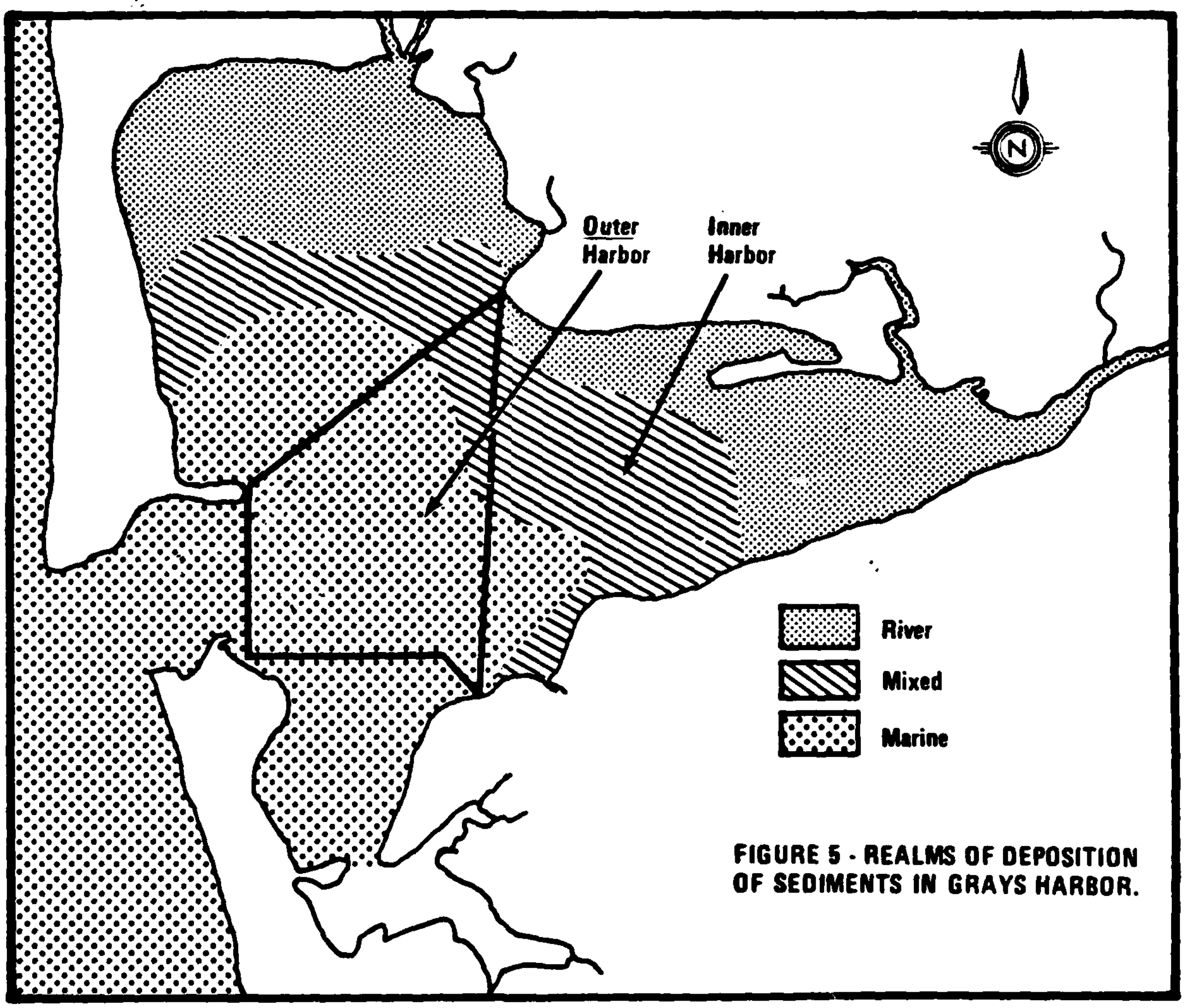

FIGURE 5 - REALMS OF DEPOSITION OF SEDIMENTS IN GRAYS HARBOR.

6.0 Sediment Discharge Research.

6.1 Introduction. With the identification of sediment as the primary source of nonpoint pollution in the United States, a great deal of research has been initiated to quantify the degree to which sediment is being generated from various geographic areas and land uses. Work is also being performed to estimate the degree to which man's activities are exacerbating the natural erosion rates and subsequent sediment discharge levels from different land areas. This section will present research on sediment discharge levels in other areas of the Pacific Northwest, review studies conducted on the effect of silviculture activities on sediment discharge levels in forested areas, and summarize suggestions for minimizing increases in sediment discharge levels resulting from these activities. Lastly, studies which outline the areas of extensive channel erosion in the Chehalis River basin and the management strategies that have been suggested for dealing with these areas will be discussed.

Comparison of the sediment discharge rates in the Chehalis River basin to other similar basins in the Pacific Northwest will help to establish a reference with which excessive discharge rates can be identified. One such closely studied basin is the Tillamook River basin on the coast of Oregon. In this basin in 1976, the U.S. Forest Service (USFS) conducted a study which examined the gross erosion rate (in tons/square mile/year) and gross sedimentation rate (in tons/square mile/year) for a 500-square-mile area on the western side of the Cascade Mountain Range (Benoit, 1978). Elevations in the area range from sea level to over 4,000 feet. Eleven subbasins draining into Tillamook Bay were examined, and suspended sediment levels were recorded, along with hydrographic data. Table 11 and figure 6 compares the gross sedimentation rates of these areas to the subbasins of the 2,100 square mile Chehalis River system.

Annual gross sedimentation rates shown for the Tillamook River basin are among the highest of any forested lands in the State of Oregon due to the impacts from several major fires, salvage logging disturbance, and severe climatic events during the 1930's and 1940's.[1/] While comparisons between the basins can be made, it should be noted that several physical factors vary between the two river basins. Annual rainfall levels in the Tillamook River basin do not generally exceed 150 inches; the Chehalis River basin, however, reaches an upper limit of approximately 220 inches. Elevations in the upper portions of the Wynoochee River subbasin reach 5,000 feet, but only reach 4,000 feet in the higher elevations of the Tillamook River basin. Additionally, although marine sedimentary rock is prevalent in both areas, the Wynoochee River subbasin and other northern portions of the Chehalis River basin also contain extensive areas underlain by unconsolidated glacial debris, which

1/Benoit, Clifford, Hydrologist, USFS. Personal communication, August 1981.

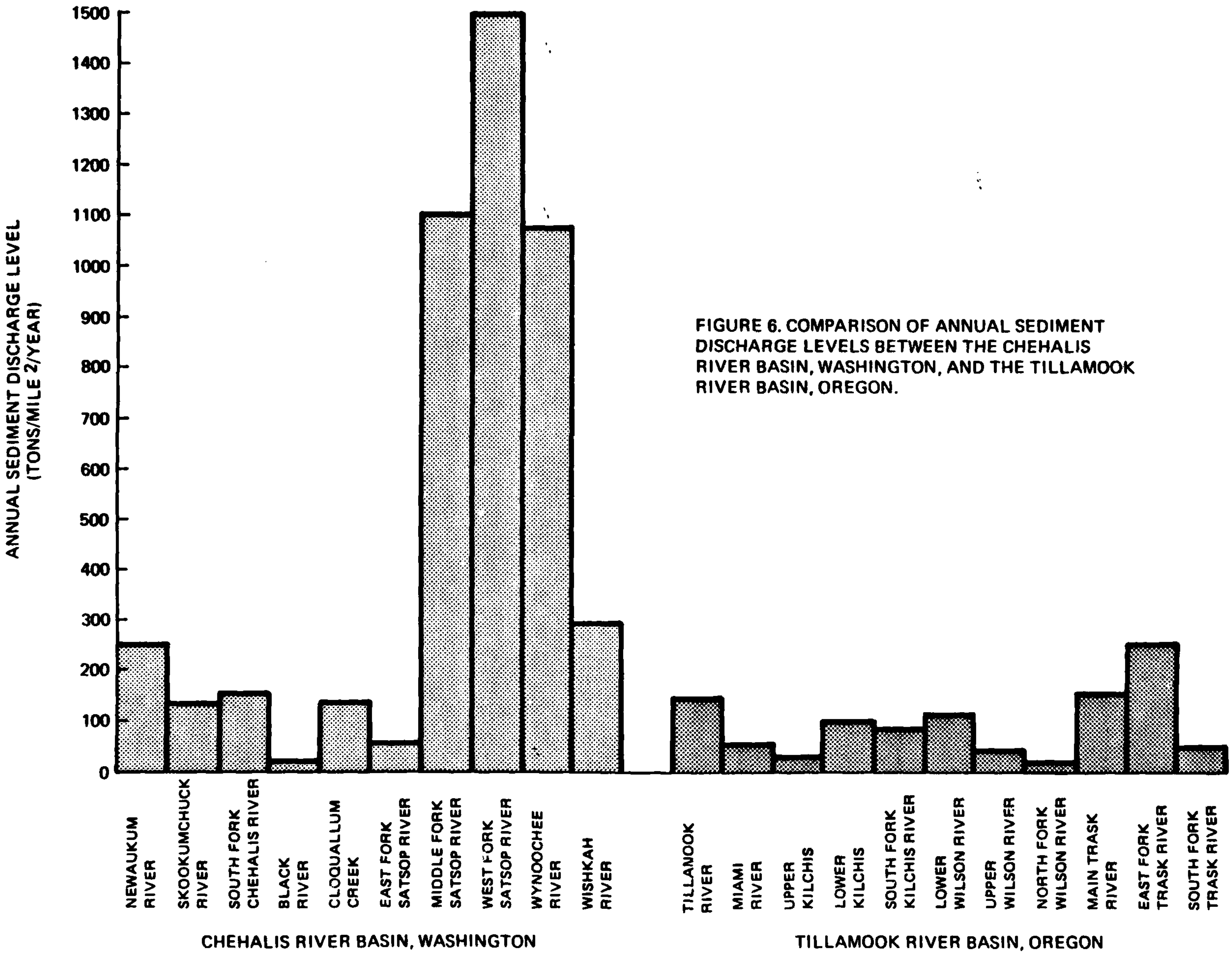

FIGURE 6. COMPARISON OF ANNUAL SEDIMENT DISCHARGE LEVELS BETWEEN THE CHEHALIS RIVER BASIN, WASHINGTON, AND THE TILLAMOOK RIVER BASIN, OREGON.

TABLE 11

COMPARISON OF THE ANNUAL GROSS SEDIMENT DISCHARGE YIELDS FROM TWO COASTAL MOUNTAIN RANGE DRAINAGES IN THE PACIFIC NORTHWEST

	Gross Sedimentation Discharge Rate (Tons/square mile/year)
Chehalis River Basin*	
Newaukum River	237
Skookumchuck River	130
South Fork Chehalis River	150
Black River	20
Cloquallum Creek	136
East Fork Satsop River	60
Middle Fork Satsop River	1,100
West Fork Satsop River	1,500
Wynoochee River	1,070
Wishkah River	290
Tillamook River Basin**	
Tillamook River	135
Miami River	53
Upper Kilchis	32
Lower Kilchis	98
South Fork Kilchis River	92
Lower Wilson River	114
Upper Wilson River	46
North Fork Wilson River+	16
Main Trask River	150
East Fork Trask River++	246
South Fork Trask River	53

* = Glancey, P. A. USGS Water Supply Paper, 1978H.
** = Benoit, Clifford USFS Hydrologic Analysis for Forested Lands, Tillamook Basins.
\+ = Least historic fire damage.
++ = Most historic fire damage.

provides more material for reworking and transport by erosional processes. At least partially due to the above mentioned variations in the physical environment of the two basins, it is clear that two subbasins (Wynoochee River and West and Middle Forks Satsop River subbasins) in the Chehalis River system are discharging suspended sediment at very high rates.

6.2 Silviculture Effects on Sediment Discharge Rates. Sediment from logging roads is the major water quality problem related to logging activity in the Pacific Northwest (EPA, 1975). Logging roads have long been known to cause increased erosion and sedimentation. A review (Gibbons, 1973) of over 25 articles on the impact of timber harvesting on stream environments concluded that forest roads are the primary initiator of erosion caused by human activities in the Pacific Northwest. The next question is: to what degree does logging activity contribute to increases over the natural sediment discharge rate of the three problem subbasins in the Chehalis River basin?

Since commercial forestry and silviculture activity account for over 90 percent of the land use activities in these problem subbasins, examination of the effect these activities have on sediment discharge levels is required. Extensive work on sediment discharge rate variations due to silvicultural activities has been performed in areas adjacent to the Chehalis River basin and in the Clearwater River basin on the western slope of the Olympic Mountain Range by Reid (1981) and Cederholm (1980). Limited to the measurement of the rate of transfer of material from hillslope to stream system, these reports (Reid, 1981; Cederholm, 1980) provide an estimate of an average suspended sediment yield of 212 tons/square mile/year in undisturbed basins in the Pacific Northwest. This suspended sediment discharge yield would increase over the level in an undisturbed basin by approximately 3.4 to 4.9 times if the basin were 40 percent logged (by clearcutting) and had 4 miles/square mile of gravel surfaced road with a typical distribution of road use intensities. This would cause sediment discharge levels to increase to as much as 720 to 1,038 tons/square mile/year (Cederholm, 1980; and Reid, 1981). Since their calculations of sediment yields considered the sediment production rates independently of the amount being stored within the system in alluvial fans, etc., the above figures should be considered only as general indications of the magnitude of the expected increase in yield. These studies show that erosion from roads in logged areas was the primary source of suspended sediments, but also that 60 percent of the road-related sediment production is caused by landslides, while erosion on road surfaces accounts for 18 to 26 percent of the total erosion occurring.

Logging road densities in the Olympic National Forest lands in the Satsop River subbasin are 4.8 miles/square mile and in the Wynoochee River subbasin are 3.0 miles/square mile, slightly less than the densities in the Clearwater River basin. These lands in the higher elevations of the subbasins have been extensively logged. The Satsop River subbasin has been virtually all roaded and logged, but some additional roadbuilding and logging may still be done on Olympic National Forest lands in the Wynoochee River subbasin.1/ No estimates of logging road densities could be obtained for private forest lands in the lower portions of these subbasins.

1/Stevens, Roger, USFS Hydrologist. Personal communication. August 1981.

6.3 Reduction of Upland Erosion and Mass Wasting Due to Silviculture. Many suggestions have been made in an attempt to minimize the impact of logging activities on sediment discharge levels in steep, forested terrain. Since logging roads have been demonstrated to be an important source of sediment, many suggestions center around improvements in the design, construction techniques, and maintenance activities afforded these structures. Reid (1981) feels that a large amount of the sediment in the Clearwater basin has come from roads built before 1972. She believes that current methods of road construction and erosion prevention have vastly reduced high sediment discharge level problems. The same is probably true for the surrounding basins, including the Wynoochee and Satsop River subbasins in the Chehalis River basin study area.

A detailed review of all the professional engineering considerations and technology necessary in the planning, design, and construction of logging roads and logging activities is beyond the scope of this report, but the following is a brief outline of some of the engineering and silviculture practices that could reduce sediment discharge levels resulting from logging activities.

(1) Reduce road construction by using logging techniques that allow long yarding distances (distances the fallen tree must be moved to reach the logging trucks).

(2) Use long-line logging techniques with suspension of cut logs over streams (logs not dragged through the stream).

(3) Direct the fall of trees to prevent them from entering stream courses.

(4) End-haul material to safe waste areas and eliminate sidecast (material carved from the hill being roaded and deposited on the downhill side) in steep country (slopes over 40 percent).

(5) Grass-seed steep cut and fill areas to stabilize soil and reduce sediment loss.

(6) Clean out all streams concurrently with logging, while avoiding removal of older, naturally deposited debris.

(7) Build a blacktop road system of main lines and secondary roads, thus nearly eliminating sediment loss from these segments during periods of heavy rainfall. Place flumes and energy dissipators on all critical cross drainages to prevent erosion of fills and steep slopes.

(8) Institute an aggressive culvert patrol covering all roads in the system during periods of heavy rainfall, resulting in immediate care of landslides and culvert or bridge failures.

(9) Build sediment traps below landslides to intercept silt before it enters streams.

(10) Put old roads "to bed" (closing them off and water sealing them) to prevent surface erosion.

(11) Use balloon and helicopter logging techniques in some areas of difficult access.

(12) Plan roads to take maximum advantage of natural log landing areas, thereby reducing soil disturbance for landings and temporary work roads.

(13) Take advantage of benches, ridge tops, and the flatter transitional slopes near the ridges and valley bottoms. Avoid midslope locations on steep, unstable, dissected slopes, particularly in areas of weathered and decomposed rock formations. The road gradient should be steepened, consistent with traffic safety, to avoid unstable slopes. With present-day vehicle capabilities, grades of 14 to 16 percent are quite practical for low-use roads to reduce road length and soil disturbance.

(14) Roads in valley bottoms should be located to provide a natural vegetation buffer or filter strip between road and stream. These undisturbed filter strips will substantially reduce stream siltation discharging from road drainage structures and surfaces. Position roads on the transition between the toe slope and terrace to protect the road slopes from flood erosion, being careful to avoid undercutting an old slide or landflow. Road drainage structures will also function better and discharge less turbid water into live streams. Valley bottoms should not be roaded where the only choice is encroachment on the stream.

(15) Locate ridge-top roads to avoid headwalls (side slopes of the road) at the source of tributary drainages. These are often extremely unstable slopes, and any erosion or slope failure will flow directly into live streams.

(16) Vary road grades, when possible, to reduce culvert and road drainage ditch flows, road surface erosion, and concentrated culvert discharges.

(17) Select stream crossings with particular care. Preplan the overall location to take advantage of the best drainage crossings to minimize channel disturbance, approach cuts, and fills where the drainage structure will have as little influence as possible on the natural streamflow.

Since the majority of logging roads necessary to completely clearcut the Middle and West Forks of the Satsop River have already been constructed, erosion reduction techniques would need to be aimed at proper maintenance (as listed above) of these logging roads to minimize their impacts on sediment discharge levels. In the Wynoochee River subbasin, where further road construction will be necessary, attention to road planning and route selection, in addition to proper maintenance of already constructed roads, will help to reduce suspended sediment discharge levels from this subbasin.

The degree to which the above actions will help to reduce suspended sediment loads from these problem subbasins is not precisely known. However, implementation of the above techniques could decrease suspended sediment discharge levels from these subbasins up to 4.9 times as indicated by Reid's (1981) research.

6.4 Reduction of Channel Erosion. As shown in chapter 5, channel erosion has been stated to contribute approximately 15 percent of the suspended sediment load carried by the Chehalis River system. Norman Associates (1974) outlined a number of alternative methods by which the channel erosion process could be minimized in Grays Harbor County. Briefly, these measures are:

- o bank protection,
- o channelization and flow regulation, and
- o nonstructural methods.

Bank protection is generally used to provide local relief from erosion and includes construction of revetments and/or retaining walls or planting of vegetation along channel banks. All of these methods provide a cover for stream borders from direct erosion and scour.

Channelization and flow regulation by dams and reservoirs can also reduce the erosion potential of the streams in the area. The Wynoochee Dam on the Wynoochee River and the Skookumchuck Dam on the Skookumchuck River are the only flow regulating structures within the Chehalis River basin. Erosion control by channel modification (except by natural methods, i.e., planting of grass and shrubs) is not considered a sound management alternative due to environmental concerns.

Nonstructural measures include: regulatory controls such as zoning ordinances and building codes, the Federal Flood Insurance Program, and the Forest Practices Act; formation of organizations such as Flood Control Zone Districts; and usage of planning methods such as land use planning.

For a more in depth discussion of the above channel erosion control methods, the reader is referred to the Norman Associates Study (1974). Norman Associates predicted that the suspended sediment discharge levels would be reduced with the implementation of the above controls by approximately 340,000 c.y. or 476,000 tons annually. The methodology issued to make these estimates was not presented.

7.0 Results/Discussion. In comparison to sediment production in other watersheds of western Washington and Oregon, the literature reviewed indicates that the Wynoochee and the Middle and West Forks of the Satsop subbasins in the Chehalis River basin are discharging suspended sediment at extremely high annual rates. These subbasins in the northernmost portion of the study area, are also the regions with the greatest topographic relief and highest annual rainfall levels. In contrast, however, the balance of the Chehalis River basin contributes sediment to the system at moderate to low annual rates. These are generally regions of gentle topography and with moderate amounts of rainfall. Commercial forest is the primary land use throughout the basin, occurring in the subbasins which have high annual suspended sediment discharge rates as well as in those with lower suspended sediment discharge levels. Cropland and urban areas generally occur on flat terrain, contiguous to the riverways which define the basin. Natural variations in sediment discharge levels are generally due to differences in topography, the type and amount of precipitation, land use, and geologic characteristics of an area.

Even though suspended sediment discharge levels are naturally high in the two subbasins identified in this report, research conducted in various river basins of western Washington has shown that man's activities (particularly silviculture) in the higher, steeper elevations of the basins tested usually result in increases of suspended sediments far above the natural levels in these basins.

No studies could be found which examined the contribution of agricultural practices to suspended or bedload sediments in the waterways of western Washington. However, based on the fact that the majority of agriculture occurring in the basin is in places identified as low level sediment production areas, this land use activity is not considered to be a significant contributing factor to the high sediment discharge levels found in some parts of the basin. Urban runoff also supplies some sediments to Grays Harbor, although extensive urbanization has not occurred throughout the study area and, therefore, is not a significant contributor to the sediment reaching the estuary. However, small urban streams are being impacted by increasing flow, habitat degradation, and sedimentation as population growth continues.

Glancey (1969) stated that the Wynoochee and Satsop River subbasins, covering a total of 354 square miles, contribute 401,160 tons/year of suspended sediment to the Chehalis River system, or an average of 1,133 tons/square mile/year. Norman Associates (1974) stated that the annual contribution of bedload sediments from these two subbasins is approximately 308,000 tons/year. Annual total sediment loads from these two subbasins is therefore estimated by Glancey (1969) and Norman (1974) to be approximately 709,160 tons/year as noted previously; however, the basis for the bedload sediment load calculations was not presented by Norman (1974).

Neither the proportion of this material reaching Grays Harbor nor the proportion which contributes to the shoaling of the navigation channels is known. Suspended sediments are carried into the estuary more readily than are bedload sediments. Upon reaching the estuary, suspended materials tend to be dispersed across the entire eastern part of the estuary, while bedload material is usually confined to the navigation channels.

According to the most recent study of sediment discharge rate changes due to commercial forestry practices in western Washington by Reid (1981), logging roads are the primary contributors of sediment during logging operations. In a hypothetical 3.9-square-mile, 40-percent logged basin with a road density of 4 miles per square mile and a typical distribution of road use intensities, sediment production rates in the basin increased 70 to 80 percent over the average reported rate of 212 tons/square mile/year for undisturbed basins in similar areas. The average sediment production rates for the Chehalis River basin is 300 tons/square mile/year and is 1,133 tons/square mile/year for the Wynoochee and Satsop River basins.

It is not possible to precisely assess the percent of the sediment discharged from these two subbasins which is a result of silviculture activities. Reid (1981), however, indicates that the logging roads built in these subbasins have probably caused sediment discharge rates to increase in these basins somewhere between the level that existed prior to any logging activities up to as much as 3.4 to 4.9 times that level.

The above information indicates, at least in a general sense, the degree to which forest practices in areas of high rainfall and rugged terrain impact the sediment discharge rate of a basin. The WDE, which is responsible for protection of water quality in the State of Washington, conducted an assessment of the adequacy of Washington's FPA rules and regulations in protecting water quality in 1980 (WDE, June 1980). This law establishes the forest practices which shall be followed in order to minimize sediment discharge levels, and is enforced by the DNR. Their survey, which consisted of examination of approximately 100 sites throughout the state, found that 80 percent of the permit actions examined were in compliance with the FPA rules and regulations.

The forest operations performed in compliance had little or no effects on water quality, including sediment discharge rates. Excessive sediment discharge rates occurred in almost 70 percent of the forest operations that were not in compliance with the regulations. Overall, 13 percent of the forest operations surveyed statewide were in violation of the FPA and were contributing excessive sediment (as defined by the survey) to the local streams.

Caution must be used in extrapolating this information of statewide FPA compliance to individual basins, where cumulative impacts may be occurring.

The current logging techniques which are economically practical are dependent on a system of logging roads through subbasins for log removal. In areas of unstable soil, steep terrain, and high precipitation levels, this road system has a much greater chance of increasing the local sediment discharge levels, even when the forest operation is in compliance with the FPA rules and regulations.

Since the economy of Grays Harbor and the Chehalis River basin are based to such a large extent on the forest products industries, reducing or halting logging in the two subbasins is not economically feasible. As noted previously, the economic future of the basin appears to be tied closely to the possibilities of maintaining or possibly increasing forest products manufacture and export.

8.0 Conclusions/Recommendations. This report has reviewed literature addressing sediment loads carried by rivers in the Chehalis River basin. This literature states that excessive suspended and bedload sediment discharges are occurring from some areas of the Chehalis River drainage basin. They also state that two subbasins in the study area can be isolated as major sediment producers which contribute sediments to the Chehalis River system at levels of 1.6 to 11 times those levels from the other subbasins in the watershed.

Forestry is the major land use, both in these subbasins and in those without any significant sediment discharge problem. This indicates that by itself silviculture activity is not the primary reason for the extensive total sediment discharge levels in the basin. A combination of steep topography, high rainfall levels, and a deeply weathered surface soil layer makes these problem subbasins inherently susceptible to erosion and subsequent high sediment discharge levels. The sediment discharge levels are further aggravated when silviculture activities are conducted in these areas.

Recent research in forested river basins of western Washington has demonstrated that silviculture activities, especially construction of logging roads, exacerbate the sediment discharge levels from basins (comparable to the Wynoochee and Satsop River subbasins in Grays Harbor) an average of 3.4 to 4.9 times above the discharge rates found in similar unlogged basins (Ried, 1981).

Other land use activities, such as agriculture, urbanization, and construction, also contribute to the sedimentation of the inner harbor and, although the degree to which these are contributing sediment is not known, the areas in which these land use activities are located do not have high sediment discharge rates (relative to the Wynoochee and Satsop River subbasins), perhaps partly due to topography and other physical characteristics. Additionally, the percentage of land being used for these activities is small enough so that their relative contributions are small.

The methods used to gather the data referenced in this report have been noted throughout this document. This information should be used with the caveats presented. The least amount of information was found on the fate of the total sediment load as it moved into the Grays Harbor estuary. Additionally, little work has been done to investigate the reworking of the sediments previously deposited in Grays Harbor and its impact on the shoaling of the navigation channels.

On an average, 80 percent of the forestry practices occurring in the State of Washington are in compliance with the FPA, which is the law responsible for controlling sedimentation resulting from forest practices (WDE, 1980). When complied with, this law has been shown to provide protection to streams from water quality impacts, including sedimentation, most of the time. However, over half of the time that the FPA is not complied with (statewide), excessive sediment was introduced into the adjacent streams.

Caution must be used in extrapolating the information of statewide FPA compliance to individual basins. In areas of steep topography, high rainfall (such as the Wynoochee and Satsop River subbasins), and cumulative logging impacts, compliance with the FPA occurs less often.[1/] The degree to which stricter compliance with the FPA would reduce sedimentation from these areas and, consequently, dredging in Grays Harbor is not known.

The environmental benefits resulting from any significant decrease in the total sediment load carried by the Chehalis River cannot be precisely defined. If sediment discharge levels decreased in the Chehalis River system, a decrease in the amount of dredging necessary in the inner harbor may result. The environmental effects on infauna would not be altered, however, since the same area would be dredged; the only difference would be that the dredging would occur less often. There would be a decrease in the impacts on mobile epibenthic and pelagic organisms around dredged areas, since the dredging would occur less often, affect water quality less, and result in uptake and destruction of fewer organisms. Additionally, the impacts to the biota in upland and open water disposal areas would decrease in relation to the decrease in the frequency and quantity of material deposited at these sites.

This report is intended to assist the agencies involved in sediment control from upland areas to isolate specific problem regions in the Chehalis River basin. Focus of sedimentation control efforts into these regions will be the most efficient use of these agencies' limited time and resources. Also, advances in logging road construction technology and increasing logging on previously cut forest lands will serve to help stabilize any further increases in sediment discharges from the Chehalis River basin.

But most importantly, all agencies and private groups must look beyond their immediate areas of jurisdiction and interest and realize that sound management practices require a cognizance of the effects of each of their activities on the overall ecological system. Interagency communication and cooperation, as well as acceptance of individual agency responsibilities, are vital parts of this effort.

1/WDE. Personal communication, November 1981.

BIBLIOGRAPHY

1. Benoit, Clifford. Hydrologic Analysis for Forested Lands, Tillamook Basin, Tillamook County, Oregon. U.S. Department of Agriculture, Forest Service, Portland, Oregon. February 1978.

2. Brown, G. and J. Kruggier. Clear-Cut Logging and Sediment Production in the Oregon Coast Range. Oregon State University, School of Forestry, in Water Resources Research, Volume 7, No. 5. October 1971.

3. Cederholm, C. J. and L. C. Lestelle. Observation on the Effects of Landslide Siltation on Salmon and Trout Resources of the Clearwater River, Jefferson County, Washington, 1972-1973. Final Report, Part I. University of Washington, College of Fisheries. FRI-UW-7404. April 1974.

4. Cederholm, C. J., L. M. Reid, and E. O. Salo. Cumulative Effects of Logging Road Sediment on Salmonid Populations in the Clearwater River, Jefferson County, Washington. Conference Contribution No. 543, University of Washington, College of Fisheries. October 1980

5. Environmental Protection Agency. Supplemental Water Quality Management Program Guidance for FY 81. June 1980.

6. Environmental Protection Agency. Methods for Identifying and Evaluating the Nature and Extent of Non-Point Sources of Pollutants. EPA-430/9-73-014. October 1973.

7. Environmental Protection Agency. Water Quality Management Five Year Strategy FY 81-Baseline. January 1980.

8. Environmental Protection Agency. Rules and Regulations for Grants for Water Quality Planning, Management and Implementation, Part II. Federal Register, Volume 44, No. 101. May 23, 1979.

9. Environmental Protection Agency. Processes, Procedures, and Methods to Control Pollution Resulting from Silvicultural Activities. EPA 430/9-73-010. October 1973.

10. Environmental Protection Agency, Region X. Forest Harvest, Residue Treatment, Reforestation, and Protection of Water Quality. EPA 910/9-76-020. April 1976.

11. Environmental Protection Agency. Logging Roads and Protection of Water Quality. EPA 910/9-75-007. March 1975.

12. Letter from Environmental Protection Agency to Governor Ray, Olympia, Washington, Concerning Review of the Forest Practice Water Quality Management Plan dated December 11, 1979.

13. Federal Water Pollution Control Administration, Chehalis River Basin Reconnaissance Report. March 1967.

14. Fiksdal, A. and M. Brunego. Forest Slope Stability Project, Phase I. Washington Department of Ecology. DOE Report No. 80-2a.

15. Fredriksen, R. L. Erosion and Sedimentation Following Road Construction and Timber Harvest on Unstable Soils in Three Small Western Oregon Watersheds. U.S. Department of Agriculture, Forest Service, Portland, Oregon. Research Paper PNW-104. 1971.

16. Gibbons, Dave and Ernest Salo. An Annotated Bibliography of the Effects of Logging on Fish of the Western United States and Canada. U.S. Department of Agriculture, Forest Service, Technical Report PNW-10. 1973.

17. Glancy, P. A. Sediment Transport by Streams in the Chehalis River Basin. U.S. Geological Survey. Water Supply Paper 1798-H. June 1969.

18. Golde, Marcy. Report: Logging Violations in the Clearwater Basin, A Case Study: East Kunamakst Creek. Washington Environmental Council. July 1980.

19. Grays Harbor Regional Planning Commission Water Resources Committee. Water Problems and Priorities Planning for 1970 to 2000. February 1971.

20. Grays Harbor Regional Planning Commission. Report of the Grays Harbor Agricultural Study Committee to the Grays Harbor County Planning Commission and Board of Commissioners. April 1980.

21. Megahan, W. and W. Kidd. Effect of Logging Roads on Sediment Production Rates in the Idaho Batholith. U.S. Department of Agriculture, Forest Service. Research Paper INT-123. May 1972.

22. Nelson, Leonard M. Sediment Transport of the Wynoochee River and Its Tributaries Above Mile 51.8, Washington. U.S. Geological Survey, Administrative Report. 1967.

23. Norman Associates. Grays Harbor Erosion Management Study. June 1974.

24. Reid, Leslie. Sediment Production from Gravel-Surfaced Forest Roads, Clearwater Basin, Washington. Master of Science Thesis. University of Washington, College of Fisheries. FRI-UW-8108. March 1981.

25. U.S. Army Corps of Engineers. Maintenance Dredging and the Environment of Grays Harbor, Washington. Appendixes A-F. December 1976.

26. U.S. Army Corps of Engineers. Water Resources Development by the U.S. Army Corps of Engineers in Washington. North Pacific Division. January 1973.

27. U.S. Department of Agriculture, Agricultural Research Service. Present and Prospective Technology for Predicting Sediment Yields and Sources. Report No. ARS-S-40. June 1975.

28. U.S. Department of Agriculture, Forest Service. Implementation Plan for Water Quality Planning on National Forest Lands in the Pacific Northwest. Portland, Oregon. December 1978.

29. U.S. Department of Agriculture, Forest Service. Land and Water Resource Information, Chehalis Subarea. No date.

30. U.S. Department of Agriculture, Soil Conservation Service. Southwestern Washington River Basins Type IV Survey. 1974.

31. U.S. Department of the Interior, Bureau of Reclamation, Boise, Idaho. Upper Chehalis River Basin, Washington, Reconnaissance Report. May 1965.

32. State of Washington, Departments of Ecology and Social and Health Services, and the U.S. Environmental Protection Agency. Washington State/EPA Agreement, FY 81. September 1980.

33. Wald, Alan R. The Impact of Truck Traffic and Road Maintenance on Suspended Sediment Yield from A 14 Foot Standard Forest Road. Master of Science Thesis. University of Washington, College of Forest Resources. June 1975.

34. Washington Department of Ecology. Suspended Sediment Transport and Forest Road Construction. DOE Report No. 79-5a-1. March 1979.

35. Washington Department of Ecology, Storet Data. River Flow Data, Chehalis River Bain. 1974-1980.

36. Washington Department of Ecology. Suspended Sediment from Truck Traffic on Forest Roads. DOE 79-5a-3. March 1979.

37. Washington Department of Ecology. Amendments to the State Forest Practice Rules and Regulations Adopted by the Forest Practice Board as of December 11, 1980. 1980.

38. Washington Department of Ecology. Agricultural Alternatives in Southwest Washington. Southwest Washington River Basins Study. June 1973.

39. Washington Department of Ecology. Water Resources of Southwest Washington. Southwest Washington River Basins Study. June 1972.

40. Washington Department of Ecology. An Assessment of the Adequacy of Washington's Forest Practice Regulations in Protecting Water Quality. Summary Report No. DOE 80-7. June 1980.

41. Washington Department of Ecology. Forest Practice Water Quality Management Plan. Report No DOE 79-5a. September 1979.

42. Washington Department of Ecology. Forest Road Construction and Suspended Sediment. DOE Report No. 79-5a-2. March 1979.

43. Washington Department of Natural Resources. Selected Laws Administered by the Department of Natural Resources. 1979.

44. Yee, C. and T. Roelofs. Planning Forest Roads to Protect Salmonid Habitat. U.S. Department of Agriculture, Forest Service. General Technical Report PNW-109. July 1980.

APPENDIX A

This appendix briefly describes each of the laws and programs listed in Section II. These annotations have been provided for the reader who wishes to gain a general understanding of the requirements and objectives set forth under each of these authorities. Further information on any specific law may be obtained from the agency responsible for its implementation.

Public Law 92-500. The Clean Water Act (86 Stat. 816). Provides that water quality planning on Federal lands be in cooperation with applicable state laws and agencies. It also recognizes nonpoint pollution, and requires all Federal facilities and activities to comply with the provisions stated that deal with the control and abatement of pollution through water quality management planning.

Public Law 95-217. Clean Water Act of 1977 (91 Stat. 1566). This law amends the Clean Water Act and reaffirms the role of Federal agencies in participating in and complying with all Federal, state, interstate, and local water pollution control requirements.

Executive Order No. 11288. Requires agency heads to provide leadership in water quality management regardless of the type of contaminant which is adversely affecting water quality.

Executive Order No. 12088. Prescribes the responsibility of the head of each executive agency for compliance with applicable pollution control standards and Federal policy for control of pollution from Federal properties, facilities, and activities. Requires compliance with Federal, state, and local water quality standards and effluent limitations.

Executive Order No. 11752. Assures leadership by the Federal Government in the nationwide effort to protect and enhance the quality of our air, water, and land resources through compliance with Federal, state, interstate, and local standards.

Public Law 83-566. The Watershed Protection and Flood Prevention Act. Provides for action by the Soil Conservation Service (SCS) on small watershed projects, allowing for accelerated land treatment on critical erosion and sediment producing sites within the watershed.

Rural Environmental Conservation Program. Authorizes certain Federal agencies to provide cost sharing to landowners for carrying out certain soil and water conservation practices such as those effective in reducing or controlling erosion and the resulting sedimentation.

Resource Conservation and Development Projects. Financial and technical assistance can be provided on locally initiated, sponsored, and directed projects which are aimed at critical erosion areas, soil and water conservation for agriculture related pollution, water quality problems, etc.

Public Law 94-588. National Forest Management Act of 1976 (90 Stat. 2949). Establishes procedures for creation of regulations to insure that timber will be harvested only where soil, slope, and certain pristine watershed conditions will not be irreversibly impacted.

58 USC 132 As Amended. Sustained Yield Forest Management Act, March 29, 1944. Authorizes the Secretaries of the Interior and Agriculture to establish federally owned or administered sustained yield forest units to aid in the prevention of soil erosion and other conservation practices.

Public Law 83-566. The Watershed Protection and Flood Prevention Act. Allows loans to be made to individuals, groups, and local organizations for the purpose of developing water supply systems and for carrying out soil conservation practices.

Public Law 94-579. Federal Land Policy and Management Act of 1976. Directs the BLM to perform consistent land use planning, including water quality considerations from all other pertinent state and Federal laws.

33 USC 401, 403, 409. Sets forth rules governing work on structures in or affecting the navigable waters of the United States.

Rivers and Harbors Act of 1899. Section 10 of this act sets forth rules governing work on structures in or affecting the navigable waters of the United States.

33 USC 540. Gives the U.S. Army Corps of Engineers (COE) authority to grant permits for river improvement projects.

33 USC 407. Delegates authority to enjoin or force removal of refuse placed in or on the banks of a navigable water or its tributary.

33 USC 565. Allows granting of permits for private projects to improve navigable waters.

Public Law 78-526. Flood Control Act of 1946. Section 14 of this law allows the COE to provide emergency bank protection for qualified public works endangered by bank erosion due to floods.

RCW 76.01-28. Forest Practices Act (FPA) of 1974. Designed to meet the requirements of Section 208 of the Clean Water Act. Includes the initiation of statewide forest practice regulations, authorizes the existence of the Forest Practices Boards, and delegates the authority to promulgate forest practice regulations.

WAC 222-10-010. Creates forest practice regulations, supplemental directives, enforcement practices, and conditions for appeals.

WAC 222-16 through WAC 222-34. Natural water categories and erosion control practices pertaining to logging operations are defined and outlined.

RCW 90.48. State Water Pollution Control Act. This gives Washington Department of Ecology (WDE) authority and responsibility to identify sources of water pollution, develop plans, promulgate and enforce rules, implement control measures, and levy fines. WDE has also been designated as lead agency by the governor for water quality planning under the Federal Clean Water Act.

WAC 173-201. Washington State Water Quality Standards. Establishes water quality standards, setting specific requirements for various water quality parameters.

RCW 76.09.040 (2). This portion of the FPA of 1974 delegates to the WDE the authority to write regulations addressing water quality protection for forest lands in conjunction with the Forest Practices Board. It also requires that comments be solicited from both Washington Department of Game (WDG) and WDF prior to adoption of any forest practices regulations.

RCW 75.20.100. Hydraulic Project Approval Law. Permit approval must be obtained from WDG and WDF prior to any work that will use or alter the natural flow or bed of any river or stream of the state.

RCW 76.09.200. Representatives from WDG and WDF shall participate in promulgation of forest practices regulations as members of the Forest Practices Advisory Committee.

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