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Riverine Gravel Mining in Washington State, Physical Effects with Implications for Salmonid Habitat, and Summary of Government Regulations

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EXECUTIVE SUMMARY

Purpose

Mining sand and gravel from river bars and floodplains can change the riverine environment, including salmonid habitat. Planners, resource agency personnel and others are required to regulate riverine mining so as to avoid these impacts. The purpose of this report is to provide regulators with information that supports that task. It has four objectives: (1) Describe recent locations and rates of riverine sand and gravel mining; (2) Review effects of mining on rivers, with emphasis on salmonid habitat; (3) Summarize government regulation of riverine mining in Washington; (4) Recommend ways for mine regulation to better protect the river environment and salmonid habitat.

Riverine Mining in Washington State

Floodplains and rivers are dynamically related. However, late-19th and early-20th century land uses, such as diking and bank protection, and the ditching and draining of floodplains, isolated floodplains from rivers, facilitating floodplain mining. Two-thirds of the state's floodplain mines are along the Yakima River and two of its tributaries, the Cle Elum and Naches rivers. Mining in the Yakima River basin began in the early 1950s. In other rivers, floodplain mining began in the 1940s, but most has occurred since the early 1970s. The Chehalis River system has the second largest concentration of lakes after the Yakima system, and includes mines along the Chehalis, Wynoochee, Satsop, Skookumchuck, and Newaukum rivers. The Yakima and Chehalis river systems combined account for four-fifths of state floodplain mines. The Cowlitz and East Fork Lewis rivers also have significant amounts of mining. Five other rivers have smaller amounts of floodplain mining. River bars are mined or have been mined since about 1970 on a regular basis commercially or for flood control in about 20 rivers. The largest operations at present are located in the Nooksack, Stillaguamish, White, Puyallup, Carbon, and Dungeness rivers.

A rough estimate of floodplain mine volume compared to published estimates of total state sand and gravel production indicates that floodplain mining accounted for one-sixth to one-ninth of the state's total from 1970 to 1991. A rough estimate of sand and gravel mined from river channel bars in 1970-1991 indicates that it accounted for about 2-4% of total statewide production. Overall, riverine sand and gravel mined from 1970 to 1991 accounted for 13-21% (one-eighth to one-fifth) of the state's total production. About half of this was from floodplains of the Yakima River and its tributaries.

Physical Effects of Mining with Implications for Salmonid Habitat

There are few studies of the effects of floodplain mining. An historical overview of mine operations in Washington indicates that floodplain mine siting often eradicated floodplain water features connected to the channel. The presence of floodplain mines can also indirectly affect channels. River banks are commonly armored to protect floodplain mines from channel migration, and can eliminate the gradual lateral scrolling and sudden avulsions that create and maintain floodplain aquatic habitats, can narrow a channel and simplify its morphology, reduce the supply of bed material from bank erosion, and reduce wood recruitment. The presence of mine lakes can also limit the potential to restore floodplain function and habitat lost to earlier land uses. On the other hand, it may be possible to site and size floodplain mines in such a way as to create static replicas of dynamic floodplain habitats that formerly existed, providing habitat, and in a way that does not interfere with restoration at a later time of a dynamic river-floodplain connection.

Floodplain mine lakes have the potential to be breached by unplanned, rapid river migration. Especially if floodplain pits are deep and broad relative to the river, such a sudden breaching could cause rapid bed scour upstream or downstream, channel abandonment, and change water temperature and flow, and channel substrate conditions if the channel routes through a breached lake. No studies were found of how floodplain mine lakes might affect the flow, temperature, chemistry, or biota of hyporheic groundwater, or the patterns and locations of groundwater and channel water exchange, which could be particularly important to salmonids during seasonal low flows.

Mining a river bar can affect the bar, the near-bar channel, and the downstream channel. Few studies link physical changes to salmonid habitat. Proximal effects include: removing vegetation and woody debris, important for shade and stream structure; reducing the area of pools or riffles adjacent to a bar; and scour of upstream riffles. By interrupting the downstream transport of bed material, repeated mining of a bar or several bars can diminish downstream bars and decrease the downstream bed elevation. River-bed lowering can in turn cause coarsening or loss of spawning gravels and exposure of cohesive substrates; drop the groundwater table, and alter surface-groundwater interactions and affect riparian vegetation; and eliminate or reduce hydrologic connection between the river and floodplain.

Mine reclamation traditionally focuses on establishing a productive use after mining. A 1993 revision in Washington's reclamation law requires functional wetlands be developed in floodplain mines, and thus focuses on rehabilitating selected attributes of the riverine ecosystem. Reclamation law also requires bar mine reclamation; in practice this has been limited to grading requirements. Reclamation does not at present focus on preserving or restoring natural riverine landscape function or character.

Regulation of Riverine Mining

Three state laws have a primary role in regulating riverine mining. Washington's Shoreline Management Act of 1971 has the potential to broadly regulate floodplain and channel mining because it focuses on balancing the use and protection of shorelines.

Counties implement the Shoreline Act through master plans, overseen by the Washington Department of Ecology. The State Environmental Policy Act (SEPA) is generally triggered by permit applications through the Shoreline Act. The Washington Surface-Mined Land Reclamation Act (1970) is administered by the state Department of Natural Resources, and regulates reclamation of all mines larger than three acres (1.2 ha). The Washington Department of Fisheries and Wildlife must issue Hydraulic Project Approval for all channel mines and any floodplain mine that has a surface water connection with the river. Section 404 of the federal Clean Water Act is the primary federal law that bears on mine regulation, and is administered by the Army Corps of Engineers and Environmental Protection Agency. Rule changes in 1993 broadened Section 404 regulation to include the "mechanized clearing, ditching, channelization, and other excavation activities" of floodplains, which includes most floodplain mines.

Recommendations

This broad overview suggested the following ways to improve regulation of the effects of mining on the riverine environment and salmonid habitat: (1) Focus policy on protecting and restoring natural function of the riverine environment; (2) Develop better understanding of impacts; (3) Evaluate alternatives to riverine mining; (4) Improve record keeping; (5) Evaluate mining for flood control in the context of comprehensive flood hazard management.

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INTRODUCTION

Washington's river landscapes are sculpted in sand and gravel, which are particularly abundant in river bars and floodplains. Rivers typically form bars and floodplains where they emerge from mountainous terrain onto more gently sloping lowlands. Many of these rivers augment their mountainous-headwater-derived supply of coarse sediment as they meander across lowlands by eroding sand and gravel that derived from Pleistocene glaciation (for example, King County 1993; Collins 1994; Church and Slaymaker 1989).

The complex and dynamic morphology of laterally mobile, lowland rivers make them biologically rich and diverse. Lowland rivers and their floodplains are important salmonid habitat (Williams and others 1975; Groot and Margolis 1991) or were so historically (Beechie and others 1994; Sedell and Luchessa 1982; Northwest Power Planning Council 1986) prior to historic land and river modifications.

The abundance of sand and gravel in lowland rivers and their proximity to population centers also make them attractive sites for commercial sand and gravel mining. Sand and gravel are integral to the constructed environment, and demand is high. In 1991, per-capita demand was about 12 tons, or one truckload per person (Lingley and Manson 1992). Washington produced an estimated 60 million tons, valued at about $190 million (Lingley and Manson 1992). While most sand and gravel in Washington is mined from upland Pleistocene glacial deposits (Lingley and Manson 1992), riverine mining is an important contributor to the state's production.

Sand and gravel build up in some rivers over the long term. Some aggrading lowland reaches are mined on an annual basis to maintain flood conveyance (for example, Prych 1988). Previous to levee construction and other engineering modifications earlier this century, this accumulation was spread across a broad valley floodplain. Historic river modifications in some rivers focused deposition to a narrower area, which may have accelerated deposition. In addition, forest land use in the last several decades has increased headwater erosion over previous rates (for Washington examples see Reid and others 1981, Eide 1990; for regional summaries see Sidle and others 1985, Swanson and others 1987, Meehan 1991). It is possible that increased headwater erosion has increased deposition in lowland portions of some rivers. However, neither the effects of increased headwater erosion or historic lowland channel modifications on lowland deposition have been systematically evaluated in the state's rivers.

Thus, sand and gravel in lowland river landforms are biologically important, an economic asset, and the focus of flood and channel engineering efforts. Government agencies regulate riverine mining because of the potential for conflicts. Primary Washington laws are: 1) the Shoreline Management Act of 1971, administered by the state's Ecology Department; 2) the Washington Surface-Mined Land Reclamation Act (1970 and subsequent revisions), overseen by the Department of Natural Resources; and 3) the Hydraulic Project Approval statute, administered by the Department of Fish and Wildlife. Principle federal statutes pertaining to the regulation of riverine mining include Section 404 of the Clean Water Act.

In the decades since these and other regulations have been in effect, there has not been a "taking stock" of riverine mining in the state, either of its environmental effects, or of the regulatory framework's effectiveness at accomplishing environmental protection. This study is a first step toward that goal. It has several objectives:

- To develop an inventory and history of channel and floodplain mines in the state. This provides a basis for evaluating environmental effects, including on a spatially and temporally cumulative scale. It also indicates the relative importance of riverine mining as part of the state's overall sand and gravel production, for assessing the relative benefits and costs of riverine mining;

- To review scientific knowledge about how riverine mining affects salmonid habitat in order to identify key issues and those in need of further study;

- To summarize and review the regulatory framework that applies to riverine sand and gravel mining in Washington;

- To broadly assess the efficacy of regulations at protecting riverine areas, and to recommend wayst to improve regulation.

INVENTORY OF WASHINGTON RIVERINE GRAVEL MINES

Geomorphic Environments and Mining Methods

This inventory includes river bar and floodplain mining. It does not include low-flow channel dredging.

River Bars

"Skimming," "scalping," or "harvesting" of gravel bars is the most common type of bar mining in Washington. State Hydraulic Project regulations (see later in this report) since 1972 have restricted bar skimming to two feet vertically above the low-water level, with the finished excavation surface sloping at least two percent upward toward the bank. Mining is sometimes restricted by season to protect fish, and the presence of pits at the end of a day's activity is also prohibited (220-110-140 Washington Administrative Code). Most commercial bar mining takes place annually or every several years during summer, but in some cases is ongoing throughout the year. Bar skimming is also used to maintain channel capacity for flood control in several rivers.

Digging pits in bars was a common commercial practice prior to its restriction by the Hydraulic Project Code in 1972. In the last few years, commercial operations and government agencies have excavated pits in bars as a flood-control measure in some state rivers. At present, these pits, recently called "gravel traps," are dug several meters deep in river bars near the low-flow channel. Some pits are connected to the low-flow channel to allow access by fish. Sand and gravel that deposit in the intervening flood season is excavated in the subsequent low-flow season.

The inventory focused on operations that have been ongoing in the period since about 1970 because there are few earlier records.

Floodplain Pits

Beginning in the 1940s (see following section of report), pits have been excavated in the geomorphic floodplain of several Washington rivers. In most cases, landscape changes in the last 150 years of European settlement have facilitated mining in these locations, which were formerly dynamic. During that time period, floodplains were ditched and drained, and surface water channels and wetlands were obliterated or disconnected from the river (Sedell and Luchessa 1982). In addition, rivers were narrowed and fixed in place by bank protection or dikes, which prevented their migrating laterally across their floodplains. Thus, geomorphic floodplains are now commonly hydraulically and erosionally disconnected from their rivers.

Typically pits are excavated behind bank protection or levees to a depth of 5-15 m. In the last decade, new and existing floodplain pit mines have been permitted to a depth of 20-30 m. These deeper pits are generally excavated using a drag-line dredge. Floodplain pits commonly fill with groundwater. This report includes only such "wet" floodplain pits, and does not include "dry" pits on river terraces, or shallow floodplain excavations that do not penetrate the groundwater table. This criterion was used because it was judged from the scientific literature (see later in report) that deeper, wet pits potentially cause greater impact to salmonid habitat than shallower, dry pits.

Channel Dredging

In the past, earth moving equipment or drag-line dredges were used to dig pits in or to dredge the low-water channel of rivers. Many state rivers may have been regularly dredged until regulations instituted in the early 1970s. No operations of this type are on record at present. Deep-water dredging using drag-line or other methods takes place in the Columbia and Snake rivers and the lower reaches of several other rivers, including the Cowlitz and Lewis. Deep-water dredging was excluded from this study.

Floodplain Mine Inventory

Most floodplain mines in Washington are along a few rivers (Figure 1). About two-thirds are along the Yakima River or the lower reaches of two of its tributaries, the Naches and Cle Elum rivers (Table 1). Mining in the Yakima River began in the 1950s. All but four of about 150 lakes in the basin are in four reaches: the Cle Elum area, Ellensburg area, Selah-Moxee valleys, and lower Yakima valley (Table 1). The four reaches of the Yakima River total 151 kilometers in length and contain on average roughly one floodplain-mine lake per kilometer. Pits were identified from aerial photos with no ground checking. While the total area of pits could be measured relatively precisely, the number of individual pits is approximate, because boundaries and hydraulic connections between pits are sometimes indistinct, and change through time. Four additional lakes are located at RM 2.4 near Richland, and at RM 13.2. The most recent map and photo information consulted for the Yakima River basin is from 1986. By 1986, mine lakes in the Yakima River basin had an area of 6×10^2 ha.

Most mining occurred in other Washington rivers after about 1970, except for a small amount between 1940 and 1960 (Figure 2). The Chehalis River and four of its tributaries account for one-fifth of floodplain mine lakes. Most of these are either within a 32-km-long reach near the river's mouth, or along its tributaries the Wynoochee and Satsop rivers (Figure 1 and Table 1). Mine lakes are also present along the lower Skookumchuck River, the lower Newaukum River, and the Chehalis River in Centralia. Together, the Yakima and Chehalis river systems account for four-fifths of the state's floodplain-mine lakes. Other rivers having mined floodplains are given in Table 1. By 1990-1992, which are the

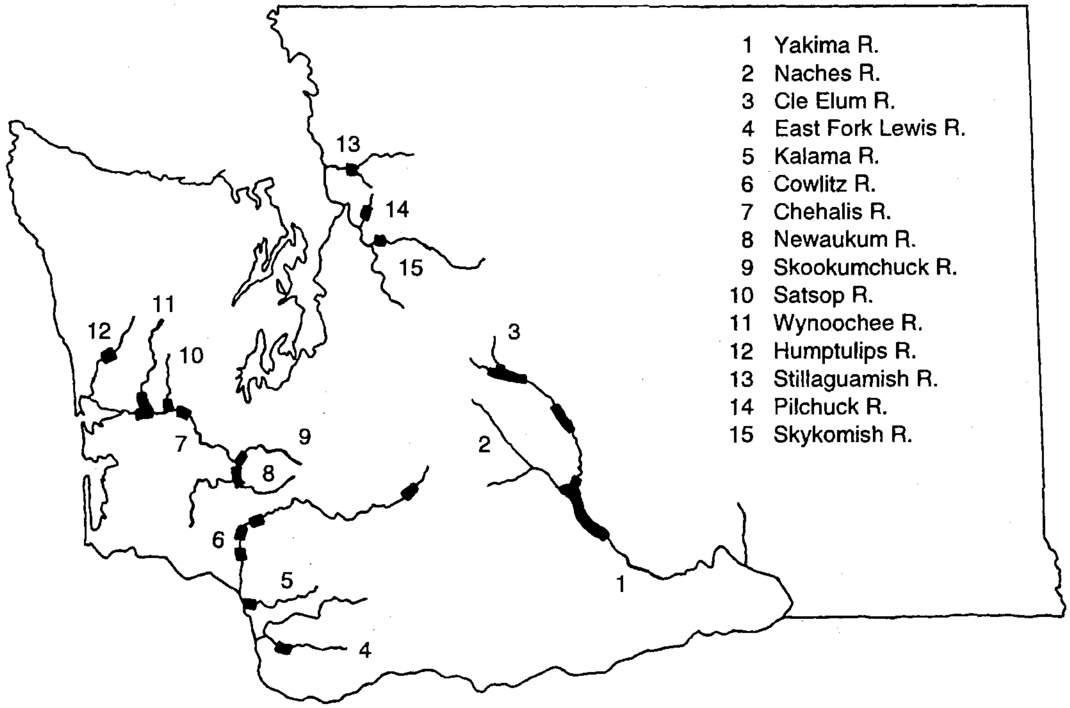

Figure 1. *Generalized reaches having sand and gravel mines in active floodplains. Mines were included if: (1) excavated to below the ground-water table; (2) at least three acres (1.2 ha), the minimum size regulated by the state Surface Mined Land Reclamation Act (see later); (3) within the geomorphic floodplain of the river. Information was gathered from topographic and orthophoto maps and aerial photos, and from Washington Department of Natural Resources (WDNR) Surface Mined Land Reclamation Permit files and Washington Department of Ecology (WDOE) Shoreline Permit files. Information was not field checked.*

Table 1. Floodplain mine lakes in Washington state. To be included, pits or clusters of pits are >1.2 ha in area and deeper than groundwater table.

River Basin[1]	River Kilometer[2]	Area (ha)[3]	Number of Lakes	Percent of Total (by area)
Yakima River				
Lower River --	4, 21, 123	18	8	2
Zillah Reach (1986)	132-171	111	27	12
Selah-Moxee Valleys (1986)	173-195	187	36	21
Ellensburg Reach (1986)	238-258	168	44	19
Cle Elum Reach --	286-337	53	22	6
Naches River --	0-9	34	9	4
Cle Elum River --	1-2	7	6	1
Yakima River Basin Total		**578**	**152**	**64**
Chehalis River				
Lower Chehalis River (1988-1993)	17-49	68	21	8
Upper Chehalis River --	108	9	1	1
Wynoochee River (1988-1992)	0-17	28	13	3
Satsop River (1991)	2, EF 13	9	4	1
Skookumchuck River (1990-1992)	0-8	27	9	3
Newaukum River --	1-2	9	2	1
Chehalis River Basin Total		**150**	**50**	**17**
Cowlitz River				
Castle Rock Reach --	29	3	1	<1
Toledo Reach (1990)	45-59	51	16	2
Packwood Reach (1990)	202	4	1	<1
East Fork Lewis River (1990)	13-14	40	10	4
Kalama River (1990)	3	17	8	2
Pilchuck River (1991)	8-10	16	4	2
Humptulips River --	39-43	5	3	1
Skykomish River (1992)	5	33	1	4
Stillaguamish River (1991)	25	3	1	<1
Other River Basins		**172**	**45**	**19**
State Total		**900**	**247**	**100**

[1] For reaches with active mining, year is given of most recent aerial photo or map information consulted to measure lake areas. [2] River kilometers are from river miles indicated on 1:24,000 scale topographic maps. [3] Area measured as of date indicated in column 1 in cases where mining may be ongoing.

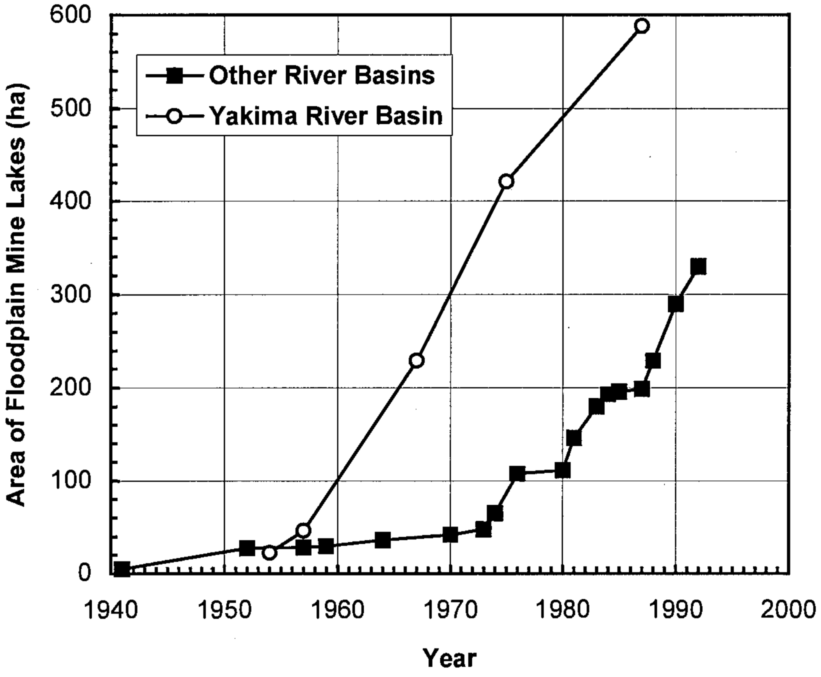

Figure 2. *Cumulative area of floodplain-mine lakes for the Yakima River basin through 1986, and for other rivers combined, through 1991.*

dates of the most recent map or photo information consulted for this inventory, floodplain mine lakes excepting the Yakima basin had an area of 2×10^2 ha (Table 1).

Individual lakes ranged in size from 1 to 49 ha. The largest single complex of lakes was 92 ha (in 1986), along the Yakima River near Selah. There is limited information available on mine depths. Planned mine depths and in a few cases actual mine depths are given in DNR reclamation permit files. In the absence of more complete information, these were used to estimate floodplain mine-lake volume. Applying an average depth of 10 m to the 9×10^2 ha area gives a volume of 9×10^7 m^3. This excludes pits that were too shallow or too small to be included in this inventory.

River Bar Mines

Bars have been mined commercially or for flood control purposes in a number of reaches (Figure 3 and Table 2), mostly in western Washington. This may be because bedloads of western Washington streams (e.g. Nelson 1971; 1979; 1982) are generally greater than in eastern Washington (e.g. Nelson 1973), and consequently more sand and gravel would be available.

No agency has record of all operations, and the existence of bar mines was determined from several sources. The WDNR's Aquatic Lands Division collects royalties from commercial operations (see later), and in 1993, the state had royalty contracts for sand and gravel mined from five rivers: the Nooksack, Skagit, Snohomish, Stillaguamish, and Cowlitz (excluding the Columbia, for which the state also had royalty contracts for deep-water dredging). Royalty records back to 1970 included an additional 15 rivers. Information could not be gathered from Hydraulic Project Approval or Shoreline Permit records without inspecting thousands of archived files, and this was not done for this inventory. Information was also dispersed throughout archives of the WDOE, some of which were inspected. Finally, various geotechnical, fisheries, or engineering investigations identified the presence of operation on individual rivers. The list in Table 2 is based on these various sources, and may not be complete or fully accurate.

Information on sand and gravel offtake amounts is very limited. WDNR royalty records and WDOE records sometimes include permit amounts, but generally not actual off-take. Offtake data exists only for rivers for which such data was gathered as part of various studies. The information that was gathered for this report (Table 2) indicates that bars have been mined on an ongoing, substantial basis within the past 25 years on 20 rivers. Based on the sources given in the table, a rough estimate of average production during period 1970-1991 is 5×10^5 m^3/yr. This is estimated accurate to within about $\pm$ 30%.

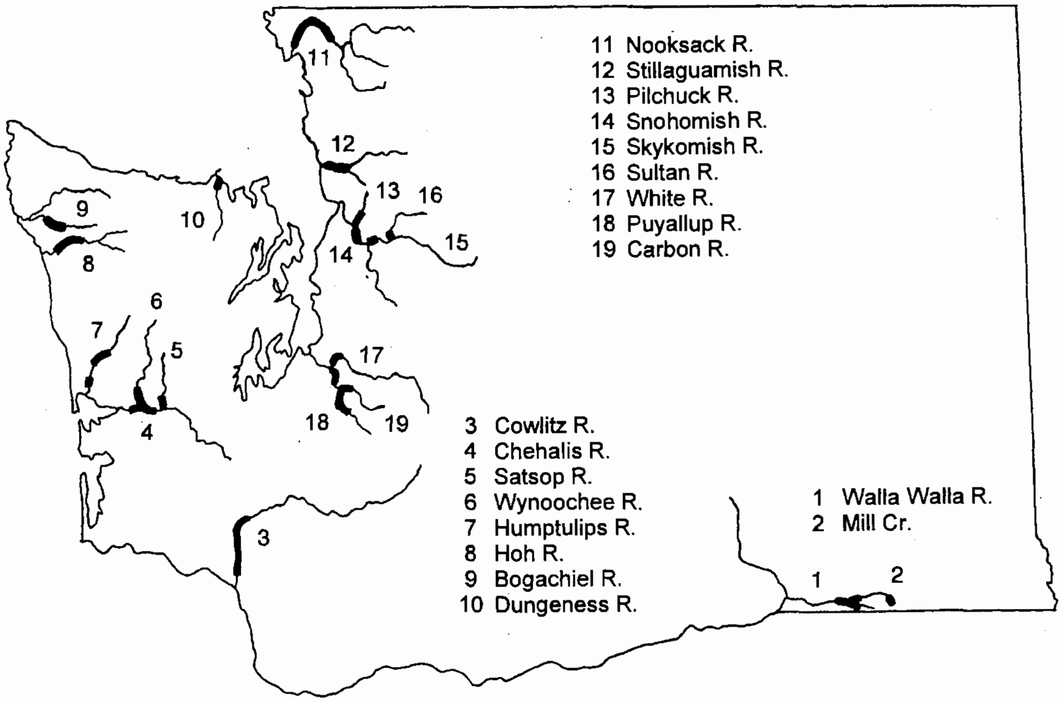

Figure 3. *Generalized reaches that have or have had on-going commercial or flood-control mining of the channel bars. Sources of information are given in Table 2.*

Table 2. Rivers having gravel bar mining since 1970, based on information in listed references.

River and County	Location (river kilometer)	Years and Amount
Bogachiel (Clallam and Jefferson)	16-33	Contracts with WDNR at various times between 1965 and 1991.[1]
Carbon (Pierce)	0-2 and 9-11	368,675 m^3 removed 1974-1985 by Pierce County and Inter-County River Improvement (30, 723 m^3 /yr average).[2]
Chehalis (Grays Harbor)	9-29	Contracts with WDNR 1950-1982.[1]
Cowlitz (Lewis and Cowlitz)	10-55	Contracts with WDNR at various times 1934-1985.[1]
Dungeness (Clallam)	3-14	WDOE permits 1992-1997.[2]
Hoh (Jefferson)	8-40	Contracts with WDNR at various times between 1961 and 1986.[1]
Humptulips (Grays Harbor)	4-9 and 26-45	Estimated 30,000 m^3/yr to 70,000 m^3/yr in 1950-1985.[4]
Mill Creek (Walla Walla)	4-6 and 30-32	About 9,000 m^3/yr permitted by WDOE 1986-1994.[2]
Nooksack (Whatcom)	2-33	Contracts with WDNR from 1961-1995.[1] Current WDOE permits for extraction of 526,000 m^3/yr.[3] Average removal 1960-1993 49,000 m^3/yr; 1990-1993 average 147,000 m^3/yr.[5]
Pilchuck (Snohomish)	2-11	35,000 m^3 /yr removed in 1969-1972, and 11,000 m^3 /yr in 1972-1991.[6]
Puyallup (Pierce)	17-40	637,393 m^3 removed 1974-1985 by Pierce County and Inter-County River Improvement (53,116 m^3 /yr average).[2]
Satsop (Grays Harbor)	2-6	Rough estimate of 15,000 m^3 /yr removed from 1950s to 1985.[4]
Skagit (Skagit)	21-43	Contracts with WDNR at various times 1949-1993.[1]
Skykomish (Snohomish)	5	Removal of 38,000 m^3/yr in 1961-1969, 11,000 m^3/yr in 1969-1976, and 7,600-11,000 m^3/yr in 1977-1978.[7]
Snohomish (Snohomish)	27 22	km 27: Removal of 1,500-2,300 m^3/yr in 1952-1978.[7] km 22: Removal of 3,800-4,600 m^3/yr from at least 1962 to 1991.[6]
Stillaguamish (Snohomish)	6-28	Removal 1965-1985 averaged 41,000 m^3/yr. 1985-1991 averaged 103,000 m^3/yr.[8]
Sultan (Snohomish)	0-1	Removal 1968-1978 ranged 380-2,800 m^3/yr and averaged 1,100 m^3/yr.[9]
Walla Walla (Walla Walla)	42-59	About 50,000 m^3/yr permitted by WDOE 1986-1994.[2]
White (Pierce)	5-19	596,000 m^3 removed 1974-1985 by Pierce County and Inter-County River Improvement (50,000 m^3 /yr average). [2]
Wynoochee (Grays Harbor)	3-24	Ranged from 7,600-46,000 m^3/yr from at least 1960s to 1985.[4] 3,800 m^3/yr since 1985.[3]

Sources:[1] WDNR Division of Aquatic Lands records. [2] Prych (1988). [3] WDOE Shoreline permits. [4]Survey of mining operators reported in Collins and Dunne (1986). [5]KCM (1994). [6]Survey of mining operators reported in Collins (1991).[7]Dunne (1978). [8]Survey of mining operators reported in Collins (1993). [9]Snohomish County PUD No. 1 (1984).

Volumetric Comparison to Other Sources

Riverine sand and gravel sources account for a significant amount of total state production. Between 1970 and 1991, sand and gravel produced from all sources in Washington ranged between 9 x 10^6 m^3 in 1982 and 23 x 10^6 m^3 in 1991, averaged 14 x 10^6 m^3/yr, and totaled 308 x 10^6 m^3, according to U. S. Bureau of Mines records (Lingley and Manson 1992). A survey of mine operators in 1991 conducted by the WDNR, Division of Geology and Earth Resources (DGER) found that the federal figures underestimated production in that year. The DGER estimated 1991 production at 34 x 10^6 m^3 (Lingley and Manson 1992), or 150% of the federal estimate of 23 x 10^6 m^3. If the federal amount underestimates production in earlier years by a similar quantity as the DGER survey found to be the case in 1991, then production between 1970 and 1991 would average 24 x 10^6 m^3/yr and total 538 x 10^6 m^3.

In the previous section, floodplain mining during this period was estimated at 9 x 10^7 m^3. According to Figure 2, about 60% or 5 x 10^7 m^3 of this was mined between 1970 and 1991. Comparing this to Bureau of Mines and DGER totals for 1970-1991 of 308 and 538 x 10^6 m^3, respectively, indicates that between 1970 and 1991, floodplains were the source of about 11% or 17% of total state production, depending on whether total production is taken as 14 or 24 x 10^6 m^3/yr. This estimate is based on a limited number of mine depths, and excludes mines too small or shallow to be included within this inventory. It also excludes Yakima River production since 1986. Channel bar mines produced an estimated 5 x 10^5 m^3/yr of sand and gravel in 1970-1991. This would have accounted for between 2% and 4% of total state production.

According to the above information, altogether, riverine sources in 1970-1991 would have accounted for 13-21% of sand and gravel produced in Washington. About half of this (7-11% of the state total) was from the floodplain of the Yakima River and the lower reaches of two of its tributaries. These estimates are based on incomplete data and several assumptions, and should not be taken as precise estimates. However, they serve to roughly indicate the relative importance of riverine sources as a portion of the state's overall production.

PHYSICAL EFFECTS AND IMPLICATIONS FOR SALMONID HABITAT

The environmental effects of river bar and floodplain mining have not been widely studied. The available scientific literature emphasizes physical effects, rather than effects on aquatic or salmonid ecology. The following review reflects the limited amount of available information, and the limited attention given to biological effects.

Historical Channel Modifications

Historic land uses dramatically reshaped the environment and functioning of most of the region's lowland rivers prior to floodplain mining, which generally did not begin in Washington on a large scale until the 1950s (Figure 2). Summarizing historic changes to rivers and their function is useful for providing context for more recent effects, or potential effects, of mining.

Lowland river floodplains in Washington commonly had extensive systems of sloughs, sidechannels, and wetlands (Sedell and Luchessa 1982) which provided extensive and diverse salmonid habitat (Sedell and Luchessa 1982; Beechie and others 1994) especially rearing area for juvenile coho salmon and high-flow refugia during winter floods (Cederholm and Scarlett 1982; Peterson and Reid 1984; Bryant 1984). The morphology and hydrology of floodplains and channels tended to be dynamic and interrelated. Laterally mobile rivers scroll across their floodplains or avulsed, and both processes create, maintain, and modify floodplain hydrographic features (Leopold and others 1964; Hickin and Nanson 1975), and diverse vegetative patterns (e.g. Shankman 1993), which result in diverse aquatic and terrestrial habitat types. Logjams played an important role in creating extensive secondary channels and off-channel sloughs and marshes (Sedell and Frogatt 1984; Triska 1984).

Late in the 19th century and early in the 20th century, the diking and draining of floodplains for agriculture and settlement commonly eliminated many of these floodplain hydrographic features and their habitat, and disconnected the remaining features and habitat from the river (e.g. Beechie and others 1994). The diking and armoring of banks and removal of wood from channels reduced the ability of rivers to recreate historic floodplain hydrographic features, and provided a stable environment for new land uses in formerly active floodplains.

In addition to changing floodplains and their connection with rivers, historic land and river uses often reduced the diversity and amount of habitat in main channels. River clearing and channelizing in the late 19th and early 20th centuries (Sedell and Luchessa 1982) would have reduced the complexity of channel morphology, removed wood, and narrowed channels, reducing both amount and diversity of habitat. In some rivers, bank protection could have reduced sand and gravel supplied to a river from bank erosion (e.g. Buer and others 1989), which is an important source of bed material and spawning gravel in some lowland rivers having few tributaries (e.g. Collins 1984; King County 1994). Levees, bank protection, and removal of riparian forests sometimes reduced opportunities for recruitment of large woody debris, and shading and cover for salmonids.

As mentioned earlier, headwater land uses, primarily intensive forestry, increased the sediment loads of many regional rivers in the last few decades. Whether or how this increased sediment load has influenced the amount or grain size of sediment deposited in lowland reaches has not been examined in detail.

Gravel has been mined for engineering purposes from Washington rivers since the late 19th century, according to early Reports of the Chief of Engineers (Reports of the Secretary of War, 1975-1986) and state royalty records on file with the WNDR in Olympia. However, while the early history of mining is not well known, in most rivers and floodplains, large-scale commercial mining does not appear to have begun until the last three or four decades. Thus, both river bar and floodplain mining have taken place in rivers that have been heavily modified from their natural condition.

Bar Mining

The literature on effects of bar mining on rivers is summarized as follows: effects on the bar and near-bar channel; channel effects upstream and downstream from a mined bar; hydrologic effects; effects on vegetation.

(1) *Effects on the Bar and Near-Bar Channel.*

Mining a bar can change physical channel characteristics and habitat in the bar's immediate vicinity, although only one study was found of these effects. That study, in Washington's Puyallup River drainage (Pauley and others 1989; Weigand 1991), included cross sections, photographs, and field surveys of salmonid abundance to document changes to salmonid habitat associated with gravel bar scalping. Mining was presumably consistent with state Hydraulic Permit regulations, which includes sloping excavation at least 2% toward the bank. Study investigators found that riffles scoured upstream of the scalped bar, which could decrease survival of eggs in spawning redds (Pauley and others 1989). This scour presumably occurs because lowering the bar height increases the water surface slope.

The Puyallup study also concluded that juvenile steelhead trout (*Oncorhynchus mykiss*) and juvenile coho salmon (*Oncorhynchus kisutch*) preferred pool or riffle habitats in narrow channels adjacent to bars, and that bar mining reduced the area of these habitat types and increased the area of main-channel habitats. The effect persisted until a bedload-transporting flow or flows rebuilt the bar. The study concluded that bar mining could be forcing juvenile salmonids into marginal or unsuitable habitat. However, the authors also caution that the effects they documented cannot confidently be associated with mining because they studied a small number of sites for only two years (Pauley and others 1989).

Based on examination of the history of bars in the Snohomish River drainage, Dunne and others (1981) concluded that if a point bar is lowered by a large amount, the bend can be cut off as streamflow forms a new channel. They report that the consequences of such a channel change are typically a short-term redistribution of sediment and of the locations of pools and riffles.

No studies were found of the consequences of bar pits or "gravel traps" on channel form and habitat. Typically bar pits are connected with the low-water channel, and potentially provide pools available to salmonids and other species during the time between excavation in summer and pit filling during fall and winter floods. Based on observations of pits in bars on the Dungeness River, pits located near the low-flow channel can breach, which can increase the proportion of shallow low-water habitat. This would presumably have similar results as observed in the Puyallup River study by Pauley and others (1989). Pits and breached pits can also fill with fine-grained sediments, creating a finer-grained bed which can undergo more frequent transport. This might attract spawning salmonids to sites with suitable grain sizes, but which are exposed to frequent transport (S. Ralph, personal communication 1994), but this has not been studied.

(2) *Physical Effects on Stream Channel Upstream and Downstream.*

Repeatedly removing sand and gravel from a bar can also affect physical channel conditions at a distance from the bar by changing the river's sediment mass balance. A number of field studies document some of these channel adjustments, but few provide a detailed analysis of them, and none relate these changes in detail to aquatic habitat. Because a channel is formed and continually reshaped by its supply of sediment, a channel might respond in a variety of ways to interruptions in its sediment supply, as discussed below.

In a channel in which the transport into a reach is naturally greater than the transport out of it, bar mining can reduce that aggradation. This is the rationale of mining bars for flood control. If removal is large relative to downstream aggradation, or in channel reaches having an approximate long-term balance between input and output, the bed elevation downstream can decrease, because the sediment supply into it is exceeded by transport out of it. Field observations (Sato 1971; Meserlyans 1974; Page and Heerdegen 1985; Harvey and Schumm 1987; Collins and Dunne 1989, 1990; Collins 1991, 1992; Kondolf and Swanson 1993) suggest that degradation occurs downstream for several hundred meters to several kilometers and for a shorter distance upstream.

Reduced bed material supply and resulting river-bed lowering can have several effects on the river which could be of potential consequence to salmonids. Bed coarsening can reduce habitat for invertebrates, which is limited to particle surfaces not embedded in the streambed (Rivier and Seguier 1985), and change the suitability of gravels for salmonid spawning or rearing. Where river-bed gravels are thin and overlay clay, bedrock, or other cohesive materials, bed degradation can deplete gravels (e.g. Kondolf 1995).

Interrupting the downstream transport of bed material has been related to reduction in size and number of downstream bars (Dunne and others 1981; MacDonald 1988). Effects of these changes or of accompanying channel adjustments (Dunne and others 1981) on habitat have not been studied. It is possible that removing large amounts of sand and gravel could modify a river's overall pattern. Other engineering modifications that remove large amounts of sediment from a river system, such as large storage dams, can significantly change a river pattern. No studies were found of the effects of mining alone on channel pattern. However, a few studies have examined the effects of mining in conjunction with dams. For example, Kondolf and Swanson (1993) documented the change through time of Stony Creek, California, from a braided stream to a narrower, single-thread channel as a result of interruption in sediment supply by a dam. Vick (1995) documented the effects of dams and mining in changing the Merced River from a dynamic, migrating channel to a narrow, stable remnant having numerous slackwater lakes from old gravel mines, and localized channel steepening associated with mines.

(3) *Hydrologic Effects.*

Where a riverbed overlies deep alluvium or other erodible materials, and there is a significant interruption in downstream supply of bedload, bed lowering can be substantial. This can in turn lower the groundwater table, which can variously affect floodplain hydrology (Goodwin and others 1992; Evoy and Holland 1989) and habitat. A lowered groundwater table can kill riparian vegetation (Kondolf and Curry 1986). In many cases where bed lowering occurs, depending on vegetation and site conditions, it may be slow enough for some riparian plants to colonize newly exposed streambanks, but this could change the age and species structure of riparian communities. Groundwater lowering can also kill vegetation in floodplain wetlands and along sloughs, where trees might play important roles in providing cover, shade, and a supply of large wood for salmonid habitat.

Groundwater table lowering can eliminate recharge to a stratigraphically higher aquifer or breach and contaminate a lower aquifer. This could in turn affect a river's low-flow regime. Examples of the interplay of bed lowering and groundwater flow changes are Cache Creek, California (Wahler 1981; Woodward-Clyde Consultants 1976; Collins and Dunne 1990) and Russian River (Goodwin and others 1992). Evoy and Holland (1989) includes a discussion of the interplay between groundwater change and bed lowering.

Where bed lowering is large (meters to tens of meters), overbank flooding can be virtually eliminated (see Cache Creek references cited above). This reduction in overbank flooding can reduce the supply of organic-rich fine sediments to the floodplain, and could reduce the replenishment of water to floodplain wetlands and sloughs and to aquifers. Reduction of overbank flooding can also aggravate downstream flooding because of the loss of floodplain water storage. Large amounts of lowering can also increase bank heights and induce bank erosion and can cause tributary streambeds to erode.

(4) *Vegetation Effects.*

Mining removes vegetation from the bar and adjacent bank, which can increase water temperature (Beschta and others 1987; Sullivan and others 1990), although this effect may be unimportant in most mined rivers which are relatively wide. Removing standing and downed trees on bars reduces the river's load of large woody debris, which is important in creating habitat and supplying nutrients (summarized in Bisson and others 1987, and Murphy and Meehan 1991), and in promoting vegetative colonization of bars following the disruption of bars by floods (e.g. Abbe and others 1993) which can create and stabilize off-channel habitats.

Floodplain Mining

Floodplain gravel mines were commonly sited in floodplain channels or abandoned meander bends, which commonly included ponds and channels connected to the river. While in many cases many of these floodplain features and their connection to the river had been lost from earlier land uses, the clearing of land and excavation for large-scale pit mining often eliminated or altered remaining floodplain hydrographic features and their habitat (Collins and Beechie, unpublished manuscript).

The potential exists to restore a floodplain's morphologic complexity and its connections with a river (Kern 1992; Petersen and others 1992; Petts and others 1992), and the presence of large, deep floodplain pits may limit the success or range of options of restoration activities (Collins and Beechie, unpublished manuscript). For example, in mined reaches, prior bank protection is either maintained or new bank protection is installed to protect mine operations from uncontrolled river breaching, and to guard against potentially dramatic river channel changes in the event of such a breaching event. In addition, restoring natural floodplain habitats may be limited in the short term if a substantial amount of floodplain has been converted to lakes. It may be possible in the short term to use mine lakes to simulate some of the habitats that are found in a natural, dynamic floodplain (see later discussion of mine reclamation). Physical floodplain restoration might in general require a substantial amount of time if accomplished by natural sediment transport events, if pit volume is very large relative to the river's transport of bed material, and if there are a large number of pits in a reach (Netsch and others 1981; Woodward-Clyde Consultants, 1980; Collins and Beechie, unpublished manuscript). The time required for some pits or systems of pits to fill in Washington could be decades to a century (Collins and Beechie, unpublished manuscript).

Floodplain pits can potentially create short-term hazards. Because rivers with alluvial floodplains are laterally mobile, it is probable that over a long time period a river will migrate into a pit created by floodplain mining. Dunne and others (1981) document physical consequences of a rapid, unplanned avulsion along the Yakima River. Effects can include rapid bed scour upstream or downstream, if floodplain pits are deep, and abandonment of existing channel and its habitat, and replacement with a wide, deep channel. Several studies are available of mining in the bed of ephemeral streams in the American Southwest (Bull and Scott 1974; Scott 1973; Chang 1987; Simons, Li & Associates 1983) which experienced rapid channel adjustment during subsequent floods. Upstream and downstream erosion can be accompanied by catastrophic channel realignment and bank erosion (for example, see Scott 1973).

Scour upstream and downstream of a breached pit can disrupt benthic organisms. In one study, biomass of benthic invertebrates in a location not influenced by suspended sediment or directly by mining activities, but in a zone of upstream bed scour associated with gravel mining, was 40% lower than in control reaches (Rivier and Seguier 1985). Channel pits can also change water temperature and velocity and decrease riffle habitat (Rivier and Seguier 1985). These effects would persist until the pit refills with bed sediment. MacDonald (1988) estimated that morphologic recovery of reaches of the Naugatuck River having channel pits is likely to be several hundred years because the rate of bedload transport is low relative to the morphologic change. Netsch and others (1981) studied 25 Alaska rivers that had been subject to channel or floodplain mining within 2 to 20 years previous to the study. They found that fine sediments deposited and channels were laterally unstable in many cases, with the extent of disturbance and time frame of recovery related to stream size in proportion to the size of original excavation.

The presence of floodplain pits may also affect conditions within the hyporheic zone, or the groundwater in the riverine corridor. Groundwater in the hyporheic zone moves downvalley through interstitial spaces in floodplain and river bed sediments and is connected to stream waters; the hyporheic zone extended as much as 2 km away from the channel of Montana's Flathead River (Stanford and Ward 1988) and was a greater source of nutrients to the stream than surface water. In addition, the hyporheic groundwater provides important habitat for aquatic insects and arthropods (Williams 1984); in some rivers this may be more voluminous than benthic habitat in the river itself (Stanford and Ward 1988). Artificially-created floodplain lakes have the potential to affect the chemistry or biota of hyporheic water and surface water, but no studies were found that explored these changes and whether they could be significant to habitat, and under what conditions. A lake or series of floodplain mine lakes could also affect the exchange of groundwater and channel water. Lakes control the groundwater gradient, and have the potential to reduce or alter the location of groundwater influx to the channel during the low-flow season. No studies were found of these effects.

Mine Reclamation and Restoration

Cairns (1990) discusses four broadly defined goals that might apply to the restoration of ecosystems that have been altered by human actions. These goals include: 1) restore to original condition; 2) rehabilitate selective attributes of a system; 3) create an alternative ecosystem; and 4) allow to recover without intervention. This framework is useful for assessing the goals of mine reclamation. The concept of mine reclamation originated from regulation of large, upland surface mines, typically coal mines (Kondolf 1993) and traditionally focuses on establishing a productive use after mining is completed. In the range of goals identified by Cairns (1990), this objective sometimes involves rehabilitating selected attributes of an ecosystem, or creating an alternative ecosystem. In other cases it involves converting mine sites to developed land uses.

Most states currently have programs for mine reclamation (Prange 1992). Until a 1993 revision, Washington's reclamation law (discussed in more detail later in this report) focused on establishing a productive subsequent use, including developed land uses. The 1993 revision requires that functional wetlands be developed in floodplain environments and thus focuses, in terms of Cairns (1990) framework, on rehabilitating selected attributes of the riverine ecosystem. Approaches to creating wetlands in gravel pits are reviewed by Norman and Lingley (1992), Michalski and others (1987), and Prange (1993).

Reclamation law also typically requires that gravel bar mines be reclaimed. The concept of reclamation is arguable in its application to channel mining (Kondolf 1993) because mining often causes changes that cannot be undone afterward, including changes at a distance upstream and downstream from a mine. Washington's mine reclamation law applies to river bars for which reclamation has generally been interpreted to encompass requirements for final grading (discussed later). It has not generally been taken to include effects discussed in this report.

Mine reclamation law does not at present focus on preserving or restoring original riverine landscape function or character, and such a goal is not typically adopted in siting or reclaiming mines. In most rivers that have experienced substantial bed elevation lowering and associated groundwater changes from channel mining, the period of time required to restore original physical conditions is probably long. In some cases, it may be possible by mechanically reshaping the landscape to restore some elements of lost function. Goodwin and others (1992) describe a plan to restore the geomorphic floodplain to reaches of the Russian River, in which mining has substantially lowered the bed level. The plan proposes mining terrace sand and gravels to a level of the former floodplain, in order to restore the floodplain's role in groundwater recharge and floodwater storage.

Many historic changes to the function of riverine systems occurred prior to excavation of floodplain pits. Restoring dynamic river-floodplain connection that existed in earlier conditions is complicated by the presence of concentrations of large pit lakes. On the other hand, it may be possible to site and size floodplain mines in such a way as to create static replicas of dynamic habitats that existed on floodplains, prior to 19th and 20th century land uses. Some successful attempts have been made in non-mining contexts to create or enhance these habitats for juvenile coho salmon (Cederholm and others 1988; Cederholm and Scarlett 1991). It may be possible to do so in the context of floodplain mining in a way that does not interfere with restoration at a later time of a dynamic river-floodplain connection. Partee and others (1993) describe an example of such an experiment on Washington's Wynoochee River.

Table 3. Effects of river bar and floodplain mining on rivers, and implications for salmonid habitat.

Element of Bar Mining	**Physical Effect**	**Possible Consequence for Salmonid Habitat**
Removal of sand and gravel from bar.	Scour of upstream riffle.	Lower success of spawning redds.
"	Diminishment of side-channel area.	Possible loss of spawning and rearing habitat.
Interruption of downstream bed material transport.	Bed surface armoring.	Lower quality of spawning and rearing habitat; changes to invertebrate community.
"	Diminishment of downstream bars and accompanying channel adjustment.	Possible loss of spawning habitat.
"	Downstream depletion of alluvial bed.	Reduced amount of spawning gravel.
"	Lower groundwater table	Possible reduction of summer low flows; possible reduction of water recharge to off-channel habitat.
Removal of vegetation and woody debris from bar and bank.	Reduce shade.	Increase water temperature in narrow rivers.
"	Decrease channel structure from wood.	Possibly reduce cover; reduce number and depth of pools; reduce area of spawning gravel; limit channel stability.
"	Decrease nutrient input.	Decrease stream productivity.
Element of Floodplain Mining	**Physical Effect**	**Possible Consequence for Salmonid Habitat**
Clearing or filling of floodplain hydrographic features.		Loss of off-channel overwintering and refugia habitat.
Persistence of pits in time, and need to maintain existing or install new bank protection.	Possible narrowing and simplification of channel; loss of gravel recruitment from banks; reduced recruitment of large woody debris from banks.	Reduction in total amount of habitat; possible reduction in spawning habitat; effects of reduced wood recruitment (see earlier).
Potential for uncontrolled breaching of pit by river.	Potential for rapid upstream and downstream bed scour, channel abandonment, change in stream morphology, water temperature, and ecology.	Potential for short- and long-term changes to types, amount, and quality of habitat.
Presence of lakes near channel.	Possible effects on flow, temperature, chemistry, or biota of hyporheic groundwater, or the patterns and locations of groundwater and channel water exchange.	Not studied.

GOVERNMENT REGULATION

Overview

Primary state and federal laws governing riverine mining in Washington are listed in Table 4. More detail is given in the next section. Briefly summarized:

The Shoreline Management Act of 1971 provides for shoreline management to foster "all reasonable and appropriate uses" while promoting the public interest and protecting "resources and ecology of the shoreline" (90.58.020 RCW). The state Department of Ecology administers the Shoreline Management Act, and counties implement it through a county master plan, under WDOE's guidance and review.

The Washington Surface-Mined Land Reclamation Act (1970) directs the state's Department of Natural Resources to permit surface mine reclamation for operations greater than three acres (1.2 ha) in size or with pit walls more than 30 ft high (9 m) and steeper than 45 degrees (78.44 RCW).

Washington State Hydraulic Code Rules require the Department of Fish and Wildlife to issue permits for all work that will "use, divert, obstruct, or change the natural flow or bed" of any state waters (75.20 RCW).

The State Environmental Policy Act (SEPA) (43.21 RCW) is designed to evaluate environmental impacts of proposed projects, including mining, and to identify methods to reduce those impacts. The evaluation process can be triggered whenever a state agency must consider an application for a mining permit. For riverine mining, the county is generally the lead agency as administrator of its master plan through the Shoreline Management Act. The Department of Natural Resources is sometimes the lead agency when it requests a mining applicant change a proposed reclamation plan.

The Growth Management Act (1991) requires cities and counties to designate critical areas, including wetlands, as well as to designate mineral resource lands, and so has the potential to regulate mine siting.

The state's Floodplain Management Program gives the Department of Ecology authority over planning, construction, and operation of activities or structures that might affect flooding, which could apply to some mine operations.

The state Water Pollution Control Act gives Ecology jurisdiction and rule-making authority to control and prevent pollution of the state's waters. The law governs the State Waste Discharge Permit Program, which applies to discharge from industrial, commercial, and municipal operations into ground and surface water, except for point

Table 4. *Primary regulations governing riverine gravel mining in Washington state.*

STATE
Washington Surface-Mined Land Reclamation Act (1970). Department of Natural Resources. Requires permits and reclamation plans for surface mines.[1]
Shoreline Management Act (1971). Department of Ecology. Comprehensive shoreline management administered through county master plans.[2]
Hydraulic Project Approval (1949 and subsequent). Department of Fish and Wildlife. Requires permits for all projects affecting the flow or bed of state waters.[3]
State Environmental Policy Act (SEPA). Lead agency (generally a county) oversees environmental impact statement.[4]
Growth Management Act (1991). Requires counties to designate sensitive areas and mineral resource areas as part of comprehensive planning for population growth.[5]
Floodplain Management Program. Gives Department of Ecology authority over planning, construction and maintenance of projects that might affect flooding.[6]
FEDERAL
National Pollutant Discharge System Permit Program (NDPES). Section 402 of Clean Water Act[7] designates U.S. EPA administrator, which authorizes state to regulate point-source discharges into navigable waters under Water Pollution Control Act.[8]
Section 404 of the Clean Water Act. U.S. ACOE and U.S. EPA jointly administer permits for placing dredged or fill material in waters of the United States, including wetlands.
National Environmental Policy Act (NEPA) (1969).[9]
Materials Act (1947)[10] and Federal Land Policy and Management Act (1976)[11] govern mining of sand and gravel on federal lands.
Indian Mineral Development Act (1982)[12] regulates mining on Indian lands under supervision of Bureau of Indian Affairs.
[1]78.44 RCW; 332-18 WAC; [2]90.58 RCW; 173-14 through 173-28 WAC; [3]75.20 RCW; 220-110 WAC; [4]43.21C RCW; 197-11 WAC; [5]36.70A RCW; 365-90 WAC; [6]86.16 RCW; 173-158 WAC; [7] Title 33 U.S.C., Sections 1251-1387; [8] 90.48 RCW; 173-216 WAC; [9]Title 42 U.S.C., Sections 4321-4370b; [10] Title 30 U.S.C., Sections 601-615; [11]36 C.F.R. Chapter II, Part 228, Subpart C and 43 C.F.R., Chapter II, Part 3600, Subpart C; [12]Title 25 U.S.C., Sections 2101-2108.

into navigable waters. The state also administers the National Pollutant Discharge System Permit Program (NDPES), from Section 402 of the federal Clean Water Act, which is source discharge administered by the U.S. Environmental Protection Agency. The NDPES program governs point source discharges into navigable waters, which includes most rivers mined commercially or for flood control.

Section 404 of the federal Clean Water Act regulates the placement of dredged or fill materials, and is jointly administered by the Army Corps of Engineers and Environmental Protection Agency. Rule changes in 1993 (Federal Register:58[163]:45008-45038) clarifies and expands the application of Section 404 to include "mechanized clearing, ditching, channelization, and other excavation activities," which significantly expands the statute's application to riverine gravel mining.

The Army Corps of Engineers also administers Section 10 of the Rivers and Harbors Act (1899) which regulates obstructions in navigable waters, which could apply to some mining operations. The National Environmental Policy Act (NEPA) (1969), which predated and parallels the State Environmental Policy Act (SEPA), can be triggered by federal permits required under the Clean Water Act or the Rivers and Harbors Act.

Mining of sand and gravel on federal lands is regulated by the Materials Act (1947) and the Federal Land Policy and Management Act of 1976. Sand and gravel may not be mined in national parks and monuments, but may be purchased from Forest Service and Bureau of Land Management lands. Mining on Indian lands is regulated by the affected Indian tribe, under supervision of the Bureau of Indian Affairs, as provided by the Indian Mineral Development Act (1982).

Regulation of Commercial Floodplain Mining

Potential impacts from floodplain gravel mining identified in this report are potentially avoided or mitigated through the siting, design, and reclamation of floodplain mines. The Shoreline Management Act may have the broadest potential to regulate the siting of floodplain mines among state laws because of its directive to protect the "resources and ecology of the shoreline." Individual counties through their Shoreline Master Plans determine the approach to regulation (Tom Mark, WDOE, telephone interview, 1994); county plans were not systematically evaluated for this report. The Shoreline Act provides that Ecology review county master plans every five years. In practice, plans are amended irregularly, with some counties updating plans continually, and others operating under their original plan dating to 1971 (Tom Mark, WDOE, telephone interview, 1994).

According to State Environmental Policy Act (SEPA) rules, the county has priority over state agencies as lead agency in the SEPA process. When SEPA is triggered in connection with riverine mining, it is generally through the Shoreline permitting process. The SEPA rules give counties latitude in determining whether a SEPA Environmental Checklist or the more complete, and more widely circulated Environmental Impact Statement (EIS) is prepared. An EIS has generally not been prepared for riverine mines in Washington.

The Growth Management Act also has the potential to broadly regulate siting of floodplain mines, because it directs counties to designate "mineral resource areas" and also "critical areas" such as wetlands or "fish and wildlife conservation areas" which include Waters of the State. This could result in the zoning of rivers and floodplains in either designation. Similar to the Shoreline Management Act, the Growth Management Act gives counties broad latitude in the Act's implementation. The Act is in early stages of implementation, and has not yet significantly affected riverine mine regulation.

The Washington Surface-Mined Land Reclamation Act primarily regulates mine reclamation. However, the WDNR can also prohibit or modify a proposed mine if a reclamation plan is not provided, if the plan is not judged adequate, or reclamation is not feasible. The effect of the Act thus hinges on how mine reclamation is defined. Prior to a 1993 revision, the Act in its approach to reclamation emphasized the mine's subsequent use rather than the landscape's previous condition or character, defining restoration as the reestablishment of plants, land stability, water, and safety conditions "appropriate to the intended subsequent use of the area" (78.44.030 RCW). It required that reclamation be completed within two years following the completion or abandonment of mining. For floodplain pit mines, unconsolidated banks were required to have a minimum of 1.5 feet horizontal to 1.0 foot vertical in excavations greater than 2 feet below the low groundwater mark.

The 1993 revision shifts emphasis from subsequent use toward establishment of natural conditions. The revised regulations require, in cases where the water table has been penetrated, which generally occurs in floodplain pit mines, establishment of "a beneficial wetland by developing natural wildlife habitat and incorporating such measures as irregular shoreline configurations, sinuous bathymetry and shorelines, varied water depths, peninsulas, islands, and subaqueous areas less than 1.5 foot deep during summer low-water levels." The law also now provides for evaluation of the potential for the river to breach a mine and requires a "thoroughly documented hydrologic evaluation" to "outline measures that would protect against or would mitigate avulsion and erosion as determined by the department." These provisions in the Surface-Mined Land Reclamation Act are the first regulations that address the hazard of pit breaching, or the long-term habitat value of floodplain mines.

Hydraulic Project regulations do not apply to floodplain mines in most cases, because floodplain pits are not within Waters of the State. However, where a pit is connected by surface water to a Water of the State, a permit can be required. As part of the permit WDFG can require that conditions within the pit be regulated to provide habitat, or that the outlet be blocked to fish access.

Section 404 of the Clean Water Act regulates the placement of fill in Waters of the United States, which includes most of the mines included in this report. Previous to rule changes in August 1993, the Army Corps of Engineers was not typically involved in regulating mines except where a levee or other structure was present (Bob Martin, USACOE, telephone interview, 1994). However, the 1993 rule interpretation significantly expands permitting of riverine mining under Section 404. New rules required ongoing operations within ordinary high water or on adjacent wetlands to apply for a permit before August 25, 1994. Permitting for each operation will be carried out under the National Environmental Policy Act (NEPA) guidelines, including public comment. This process will differ significantly from state regulatory process, in that it includes a consideration of alternate sites for mining within the operation's market area. This could cause riverine mining to be evaluated with respect to alternate, upland sources, which is not now done under state permitting. Completing an environmental impact statement to satisfy SEPA will not satisfy NEPA, although completing a statement under NEPA will satisfy SEPA requirements, under SEPA rules (197-11-610 WAC).

Point source discharges into navigable waters are regulated by the National Pollutant Discharge Elimination System Permit Program (NPDES). The state Department of Ecology is currently developing a general permit for sand and gravel mining. It is expected to be issued in 1994 and to require completion of a Stormwater Pollution Prevention Plan.

Regulation of Commercial Bar Mining

Many effects of in-channel mining on aquatic habitat are related to the amount mined relative to the size of a given river and its supply of bed material sediment. County Shoreline Master Plans and state Hydraulic Project Approval regulations regulate the location and amount of gravel-bar mining. County master plans under the Shoreline Management Act were not systematically evaluated for this report. At least two counties include provisions for regulating overall quantity. Grays Harbor County limits annual removal to river-specific estimates of the long-term average deposition. Snohomish County ties removal to the amount that can predictably be replenished. Snohomish County also regulates the potential effects of mining on the bar or near-bar bed morphology or habitat.

Rules for Hydraulic Project Approvals prohibit mining below two feet vertically above the low water level, and require that excavation proceed perpendicular to the stream and toward the bank and a minimum two-percent gradient sloping upward toward the bank. The code prohibits stockpiling of materials and the presence on bars of pits or potholes at the end of each day's activities (220-110-140 WAC) to prevent fish trappage. The time of year in which mining can take place is often restricted to protect fish.

Recently revised Hydraulic Project Approval rules limit removal to the "average annual recruitment" (220-110-140 WAC). The code does not provide a rationale for use of that criterion. The new rules also allow removal of additional gravel where an applicant "can demonstrate the channel capacity has been significantly reduced" (220-110-140 WAC). The new code includes a provision that the "upstream end of the gravel bar shall be left undisturbed to maintain watercourse stability waterward of the ordinary high water line" (220-110-140 WAC).

Other regulations have had less bearing on bar mining. The Mined-Land Reclamation law requires that applicants submit reclamation plans for approval by the Department of Fish and Wildlife as part of application for a hydraulic project approval (75.20 RCW and 220-110 WAC). The law does not provide guidelines for reclaiming bar mines, and in practice, reclamation plans are not required of bar skimming operations. The relevance of the reclamation concept to channel mines is arguable. Kondolf (1993) suggests the reclamation concept is not appropriate for channel mining, because impacts are not limited to the site nor are they reversible. For example, he points out that bar mining can cause channel incision upstream and downstream, and it is not possible to undo this damage to the channel form or aquatic ecology after the fact.

The WDNR Aquatic Lands Division manages mining on state-owned lands, which includes the bed of all navigable streams. State law (79.90 RCW and 79.01 RCW) authorizes the department to collect royalties from sand and gravel mining on state-owned lands, which includes most or all commercial gravel bar mines. Offtake amounts are not generally maintained as part of HPA or Shoreline permitting.

Regulation of Mining for Flood Control

Regulation of mining for the purpose of maintaining flood conveyance may differ from the regulation of commercial mining in several respects:

- Royalty rates paid to WDNR can be reduced if gravel removal enhances flood control (332-30-126 WAC).

- Verbal Hydraulic Project Approval "shall be granted immediately upon request for emergeny work to repair existing structures, move obstructions, restore banks, or protect property that is subject to immediate danger by weather, flow, or other natural conditions" (220-110-030 WAC).

- Requirements may be different for flood control mining than for commercial mining under county Shoreline Master Programs, and WDOE may use different criteria in evaluating mining proposed for flood control (Tom Mark, WDOE, telephone interview 1994).

RECOMMENDATIONS

This project's objectives include making a broad overview of Washington riverine mining, its potential effects on salmonid habitat, and outlining existing government regulation for protecting salmonid habitat. A fourth objective is to suggest how mining could be better regulated, based on this broad overview. These conclusions include possible changes to regulations or their implementation, and additional scientific knowledge needed as a basis for improving regulation.

(1) Focus Policy on Protecting and Restoring Natural Function of the Riverine Environment.

At present, permitting does not always focus on the range of specific, potential impacts to the river environment that were identified in the literature review of this report. This may be in part because policy direction underlying key statutes is general, and does not set a clear overall objective for the management of the riverine environment. For example, the Shoreline Act requires protection of "resources and ecology of the shoreline." The Hydraulic Project code requires "protection of fish life." Reclamation law requires prevention or mitigation of conditions that "would be detrimental to the environment...." Policy that explicitly focuses on protecting and restoring the natural functioning of the riverine environment might better guide regulations and regulators toward identifying specific ways in which mining alters the functioning of that environment, and how this in turn affects salmonid habitat.

Focusing on the natural function of the riverine environment could also encourage the evaluation of mining within a river's historical context. This would include developing an understanding of how the river system has been changed by various earlier river and land uses, and how mining could interact with those changes in a positive or detrimental way toward the goal of protecting or restoring landscape function. Finally, a focus on landscape function might also encourage the consideration of spatially cumulative effects of mining, and of the interaction of mining with other land and river uses.

(2) Develop Better Understanding of Impacts.

Effects of mining are not well understood or well documented, and consequently potential issues are not always addressed in the permitting process. There is sufficient understanding to significantly improve regulation with respect to some issues. For example, for bar mining, there is a general understanding on a scale of a several-kilometer-long reach, of the effects of interrupting bedload transport on the mass balance of a river, and assessment methods exist. On the other hand, issues such as the effects of bar mining on local channel morphology, sediment transport, and habitat are not well understood. Policy direction is needed on how to proceed in the absence of more complete understanding. This could include sponsoring needed research, or requiring applicants to sponsor such research.

(3) Evaluate Alternatives to Riverine Mining.
To better avoid conflicts between riverine values, riverine sand and gravel mines could more often be evaluated in a planning context which compares them, individually and cumulatively, to alternate upland sources with an accounting for the environmental costs and benefits of both. Several existing regulations provide a vehicle for such evaluations, on a regional, county, or river-basin level. These include the Growth Management Act and the Shoreline Management Act. New permitting under Section 404 may also promote this.

(4) Improve Record Keeping.
Verified reporting and complete, accessible records are prerequisite to regulating mine impacts. Sand and gravel operations should report production, on at least an annual basis. This is especially true of bar mining. Reporting should include information on whether sand and gravel was mined by bar skimming, bar pits, or floodplain pits. Data should be collected, verified, and maintained for use by all agencies having statutory responsibility for mine regulation.

(5) Evaluate Flood-Control Mining in Flood Hazard Management Context.
River channel mining for flood control is not always planned or evaluated in a flood hazard management context. This includes developing an understanding of the causes, history and future of channel conditions and other factors that influence flooding; whether or how mining would affect flooding; how mining would affect other processes or attributes, including salmonid habitat; and evaluating alternative options for flood hazard management in a comprehensive planning context.

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