SEDIMENT REMOVAL FROM ACTIVE STREAM CHANNELS IN OREGON:

Considerations for Federal Agencies for the Evaluation of Sediment Removal Actions from Oregon Streams.

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1 INTRODUCTION AND SCOPE

Federal agencies, including the Fish and Wildlife Service (FWS), National Marine Fisheries Service (NMFS), the US Army Corps of Engineers (USACE), and the Environmental Protection Agency (EPA) frequently review permit applications and/or issue permits for instream aggregate mining activities. A comprehensive guidance document for instream sediment removal is needed to increase consistency between Federal agencies and to adequately address potential impacts to aquatic habitat due to mining operations. For the purposes of this document, "instream" refers to that area of a channel at or below the Ordinary High Water as defined by the USACE.

This document identifies the potential effects of sediment removal on freshwater habitats, and it provides recommendations and guidance for the evaluation, design, and monitoring of sediment removal activities in streams. The potential effects of, and recommendations for, floodplain mining will be addressed in a separate document.

The purpose of the document is to present a thorough discussion of scientific information that may be used to help evaluate proposed actions that would remove sediment from streams. This information will help staff identify circumstances where the adverse effects of sediment removal actions can be reduced by, for example, limiting disturbances to locations, times, and excavation designs and methods that are less environmentally harmful.

The types of activities referred to in this Oregon Sediment Removal considerations document (hereafter called the OSR) include commercial sediment production from active streams and stream corridors. Commercial sediment products include sand, gravel, boulder and aggregate used for construction, road building, cement, and landscaping. It does not address navigational and maintenance dredging, channel stability, diversion maintenance, or flood control activities.

The recommendations contained herein are intended to provide constructive direction and assistance to Federal agency personnel involved in project review and assessment. Being general in nature, the OSR recognizes there may be site constraints or unusual circumstances that necessitate variances from the methods recommended. The OSR is intended as a working document that will be updated continually as our knowledge of stream systems improves and as new technology is developed.

This paper is intended for use by FWS, NMFS, USACE, and EPA staff, in conjunction with site specific data, for the evaluation of project proposals that fall within the USACE jurisdiction under Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act (CWA), as well as Fish and Wildlife Coordination Act (FWCA), Endangered Species Act (ESA), or Magnuson-Stevens Fishery Conservation and Management Act.

A similar guidance document, and the model for this document, "The Effects of Sediment Removal from Freshwater Salmonid Habitat" (Cluer 2004), can be downloaded at the following site: http://swr.nmfs.noaa.gov/hcd/policies/April19-2004.pdf. NMFS has also completed national guidance regarding instream sediment removal, "National Marine Fisheries Service National Gravel Extraction Guidance" which can be downloaded from the following site: http://www.nwr.noaa.gov/1habcon/habweb/habguide/gravel_policy_2005.pdf. For additional information, the reader is referred to "Gravel Disturbance Impacts on Salmon Habitat and Stream Health" (OWRRI 1995), and "Freshwater Gravel Mining and Dredging Issues" (Kondolf, Smelzer, and Kimball 2002). Additional references can be found in the References Cited.

1.1 RELEVANT STATUTES

The USACE has jurisdiction over certain activities occurring in waters of the United States (U.S.) under two regulatory authorities, Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act. If a project would result in a discharge of dredged or fill material into a water of the U.S. or would affect a navigable water of the U.S., a USACE permit is required. Before a permit can be issued, the USACE is required to ensure the project activities are in compliance with applicable Federal laws and statutes. For an activity regulated under Section 404 of the CWA, a permit cannot be issued if the project is not in compliance with the EPA's Section 404 (b)(1) Guidelines.

Under the Fish and Wildlife Coordination Act, FWS and NMFS reviews Section 10 and Section 404 permit applications for environmental impacts to all of their trust resources. Section 7 of the Endangered Species Act requires Federal action agencies, including USACE, to consult with NMFS and the FWS. If it is believed that a listed species may be affected by a project, ESA Section 7 requires consultation in order to ensure that such actions are not likely to jeopardize the continued existence of any endangered or threatened species, including harm to habitat of listed species.

The FWS and NMFS have the authority and obligation under several statutes, including the ESA, the Fish and Wildlife Coordination Act, and the Magnuson-Stevens Fishery and Conservation Management Act to review actions that might harm living aquatic and terrestrial resources or the habitats that support them.

The Magnuson-Stevens Fishery Conservation and Management Act also addresses the effects of changes to habitats that support commercially important fish. Coordination between Federal Agencies is required under the EFH provisions of the Magnuson-Stevens Fishery Conservation and Management Act. Further description of the Federal legal authorities can be found in Appendix 1.

1.2   EXTENT

Aggregate mining generally occurs within 30 to 50 miles of the intended market because the cost of transport is the primary expense in this industry (Meador and Layher 1998). In Oregon, haul costs are approximately $0.25 per cubic yard per mile (Frost 2004). Hence, many large-scale aggregate operations are found near cities and along major roadways. The focus of much instream aggregate mining activity in Oregon is along the I-5 corridor in the Willamette Valley and in the Umpqua basin (OWRRI 1995). The market for this aggregate includes Portland, Salem, Albany, Eugene, and Roseburg, plus many other smaller municipalities and counties. According to Oregon Department of State Lands (DSL) records, there are currently about 65 active sand and gravel operations in streams in Oregon, including the South Umpqua, Willamette, Columbia, Chetco, and Rogue Rivers. Almost all operations except those on the Columbia River utilize bar scalping to obtain material.

On a nationwide level, most aggregate (96%) is used for construction purposes including concrete, road fill, asphalt, and drain rock. The remainder is used for filtration beds, abrasives, glass manufacturing, and foundry operations (Meador and Layher 1998). Instream deposits of gravel are valuable because they are easily and cheaply accessible, well-sorted, and are generally free from fine sediments such as silt and clay. However there are drawbacks as well. According to Frost (2004), alluvially deposited gravels are less desirable for the Oregon Department of Transportation (ODOT) because they generally (1) have a higher percentage of reject material, (2) have problems with coatings on the rock which make them more difficult to clean, and/or (3) are found in environmentally sensitive areas, which may require numerous permits before mining is allowed.

In Oregon, aggregate extraction that occurs outside of the active channel is regulated by the Oregon Department of Geology and Mineral Industries (DOGAMI) through their Mineral Land Regulation and Reclamation Program housed in the Albany Field Office. Instream aggregate extraction is regulated by DSL. DOGAMI indicates that annual removal of aggregate from floodplains and upland sites ranges from 44 to 52 million cubic yards per year (based on records from 1998 to 2003). DSL reports that annual *permitted* aggregate extraction rate (based only on the operations that pay royalties to the state) from streams is approximately 5.5 million cubic yards per year. However, the amount permitted is generally 30 to 50 percent greater than the actual amount extracted (OWWRI 1995), resulting in actual extraction rates of 3.7 to 4.2 million cubic yards per year. Based on these numbers, an average of 8.2 percent of commercial aggregate is derived from Oregon streams each year, although the distribution of instream extraction is not equal throughout the state (OWRRI 1995). Whelan (1995) reported similar findings for sand and gravel obtained from Oregon waterways in 1993; 5.8 percent of the total apparent consumption for the year was derived from Oregon streams.

Sand and gravel usage also varies temporally throughout the state, and is dependent upon major construction activities such as highway and dam building projects. In the near future, aggregate usage will again increase as the ODOT undertakes a vast program to

replace Oregon's highway bridges.   ODOT uses approximately 8.5 million tons of aggregate products annually (22% of project costs), which composes 90 percent of every roadway (Frost 2004).

While the use of sand and gravel varies both spatially and temporally, overall permitted aggregate extraction has increased from 1967 to the 1990's (OWRRI 1995); however, increases in permitted extraction quantities does not directly correlate to actual increases in extraction.

1.3   GENERAL METHODS FOR MINING AGGREGATE

Permit conditions issued by the USACE and DSL limit the extent and quantity of gravel removal in Oregon streams. There are generally requirements for the post-mining site conditions including point bar slopes and buffer zones. Some permits now require pre- and post-extraction surveys with elevational limitations corresponding to a set vertical datum rather than a floating datum. This is often referred to as the "red-line" method (see Chapter 4).

There are two predominant methods that are utilized when removing sand and gravel from the landscape: instream extraction and land mining. Floodplain pits are sometimes considered upland mining and at other times are considered as part of instream extraction. This distinction depends on the adjacency to the stream channel and the likelihood of a channel capture. Only instream extraction, generally excluding floodplain pits, will be addressed in this paper.

Instream extraction can be completed by various methods including scraper, dragline, bulldozer, front-end loader, shovel, and dredge (Meador and Layher 1998). In Oregon, the primary means of obtaining instream aggregate include instream pit extraction and bar scalping, which are described in more detail below.

1.3.1   Instream Pit Extraction

Major instream pit extraction activities have historically occurred in the Willamette, Columbia, and the lower Umpqua Rivers (OWRRI 1995), although there are only a few remaining operations in Oregon.

Instream pit extraction generally uses a clamshell dredge or dragline. Sediment is removed from the bed of the channel and transferred to barges. The sediment can be cleaned and sorted on the barge or it can be delivered to a processing site for further sorting. The location of the dredging site can be restricted to individual locations within a stream system, or may be undefined to specific locations but rather constrained by river miles. Depth, extent, and timing of dredging are conditioned in the individual COE and DSL permits.

1.3.2   Bar Scalping

Bar scalping has occurred in many streams throughout Oregon and is currently the most common type of instream mining utilized in the state. Bar scalping occurs throughout western Oregon, but is concentrated in the Willamette and Umpqua basins and in several coastal streams.

Bar scalping typically occurs during low water periods. The aggregate is removed from exposed bar areas (typically alternate bars) with scrapers or other heavy equipment, and then the material is generally carried to a collection point where it is transferred to a processing facility. Excavation depths are often limited to an elevation above the low water surface. Depending upon the water year, this datum can fluctuate considerably. During wet years, the depth of excavation may be quite minimal, while dry years may allow significant excavation due to the greater exposure of river gravel. The amount of material removed is also dependent on the level of sediment transport that occurs in any given year, reach-wide incision or aggradation of the channel, depositional patterns, and limits imposed by the COE and DSL permits. A significant amount of sediment is not necessarily transported every year, but is rather episodic and is related to high flow and event history in the watershed (*i.e.,* bank erosion, landslides, and debris flows).

Even though bar scalping is the most common method for instream gravel removal in Oregon, each operation is conducted differently and each stream reach has unique characteristics. It is important to evaluate potential effects and recommendations in light of site specific constraints and opportunities.

Channel geometry and geomorphic features within channels are the products of interactions among stream flow, sediment delivered to the channel, the character of the bed and bank material, and vegetation. A stream that is free to develop its own geometry evolves through time to develop a channel shape, dimensions and planform pattern (together termed morphology) that reflect a balance between the sediment and water inputs, the stream's relative energy and the dominant characteristics of the sediments forming the bed and banks. Self-formed channels also adjust their conveyance capacity so that flow inundates the surrounding floodplain on average every 1-2 years. Streams in which the channel geometry and capacity are adjusted in this way are said to be in dynamic equilibrium. The concept of morphological adjustment towards dynamic equilibrium is fundamental to the theory and management of stream corridor processes.

2.1 STREAM CHANNEL DYNAMICS

A qualitative expression describing the balance between sediment discharge (Qs), stream discharge (Q), median particle size (d50) and the long-stream slope (S) was presented by Lane (1955). The expression states that:

Qs d50 ~ Q S

This relationship is often characterized as a pair of scales and is commonly referred to as 'Lane's balance' (figure 1).

$$Q_s \cdot D_{50} \propto Q_w \cdot S$$
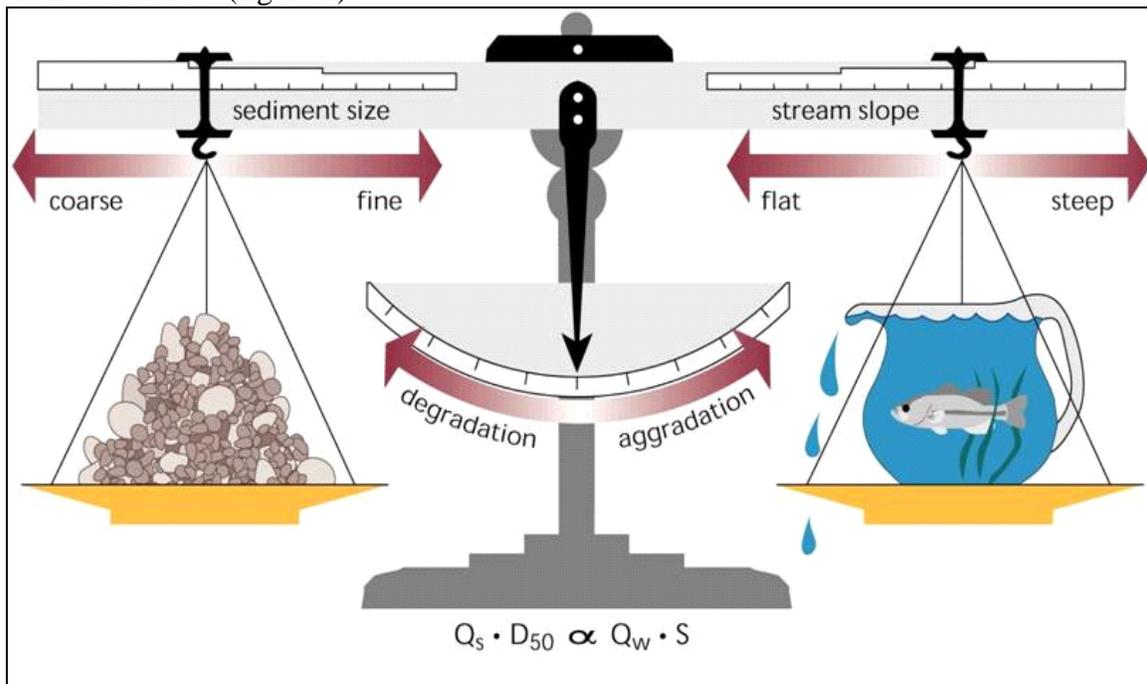
Figure 1. Lane's 'balance' diagram, a useful visual model for predicting stream responses to common disturbances. *From: Federal Interagency Stream Restoration Working Group. 1998. Stream Corridor Restoration: Principles, Processes, and Practices.*

In addition to illustrating the interactions between sediment, water, and slope, Lane's relation is often used to obtain a general understanding of the way a stream will respond to changes. For example, if Qs decreases in a stream reach due to sediment extraction in the supply reach upstream, Lane's relation suggests that the disturbance would result in (1) increased particle size (d50) or (2) decreased slope (S)(assuming the channel forming discharge, Q, is independent of local channel disturbances). In other cases, the conveyance capacity of a stream is often increased in an attempt to reduce flood risk. If the channel cross-section is enlarged (Q increases), or the planform straightened (S increases), Qs and d50 can both increase, thus triggering further channel change as the stream responds to artificial enlargement. Significantly, Lane's relation shows us that both Qs and d50 may increase in response to an increase in slope, even if Q remains constant. It should be remembered, however, that Lane's balance provides only a simplified schematization of the complex process-response system that actually operates in alluvial streams.

A problem that underlies all simplified approaches to the treatment of stream morphology and equilibrium is the need to represent the wide range of flows actually experienced by the channel by a single representative flow. In this context, the concept of a channel forming or "dominant" discharge is often invoked and has in the past proven useful for analytical and discussion purposes. The dominant discharge is the single, steady flow that, if it were to occur all of the time, would produce a channel with the equivalent size and shape to that produced by the actual variety of flows occurring (Biedenharn et al. 2001). It can, therefore, for analytical purposes replace the range of discharges that mold the shape and size of the channel (Copeland et al. 2001).

It is recognized that the gross form of the river and its floodplain are, in reality, shaped by larger, less frequent discharges, and modified by local geology and watershed characteristics. However, dominant discharge theory argues that maintenance of channel dimensions and smaller-scale features such as bars, riffles, pools, and islands (habitat features) are most closely related to more frequent, within-bank discharges (Soar and Thorne 2001). It follows that the formation and maintenance of anadromous salmonid habitat is closely controlled by the dominant discharge, although valuable habitat functions do require a wider range of flows.

Maintaining equilibrium channel size requires that the sediment transport capacity of the channel is, on average, matched to the supply from upstream, so that over the long term the channel neither degrades nor aggrades (Emmett 1999). This assumes an available supply of sediment; if there is not an adequate supply, then transport causes incision. Therefore, channel-forming processes are most effectively conducted by the flow that transports the most sediment load over time (Wolman and Miller 1960; Leopold et al. 1964; Knighton 1984). The stream flow transporting most sediment is referred to as the 'effective discharge' (Biedenharn et al. 2001). This is an intermediate discharge event with a return period usually in the range of 1 to 2 years (Soar and Thorne 2001). Although extreme discharge events can transport vast quantities of sediment, they occur infrequently. It is the more frequent storms that cumulatively deliver the most material.

2.1.1 Channel Form and Function

The dimensions of self-formed, alluvial stream channels are influenced by the dominant discharge. Through time, those dimensions adjust so that the bankfull discharge (the maximum flow contained within the channel) converges with the effective discharge (the stream flow doing the most sediment transport). Hence, for a stream in equilibrium with its watershed, bankfull and effective discharges are approximately the same and flow spills onto the floodplain every 1 to 2 years.

Stream channels are highly organized both longitudinally and in planform. Stream channel planforms can be characterized as straight, meandering, braided, or anastomosing, although the existence of intermediate patterns means that there is actually a continuum of patterns. Even in undisturbed straight channels, the fundamental geomorphic pattern features a sinuous low-flow channel (thalweg). The thalweg switches from bank to bank as the flow meanders around accumulations of coarse bed material known as alternate bars.

a. Alternate Bars and Point Bars. Alternate bars and point bars, and the associated pool-riffle sequences, are the fundamental geomorphic units found in alluvial channels. Composed of deposited coarse sediments, alternate bars occur in straight, sinuous and meandering channels as well as within straightened and levee-confined, engineered channels. Coarse bed materials are typically transported and deposited in appreciable quantities along streams during flood flows on only a few days per year (e.g., Emmett 1999).

It is useful to consider that bars "grow" from an incipient condition to maturity, and can recover from various disturbances to approximately pre-disturbance conditions. This view of bar dynamics allows the conceptual connection to valuable fish habitat that disturbed bars can provide if allowed to re-establish. Bars develop a maximum height corresponding to the elevation that the river currents (Church et al. 2001) can carry gravels, often near normal flood water levels. Sand can be transported to higher elevations and deposited on bar tops. Once vegetation becomes established on the bartop, sand is more rapidly trapped and the bar top approaches the elevation of the adjacent floodplain.

Mature bars in undisturbed channels are connected to the adjacent floodplain, having elevations corresponding to the water surface elevation associated with the bankfull stage. In altered channels, "mature" bars can adjust their heights to correspond to other benchmarks including the dominant discharge, and possibly to heights associated with extreme flood events.

b. Pools and Riffles. The long-profile of the bed of a natural stream channel usually displays a systematic pattern of alternate deep and shallow units termed pools and riffles. A significant feature of riffle-pool geometry is the more or less regular spacing of successive pools or riffles at a distance of 5-7 times the channel width (Keller and Melhorn 1978). Pool-riffle formation can be thought of as a vertical expression of the

same processes that drive meandering in the horizontal plane. Pools combine with alternate bars to confine the most frequent flows, those less than bankfull, into relatively narrow cross-sections. The greatest channel confinement occurs adjacent to the widest points of bars, where the thalweg lies close to the opposite stream bank. Strong secondary currents and plunging flow occur at these locations, accentuating pool scour to provide important fish habitat. Pools associated with resistant channel boundaries (i.e., rock outcrop) may be spaced at different length intervals (greater or less than 5-7 channel widths) but are maintained by the same geomorphic processes described in Chapter 3. Meandering (next section) and alternate bar formation are the dominant controls on the pool-riffle sequence and the quality of these habitats.

Pools are an essential habitat element for salmonids (Bjornn and Reiser 1991). Pools provide a complex of deep, low-velocity areas, backwater eddies, and submerged structural elements that provide cover, winter habitat, and flood refuge for fish (Brown and Moyle 1991). During their upstream migrations, adult salmonids typically move quickly through rapids and pause for varying duration in deep holding pools (Briggs 1953; Ellis 1962; Hinch et al. 1996; Hinch and Bratty 2000). Holding pools provide salmon with safe areas in which to rest when low-flows and/or fatigue inhibit their migration (Moreau and Moring 1993).

Pools are also the preferred habitat of juvenile coho salmon (Hartman 1965; Fausch 1986; McMahon 1983), and they are a preferred habitat of juvenile steelhead, although this latter species is also able to utilize riffle habitat if it is complex with velocity refuges behind cobble and small boulders (Nielsen et al. 1994; Hartman 1965; Raleigh et al. 1984; Hearn and Kynard 1986). Pools with sufficient depth and size can also moderate elevated water temperatures stressful to salmonids (Matthews et al. 1994). Deep, thermally stratified pools with low current velocities, or connection to cool groundwater, provide important cold water refugia for cold water fish such as salmonids (Nielsen et al. 1994).

Between alternate bars, riffles and runs form where the stream crosses from one bank to the other and the channel cross-section is substantially wider. Riffles are composed of relatively coarse bed material that is selectively mobilized by flows approaching the dominant or bankfull discharges. Fine sediment is flushed through riffles, while the gravel and cobble material comprising the riffles is mobilized and reworked less frequently, resulting in well-sorted, clean substrate. Gravel beds within riffles provide important spawning habitat for anadromous salmonid species.

All spawning salmonid species excavate depressions within gravel deposits into which they lay their eggs, which are then fertilized and covered by a porous layer of gravel. The embryos incubate within these gravel nests (redds) for several weeks to months before hatching. Alevins, newly hatched fish, reside within the gravel pore spaces for additional weeks, taking nourishment from their abdominal yolk sac. Embryos and alevins depend on the flow of intragravel water (hyporheic flow) to carry off metabolic wastes and supply them with well-oxygenated water. Upon final absorption of the yolk sac, the young fish must then pass up through the gravel pore-spaces to the bed surface

(Bjornn and Reiser 1991).

In addition to spawning habitat, the shallow, swift flows over riffles and runs are also important habitats for numerous species of invertebrates, many of which are important food sources for salmonids. Coarse riffle-run substrates are the among the most productive stream habitats, supporting much higher densities of organisms than sandy or heavily sedimented substrates (Hynes 1970; Fields 1991).

c. Sinuosity and Meandering. Undisturbed alternate bars deflect low (high frequency) flows around them, thus creating a sinuous flow pattern at discharges up to high, over-bank flood events. The flow field converges as it flows around the alternate bars, then it diverges as it flows over the riffles (Keller 1971). Even in a relatively straight channel, the flow path is longer than the distance along the channel. The degree of meandering is indicated by the sinuosity, which is the ratio between the actual length of the flow path and the equivalent straight-line distance. The longer flow path in a natural channel with a sinuous thalweg results in a lower slope and greater energy dissipation than in an equivalent engineered channel with a uniform, trapezoidal cross-section.

In nature, sinuosity and slope are adjusted towards achieving dynamic balance between the dominant discharge and the sediment load. When flood flows overtop the alternate bars, the sinuosity decreases toward unity, and the slope increases to nearly that of the floodplain as the stage increases. Thus, natural (unaltered) alluvial channels have two hydraulic efficiencies; low efficiency for flows significantly less than bankfull, and higher flood flow efficiency.

As water flows around geomorphic features such as alternate bars, sinuosity in the flow field may lead to development of a meandering channel pattern. This occurs because bank retreat is concentrated opposite alternate bars where flow is concentrated and scour depth is greatest. Meanders gradually grow in amplitude and migrate down valley through erosion at the outside of bends that is greatest just downstream of the bend apex. Bank retreat is, on average, balanced by deposition at the inside of bends, so that channel-width remains about constant.

The meandering stream channel pattern represents a continuation of the development of sinuosity as a process of self-regulation of slope and sediment transport to achieve equilibrium. In streams in equilibrium with their watersheds, meanders develop consistent dimensions of wavelength and radius of curvature adjusted to provide a channel slope and degree of energy dissipation that is adjusted to the discharge and sediment load. Meandering streams shift and migrate to rework entire valley bottom widths over short geologic time spans. Meandering and alternate bar formation is consequently the dominant process of floodplain development, with overbank deposition of fine sediment the secondary process.

d. Sediment Sorting. In addition to the general progressive downstream reduction in size (fining) of particles forming the bed of alluvial channels, local sorting occurs related to the local distribution of stream forces. Channel bed topography causes flow to diverge

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at riffles and converge in the narrower cross-sections at pools (Keller 1971). Convergent and divergent patterns of flow paths can be inferred from map views of stream channels, and from the shapes and ratios of cross-section width to depth. Undisturbed bars and their associated pools and riffles are arranged in an alternating pattern of convergence and divergence zones. Complex topographic and sedimentary features are maintained by the convergence and divergence of the stream's flow field (e.g., Keller 1971; Keller and Melhorn 1978; Lisle 1979; Andrews 1979).

The non-uniformity of energy dissipation in the zones of convergence and divergence sets up particle sorting mechanisms, and diverse habitat features result (Trush et al. 2000). Where the apex or maximum width of an alternate bar is intrinsically linked with the zone of highest flow convergence, the increased depth and turbulence in the flow field form relatively deep scour holes that contain the coarsest bed particles. Such coarse-bedded scour holes form the pool habitats important to fish at lower flows. During low summer flows, when pools are most readily observed, a fine-grained veneer may cover the coarse bed.

Where flow diverges over riffles, the flow depth and velocity-field become more uniform, providing conditions conducive to the formation of well-sorted patches of gravel. It is these gravel patches, combined with the gradient of the hyporheic flow field (subsurface water), that provide optimal substrates for spawning salmonids (Groot and Margolis 1991).

e. Armor Layer. Undisturbed bars and channel bottoms of gravel-bedded streams are typically armored with a layer of larger rock that overlies mixtures of finer-grained material. Armoring is especially evident on the heads (upstream end) of bars. The armor layer reduces the mobility of bed sediment, making bar heads and the channel bottom resistant to high flow stresses and providing stability to the channel during flood flows. Areas of heavy armor can provide valuable fish habitat during high flows (Church et al. 2001) because of low near-bed velocity, and productive benthic habitat whenever inundated (Bjornn et al. 1977). In both altered and unaltered channels, when the balance between bed material transport and bed mobility is reached, a coarse surface layer "armor" develops on the bar surface that hinders or prevents erosion (Leopold and Emmett 1976).

f. Hyporheic Zone. The hyporheic zone is the subsurface stream flow and shallow groundwater environment known to be critical for stream ecosystems. Water in the hyporheic zone moves down valley through interstitial spaces in floodplain and stream bed sediments and is connected to stream waters. For example, the hyporheic zone extends as much as 2 km away from Montana's Flathead River channel and it is a greater source of nutrients to the stream than surface water (Stanford and Ward 1988).

Water diversion or pumping associated with sediment excavation can lower groundwater tables. Where a depressed groundwater table intersects nearby stream channels, especially during low flow seasons, the stream flow will be reduced and possibly subside below the surface of the streambed. This can cause direct mortality to affected fish and

the aquatic food base of the stream ecosystem. Locally depressed water tables can reduce stream flows for great distances down stream.

g. Habitat. The incremental growth and movement of stream meanders gradually erodes the outside of bends while depositing sediment on the point bar at the inner bank. Channel migration in floodplain riparian communities recruits large wood to the channel which can cause localized bed scour and sediment sorting that augment pool habitats and add cover and shade. As described below, the disruption of stream channels affects many attributes of salmonid habitat. In general, the health and function of the stream ecosystem are positively related to the degree of dynamism and topographic complexity of the stream channels.

2.2   WATER QUALITY

Unaltered stream channels have high levels of variability and complexity at the channel margin, including stream-side wetlands, oxbow lakes, and riparian stands at various elevations and stages of maturity. Such areas are protected from direct flood currents and are commonly associated with springs. All elements of channel margin complexity are important habitat for salmonids during floods, and also during low flow periods. Such areas form low-velocity zones during floods where water quality improves (or remains better than the main channel) as suspended sediment settles. Anadromous salmonids are adapted to migration and feeding in relatively clear water, and so floods transporting high suspended sediment concentrations can cause behavioral or physical harm, particularly if the fish cannot find refuge until the flood passes. Consequently, migrating salmonids may be found in large numbers taking advantage of complex channel margin habitats during floods (Church et al. 2001).

One of the most valuable floodplain functions is providing a sink for suspended sediment during floods. Unaltered streams inundate floodplains frequently, about every 1-2 years for channels that are in dynamic equilibrium. Channels that have been channelized for flood control, or land development, or have undergone natural incision, do not interact with their surrounding floodplain as frequently. In fact, the goal of many river management schemes is to prevent floodplain interactions for floods of up to the 100-year recurrence interval. The combination of higher capacity channels and reduced channel complexity effectively increases the magnitude of flood flows that salmonids are subjected to, and reduces habitat used for refuge during floods. These effects are discussed in Chapter 3.

2.3   FLOODPLAIN / CHANNEL CONNECTION

Stream corridors are ecosystems containing the stream channel(s) and adjacent floodplain. Water, sediment, nutrients, organisms, and energy transfer dynamically between the stream channels and floodplain. Floods in non-manipulated streams overtop the banks (bankfull flow condition) every 1-2 years. Overbank floods transport water, sediment, and nutrients onto floodplain surfaces, which support ecologically rich riparian forests and calm water habitats for breeding and feeding of aquatic species.

2.3.1 Floodplains as Sources and Sinks.

Floodplains retain and absorb flood flows, reducing downstream flood peaks and in turn providing an important source of shallow groundwater (hyporheic zone) that nourishes the stream during dry seasons. The dry season flow of streams is the result of water seepage from floodplain storage and other sources such as springs and tributaries. The quality of the hyporheic water discharging into streams is high, and the temperature is low, conditions highly favorable for anadromous salmonid rearing. Inflowing groundwater can substantially reduce water temperature in pools during high summer ambient temperatures.

Much of the suspended sediment transported to floodplain areas is deposited, adding to the soil and supporting the riparian community. Frequent communication with the floodplain reduces the concentration of suspended sediment in the channel, thus improving water quality for the more frequent flows contained within the channel.

Another criterion of streams in equilibrium is the erosion of stream banks balanced by deposition of bars during frequent winter flows. The "damage" done by large, less frequent floods, which disturb the channel or floodplain, is quickly returned toward dynamic equilibrium because (1) floodplains have great capacity for detaining flood peaks, and (2) the energy within the channel cannot substantially increase beyond the energy applied during the more frequently occurring bankfull condition (Knighton 1984). Incised and levee-lined streams contain larger, less frequent floods, and are therefore not in dynamic equilibrium.

The ecosystems of streams in dynamic equilibrium have remarkable resiliency to natural disturbances (extreme events) (Pearsons et al. 1992), and benefit from large floods (Platts and Nelson 1985). Floods exceeding 10-20 year recurrence scour and rebuild in-channel features, avulse main stem channels, rejuvenate mature riparian stands to early successional stages, form and maintain side channels, and reshape or redirect entire meander sequences-forming oxbows and off-channel wetlands (Gordon et al. 1992).

2.3.2 Riparian Communities.

Riparian vegetation provides many ecological functions that are important to salmonids. Vegetative structure increases hydraulic boundary roughness resulting in relatively lower velocities near the flow-substrate interface (Beschta and Platts 1986), and it increases channel and habitat stability (Lisle 1986). These low-velocity zones provide refuge habitat to salmonids during high-flow events. Many salmonids seek out low-velocity areas close to high-velocity areas in order to optimize foraging and maximize net energy gain (Fausch 1984).
Mature, late succession vegetation provides additional benefits to juvenile salmonids in the form of physical structure. Structure in the form of large wood, when recruited into the active channel promotes localized scour, pool formation and is, itself, utilized as cover. Cover is also provided to juvenile salmonids by overhanging vegetation,

submerged vegetation and exposed roots. The cover provided by complexities in structure can increase survival rates for salmonids rearing in summer, overwintering, and outmigrating as smolts (Meehan 1991).

Ecological energy is typically derived from detritus in streams (Cummins et al. 1973; Vannote et al. 1980) and is processed by different organisms (Anderson and Sedell 1979) in a continuum from larger to smaller particles (Boling et al. 1975). Riparian vegetation provides important nutrient inputs to streams such as leaf litter (Cummins et al. 1973) and terrestrial invertebrates that drop into the stream. Such "allochthonous inputs" can be the principal source of energy for higher trophic levels in stream ecosystems (Reid 1961; Gregory et al. 1991). Leaf litter provides the trophic base for aquatic macro-invertebrate communities that in turn are the fundamental food source for salmonids (Beschta 1991; Bretscko and Moser 1993; Hawkins et al. 1982).

The temperature of stream waters at any given time reflects a balance of heat transfer between the water and the surrounding environment. Although heat exchange occurs via several processes, direct insolation (solar radiation) is generally the dominant source of energy input into streams (Beschta et al. 1987; Spence et al. 1996). Riparian vegetation protects stream temperatures from rising by providing canopy that shades the water and reduces direct solar radiation reaching the water surface (Beschta 1991; Hetrick et al. 1998).

3   EFFECTS OF SEDIMENT REMOVAL FROM STREAMS

This chapter provides a brief summary of potential instream aggregate mining effects on streams. This does not infer that all effects will occur in every stream or with every mining operation. Further, it is also acknowledged that many of the major impacts discussed throughout the paper may not be solely attributable to aggregate mining. Other land management activities including, but not limited to, forest practices, livestock grazing, agriculture, flood control, irrigation diversion, and urban development, may lead to similar impacts.

With few exceptions, sediment removal activities for commercial sediment production occur in coarse bed alluvial stream channels (sand, gravel, and cobble) that are structured with alternating bar and sequential pool-riffle complexes (Keller and Melhorn 1978, Trush et al. 2000). The removal of alluvial material from a streambed has direct impacts on the stream's physical boundaries, on the ability of the stream to transport and process sediment, and on numerous associated habitat qualities. Immediate local effects that may occur following removal include: 1) changes in channel geometry, 2) decreased bed and/or bar elevation, 3) changes in bed and/or bar substrate composition, 4) reduced form roughness, 5) loss of instream roughness elements, 6) decreased average stream depths, and 7) changes in velocity patterns. In addition, increased turbidity, changes in sediment transport patterns and timing, and changes in air and water temperature, especially if riparian vegetation is removed, may also occur (Rundquist 1980; Pauley et al. 1989; Kondolf 1994a, 1994b; OWRRI 1995).

In addition to the local and immediate effects, there are delayed effects that may occur over wide areas. Improvement from some effects can occur quickly once disturbance ceases. However, other effects require longer periods for restoration, and some effects are not recoverable. For example, alternate bars that have been skimmed to low elevations will regain height and a dimension similar to pre-disturbance conditions during subsequent high flow events, but only if adequate sediment supply is available from upstream. Delayed re-establishment of particle-sorting processes that lead to armor layer development, establishment of riparian vegetation, and the formation and maintenance of the riffle-pool complex cannot occur until bar geometry is regained and substrate stability is returned.

Channel hydraulics, sediment transport, and stream morphology can be directly affected by sediment removal activities. Channel modifications can lead to shifts in flow patterns and subsequent changes in local sediment-sorting patterns and sediment transport rates and timing. These physical changes can adversely affect instream biota (Kanehl and Lyons 1992; Hartfield 1993; Benke 1990; Newport and Moyer 1974; Waters 1995; Brown et al. 1998) and the associated riparian habitats (Rivier and Seguier 1985; Sandecki 1989). For example, sediment removal can reduce fish populations in the disturbed area, replace one species by another, replace one age group by another, allow successful invasion by exotic species (Baltz and Moyle 1993), or cause shifts in species age distributions (Moulton 1980; Benke 1990).

Activities that disturb stream channels can disrupt the ecological continuum in several ways. Local channel modifications can propagate changes upstream and downstream, as well as up tributaries (Pringle 1997). Modification can also trigger lateral migration of the channel or channel widening within the floodplain. Alterations of the riparian zone due to extraction operations can change instream habitats as extensively as some activities within the channel (OWRRI 1995). The potential effects of sediment removal activities on stream form and function, riparian habitat, and aquatic habitat are reviewed in the following subsections.

3.1 EFFECTS ON CHANNEL MORPHOLOGY AND HYDRAULICS

The morphology of a stream is controlled by a dynamic balance between the amount of water flowing in the channel, the amount and size distribution of sediment delivered from upstream sources, the composition of the bed and banks, and the type and quantity of vegetation on the banks. When any of these components are altered, channel adjustments occur until a new dynamic equilibrium is achieved. Habitat alteration is inevitable when morphological adjustments take place.

The effects of sediment removal on channel hydraulics and thus morphology in alluvial channels can show repeated, predictable patterns; however, the extent of these effects depends upon the type and scale of the sediment removal operation, minimization efforts, the channel's resistance to erosion, and hydrology and sediment transport characteristics of the watershed. Effects may be delayed due to the frequency of flood events required to transport the available sediment and thus modify channel and floodplain characteristics. Thus, effects that are attributed to large flood events may actually be the result of previous years activities that have "set the stage" for major morphologic changes. Therefore, all rivers do not respond exactly alike to the same disturbance, and the same river may not respond consistently to the same disturbance over time. The following sections describe some of the more predictable and widely observed changes initiated by large-scale sediment removal.

3.1.1   Increased Width / Depth Ratio.

The ratio of flow width to average flow depth is a commonly used measure of channel cross-sectional dimensions because the ratio is related to sediment transport processes and has biological relevance. The removal of bar sediments changes the width/depth ratio (W/D) of channel cross-sections by decreasing the height of bar deposits, which results in a wider channel for any given discharge that overtops the altered surface. The greatest effect of increased W/D is observed at alternate bars and islands, with relatively little change observed at the riffles.

These effects are pronounced in hydraulic modeling analyses (*e.g.*, HEC-2; HEC-RAS); however, sophisticated analyses are not typically used to support environmental assessments for sediment removal operations. Instead, one-dimensional continuity equations are often applied:

$$(WD)_1 V_1 = (WD)_2 V_2,$$
$$A_1 V_1 = A_2 V_2$$
$$Q_1 = Q_2$$

where **W** is width; **D** is depth; **V** is velocity; **A** is area; and **Q** is discharge; where **A = WD**
.

It is possible to predict the effects of sediment removal upon average channel width and depth, and the relationship between area and velocity for a steady flow where the discharge (**Q**) is, by definition, the same at all cross-sections.

3.1.2   Bank Erosion.

Bank erosion is commonly observed in the vicinity of long-term sediment extraction areas. Streambanks derive their strength and resistance to erosion largely from vegetation (Yang 1996) and to lesser degrees from their composition, height, and slope. Simon and Hupp (1992) show that there is a positive correlation between initial bed lowering and then channel widening. Bank strength, and thus resistance to erosion, can be reduced when: (1) bank heights increase because of sediment extraction, and (2) riparian vegetation is removed at equipment access points. Bank strength can be further reduced if shallow groundwater drains into the stream through the banks, as may be the case in an incising stream.

Once banks become weakened and erosion begins or accelerates, a common solution has been to repeatedly remove sediment from adjacent bar deposits. Although there is a flow steering effect associated with bars, removing the bar does not remove the cause of bank retreat – the weakened bank. *It is a common fallacy that bars cause bank erosion, while the well-accepted geomorphic model recognizes bars as migrating deposits following the natural retreat of meanders* (Knighton 1998). An exception to the above argument is observed in highly disturbed stream channels (incised, straightened, leveed, or widened) where the banks have become weakened. In this case, riparian vegetation may become temporarily established on bars, making the bars stronger than the banks. However, even in this case, removing bars only temporarily reduces bank retreat and the weakened bank condition persists.

3.1.3   Changes in Sediment Transport.

The ability of stream flow to transport sediment is often represented by shear stress calculations which are commonly used to estimate the ability of a moving fluid to entrain and transport sediment from the streambed. The sediment particles on the streambed become mobile when the resistance to shear is exceeded, which is referred to as the

critical shear stress or incipient motion condition. Where shear stress increases, sediment is transported in greater volume, greater particle size, or both, as long as there is sediment available for transport. Where shear stress decreases below a transport threshold, the mobile particle size and/or total transport volume decreases.

Shear stress equations are the physical basis of sediment transport models. It is essential that assessments include both the effects on hydraulics and on the ability of the stream to transport sediment in the vicinity of channel modifications. For example, the incipient motion condition and the relative stable grain sizes in particular habitats can be calculated utilizing shear stress formulas and results from simple hydraulic models. Analysis of changes in shear stress on the bed can provide insight as to the fate of macroinvertebrate habitat, spawning areas, and other habitat types.

Using the shear stress equations and the flow continuity equations, one can expect that shear stress will increase most in the upper part of sediment removal areas where the slope increase is generally most pronounced. Laboratory experiments (Begin *et al.* 1981) verified this effect. When sediment removal reduces the size of alternate bars, increased shear stress values can occur at riffles while decreasing at pools. Consequently, the changes in channel geometry and flow energy resulting from sediment removal can cause sediment accumulation in pools and erosion from riffles, opposite of what normally occurs.

3.1.4   *Reduced Sinuosity of the Mid-High Flow Channel.*

A naturally functioning channel, with mature alternate bars, has two efficiencies: a lower conveyance efficiency when flows are contained within and steered around alternate bars, and a higher efficiency when flood flows overtop the bars. Sediment removal projects that decrease bar elevation (*e.g.*, bar skimming) cause bar overtopping to occur at lower discharges. One result is greater flow velocities over the skimmed bar surface during more frequent, lower discharges that occur in early winter. This functionally reduces sinuosity by creating a straighter flow path and can result in erosion of these bar features at relatively lower flow levels. Localized erosion can increase the delivery of sediment to downstream areas (Olson 2000), potentially damaging habitats of species and life stages that are sensitive to increases in fine sediment.

3.1.5   *Altered Sediment Sorting Processes.*

In addition to the progressive downstream reduction in size (fining) of alluvial streambed particles, local sorting occurs because of the local distribution of stream forces and shear stress variations. In a pool/riffle channel, topography causes the stream's flow-field to spread out over riffles (divergence) and concentrate over pools (convergence). Complex morphologic and well-sorted sediment features are maintained by the convergence and divergence of the flow-field (*e.g*., Keller 1971; Keller and Melhorn 1978; Lisle 1979; Andrews 1979), which creates and maintains sediment patches and hence habitat units.

Sediment removal for commercial aggregate production typically reduces alternate bar heights. Flow that overtops bars with reduced height has relatively less variation in the flow pattern, and thus reduced convergence and divergence. This can result in a more simplified channel (*i.e.* fewer pools and riffles) and less concentrated and less effective particle-sorting processes. Therefore, it can be reasonably predicted that reductions in bar height will likely induce decreases in the area of spawning beds, reductions in pool area and depth, and a general loss of microhabitats within the stream reach.

3.2   ALTERATION OF THE SEDIMENT TRANSPORT CONTINUUM

Over time, stream channels obtain equilibrium between the sediment load and dominant sediment transporting flows. A gradual migration of the stream channel by eroding the outside of bends and depositing equal volumes on the inside of bends creates the dynamic equilibrium condition where the bed and banks are not net sources of sediment. Therefore, the equilibrium stream channel is efficient at maintaining its geomorphic form and pattern, although the system remains dynamic as it responds to cyclic floods and sediment delivery events. Dunne and others (1981) stated "*bars are temporary storage sites through which sand and gravel pass, most bars are in approximate equilibrium so that the influx and downstream transport of material are equal when averaged over a number of years. If all the sand and gravel reaching such a bar is removed, the supply to bars downstream will diminish. Since sand and gravel will continue to be transported from these downstream bars by the river, their size will decrease.*" In Oregon, this phenomenon was observed on the mainstem McKenzie River downstream of Trailbridge Dam. Reduction in sediment supply and decreased peak flows, both due to the dam, resulted in a 57% reduction in exposed gravel bars from 1949 to 1986 between Trailbridge Dam and Leaburg Dam (OWRRI 1995). A coarsening of the substrate was also noted (OWRRI 1995).

Sediment removal disturbs the dynamic equilibrium of a stream channel because it intercepts material load moving within a dynamic system and triggers an initial morphological response to regain the balance between supply and transport. Sediment removal may also drive more widespread instability because the discontinuity in the sediment transport-supply balance tends to migrate upstream as the bed is eroded to make up for the supply deficiency. If stream bed lowering leads to bank heights that become unstable, rapid bank retreat may occur. This further destabilizes the width while supplying the channel with sediments that corrects for the transport-supply imbalance. Further degradation is prevented until the available sediments are flushed out (Knighton 1984). Thus sediment removal from a relatively confined area can trigger erosion migrating upstream causing erosion of the bed (incision) and banks which may increase sediment delivery to the site of original sediment removal.

The ultimate effect of channel bed lowering can be degradation along the entire length of alluvial channel by approximately the same amount, leading to a new channel profile, assuming that the channel is not longitudinally disconnected from the lowered channel by bedrock or other grade control features. Within the new channel the geometry changes, initially becoming narrower, deeper, and less complex. If further disturbance is arrested,

the disturbed channel will ultimately progress to a wider channel where inset floodplains develop, partially restoring ecosystem functions (Thorne 1999). This process is fully described by channel evolution models (Schumm *et al*. 1984). Few monitoring programs associated with commercial sediment removal projects in Oregon are capable of detecting the fundamental bed degradation over time scales, or spatial areas, relevant to the potentially effected aquatic ecosystem. This is due, in part, to the use of cross-sectional surveys which have not been tied to a set vertical datum and to the length of the surveyed area. By extending the surveyed area beyond the project footprint, and correlating the surveys to a set vertical datum (such as NGVD), bed degradation or aggradation could be detected.

There are other potential effects from sediment removal and the subsequent increased sediment load from upstream. For example, within the removal area the incoming sediment load encounters relatively less transport capacity (because of the wider, shallower channel) and deposition may occur. Deposition in this zone is generally less organized than the repeating alternate bars of the equilibrium channel, and deposition can occur across the entire channel width. Stream channels in sediment removal areas typically become progressively wider as the channel is less stable. Fish habitat is also reduced in unstable channels (*e.g.* Kanehl and Lyons 1992; Hartfield 1993; Benhke 1990; Newport and Moyer 1974; Waters 1995; Brown *et al.* 1998) and the associated riparian habitat may deteriorate (Rivier and Seguier 1985; Sandecki 1989).

Disturbing or harvesting the armor layer (a coarse, protective layer formed by the washing away of finer materials) of streambeds and bar deposits provides the stream a readily erodible sediment supply, because relatively finer grained sediment is now available for transport at a lower discharge. The new supply of fine sediment derived from the streambed can be transported downstream, where it can adversely affect aquatic habitats. The effects may extend considerable distances downstream if the area of disturbance is large (potentially several consecutive bars).

Two factors ameliorate bed and bank erosion caused by sediment removal: (1) resistance of the bed and banks to increased shear stress, and (2) the scale of sediment removal relative to the stream's sediment budget. A sediment budget is analogous to a bank account. If funds withdrawn (sediment removed + natural export) exceed funds deposited (sediment input), a negative budget results in a diminishing balance. Erosion of sediment from the bed and banks (savings) makes up for the import/export deficit. While this is conceptually simple, annual sediment replenishment to a particular sediment removal site is, in fact, highly variable. The variability is not well understood, and the effects of sediment removal are easily masked by variability in the sediment budget and general lack of sufficiently detailed monitoring data. To compound this complexity, Oregon streams that are utilized for sediment extraction often have numerous aggregate removal sites that are being mined concurrently. The quantity of material removed from each of these sites must be taken into account when developing a sediment budget for a particular stream system.

The ratio of sediment extraction to sediment influx not only dictates the scale and severity of potential adverse effects on the channel geometry and habitat, but it also controls the time-scale of recovery between disturbances. Alluvial streams lacking natural or artificial control that are repeatedly harvested at rates in excess of sediment influx can undergo significant channel degradation, possibly causing incision of a stream reach or stream network, including its tributaries. Striking cases of excessive sediment removal are summarized by Harvey and Schumm (1987), Sandecki (1989), Collins and Dunne (1990); Kondolf and Swanson (1993), and Florsheim and others (1998).

3.3   EFFECTS ON HABITAT COMPONENTS

The removal of sediment in stream channels can adversely affect aquatic habitats used by various species and their respective life stages. The riparian zone can also be affected by instream mining operations both directly (removal of vegetation) and indirectly (reduced sediment inputs and reduced stream stability).

3.3.1   Effects on Riffle Habitats.

Sediment removal practices can adversely affect riffle habitats by increasing fine sedimentation of the substrates, changing hyporheic flow patterns, causing barriers to adult fish migration (due to over-widened channels with shallow flow), reducing benthic invertebrate production, and directly affecting eggs, embryos, and/or young fish inhabiting the interstitial spaces within the substrate.

a.   Changes in Bar Substrate and Spawning Habitat. Mature gravel bars have a height slightly less than the floodplain (if the channel is in equilibrium, or related to the dominant flow elevation), a coarse armor layer at its head, and vegetation elsewhere that is not frequently disturbed by floods (Church et al. 2001). The condition of maturity is obtained where bars are not frequently disturbed. Bars remain dynamic during frequent floods because they are a source of sediment from temporary storage that is regularly replaced from an upstream supply. The partial removal (or surface disturbance) of bars can adversely affect aquatic habitats, including spawning areas.

Riffle habitats can be scoured and swept downstream as the result of increased shear stress. This process can also preclude the deposition of new gravel from upstream sources. When channel bars are removed, the channel is effectively widened at low and moderate flows while channel slope is increased (due to straighter flow path), and migrating gravel particles are then more likely to continue moving across the riffle and accumulate in pools where the shear stress has been locally reduced, thus reducing pool depth and its valuable habitat. Spawning habitats are especially vulnerable to these changes. The loss of eggs from salmonid nests constructed in riffles was documented by Pauley and others (1989). They concluded the eggs were scoured because bar skimming reduced bar heights, increasing shear stress on the streambed.

Sediment removal can increase the available load of fine sediments that can clog, or embed, the interstitial pores of coarse substrates. Because mature alternate bar surfaces

are covered with an armor layer of coarse particles, channel bars are coarser at their surface than at depth. Bar skimming thus exposes smaller sediment particles (Figure 1) that are more readily transported downstream, and are transported earlier in the season since higher flows are not required to disrupt the protective armor layer. This newly exposed sediment will not become hydraulically stable until the sediments have been exposed to flows of sufficient magnitude to sort the exposed material. If spawning occurs in these unstable sediments, shifting gravels could cause mortality of incubating embryos (OWRRI 1995).
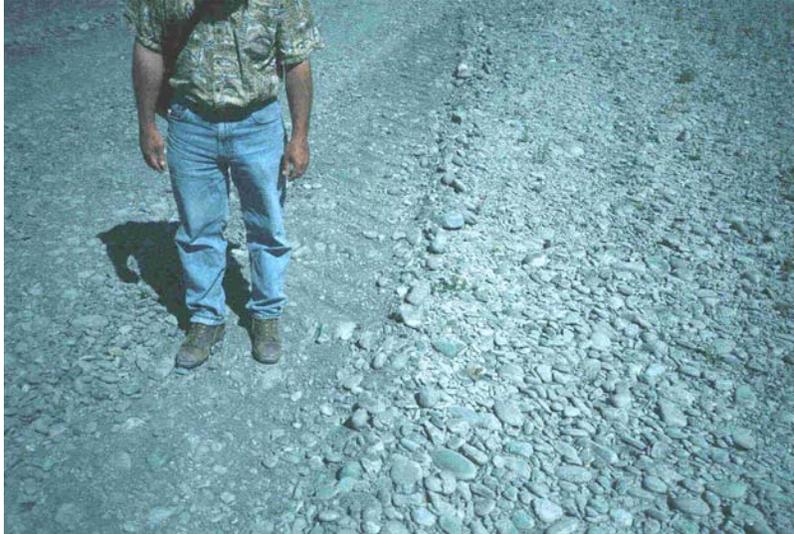
Figure 1. Photo of grain-size differences between skimmed (left) and unskimmed (right) bar surface.

b.   Sediment Intrusion. Sedimentation of streambeds is caused by the settling of suspended particles in low velocity areas and by the process of sediment intrusion. McDowell-Boyer and others (1986) identified two mechanisms by which porous substrates can become clogged with fines: (1) particle straining, and (2) the formation of surface cakes. Jobson and Carey (1989) defined particle straining as the process where fine particles move into the porous media until they encounter pore spaces too small for passage. Beschta and Jackson (1979) found that the potential for particle penetration is a function of the effective pore diameter of the streambed surface media and the size distribution of the particles moving in occasional contact with the bed. They also found that most intrusion occurred quickly, during the first 15-20 minutes of experimental fine sediment input events. These experiments were probably detecting the simple geometric relationship between bed particle pore-space and the diameter of the mobile particles. Essentially, entrained particles can enter streambed material if the particles are smaller than the pore spaces and there is occasional bed contact.

Surface caking is the filling of pore spaces of gravel/cobble beds from the bottom up. Surface caking experiments were conducted by Einstein and Chien (1953), and by Simons and others (1963). The authors examined the transport of well-graded material and observed fine sediment accumulations on the bed surface following injection of large concentrations. The accumulated material was then selectively removed as the supply was decreased. When selective removal ceases, the fine sediment trapped in the bed will probably be retained even if upwelling flow is present (Jobson and Carey 1989). Gravel

deposits clogged with fines have decreased hydraulic conductivity that contributes to diminished oxygen concentrations in subsurface flow and resulting impacts to incubating embryos and macroinvertebrates (Kondolf and Williams 1999).

Bar skimming necessarily removes the armor layer, thus exposing finer sediment to the flow. This sediment is now available for transport during much lower flows than when it was protected by a coarser armor layer. The finer-grained disturbed surfaces, which are at a reduced elevation, create a new source of fine sediment within the active channel that can be mobilized by the first freshets during late fall or early winter. The first freshets may lack the magnitude or duration to transport the locally derived fine sediment sufficiently downstream. Fine sediments generated during sediment removal operations may contribute to the anthropogenic-induced concentration of sand and fines that is known to be a factor contributing to the decline or loss of salmon and steelhead populations (Cordone and Kelley 1961).

c. **Hyporheic Flow.** The movement of water does not cease at the interface between the stream and its substrate. Water moves through pore spaces in the streambed, particularly where the bed has topographic relief. Predictable zones of inflow and outflow (downwelling and upwelling) are found on the streambed. The more complex the channel pattern and surface topography, the more strongly developed are downwelling and upwelling hyporheic zones (subsurface flow) (Brunke and Gonser 1997). Zones of downwelling flow are located at the heads of riffles, where the bed topography is sloped slightly upstream and where there is an increasing hydraulic gradient (Thibodeaux and Boyle 1987).

d. **Boundary Layer Habitat.** A relatively low velocity sublayer develops when fluids flow across any surface. The thickness of the sublayer is related to the height of the roughness elements on the surface. Most natural streams have rough beds created by coarse substrates, frequent larger particles, woody debris (notably large wood, however aggregates of smaller woody debris also influences the boundary), and vegetation along the banks (Knighton 1998).

Two scales of boundary layer thickness are important to aquatic species. The layer created by woody debris, bank complexity, and large cobble-boulder sized particles provides habitat for large and small fish where they can move about efficiently, while smaller scale boundary layer roughness created by gravel-sized particles is rich invertebrate habitat. Sediment removal, particularly bar top removal, reduces exposed particle size and LWD. Reduced boundary layer height reduces macroinvertebrate production because of the loss of the boundary layer microhabitat.

e. **Adult Fish Migration and Passage.** In natural streams, shallow riffles can be migration barriers to upstream migrating fish species. The shape of the low flow channel and flow depth governs the extent of the barrier during migration seasons. Thompson (1972) provided minimum depths and maximum velocities that enable upstream migration of adult salmon species -- criteria that have been widely cited (Bovee 1982; Bjornn and Reiser 1991). According to those recommendations, Chinook salmon, the

largest salmonid species, requires minimum riffle depths of 24 cm; for successful passage, this depth should be provided "on at least 25% of the total [cross-sectional] transect width and a continuous portion equaling at least 10% of its total width." Sediment removal operations that increase width to depth (W/D) ratios (particularly bar scalping) increase the probability that shallow riffles will form migration barriers for some fish species. Pauley and others (1989) and Woodward-Clyde (1980) verified what the basic river mechanics equations predict -- that flow depths decrease over riffles, creating barriers to upstream-migrating adult fish, adjacent to and upstream from skimmed bars. This phenomenon has been directly observed at a gravel mining site on the South coquille River in southwestern Oregon.

f. Effects on Aquatic Macroinvertebrates. Aquatic macroinvertebrates provide the principal food source for many aquatic species (Spence et al. 1996). Immature mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera), referred to collectively as EPT, are considered the most productive, preferred, and available foods for stream fishes (Waters 1995). Indeed, the abundance of these three groups of aquatic macroinvertebrates is commonly used as a food availability index (Lenat 1988). The diversity and abundance of EPT can be affected by sediment removal operations because they are dependent upon substrate conditions (Benhke et al. 1987). The EPT group typically inhabit the interstitial spaces of coarse substrates (gravel to cobble sized particles), although some species of mayfly and certain other aquatic insects (e.g., midges) prefer highly organic fine sediments. Sands and silt are the least productive substrates for aquatic macroinvertebrates (Hynes 1970) and are more easily mobilized, making them unsuitable because they are less stable (Fields 1982). Therefore, sediment intrusion that reduces the interstitial spaces of cobbles and gravel directly decreases the habitable area for EPT (Bjornn et al. 1974; 1977).

Impacts to aquatic macroinvertebrates may be protracted. The average life cycle of EPT species is one year, although several species have two-year life cycles. Fine sediments intruded deeply into the bed require mobilization of the bed itself to remove fines (Beschta and Jackson 1979; Diplas and Parker 1985). Bed mobilizing flows generally do not occur annually, so there is potential for the aquatic invertebrate food base to be diminished for some time and for some distance downstream from sediment removal areas. Brown and others (1998), who sampled substrates upstream, downstream, and within an instream gravel mining project area in the southeastern United States, found that upstream from the disturbance: 1) biomass densities of all invertebrates were higher, 2) total fish densities in pools were higher, and 3) silt-sensitive fish species were more abundant than within the project area or in downstream reaches.

3.3.2   Effects on Pool Habitats.

Pools provide a complex of deep, low velocity areas, backwater eddies, and submerged structural elements that provide cover, winter habitat, and thermal refugia for fish (Brown and Moyle 1991). Pools are highly productive aquatic habitat that can be easily impacted by changes in the watershed causing increased sediment load as well as local changes in bars and pool scour processes.

Removal of alternate bars and other streambed sediments can adversely affect fundamental physical processes related to pool maintenance. The scour of pools during the high flows of winter and their subsequent reversal to sedimentation during summer are widely accepted physical processes. During high flows, coarse particles eroded from upstream riffles are transported through pools to downstream riffles. The process responsible for pool and riffle maintenance has been termed "velocity reversal" (Keller 1971) or "shear stress reversal" (Andrews 1979; Lisle 1979). Under this mechanism, as discharge increases, the energy to transport coarse sediment increases in pools at a faster rate than in riffles due to the greater flow depth. As a result, when flows exceed about 60% of bankfull flow, the "reversal" process begins and coarse sediment eroded from upstream reaches can continue to move through pools to downstream riffles where they may become deposited. The "reversal" process becomes most effective at bankfull flow in undisturbed stream channels, as flow depth and velocity can increase only incrementally once the banks are overtopped.

Another consequence of the "reversal" process is that the beds of pools typically have the largest substrate particles, although this may not be immediately apparent during low flow periods when pool substrates are covered with sand or gravel. The predominantly large substrate beneath this veneer is due to the concentrated energy that sweeps smaller particles downstream through pools during episodes of high flow.

Removing or altering in-channel bars can reduce or eliminate the convergence of flows through pools, thereby reducing the effectiveness of the physical process that maintains pools. The reduced confinement of flows can be expressed as an increased width to depth (W/D) ratio. Bar skimming for commercial sediment production typically increases W/D by varying degrees. As a result, pool maintenance processes can be significantly impaired when alternate bars are removed.

3.3.3   Effects on Riparian Vegetation

The riparian zone represents the transitional area between uplands and stream channels, and is itself a transitional feature with varying zones of disturbance, moisture, and vegetation. Riparian areas are used by both aquatic and terrestrial species, thus concentrating many species into a relatively small land area. According to the Natural Resources Conservation Service (NRCS 1999) "riparian corridors are used by over 70% of all terrestrial species during some part of their life cycle, including many threatened and endangered species." Examples of some of the more aquatic dependent species are Pacific giant salamander, red-legged frog, tailed frog, great blue heron, harlequin duck, belted kingfisher, American dipper, water vole, beaver, and river otter (Knutson and Naef 1997). Other benefits of properly functioning riparian zones include: reduced flooding, reduced soil erosion, improved water quality, increased water quantity, groundwater recharge, bank stabilization, and improved air quality (NRCS 1999).

The presence of riparian vegetation adjacent to the low flow channel and within the flood prone area controls or affects morphological stability, microclimate, habitat complexity

and diversity, migration corridors, abundance and retention of large woody debris, filtering of sediment and nutrient inputs from upland sources, nutrient cycling, particulate terrestrial inputs, and seed dispersal (Gregory et al. 1991). Riparian vegetation influences the evolution of geomorphic surfaces and is therefore critical in defining and maintaining the character of a river system (Gregory et al. 1991).

Vegetation, particularly when it is mature, provides root structure, which consolidates the substrate material and encourages channel stability that resists erosion forces (Beschta 1991) and helps to maintain or reduce channel width to depth ratios. By strengthening the form of gravel bars, vegetation enhances the frictional resistance of the bar that acts to dissipate hydraulic energy (Kondolf 1997). This decreases the effective channel gradient, moderates flow velocities, and prevents undue erosion downstream. The reduction in size or height of bars can cause adjacent banks to erode more rapidly or to stabilize, depending on how much sediment is removed, the distribution of removal, and on the geometry of the particular bed (Collins and Dunne 1990).

Forested riparian zones create their own microclimates by moderating solar input during the summer and reducing heat loss during the winter. Reduced solar input along with increased humidity combine to form a moderated microclimate that is heavily utilized by various terrestrial species. The degree of shading is related to the canopy height and density in relation to the channel width and to the geographic location and directional orientation of the channel (Gregory et al. 1991).

Functioning riparian zones provide the necessary stability to support a diversity of backwater and microhabitat features in the floodplain. These features are created during scouring flood events, channel avulsions, wind throw, and other natural disturbances. Chute cut-off channels that are "sealed" with large wood on the upstream end provide excellent backwater habitat and also provide refugia during flood events. The diversity and complexity of the riparian zone and floodplain add diversity and complexity to the stream system as flows expand into the floodplain during high flow events.

Since riparian zones tend to be linear, they provide a natural migration corridor for terrestrial species. This is especially important in disturbed areas where habitat is fragmented. Marbled murrelet, elk, marten, some types of bats, beaver, and bald eagle use riparian zones as travel corridors for seasonal migration (Knutson and Neaf 1997). Riparian corridors can be narrow to wide, can have a simple to complex plant community structure, and can have low to high connectivity (NRCS 1999). Bar scalping typically widens the stream channel and hence decreases the width of the riparian zone. Connectivity is also decreased as access roads increase edge habitat and cause habitat fragmentation.

Riparian vegetation can also be adversely affected by the removal of large woody debris within the riparian zone during sediment removal activities (Weigand 1991; OWRRI 1995). Large woody debris often protects and enhances the recovery of vegetation in streamside areas (Franklin *et al.* 1995) because it influences hydraulics and disrupts sediment transport (Hupp and Ostercamp 1996). The riparian zone acts as both a source

for large woody debris and a factor in retention time. Natural bank erosion and tree mortality provide a source for large and small woody debris in stream channels. Floodplain roughness due to riparian vegetation disrupts flow paths and intercepts floating woody debris which may: (1) create initially small jams that form new floodplains, (2) collect at the head of existing islands, or (3) reinforce an existing floodplain (Gregory *et al.* 1991).

Nutrient, sediment, and environmental pollutant filtration, retention, and processing is another important component of the riparian zone. Riparian buffer widths are often determined based on their ability to filter out sediments and/or specific nutrients. According to Knutson and Neaf (1997), 40 – 99% of organic debris and environmental pollutants can be filtered and biodegraded by riparian vegetation and soils. Decreasing the width of the riparian zone, either directly or indirectly, results in a decrease in the buffering or filtering capacity and may negatively affect water quality.

According to Gregory and others (1991) much of the food base for stream ecosystems is derived from adjacent terrestrial ecosystems. Riparian vegetation is an important component of the food web because it supplies nutrients via leaf fall and insect drop into the active stream channel. Both aquatic invertebrates and vertebrates consume this "outside" source of energy which provides one of the building blocks for the aquatic ecosystem (Gregory *et al.* 1991).

Sediment removal conducted at rates exceeding sediment influx that results in channel degradation will trigger similar declines in the water table. The riparian vegetation may not be able to reach the lowered water table, or stress may occur in lifting the water from greater depth. This may result in a complete loss of riparian vegetation or a change in the community structure.

Sediment removal projects can cause the direct or indirect destruction of riparian vegetation along one or both streambanks in the project area. Annual bar skimming removes riparian vegetation that would otherwise colonize gravel bar surfaces. In the stream reaches that are not confined by levees or naturally resistant boundaries, long-term or repeated modification of gravel bars at low elevations promotes frequent channel shifting that precludes the establishment of mature riparian vegetation. In the absence of anthropogenic disturbance, this vegetation would have the potential to grow and develop through several stages of ecological succession (Hupp and Ostercamp 1996; Sonoma County 1994). Gravel bars are incipient floodplain features. Left undisturbed, these bars may aggrade over time, allowing for the establishment of vegetation and further development of floodplain. Opportunities for colonization and succession of riparian plant communities are limited for the duration of sediment removal activities and remain limited until the bars recover to a height where flood flows no longer scour emergent vegetation annually.

Heavy equipment, processing plants and sediment stockpiles at or near the extraction site can destroy riparian vegetation (Joyce 1980; Kondolf 1994a, OWRRI 1995). Heavy equipment also causes soil compaction, potentially increasing erosion by reducing

rainfall infiltration and causing overland flow. Road construction, road use, and temporary bridges associated with sediment removal projects can also degrade the riparian zone.

Plant communities in the floodplain include submerged species in the channel, emergent species along the margins of the river, and species along the banks and adjacent of the river. Any change in substrate and/or depth is likely to affect species composition (Bolton and Shellberg 2001). A few rare plants in Oregon that may occupy gravel areas, stream terraces, floodplain pools, ponds, and backwater channels include: Astragalus diaphanus var. diurnus, Howellia aquatilis, Lomatium cookie, Rorippa columbiae, and Sphaerocarpos hians (J. Christy personal communication 2003).

3.3.4   Effects on Stream Complexity and Diversity

Sediment removal from bars can create a wider, more uniform channel section with less lateral variation in depth, and can reduce the prominence of the pool-riffle sequence in the channel (Collins and Dunne 1990). Channel morphology is simplified as a result of degradation following sediment removal (Church et al. 2001). Reporting on an experiment, Lisle and others (1993), elegantly illustrate the channel degradation process. In a laboratory flume, a series of alternate bars were developed by flow and sediment feed until equilibrium developed. Sediment feed was then reduced to one-third of its former rate to simulate sediment removal at a point upstream. The artificial channel incised by twice its former mean depth and bed particle size increased (increased armoring). The downstream bars emerged and became inactive surfaces. Degradation initially creates a deeper, narrower channel. Back channels are cut off and adjacent wetlands are dewatered. Initially complex channels tend to degenerate toward less sinuous, single-thread channels; these effects directly reduce habitat diversity.

Removal or disturbance of instream roughness elements that may occur during sediment removal activities diminishes habitat complexity and the quality and quantity of fish habitat. Instream roughness elements, particularly large woody debris, play a major role in providing structural integrity to the stream ecosystem and providing critical habitat features (Koski 1992; Naiman et al. 1992; Franklin et al. 1995; Murphy 1995; OWRRI 1995). These elements are important in controlling channel morphology and stream hydraulics, in regulating the storage of sediments, and in creating and maintaining habitat diversity and complexity (Franklin et al. 1995; Koski 1992; Murphy 1995; OWRRI 1995).

Large woody debris in streams creates pools and backwaters that fish use as foraging sites, overwintering areas, refuges from predation, and rearing habitat (Koski 1992; OWRRI 1995). Large wood jams at the head of sediment bars can anchor the bars, creating more stable features, and increase sediment recruitment behind the jam. Loss of large woody debris from sediment bars can also negatively impact aquatic habitat (Weigand 1991; OWRRI 1995). The importance of large woody debris has been well-documented, and its removal can often result in an immediate decline in fish abundance (e.g., see citations in Koski 1992; Franklin et al. 1995; Murphy 1995; OWRRI 1995).

3.3.5   Effects on Water Quality

a. Episodic turbidity. Various instream sediment disturbance or removal actions may increase turbidity at different time periods. Extraction of sediment from wet stream channels suspends fine sediment during times of the year when concentrations may normally be low and hence the stream is less able to assimilate suspended sediment (Weigand 1991). Newly exposed areas of fine sediment will cause elevated levels of turbidity during the first freshet. Sediment removal or disturbance above the wetted stream may still create a persistent source of turbidity from the crossing of streams by heavy equipment and from activities associated with bridge construction occurring during the summer low-flow period. Stream crossing and bridge building activities are likely to cause short-term increases in turbidity during periods of low stream flow when aquatic species present may be stressed by other environmental factors such as high water temperatures.

The severity of impacts to fish from suspended sediment pollution is generally acknowledged to be a function of sediment concentration and duration of exposure. Newcombe and Jensen (1996) performed a meta-analysis of 80 published studies on fish responses to suspended sediment in streams and developed empirical equations that relate biological response to duration of exposure and suspended sediment concentrations.

b. Temperature. Stream temperature is affected by numerous factors, but the four predominate factors include climate, stream morphology, groundwater interaction, and riparian condition (Poole and Berman 2001). Impacts associated with some mining operations, such as increases in the channel width to depth ratio, loss of hyporheic storage, loss of floodplain connectivity, removal or exclusion of riparian vegetation, and loss of channel complexity, can lead to increases in water temperature during summer months and decreases during winter months (Poole and Berman 2001, Beschta et al. 1987). Disturbance of streambed structure, particularly gravel bars, affects hyporheic exchange, which may be one of the most important stream temperature buffers (Poole and Berman 2001).

c. Dissolved Oxygen and pH. According to the Oregon Water Resources Research Institute's 1995 report concerning gravel mining impacts in Oregon, "[e]xposure of unoxidized (anaerobic) layers of sediments by gravel removal and other operations can lead to appreciable oxygen demand, both as biochemical oxygen demand (BOD) and as chemical oxygen demand (COD) from oxidation of reduced inorganic compounds (e.g., ferrous iron, sulfides, ammonia). Oxygen depletion of the water column occurs in the vicinity of and downriver from the gravel removal operation." (OWRRI 1995). Reactive sediments may undergo a chemical change when resuspended, potentially reacting with hydrogen ions which can result in a change in pH. Except under unique circumstances, changes in pH due to aggregate extraction are expected to be minimal (OWRRI 1995).

d. Toxic Compounds and Heavy Metals. Gravel bars proposed to be excavated located near urban centers or downstream of known contaminated sites (such as Superfund sites), may pose a risk of disturbing and mobilizing contaminated sediments and heavy metals that may be temporarily stored in the bed or banks of the stream. In such cases, the material in the area proposed to be excavated will be required to be fully characterized to ensure that the proposed project will not disturb any contaminated material in such a way that would likely cause elevated levels of any water quality criteria for those contaminants.

3.3.6   Fish and Wildlife

Sediment removal operations use heavy equipment and need access to sediment deposits. Interactions with equipment and sediment removal surfaces can be potentially harmful or lethal to aquatic and riparian dependent species. Access roads through the riparian zone may require removal of vegetation and can compact soils. Impacts may be immediate (e.g. crushing, turbidity, noise, light), or delayed (e.g. stranding, loss of habitat, passage blockage or delay). Many impacts are delayed since most gravel removal in Oregon occurs during low flow periods when many species of concern are not present.

a. Salmonids. Cover is an important habitat component for juvenile salmonids, both as velocity refuge and as a means of avoiding predation (Shirvell 1990; Meehan and Bjornn 1991). Salmonid juveniles will balance their use of cover and foraging habitats based on their competing needs for energy acquisition and safety (Bradford and Higgins 2001). Critical forms of cover include submerged vegetation, woody debris, and the interstitial spaces of streambed gravel substrate (Raleigh et al. 1984). Steelhead juveniles will respond to threats of predation, including overhead motions, by huddling together and/or fleeing to nearby cover (Bugert and Bjornn 1991). Few young of the year (YOY) salmonids are found more than one meter from cover (Raleigh et al. 1984). Juvenile steelhead, particularly the younger, smaller individuals, have a notably docile response to disturbance; they rely on nearby substrate particles (i.e., gravel) for cover more so than other salmonids (Chapman and Bjornn 1969; Wesche 1974; Everest and Chapman 1972).

Frequently disturbed stream channels have relatively less abundance and diversity of cover habitat for juvenile salmonids. Therefore, in sediment removal areas, hiding in substrate pores may be the main response to threats. Even where other forms of cover are present, YOY will respond to noise, movement, and other disturbances by entering pore spaces in the streambed at riffles.

Equipment used for sediment removal usually cross wet stream channels where water depth is shallowest, at riffles. Because this is an important habitat for salmonid juveniles, where these fish occur in areas of channel crossing, it is likely that a portion of the juveniles in the path of equipment would take cover within the gravel and be crushed as the equipment passed over. Multiple observations by NOAA Fisheries biologists indicate that even wading fishermen can crush juvenile salmonids hiding within gravel substrate. Therefore, it is difficult to scare, herd, or chase juveniles, with certain effectiveness, from stream crossings ahead of equipment.

b. Bull Trout. Bull trout have more specific habitat requirements than most other salmonids (Rieman and McIntyre 1993). Habitat components that particularly influence their distribution and abundance include water temperature, cover, channel form and stability, spawning and rearing substrate conditions, and migratory corridors (Fraley and Shepard 1989; Watson and Hillman 1997).

Bull trout are closely associated with stream substrates and are particularly vulnerable to substrate alterations, fine sedimentation, and channel instability. Spawning areas often are associated with cold-water springs, groundwater infiltration, and the coldest streams in a given watershed (Pratt 1992; Rieman and McIntyre 1993; Rieman and Clayton 1997). The preferred spawning habitat of bull trout consists of low-gradient stream reaches with loose, clean gravel (Fraley and Shepard 1989). Depending on water temperature, egg incubation is normally 100 to 145 days (Pratt 1992). Juveniles remain in the substrate after hatching, such that the time from egg deposition to emergence of fry can exceed 200 days. During the relatively long incubation period in the gravel, bull trout eggs are especially vulnerable to fine sediments and water quality degradation (Fraley and Shepard 1989). Increases in fine sediment appear to reduce egg survival and emergence (Pratt 1992). Juveniles are likely similarly affected. High juvenile densities have been reported in areas characterized by a diverse cobble substrate and a low percent of fine sediments (Shepard *et al*. 1984). Baxter and McPhail (1996) reported that newly emerged fry are secretive and hide in gravel along stream edges and in side channels. The stability of stream channels and stream flows are important habitat characteristics for bull trout populations (Rieman and McIntyre 1993). The side channels, stream margins, and pools with suitable cover for bull trout are sensitive to activities that directly or indirectly affect stream channel stability and alter natural flow patterns. For example, altered stream flow in the fall may disrupt bull trout during the spawning period, and channel instability may decrease survival of eggs and young juveniles in the gravel during winter through spring (Fraley and Shepard 1989; Pratt 1992).

Bull trout typically spawn from August to November during periods of decreasing water temperatures. Such areas often are associated with cold-water springs or groundwater upwelling (Rieman and Clayton 1997). Bull trout rely on migratory corridors to move from spawning and rearing habitats to foraging and overwintering habitats and back. Bull trout are opportunistic feeders; resident and juvenile migratory bull trout prey on terrestrial and aquatic insects, macro-zooplankton, and small fish (Donald and Alger 1993; Baxter and McPhail 1996). Adult migratory bull trout feed almost exclusively on other fish (Rieman and McIntyre 1993). Throughout their lives, bull trout require complex forms of cover, including large woody debris, undercut banks, boulders, and pools (Fraley and Shepard 1989).

Disturbed channels can directly affect the ability of bull trout to migrate, spawn, and rear. While bull trout may not spawn in most areas utilized for gravel mining in Oregon they may be affected while over-wintering, foraging, and migrating. They may also be affected indirectly from a reduction in forage base, loss or reduction of available cover habitat, migration barriers, or thermal barriers.

c. Oregon Chub. The Oregon chub (Oregonichthys crameri) is a small minnow endemic to the Willamette River drainage of Oregon. This species was formerly distributed throughout the Willamette River Valley in off-channel habitats such as beaver ponds, oxbows, stable backwater sloughs, and flooded marshes. These habitats usually have little or no water flow, have silty and organic substrate, and have an abundance of aquatic vegetation and cover for hiding and spawning (Scheerer et al. 2003). Historically, rivers overflowed their banks, scouring new side channels and backwaters while filling in other areas. Habitat loss has occurred from the loss of these floodplain habitats. This loss of habitat combined with the introduction of nonnative species to the Willamette Valley resulted in a sharp decline in Oregon chub abundance.

Oregon chub can be affected by aggregate extraction activities by the direct loss of backwater habitats and riparian vegetation, and indirectly through the change in flooding regimes or channel degradation.

d. Lamprey. Three species of lamprey (Lampetra sp.) occur in Oregon; the Pacific, river, and western brook lamprey. The Pacific and river lamprey are anadromous and parasitic, while the western brook lamprey is neither anadromous nor parasitic. Lampreys spawn in similar conditions to salmon -- in riffle areas of gravel bottom streams within nests. However, occasionally they construct nests in sandy substrates. Most of the adults die after spawning. When lampreys hatch, they are a larval form called ammocoetes that are carried by the current to low velocity areas of soft mud or sand in pools, side channels, or other backwater habitats. They burrow themselves with their head up and filter feed on algae and organic matter. These worm-like filter-feeders spend 4-6 years in freshwater before transforming into young adults with eyes and teeth. The anadromous lampreys move to the ocean or estuaries where they grow and feed by parasitizing other fish. They spend a few months to several years in the ocean and then return to freshwater, and like salmon they do not feed during their migration.

High concentrations of ammocoetes are important because they filter organic matter from the water column and they are a food source for other fish such as salmon and sturgeon, and other animals as well. The adults are an important food source for many birds, fish, and mammals such as seals and sea lions.

Their unique life history makes them susceptible to the same habitat impacts as salmon, but their larval form makes them even more prone to impacts that affect water quality and quantity and stream channel changes. Some of the potential threats to lamprey include: dams, culverts and other artificial barriers; water diversions and low stream flows; water quality impairments; streambed degradation from dredging, bed-scouring, channelization, and destruction of riparian vegetation; altered ocean conditions; over-utilization for commercial or recreational purposes. Their close association with channel bottoms makes them very susceptible to substrate disturbances such as gravel extraction, streambed degradation, sedimentation, and loss of floodplain wetlands, side channels, and other slow backwater habitats.

e. Wildlife. Many semi-aquatic and terrestrial wildlife species are very dependent upon the various floodplain habitats. A variety of species use early successional and emergent vegetation along gravel bars for cover and foraging. The near-stream, riffle, and flatwater habitats are also used by many amphibians, reptiles, birds, and mammals for foraging. Gravel bars with large wood and a variety of substrate can serve as cover for small mammals and other wildlife, as well as basking habitat for pond turtles. Floodplain habitats are very high in overall species richness, and gravel bar habitat has been shown to contain a great abundance, high species richness, and unique species composition for riparian beetles (LaBonte 1998). Arthropods play a critical link in the food web as well and are essential to ecosystem function.

Some amphibians utilize streams for breeding -- generally the slower backwater habitat and ponds associated with gravel bars. Stream breeders include tailed frogs and Cope's and Pacific giant salamander. Many amphibians also utilize flatwater and riffle habitats. Gravel bars, stream edges, and backwater areas provide foraging, cover, and basking areas for many reptiles and amphibians (Table 1). Disturbance and alteration of gravel bar topography, backwater ponds, and microhabitats reduces habitat for feeding and breeding areas for a variety of amphibians and reptiles.

A high percentage of birds are dependent on riparian areas for at least a portion of their lifestage. In Washington, one study found that 101 bird species depend on riparian habitats exclusively (Knutsen and Naef 1997). Eagles, osprey, and great blue herons are a few of the birds that depend on other prey species, such as fish, frogs, and small mammals, in the riparian area. Many birds use gravel bars for foraging and roosting, and some, such as killdeer, may use them for nesting areas.   A variety of species such as the American dipper, harlequin duck, least tern, piping plover, and spotted sandpiper are closely associated with stream systems and their habitats (Table 1).

The value and use of floodplain habitats for wildlife movement, foraging, cover, and reproduction is critical and well-documented for many species. Loss and/or disturbance to these areas will have deleterious effects on wildlife populations and ecosystem function.

Table 1. Table of wildlife species use of stream and associated floodplain habitats that may be affected by gravel mining operations (not all inclusive).

Species	Stream Use	Gravel Bar Use	Backwater Use	Other notes
Pacific giant salamander *Dicamptodon tenebrosus*	Breeding	Cover, forage		Impacted by sedimentation
Northwestern salamander *Ambystoma gracile*	Breeds in slow streams		Breeding	Lives underground
Southern torrent salamander *Rhyacotriton variegatus*	Breeding	Cover & forage	Cover	
Northern red-legged frog *Rana aurora aurora*	Slow streams for breeding	Cover	Ponds for breeding	Terrestrial outside of breeding period
Oregon spotted frog *Rana pretiosa*	Forage & cover	Cover, forage, and	Ponds for breeding & cover	Most aquatic native frog using floodplain habitats
Foothill yellow-legged frog *Rana boylii*	Breed low gradient rivers gravel substrate	Cover, forage	Pools for foraging & cover	
Western toad *Bufo boreas*	During dry periods	Basking	Ponds for breeding	Adults live underground & debris
Pond turtle *Clemmys marmorata*	Foraging	Basking and cover, LWD	Foraging & cover	Nest and torpor in upland areas
Garter snake *Thamnophis elegans*	Stream margin for cover & feeding	Basking, cover, feeding	Cover, foraging	Upland areas for breeding
Spotted sandpiper *Actitis macularia*	Foraging	Nesting		
Harlequin duck *Histrionicus histrionicus*	Foraging	Nests under banks or vegetation		
Killldeer *Charadrius vociferus*	Foraging	Nesting		
American Dipper *Cinclus mexicanus*	Foraging	Nesting		
Wood duck *Aix sponsa*	Foraging	Foraging, loafing	Foraging	Nests in trees, needs vegetation
American belted kingfisher *Megaceryle alcyon*	Foraging			Nest in streambanks
Great Blue Heron *Ardea herodias*	Foraging	Foraging	Foraging	Nests in tree tops in colonies
Water shrew *Sorex palustris*	Foraging		Nesting	Nests in vegetation, tunnels or under logs
River Otter *Lutra canadensis*	Foraging	Basking	Foraging, cover	Breeds in river banks
Beaver *Castor canadensis*	Forage, breed		Breed, forage	
Black bear *Ursus americanus*	Forage	Forage	Cover	
Bats *Myotis sp.*	Foraging and drinking		Roosts in trees	
Mink *Mustela vison*	Foraging, travel	Forage	Cover	Breed in streambanks

3.4 DISTURBANCE REGIMES

Stream systems are disturbance driven. Disturbances include natural variations in flow regimes and flood events, sediment delivery to the system, large inputs of organic materials, changes in base level, and other mechanisms which serve to temporarily or permanently alter the character of a stream or river. Disturbances are often described by their frequency (such as the 100-year flood), duration (length of time), magnitude (areal extent), intensity (force exerted), and severity (biological response) (OWRRI 1995). In Oregon, the two most recent major disturbances that are considered "benchmarks" for stream processes are the 1964 and 1996 floods.

Although sediment transporting events may occur on an annual basis, and may be compared to aggregate extraction activities, they are temporally distinct from natural events. Natural sediment transporting events in Oregon generally occur during the late fall, winter, and spring, whereas sand and gravel excavation typically occurs in the summer months during low flow periods. "Over the last six million years salmonids have evolved within the natural disturbance regime. Novel disturbances can shift the ecological rules governing community structure making the recovery of the original biota impossible" (OWRRI 1995).

Streambeds within the active stream channel experience the greatest frequency of geomorphic disturbance that may be on the order of every year or two (sediment transporting events). Side channel and backwater areas are not as frequently disturbed, but are affected by higher flow events and channel avulsions (perhaps 5 to 10-year flows). Generally, floodplains have even less frequent disturbances than the main and side channels; it may require a 10-year or larger flood event before a floodplain can be significantly altered. Terraces and hillslopes typically have the lowest frequency disturbance regime when placed in context of stream processes (slope failures and mass movement). Common to all of these disturbances is the episode of disturbance followed by a period of recovery (OWRRI 1995). If the disturbances become so frequent that the system cannot recover before the next disturbance event, then the stream is held in a constant state of disequilibrium or instability.

According to Poff (1992) "[t]hat a physical event may constitute a disturbance at one level but not another indicates the hierarchical nature of disturbances." Related to this hierarchy of physical disturbances, is relative stability of various habitat types. Habitat stability in the main channel is generally on the order of years (even though habitat units may form and reform in the same place for tens of years), whereas habitat stability on the floodplain may be on the order of decades.

Organisms respond to disturbances very differently depending upon their differences in developmental times, behavioral movements, and responses to environmental factors (OWRRI 1995). For instance, anadromous salmonids recover from massive disturbances, such as extreme floods, by having multi-year life spans that ensure a stable population even if an entire year class of fish are lost in a single flood event. Pringle (1997) argues that downstream human activities such as urbanization, dams, gravel

mining, and channelization can cause upstream biological legacies such as genetic isolation, population-level changes, and ecosystem-level changes.

Alteration of a punctuated disturbance regime (as described above) to one of chronic disturbance overlain with larger infrequent disturbances, often results in a change of plant, fish, and wildlife communities that are more adapted to constant disturbance (OWRRI 1995). Incised streams and engineered channels may be subject to chronic disturbance because of floodplain disconnection. Instream activities, such as aggregate extraction, can cause chronic disturbance with a concomitant change in habitat and species.

3.5   SUMMARY OF EFFECTS

Sediment removal from streams can result in bed degradation, bank erosion, channel and habitat simplification, reduced geomorphic processes such as pool maintenance, sediment sorting, and sediment intrusion, reduction in large woody debris, direct or indirect loss of riparian zones, and lowering of the shallow aquifer/hyporheic zone. Adverse biologic effects may include reduced primary productivity and macroinvertebrate populations, reduced ability for fish to avoid predators, reduced fish growth and success, reduced riparian vegetation and all associated aquatic and terrestrial benefits, reduced water quality, and direct mortality of fish.

Most rivers experiencing sediment removal activities are also subject to additional anthropogenic influences that could induce physical and biological changes similar to, or compounded by, those caused by instream sediment removal. Other influences include increased peak runoff from land use changes in the catchment, bank protection and flood control works, or upstream dam construction and water withdrawal. Stream alterations typically increase sediment transport rates and lead to deeper incised channel geometry. Channel degradation is caused by individual or compounded stream management actions including: channelization, flood control, riparian vegetation removal, encroachment, dam construction, water table declines, and sediment extraction. Most Oregon streams have had more than one such alteration visited on them in the past century. The only system-wide alteration that can counteract the degradation tendency is increased sediment production within the watershed. Although land use practices have increased sediment production in many of Oregon's watersheds, the era of greatest impact is waning. Past sediment removal may have benefited the recovery of channels disturbed by increased sediment loads, but as the production of sediment returns to semi-natural levels, the continued removal may need to be curtailed to prevent unwanted channel degradation. This has already happened in some California streams (e.g. Kondolf and Swanson 1993; Collins and Dunne 1990; Florsheim et al. 1998).

The current scientific and gray literature, reviewed in this document, explains a wide range of harmful physical and biotic effects resulting from sediment removal. Table 2 briefly lists the effects of sediment removal from streams.

Table 2. Summary of effects of instream sediment removal.

Element of Instream Sediment Removal	Physical Effect
Removal of sand and gravel from a location or from a limited reach.	Upstream and downstream propagating degradation.
	Scour of upstream riffle.
	Reduced pool area.
	Bed surface armoring.
Removal of sand and gravel from a bar.	Loss of sand and gravel from neighboring bars.
	Wider, more uniform channel section, less lateral variation in depth, reduced prominence of the pool-riffle sequence.
Removal of sediment in excess of the input.	Channel degradation (incision).
	Lower groundwater table.
	Complex channels regress to single thread channels.
	Armoring of channel bed, may lead to erosion of banks and bars.
Reduced sediment supply to downstream.	Induced meandering of stream to reduce gradient. Erosion on alternate banks downstream.
Removal of vegetation and woody debris from bar and bank.	Reduce shade.
	Decrease channel structure from wood.
	Decrease drop-in food, nutrient inputs.

Geomorphic features within stream channels can recover from disturbances given adequate time, sufficient flow magnitude, and sediment supply. With alteration in runoff hydrology and sediment supply due to dams and land management, geomorphic recovery may be protracted. The basic building blocks for recovery, floods and sediment, are generally lacking. Once there is geomorphic recovery, we can expect ecologic recovery to follow.

Many of Oregon's major rivers have been subjected to repeated sediment removal activities, periodic dredging to maintain navigation, significant channel alteration for flood security reasons, floodplain/channel encroachment, and bank stabilization projects. This has resulted in substantial changes in the quality, quantity, and diversity of aquatic habitats. Channels have been simplified through straightening, large wood removal, and levee confinement. Many channels have either purposefully or inadvertently been disconnected from their floodplains resulting in the loss of side channel and back water areas. Where riparian areas remain, their extent and integrity have been diminished. All of these activities have culminated in simplified stream channels that may not provide sufficient habitat type, quantity, and quality for maintenance and recovery of native aquatic communities.

4   CURRENT METHODS & RECOMMENDATIONS FOR SEDIMENT REMOVAL

4.1   HISTORY

In the 1995 report "Gravel Disturbance Impacts on Salmon Habitat and Stream Health", the Oregon Water Resources Research Institute (OWRRI) set forth numerous recommendations to the Oregon Department of State Lands (DSL) for minimizing impacts to Oregon streams; these are summarized below.

1. Recommendations to Improve Present Management of Removal-Fill Operations
    a. Improve data collection related to removal-fill operations;
        i. Conduct monitoring and research to evaluate impacts;
        ii. Improve DSL database capabilities and use;
        iii. Implement GIS-based resources management;
        iv. Allocate sufficient financial resources and staff to monitor resource abundance, condition, and use.
    b. Minimize Additional Degradation of Salmonid Habitat
        i. Prohibit, regulate, or otherwise manage small operations;
        ii. Conduct removal-fill operations in a manner to minimize potential impacts on salmonid habitats;
        iii. Allow bar skimming gravel removal under restricted conditions;
            1. The gravel bar is not an active spawning, rearing, or feeding area for salmonids;
            2. Adequate recruitment exists so that the bar is typically replenished each year;
            3. Berms and buffer strips be used to control stream flow away from the location of gravel removal;
            4. Gravel is removed only during low flows and from above the low-flow water level; and
            5. The final grading of the gravel bar does not significantly alter the flow characteristics of the river at high flows.
        iv. Restrict deep water dredging for gravel production to areas where presently practiced;
        v. Do not allow a net loss of wetlands for all removal-fill operations;
        vi. Use biological streambank stabilization methods where possible.
2. Recommendations to Improve Comprehensive Management of Removal-Fill Operations
    a. Improve present policy by the burden of proof of "no significant impact" shifting to permit applicants;
    b. Do not allow gravel extraction from reaches of DSL-managed streams that support sensitive, threatened, or endangered species;
    c. Do not allow gravel extraction from reaches of DSL-managed streams that are a part of aquatic diversity areas or support source salmon populations;
    d. Promote recycling efforts.

3. Recommendations for Research Activities Related to Removal-Fill Operations
    a. Develop plans to increase gravel availability;
    b. Develop strategies to increase salmonid and aquatic habitat;
        i. Develop methods to convert former flood plain gravel pits into productive habitat;
        ii. Use gravel mining as a potential method for developing wetlands, off-stream channels, lakes and ponds, and potential salmonid spawning beds.
    c. Ensure compatibility of policies with existing watershed initiatives in Oregon.

In 2002, at the request of DSL, the Independent Multidisciplinary Science Team (IMST 2002) reviewed the OWRRI Recommendations (listed above) and actions that have been taken by the state. The IMST found the OWRRI report to be technically sound, endorsing both the report and the recommendations (IMST 2002). Furthermore, the IMST provided additional technical information regarding channel morphology (i.e. increased stream gradient due to channel straightening), bedload transport and sediment budgets, cumulative effects (permit statistics are not a surrogate for proper evaluation), and monitoring (effectiveness monitoring vs. compliance monitoring). The IMST went on to make 10 additional recommendations:

1. The Oregon Plan core Team should develop a statewide policy on the management of stream sediments and bedload transport;
2. DSL should develop and integrate a basin level approach into its management policies;
3. DSL should determine sediment budgets and bedload transport rates on stream reaches with permitted aggregate mining operations;
4. DSL should track the actual amount of aggregate removed by permit holders;
5. DSL, in cooperation with ODFW, should assess the cumulative impacts of aggregate mining on streams with declining salmonids;
6. DSL should increase the technical expertise of geomorphology and hydrology within the agency;
7. ODFW and DSL should identify critical salmonid migration routes not currently protected under the *Essential Indigenous Salmonid Habitat* (ORS 196.810(b); OARS 141-102-0000 thru 0040) designation where impediments to migration be occurring due to removal-fill activities;
8. DSL and ODFW should develop an effectiveness monitoring program to determine if permit conditions under the Removal-Fill Law and General Authorizations maintain and protect salmonid fish habitat including gravel substrate, fish populations, and riparian conditions;
9. State land Board and DSL should develop an adaptive management process that is linked to the effectiveness monitoring program; and
10. DSL should incorporate both the technical aspects of the 1995 report, *Gravel Disturbance and Impacts on Salmon Habitat and Stream Health*, prepared by the Oregon Water Resources Research Institute into their operations and policies, and the recommendations in this report.

The OWRRI (1995) and IMST (2002) recommendations laid heavy emphasis on program and management level changes that could be made to minimize natural resource impacts due to instream gravel mining. The remainder of this chapter focuses on project and operational level changes that can be made in order to minimize impacts to aquatic habitat, assuming that the appropriate program and management changes have been implemented.

4.2 INTRODUCTION

Sediment removal from within stream channels can immediately alter channel geomorphology, hydraulics and sediment transport, and fish habitat (see Chapter 3). Depending on the scale and method of removal, many of the adverse effects can last for many years to as little as one year. However, effects can last for centuries if channel incision occurs. The adverse effects of excavating alluvial sediment from stream terraces or floodplains may not occur for several decades, but the potential effects of pit capture by streams can be long lasting and severe. Therefore, proper assessment of the effects of stream sediment removal should consider two time-scales: short-term (up to 5 years), and long-term (> 5 years), which corresponds to the typical permit length.

The effects of sediment removal should also be considered at two spatial scales: the area of direct disturbance (local), and a much larger area that has physical or biological connection to the disturbed area (off-site). When quantifying the extent of disturbance, both the local and off-site areas should be included. If mining is conducted at a small scale (relative to channel size), the effects of sediment removal from the channel may only be localized; furthermore, those effects may last only a few years or until the next large storm flow occurs. On the other hand, large scale sediment removal, the combined effects of multiple mining operations in a given stream length, or sediment removal combined with other stream management techniques (such as bank armoring) that can alter the sediment budget, can have far reaching effects that extend both upstream and downstream (off-site effects). Therefore, it is recommended that potential effects to aquatic habitat be considered at a variety of temporal and spatial scales when evaluating a sediment removal proposal.

The intent of this chapter is to describe how different excavation methods result in altered physical processes that create and/or maintain important aquatic habitat, and to provide an understanding of the limitations of existing regulatory methodologies. The recommendations in the following sections are not meant to be all inclusive or binding, rather, they are suggestions which will be modified and improved upon as more data are collected on the various methodologies presented and as new techniques are developed. Project recommendations must be made specific to individual sites, streams, and watersheds.

Although the commercial extraction of stream sediment is a historical industry within which there is copious accumulated practical experience, there is surprisingly little in the scientific literature in regards to minimizing adverse ecological impacts while

maintaining present extraction rates. In the face of limited information, it is prudent to proceed with caution.

Commercial sediment removal generally poses low risk in channel locations where: (1) degraded habitat can be improved by sediment removal, (2) the interactions between aquatic species of interest and negative effects due to sediment removal are known (and are rare or non-existent), and where (3) risks of habitat loss caused by long-term geomorphic adjustments are low. Various methods have been developed to help minimize harmful effects of sediment removal for commercial purposes and are discussed in the following sections.

4.3   RECOMMENDED PROCESS TO EVALUATE SEDIMENT REMOVAL PROPOSALS

The most effective way to protect or restore aquatic habitats is by protecting the physical processes that create and maintain these habitats. Habitats in properly functioning condition can generally be protected by implementing a combination of three methods that can minimize both the local and off-site disturbances to stream channel habitat: (1) maintain a positive sediment budget, (2) minimize direct habitat modification, and (3) maintain physical processes that create habitat. Habitats that are not in properly functioning condition may need a rest period from active mining while the system recovers, if the habitat degradation is due to the mining activities. Once recovered, the three methods listed above should provide adequate protection of the stream channel habitat.

It is very important that sediment extraction does not intercept high percentages of the incoming coarse sediment load. Methods for estimating sediment budgets are defined in the scientific literature (e.g. Reid and Dunne 2003), but the appropriate percentage that should be allowed to pass downstream requires site specific studies and understanding of the watershed. It is reasonable that commercial sediment removal operations be limited to extracting only portions of the total coarse sediment load if the ultimate goal is to protect aquatic habitat. Providing for a positive sediment budget downstream from extraction sites is a fundamental requirement for the continued ecological function of downstream habitats.

In addition to maintaining a positive sediment budget that supplies coarse sediment to downstream habitat, it is also recommended that physical processes, geomorphic features, and site-specific habitat be protected. To that end, a four-step process for evaluating the effects of sediment removal proposals on aquatic habitat is recommended. The steps include: (1) identify appropriate sediment harvest locations, (2) identify the habitat needs of the existing aquatic species and life stages, and/or habitat needs for species historically found in the area, (3) determine the physical (hydrologic and geomorphic) processes that create or maintain those habitats, and (4) choose a sediment extraction strategy that is adequate to protect those habitats and physical processes. These steps are discussed in detail below.

4.3.1 Identify appropriate sediment harvest locations.

Upland aggregate sources, terraces, and inactive floodplains should be used preferentially to active stream channels, their deltas, and floodplains (NMFS 2005). If floodplain pits are located on adjacent floodplains or terraces, they should be outside of the channel migration zone, as far from the stream as possible (NMFS 2005). If these sources are not available, then other alternatives to instream mining should be evaluated; these include, but are not limited to, placer mine tailings in the channel and floodplain and dredge disposal material from navigation channel maintenance and/or flood control projects. If an instream source of aggregate is identified as the only feasible alternative, then the following should be considered:

a. The cumulative effects of changes in sediment supply should be considered at the watershed scale. Reservoir construction, stream channel straightening, levee construction, bank protection works, and flow regulation can all substantively change the sediment load, morphology and habitat qualities of streams. The effects may occur shortly after project completion or be delayed and/or prolonged for decades. In general, sediment removal from streams is imprudent downstream from reservoirs or where channels are confined between levees or bank protection works, because these changes reduce coarse sediment supply. A sediment budget that accounts for the effects of reservoirs and channel stabilization activities can be used for planning and long-range management of sediment extraction industries.

A sediment budget can be used to limit the volume of material extracted by commercial sediment removal operations to some percentage of the overall sediment load, thus avoiding many of the negative impacts discussed in Chapter 3. However, regulating extraction to a sediment budget does not provide for maintenance of geomorphic features that serve ecological functions including fish habitat.

Regulating extraction by the sediment budget method typically allows for fairly consistent annual extraction rates even though sediment delivery depends on decadal to century-long cycles. Commercial operators and local regulatory agencies may prefer this method because it implies that a long-term average production will protect stream habitats from degradation. Large sediment replenishment events are naturally cyclic and infrequent, hence average sediment yield is a mathematical derivation rather than a physical reality. Progressive levels of disturbance and loss of habitat result from protracted annual extraction rates during prolonged periods between large replenishment events. Maintenance of a steady rate of extraction through prolonged dry periods is undesirable. Neither should extraction rates be increased automatically in response to a major flood.

Sediment transport in streams is exceedingly variable because sediment transport is a power function of stream flow, which varies significantly from year to year, and depends on sediment availability, which is difficult to characterize. Thus, an annual average sediment load may be meaningless (Kondolf 1993; 1994b). A calculated annual average deposition rate could bear little relation to the actual sediment load in a river in any given

year. Moreover, sediment transport processes are very difficult to model, so calculations or other estimates of bedload transport may prove unreliable.

Managing extraction volumes within a sediment budget, and retaining minimal geomorphic form (to define a low flow migration channel, or head of bar to reduce headcutting), is used in California for commercial sediment regulation. The limitations of this approach are that rigorous and reliable sediment budgets are difficult to develop, subject to change from many variables, never provide a definitive metric of safe yield that allows for downstream sediment needs, and are often not carefully interpreted. Even the best sediment budgets provide limited information that will probably not be improved upon soon (Church et al. 2001). The inherent uncertainty in the calculation, as well as poor reporting of volumes extracted, cultivates debates over the formulation and interpretation of sediment budget results. A general lack of understanding or appreciation for the ecological value of sediment continuity can result in an excessive allocation of the long-term average sediment load (Kondolf 1995) rather than a careful interpretation and preservation of the coarse sediment that supplies downstream habitat or even downstream sediment extraction sites.

b. Determine if proposed site is in equilibrium. Determine if the stream reach, which includes the proposed extraction site, is in, or is approaching, a condition of dynamic equilibrium (e.g., Florsheim et al. 1998). Degraded and incised channels are not desirable extraction locations because they are often indicative of a sediment deficit. Channels in approximate equilibrium are also not good candidates for sediment extraction because the sediment input roughly equals the sediment output; large scale sediment extraction would cause the stream reach to become degradational, resulting in channel incision.

Clearly aggrading stream channels, indicated by relatively high width to depth ratios coupled with frequent overbank flooding, are candidates for sediment removal when their sediment loads significantly exceed local transport capacity. Indeed, the morphology and habitats provided by stream channels that have experienced excessive sediment delivery events in recent history, and have clearly aggraded as a result, may be improved by strategic sediment excavation to increase topographic complexity. Naturally aggrading streams are often found in areas where stream gradient abruptly decreases and/or where channel confinement decreases (e.g. alluvial fans).

To determine if a stream is aggrading requires a reconnaissance survey consisting of a combination of fieldwork and examination of existing data, which may include some combination of the following:
- analysis of stream gauge records, especially long-term comparison of individual flow measurements and rating curve shifts (the number of rating tables will give an indication of channel cross-sectional stability and a trend of aggradation or degradation);
- analysis of bathymetry from bridge scour evaluations and/or analysis of bridge as-built conditions with current conditions;
- review of bridge maintenance records, specifically added scour protection;

- examination of in-channel or channel-adjacent cultural features for evidence of scour or deposition (i.e. riprap, diversions, boat launches, etc.);
- analysis of peak flow hydrology, including shifts in magnitudes of index floods or flood patterns (extensive gravel exposure due to recent large floods has the subjective appearance of aggradation when it may actually be a redistribution of sediment and a change in channel cross-sectional shape);
- evidence for changes in cross section shape and area, especially widening and shallowing of channel cross-section, which can be evaluated even where cross-sections are not precisely located;
- examination of streambank heights and relationship with geomorphic bankfull;
- examination of floodplain and bank areas to determine if there is a buried soil horizon;
- review of aerial photos, with ground truthing, to determine if riparian vegetation has been lost due to prolonged saturation, or if there has been a shift from drought tolerant species to species that can tolerate prolonged periods of saturation;
- Semi-quantitative field examination of streambed sediment patterns, including:
    - pavement to sub- pavement size relationships,
    - evidence for pool in-filling
    - buried pavement layers
    - bimodal sediment distributions

None of these study elements alone is capable of driving the conclusion that aggradation is occurring, but taken together they can provide cumulative evidence for that argument.

Incised stream channels experience increased shear stress during a normal range of flood flows. They lack side channels, connected floodplains, and riparian areas, and typically have high, unstable banks, all of which result in limited, low quality aquatic habitat. Restoration of incised streams can involve the excavation of large quantities of floodplain sediment to create inset floodplains and side channels along the existing channel. Through careful design and analysis, stream habitat can be restored or enhanced using sediment excavation strategies (see 4.5.5). Considering the large number of incised streams found throughout the United States, this area of channel restoration and habitat enhancement deserves further research.

c. Stream channel type should be considered. Removal of sediment from stream channels with naturally high width to depth ratios is less risky than from low width to depth ratio streams. For example, braided river channels are better candidates for sediment removal than other river channel types (Dunne et al. 1981). Because braided river systems are highly dynamic and channel shifting is relatively frequent and rapid, channel shifting due to sediment extraction may have less of an impact (Follman 1980). However, not all braided streams are necessarily aggrading (Simpson and Smith 2001).

d. Larger streams are better candidates for sediment removal than smaller streams. Larger stream systems are preferable to smaller stream systems because they have comparatively more sediment, larger channels, and wider floodplains, and the proportionally smaller disturbance in large systems will reduce the overall impact of

sediment removal (Follman 1980). On a smaller stream, the location of the extraction site is more critical because of the limited availability of exposed sediment deposits and the relatively narrower floodplain.

e. Seasonally dry stream channels are better candidates for sediment removal than channels with perennial flow. Perennial streams potentially provide habitat for the entire life histories of a variety of aquatic species. Operations within seasonally dry channels may be less risky than operations in perennial stream channels because immediate impacts can be more effectively addressed, although significant delayed effects might go unnoticed for many years. It is recommended that the methods of sediment removal be tailored to the site in order to enhance channel topographic complexity and channel confinement since fish passage is of special concern in these seasonally dry channels. Additionally, seasonally dry stream channels often have highly mobile beds and unstable banks because of limited riparian stands, making them naturally tend toward lateral and vertical instability. Extraction designs should not compromise the integrity of the stream banks.

4.3.2   Identify species, life stages present, and habitat elements needed.

Site specific geomorphic features (i.e. pools, riffles, bars, and side channels) and their related habitat values should be used to define post-extraction habitat conditions in order to minimize potential deleterious effects of sediment removal. It is recommended that sediment extraction plans promote sediment harvest methods that avoid impacts to all aquatic species known to exist upstream, downstream, as well as within the project area.

Specific life stages for anadromous salmonids to be considered include migratory stages (both upstream and downstream), spawning, egg incubation, fry emergence, and juvenile rearing. Habitats for these life stages are maintained, in part, by the duration and frequency of certain magnitude flows and the effects of those flows on channel morphology. Therefore, to minimize impacts to salmonid habitats, it is recommended that sediment extraction operations preserve important channel features and habitats by anticipating and minimizing adverse geomorphological responses to sediment removal. The following identifies specific geomorphic features and habitat elements that should be preserved for various life stages of anadromous salmonids.

a. Spawning and egg incubation habitat. Where spawning habitat is (or was) important for salmonids, it is recommended that sediment removal activities: 1) maintain pools in size, depth, frequency, and habitat value, 2) maintain or increase topographic complexity of the channel bed riffle-pool complex, 3) protect areas of spawning gravel, and 4) preserve hyporheic flow to incubating eggs and fry. Furthermore, sediment removal surfaces should not increase the likelihood of sediment intruding into redds during incubation or emergence periods.

b. Rearing habitat. Where juvenile rearing habitat is (or was) important for salmonids, it is recommended that sediment removal activities: (1) maintain pools in size, depth, frequency, and habitat value, (2) prevent contamination of coarse riffles with

smaller sediment, and (3) not increase the channel width at riffles. Riparian vegetation should not be disturbed because it contributes to beneficial riparian functions, providing shade, overhanging cover, large woody debris (LWD), and allochthonous energy inputs.

c. Juvenile migration habitat. Where downstream migration of smolts and the unimpeded movement of juveniles between habitats is (or was) important, sediment removal activities should not reduce riparian vegetation that could potentially provide cover, LWD, or roughness and complexity of the channel bed and banks. Food production within the substrate is important to the juvenile life stage. It is recommended that sediment removal not reduce the availability of cobble-sized sediment particles known to support the highest production of macroinvertebrates (*i.e.* food sources) for juvenile rearing.

d. Adult migration habitat. Where anadromous salmonids migrate upstream, it is recommended that sediment extraction not adversely affect the migration pathway. Migrating adult salmonids should not be subjected to migration delays or increased energy expenditure resulting from channel simplification over the range of flows during which the target fish species migrate.

4.3.3   Identify physical processes that create or maintain habitat elements.

This step of the recommendations identifies the physical processes that coincide with specific hydrologic and geomorphic events necessary for the creation and maintenance of aquatic habitat.

a. Mature riparian vegetation provides cover. Stable substrate, infrequent disturbance, and adequate moisture are needed to sustain the ecological succession of riparian plant communities. Dense vegetation on stream banks and mature bars support plant succession. LWD inputs arise through the interaction of mature riparian forests and normal channel migration processes. Riparian forests provide refuge for many aquatic species during high flow events, air and water temperature amelioration throughout the year, bank stability, aquatic and terrestrial cover, and allochthonous inputs to the stream.

b. Dominant flow maintains channel morphology. Sediment mining areas can become so highly disturbed by repetitive extraction at rates in excess of the sediment supply that pool-riffle formation processes can no longer function during channel forming flows. Areas in this condition do not provide adequate rearing, spawning, or even effective migration habitat for fish. Continued removal of sediment exacerbates and prolongs the time needed for natural recovery of the geomorphic forms and functions that contribute to provision of aquatic habitat. The appropriate action to remedy the effects of excessive disturbance should include restoration of geomorphic attributes and physical processes that ensure habitat recovery.

c. High flow events maintain pools. During high flow events (generally in excess of 60% of dominant flow), bed shear stress in pools exceeds that of the riffles, and hence pools are cleaned of finer substrate leaving coarser material that cannot be transported.

Pool maintenance processes can be protected by avoiding disturbance of bars with elevations lower than the dominant flow elevation. In altered channels, pool maintenance processes may occur during mobilization of a significant bed particle size (*i.e.*, D_{50}), under flows approximating the dominant range of discharges.

d. Receding flows following a high flow event sort gravel. Spawning gravel patches collect in riffle locations because the pool maintenance process effectively sorts incoming sediment into discrete patches located near riffle crests. Where spawning may occur, it is recommended that disturbance of the hydraulic flow field and fluvial processes that result in spawning gravel sorting and accumulation at riffles be avoided. This can be accomplished by avoiding the disturbance of bars with elevations below the bankfull stage in natural channels, or below the effective discharge stage in manipulated channels.

e. Artificially disrupted armor layers can result in premature scour. Natural armoring of the streambed occurs during low to moderate flows as finer substrate is winnowed from the channel bed. When this armor layer is mechanically removed through mining activities, the protected substrate becomes available for transport earlier in the season than under natural conditions. Protecting salmonid redds from premature scour events requires avoiding bar disturbance that results in increased bed shear stress in spawning areas during the period that encompasses spawning through alevin emergence.

f. Low flows that carry increased fine sediment loads can cause sediment intrusion and caking. This process can reduce hyporheic flow to incubating eggs and macroinvertebrates, and may also impact fry emergence. Where spawning occurs, redds should be protected from sedimentation intensified by sediment removal actions. This can be achieved by not contributing to the increase of fine-grained or loose surface materials at elevations that may be inundated by relatively low flows during late fall and early winter when incubating salmon eggs and alevins are within gravel substrates.

4.3.4   *Select alternatives that minimize habitat disturbance and disruption of physical processes that create and maintain habitat.*

Localized methods for sediment removal that conserve the physical processes that create or maintain identified habitat elements are preferable to other instream mining techniques that result in greater disturbances. It is recommended that site specific geomorphic features and habitat values be used to identify preferred post-extraction conditions, with the findings applied to minimize the deleterious effects of sediment removal. Further, it is recommended that the methods of sediment removal be designed to enhance topographic complexity within the channel, and to encourage natural restoration of self-sustaining geomorphic features and associated aquatic and riparian habitats. The rate and volume of sediment removal should not exceed that needed to promote the properly functioning habitats appropriate for the stream. It is also recommended that the duration of removal operations be finite, ending as soon as the aggradation problem is solved and/or when the target habitat conditions are achieved. For naturally aggrading stream systems, on-going sediment removal may be appropriate.

A description of recommended methods of sediment removal can be found in section 4.4.

4.4 SUMMARY OF CURRENT MANAGEMENT TECHNIQUES IN OREGON AND THEIR LIMITATIONS

While permit conditions issued prior to 2004 by the Oregon Department of State Lands and the US Army Corps of Engineers addressed many of the immediate effects discussed in Chapter 3, they did not address delayed, off-site, and cumulative impacts such as channel incision, disruption of the sediment supply, and changes in channel morphology. The intent of the project conditions was to prevent immediate negative impacts to both riparian and aquatic habitat, so it is important that these permit conditions continue to be included in extraction permits in combination with other conditions that address the delayed, off-site, and cumulative effects. The following sections briefly discuss the most common permit conditions issued by both the state and federal government in Oregon.

4.4.1   Construction Best Management Practices

All sediment extraction operations must follow Best Management Practices (BMP's) as conditioned by the Oregon Department of State Lands in the individual permits issued for these project types. These generally include provisions for hazardous materials, disposal of dredge waste and wash water, entry and exit points, removal of vegetation, and soil stabilization. The intent of BMP's is to minimize immediate effects due to construction activities; hence many BMP's are similar for a broad spectrum of project types.

4.4.2   In-Water Work Period

Timing restrictions for in-water work, including work within the active stream channel even if the channel is dry, are set by the Oregon Department of Fish and Wildlife. Generally, all sediment extraction operations must follow these guidelines unless they have received an exemption from the permitting agency in consultation with the fisheries agencies. The purpose of the in-water work window is to ensure that sensitive fish species are not impacted during a critical life stage by physical disruption of the stream channel, direct mortality or harassment, and/or a change in critical habitat requirements, such as turbidity or water temperature.

4.4.3   Turbidity

The US Army Corps of Engineers permit that allows for in-water work is not valid unless accompanied by a 401 Water Quality Certification (WQC) issued by the Oregon Department of Environmental Quality, unless the WQC is waived or not acted on within one year of the request . The WQC's include additional permit conditions specifically focused on Oregon's water quality standards, including turbidity. Typical conditions in WQC's for these project types include BMP's to reduce turbidity levels from the project site and water quality monitoring requirements .

4.4.4 No Operation within the Active Flowing Stream or Below the Low Water Line

Bar scalping operations have generally been limited to dry gravel bar surfaces above the summer low water level. Excavation depth limitations vary in elevation between zero and two feet above low water. Because water levels vary from year to year, the actual depth of excavation varies as well. This leads to late season extraction when water levels are lowest for maximum sediment removal from a site. Based on this approach, and considering that permanent benchmarks have not been required as part of on-going surveys, actual sediment recruitment at any given site cannot be determined from year to year. This method is similar to the "Redline" method used in other states.

The "Redline" method is used to regulate maximum channel disturbance, and indirectly limit extraction quantities. Redlines define an initial extraction surface (i.e., elevation, slope, area) with vertical and horizontal offsets from the banks and the low flow channel. In subsequent years, only the aggregate that is replenished above the redline surface is allowed to be extracted. During wet years, deposition above the redline can be voluminous, while during dry years there may not be any deposition. One advantage of the redline management method is that it can allow for varying climatic and sediment transport events. It can tie sediment extraction more closely to the natural hydrologic and sediment cycles than can simply allocating via sediment budget. However, local sediment depletion can occur when only the redline method is used for regulating extraction in large-scale sediment production areas. In effect, a consistently applied redline regulation imposes a localized sediment budget approach to managing extraction, but it can allow for extracting 100% of the incoming load, which can significantly reduce sediment supply to downstream habitat.

The purpose of defining a redline is simply to limit sediment removal to control gross degradation of the streambed. Unless applied judiciously, with relatively large vertical and horizontal offsets from the low flow channel, redline methods do not maintain a positive sediment budget so that downstream habitats receive coarse sediment input and in-channel geomorphic features continue contributing to ecosystem health. Additionally, the redline method can result in expansive areas that are flat and devoid of vegetation. As flows increase in the fall and early winter, these areas are quickly inundated and can just as rapidly dry up as storm driven flows recede, potentially resulting in fish stranding.

Redline methods can provide adequate short-term protection of low flow channel habitat for fish migration. However, the long-term protection of the geomorphic processes that maintain riffle-pool complexes and deep pool habitats cannot be provided by the use of redline methods alone, unless accompanied by relatively high vertical offsets.

4.4.5 Grading and Shaping

The Oregon Department of Fish and Wildlife has strongly recommended that permit conditions include a requirement for grading and shaping of the site post-extraction to

ensure that there are no potholes, pits, or small pools left at the extraction site that may cause fish entrapment. They also recommend that the bar be sloped to maintain a positive flow back toward the main channel to prevent stranding.

4.4.6   No Removal of Live Woody Vegetation

Permit conditions which include "no removal of live woody vegetation" are intended to protect riparian areas and floodplains where vegetation is mature or is becoming established. There is no clear definition of what constitutes "woody vegetation" such as stem diameter.

4.4.7   Leave Strips and Berms

Leave strips or berms are often listed as a permit condition to isolate the mining area from the stream channel. Leave strips are undisturbed sections of the bar, while berms are constructed prior to mining. Berms are removed at the cessation of mining to prevent excessive sedimentation during the first freshets. A positive attribute of leave strips is that the vegetation is undisturbed, while berms, by there very nature, are disturbed each season that mining is conducted, hence vegetation is not allowed to establish.

4.5   RECOMMENDED METHODS OF SEDIMENT REMOVAL

This section summarizes the current recommended approaches for instream aggregate mining in Oregon. These are not considered independent activities, but rather should be components of an overall management plan. It is expected that as new techniques are developed, or as older techniques are eliminated, that this list will be updated and/or modified as appropriate. Current management techniques and techniques from other states can easily be used in conjunction with the recommended techniques.

In order to minimize the potential harmful effects discussed in Chapter 3, and meet the habitat needs of a variety of aquatic species, it is recommended that sediment removal plans not substantially reduce the topographic complexity that exists in unaltered reaches of the stream. Altered reaches should not be maintained in altered dysfunctional states by continued use of harmful methods. It is recommended that the complexity of the stream channel be measured by cross-sections and longitudinal profiles, by topographic maps, and/or by a digital elevation model (DEM). In general, it is recommended that the elevation variation or other suitable shape parameters of the entire channel utilized by aquatic species should not be significantly reduced.

It is recommended that acceptable instream sediment removal methods not disturb bar form in its natural configuration and size for elevations related to a design discharge (see 4.4.1 and 4.4.2). Geomorphic functions and habitats may be least adversely affected by an ongoing mining operation by retaining the wet edges of bars, and mining from the downstream interior of the bars (see 4.4.2). If fish passage is a specific concern, there are design modifications that can be applied to ensure various flow depths over riffles (see 4.4.3). Geomorphic functions and habitats may potentially be improved through a

restoration approach that provides aggregate as a byproduct during construction (see 4.4.4); hence this would not be an on-going source of aggregate. Another approach that combines both aggregate removal and the reclamation of some natural geomorphic function is the creation of floodplains and wetlands adjacent to incised stream channels (see 4.4.5). Again, this is a one-time removal but is likely to be on a larger spatial scale than restoring side channels and alcoves. A similar approach can be considered for estuaries (see 4.4.6); if limiting factors in a specific estuary have been documented, it may be possible to develop a plan to create or restore the limiting habitat.

All of these recommended actions require thorough planning, development, implementation, and especially monitoring. Expected benefits and unintended limitations should be documented so that techniques can be evaluated and improved upon.

4.5.1   Design Discharge

The selection of the design discharge should be based on retaining the physical processes that create, maintain, or naturally modify specific habitat elements, such as (1) bed mobilization and sediment sorting, (2) pool scouring and maintenance, or (3) flushing flows for spawning beds and/or macroinvertebrates. Figure 4 provides an example of using discharge-based design strategies for sediment removal activities to minimize geomorphic and biologic impacts.

The selection of water surface elevations, associated with morphologically important discharges, as criteria for designing sediment excavations can control the effects of disturbance on physical processes, and help maintain habitat for different species and life stages. For example, migrating adult salmonids require a minimum flow depth over riffles, adequate cover, roughness, and non-degraded water quality. The water quality condition can be met by selecting a discharge that gives reasonable certainty that fines will not degrade water quality as they are transported from disturbed surfaces by ensuring that the excavated area is not inundated until flows are sufficient to move the fine sediment through the system.

If protecting spawning habitat is the desired management goal, then channel disturbances should minimize the possibility of sediment intrusion in redds, siltation of riffles, or filling of pools, again until flows are sufficient to reliably move sediment through the system. Also, successful spawning requires that premature redd scour does not occur. Where rearing habitat is the desired management goal, it is necessary to protect pool maintenance processes. Pool maintenance is most effective when velocity reversal reaches its maximum at flows close to the bankfull condition.
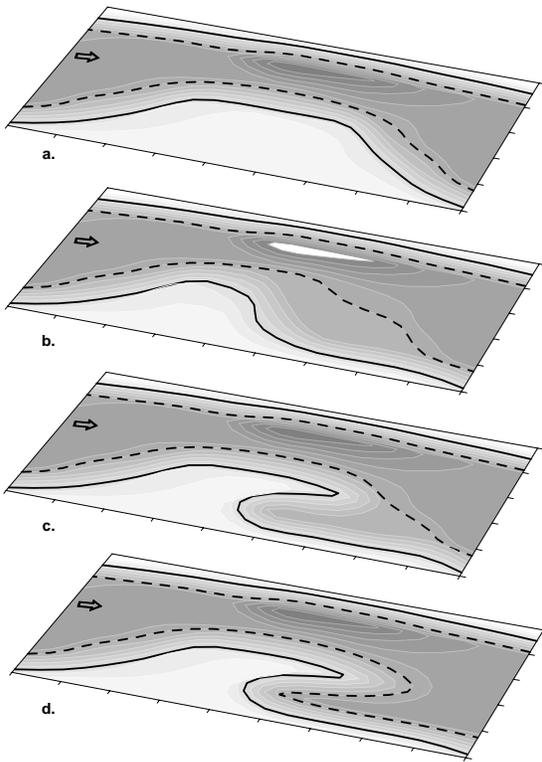
Figure 4. Topographic sketch of a typical alternate bar and pool providing habitat. The arrow indicates stream flow from left to right. The dashed line indicates the water surface elevation for a representative low flow condition, summer base flow, or migratory flow channel. The solid line represents the water surface elevation for a relatively high flow such as the effective discharge. 4a is the undisturbed condition. 4b depicts an excavation strategy that removes the downstream portion of the alternate bar. While not disturbing the low flow channel, pool filling may result. 4c illustrates an excavation strategy that retains more of the bar area enclosed by the effective discharge, adjacent to the pool, to retain pool maintenance processes. 4d is an alternative to 4c that connects the excavated backwater to the stream during low flow, providing resting habitat.

4.5.2   Retaining Bar Form

Protecting geomorphic processes is probably one of the most effective ways to protect, restore, and maintain aquatic habitat. The Bar Form method protects the upper one-third of the depositional bar, but also has undisturbed lateral set-backs from the stream channel along the periphery of the bar which maintains channel confinement. Mining utilizing this method often includes excavation of a backwater into the interior of the bar, which may or may not be below ordinary low water. If shallow water and/or off-channel habitat are limiting in the stream reach, then backwater excavation below ordinary low water may provide some habitat benefit.

The purpose of this method is to retain both the hydraulic control exerted by bars during high flows and channel constriction up to channel forming or effective discharge flow levels, which allows for sediment transport and pool maintenance processes. Pool maintenance processes function where the channel is most confined by bars, which occurs at a point midway or slightly further down the bar.

This approach appears to be working well at a few sites in California; however, since it is a relatively new approach, it has not been rigorously evaluated for effectiveness over the long-term. Application of this method should be considered experimental, and should be accompanied by a robust monitoring effort.

Design considerations for this method include, but are not limited to protecting the head of the bar and bar areas that are above the effective or bankfull discharge elevation, as

defined by a site-specific hydraulic model or the 2-year flow elevation. General design considerations include:

1.   Head of bar. Protect upper 1/3 of the bar from any excavation activities. The protective armor layer should not be disrupted and vegetation should be planted or allowed to naturally establish. Coarse sediment can be added to the head of the bar mechanically to accelerate recovery of the bar feature.

2.   Lateral buffer. The undisturbed set-back area between the low flow channel and the active mining area should be no less than 20% of the active channel width. The protective armor layer should not be disrupted and vegetation should be planted or allowed to naturally establish.

3.   Excavated backwater depth. The depth should vary so that there is always positive flow back into the low flow channel. Maximum depth should be less than the thalweg depth of the main channel to minimize avulsion potential. Excavated backwater depth below ordinary low water should generally be no greater than three to five feet depending upon local conditions and limiting factors in the stream reach.

4.   Excavated backwater area. The area of the excavated backwater will be constrained by the established buffers, but should be evaluated for effects on stream temperature. For temperature limited streams, it is prudent to have either no water in the excavated backwater area during low flow or to have a narrow, deep backwater to prevent excessive heating from solar radiation.

5.   Excavated backwater length. Maximum excavated backwater length is 2/3 of the bar feature, but this area must incorporate the head slope and side slope of the backwater (see below).

6.   Excavated backwater head slope. No steeper than 10:1 (horizontal to vertical). This is the slope transition between the protected head of bar and the bottom of the backwater. This parameter is established to reduce the risk of channel avulsion, and should be adjusted depending upon the material size of the bar feature (i.e. gravel vs. cobble).

7.   Excavated backwater side slopes. No steeper than 4:1 (horizontal to vertical). This is the transition between the lateral buffer area and the excavated backwater bottom. Again, the slope should be determined on a site specific basis and related to the particle size distribution of the bar.

4.5.3   Fish Passage

Although adult fish are known to migrate through shallow channels for short distances on the order of 1-foot or less (Thompson 1972), additional depths are necessary for fish to migrate extended distances. Bovee (1982) states that when considering minimum depth passage criteria, investigators should factor in the number and length of shallow crossings the fish must make. Fish that encounter very few passage barriers can probably negotiate some fairly shallow water, whereas the same species moving up a stream with many passage barriers may arrive at the spawning area in poor condition if the passage depths are minimal (Bovee 1982). Fish passage can be improved simply by increasing the

vertical offset of skim floors as natural deposition events allow. As an example, if a summer stream flow over riffles was ½ foot deep and bar skimming was permitted to within 1-foot of the summer water surface elevation, migration flows during fall would be temporarily limited to 1.5-feet depth. Simply increasing the elevation of skim surfaces from one to two feet would substantially increase the depth of early winter migration flows. This change can be justified because frequently manipulated areas offer little of the cover, resting, or hiding attributes of undisturbed channels. In some cases, fish can utilize increased flow depth as surrogates for those missing attributes in disturbed areas (Bjornn and Reiser 1991).

4.5.4   Restoration-Based Approach

A restoration based approach should be approached cautiously (NMFS 2005). The driving force in this type of project is restoring habitat, not obtaining aggregate; however, there are restoration activities that result in a net export of alluvial materials during construction. Projects that might fit into this category include restoring historical alcoves and side channels. The size, location, and morphology of these features should be dictated by a geomorphic assessment and not extraction quantity. Additionally, these channel features should be developed to be self-sustaining; hence, the excavation would occur only once. However, a well-planned restoration-based sediment removal project may significantly reduce or eliminate the need for compensatory mitigation.

Design considerations for this method include, but are not limited to:

1. Historic features. A geomorphic analysis of a site, which includes a thorough review of old photos, maps, and soil surveys, will help to define which geomorphic and habitat features are missing that once existed at the site.
2. Limiting factors analysis. An inventory of species and habitat types for the area will help determine specific habitat needs for the area.
3. Current condition and feasibility. After the geomorphic analysis and habitat inventory have been completed, an analysis of the watershed condition and resultant hydrology and sediment load should be evaluated. Even if historic geomorphic features have been identified which correspond to a limiting habitat type, it may not be possible to restore such features in or along a stream channel due to increased or decreased sediment loads or significant changes in the hydrology (quantity, timing, and duration).

4.5.5   Floodplain/Wetland Creation

This recommendation does not include instream activities, but is rather a floodplain mining option. Once a floodplain mining document has been completed, which outlines the potential effects to stream systems, this section will be incorporated into that new document.

Many streams within Oregon are incised due to channelization, bank stabilization, and land use activities including gravel mining. In areas where it is not possible to reconnect

a stream with its historic floodplain (generally due to flooding concerns), it may be possible to excavate a floodplain on one or both sides of the stream channel. Abandoned floodplains (terraces) that have a thin mantle of soil overlaying coarser sediments, with only minimal vegetative cover (or undesirable species), may be good candidates for floodplain creation. Removing large stands of mature woody vegetation near an active stream channel to obtain aggregate will have significant negative effects and is not recommended.

Design considerations for this method include, but are not limited to:

1.   Floodplain elevation. A geomorphically active floodplain should be inundated on a relatively frequent basis (1.0 to 1.5 year flow event) to provide for vegetative establishment, energy dissipation, nutrient cycling, and high flow refuge for aquatic species.
2.   Floodplain extent. The size of the excavated floodplain should be sufficient to provide the functions listed above, and should also be wide enough that velocities over the floodplain are sufficiently low so that hard bank armoring is not required. Since it is likely that the newly excavated floodplain will be connecting to confined stream reaches both upstream and downstream, transition areas will be required to avoid strong eddy formation. Generally, steeper streams will have narrower floodplains.
3.   Floodplain slope. The slope of the excavated floodplain should match the local valley slope.
4.   Soils. The productive top soil should be removed and stock piled during excavation. When the excavation is complete, the top soil should be replaced to provide a planting medium for vegetation. The soils should be checked for contaminates. If the pre-project site is covered in invasive and/or exotic vegetation, another source for top soil should be considered.
5.   Roughness elements. Since floodplains have steeper slopes than their adjacent stream channel, there is a risk of channel avulsion if the excavated floodplain is relatively smooth. To increase roughness, add large wood and vegetative planting such as live poles.

5   MITIGATION

5.1   MITIGATION REQUIREMENTS

The responsibility and authority to address the effects of gravel extraction activities when the activities affect marine or anadromous fish or their habitats has been delegated to NMFS, while freshwater fish or their habitats are under USFWS jurisdiction.[1] These agencies must ensure that federal actions, including authorizations to conduct gravel extraction operations, **avoid, minimize, or mitigate** to the greatest extent possible, any adverse impacts to anadromous fishes and their habitats.

5.2   MITIGATION GOALS

Commensurate with the CWA section 404 rationale, *avoiding* impacts, *minimizing* (when not reasonably possible to avoid), and then *mitigating* unavoidable impacts (when not reasonably possible to minimize) provides the framework for mitigation goals. Avoidance for salmonids requires that gravel extraction operations not interfere with anadromous fish migration, spawning, or rearing, or negatively impact viable existing or historic anadromous fish habitat. This would follow from the NMFS recommendation that **reasonable efforts be made to identify gravel sources in upland areas and terraces before deciding to site project operations in or near streams** (NMFS 2005).

In attempting to minimize effects of mining, gravel extraction operations must be reviewed in the context of their spatial, temporal, and cumulative impacts, and the review of potential impacts to habitat must include a watershed management perspective. As noted in Chapter 4, sediment removal effects can be minimized where degraded habitat can be improved by sediment removal, where negative effects due to sediment removal are known and are rare or non-existent; and where risks of habitat loss caused by long-term geomorphic adjustments are low. In these rare cases, the opportunity for mitigation exists.

When proposing mitigation, in accordance with the Corps' Regulatory Guidance Letter (RGL) on compensatory mitigation projects for permits issued under section 404 of the Clean Water Act and section 10 of the Rivers and Harbors Act of 1899 (No. 02-02, December 24, 2002), the appropriate level of mitigation to replace functional losses must include clear descriptions of the functions lost or adversely affected because of impacts to aquatic resources.

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1 This authority is delegated under several Federal laws; see Appendix I for details.

5.3   Limits to Mitigation

Mitigation will prove difficult, if not impossible, in areas where streambeds have ongoing degradation or blocked sediment sources. Dams, revetments and past mining are all considerations at the watershed scale of the potential for mitigation to cover project effects as part of cumulative impacts.

To date, approaches to the mitigation and restoration of instream gravel removal sites based primarily on assumptions about annual gravel recruitment have been inadequate. The idea of reclamation as derived from open-pit surface mining assumes that the environmental impacts are confined to the site (Kondolf 1993, 1994b). Therefore, site treatment is considered in isolation from changes in the surrounding terrain and treats the project site as an essentially static feature of the landscape. These assumptions may work for extraction operations in inactive stream or river terraces. However, channels are dynamic environments where disturbances can spread rapidly upstream and downstream for many miles from the site during and after the time of operation. Even if the channel profile eventually recovers due to an influx of fresh sediment from upstream, habitats will still have been lost during the natural recovery period that may take years, depending on high flow event frequency. However the frequency of such events may be limited by upstream flood control dams, which also reduce bedload, making gravel a limited resource; the Willamette River provides an excellent example. Thus, degradation of the aquatic ecosystem cannot be confined to a single, detached location, then subsequently reversed. Mitigation applicable to gravel pits in terrace deposits above the water table is unworkable for regulating instream gravel extraction.

5.4   Mitigation Approaches and Examples

Ideally, using a combination of best available technologies and methods, it is recommended that the following be assessed:

- Aquatic and terrestrial species distributions, abundances, and life stages;
- Habitat requirements and limiting environmental factors for affected species;
- Basin hydrology, including flow frequency curves;
- Channel morphology and sediment transport, including sediment budgets;
- Water quality;
- Cumulative impacts;
- Mitigation and restoration strategies that address all immediate and cumulative impacts, both on-site and off-site.

1. Avoidance examples:
   a. Locate extraction sites outside of the active floodplain and avoid excavating gravel from below the water table.
   b. Avoid the formation of isolated ponded areas.
2. Minimization examples:
   a. Minimize the need for crossing active channels with heavy equipment.

        b. Leave large vegetated buffers between the mined area and the active channel.

3. Mitigation examples:
    a. Habitat elements to be replaced on mined bars:
        i. Place boulders and/or large wood to help create and maintain pools and riffles, which will also **enhance the bar structure, encouraging deposition**.
        ii. Vegetation placement at bar head to **stabilize, shade/cool, and provide organic inputs.**
    b. Loss of gravel substrate:
        i. Remove artificial revetments to allow natural channel migration and gravel recruitment.
        ii. Modify dam operations to allow coarse sediment to be transported downstream.

6 MONITORING AND PERFORMANCE CRITERIA FOR STREAMS

The OSR is designed to minimize adverse effects to aquatic and aquatic dependent species due to instream sediment removal projects. To accomplish this goal, it is recommended that proponents of sediment removal projects and reviewing regulatory authorities consider the potential adverse effects of such projects upon the habitats of aquatic species at various lifestages and seasons. Proponents and regulatory authorities should then cooperatively develop sediment removal projects that avoid, or at least minimize, those impacts.

As discussed in Chapter 4, this can be accomplished through alternative strategies and methods of sediment harvest; although as noted, some methods afford a greater likelihood of protection for aquatic species and their habitats. For example, excavation down to the stage elevation of the effective discharge within the internal portions of the downstream end of gravel bars may have minimal effects upon a river's morphology and pool maintenance processes. Whereas, a harvest strategy that only maintains the upstream one-third of a bar with excavation to a level appreciably lower than the effective discharge stage, has the potential to diminish pool maintenance processes, with resulting degradation of pool-riffle complexes. To ensure that multi-year sediment removal projects do not adversely affect aquatic resources, it is recommended that sediment removal projects be conditioned with environmental monitoring and performance standards commensurate with the potential impacts of the adopted sediment removal methods.

Sediment removal projects that conform to the four steps outlined in section 4.2 should minimize affects on aquatic species, especially anadromous salmonids. Collectively, these steps protect the physical processes that create or maintain habitats for a variety of species and lifestages, and they involve the choice of sediment extraction strategies that minimize disturbance of those habitats. After meeting all state monitoring requirements (See Appendix III), projects that fully and clearly conform to these recommendations should need only minor follow-up monitoring to confirm habitat protection.

For projects that adopt harvest strategies that have the potential to disturb habitats or diminish physical stream maintenance processes, additional physical and biological monitoring is warranted. It is recommended that such projects include monitoring surveys to be done during each year of extraction. Project owners should anticipate that operations may need to be modified in succeeding project years if adverse environmental effects exceed those anticipated during environmental review for the project.

Performance criteria can be established that identify deviations necessitating project modifications. This could effectively build an adaptive monitoring and management strategy for the project. It is recommended that applicants be encouraged to use modern data collection methods to support evaluation of existing conditions and the monitoring of changes to landforms and habitats.

6.1 STREAM CHANNEL MONITORING METHODS

Physical monitoring of instream gravel mining sites in Oregon has been conducted for many years as part of the permit conditions from the Oregon Department of State Lands; however, the survey data has generally not been tied to a permanent benchmark, so yearly surveys cannot be compared to determine morphologic changes in the stream channel. Additionally, the surveys are generally limited to the mining site and often do not include the entire channel cross-section or areas upstream and downstream of the operation. Where robust cross-section monitoring programs do exist and are tied to an established benchmark, it is recommended that any new method fully integrate with the older system to maintain temporal continuity. If a benchmark has not been established, and/or the survey method is not robust, the following survey protocol is recommended:

Each year of gravel removal activity, two surveys should be conducted, once, no more than 30 days before initiation of operations, and again, no more than 30 days after completion of operations for the season. Surveys should meet the following specifications:

a. A registered surveyor should perform the survey. Desired accuracy is +/- 0.1 foot (ft).
b. The survey report should include: a site plan; a minimum of seven section drawings and a profile drawing, or a full topographic survey; and photos. If a topographic map is developed, the desired scale is 1 inch (in) = 100 ft., with a contour interval of 1 ft. Section drawings should be 1 in = 60 ft horizontal, and 1 in = 6 ft vertical.
c. Elevation data should reference a standard geodetic datum (NGVD 29 or NAD 83, etc.). A survey baseline is highly recommended, and should be composed of a minimum of 4 benchmarks. One benchmark should be set near a roadway, utility pole, or other public works infrastructure, or near a permanent site improvement, such as a gate or driveway. Additional monuments should be located where cross sections #1, 3 and 7 would intersect the baseline, if extended.
d. The site plan (or topographic map) should include:
    i. Date and time of survey data;
    ii. north arrow;
    iii. survey baseline with monument elevations, location and description;
    iv. stream banks within the survey area;
    v. direction of stream flow;
    vi. bankfull width at cross section #3, measured from top of bank to top of bank;
    vii. limits of gravel extraction and access area;
    viii. cross section locations (except topo);
    ix. angle of channel cross sections from survey baseline (except topo);
    x. location and dimension of bank erosion, scour and debris.

e. Channel cross sections should extend to the edge of the floodplain, or a minimum of 100 feet beyond top of bank. Sections should be perpendicular to the direction of channel flow (high flow). Cross sections should be shown looking downstream, and should be taken at the following locations:
    i. Section #1 is located two bankfull widths upstream of the limit of excavation;
    ii. Section #3 is at the upstream limit of excavation;
    iii. Section #2 is mid-way between sections #1 and 3;
    iv. Section #4 is mid-way through the area of excavation;
    v. Section #5 is at the downstream end of the area of excavation;
    vi. Section #7 is two bankfull widths downstream of the limits of excavation;
    vii. Section #6 is mid-way between sections #5 and 7;
    viii. additional sections are desirable if the distance between consecutive sections is greater than 100 ft. or ½ the channel width, whichever is less.
f. Sections should include the following information:
    i. multiple ground points to accurately define the channel bottom and the shape of the banks and floodplain, including submerged sections;
    ii. the water surface elevation at the time of the survey;
    iii. notes of where vegetation changes (e.g. from grass to brush);
    iv. high water mark elevation (floating grasses and twigs caught in brush during high flow);
    v. proposed gravel removal (sketch on Section #4 and site diagram)
    vi. the date of the survey.
g. The stream profile should extend from cross-section # 1 to cross-section # 7and should show the channel bottom, water surface and top of bank. The profile should be drawn from channel bottom data collected during section surveys with additional data as required to show significant grade breaks. Stationing along the profile should increase going downstream, and section locations should be shown.
h. Photographs: Each photograph should include a description of the items shown. Photos should be taken of:
    i. bar / channel reach to be mined, from upstream showing the full stream width at the upstream limit of the site;
    ii. the channel upstream of the site, from downstream showing the full stream width at the upstream limit of the excavation;
    iii. the floodplain upstream and downstream, including vegetation;
    iv. bank erosion, scour and debris.

Cross-sections, topographic mapping, and aerial mapping by various methods can provide the information necessary to manage and monitor fluvial systems. Stream channel monitoring has traditionally been accomplished using cross-sections. However, newer techniques provide broader coverage, greater point density, and more flexibility for analysis. Although somewhat dependent on the project scale and stream size, costs between new and old methods are now comparable or favor new methods, especially for larger rivers.

The disadvantages of some new mapping methods (e.g. LIDAR) are that they are unable to provide information from below the water surface and produce poor data in the densest riparian areas. In addition, most monitoring data from commercial sediment excavation has either not included data from the wet portion of the channel or has not extended across the entire channel cross-section. Given these limitations, it is important that projects, which may adversely affect stream maintenance processes, include: (1) physical monitoring of wetted areas of the channel including habitat features such as pools, runs, and riffles, (2) full cross-section monitoring, potentially including floodplains, and (3) longitudinal monitoring of the stream channel that extends well above and below the project site.

Where cross-sections continue to be used for monitoring sediment extraction, it is recommended that monitoring elements include a component of flexibility that allows for tracking important geomorphic features such as riffle crests and pools. Stream channels and their geomorphic features are dynamic, generally migrating incrementally downstream as erosion occurs on the upstream side of bars and deposition happens on the downstream side. Using geo-referenced cross-sections and the assumption that bars will be replenished in the same location year after year, together with rigid redline surface definitions to regulate aggregate extraction from downstream migrating bars, results in progressively enlarged areas and/or reduced bar sizes.

A dynamic monitoring method should be used to accommodate the dynamic bar relocation process. This would include additional cross-sections for habitat including pools and riffles that are all geographically referenced. Similarly, a longitudinal profile running the length of the stream channel should be used to compliment a network of fixed cross-sections. It is recommended that geomorphic features be monitored using methods that quantify their physical dimensions and changes at appropriate time scales. Monitoring programs should use sufficient numbers of cross-sections to adequately cover the geomorphic features. It is also recommended that they use topographic mapping techniques that do not rely solely on cross-sections but rather follow terrain and habitat features. All physical monitoring of the stream channel should allow discernment of features as small as 1-foot. As with cross-sections, it is recommended that any mapping be repeatable, that is, geographically referenced to permanent datum points that are protected from fluvial processes.

Because sediment removal can have effects upstream and downstream from the excavation site, monitoring should extend appropriate distances depending on the scale of excavations. Where one or two bars are disturbed by small-scale excavation, it is recommended that monitoring extend upstream and downstream one pool-riffle complex.

Where three or four bars are disturbed, it is recommended that monitoring extend two pool-riffle complexes upstream and downstream. In areas where pool-riffle complexes are difficult to discern, the widely recognized ratio of five to seven channel widths per pool-riffle complex can be used instead to scale monitoring activities.

Stream channel size will help determine the spacing between cross-sections. Unless previously established at a closer spacing, it is recommended that maximum cross-section spacing be approximately ½ the distance as the channel is wide. In addition, it is recommended that sediment excavation surfaces be quantified using at least five cross-sections. Where more closely spaced cross-sections or more detailed mapping is already used for monitoring sediment removal programs, the data density should be maintained at the higher level.

6.2   BIOLOGICAL MONITORING METHODS

To determine potential effects on various aquatic species, a variety of physical and biological attributes can be measured to determine if changes in habitat variables are occurring. Baseline data are necessary for any methods that seek to determine quantitative changes in habitat attributes at a given site. For sites that are already disturbed, or where disturbance is on-going, a paired study, which includes an appropriate reference reach, can be used in lieu of baseline data at the project site.

The types of biological monitoring that may be requested should be dependent upon the affected species and life stages. For example, if pool maintenance processes or salmonid juvenile rearing habitat is potentially affected, then pool habitats should be monitored to ensure that existing pool cover (e.g., LWD and boulders), maximum pool depths, pool volume, and adjacent riparian vegetation are not diminished. It is recommended that potentially affected pools also be monitored if they may be used as resting areas by upstream or downstream migrating salmonids. If upstream passage of migrating adults is potentially affected by anticipated increases in W/D ratio, then cross-sectional depth profiles could be collected during early seasonal runoff events. Such an exercise need not be a safety risk, but rather a demonstration that depths of 1 to 2 feet are maintained across substantial portions of the channel when salmon are expected to migrate past areas affected by the project.

For projects that may pose a potential adverse cumulative effect on spawning, egg incubation, or invertebrate production due to possible measurable increases in suspended sediment, it is recommended that suspended sediment concentrations and the percentage of fines in substrates be quantified upstream, downstream, and within the project site during early seasonal runoff events. It is recommended that monitoring of fine sediment deposition in substrates be done in a systematic, quantitative fashion to document possible lost macroinvertebrate and spawning habitat. Projects that may pose a risk to invertebrate production could include a benthic invertebrate monitoring component. Other biological parameters of importance may include for example the age, size, and density of riparian vegetation, changes in stream shading, water temperature, LWD, and channel margin complexity. Each of these should be monitored as appropriate.

6.3 ADDITIONAL RECOMMENDATIONS FOR ALL SEDIMENT REMOVAL PROJECTS

Prior to any sediment removal, it is recommended that a thorough review be undertaken of potentially toxic sediment in or near the streambed where sediment removal operations are proposed or where bed sediments may be disturbed by the operations (including upstream and downstream adjacent banks and floodplain).

It is recommended that sediment contaminants be thoroughly analyzed and addressed. Generally, there should be no reasonable justification for disturbing contaminated sediment that could conceivably enter the stream ecosystem if disturbed. However, the removal of contaminated sediment from future interaction with the stream ecosystem may be of benefit if it can be accomplished with sufficient isolation and little risk. Therefore it is recommended that contaminated sediment disturbance be evaluated on a case-by-case basis.

Noxious and/or invasive plants should be removed using methods that prevent spreading. For example, Japanese Knotweed is spread by cuttings, so vegetation removal that results in the dispersal of plant cuttings is inappropriate. It is recommended that an invasive plant management plan be developed as part of all sediment removal or redistribution actions that addresses noxious or invasive plants in a long-term management context.

Extracted aggregates and sediments should not be washed directly in the stream or within the riparian zone. It is recommended that turbidity levels be monitored and significant increases above background turbidity levels should not be exceeded.

Instream roughness elements (LWD, rocks, etc.) should not be removed during sediment extraction activities. It is recommended that roughness elements that are disturbed be replaced or restored. Additional roughness elements may be placed in mining areas to improve habitat and contribute to partial mitigation for habitat disturbance.

Sediment removal operations should be managed to avoid or minimize damage to stream/river banks and riparian habitats. It is recommended that sediment removal in vegetated riparian areas be avoided. Access roads should not encroach into the riparian zones. Undercut vegetated banks are highly productive aquatic habitat and should not be altered.

All support operations (e.g., sediment washing, refueling) should be done outside the riparian zone and floodplain and at elevations that can be protected from infrequent flood events. It is recommended that sediment stockpiles, overburden and/or vegetative debris not be stored within the riparian zone. Operation and storage of heavy equipment within riparian habitat should be restricted.

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8 APPENDIX 1 – SUMMARIES OF RELEVANT FEDERAL STATUTES

The following summaries of the major Federal statutes mentioned in this document, with the exception of the River and Harbor Act of 1899, were obtained from Buck2.

8.1 ANADROMOUS FISH CONSERVATION ACT

The Anadromous Fish Conservation Act (16 U.S.C. 757a-757g) authorizes the Secretary of Commerce, along with the Secretary of Interior, or both, to enter into cooperative agreements to protect anadromous and Great Lakes fishery resources. To conserve, develop, and enhance anadromous fisheries, the fisheries which the United States has agreed to conserve through international agreements, and the fisheries of the Great Lakes and Lake Champlain, the Secretary may enter into agreements with states and other non-Federal interests. An agreement must specify:

(1) the actions to be taken;
(2) the benefits expected;
(3) the estimated costs;
(4) the cost distribution between the involved parties;
(5) the term of the agreement;
(6) the terms and conditions for disposal of property acquired by the Secretary; and
(7) any other pertinent terms and conditions.

Pursuant to the agreements authorized under the Act, the Secretary may: (1) conduct investigations, engineering and biological surveys, and research; (2) carry out stream clearance activities; (3) undertake actions to facilitate the fishery resources and their free migration; (4) use fish hatcheries to accomplish the purposes of this Act; (5) study and make recommendations regarding the development and management of streams and other bodies of water consistent with the intent of the Act; (6) acquire lands or interests therein; (7) accept donations to be used for acquiring or managing lands or interests therein; and (8) administer such lands or interest therein in a manner consistent with the intent of this Act. Following the collection of these data, the Secretary makes recommendations pertaining to the elimination or reduction of polluting substances detrimental to fish and wildlife in interstate or navigable waterways. Joint NMFS-FWS regulations applicable to this program are published in 50 *C.F.R.* Part 401.

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[2] Buck, E.H. 1995. Summaries of major laws implemented by the National Marine Fisheries Service. CRS Report for Congress. Congressional Research Service, Library of Congress, March 24, 1995.

8.2 CLEAN WATER ACT

The Clean Water Act (CWA) (33 U.S.C. 1251-1387) is a very broad statute with the goal of maintaining and restoring the chemical, physical, and biological integrity of waters of the United States. The intent of the CWA § 404 program and its 404(b)(1) "Guidelines" is to prevent destruction of aquatic ecosystems including wetlands, unless the action will not individually or cumulatively adversely affect the ecosystem. The CWA authorizes water quality and pollution research, provides grants for sewage treatment facilities, sets pollution discharge and water quality standards, addresses oil and hazardous substances liability, and establishes permit programs for water quality, point source pollutant discharges, ocean pollution discharges, and dredging or filling of wetlands. The U.S. Army Corps of Engineers (USACE) administers the Section 404 program, including permit decisions and jurisdictional determinations, and enforces Section 404 provisions. Pursuant to Section 404 of the CWA, a Department of Army permit is required for the discharge or dredged or fill material into a water of the U.S., as defined in 33 CFR 328.3. Important to note is the Environmental Protection Agency (EPA) and Corps regard the use of mechanized earth-moving equipment to conduct landclearing, ditching, channelization, in-stream mining or other earth-moving activity in the United States as resulting in a discharge of dredged material unless project-specific evidence shows that the activity results in only incidental fallback (33 CFR 323.2). All Department of Army authorizations must comply with the Section 404 (b)(1) Guidelines.

Through the Fish and Wildlife Coordination Act, National Marine Fisheries Service (NMFS), Fish & Wildlife Service (FWS), and heads of appropriate state agencies may provide comments to the USACE as to the potential adverse effects to wildlife resources, including fish that may occur as a result of permits issued for USACE regulated activities and recommends methods for avoiding such impacts.

8.3 ENDANGERED SPECIES ACT

The purpose of the 1973 Endangered Species Act (ESA) (16 U.S.C. 1531-1543) is to provide a means whereby the ecosystems upon which endangered or threatened species depend may be conserved and to provide a program for the conservation of such endangered and threatened species. All Federal departments and agencies should seek to conserve endangered and threatened species and should utilize their authorities in furtherance of the purposes of the ESA. Under Section 7 of the Endangered Species Act, federal agencies are required to consult with the appropriate federal resource agency if a proposed action would affect threatened or endangered species.

8.4 FISH AND WILDLIFE COORDINATION ACT

The Fish and Wildlife Coordination Act (16 U.S.C. 661-666c) requires that wildlife, including fish, receive equal consideration and be coordinated with other aspects of water resource development. This is accomplished by requiring consultation with the FWS, NMFS and appropriate state agencies, whenever control or modification of any water body is proposed by a Federal agency, including issuance of a Federal permit or license.

These agencies determine the possible harm to fish and wildlife resources, the measures needed to both prevent the damage to and loss of these resources, and the measures needed to develop and improve the resources, in connection with water resource development. NMFS submits comments to Federal licensing and permitting agencies on the potential harm to living marine resources caused by the proposed water development project, and recommendations to prevent harm.

8.5 MAGNUSON FISHERY CONSERVATION AND MANAGEMENT ACT

The Magnuson Act requires that fishery management plans should "include readily available information regarding the significance of habitat to the fishery and assessment as to the effects which changes to that habitat may have upon the fishery" 16 U.S.C. 1853 (a)(7).

8.6 NATIONAL ENVIRONMENTAL POLICY ACT

The National Environmental Policy Act (NEPA) (42 U.S.C. 4321-4347) requires Federal agencies to analyze the potential effects of a proposed Federal action which would significantly affect the human environment. It specifically requires agencies to use a systematic, interdisciplinary approach in planning and decision-making, to insure that presently unquantified environmental values may be given appropriate consideration, and to provide detailed statements on the environmental impacts of proposed actions including: (1) any adverse impacts; (2) alternatives to the proposed action; and (3) the relationship between short-term uses and long-term productivity. The agencies use the results of this analysis in determining if an environmental assessment or environmental impact is required. The alternatives analysis allows other reasonable options to be considered. NMFS plays a significant role in the implementation of NEPA through its consultative functions relating to conservation of marine resource habitats. For the purposes of the USACE regulatory program a decision on a permit application cannot be made until the USACE determines the project is in compliance with the NEPA.

8.7 RIVERS AND HARBORS ACT OF 1899

The Rivers and Harbors Act of 1899, § 10 (33 U.S.C. 403) prohibits the unauthorized obstruction or alteration of any navigable water of the United States. Construction of any structure, excavation, or deposition of materials or any other work affecting the course, location, condition or capacity of any navigable water requires Department of Army authorization. Section 10 jurisdictional authority extends over waters subject to the ebb and flow of the tide shoreward to the mean high water mark, and/or are presently used or have been used in the past or may be susceptible to use to transport interstate or foreign commerce. Artificial islands, installations and other devices located on the seabed to the seaward limit of the outer continental shelf are regulated under Section 10 authority. Department of Army authorization under Section 10 is also required for alterations within the limits of any breakwater or channel of any navigable water of the United States.

9 APPENDIX 2 – SUMMARIES OF RELEVANT STATE STATUTES & PROGRAMS

9.1 STATE FILL/REMOVAL LAW

The Oregon Removal-Fill Law was enacted in 1967 to protect, conserve and allow the best use of the state's water resources. Waters of the state generally include, but are not limited to, intermittent and perennial watercourses, lakes, wetlands, estuaries and the Pacific Ocean. The Department of State Lands administers the Removal-Fill Law under Oregon Revised Statutes (ORS) 196.800-196.905 and Oregon Administrative Rules (OAR) 141-085-0005-141-089-0615. Typically, impacts to waters of the state greater than 50 cubic yards require a permit. Notable exceptions to the 50 cubic yard threshold include State Scenic Waterways and areas designated Essential Salmon Habitat, where a permit is required for all activity in regulated features, regardless of material involved.

9.2 OREGON STATE ENDANGERED SPECIES ACT

The Oregon State Endangered Species Act (ESA) provides for the Oregon Department of Fish and Wildlife to adopt a list of threatened and endangered species by rule. The state ESA establishes requirements for activities on state-owned land that may affect state threatened or endangered species. In addition, a state incidental take permit is required for the incidental taking of state-designated threatened or endangered species not listed by the federal government (ORS 496.171- ORS 496.192).

9.3 FISH PASSAGE ACT

ORS 509.580 requires that an owner or operator of an artificial obstruction located in waters in which native migratory fish are currently or were historically present must address fish passage requirements prior to installation, major replacement, a fundamental change in permit status (e.g. new water right, renewed hydroelectric license), or abandonment of the artificial obstruction. Addressing fish passage requirements entails the owner/operator obtaining from the Oregon Department of Fish and Wildlife (ODFW): 1) approval for a passage plan when passage will be provided, 2) a waiver from providing passage, or 3) an exemption from providing passage. Laws regarding fish passage may be found in ORS 509.580 through 910 and in OAR 635, Division 412.

9.4 FISH SCREENING ACT

Any person who diverts water, at a rate of less than 30 cubic feet per second, from any body of water in this state in which any fish, subject to the State Fish and Wildlife Commission's regulatory jurisdiction, exist may be required to install, operate and maintain screening or by-pass devices to provide adequate protection for fish populations present at the water diversion. The state has established a cost share program for these under 30 cfs diversions. Any person who diverts water, at a rate of 30 cubic feet per second or more, from any body of water in this state in which game fish exist shall

install, operate and maintain, at the expense of the person, all fish screening or by-pass devices that the State Department of Fish and Wildlife determines necessary to prevent fish from leaving the body of water and entering the diversion (ORS 489.301-346).

9.5   OREGON'S WATER QUALITY CERTIFICATION PROGRAM

The Oregon Department of Environmental Quality (DEQ) administers Section 401 of the CWA (33 U.S.C. 1341) through issuance of a 401 Water Quality Certification (WQC). The WQC is a determination by DEQ that federally licensed or permitted activities which may result in a discharge to waters of the state comply with the states water quality standards. DEQ's WQC program is administered through OAR 340-048-0005 to 340-048-0050. The federal permit cannot be issued without the issuance of the WQC unless DEQ provides a waiver or does not respond to the request for it within one year. The review and evaluation of a project requiring a WQC consists of state water quality standards which are approved by the Environmental Protection Agency (EPA). These approved standards cover beneficial uses, policies, and criteria, and are listed in Oregon Administrative Rules (OAR) 340 Division 41, and include: Antidegradation, Narrative Criteria, Bacteria, Biocriteria, Dissolved Oxygen, Nuisance Phytoplankton Growth, pH, Temperature, Total Dissolved Gas, Total Dissolved Solids, Toxic Substances, Turbidity, Water Quality Limited Waters, Mixing Zones, Implementation at Wastewater Treatment Works, Other Implementation of Water Quality Criteria, and Basin-Specific Criteria. Additionally, WQC determinations and conditions are based Load Allocations in approved Total Maximum Daily Loads (TMDLS) for water quality limited water bodies, subsequent TMDL implementation plans, specific management measures in Oregon's Coastal Nonpoint Source Program, and sediment contaminate, solid waste, and related clean-up issues.   DEQ also provides DSL input and conditions if applicable during the state permit process to ensure any water quality conditions are consistent in both the state and federal permit processes and that proposed projects will comply with water quality criteria as well as not impair beneficial uses.

9.6 OREGON'S COASTAL ZONE MANAGEMENT PROGRAM

The Oregon Department of Land Conservation and Development (DLCD) is the state's coastal management agency under the federal Coastal Zone Management Act (CZMZA). DLCD administers the Oregon Coastal Management Program (OCMP) for areas within the state's coastal zone based on requirements of federal law. The Coastal Zone Management Act requires federal agencies to assure that actions, including licenses and permits in the coastal zone, are consistent with the enforceable policies of the OCMP.

The Oregon Coastal Management Program includes the statewide planning goals adopted by the Land Conservation and Development Commission (LCDC); comprehensive plans and land use regulations adopted by local governments and approved by LCDC as complying with the statewide planning goals; and the regulatory authorities of state agencies that are part of the coastal management program (e.g. DEQ, DSL, ODFW, OPRD, ODE, WRD).

Projects require DLCD federal consistency review and concurrence prior to federal authorization. This consistency review process is governed by requirements of federal law and begins with notice from the federal agency. The notice includes the applicant's consistency determination, a review of the project against the state program's enforceable policies. Following public review, DLCD either concurs, objects or conditionally concurs with the consistency determination.

10 APPENDIX 3 – GENERALIZED CONSERVATION MEASURES: Sand and Gravel Excavation by Bar Scalping

UNDER CONSTRUCTION

The following conservation measures are applicable to sand and gravel operations based on the bar scalping method. These measures apply current knowledge of aquatic biology, sediment recruitment, and stream dynamics to qualify the time, place, and methods of bar scalping. The intent of these measures is to ensure that the physical removal of habitat substrate will not cause an unacceptable level of damage to those parts of the aquatic ecosystem that have the highest conservation value and greatest sensitivity to disturbance. Monitoring procedures are specified to ensure that a bar scalping operation does not cause unanticipated adverse effects, exceed the anticipated level of habitat damage, and is complying with the conservation measures described here. These measures also include mitigation requirements to offset long term adverse effects in the extraction area by replacing habitat functions lost within the area scalped.