

National Marine Fisheries Service National Gravel Extraction Guidance

A review of the effects of in- and near-stream gravel extraction on anadromous fishes and their habitats, with recommendations for avoidance, minimization, and mitigation

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA Technical Memorandum NMFS-F/SPO-70
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Suggested citation:

Packer, D. B., K. Griffin, and K. E. McGlynn. 2005. National Marine Fisheries Service National Gravel Extraction Guidance. U.S. Dep. Commerce, NOAA Tech. Memo. NMFS-F/SPO-70, 27p.

A copy of this report may be obtained from:

Office of Habitat Conservation
NMFS, NOAA
1315 East-West Highway, F/HC2
Silver Spring, MD 20910

Or online at:

<http://www.nmfs.noaa.gov/habitat/habitatprotection/anadfish/gravel.htm>

NATIONAL MARINE FISHERIES SERVICE NATIONAL GRAVEL EXTRACTION GUIDANCE

I. INTRODUCTION

The National Marine Fisheries Service (NMFS) is responsible for protecting, managing and conserving marine, estuarine, and anadromous fishes and their habitats. The watersheds of the United States provide essential spawning and rearing habitat for anadromous fishes including salmon, shad, sturgeon, and striped bass.

A national guidance document on gravel extraction is necessary because extraction in and near streams can cause many adverse impacts to anadromous fishes and their habitats. Potential impacts include: direct harm to trust species; loss or degradation of spawning, rearing, resting, and staging habitat; migration delays and/or blockages; channel widening, shallowing, or ponding; loss of channel stability; loss of pool/riffle structure; increased turbidity and sediment transport; increased bank erosion and/or stream bed downcutting; and loss or degradation of riparian habitat. The impacts can extend far beyond the mining site, and stream recovery can take decades.

In the context of Federal trust responsibilities, as defined in the collective body of Federal law and regulations, NMFS 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. NMFS has been delegated the responsibility and authority under several Federal laws to address the effects of gravel extraction activities when the activities affect marine or anadromous fish under NMFS jurisdiction or their habitats. These authorities are summarized in the Appendix I, and include the Endangered Species Act (ESA), Clean Water Act (CWA), National Environmental Policy Act (NEPA), Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), and the accompanying implementing regulations of each law.

This document revises and replaces NMFS' 1996 National Gravel Extraction Policy. The objectives of the NMFS Gravel Guidance are to (1) assist NMFS staff in determining whether proposed gravel extraction operations will be conducted in a manner consistent with Federal law, while (2) avoiding, minimizing, and mitigating any adverse impacts to anadromous fishes and their habitats. NMFS recommends that gravel extraction operations not interfere with anadromous fish migration, spawning, or rearing, or negatively impact viable existing or historic anadromous fish habitat. Further, it is recommended that individual gravel extraction operations be judged in the context of their spatial, temporal, and cumulative impacts, and that potential impacts to habitat be viewed from a watershed management perspective. Although this Guidance applies nationwide, it is not to be regarded as static or inflexible, as project recommendations must be made specific to individual sites, streams, and watersheds.

This Guidance does not specify the measures, if any, that would need to be implemented by parties engaged in gravel extraction activities in any given case to comply with applicable statutory requirements. In formulating its recommendations or prescriptions, NMFS will

determine the acceptable means of demonstrating compliance with statutory requirements based on information available to the agency, as appropriate under the circumstances presented. As such, the language of this Guidance for NMFS staff should not be read to establish any binding requirements on agency staff or the regulated community.

II. SCOPE OF GRAVEL GUIDANCE

This Guidance document addresses freshwater and tidal reaches of rivers and streams, tidal sloughs, and their associated wetlands and riparian zones where anadromous fish are currently or were historically present. Gravel extraction, as well as sand mining and dredging, also occurs in marine habitats such as the lower reaches of large tidal streams, estuaries and offshore. Marine extraction operations generally raise different concerns than those in streams. Although many elements of this Guidance are germane to all areas where gravel extraction occurs, the primary focus of this Guidance is extraction of gravel in streams rather than in marine environments.

The types of gravel extraction activities referred to in this Gravel Guidance generally entail commercial gravel mining (i.e., removing or obtaining a supply of gravel for industrial uses, such as road construction material, concrete aggregate, fill, and landscaping). Gravel can also be removed from stream channels for navigation and flood control purposes. Gravel extraction often occurs at multiple times and at multiple sites along a given stream, resulting in impacts that are likely to be both chronic and cumulative. When the rate of gravel extraction exceeds the rate of natural deposition over an extended time period, a net cumulative loss of gravel occurs (Oregon Water Resources Research Institute [OWRRI] 1995).

This Gravel Guidance document addresses three types of instream gravel mining, described as dry-pit and wet-pit mining in the active channel, and bar skimming (or “scalping”) (Kondolf 1993, 1994a, 1997, 1998a). Dry-pit refers to excavation on dry ephemeral stream beds and exposed bars with conventional bulldozers, scrapers, and loaders. Wet-pit mining involves the use of a dragline or hydraulic excavator to remove gravel from below the water table or in a perennial stream channel. Bar skimming or scalping removes the surface from gravel bars without excavating below the low water flow level.

In addition to the instream mining described above, this Guidance document also addresses another method, which involves the excavation of pits on the adjacent floodplain or river terraces (Kondolf 1993, 1994a, 1997, 1998a). Pits located above the water table are also known as dry-pits, whereas wet-pits are below, depending on the elevation of the floodplain or terrace relative to the baseflow water elevation of the channel. The isolation of these pits from an adjacent active channel may be only short-term. During a sudden change in channel course during a flood, or as part of gradual migration, the channel may shift into the gravel pits (Kondolf 1998a). Because floodplain pits can become integrated into the active channel, Kondolf (1993, 1994a) suggests that they should be regarded as part of the active channel if considered on a time scale of decades, and managed accordingly.

III. ENVIRONMENTAL EFFECTS OF GRAVEL EXTRACTION

Extraction of alluvial material from within or near a stream bed has a direct impact on the stream's physical habitat parameters such as channel geometry, bed elevation, substrate composition and stability, instream roughness elements (large woody debris, boulders, etc.), depth, velocity, turbidity, sediment transport, stream discharge, and temperature (Rundquist 1980; Pauley et al. 1989; Kanehl and Lyons 1992; Kondolf 1994a, 1994b, 1997, 1998a; OWRRI 1995; Brown et al. 1998; Florsheim et al. 1998; Meador and Layher 1998; Langer 2001, 2003). OWRRI (1995) states that:

Channel hydraulics, sediment transport, and morphology are directly affected by human activities such as gravel mining and bank erosion control. The immediate and direct effects are to reshape the boundary, either by removing or adding materials. The subsequent effects are to alter the flow hydraulics when water levels rise and inundate the altered features. This can lead to shifts in flow patterns and patterns of sediment transport. Local effects also lead to upstream and downstream effects.

Altering these habitat parameters can have deleterious impacts on instream biota, food webs, and the associated riparian habitat (Sandecki 1989; Kanehl and Lyons 1992; Koski 1993; Spence et al. 1996; Brown et al. 1998). For example, impacts to anadromous fish populations due to gravel extraction can include reduced fish populations in the disturbed area, replacement of one species by another, replacement of one age group by another, or a shift in the species and age distributions (Moulton 1980). Changes in physical habitat characteristics of aquatic systems can alter competitive interactions within and among species; similarly, changes in temperature or flow regimes may favor species that prey on anadromous fish populations (Spence et al. 1996). In general terms, Rivier and Segquier (1985) suggest that the detrimental effects to biota resulting from bed material mining are caused by two main processes: (1) alteration of the flow patterns resulting from modification of the river bed, and (2) an excess of suspended sediment. OWRRI (1995) adds:

Disturbance activities can disrupt the ecological continuum in many ways. Local channel changes can propagate upstream or downstream and can trigger lateral changes as well. Alterations of the riparian zone can allow changes in-channel [*sic*] conditions that can impact aquatic ecosystems as much as some in-channel activities.

One consequence of the interconnectedness of channels and riparian systems is that potential disruptions of the riparian zone must be evaluated when channel activities are being evaluated. For example, aggregate mining involves the channel and boundary but requires land access and material storage that could adversely affect riparian zones; bank protection works are likely to influence riparian systems beyond the immediate work area.

It should be emphasized that cobble and gravel substrates are in and of themselves extremely important habitat for anadromous fish, including salmon, shad, striped bass, and sturgeon. Gravel habitat provides

protective crevices and well-oxygenated interstitial spaces that are important for anadromous fish egg hatching. Gravel habitat also contains rich assemblages of benthic nutrients used as food for developing fish larvae, and provides macroinvertebrate food sources for post-larval juveniles.

The potential effects of gravel extraction activities on stream morphology, riparian habitat, and anadromous fishes and their habitats are summarized as follows:

- 1. Instream gravel mining can disrupt the preexisting balance between sediment supply and transporting capacity, and can result in channel incision and bed degradation** (Kondolf 1997, 1998a; Florsheim et al. 1998; Meador and Layher 1998; Langer 2001, 2003). This is partly because gravel “armors” the bed, stabilizing banks and bars, whereas removing this gravel causes erosion (Lagasse et al. 1980; OWRI 1995; Kondolf 1997, 1998a). Degradation and erosion can extend upstream and downstream of an individual extraction operation, and can result from bed mining either in or above the low-water channel (Collins and Dunne 1990; Kanehl and Lyons 1992; Kondolf 1994a, 1994b, 1997, 1998a; OWRI 1995; Pringle 1997; Brown et al. 1998). For example, headcutting (upstream erosion), increased velocities, concentrated flows, and bank undercutting with subsequent loss of riparian habitat can occur upstream of the extraction site due to a steepened river gradient (Kanehl and Lyons 1992; OWRI 1995; Kondolf 1997; Pringle 1997), resulting in the release of additional sediment to downstream reaches, where the channel may aggrade and become unstable (Kondolf 1997). Accelerated delivery of sediment from upstream can falsely indicate recruitment in balance with removal. Degradation can deplete the entire depth of gravel on a channel bed, exposing other substrates that may underlie the gravel, reducing the amount and quality of usable anadromous spawning and rearing habitat (Collins and Dunne 1990; Kondolf 1994a, 1997, 1998a; OWRI 1995). For example, gravel removal from bars may cause erosion if they subsequently receive less bed material from upstream than is being carried away by fluvial transport (Collins and Dunne 1990). Thus, gravel removal not only impacts the extraction site, but also may reduce gravel delivery to downstream spawning and rearing areas (Pauley et al. 1989; Brown et al. 1998). Gravel mining itself often selectively removes gravels of approximately the same sizes as needed by salmonids for spawning (median diameters between 15 and 45 mm [Kondolf and Wolman 1993; see also Kondolf 2000]), again reducing the amount of usable spawning and rearing habitat.
- 2. Instream gravel extraction can increase suspended sediment, sediment transport, water turbidity, and gravel siltation** (Kanehl and Lyons 1992; OWRI 1995; Kondolf 1997). The most significant change in the sediment size distribution resulting from gravel removal is a decrease in sediment size caused by fine material deposition into the mining site (Rundquist 1980). Brown et al. (1998) also note that the fine material can travel long distances downstream as a plume of turbidity while the gravel is being removed and, during floods, turbidity is likely to be higher than normal for even longer distances downstream due to the higher flow rate and increased entrainment of sediments as a result of channel deformation or armor layer removal. As reviewed by Everest et al. (1987), fine sediments in particular are detrimental to salmonid redds (nests) because (1) interstitial spaces blocked by deposited silt prevents oxygenated water from reaching the incubating eggs within the redd, and inhibits the removal of waste metabolites; (2) embryos or sac fry can be smothered by high concentrations of suspended sediments that enter the redd; and (3) emerging fry can become trapped if enough sediment is deposited on the redd (Koski 1966, 1981; Chapman 1988; Reiser and White 1988; Waters 1995). High silt loads may also inhibit larval, juvenile, and

adult behavior, migration, or spawning (Snyder 1959; Cordone and Kelly 1961; Koski 1975; Bisson and Bilby 1982; Berg and Northcote 1985; Bjornn and Reiser 1991; Kanehl and Lyons 1992; Servizi and Martens 1992; OWRRI 1995). Excessive amounts of suspended material can abrade the protective slime coatings on the surface of the fish and their gills, which can lead to increased bacterial and fungal infections (Cordone and Kelly 1961; Rivier and Segquier 1985). Increased suspended sediments may block vision and impede feeding (Sigler et al. 1984; Rivier and Segquier 1985). Siltation, substrate disturbances and increased turbidity also negatively affect the invertebrate food sources of fishes and severely alter the aquatic food web, thus affecting the growth and survival of the fish (Kanehl and Lyons 1992; OWRRI 1995; Spence et al. 1996; Brown et al. 1998).

- 3. Bed degradation can change the morphology of the channel and decreases channel stability** (Moulton 1980; Rundquist 1980; Sullivan et al. 1987; Collins and Dunne 1990; Kanehl and Lyons 1992; Kondolf 1994a, 1994b, 1997; OWRRI 1995; Brown et al. 1998; Florsheim et al. 1998). Gravel extraction can cause a diversion or a high potential for diversion of flow through the gravel removal site (Rundquist 1980). Mined reaches of a river or stream that show decreased depth and/or surface flow, which can occur where the flow is spread over a wide area and there is considerable intergravel flow, could block fish migration during periods of low flows (Moulton 1980). This could be caused by gravel bar skimming in particular (see Environmental Effect Number 4, below), and may compound problems in many areas where flows may already have been altered by hydropower operations, irrigation, or other human uses. Even if the gravel extraction activity is conducted away from the active river channel during low water periods (see Environmental Effect Number 8, below), substrate stability and channel morphology outside the excavated area's perimeter could be affected during subsequent high water events (Kondolf 1997, 1998a).
- 4. Gravel bar skimming can significantly impact aquatic habitat.** Bar skimming creates a wide, flat cross section, eliminating confinement of the low flow channel, which can then result in a thin sheet of water at baseflow (Kondolf 1994a, 1997). Sediment transport efficiency may be reduced through the unconfined reach due to the increased width-to-depth ratio, causing deposition and subsequent instability (Kondolf 1998a). Removal of the bar may alter channel hydraulics upstream as well as at the gravel extraction site (Kondolf 1998a). Bar skimming can also remove the gravel "pavement," leaving the finer subsurface particles vulnerable to entrainment (erosion) at lower flows (Kondolf 1994a, 1998a; OWRRI 1995). A related effect is that bar skimming lowers the overall elevation of the bar surface and may reduce the threshold water discharge at which sediment transport occurs (OWRRI 1995). Salmon redds downstream are thus susceptible to deposition of displaced alluvial material, resulting in egg suffocation or suppressed salmon fry emergence, while redds upstream of scalped bars are vulnerable to regressive erosion (Pauley et al. 1989). Gravel bar skimming also appears to reduce the amount of side channel areas, which can reduce and/or displace juvenile salmonid fishes that use this habitat (Pauley et al. 1989). All these effects can be particularly problematic if upstream flows are already reduced by diversions, dams, or other human activities.
- 5. Operation of heavy equipment in the channel bed can directly destroy spawning habitat, rearing habitat, the juveniles themselves, and macroinvertebrates; can produce**

increased turbidity and suspended sediment downstream; and has the potential to cause toxic chemical spills (Forshage and Carter 1973; Kondolf 1994a). Heavy equipment usually crosses stream channels where the stream is shallowest, at riffles. Riffle habitat is important for juvenile salmonids (Bradford and Higgins 2001) because, for example, the juveniles often respond to disturbances by entering the interstitial spaces between the gravel substrate at riffles (Shrivell 1990; Meehan and Bjornn 1991). These pore spaces in the gravel substrate are important sources of cover or refuge (Raleigh et al. 1984). Therefore, juveniles in this riffle habitat could be susceptible to crushing from heavy equipment. Additional disturbances to redds may occur from increased foot and vehicle access to spawning sites, due to access created initially for gravel extraction purposes (OWRRI 1995). Also, heavy equipment is powered by diesel fuel and lubricated by other hazardous petroleum products, leading to the potential for toxic chemical spills.

- 6. Stockpiles of overburden and gravel left or abandoned in the channel or floodplain can alter channel hydraulics during high flows.** During high water, the presence of stockpiles can cause fish blockage or entrapment, and fine material and organic debris may be introduced into the water, resulting in downstream sedimentation (Follman 1980). The stockpiles may also concentrate flows on the stream bed or floodplain resulting in increased, localized erosion.
- 7. Removal or disturbance of instream roughness elements during gravel extraction activities can negatively affect both quality and quantity of anadromous fish habitat.** Instream roughness elements, including the gravel itself and large woody debris, play a major role in providing structural integrity and complexity to the stream or river ecosystem and provide habitat critical for anadromous fish (Koski 1992; Naiman et al. 1992; Franklin et al. 1995; Murphy 1995; OWRRI 1995; Abbe and Montgomery 1996; Collins and Montgomery 2002; Collins et al. 2002). These elements are important in controlling channel morphology and stream hydraulics; in regulating the storage of sediments, gravel and particulate organic matter; and in creating and maintaining habitat diversity and complexity (Franklin 1992; Koski 1992; Murphy 1995; OWRRI 1995). Large woody debris in streams creates pools and backwaters that fish use as foraging sites, critical overwintering areas, refuges from predation, and spawning and rearing habitat (Koski 1992; Maser and Sedell 1994; OWRRI 1995). Large wood jams at the head of gravel bars can anchor the bar and increase gravel recruitment behind the jam (OWRRI 1995). Loss of large woody debris from gravel bars can also negatively impact aquatic habitat (Weigand 1991; OWRRI 1995). The importance of large woody debris has been well documented, and its removal results in an immediate decline in salmonid abundance (e.g., see citations in Koski 1992; Franklin et al. 1995; Murphy 1995; OWRRI 1995). It is also important to remember that gravel deposits are themselves instream roughness elements, which is key to recognizing that the same type of effects apply (i.e., linking hydraulics and habitat is also applicable for gravel deposits underwater or on bars).
- 8. Dry pit and wet pit mining in floodplains may reduce groundwater elevations, reduce stream flows, increase water temperature, and create potential for fish entrapment** (Langer 2003; NMFS 2004). A reduction in groundwater elevation may occur when floodplain pits are pumped by operators to increase production, and by evaporation of

surface water in large pits. Reductions in groundwater elevations can consequently result in a decrease in stream flow, which is particularly hazardous to fish during low flow periods. Subsurface connectivity between pits and streams also presents a possibility of increased stream temperatures when pit surface water is heated by the sun and eventually drains to the stream. The risk of fish entrapment associated with floodplain pit mining is due to two processes: (1) floods overtopping the pit perimeter, and (2) natural migration of the channel into the excavated area (Kondolf 1998a). Ponded water isolated from the main channel may strand or entrap fish carried there during high water events (Moulton 1980; Palmisano et al. 1993; Kondolf 1997). Fish in these ponded areas could experience higher temperatures, lower dissolved oxygen, increased predation compared to fish in the main channel, an altered food web, desiccation if the area dries out, and freezing (Moulton 1980; Spence et al. 1996; Kondolf 1997, 1998a).

The likelihood and extent of groundwater, stream flow, water temperature, and entrapment effects associated with floodplain mining are directly related to the pit's proximity to the active stream channel, pit size relative to the stream, and the frequency of flood inundation (Langer 2003; NMFS 2004).

- 9. Destruction of the riparian zone during gravel extraction operations can have multiple deleterious effects on anadromous fish habitat.** The importance of riparian habitat to anadromous fishes (Koski 1993) should not be underestimated. For example, Koski (1992) states that a stream's capacity to produce salmonids is controlled by the structure and function of the riparian zone. The riparian zone includes stream banks, riparian vegetation, and vegetative cover. Damaging any one of these elements can cause stream bank destabilization resulting in increased erosion, sediment and nutrient inputs, and reduced shading and bank cover leading to increased stream temperatures. Destruction of riparian trees also means a decrease in the supply of large woody debris. This results in a loss of instream habitat diversity caused by removing the source of materials partially responsible for creating pools and riffles that are critical for anadromous fish growth and survival, as outlined in Environmental Effect Number 7, above (Koski 1992; Murphy 1995; OWRRI 1995).

Gravel extraction activities can damage the riparian zone in several ways:

- If the floodplain aquifer discharges into the stream, groundwater levels can be lowered because of channel degradation. Lowering the water table can kill riparian vegetation (Collins and Dunne 1990).
- Long-term loss of riparian vegetation can occur when gravel is removed to depths that result in permanent flooding or ponded water. Also, loss of vegetation occurs when gravel removal results in a significant shift of the river channel that subsequently causes annual or frequent flooding into the disturbed site (Joyce 1980).
- Heavy equipment, processing plants, and gravel stockpiles at or near the extraction site can destroy riparian vegetation (Joyce 1980; Kondolf 1994a; OWRRI 1995). Heavy equipment also causes soil compaction, thereby increasing erosion by reducing soil infiltration and causing overland flow. As mentioned in Environmental Effect Number 5 above, the use of heavy equipment also leads to the increased risk of chemical pollution;

hazardous chemicals may also be used in nearby sediment processing plants. In addition, roads, road building, road dirt and dust, and temporary bridges can also impact the riparian zone.

- Removal of large woody debris from the riparian zone during gravel extraction activities negatively affects the plant community (Weigand 1991; OWRRI 1995). Large woody debris is important in protecting and enhancing recovering vegetation in streamside areas (Franklin et al. 1995; OWRRI 1995).
- Rapid bed degradation may induce bank collapse and erosion by undercutting and by increasing the heights of banks (Collins and Dunne 1990; Kondolf 1994a, 1997).
- Portions of incised or undercut banks may be removed during gravel extraction, resulting in reduced vegetative bank cover, causing reduced shading and increased water temperatures (Moulton 1980).
- Banks may be scraped to remove overburden to reach the gravel below. This may result in destabilized banks and increased sediment inputs (Moulton 1980).
- The reduction in size or height of bars can cause adjacent banks to erode more rapidly or to stabilize, depending on how much gravel is removed, the distribution of removal, and the geometry of the particular bed (Collins and Dunne 1990).

10. Gravel mining can cause a change in disturbance regimes and patterns with a concomitant change in habitat and species (Castro and Cluer, unpublished report). Stream and river systems are disturbance driven, which can temporarily or permanently alter the character of the system. These disturbances include natural variations in flow regimes and flood events, sediment delivery to the system, large inputs of organic materials, changes in base level, etc. Disturbances can be described by their frequency (e.g., the 100-year flood), duration (length of time), magnitude (areal extent), intensity (force exerted), and severity (biological response) (OWRRI 1995). The bed within the active stream channel experiences the greatest disturbance frequency, which could be as often as every year (i.e., sediment transport events). The 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). Floodplains are disturbed even less frequently than the main and side channels; it may take a major flood event on the order of a decade or longer before the floodplain shows significant alteration. Finally, terraces and hillslopes have the lowest disturbance frequency (e.g., slope failures and mass movements).

Common to all these disturbances is that the episode of disturbance is followed by a period of recovery (OWRRI 1995). If the disturbance events become so frequent that the system cannot fully recover before the next event, then the system is held in a constant state of disequilibrium or instability (Castro and Cluer, unpublished report). Organisms in these habitats show different responses to these disturbances, depending on such factors as their differences in developmental times, behavior, and their responses to environmental factors (OWRRI 1995). Pringle (1997) contends that anthropogenic activities downstream, including urbanization, dams, gravel mining, etc., can cause effects on organisms upstream, 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 shift of the plant and animal communities to ones that are more adapted to constant disturbance (OWRRI 1995). Incised

streams and rivers may be subject to chronic disturbance because of the disconnection of the floodplain. Instream gravel mining may cause chronic disturbance with a concomitant change in the habitat and associated species. Although sediment transport events may occur annually, and may be compared to gravel mining activities, the latter are temporally distinct from natural events. As OWRRI (1995) affirms about salmonids:

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.

IV. RECOMMENDATIONS

The following recommendations do not specify the measures, if any, that would need to be implemented by parties engaged in gravel extraction activities in order to comply with applicable statutory requirements. In formulating its recommendations or prescriptions, NMFS will determine the acceptable means of demonstrating compliance with statutory requirements based on information available to the agency, as appropriate under the circumstances presented. As such, the language of this Guidance should not be read to establish any binding requirements on agency staff or the regulated community. The recommendations should not be regarded as static or inflexible, and are meant to be revised as the science upon which they are based improves and areas of uncertainty are resolved. Furthermore, the recommendations are meant to be modified for regional or local use, so a degree of flexibility in their interpretation and application is essential.

In general terms, gravel extraction operations located in or immediately adjacent to streams have greater impacts to anadromous fish resources and habitats than operations located farther from the stream. **Therefore, NMFS recommends that all reasonable efforts be made to identify gravel sources in upland areas and terraces before deciding to site project operations in or near streams.** This is commensurate with the CWA section 404 rationale of *avoiding* impacts, *minimizing* (when not reasonably possible to avoid), and then *mitigating* (when not reasonably possible to minimize).

If, after a thorough alternatives analysis, instream, floodplain, or terrace mining is going to proceed, NMFS recommends that project operations be carefully designed to minimize impacts to trust resources, including habitat. If the recommendations outlined in this Guidance are followed, such that (1) anadromous fishes and their habitats are protected and (2) appropriate and timely restoration is implemented to mitigate unavoidable impacts, gravel mining can, as suggested by Langer (2003), take place within acceptable limits. Many factors must be considered when designing a gravel mining project that conforms to environmental constraints. The recommendations below present only a general list of these considerations. Each project should be considered in its own context, based on project design, stream type and condition, natural resources, and cumulative impacts. NMFS Regional Offices are encouraged to adopt more detailed guidelines tailored to specific physical settings and biological needs.

- 1. NMFS recommends that upland aggregate sources, terraces and inactive floodplains be used preferentially to active channels, their deltas and floodplains.** It is recommended that gravel extraction sites be situated outside the active floodplain and that the gravel not be excavated from below the water table. In other words, dry-pit mining on upland outcrops, terraces, or the floodplain is preferable to any of the instream alternatives. Bar skimming is generally preferable to wet-pit mining (deep water dredging) within the active channels if no upland or floodplain sources are reasonably available (see Recommendation Number 6, below). In addition, it is recommended that operators not divert streams to create an inactive channel for gravel extraction purposes, and avoid the formation of isolated ponded areas that cause fish entrapment. In all cases, it is recommended that efforts be made to minimize the need for crossing active channels with heavy equipment.
- 2. NMFS recommends that pit excavations located on the adjacent floodplain or terraces should be preferentially sited outside the channel migration zone, and as far from the stream as possible. NMFS recommends that pits be separated from the active channel by a buffer designed to maintain this separation for several decades.** As previously discussed in Section II, the effects of floodplain mining are related to the subsurface hydrological connections between pits and streams, as well as the potential for active channel migration into the floodplain pits (“pit capture”). Therefore, as noted by Kondolf (1993, 1994a), NMFS recommends that pits be considered as potentially instream when viewed on a time scale of decades. Consequently, it is recommended that floodplain pits be located outside the channel migration zone and as far from the stream as possible. This is particularly important given that the likelihood and extent of adverse effects associated with floodplain mining is directly related to the pit’s proximity to the active channel (Langer 2003; NMFS 2004). It is recommended that buffers or levees that separate the pits from the active channel be sufficient to accommodate long-term channel migration, infrequent flooding, or inundation; and to avoid fish entrapment. Kondolf (1997) reminds us that:

A river channel and floodplain are dynamic features that constitute a single hydrologic and geomorphic unit characterized by frequent transfers of water and sediment between the two components. The failure to appreciate the integral connection between floodplain and channel underlies many environmental problems in river management today.

Generally, the physical setback of the pit from the channel should be based on several channel widths, or on the meander belt. Pit size should also be considered in determining appropriate buffers. Larger pits have the capacity to absorb a much greater volume of sediment than smaller pits, upon pit capture.

- 3. NMFS recommends that larger rivers and streams be used preferentially to small rivers and streams.** Larger systems generally have more gravel and a wider floodplain, and a proportionally smaller disturbance in large systems will reduce the overall impact of gravel extraction (Follman 1980). On a smaller river or stream, the location of the extraction site is more critical because of the limited availability of exposed gravel deposits and the relatively narrower floodplain (Follman 1980). In either case, NMFS recommends that the extraction volume relative to coarse sediment load be low.

4. **NMFS recommends that braided river systems be used preferentially to other river systems.** The river systems, listed in the order of increasing sensitivity to physical changes caused by gravel extraction activities, are: braided, split, meandering, sinuous, and straight (Rundquist 1980). Because braided river systems are dynamic and channel shifting may be a frequent occurrence, channel shifting resulting from gravel extraction might have less overall impact because it is analogous to a naturally occurring process (Follman 1980). However, gravel extraction from braided streams is still considered instream extraction, and NMFS recommends that it be avoided.

5. **NMFS recommends that instream gravel removal quantities be strictly limited so that gravel recruitment and accumulation rates are sufficient to avoid prolonged impacts on channel morphology and anadromous fish habitat.** While this is conceptually simple, annual gravel recruitment to a particular site is, in fact, highly variable and not well understood. Recruitment is the rate at which bedload is supplied from upstream to replace the extracted material. Kondolf (1993, 1994b) dismisses the common belief that instream gravel extraction can be conducted safely as long as the rate of extraction does not exceed the rate of replenishment. Kondolf (1993, 1994b) states that this approach to managing instream gravel extraction is flawed because it fails to account for the upstream/downstream erosional effects that change the channel morphology as soon as gravel extraction begins. In addition, Kondolf (1993, 1994b, 1997) reiterates that flow and sediment transport for most rivers and streams is highly variable from year to year, thus an annual average rate may be meaningless. An “annual average deposition rate” could bear little relation to the sediment transport regimes in a river in any given year. Moreover, sediment transport processes are very difficult to measure and to model, so estimates of bedload transport may prove unreliable (Kondolf 1997). These problems and uncertainties indicate a need for cautious interpretation of sediment yield results, and the conservative application of volume limitations on extraction projects. Any gravel removal in streams or rivers that have a recent history of eroding bars or banks and/or stream bed lowering is not recommended.

Collins and Dunne (1990) recommend that appropriate rates and locations for instream gravel extraction should be determined on the basis of:

- the rate of upstream recruitment;
- whether the river bed elevation under undisturbed conditions remains the same over the course of decades, or the rate at which it is aggrading or degrading;
- historic patterns of sediment transport, bar growth, and bank erosion;
- prediction of the specific, local effects of gravel extraction on bed elevations, and the stability of banks and bars, taking into account an analysis of present or past effects of gravel extraction at various rates; and
- a determination of the desirability or acceptability of the anticipated effects.

In addition, it is recommended that the habitat values of remaining (or newly recruited) sediments be functionally adequate or equivalent for the purposes of migration, spawning, rearing, benthic invertebrate production, and any other identified habitat needs. Upstream recruitment is ineffective if the necessary ecological functions are not replaced or restored.

6. NMFS recommends that gravel bar skimming be allowed only under restricted conditions. (See Section III, Environmental Effect Number 4, for the environmental impacts of gravel bar skimming.) Therefore, NMFS recommends that:

- gravel be removed only during low flows and from strictly defined areas above the low-flow water level;
- berms and buffer strips be used to direct stream flow away from the site and to provide for continued migratory habitat;
- the final grading of the gravel bar not significantly alter the flow characteristics of the river during periods of high flows (OWRRI 1995);
- bar skimming operations be monitored to ensure they are not adversely affecting gravel recruitment or channel morphology either upstream or downstream from the site;
- geomorphic features be monitored using methods that quantify their physical dimensions and changes at appropriate time scales. This will likely include densely spaced cross sections to cover the geomorphic features, topographic mapping techniques that do not rely solely on cross sections but follow terrain features, and modern mapping techniques that grid entire areas with closely spaced data; and
- any gravel removal in streams or rivers that have a recent history of eroding bars or banks, or stream bed lowering, be discouraged.

7. NMFS recommends that, prior to gravel removal, a thorough review of sediments and point and non-point sources of contaminants be conducted. Toxic compounds from a variety of sources (municipalities, manufacturing plants, hardrock mines, etc.) may be present in sediments, and can be released into the stream when disturbed during gravel extraction operations. It is recommended that sediment testing be conducted to detect metals and organic compounds (DDT, PCBs, etc.), and residual acid or heavy metal drainage from hardrock mining operations; and that during project operations, extracted gravel, sand, and sediments not be washed directly in the stream or river or within the riparian zone.

In addition, it is recommended that an assessment of contaminant sources be completed to assist in determining potential problems with contaminated sediments. Sources can include farming, mining, National Pollutant Discharge Elimination System (NPDES)-permitted activities, forestry, sewage treatment plants, and other municipal infrastructure.

To minimize the suspension of sediments, it is recommended that measures be taken to contain turbidity plumes, and to avoid excessive disturbance of sediments. It is also recommended that turbidity levels do not exceed maximum allowable turbidity limits for anadromous fish and their prey.

8. NMFS recommends that removal or disturbance of instream roughness elements during gravel extraction activities be avoided, and that those that are disturbed be replaced or restored. As previously stated in Section III, Environmental Effect Number 7, instream roughness elements, particularly large woody debris, are critical to stream and river ecosystem functioning. This may be particularly true in small streams where large woody

debris plays a relatively greater role in channel morphology and sediment dynamics than it does in larger streams or rivers. In addition, it is recommended that gravel itself be considered an instream roughness element, and that consideration be given to leaving similar-sized gravel in the stream bed, in addition to replacing large woody debris.

9. NMFS recommends that gravel extraction operations be managed to avoid or minimize damage to stream/river banks and riparian habitats. Therefore, NMFS recommends that:

- gravel extraction in vegetated (or those that would be vegetated without repeated anthropogenic disturbances) and riparian areas be avoided;
- gravel pits located on the adjacent floodplain not be excavated below the water table;
- berms and buffer strips in the floodplain that keep active channels in their original locations or configurations be maintained for several decades (as in Recommendation Number 2, above);
- undercut and incised vegetated banks not be altered;
- large woody debris in the riparian zone be left undisturbed or replaced when moved;
- all support and processing operations (e.g., gravel washing) be done outside the riparian zone;
- gravel stockpiles, overburden and/or vegetative debris not be stored within the riparian zone, and they be disposed of properly after extraction;
- operation and storage of heavy equipment within riparian habitat be restricted;
- access roads not encroach into the riparian zones; and
- riparian zone protection extend well upstream and downstream from the project site when possible because the erosional effects of instream gravel mining can be manifested miles upstream and downstream from the site of operations.

10. NMFS recommends that the cumulative impacts of gravel extraction operations to anadromous fishes and their habitats be addressed by the Federal, state, and local resource management and permitting agencies and be considered in the permitting process. The cumulative impacts on anadromous fish habitat caused by multiple extractions and sites in a given stream, river, or watershed are compounded by other riverine impacts and land use disturbances in the watershed. These additional impacts may be caused by river diversions/impoundments, flood control projects, logging, grazing, and channel/riparian encroachment. The technical methods for assessing, managing, and monitoring cumulative effects are a future need outside the scope of this Gravel Guidance document. Nevertheless, it is recommended that individual gravel extraction operations be judged from a perspective that includes their potential adverse cumulative impacts (Kondolf 1997, 1998a; see also Council on Environmental Quality 1997 and U.S. EPA, Office of Federal Activities 1999 for general cumulative impact guidance). It is recommended that this be reflected in any gravel extraction management plan. NMFS will promote the same watershed approach to cumulative impact analysis when reviewing non-mining activities in or near the aquatic environment.

11. NMFS recommends that an integrated environmental assessment, management, and monitoring program be a part of any gravel extraction operation, and encouraged at Federal, state, and local levels. Assessment is used to predict possible environmental impacts. Management is used to implement plans to prevent, minimize, and mitigate negative impacts. Monitoring is used to determine if the assessments were correct, to detect environmental changes, and to support management decisions.

Before gravel mining operations commence, it is recommended that operators submit plans to the appropriate Federal, state and local agencies outlining their proposed project, including but not limited to location, methods, timing, duration, proposed extraction volumes, and post-mining landscape morphology. Prior to extraction, it is important to establish existing biological and physical conditions, evaluate possible environmental impacts, and describe ways in which adverse environmental impacts are to be prevented or minimized, with the goal of achieving and maintaining the natural ecological functions of the habitat. Using a combination of best available technologies and methods, it is recommended that the following be assessed:

- Characterize and identify fish species distributions, abundances, and life stages.
- Identify habitat requirements and determine limiting environmental factors of the anadromous fish populations. In addition to the limiting factors identified by Koski (1992), it is recommended that this analysis evaluate the proposed timing of extraction operations relative to adult and juvenile migration patterns and choose in-water work windows accordingly.
- Develop a flow frequency curve.
- Calculate sediment budgets, taking into consideration such periodic natural events as floods (Meador and Layher 1998).
- Predict possible changes in water quality, channel morphology, and potential adverse cumulative impacts.
- Propose a mitigation and restoration strategy based on preventing impacts, minimizing unavoidable impacts, and mitigating for all immediate and cumulative impacts (see Recommendation Number 12, below).

NMFS recommends that the operators also check with their NMFS Regional Offices for any regionally specific procedures and guidelines.

While gravel mining operations are ongoing, it is important to monitor permitted operations and verify environmental safeguards. At a minimum, it is recommended that the following attributes be monitored on a regular basis:

- extraction rates and volumes;
- impacts to the river bed, banks, and bars adjacent to, upstream, and downstream of the project using benchmarked channel cross sections, Digital Elevation Models, and aerial photographs;
- species distributions and abundances;
- water quality, including turbidity, dissolved oxygen and contaminants; and
- effectiveness of mitigation activities.

NMFS recommends that permits have a maximum 5-year limit and be subject to annual review and revision to protect anadromous fish and their habitats (e.g., it is recommended that one element of the annual review determine whether resource management and monitoring objectives are being met). NMFS recommends that a third party be responsible for carrying out monitoring activities and reporting these results to the permitting agency, the operator, the appropriate natural resource agencies, and other stakeholders.

12. NMFS recommends that mitigation be an integral part of the management of gravel extraction projects. It is important that mitigation be based on replacing equivalent habitat values and functions, as per the U.S. Army Corps of Engineers (USACE) Regulatory Guidance Letter No. 02-2 (2002) on compensatory mitigation. It is recommended that a mitigation strategy be included in the management program of each project, and, where possible, mitigation activities be initiated concurrently with the gravel mining operations. NMFS recommends that a mechanism for correcting problems identified via monitoring be written into the permit, as monitoring is not worthwhile unless there is a mechanism to address problems that are identified as a result of the monitoring program. In terms of National Environmental Policy Act (NEPA) regulations, mitigation includes, in sequential order:

- avoidance of direct or indirect impacts or losses;
- minimization of the extent or magnitude of the action;
- repair, rehabilitation or restoration of integrity and function;
- reduction or elimination of impacts by preservation and maintenance; and
- compensation by replacement or substitution of the resource or environment.

Thus, restoration follows avoidance and minimization. The preceding definitions recommend that restoration aim to restore the biotic integrity of a riverine ecosystem, not just repair the damaged abiotic components. An overview of river and stream restoration can be found in Gore et al. (1995). A universal, prototype long-term monitoring strategy for watershed and stream restoration can be found in Bryant (1995); see also the various papers by Kondolf and others (e.g., Kondolf and Larson 1995; Kondolf and Micheli 1995; Kondolf 1998b). In addition, see Beechie and Bolton (1999), who discuss approaches to restoring salmonid habitat-forming processes in Pacific Northwest watersheds, and Roni et al. (2002), who review stream restoration techniques and present a hierarchical strategy for prioritizing restoration in these watersheds.

Koski (1992) states that the concept of stream habitat restoration as applied to anadromous fishes is based on the premise that fish production increases when those environmental factors that limit production are alleviated. Thus, an analysis of those “limiting factors” is critical to the restoration process. Koski (1992) further states that effective stream habitat restoration must be holistic in scope, and approached through a three-step process:

1. First, a program of watershed management and restoration must be applied to the watershed to ensure that all major environmental impacts affecting the entire stream ecosystem are addressed (i.e., cumulative impacts). Obviously, an individual gravel extraction project is not expected to restore an entire watershed

suffering from cumulative effects for which it was not responsible. Rather, needed mitigation and restoration activities in a riverine system should focus on direct and indirect project effects and must be designed within the context of overall watershed management.

2. Next, restore the physical structure of the channel, instream habitats, and riparian zones (e.g., stabilize stream banks through replanting of riparian vegetation, conserve spawning gravel, and replace large woody debris). This would reestablish the ecological carrying capacity of the habitat.

3. Finally, the fish themselves should be managed to ensure that there are sufficient spawning populations for maximizing the restored carrying capacity of the habitat.

Without restoration, stream recovery from gravel mining can take decades (Kanehl and Lyons 1992). However, NMFS recommends that reliance on restoration be put into proper perspective. It is important to acknowledge that there are significant gaps in our understanding of the methodology and effectiveness of restoration of streams and anadromous fish habitat affected by gravel extraction activities. Overall, restoration as a science is relatively young and experimental, and the processes and mechanisms are poorly understood. Little is known about the functional value, stability and resiliency of many so-called “restored” habitats. To date, existing regulations or plans pertaining to the mitigation and restoration of gravel extraction sites have been simplistic or vague, and, because restoration science and planning is still rudimentary, NMFS recommends that each project first begin its mitigation analysis with avoidance and minimization.

As an example, gravel extraction in California is regulated under the concept of “reclamation,” which is derived from open-pit surface mining, such as large coal mines. Although the definition and implementation of reclamation may vary among states, Kondolf (1993, 1994b) states the concept of reclamation, as applied to open-pit mines, often assumes that the environmental impacts are confined to the site; therefore, site treatment is considered in isolation from changes in the surrounding terrain. Kondolf (1993, 1994b) suggests that this definition treats the site as an essentially static feature of the landscape. He argues that, while these assumptions may work for extraction operations located in inactive stream or river terraces, active channels and floodplains are dynamic environments, where disturbances can spread rapidly upstream and downstream from the site during and after the time of operation. The stream or river will irrevocably readjust its profile during subsequent high flows, eradicating the gravel pits and giving the illusion that extraction has had no impact on the channel. Kondolf (1993, 1994b) claims that a survey of bed elevations will show a net lowering of the bed, which reflects the more even distribution of downcutting (erosion) along the length of the channel. Even if the channel profile were to recover after project completion due to an influx of fresh sediment from upstream, habitat will have been lost in the meantime. Thus, it is not possible to disturb one site in isolation from the rest of the ecosystem, or confine the disturbance to a single, detached location, and then subsequently reclaim or reverse the impacts (Brown et al. 1998). Kondolf (1993, 1994b) concludes that reclamation can be applied to gravel pits in terrace deposits above the water table, but the reclamation concept is not workable for regulating instream gravel extraction. Similarly,

regarding instream gravel mining, Brown et al. (1998) conclude that “total restoration of severely affected streams would probably be impossible.”

Moreover, Kondolf (1998a) reminds us that:

The effects of instream gravel mining may not be obvious immediately because active sediment transport is required for the effects (e.g. incision, instability) to propagate upstream and downstream. Given that geomorphically-effective sediment transport events are infrequent on many rivers, there may be a lag of several or many years before the effects of instream gravel mining are evident and propagate along the channel. Thus, gravel mines may operate for years without apparent effects upstream or downstream, only to have the geomorphic effects manifest years later during high flows. Similarly, rivers are often said to have “long memories,” meaning that the channel adjustments to instream extraction or comparable perturbations may persist long after the activity itself has ceased.

This delayed manifestation of geomorphic effects leads to the false assumption that floods cause damage to stream systems, when in actuality anthropogenic changes often “set the stage” for geomorphic change. Large flood events simply provide the necessary stream power for the changes to occur.

For further guidance on mitigation, refer to the USACE Regulatory Guidance Letter (USACE 2002) noted above and the joint guidance on the Use of In-Lieu-Fee Arrangements for Compensatory Mitigation Under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act (65FR 66913, November 7, 2000).

13. NMFS recommends that gravel extraction projects proposed as stream restoration activities be regarded with caution. Resource management agencies acknowledge that, under the right circumstances, some gravel extraction projects, whether commercial or performed by the agencies themselves, may offer important opportunities for anadromous fish habitat enhancement. That is, gravel removal itself can be used beneficially as a tool for habitat creation, restoration, or rehabilitation (OWRRI 1995). While it is tempting to promote gravel extraction as a means to enhance or restore stream habitat, the underlying objective of this Guidance document is to prevent adverse impacts caused by commercial gravel extraction operations. Therefore, NMFS recommends that gravel extraction for habitat enhancement purposes, done in conjunction with commercial gravel operations, not take precedence over, and not be a substitute for, habitat protection. It is recommended that any proposals to perform gravel extraction for habitat enhancement purposes be done in consultation with NMFS regional field offices and technical experts.

NMFS recommends that either a mitigation fund, with contributions paid by the operators, or royalties from gravel extraction be used to fund mitigation programs and to perform effectiveness monitoring. A possible use of mitigation funds and royalties could include conducting studies to further the knowledge of extraction impacts in a given watershed. Such studies might include: a review of historical impacts; identification of alternative aggregate sources; a watershed-based evaluation of mitigation alternatives; identification of sites where

it is recommended that extraction activities be avoided; and recommended removal thresholds.

In light of the dynamic, unpredictable, and episodic nature of stream hydrology and sediment transport, NMFS cautions against relying too heavily on restoration, and agrees with both Murphy (1995) and Langer (2001) that the best form of habitat mitigation is to avoid or minimize adverse impacts to the environment.

V. LITERATURE CITED

- Abbe, T.B. and D.R. Montgomery. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. *Regulated Rivers: Res. Manage.* 12: 201-221.
- Beechie, T. and S. Bolton. 1999. An approach to restoring salmonid habitat-forming processes in Pacific Northwest watersheds. *Fisheries* 24: 6-15.
- Berg, L. and T.G. Northcote. 1985. Changes in territorial, gill-flaring, and feeding behavior in juvenile coho salmon (*Oncorhynchus kisutch*) following short-term pulses of suspended sediment. *Can. J. Fish. Aquat. Sci.* 42: 1410-1417.
- Bisson, P.A. and R.E. Bilby. 1982. Avoidance of suspended sediment by juvenile coho salmon. *N. Amer. J. Fish. Manage.* 2: 371-374.
- Bjornn, T.C. and D.W. Reiser. 1991. Habitat requirements of salmonids in streams. *In: Influences of forest and rangeland management on salmonid fishes and their habitats* (W.R. Meehan, ed.), pp. 83-138. *Amer. Fish. Soc. Spec. Pub.* 19. 751 pp.
- Bradford, M.J. and P.S. Higgins. 2001. Habitat-, season-, and size-specific variation in diel activity patterns of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead trout (*Oncorhynchus mykiss*). *Can. J. Fish. Aquat. Sci.* 58: 365-374.
- Brown, A.V., M.M. Lyttle, and K.B. Brown. 1998. Impacts of gravel mining on gravel bed streams. *Trans. Amer. Fish. Soc.* 127: 979-994.
- Bryant, M.D. 1995. Pulsed monitoring for watershed and stream restoration. *Fisheries* 20: 6-13.
- Castro, J. and B. Cluer. Unpublished report. Instream aggregate mining issues in Oregon. Draft report developed for the U.S. Fish Wildl. Serv., Oregon Fish Wildl. Office, Portland, Oregon, October 2003.
- Chapman, D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. *Trans. Amer. Fish. Soc.* 117: 1-21.
- Collins, B. and T. Dunne. 1990. Fluvial geomorphology and river-gravel mining: a guide for planners, case studies included. *Calif. Depart. Conserv., Div. Mines Geol., Spec. Pub.* 98. 29 pp.
- Collins, B.D. and D.R. Montgomery. 2002. Forest development, wood jams, and restoration of floodplain rivers in the Puget Lowland. *Restoration Ecol.* 10: 237-247.
- Collins, B.D., D.R. Montgomery, and A.D. Haas. 2002. Historical changes in the distribution and functions of large wood in Puget Lowland Rivers. *Can. J. Fish. Aquat. Sci.* 59: 66-76.

- Cordone, A.J. and D.W. Kelley. 1961. The influences of inorganic sediment on the aquatic life of streams. *Calif. Fish Game* 47: 189-228.
- Council on Environmental Quality. 1997. Considering cumulative effects under the National Environmental Policy Act. Council on Environmental Quality, Exec. Office of the President, Washington, DC.
- Everest, F.H., R.L. Beschta, J.C. Scrivener, K.V. Koski, J.R. Sedell, and C.J. Cederholm. 1987. Sediment and salmonid production: a paradox. *In: Streamside management: forestry and fishery interactions* (E.O. Salo and T.W. Cundy, eds.), pp. 98-142. *Proc. Symp., Univ. Wash., Contrib. No. 57, Inst. Forest Resour., Univ. Wash., Seattle, WA.*
- Florsheim, J., P. Goodwin, and L. Marcus. 1998. Geomorphic effects of gravel extraction in the Russian River, California. *In: Aggregate resources: a global perspective* (P.T. Bobrowsky, ed.), pp. 87-99. A.A. Balkema, Rotterdam. 470 pp.
- Follman, E.H. 1980. Interdisciplinary overview of gravel removal. *In: Gravel removal studies in arctic and subarctic floodplain in Alaska—technical report* (Woodward-Clyde Consultants, ed.), pp. 331-384. U.S. Fish Wildl. Serv., Biological Services Program, FWS/OBS-80/08. 403 pp.
- Forshage, A. and N.E. Carter. 1973. Effect of gravel dredging on the Brazos River. *Southeast. Assoc. Game Fish Comm.* 24: 695-708.
- Franklin, J.F. 1992. Scientific basis for new perspectives in forests and streams. *In: Watershed management* (R.J. Naiman, ed.), pp. 25-72. Springer-Verlag, New York. 542 pp.
- Franklin, J.F., P.M. Frenzen, and F.J. Swanson. 1995. Re-creation of ecosystems at Mount St. Helens: contrasts in artificial and natural approaches. *In: Rehabilitating damaged ecosystems, 2nd edition* (J. Cairns, Jr., ed.), pp. 287-334. Lewis Publishers, Boca Raton, FL. 425 pp.
- Gore, J.A., F.L. Bryant, and D.J. Crawford. 1995. River and stream restoration. *In: Rehabilitating damaged ecosystems, 2nd edition* (J. Cairns, Jr., ed.), pp. 245-275. Lewis Publishers, Boca Raton, FL. 425 pp.
- Joyce, M.R. 1980. Effects of gravel removal on terrestrial biota. *In: Gravel removal studies in arctic and subarctic floodplain in Alaska—technical report* (Woodward-Clyde Consultants, ed.), pp. 215-272. U.S. Fish Wildl. Serv., Biological Services Program, FWS/OBS-80/08. 403 pp.
- Kanehl, P. and J. Lyons. 1992. Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Wisconsin Depart. Nat. Resour. Res. Rep. 155, Madison, WI. 32 pp.

- Kondolf, G.M. 1993. The reclamation concept in regulation of gravel mining in California. *J. Environ. Plann. Manage.* 36: 395-406.
- Kondolf, G.M. 1994a. Geomorphic and environmental effects of instream gravel mining. *Landscape Urban Plann.* 28: 225-243.
- Kondolf, G.M. 1994b. Environmental planning in regulation and management of instream gravel mining in California. *Landscape Urban Plann.* 29: 185-199.
- Kondolf, G.M. 1997. Hungry water: effects of dams and gravel mining on river channels. *Environ. Manage.* 24: 533-551.
- Kondolf, G.M. 1998a. Environmental effects of aggregate extraction from river channels and floodplains. *In: Aggregate resources: a global perspective* (P.T. Bobrowsky, ed.), pp. 113-129. A.A. Balkema, Rotterdam. 470 pp.
- Kondolf, G.M. 1998b. Lessons learned from river restoration projects in California. *Aquat. Conserv: Mar. Freshwat. Ecosyt.* 8: 39-52.
- Kondolf, G.M. 2000. Assessing salmonid spawning gravel quality. *Trans. Amer. Fish. Soc.* 129: 262-281.
- Kondolf, G.M. and M. Larson. 1995. Historical channel analysis and its application to riparian and aquatic habitat restoration. *Aquat. Conserv: Mar. Freshwat. Ecosyt.* 5: 109-126.
- Kondolf, G.M. and E.R. Micheli. 1995. Evaluating stream restoration projects. *Environ. Manage.* 19: 1-15.
- Kondolf, G.M. and M.G. Wolman. 1993. The sizes of salmonid spawning gravels. *Water Resour. Res.* 29: 2275-2285.
- Koski, K.V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon coastal streams. M.S. Thesis, Oregon State Univ., Corvallis, OR. 84 pp
- Koski, K.V. 1975. The survival and fitness of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence in a controlled stream environment at Big Beef Creek. Ph.D. Dissertation, Univ. Wash., Seattle, WA. 212 pp.
- Koski, K.V. 1981. The survival and quality of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence. *Rapp. P.-V. Reun. Cons. Int. Explor. Mer.* 178: 330-333.
- Koski, K.V. 1992. Restoring stream habitats affected by logging activities. *In: Restoring the nation's marine environment* (G.W. Thayer, ed.), pp. 343-404. Maryland Sea Grant College, College Park, MD. 716 pp.

- Koski, K.V. 1993. Riparian zone functions and interaction with sediment. *In: Proceedings of a technical workshop on sediments, February 3-7, 1992, Oregon State University, Corvallis, OR., pp. 61-69. Sponsored by Terrene Institute, U.S. EPA, and USFS. Terrene Institute, Washington, DC.*
- Lagasse, P.F., B.R. Winkley, and D.B. Simons. 1980. Impact of gravel mining on river system stability. *J. Waterway, Port, Ocean Div., Amer. Soc. Civil Eng., 106 (WWE) L: 389-404.*
- Langer, W.H. 2001. Environmental impacts of mining natural aggregate. *In: Proceed. 35th forum on geol. industrial minerals—the intermountain west forum 1999 (R.L. Bon, R.F. Riordan, B.T. Tripp, and S.T. Kurkowski, eds.) pp. 127-138. Utah Geol. Surv. Misc. Pub. 01-2.*
- Langer, W.H. 2003. A general overview of the technology of in-stream mining of sand and gravel resources, associated potential environmental impacts, and methods to control potential impacts. Open File Report OF-02-153. <<http://pubs.usgs.gov/of/2002/ofr-02-153/>>
- Maser, C. and J. Sedell. 1994. From the forest to the sea. The ecology of wood in streams, rivers, estuaries, and oceans. St. Lucie Press, Delray Beach, FL. 200 pp.
- Meador, M.R. and A.O. Layher. 1998. Instream sand and gravel mining: environmental issues and regulatory process in the United States. *Fisheries 23: 6-13.*
- Meehan, W.R. and T.C. Bjornn. 1991. Habitat requirements of salmonids in streams. *Am. Fish. Soc. Spec. Pub. 19: 83-139.*
- Moulton, L.L. 1980. Effects of gravel removal on aquatic biota. *In: Gravel removal studies in arctic and subarctic floodplain in Alaska—technical report (Woodward-Clyde Consultants, ed.), pp. 141-214. U.S. Fish Wild. Serv., Biological Services Program, FWS/OBS-80/08. 403 pp.*
- Murphy, M.L. 1995. Forestry impacts on freshwater habitat of anadromous salmonids in the Pacific Northwest and Alaska—requirements for protection and restoration. NOAA Coastal Ocean Program, Decision Analysis Series No. 7. 156 pp.
- Naiman, R.J., T.J. Beechie, L.E. Benda, D.R. Berg, P.A. Bisson, L.H. MacDonald, M.D. O'Connor, P.L. Olson, and E.A. Steel. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest coastal ecoregion. *In: Watershed management (R.J. Naiman, ed.), pp. 127-188. Springer-Verlag, New York. 542 pp.*
- National Marine Fisheries Service (NMFS). 2004. Sediment removal from freshwater salmonid habitat: guidelines to NOAA Fisheries staff for the evaluation of sediment removal actions from California streams. <<http://swr.nmfs.noaa.gov/hcd/policies/April19-2004.pdf>>
- Oregon Water Resources Research Institute (OWRRI). 1995. Gravel disturbance impacts on salmon habitat and stream health. A report for the Oregon Division of State Lands. Vol 1: Summary Report. 52 pp. Vol 2: Technical background report. 225 pp.

- Palmisano, J.F., R.H. Ellis, and V.W. Kaczynski. 1993. The impact of environmental and management factors on Washington's wild anadromous salmon and trout. Wash. Forest Protect. Assn. and Wash. Depart. Nat. Resour., Olympia, WA. 371 pp.
- Pauley, G.B., G.L. Thomas, D.A. Marino, and D.C. Weigand. 1989. Evaluation of the effects of gravel bar scalping on juvenile salmonids in the Puyallup River drainage. Final Report to the Washington Department of Fisheries, Service Contract No. 1620. Coop. Fish. Res. Unit, Univ. Wash., Seattle, WA. 150 pp.
- Pringle, C.M. 1997. Exploring how disturbance is transmitted upstream: going against the flow. *J. N. Amer. Benthol. Soc.* 16: 425-438.
- Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat suitability information: rainbow trout. U.S. Fish Wildl. Serv. FWS/OBS-82/10.60.
- Reiser, D.W. and R.G. White. 1988. Effects of two sediment size-classes on survival of steelhead and chinook salmon eggs. *N. Amer. J. Fish. Manage.* 8: 432-437.
- Rivier, B. and J. Segulier. 1985. Physical and biological effects of gravel extraction in river beds. *In: Habitat modification and freshwater fisheries* (J.S. Alabaster, ed.), pp. 131-146. Butterworths, London.
- Roni, P., T.J. Beechie, R.E. Bilby, F.E. Leonetti, M.M. Pollock, and G.R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. *N. Amer. J. Fish. Manage.* 22: 1-20.
- Rundquist, L.A. 1980. Effects of gravel removal on river hydrology and hydraulics. *In: Gravel removal studies in arctic and subarctic floodplain in Alaska—technical report* (Woodward-Clyde Consultants, ed.), pp. 67-140. U.S. Fish Wildl. Serv., Biological Services Program, FWS/OBS-80/08. 403 pp.
- Sandecki, M. 1989. Aggregate mining in river systems. *Calif. Geol.* 42: 88-94.
- Servizi, J.A. and D.W. Martens. 1992. Sublethal responses of coho salmon (*Oncorhynchus kisutch*) to suspended sediments. *Can. J. Fish. Aquat. Sci.* 49: 1389-1395.
- Shrivell, C.S. 1990. Role of instream rootwads as juvenile coho salmon (*Oncorhynchus kisutch*) and steelhead trout (*O. mykiss*) cover habitat under varying streamflows. *Can. J. Fish. Aquat. Sci.* 47: 852-860.
- Sigler, J.W., T.C. Bjornn, and F.H. Everest. 1984. Effects of chronic turbidity on density and growth of steelheads and coho salmon. *Trans. Amer. Fish. Soc.* 113: 142-150.
- Snyder, G.R. 1959. Evaluation of cutthroat trout reproduction in Trappers Lake inlet. *Quart. Rep. Colo. Fish. Res. Un.* 5: 12-52.

- Spence, B.C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. An ecosystem approach to salmonid conservation. TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, Oregon.
<<http://www.nwr.noaa.gov/1habcon/habweb/habguide/ManTech/front.htm>>
- Sullivan, K., T.E. Lisle, C.A. Dolloff, G.E. Grant, and L.M. Reid. 1987. Stream channels: the link between forests and fishes. *In*: Streamside management: forestry and fishery interactions (E.O. Salo and T.W. Cundy, eds.), pp. 39-97. Proc. Symp., Univ. Wash., Contrib. No. 57, Inst. Forest Resour., Univ. Wash., Seattle, WA.
- U.S. Army Corps of Engineers. 2002. Regulatory Guidance Letter. USACE, No. 02-02.
- U.S. Environmental Protection Agency (U.S. EPA), Office of Federal Activities. 1999. Consideration of cumulative impacts in EPA review of NEPA documents. EPA 315-R-99-002.
- Use of In-Lieu-Fee Arrangements for Compensatory Mitigation Under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act (65FR 66913, November 7, 2000).
- Waters, T.E. 1995. Sediment in streams: sources, biological effects, and control. Amer. Fish. Soc. Monogr. 7, Bethesda, MD. 251 pp.
- Weigand, D.C. 1991. Effects of gravel scalping on juvenile salmonid habitat. M.S. Thesis, Univ. Wash., Seattle WA.

APPENDIX 1 SUMMARIES OF MAJOR STATUTES

The following summaries of the major statutes mentioned in this Gravel Guidance document, with the exception of the Rivers and Harbors Act of 1899, are based on Buck (1995)¹.

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 waters of the United States. 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 intent of the CWA Section 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 National Marine Fisheries Service (NMFS) can provide comments to the U.S. Army Corps of Engineers (USACE) as to the impacts to living marine resources of proposed activities and can recommend methods for avoiding such impacts.

If NMFS determines that a proposed action will result in “substantial and unacceptable adverse impacts on aquatic resources of national importance,” the Assistant Secretary for Oceans and Atmosphere may request that the decision be reviewed at a higher level in the USACE. A 404(q) elevation pauses the permit process for about 2 months while the two departments exchange information to address concerns about the proposed project. Although outright permit denials are rare, there are often modifications to the project proposal resulting in a less harmful action.

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. If a Federal action may affect ESA-listed species or their critical habitat, the action agency must initiate consultation with NMFS under section 7 of the ESA. Other pertinent sections of the ESA include section 9 (direct take) and section 10 (exemptions from take prohibitions).

¹Buck, 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.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (FWCA) (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 U.S. Fish and Wildlife Service, NMFS and appropriate state agencies whenever any body of water is proposed to be modified in any way and a Federal permit or license is required. These agencies determine: (1) the possible harm to fish and wildlife resources; (2) the measures needed to both prevent the damage to and loss of these resources; and (3) 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 provides recommendations to prevent harm.

Magnuson-Stevens Fishery Conservation and Management Act

The Magnuson-Stevens Fishery Conservation and Management Act, first passed in 1976 and amended in 1996, is the primary legislation governing marine fisheries in the United States. This legislation established eight Regional Fishery Management Councils to manage fishery resources in the Exclusive Economic Zone under Fishery Management Plans (FMPs) for Federally managed fisheries. Plans may include one or several species and are designed to achieve specified management goals for a fishery.

The 1996 reauthorization of the Magnuson-Stevens Act included a provision for Essential Fish Habitat (EFH). The act states: “One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats. Habitat considerations should receive increased attention for the conservation and management of fishery resources of the United States” (16 U.S.C. 1801 (A)(9)). The definition of EFH in the legislation covers “those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity.” The legislation mandates that NMFS and the Councils implement a process for conserving and protecting EFH. Key features of this process are:

1. *Designate EFH.* Councils are required to describe and identify EFH for each life stage of the species included in their FMPs.
2. *Minimize to the extent practicable the adverse effects of fishing on EFH.* Councils must assess fishing impacts to EFH, taking Habitat Areas of Particular Concern (HAPCs) into special consideration (i.e., habitat types that are especially sensitive, ecologically important, or rare), and minimize the impacts of fishing on EFH to the extent practicable.
3. *Consult on potential fishing and non-fishing impacts to EFH.* NMFS and the Councils are required to comment on activities proposed by Federal action agencies (e.g., U.S. Army Corps of Engineers, Federal Energy Regulatory Commission, and Department of the Navy) that may adversely impact areas designated as EFH.
4. *Further review of decisions inconsistent with NMFS or Council recommendations.* If a Federal agency decision is inconsistent with a NMFS conservation recommendation, the

Assistant Administrator for Fisheries may request a meeting with the head of the Federal action agency to review and discuss the issue.

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 that would significantly affect the human environment. It specifically requires agencies to use a systematic, interdisciplinary approach in planning and decision making to ensure 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 decision making. Alternatives analysis allows other 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.

Rivers and Harbors Act of 1899

The Rivers and Harbors Act of 1899, Section 10 (33 *U.S.C.* 403), authorizes the USACE to regulate activities that affect waters of the United States. These activities include construction of wharves, piers and jetties and excavating or altering stream channels of navigable waters. NMFS may comment on proposed activities (usually via the FWCA), and the CWA 404(q) elevation process (see Clean Water Act, above) is available to NMFS under the Rivers and Harbors Act.