Appendix E

Review of Scientific Studies Relevant to EWP Program Practices

E.1 Biotic Impacts of EWP Program Practices

E.1.1 Site Preparation Impacts on an Aquatic Community

EWP Program practices may require site preparation activities before emergency practices can be implemented. Site preparation activities may involve clearing and grading sites to create access for equipment to move in, stabilizing banks for equipment placement, dewatering to allow equipment to be operated in-stream, and earth moving. These activities usually require the use of heavy equipment. Some studies and reviews of the impacts of site preparation activities on water quality and wetlands indicate that these activities can harm a system's biological, chemical, and physical components.

Darnell (1976) reviewed the impacts of construction activities on wetlands of the United States and determined that aquatic environments may be affected directly by construction that takes place within or at the margins of the wetlands, and indirectly by construction on neighboring floodplains, banks, or shores. He discussed the impacts of construction activities on wetland, riverine, and riparian areas and emphasized levee construction, dredging, construction, and disposal impacts.

Darnell finds that site preparation impacts include the removal of vegetation cover and topsoil, which may increase stream temperature by as much as 10°F; decreased habitat; increased surface runoff and soil erosion; modifications in patterns of flow and flooding; increased turbidity and sedimentation; increased pollution from heavy equipment; and the modification of water chemistry through the addition of sediments, nutrients, and pollutants.

Darnell notes that the effects of construction vary with locality and topography, season, methodology of construction activities, and the care that is taken to avoid unnecessary environmental damage. He points out that the effects of construction activities vary greatly in size and duration. He states that many construction activities do not cause significant environmental damage, but even minor effects can add up to take a devastating environmental toll.

Darnell cites a 1973 study by Hobbie and Likens that reported a 26 percent increase in surface runoff from recently devegetated forest lands, and a 1952 study by Hoover that reported a twofold increase in flood peaks.

E.1.1.1. Sedimentation

In his review of sedimentation impacts, Darnell cites a 1964 King and Ball study that reported a twofold increase in inorganic sedimentation rates during a Michigan highway construction project. Darnell noted that increases in sedimentation may the spaces between larger rocks in the substrate and cover the bottom of the stream system with layers of silt. He added that these impacts usually persist far downstream of construction sites.

Darnell points to several studies on the effects of sedimentation on primary productivity. His review indicates that algal pads and bottom-dwelling organisms can be destroyed by the smothering action of sediment and that bottom-dwelling animals may lose their attachment surfaces, which become covered by sediment, and the animals are swept downstream when flows increase.

E.1.1.2 Turbidity

Darnell's literature review suggests that suspended solids greatly reduce light penetration and cause reductions in photosynthesis and primary production. The author cites a study that found phytoplankton production to be 12.8 times higher in clear ponds than in very turbid ones.

Turbidity influences fish and invertebrate behavior as well. McCabe et al. (1993) studied the effects of suspended silt on the feeding and reproduction of *Daphnia pulex*. Their life table studies indicated that suspended silts and clays significantly reduce both filtering and assimilation, and therefore reduce population growth rates. Their study also indicated that suspended silt and clay influenced community structures by impairing the ability of visually feeding plantivorous fish to find food.

Darnell also points to studies that show a relationship between turbidity and fish behavior. These studies indicate that reduced swimming activity, modified social dominance patterns, and increased "coughing" and gill scraping occur in turbid conditions. Darnell's review also suggests that salmon avoid turbid conditions, and that turbidity levels as low as 35 ppm interfere with cutthroat trout feeding regimes. The author also cites a study that demonstrated that turbid waters act as a barrier for migrating salmon.

E.1.1.3 Siltation

Along these lines, Berkman and Rabeni (1987) studied the effects of siltation on fish communities. Their study indicates that distinctions in the composition of fish populations between pool, riffle, and run communities decreases with increased fine silt deposition. This is due primarily to the loss of inhabitants of riffle communities. Their results also point to decreases in fish species that require clean gravel for spawning.

Conversely, a study by Koonce and Teraguchi (1980) on the effects of siltation on the embryonic mortality of trout indicated that siltation alone did not influence embryonic development or mortality. The authors acknowledged that siltation is a factor in reduced spawning success and reproduction of natural trout populations, and that silt must affect the physical properties of gravel, which results in changes in flow rates and oxygen concentrations. These changes have been proven to directly influence the hatching success of trout embryos and indirectly influence embryonic development.

Thurow and King (Undated) also investigated the effects of fine sediment on fish populations. Their study indicated that steelhead trout spawning in the Salmon River are able to remove fine sediments of less than 6.35 mm from the upper strata of their egg pockets. The authors cite literature that determined that salmonids are not passive spawners and that redd-building activities remove fine sediment. The authors' data indicate that the substrate in the egg pocket contains less fine material than do other sites inside or outside the redd. Other siltation and turbidity impacts outlined by Darnell include increases in temperature, reductions in oxygen levels, increases in biological and chemical oxygen demands, and reductions in respiration.

E.1.1.4 Compacting and Rutting

In a study that relates to the impacts of construction equipment used during EWP Program construction processes, Aust et al. (1993) analyzed the impacts of skidder compaction and rutting on the physical properties of soil and water tables in a South Carolina wetland after Hurricane Hugo. The authors point out that numerous studies have revealed that forest machine traffic may have little effect on the compaction of drier soils, but a greater effect on moist soils. This is because compaction usually occurs when a soil is at or near field capacity. When a soil is near field capacity, cohesive forces of the soil are reduced, as are the soil's ability to support heavy loads (Akram and Kemper, 1979). Aust et al. also point out that deep rutting (puddling) generally accompanies forest harvest operations on very wet saturated sites. A soil near the saturation point has very low shear strength, and shear failure may occur when a load is applied. This is relevant to EWP Program processes because emergency practices are often carried out in wet conditions.

Many EWP Program projects are carried out on slopes, and impacts such as slides may occur during construction. Under these conditions, soil flows when a load is applied. The liquid nature of the soil results in soil churning and displacement, as opposed to compaction (Burger 1989). Aust et al. also note that the changes in physical properties of soil resulting from compaction versus rutting could cause different hydrologic responses on wetland sites. The study indicates that rutted areas were more highly disturbed than compacted areas. Compacted area disturbance was relatively low—due probably to the high sand and organic matter composition of the soil of this particular location. The results of the study did indicate that the macropore space values were initially low on all sites and traffic further accentuated the problem, resulting in decreased saturated water flow, increased water table levels, and decreased soil aeration. The decreases were in the areas that initially had the best drainage.

The authors suggest that traffic on better-drained sites under moist or wet conditions may result in more serious change than on sites with poorer natural drainage. In wet conditions, the authors state that serious consequences can occur from reduced air and water movement. The reduction in aeration can have serious effects on tree growth and decreased drainage may reduce the opportunity for silvicultural operations.

Fredrickson (1970) investigated erosion and sedimentation following road construction and timber harvest on unstable soils in three small watersheds in Western Oregon. His study indicates that landslides in the western Cascades are more frequent where logging roads intersect stream channels.

E.1.1.5 Mechanized site preparation

In a study on practices that relate to several EWP Program practices, including clearing and snagging, access creation, grading/filling, and excavation, Kochenderfer (1989) analyzed the impacts of mechanized site preparation before planting pine species in the central Appalachians. During mechanical site preparation, the surface litter layer commonly is removed or displaced and surface soil may be pushed into windrows. All of these practices disrupt the surface litter layer in some fashion.

Kochenderfer points out that Douglas and Goodwin (1980) reported that the mechanized site preparation practice is one of the most severe practices applied to forest land, and that Ursic and Douglas (1978) determined that a large percentage of soil exposure associated with mechanical site preparation, when combined with soil compaction, can lead to sediment-producing overland flows and large increases in storm flow volumes. Kochenderfer's study evaluated impacts on sediment yield, stream flow chemistry, water temperature, and water yield over a four-year period. Results indicated that annual sediment yields and nitrate levels were slightly higher after site preparation, but not enough to be statistically significant. Growing-season stream flow increased by 3.9, 2.8, and 1.5 inches during the first, second and third growing seasons respectively, after the treatments.

Several factors may have influenced the results. First, contoured windrows and careful raking of the litter layer probably reduced sediment losses. Second, the site was able to recolonize rather quickly after site preparation. Third, buffers were used around the stream. The practices to which the author attributes the minimal, nonsignificant changes in water chemistry and flow regimes may not be relevant to EWP Program processes in an exigency situation since practices must be installed as quickly as possible to protect life and property. The author's suggestions could be implemented in non-exigency situations where more time is available for the practice.

Boschung et al. (1981) demonstrated that, if carried out correctly, small-scale vegetation removal does not have a significant impact on water quality or fish and invertebrates. The 27-month study showed that neither turbidity, temperature, pH, nor dissolved oxygen changed significantly after clear-cutting practices were implemented. The study also indicated that changes in macroinvertebrate population dynamics, including number of taxa, total numbers, and diversity were not due to forest clear-cutting practices. Fish population dynamics showed similar results. Neither number of species abundance distributions, cumulative and average numbers of specimens, nor fish species composition showed significant changes after clear-cutting.

E.1.1.6 Dewatering

Dewatering is a site preparation process that may occur during EWP Program emergency practice installation. Reiser et al. (1983) studied the effects of complete redd dewatering on the success of salmonid egg-hatching and the development of juveniles. The authors cite several studies that point out the potential consequences of redd dewatering. These consequences include desiccated or frozen eggs and impaired embryonic development. This study indicates that the hatching success of dewatered and control steelhead salmon eggs differed with respect to neither sediment quality nor sampling time. Therefore the length of the dewatering period did not influence egg-hatching success. The hatching success of Chinook salmon eggs also was unrelated to the length of the dewatering period.

The study also determined that eggs that had been dewatered hatched earlier than control eggs. This was most evident for steelhead eggs dewatered three to four weeks, for which median hatching dates advanced by as much as 11 days and an average of about eight days. Chinook salmon hatching for dewatered eggs advanced several days. Both the steelhead trout and Chinook salmon dewatered redd temperatures were higher than the watered redds. In summary, the author's findings indicate that salmonid eggs can tolerate one to five weeks of dewatering with essentially no effects on hatching success or on the development and growth rates of alevins and juveniles. This holds true if moisture content is at least four percent by weight and sediments neither freeze nor reach temperatures that exceed incubation tolerances.

The authors did point out that previous studies of redd dewatering showed a significant increase in the mortality of newly fertilized eggs when stream flows were severely reduced over experimental redds. However, the authors also noted that those experiments were not designed to evaluate the effects of complete redd dewatering, but rather the effects of surface-flow reduction on the intragravel environment and the eggs harbored within. The result of this type of flow reduction would cause eggs to be harbored in stagnant water, thus decreasing the oxygen supply and reducing the transport of metabolites. The authors state that although salmonid embryos may withstand periods of dewatering, newly hatched alevins are less tolerant. The authors also found that the moisture content of the surrounding sediment-substrate mixture is crucial to the survival of dewatered eggs.

E.1.1.7 Temporary Structures and Stream Filling

The USACE Nationwide Permits 13, 14, 33, and 37 cover bank stabilization, temporary construction and access creation, road placement, and the EWP Program, which are all associated with site preparation. The environmental assessment prepared for these permits suggests that the construction of structures, stabilization of banks, and discharge of dredged or fill material used for construction access may destroy riparian vegetation.

Some vegetation may have to be removed before construction, while other vegetation may be crushed by construction activities, or smothered by the placement of fill material. Overhanging riparian vegetation provides shelter, shade, breeding and rearing habitats for aquatic organisms and terrestrial wildlife. It may therefore have an impact on both aquatic and terrestrial populations. Near-stream vegetation also shades the water from the intense heat of the sun and provides food for a wide variety of land and water organisms.

The Corps suggests that because structures and fill are temporary, the adverse impacts of removing or covering riparian vegetation are expected to be minimal. During construction of an access structure or fill, fish and other motile aquatic organisms usually avoid the area. Benthic, immotile, or slow-moving organisms in the path of equipment and building materials are destroyed. Some organisms are smothered by the placement of fill material or when suspended material settles to the bottom of the water column. The Corps suggests that limiting the time that structures and fill remain in place and requiring that a site be entirely restored is expected to minimize the adverse impacts of the activity. The Corps also suggests that benthic organisms are expected to recolonize the site after construction is complete and vegetation should return to the site. The Corps does acknowledge that compacted subsoils could result in lower species diversity at the site. However, construction of temporary access structures or fill is not expected to adversely alter the species composition of the area.

Depending on construction methods used, composition of the stream bottom, wind and water current conditions during construction, and fill material placed in the water and suspended in the water column temporarily, increase water turbidity. Material would once again be suspended in the water column upon removal of the structure or fill. The plume generated is limited normally to the immediate vicinity of the disturbance and dissipates shortly after each phase of the construction activity. The Corps also notes that during construction or with the use of access structures or fills, equipment may discharge small quantities of oil and grease into the watercourse. Because this activity is temporary, the frequency and concentration of these discharges are not expected to have more than minimal adverse impacts on overall water quality.

E.1.2 Impacts of Stabilization Techniques on an Aquatic Community

There are two basic approaches to bank stabilization—bioengineering, using locally available materials such as woody debris, alluvium, and bioengineered soils, and armoring techniques, using such materials as concrete, riprap, and sheet piling that optimize flood conveyance (Cairns, 1994). Cairns reported that the National Research Council recommends using soft approaches when possible, because these methods tend to encourage faster recovery. He also notes that while bioengineering costs as little as $10 per linear meter of streambank, armoring costs up to four times more.

E.1.2.1 Armoring Structures

Armoring structures appear to have a longer life and to control erosion better initially than bioengineering methods, but some of the structures provide neither habitat for riparian animals nor organic matter to enhance community dynamics within the river reach itself (Cairns 1994). Shields et al. (1995) outlined several techniques used to rehabilitate watersheds with incising channels.

E.1.2.1.1 Riprap

Riprap is the placement of boulders over soft soils on embankments and also refers to the boulders themselves. The construction activities associated with riprap are similar to those of site preparation and may include heavy equipment use, dewatering, earth moving, clearing, and creating access. Long-term impacts of installed riprap can be both beneficial and detrimental.

Cairns (1994) reports that installed riprap can provide substrate for benthos and periphyton, provide cover and reduce water current velocities, provide a stable channel bottom for colonization by mussels, provide a source of gravel substrate material for mussels and fish, and reduce erosion, thereby protecting in-stream habitat from sediment fouling. Adverse effects outlined by Cairns include the loss of riparian habitat and the incompatibility of riprap with near-stream land-use practices. The loss of riparian habitat, which includes vegetation loss, may reduce nutrient and sediment removal processes and alter aquatic systems. Another effect of riprap installation is potential temperature increases caused by the lack of vegetative cover. The effects of temperature increases caused by the lack of vegetative cover are discussed under bioengineering techniques. It is important to note that although streambanks are severely degraded when EWP Program practices are installed, and may be devoid of vegetation, the installation of riprap may inhibit the future establishment of vegetation.

According to Brown (1998), the USACE states that many streambank or shoreline protection projects transfer energy from one area to another causing increased erosion in the adjacent area. Brown studied aerial photographs of sections of the Carmel River in California that had been riprapped. His study indicated that erosion occurred downstream of installed riprap in all of the photos studied. Downstream erosion of this nature leading to the impacts associated with sedimentation and turbidity is discussed in Sections E.1.1.1 and E.1.1.2.

Lloyd (1998) also studied the frequency of erosion occurring downstream of riprapped areas on the Carmel River. In his study, he discusses a 1992 Corps of Engineers publication that outlines the positive effects of a riprap project on the Burnt River in Oregon. According to Lloyd, this project has successfully curtailed bank erosion with no degradation of plant and wildlife species. Lloyd's study reinforced Brown (1998). He found that the riverbanks directly downstream of riprapped areas suffered serious erosion problems. He points to a specific example of a river bend located immediately downstream of a 150-foot riprap project. He states that this particular bend had lost approximately 60,000 cubic feet of material. He also observed that the river moved faster through areas that had been riprapped. Lloyd did point out that even though he observed erosion problems downstream of riprapped areas, he could not prove that the riprap was causing downstream impacts since his study, like Brown's, used aerial photography and spatial data.

E. 1.2.1.2 Gabion

Gabion baskets are large-volume wire mesh baskets filled with medium cobble and are placed along streambanks to reduce erosion. Cairns (1994) reports advantages to using gabion. The voids within the baskets allow a bank to drain, and the voids that fill with sediment support vegetation growth. However, the wire mesh can corrode and the impact of heavy debris can displace the baskets. Gabions can be placed on steeper slopes than riprap and they are flexible, which allows them to be used around stream bends. Because gabion is an armoring practice and deflects flow velocities, it may cause downstream erosion (as outlined by Brown and Lloyd).

Bradt and Wieland (1978) investigated the impacts of gabion use and stream reconstruction on chemical, physical, and biological components of a naturally producing brown trout stream in Pennsylvania. The stream was channelized in the late 1960s as part of a highway straightening effort. The highway project also removed riparian canopies, widened the stream, and denuded the banks of vegetation, which increased sedimentation. The purpose of the stream reconstruction project was to restore flow velocities and habitat and stabilize the banks.

The study indicated that gabion installations in degraded systems may improve water quality and invertebrate communities. The study indicated no significant change in temperature between the sites that contained gabions and the control sites. Flow velocities and discharges within the gabion-lined channels increased. Chemical parameters, including conductivity, dissolved oxygen, percentage of oxygen saturation, pH, and alkalinity also increased significantly. The increases in dissolved oxygen and percentage of oxygen saturation can be related to increases in photosynthetic activity and turbulence. The authors reported that the gabion installation caused a deepening and narrowing of the stream channel, resulting in a cooler stream during summer months as well as a swifter moving stream. The pH increases may have been due to a combination of increased photosynthetic activity and the inflow of water from limestone springs. Macroinvertebrate populations, including taxa and organisms, as well as species diversity and biomass, also increased significantly. The increase in the number of macroinvertebrate was probably due to increased food sources and substrate diversity.

The authors also point out that gabions restrict stream flow to the central axis of a channel. This flow regime reduces bank erosion and sedimentation downstream. As with riprap, gabion baskets may inhibit vegetation re-establishment. The effects of vegetation loss or re-establishment are discussed under bioengineering techniques below.

E.1.2.1.3 Rock Weirs

Rock weirs are large boulders placed in-stream to influence geomorphologic and biological processes. Rock weirs help to stabilize banks by redirecting in-stream flow away from banks toward the center of a stream. The redirection of flow helps alleviate downstream erosion and sedimentation. The rock weirs create turbulence, which increases dissolved oxygen levels, and they create scour pools for fish and invertebrates.

E.1.2.2 Bioengineering

E.1.2.2.1 Removal and Establishment of Vegetation

Riparian vegetation plays an integral role in a healthy ecosystem. Vegetation stabilizes topsoil, buffers overland flow, provides habitat for reptiles, amphibians, mammals, and invertebrates, and contributes organic debris to aquatic systems. Removing vegetation, especially in transition zones between upland and aquatic environments, can disrupt the physical, chemical, and biological processes of both the terrestrial and aquatic community.

EWP Program practices are associated with vegetation removal and reestablishment in several ways. Vegetation can be removed by natural disasters such as tornadoes, hurricanes, landslides, floods, droughts, and fires. EWP Program construction activities such as site preparation, excavation, and access creation can also remove vegetation. After site preparation activities are complete and EWP Program practices installed, sites are re-vegetated by grading, shaping, seeding, planting, fertilizing, and mulching. After seeding or planting is complete, there is a lag before vegetation is established. During this transition, recently vegetated areas may erode and contribute sediment to the aquatic environment.

Recent studies and reviews of vegetation on slopes and streambanks indicate that vegetation influences stream morphology, transporting sediment and nutrients from terrestrial to aquatic environments, as well as influencing what types of biota are present. Beeson et al. (1995) evaluated the importance of vegetation on reducing erosion of river bends in southern British Columbia. The study indicated that streambanks without vegetation were nearly five times more likely to have eroded during flood events than streambanks with vegetation cover. Major bank erosion was 30 times more prevalent on non-vegetated bends than on vegetated bends. The authors also reference Smith (1976), who states that in cool environments with aggrading river conditions, vegetated banks resist erosion 20,000 times better than do non-vegetated banks.

Vegetation also plays a vital role in the biological resources of a stream system. Sweeney et al. (1993) studied the effects of streamside vegetation on macroinvertebrate communities in Eastern North America. They found that the presence or absence of trees on land adjacent to stream channels significantly affects the structure and function of macroinvertebrate communities in Piedmont streams. Their study revealed that the presence or absence of trees near stream systems significantly alters the quality and quantity of light striking a stream surface, affecting the seasonal pattern and magnitude of water temperature changes. The removal of streamside vegetation also decreases available macroinvertebrate habitat either directly by decreasing inputs of leaf litter and woody debris, or indirectly through shading effects and changes in algal populations. This study also illustrates how changes in temperature, food quality, and similar factors can significantly affect survivorship, growth, adult size, and fecundity of many species. In summary, this research points out that the deforested reaches of the eastern Piedmont streams included in this study had about 50 percent less habitat available for macroinvertebrates.

Conversely, Boschung et al. (1981) demonstrated that small-scale vegetation can be removed in a way that does not have a significant impact on water quality, fish, or invertebrates. The 27-month study showed that neither turbidity, temperature, pH, nor dissolved oxygen changed significantly after clear-cutting practices were implemented. The study also indicated that changes in macroinvertebrate populations, including numbers of taxa, total numbers of creatures, and diversity, were not due to forest clear-cutting practices. Fish population dynamics showed similar results. Neither species abundance distributions, cumulative and average numbers of specimens, nor fish species composition changed significantly after clear-cutting took place.

Karr (1977) reviewed available literature on the impacts of near-stream vegetation and stream morphology on water quality and stream biota. His review suggests that proper management of near stream vegetation and channel morphology can lead to significant improvements in both water and biological quality. Karr concludes that vegetation removes nutrients from subsurface runoff by removing the sediments to which the nutrients are attached. He points out that nearly all phosphorus (greater than 85 percent) and most nitrogen (greater than 70 percent) in surface runoff is attached to sediment. Data from field and laboratory studies in forestry and agriculture indicate vegetation can effectively filter sediment from both sheet and shallow channel flow. The literature does point out that sediment reduction is less likely during channel flow exceeding the height of the herbaceous vegetation. Karr also discusses the effects of near-stream vegetation on water temperature and water quality. He states that removing vegetation along headwater streams can increase water temperature by 6 to 9°C. He also points out that increases in water temperature decrease dissolved oxygen and exacerbate the impacts of organic waste within the system. Karr also describes blooms of nuisance algae and periphyton caused by near-stream vegetation removal elevating water temperatures.

Karr also discusses in his review the effects of near-stream vegetation on stream morphology and biota. His review suggests that sediments reduce the structural complexity and productivity of aquatic plant, invertebrate, and vertebrate communities. Sediments settle, cover the periphyton and essential spawning grounds of fish, and decrease bottom diversity. He also relates the removal of vegetation and the increases in temperature to community structure. He states that a shift in community structure may occur, with resident species replaced by less desirable species that tolerate increased temperatures. As with Sweeney (1993), Karr suggests that headwater streams receive much of their energy from near-stream vegetation and are extremely important to the spawning and rearing cycles of fish. The removal of the vegetation results in significant reductions in invertebrate and fish production because of the loss of allochothonous energy inputs.

E.1.2.2.2 Soil Bioengineering Techniques

Included in the EWP Program are soil bioengineering techniques. Bioengineering is the, "combination of biological, mechanical, and ecological concepts to control erosion and stabilize soil through the sole use of vegetation or in combination with construction materials" (Allen and Leech, 1997). The vegetation used can consist of both living and nonliving material. The two types of material serve different functions. Nonliving material is used for construction, "similar to engineered materials", while living vegetation is used for erosion control and wildlife and habitat material in riparian systems (Allen and Leech, 1997).

Bioengineering has been scarcely used in past USACE projects. Project design has been reluctant to incorporate the practice into erosion control ventures due to a lack of specific design guidance. Key questions still remain unanswered in the use of bioengineering techniques such as the velocity conditions under which certain types of vegetation will perform. A general lack of monitoring and data collection on vegetated streambank vegetation has led to this deficiency (Allen and Leech, 1997).

In planning a bioengineering project, several considerations must be noted. The intended functions and impacts of the project must be considered, as well as an understanding of how to fit the project into the context of the particular landscape. Also important to note are the activities located close to the stream. Human activities on an adjacent or opposite bank, as well as animal considerations such as cattle grazing or movement, should be noted (Allen and Leech, 1997).

Allen and Leech detail within their report for the USACE proposed design guidelines for the use of bioengineering streambanks. Presented is a design model for such projects, complete with example case studies highlighting various problems in streambank erosion. In their case studies, vegetation appropriate to each individual situation is suggested along with details of how to acquire and handle them.

E.1.2.2.3 Critical Area Planting

EWP Program emergency procedures include critical area planting. Critical area planting uses permanent grasses and legumes to stabilize soil and reduce damage from sediment and runoff to downstream areas. It is also used to control wind erosion of exposed topsoil. Other benefits associated with critical area planting include improved habitat conditions, water quality, and aesthetics.

Critical area planting can have both beneficial and adverse effects on an aquatic environment. Fertilizer runoff may increase the nutrient loads of aquatic systems in the short term. Increased nutrient loads may lead to excess algal blooms and eventually increased biological oxygen demands and decreased dissolved oxygen levels. The long-term effects of critical area planting on the aquatic environment are beneficial. Increased cover, as suggested by Karr (1977), effectively filters sediment from runoff. Karr suggests that nearly 85 percent of phosphorus and 70 percent of nitrogen in surface runoff is attached to sediment. Therefore, vegetative filtration of sediment-laden runoff should decrease nutrient loads on aquatic systems and benefit habitat and biota.

E.1.2.2.4 Rootwad and Tree Revetments

The use of tree revetments in preventing streambank erosion was studied in a master's thesis based in Kansas. The author examined effects on both abiotic and biotic components.

In terms of abiotic factors, the streams showed signs of changing morphology, widening, and flattening in the reaches containing the revetments. Prior research (Roseboom eta al. 1992) concluded that revetments increase sedimentation and maintain bank stability. The author surmised that stream morphologies (erosion, bank movement and channel shape) would be different if revetments had not been present during subsequent high streamflows.

In terms of biotic effects, the hypothesis that revetments would provide greater habitat for aquatic organisms was largely inconclusive, as the stream water level was below the revetments for much of the observed period. However, several authors have found increases in species richness, diversity, density and biomass of fish after installation of in-stream habitat structures (from Hunt 1976, Carline and Klosiewski 1985, House and Boehne 1985, Roseboom et. al. 1992).

E.1.3 Channel Capacity Alteration

E.1.3.1Woody Debris Removal

Debris in stream systems affects the physical characteristics of a stream and the diversity and abundance of its aquatic organisms. Debris jams may cause channel alterations, sediment accumulation, and overland flows. Micro- and macroinvertebrates use debris for anchorage and food. Fish use debris for escape cover and reproduction. Because it is abundant, large woody debris is most important in the forested areas of the eastern and western United States. In the

EWP Program, when debris forms a watershed impairment that threatens life or property, it is usually removed. To be environmentally defensible, decisions about debris removal must be taken after consideration is given to the value of the debris in the hydrology and ecology of the stream system.

Field studies and theoretical reviews of the importance of debris in causing stream alterations and in supporting critical elements of aquatic communities indicate that the role of debris depends on many interrelated factors—chief of which are the size of the debris and the size and gradient of the stream.

In low-gradient streams and rivers, debris provides cover from predators and for reproduction to aquatic organisms but does not usually alter a stream's physical characteristics substantially. Benke et al. (1985) evaluated the relative importance of woody debris snags in a low-gradient stream on the Georgia coastal plain on invertebrate production and benthic habitats. They found invertebrate diversity, biomass, and production much greater on snags than on either sandy or muddy bottoms. Snags supported 60 percent of total invertebrate biomass and 16 percent of secondary production for a sampled stretch of river. Sampling at night showed about 78 percent of drifting invertebrates came from snags, and fish stomach sampling showed four of eight major fish species obtained at least 60 percent of prey biomass from snags. The authors concluded that clearing and snagging operations in such streams may be devastating to invertebrates and dependent fish species and that reintroducing woody material might mitigate those effects.

In a USFWS report, Marzolf (1978) reviewed research on functional stream ecology to assess the impacts of clearing and snagging operations conducted for flood protection, drainage, or navigation. Marzolf defined clearing and snagging as removal of vegetation or accumulated bedload from stream channels or banks, including removal of sediment bars, drifts, logs, snags, boulders, piling, piers, headwalls, and debris. His findings, based on the importance of coarse particulate organic matter (CPOM) to aquatic organisms in streams of different sizes and regional locations, are given in Table E.1.3.1-1

Table E.1-1 Impacts of Clearing and Snagging on Functional Stream Ecology

Physical modification	Biological consequences
Decrease hydraulic roughness of stream channels	Moves decomposition of organic matter downstream
	Reduces physical habitat diversity
	Reduces benthic production
	Reduces spawning and nursery habitat
	Reduces fish cover and shelter
	Disrupts fish territoriality and orientation
	Reduces plankton production by reducing amount of quiet water
Removal of canopy	Increases light and stream temperature, encourages growth of benthic algae and macrophyte growth
	Decreases organic matter input from terrestrial vegetation
Changes in stream substrate	Changes production and kinds of benthic algae and macrophytes
	Changes distribution and species composition of benthic macroinvertebrates
Removal of snags, logs, and shoreline vegetation	Reduces habitat for nest- and case-building macroinvertebrates
	Reduces habitat for accumulation and decomposition of organic matter, resulting in less food for macroinvertebrates
	Reduces diversity and quantity of fish food
	Reduces fish cover and spawning habitat
	Disrupts fish territoriality and orientation
Source: Marzolf, 1978	

In low-order (1-3) streams, riparian vegetation reduces light exposure and water temperature. It provides CPOM (twigs and leaves), and thus energy, to the stream system; in intermediate streams (orders 4-6), aquatic plants rather than CPOM, are the primary producers of energy of the stream system; and in larger rivers (orders 7-12), phytoplankton may be important but overall respiration exceeds production.

In their review of technical studies, Keller and Swanson (1979) found that stream channel development in forested areas is fundamentally affected by large organic debris in channels. In low-gradient streams, debris enters the channel through bank erosion, mass wasting, and blowdown and collapse of trees. Debris can affect stream morphology and sediment transport because the stream may not have the strength to redistribute the debris. Larger streams, however, may have the capacity to move debris and can pile it into jams. In small and large streams, debris jams can affect streambank stability, influence the development of midchannel bars and short-braided reaches, and facilitate development of meander cutoffs.

In steep-gradient streams, debris can enter through the methods described above, as well as through debris avalanches and torrents. Smaller streams with steep valley walls and little or no floodplain may see significant effects on channel form. Debris jams can speed or slow bank erosion and sediment deposition, create places for deposits to form, and produce a stepped channel profile.

Bank stability can improve as a result of debris creating small jumps, runs, and other areas where the energy of the stream is dissipated. Organic matter may also abut the bank, thus protecting it from erosion. But banks can become unstable if debris redirects water flow into the bank, leading to lateral channel migration. Under high flow conditions, suspended debris may be thrust into the bank, battering soil and vegetation.

Living organic matter can stabilize streambanks. Root mats have been found to be 20,000 times more effective against erosion than bare streambanks. Erosion rates decline as the percentage of vegetative roots in a streambank increases (Smith 1976). Keller and Swanson found that the length of streambanks protected by rootwads can be calculated at approximately 5 times the diameter of the tree.

Swanson and Lienkaemper (1978) examined mountainous watersheds in the Pacific Northwest and found large organic debris to be a primary factor is determining the biological and physical characteristics of streams. In a stepped channel, the gradient of significant portions of a streambed may be relatively flat, leading to high rates of deposition. Debris also forms habitat for aquatic organisms both as a substrate and by modifying stream flow to form areas of deposition. They found that activity of consumer organisms tended to concentrate in wood and wood-created habitat, and that larger pieces of debris may reside in the streambed for decades, providing long-term habitat.

Swanson and Lienkaemper then suggest that management of these forested areas and streams should focus on reducing hillslope failures rather than on debris removal. Clear-cutting and logging will increase debris torrents and remove streamside vegetation. The authors of the study offered three strategies for improving debris management in these types of streams:

- Leave natural debris in the channel (selectively removing other debris) and introduce minimal new debris (through better hill slope management)
- Leave a buffer strip to minimize alteration of the stream area and provide a source of debris
- Minimize the potential for debris torrents by improving the layout of access roads (responsible for 40-130 times greater frequency of debris torrents)

Bilby (1981) examined how organic debris dams affect the transportation of dissolved and particulate matter in forested streams. He measured dissolved matter, fine particulate matter, and coarse particulate matter before and after removal of a debris dam. He found that removing the dam resulted in a 6 percent increase in export of dissolved matter and a 500 percent increase in export of both fine and coarse particulate matter.

E.1.3.2 Dredging (Sediment and Cobble Removal)

Natural disasters may cause stream channels to fill with bedload, which may reduce stream channel capacity and water flow. The EWP Program may implement practices to remove the sediment and deposited bedload from the channel. These practices involve heavy equipment use and may have the environmental consequences outlined in Section E.1.1 on site preparation impacts. Darnell (1976) categorizes the impacts of dredging into the direct effects of removing bottom materials and the effects of extracted spoil material once it is disposed. Darnell states that the general and immediate effects of dredging, whether it is carried out by means of bucket, dragline, or hydraulic dredge, include the creation of linear channels and the temporary suspension of sedimentary material, which as outlined previously, can affect chemical and biological processes of the aquatic environment. He notes that dredging may dig deep enough to hit the anoxic sediment layer of a channel bed. This may cause anoxic conditions within an aquatic system and have an impact on aquatic biota.

Environmental windows also need to be considered when dredging occurs. The USACE (1998) points out that environmental windows often are delayed or cancelled because of restrictions associated with certain biota or activity. These include avian habitat and nesting activities, sedimentation and turbidity issues involving shellfish and fish spawning, harm to juvenile or larval fishes, harm to threatened or endangered species during nesting or breeding seasons, and the burial and physical removal of protected plants.

USACE reports several broad effects associated with dredging that can be related to EWP practices. They include physical disturbance of habitat and nesting; turbidity, suspended sediments, and sedimentation impacts; migration blockages; and reduced water quality. Physical disturbance caused by dredging activities, according to USACE, can involve the generation of noise and the degradation of critical habitat. The Corps cites disturbances to fish spawning as a major concern in the aquatic system. Their concerns with sedimentation and turbidity were related to anadromous fish spawning. They suggest that sedimentation may lead to decreased spawning success due to egg smothering, or by gill abrasions in the larval stage of development. A more complete discussion of the impacts of sedimentation and turbidity on fish spawning can be found in the section on site preparation. The Corps also cites the blockage of anadromous fish migration pathways by turbidity plumes or by dredging equipment as an issue of concern. The Corps does point out that at this time no conclusive evidence has been documented that dredging operations impede fish migration.

The Corps also suggests that dredging operations may reduce dissolved oxygen. USACE (1998) reports that dissolved oxygen is a function of the amount of resuspended sediment in the water column, the oxygen demand of the sediment, and the duration of the resuspension. They also state that studies have indicated a wide variation in dissolved oxygen levels associated with dredging.

Dredging may also have an impact on benthic organisms. In a recent environmental assessment of USACE Nationwide Permit 19, which covers minor dredging, the Corps reports that benthic inhabitants of the removed material are destroyed. They also suggest that silt, when it settles out of the water column, smothers the benthic organisms that occupy areas of high turbidity. In EWP Program actions, benthic organisms are often already covered with layers of silt and sediment.

E.1.3.3 Debris and Spoil Disposal

EWP Program options associated with debris and spoil disposal include using it onsite; burning it (on- or offsite); burying it (on- or offsite); and disposing of it by other means, including chipping onsite. Woody debris or spoil can be used onsite to stabilize banks and modify channel flow. The impacts of these actions are addressed in Section E.1.2.1 on armoring, Section E.1.2.2 on bioengineering techniques, and Section E.1.1 on site preparation.

According to Darnell (1976), burning the material onsite may increase the pH of the aquatic environment. He states that when woody debris is burned in the floodplain, the ashes, which are highly alkaline, may enter the aquatic environment and cause an immediate increase in the pH of the water. He cites one study in which a stream's pH jumped from 7.8 to 11.3 and remained high for some time. He also states that heat from the fire can be exchanged between soil and water and elevate the stream temperature quickly and keep it high for some hours. In one study outlined by Darnell, the stream temperature rose from 12° to 22°C and then stabilized at 15°C for some hours.

Hauling debris offsite involves many of the impacts outlined in Section E.1.1 on heavy equipment use in site preparation.

E.2 SOCIOECONOMIC IMPACTS OF EWP PRACTICES

E.2.1 Socioeconomic Impacts Studies

Natural hazards damage and disrupt the communities that they strike. Direct effects include physical damage and destruction of structures and property. Indirect effects include employment and income loss caused by damage to economic infrastructure, individual firms, and population changes (Vogel, 1999). Indirect effects may influence a large social community or may be very localized affecting an individual farm or household.

A natural disaster can alter the patterns and structures of social life within a community. Dislocation of businesses and services disrupts neighborhoods and communities. Sources of employment and income may be temporarily or permanently lost as a result of a disaster event. Disasters can also affect the appearance, quantity, or value of land available to the community as a source of current and future investment, or of productive resources. When public revenue is required for disaster response and recovery, other social programs (such as education and recreation) may be denied funding (Myers, 1997). Services to the community may be disrupted and important cultural or social resources may be destroyed.

In a study of the economic impacts of the flooding of San Francisquito Creek in February 1998, Cushing (1999) found that the flooding resulted in extensively damaged residences, businesses, and other organizations. Local municipalities and other disaster relief agencies incurred considerable expense responding to flood emergencies and engaging in flood recovery activities.

Residential damage accounted for 91 percent of total economic impact. Municipality and other assistance agencies accounted for 5 percent, and business and organizations accounted for 4 percent of the total economic impacts.

There were other significant impacts of the flooding in addition to the monetary impacts. Many flood victims were evacuated to emergency shelters at the height of the flood; some residents had to be rescued by the fire and police departments. Residents with heavily damaged homes had to live in temporary housing, often a great distance from their homes. These households spent almost one and one half months on average living outside their homes. The study indicates that residents of Palo Alto spent over 134,000 hours on cleanup and repair, and residents of East Palo Alto spent 9,033 hours. Local businesses and nonprofit organizations had to close, losing business as a result. Organizations and businesses spent thousands of hours cleaning up and replacing items damaged by the flooding. Another important non-economic impact of the flooding not captured by the quantitative portion of this study is the impact of damage that was not addressed. Many small owner-operator businesses in the Whiskey Gulch area reported that they did not have sufficient funds to repair structural damage caused by the flooding

The consequences of a natural disaster and the conditions of the communities affected are unique to each event. As a result, no uniform or codifiable set of socioeconomic effects exists for natural disasters (Vogel, 1999). However, some general areas of impact can be defined. These are threat to human life and loss or damage of property. “In the aftermath of the disaster, recovery consists of three primary concerns; replacement of damaged infrastructure and housing, recovery of employment and income, and the recovery of economic structure (Vogel, 1999).”

On the basis of a study to assist in addressing the problems encountered by individuals and communities coping with a major 1997 flood, Morris-Oswald and S. Simonovic (1997) interviewed 54 victims on how the flood affected them. The study’s authors made a set of recommendations to address the key issues their study identified:

- Develop a public information system using state-of-the art information technology
- Develop a comprehensive flood management plan involving local communities and all levels of government
- Improve warning systems about the risk of flooding and evacuation
- Identify local communities' resource requirements and develop mobilization plans to acquire resources

As part of a study of alternative approaches to floodplain management, Galloway (1995) cited a report submitted to the White House in June 1994, in which a federal interagency floodplain management review committee proposed better ways to manage the nation's floodplains. The committee indicated that the 1993 Mississippi River flood was the result of a significant hydrometeorological event, that federal flood control efforts in the Mississippi basin had prevented nearly $20 billion in potential damages, and that, in spite of Federal flood-damage reduction efforts, people and property throughout the nation remain at risk to inevitable future flooding. The committee recommended that the division of decision-making and cost-sharing responsibilities among Federal, state and local governments be defined more clearly. It also recommended that the nation adopt a strategy of avoiding inappropriate use of the floodplain, minimizing vulnerability to damage through nonstructural and structural means, and mitigating damage as it occurs. The report did not call for abandoning the floodplain, but argued for full consideration of the economic, social, and environmental costs and benefits of all future floodplain activity.

In addition to their potential effects of loss of employment and income, flooding and other natural disasters may have a significant effect on the value of land as a natural resource, either for investment or as the source of material input to the economic production cycle. In a study of the relationships between flooding and property values in the areas of Linda and Olivehurst, California, Tobin and Montz (1997) found that flooding does have a negative impact on property values under most circumstances. That context was also important in determining the degree of impact, with respect to both the physical effect of the flood itself, as well as the socioeconomic characteristics of the communities involved.

Property values decrease immediately following a flood because the utility of flooded parcels of land is reduced. Recovery can follow multiple paths depending on the nature of the flooding in terms of frequency and magnitude. Frequent flooding may keep land prices low relative to non-flooded areas. In cases of extreme flooding (either an infrequent, perhaps a "once-in-a-lifetime" event, or catastrophic flooding, or both), property values decrease immediately after the event, but recover eventually to pre-flood levels, and may rise higher. Evidence immediately following the 1997 floods suggests that the flooding has had an impact on the residential real estate market, primarily by encouraging some individuals to move off the perceived floodplain. The flood also had a negative impact in areas flooded to the greatest depths, at least over the short term.

E.2.2 Land Use Impact Studies

E.2.2.1 Floodplain easements and coordinated land use planning

Land use planning offers several tools to manage development within floodplains, preventing long-term damage from disaster events. These management tools are not enough alone to keep all development and structures out of the floodplain. Coordinating Federal actions with local land use planning measures is needed to strengthen floodplain management. Engineering solutions such as building elevation typically have flood-proofed structures in vulnerable areas. However, purchasing easements within floodplains is increasingly popular.

Berke (1998) stresses the need for proactive approaches in land use planning to reduce disaster-related loss, and he describes various land use planning tools, including floodplain easements. He focuses on the role of local government and its partnerships with state agencies in implementing hazard-prevention land use programs. Partnerships can be formed on several levels; programs can be established between local governments, landowners, and Federal agencies. These agreements between partner organizations must maintain the integrity of local ordinances and regulations governing the areas in question.

In discussing a community's need for managing its land use to foster resilience following disaster, Deyle et al. (1998) address some of the tools available for creating safer communities and reducing the effects of disaster. The article addresses ways to clear a floodplain of development, including agricultural floodplain easements, transfer of development rights (TDR) programs, and residential relocation.

E.2.2.2 Alternate flood management tools for communities

In addition to NRCS agricultural and improved-land easements, communities have other choices of mechanisms to clear development from floodplains. Like the floodplain easements above, these tools must be coupled with local-level land use planning regulations for the most effective outcome.

Deyle et al. address TDR programs, which operate under the premise of protecting vulnerable land from development. Development rights purchased from one parcel in a low-density area are moved to another in an area of higher density. An easement is placed on the parcel from which the development rights were purchased to maintain the open-space qualities of that land (Daniels and Bowers, 1997). For landowners who wish to continue to farm, and whose lands are not repeatedly inundated , this option is often attractive.

This program works only in areas with low-density parcels to "send" the rights, and with higher density parcels to "receive" them. TDRs allow a jurisdiction to develop an urban area at a higher density than normally allowed under its land use regulations while keeping its rural areas undeveloped. An example would be in a county with both rural areas and denser, suburban and or urban centers. In areas where denser urban areas are not present, a variation of TDRs is also possible. This variation is known as the Purchase of Development Rights (PDR).

In rural areas, the PDR is a possible alternative. Allowing a farmer to continue farming, a PDR program places a conservation easement on a piece of land, optimally prohibiting development forever (AFT-ACE, 1998). This approach also helps maintain the integrity of the floodplain. The conservation easements are individually tailored to the landowner and piece of land; thus, some smaller development (e.g. a barn or outbuilding) may be allowed. It would be important to stipulate in the conservation easement that such a building not be in the floodplain portion of the protected land if PDRs were used as a floodplain protection option.

E.2.2.3 Economic value of land

Any discussion of easements as a tool for watershed planning must address economic, aesthetic, and biotic issues. Holway and Burby (1993) address the economic issues of land values within floodplains, citing studies comparing residential and vacant values within and outside floodplain boundaries. They emphasize the need for land use regulation of the floodplain, in addition to the NFIP regulations, to reduce monetary losses from disasters more effectively.

Locating structures within floodplains often decreases their market value, according to several authors. Holway and Burby cited Donnelly (1989) who found a 12-percent decrease in sales prices of homes in floodplains. In cases of levy protection of floodplains, easements would help maintain the natural condition of protected lands. The decreased market value of lands would help deter people from investing in these properties for residential uses. Furthermore, if land use planning and watershed control efforts were coordinated as described above, residential users would not be allowed to re-enter these protected areas with lower market values. Strict regulation controlling the amount of development allowed in the floodplain would alleviate the fear of resettlement.

E.2.2.4 Cost-of-community-services studies as floodplain management techniques

Also used to analyze the economic benefits of floodplain management techniques are cost-of-community-services (COCS) studies. American Farmland Trust (AFT-COCS, 1999) cites these studies as:

> "An inexpensive, easy-to-understand way to determine the net fiscal contribution of different land uses to local budgets. Municipal records are reorganized to assign the cost of local public services to privately owned farm, forest and open lands, as well as residential, commercial and industrial lands. The result is a set of ratios that compare the annual income to the annual expenditures for different land uses.
>
> COCS studies are a snapshot in time of costs versus revenues for each type of land use. They do not predict future costs or revenues or the impact of future growth. They do provide a baseline of current information to help local officials and citizens make informed land use and policy decisions."

COCS studies thus help support the use of easements and open-space protection for managing floodplains to prevent disaster-related damages. Open space is a cheap land use for local governments to maintain because it does not require the services residential use does (See Section 5.3 for more detail on costs of land uses). A tax base can be healthy with a mix of open space, residential, commercial, and industrial uses. A jurisdiction supporting the rebuilding of residential use, and its accompanying services, will encounter economic challenges. A mix, including open space, is needed to relieve the tax burden of providing community services, especially in the case of repeated rebuilding.

E.3 REVIEW OF CUMULATIVE IMPACTS APPROACHES

The NRCS Interdisciplinary Team began developing the cumulative impacts assessment methodology by reviewing the literature on considering cumulative impacts in NEPA. The Team concluded that consideration of cumulative impacts had been more effective in individual project-type EISs than in programmatic EISs. For example, a recent review of 33 selected EISs found that agencies such as the USFS and the USACE had improved their consideration of cumulative impacts in their project-specific EISs, particularly since 1990 (Cooper and Canter, 1997). The recent CEQ publication *Considering Cumulative Effects Under the National Environmental Policy Act* also served as an important source for the development of this methodology.

E.3.1 Literature Review

With these concepts in mind, the Team conducted a literature search for appropriate cumulative impact analysis approaches on which to model its cumulative impact methodology and found several useful examples. In particular, the USFWS and the USFS have made significant attempts to include cumulative impact analyze in their NEPA documents and other technical environmental studies. The following four studies were of particular interest.

E.3.1.1 U.S. Fish & Wildlife Service Study

The USFWS has recommended a cumulative impact assessment process (Williamson, 1993) as follows:

> The recommended cumulative impacts assessment and management planning process should use the following steps: (1) in the scoping phase, define the ecological situation in specific terms of individual problem statements and select one strategy for each problem; (2) in the analysis phase, investigate and document the problems and their causes in detail using the best available data and analytical tools and then set several goals; (3) in the interpretation phase, develop and document options, estimate changes using mathematical models, and develop a plan; and (4) in the direction phase, implement and incrementally improve the management plan and systematically evaluate, improve, and update the problem statements, data, analytical tools, and mathematical models. It has been useful to distinguish cumulative impacts assessment (Steps 1 and 2) as the portion of the time horizon from the past to the present and cumulative impacts management planning (Steps 3 and 4) as the portion of the time horizon from the present to the future.
>
> - Step 1 focuses on qualitative problem descriptions and is intended to accomplish problem identification, clarification, and expression. Establishing appropriate temporal, spatial, and political boundaries is difficult, but it is critical to the success of a cumulative impacts assessment. Concern about cumulative impacts by federal natural resource regulatory agencies has been pronounced in areas that are moderately large and complex (entire ecosystems with a focus on aquatic and wetland habitat). Generally, a multi-agency group of natural resource management experts should be gathered to work collaboratively in a workshop setting. The group identifies important ecological problems contributing to the overall situation, agrees on problem statements, and documents those problems using the relevant scientific literature. Careful statement of each problem goes a long way toward stimulating action on its solution.
>
> - Step 2 provides quantitative problem analyses and goal statements that are technically and scientifically credible. The status and historic trends of the priority resources are documented, graphed, and mapped. Based on an evaluation of the best data, literature, and scientific judgment available, early problem statements are accepted, modified, or rejected. The importance of causal factors is evaluated. Data gaps, research needs, and preferred predictive mathematical models are identified. Specific management goals are generated and supported, both scientifically and

institutionally. For example, in an early restoration planning workshop for Commencement Bay, WA, the natural resource trust agencies developed the following problem and goal statement: "Virtually none (less than 1%) of the original 10 km 2 (2,470 acres) of subaerial wetlands in the Commencement Bay-lower Puyallup River ecosystem remain. By 2005, restore at least x y acres (some numbers between 10% and 50%) of these wetlands in that ecosystem."

E.3.1.2 U.S. Fish & Wildlife Service Workshop

A 1983 national workshop and technical review held by USFWS outlined the following procedure:

Two groups of attendees developed cumulative impacts methodologies for three cases (a marina, a coal-fired power plant, and six coal mine developments).

Group 1, began with the marina and formulated the following 9 steps.

1. Identify the effects of the action.
2. Look at other activities producing similar effects. (Input about future scenarios for secondary actions is obtained from other specialists).
3. Bound the area of study using the boundary of these effects.
4. Decide on the analytical techniques.
5. Re-scope the area of study based on the limits of analytical techniques and known relationships.
6. Map the distribution and important life activities of species.
7. Add up effects over space by species using average conditions. If no effect when added, proceed no further.
8. Add up effects over time -- annually then monthly.
9. Look at interactions (is a minor step because of lack of knowledge; what is done uses professional judgment).

This method accumulates parameters downstream (through a river-routing model), sums the actions, then compares effects with and without the marina (and associated developments). The group determined that cumulative impact assessments for the other two cases would be conducted similarly. A participant commented that the case of the coal development might be simpler because the induced or secondary actions were more easily identified. The reasons for not conducting cumulative impact assessments were the lack of systematic databases and the lack of time and personnel.

Group 2 concluded that the marina and coal-fired power plant cases were too site-specific to develop a cumulative impact methodology. The group discussed primarily the techniques and information the field staff would need to conduct a cumulative impact assessment. First, the information needs for a cumulative impact assessment must be determined. This can be accomplished using a variety of techniques. A need was also expressed for a gross habitat suitability analysis. The group emphasized the uncertainty involved in conducting an assessment because industry plans are not well known and change at the last moment. Interagency cooperation and coordination were considered imperative.

E.3.1.3 USFWS 1994 Report

A USFWS cumulative impact analysis (Hawkins, 1994) outlined an approach as follows:

> In 1988, we initiated an extensive survey of 45 mountainous watersheds in California. Our purpose was to determine whether cumulative watershed disturbance associated with timber harvest practices on forested landscapes managed by USDA Forest Service, Region 5 were having adverse effects on stream biota. Although considerable attention has been given to the conceptual issues regarding the definition of cumulative effects, we cannot at this time either measure or predict with any degree of reliability or confidence the cumulative effects most types of land use practices will have on natural ecosystems. The development of cumulative effects assessment tools were ranked as the most pressing technical need for several federal agencies.
>
> The primary objectives of the study were to:
>
> 1. Determine whether the cumulative effects of watershed disturbance on stream biota could be measured, and
> 2. If effects were measurable, develop an ecologically sound method (model) for predicting effects in other watersheds.
>
> To address these objectives, we planned to answer the following four questions:
>
> 1. What is the magnitude of biotic response to cumulative watershed perturbation?
> 2. Which taxa are most sensitive to cumulative effects?
> 3. What are the causal linkages between hillslopes and streams
> 4. Can an empirical model of biotic response to cumulative watershed perturbation be developed that can predict magnitude of biotic response?
>
> Current conceptual models imply that hillslope disturbances such as timber harvest should alter stream habitats by affecting hydrologic, nutrient, sediment, or temperature regimes. These changes, in turn, should alter either species composition or ecosystem function within a stream. Although [these models define] what appear to be rather simple and direct linkages between hillslope processes, stream habitat, and aquatic biota; in reality the strength and nature of these linkages are both variable and complex. As a consequence, it has proved difficult to develop general process-based models useful for predicting the specific biotic impacts associated with some set of hillslope disturbances.
>
> We hypothesized that useful predictive models might be developed without complete specification and description of watershed processes if strong empirical relationships existed among measured watershed, channel, and biotic variables. Such empirical models may offer the only reasonable tool for predicting the effect of management practices in the short and moderate term. These models would be especially useful if they were based on information typically measured on managed watersheds.
>
> The study was designed to examine the relationship between watershed, stream channel, and biotic variables over a range of impact levels and forest management activities.

However, we also wanted to determine how important management related effects were relative to responses associated with natural variation among watersheds.

An adequate evaluation of cumulative effects in streams requires that three criteria be met:

1. Data must be collected at an appropriate spatial scale,
2. A sufficiently large number of basins must be sampled to generate statistically reliable data, and
3. Responses of the overall aquatic community should be quantified and not just one or just a few taxa.

E.3.1.4. USFS Stream Team

See Appendix B, Section B.5.2, for a detailed description of the approach recommended by the USFS "Stream Team" in June 1998.

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