Highway Impacts on Wetlands: Assessment, Mitigation, and Enhancement Measures

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The conservation of wetland acreage in the United States, wherever and whenever practicable, is a national policy objective. This had led to an increased awareness of the need for making wise land use decisions, especially when modification of the natural environment is anticipated. Federal agencies are required to avoid construction in wetlands whenever there is a practicable alternative. However, often there is no practicable alternative. It is important, therefore, to understand the functions, values, and ecological interrelationships of wetland systems so that an appropriate mitigation plan can be developed. General wetland types and their basic functions and values are identified, and highway construction impacts, impact assessment, and mitigation and enhancement procedures are discussed. Special emphasis is given to the reconstruction of wetlands affected by highway construction.

Executive Order 11990, Protection of Wetlands, sets forth a national policy that requires avoiding to the extent possible the long- and short-term adverse impacts associated with the destruction or modification of wetlands. Over the past decade there has developed an increasing awareness of the need for making wise land use decisions to reduce or eliminate adverse modification of the natural environment, including wetlands. Estimates indicate that nearly half of the 120 million acres of wetlands inventoried in the 1950s has already been lost (1). This loss has come largely from the alteration and destruction of wetlands through artificial draining, dredging, and filling. Although there has been a decrease in the percentage of remaining wetlands being lost annually, the subject remains one of concern.

Federal agencies are required to avoid construction in wetlands whenever there is a practicable alternative. This policy applies to any project located in or having an effect on wetlands. FHWA is committed to this policy during the planning, construction, and operation of highway facilities and projects.

DEFINITION OF WETLANDS

An awareness of local wetland statutes and ordinances and their corresponding definitions is extremely important in the environmental impact analysis of proposed highway projects. There is no single, indisputable definition of wetlands because of a high degree of diversity characterized by the continual gradation between dry and wet environments and because reasons and needs for defining wetlands vary.

The definition most commonly accepted by the U.S. Department of Transportation is that of the U.S. Army Corps of Engineers. The Corps of Engineers defines wetlands as areas inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support--and that under normal circumstances do support--a prevalence of vegetation typically adapted for life in saturated soil conditions (33 CFR § 323.2c). Consequently, many types of land can be considered. Under the Corps of Engineers definition, wetlands generally include areas such as swamps, marshes, and bogs.

WETLAND TYPES

A swamp is a type of wetland that is often waterlogged in winter and early spring but may be quite dry in the summer. Swamps are characterized by a predominance of woody plants. Swamp vegetation includes willow, oak, maple, gum, alder, and cypress. Swamps usually develop in wet upland depressions, at the edges of lakes and ponds, and along the borders or floodplains of streams and rivers (2).

Marshes can be either saltwater or freshwater. Salt marshes stretch in an almost continuous chain of undulating grasses along the Atlantic Coast and the Gulf of Mexico and account for less than 10 percent of total U.S. wetlands (2). Salt marshes also occur sporadically along the West Coast. Salt marshes are inundated daily by tides, and vegetation consists of salt tolerant plants such as cord grass and marsh hay.

Freshwater marshes account for more than 90 percent of total U.S. wetlands (2). Freshwater marshes may occur inland or adjacent to the coast in low-lying depressions and are most often covered with shallow water. Marshes may be fed by groundwater, surface springs, streams, rainwater, runoff from the surrounding terrain, or all of these. Marsh vegetation is usually characterized by soft-stemmed plants. Vegetation consists of grasses, sedges, waterlilies, reeds, and arrowheads.

The bog is a freshwater wetland most common in the northern and north-central states. Bogs often form in glaciated depressions in forested regions. A bog has very restricted drainage and therefore has almost no inflow or outflow. For this reason, dead organic matter accumulates as peat in layers that are often 40 ft or more in depth (2). Vegetation is characterized by acid-tolerant plants and includes cranberries, blueberries, sedges, and insectivorous plants.

The important point to remember about wetlands is that the dominant factor is saturation with water, which determines the nature of soil development and the types of plant communities that live in the soil or on its surface. Thus, soil types and species of vegetation are the most important physical indicators of wetlands (1).

VALUE OF WETLANDS

Wetland systems serve many functions and provide many benefits. Wetlands provide the vegetative material that is the base for many aquatic and terrestrial food chains. Moreover, vegetative production in wetland systems can be considerable because these aquatic environments act as nutrient traps. Aquatic vegetation can assimilate these nutrients and produce tremendous quantities of plant material. The rates of gross primary productivity in certain types of wetlands are among the highest recorded for any natural systems. Consequently, the potential for supporting large plant and animal populations of diverse species is also high.

Wetlands also provide a vital breeding, feeding, and nursery habitat for many species of waterfowl, fur-bearing mammals, and fishes. The dependence of such species on wetlands at some time in their life cycle is of great economic importance. Many wetlands such as marshes and swamps often act as highly effective flood and erosion buffers. The expanses of shallow water and associated vegetation can slow the velocity of flood water and thus can successfully reduce shoreline and river bank erosion.

Wetlands can also improve water quality through the assimilation of nutrients. This assimilation is accomplished through the filtering capacity of dense stands of wetland vegetation, which provide an effective means of removing suspended solids from polluted waters. In addition, depending on local geologic formations, impoundments of water can allow the slow percolation necessary to replenish underground supplies.

The value of wetlands to recreation is obvious. Many Americans visit wetland areas to observe birds and wildlife. Others enjoy recreational fishing. As noted earlier, many species of sport and commercial fish are dependent on wetlands as sources of food and as spawning areas. Equally important are the benefits of wetlands for environmental research. Wetlands provide natural laboratories where the researchers can view firsthand the many relationships vital to an understanding of ecological systems.

No discussion of the value of wetlands is complete without mention of aesthetics. Although it is difficult to measure, the unique aesthetic value of wetlands is often reason enough for conservation efforts. Some unusual types of wetlands are outstanding from a visual standpoint (1).

CLASSIFICATION OF WETLANDS

The types of wetlands found throughout North America vary widely in terms of vegetation, hydrology, water chemistry, soil, and other characteristics. Many attempts have been made to classify wetlands on the basis of one or more of these characteristics. However, each classification scheme has special advantages in terms of the particular use for which it was devised, and each has serious disadvantages when used outside its own special context. The need for wetland classification has grown out of a need to understand and describe the characteristics of all types of land and to provide uniformity in concepts and terminology for wise and effective management of wetland ecosystems. The U.S. Fish and Wildlife Service has provided the most comprehensive and complete description of classifying wetland systems (3). The primary objective of this classification is to impose boundaries on natural ecosystems for the purposes of inventory, evaluation, and management. Wetland and deepwater habitats are defined separately because the term wetland traditionally has not included deep permanent water. Deepwater habitats are permanently flooded lands where surface water is often deep and is the principal medium within which the dominant organisms live. Both wetlands and deepwater habitats must be considered in an ecological approach to classification.

WETLAND ECOLOGY

Although the characteristics of wetlands differ from system to system, there are basic ecological relationships that are generally pertinent to all wetlands: sunlight energy is transformed into the chemical energy of plants (primary producers), which is transferred to consumers (animals) and further transferred to decomposers (bacteria, fungi, and so on). These sequential transformations of energy constitute a grazing food chain. Organic matter or detritus is also used directly as food by consumers and decomposers, which constitutes a detritus food chain. The decomposition of plant material and other matter results in the release of nutrients that are used by plants and animals. Both grazing and detritus food chains are affected by mechanical energy of tides and waves, horizontal and vertical currents, and diffusion processes that affect the flow of minerals to plants and thereby allow for photosynthesis to occur (4).

HIGHWAY IMPACT ASSESSMENT

It is evident from the preceding discussion that highways can affect the ecological values of wetlands in a number of ways. Highway impacts on a single biotic (living) or abiotic (nonliving) component may affect the dynamics of an entire wetland. These factors are so complex and diverse that impact assessment can become extremely difficult. Although impact assessment has been done for many years, no single guideline for conducting impact assessment has been universally accepted. This is especially true in the area of ecological impacts. Impact assessment continues to be both an art and a science, and judgment is generally required.

A key approach to impact assessment is the ecosystem concept. This concept requires the integration of individual biotic and abiotic components of terrestrial and aquatic systems into a dynamic system (4).

Impact assessment for wetlands should include four major elements (4):

1. Evaluation of the dynamic interrelationships among biotic and abiotic components of the wetland,
2. The specific manner in which highway development can affect each of these dynamic interrelationships,
3. Alternative means of mitigating adverse effects and enhancing desirable effects, and
4. The potential for undesirable secondary impacts from all improvement measures.

The ecological impact assessment process can be divided into three key steps: description of the project, ecological studies, and impact assessments. A description of the project should be provided in as much detail as possible. Such details as grade, alignment, cut and fill, and crossings of water resources should be described. Ecological studies should include an evaluation of the biotic and abiotic factors. The prediction of impacts is the most important step in the process. This step is an integrative procedure in which ecosystem concepts, all environmental data (including abiotic and biotic data), and engineering data must be integrated. Impact assessments should include predictions of the probability, the magnitude, and the time frame of the impacts. Impact assessments must also include the consideration of alternatives and means of providing or enhancing positive impacts (5).

In evaluating the impact of the proposed project on wetlands, the following questions should also be addressed: What is the importance of the affected wetland? What is the significance of the impact on the wetland? The evaluation of importance should consider such factors as the primary function of the wetland and the relative importance of that function. The significance of the highway impact should focus on how the project affects the stability and quality of the wetland. This evaluation should consider the short- and long-term effects on the wetland, the significance of any loss of flood-control capacity, erosion control potential, water pollution abatement capacity, and the value of the wetlands as wildlife habitat. Knowing the importance of the wetland involved and the significance of the impact, the state highway agency and FHWA will be in a better position to determine what mitigation efforts are necessary and the possibilities for enhancement.

MITIGATION AND ENHANCEMENT

There are two fundamental approaches to the mitigation of highway impacts on wetlands. The first approach is to plan or design highways to avoid or minimize the probable occurrence of potential impacts. This approach lies at the heart of Executive Order 11990. The second approach stems from the fact that some impact is often unavoidable regardless of the care and creativity applied during the planning, design, and construction of a highway. Mitigation in these instances may take the form of attempting to reconstruct the basic ecological features that were disturbed by the construction of the facility. Such mitigation may include the restoration of the original hydrologic systems and the replacement of destroyed species of plants with those same species (6).

Mitigation may also take the form of creating alternative ecosystems that offer environmental values equivalent to or more desirable than those of the affected system. It may be possible to create new wetlands in one area as a substitute for areas destroyed or diminished elsewhere. Borrow pits may be located and designed so as to create new wetland habitat. There are many such opportunities for creative design both on and off the immediate right-of-way (6).

In a similar manner, practices and design features may be adapted to enhance or create positive impacts that may result from the highway project. Enhancement is the improvement of a wetland resource so that its values also increase. Some of these practices might include using borrow pits as a sports fishery resource, diversifying wetlands by increasing the mixture and diversity of wetland habitats, and increasing edge effects by the use of islands. Design features might include improving fisheries through the use of culverts for migration, increasing the area or size of a wetland, and developing new wetlands where none existed before. The enhancement concept offers highway personnel an opportunity to innovatively incorporate improvements in wetland environments in their highway projects (6). Because of the variety of potential impacts on wetlands, it is vital that early phases of project development be guided by a careful evaluation of these impacts and the various measures for mitigating them.

In some instances it may be possible to locate alignments that will actually improve the condition of an existing tributary by interrupting potentially toxic wastes that currently flow directly into the tributary. In some instances, it may be more cost effective to span wetlands on structure instead of filling. This will minimize significant adverse impacts on hydraulic flow and bottom substrate. If the decision is made to span wetlands, the alignment should be located so as to minimize impacts on sunlight penetration of underlying waters and thus on photosynthesis (4). Because structures are usually a costly item, it is essential that the impact analysis objectively justify the added expense.

Compensating unavoidable wetland losses is a central component of a mitigation plan. The determination of adequate compensation is largely subjective and involves the consideration of various mitigation and enhancement measures, including restoration, replacement, development, and diversification. A frequently considered compensation measure for highway projects involves wetland establishment. Possibilities for wetland establishment will vary according to geographic area. No general formula can be provided, but some techniques and considerations can be briefly examined.

Wetland establishment is accomplished through wetland construction. The two principal criteria that must be applied in the selection of land for wetland establishment are (a) that the land have low fish and wildlife resource value in its present state and (b) that an adequate water supply be available for connection to ensure successful wetland development (7).

Dredged spoil disposal areas are often successfully used for wetland replacement. Disposal sites for inactive dredged material that are of poor wildlife value should be considered for wetland replacement sites. The disposal materials may be acceptable for highway construction purposes, and the excavated area may qualify as a suitable location for wetland establishment. Moreover, with proper preparation the replacement location can rapidly become established after the installation of wetland plant material.

This process of creating new wetlands generally involves altering existing habitats. It is desirable that the wetlands created be of greater value to fish and wildlife than the habitats that were altered. The replaced wetland need not necessarily be of the same type as that which was lost. A different type of wetland may often provide improvements for fish and wildlife habitat or for the control of water quality, flooding, and shore erosion.

In considering the type of wetland to be replaced, thought should be given to providing a habitat that will lead to an enhancement of the wetland function. Priority should be given to types that establish rapidly, render the most important functions, and are not easily transformed into upland habitat (7).

Wooded wetlands (swamps) cannot be established rapidly because trees require years to mature. High-elevation wetlands or intermittently flooded wetlands have little value to fish and wildlife and are likely to evolve into uplands. Consequently, the best types of replacement wetlands are those that are periodically inundated by tides or permanently flooded by shallow water. Regularly flooded and permanent wetlands have the greatest longevity and the greatest value to fisheries and water-quality control.

When wetlands are replaced in an area dominated by a single wetland type, consideration should be given to establishing a wetland of a different type. Introducing new wetlands of a different type will provide diversification, which may increase the wetlands' overall value.

The junction of two types of habitat often creates a zone with a more diverse biological community than either habitat taken alone. This is known as the edge effect (7). Consequently, a wetland replacement location that offers the opportunity to develop the greatest lineal footage of new edge should be explored. For example, stabilizing an unvegetated shore through wetland establishment provides erosion control and a productive biological edge to upland areas.

The most important factor in wetland establishment is creating the proper elevation. This is accomplished by making a thorough topographic survey of the site. The vegetative composition of nearby wetlands should also be correlated with their topography. This information will be useful in designing final grades and associated vegetative zones.

In the establishment of wetlands and in enhancement measures that involve revegetation, it is important to get the designated plants growing and exhibiting maximum ground coverage and productivity as quickly as possible. In addition, leaving a graded site unvegetated will promote its instability, and grades altered by erosion may not support the designated plants. The necessary plant material may be available from a wetland plant nursery or they may have to be collected from the wild.

In transplanting material from existing natural wetlands, a checkerboard pattern of excavation is recommended to avoid the disruption of single large areas of wetland. However, the preferred method of obtaining materials is through nurseries experienced in handling wetland plants.

Wetland establishment by seeding is the most economical approach, but its success is the least predictable. Seeds must be planted to subsurface depths of generally no greater than 1 in. Seeds that are surface sown with or without mulch wash away during times of high water. Seeds are also subject to uncontrollable factors such as temperature, turbidity, salinity, and siltation, which, if adverse, will lead to reduced productivity.

The most successful as well as the most expensive method of wetland establishment is transplanting nursery-cultivated, peat-potted nursery stock. Peat-potted, nursery-stock aquatic plants can be produced economically outside or in a greenhouse in water-filled compartments. If the physical conditions of a site permit, plants can be transplanted mechanically; otherwise, transplanting must be done by hand. During the period of establishment, litter and debris deposits should be removed from the site, and all transplants lost and bare-seeded areas should be replanted. Litter and debris deposits that adversely affect wetlands might demolish transplants or seedlings unless removed expeditiously.

If there are large populations of wildlife or livestock near a new wetland site, the site may have to be protected during the period of establishment by using enclosures.

Factors that have been found to limit the success of wetland establishment projects are improper final grade, improper wetland species, restricted tidal flow to the site or inadequate water level, improper timing of incorporation of the specified plant materials, erosion, depredation by wildlife and livestock, development of a salt stress zone, and litter deposition and accumulation. All but the last two of these factors can be traced to imperfections in project design, specifications, execution, or inspection (7). The final grade of a site and the plant species assigned to the various elevation zones will dictate the ultimate success of a project.

SUMMARY

In summary, wetlands as defined here are characterized by the periodic or permanent presence of water in a sufficient amount to make it the dominant factor in determining the nature of soil development and the types of plant communities living in it or on its surface. There are many types of wetlands and a variety of classification schemes, depending on the wetland definition that is used. The benefit of classification is to provide uniformity in concepts and terminology for wise and effective management of ecological systems.

Most wetlands are important to fish, shellfish, waterfowl, and other wildlife, although specific values differ. Wetlands also perform functions that are vital to the dynamics of natural ecosystems. Wetlands provide a highly productive habitat for a diverse group of species and beneficial functions in flood control, erosion control, pollution control, and water recharge.

There are many complex ecological relationships associated with wetland systems. It is essential that these relationships be considered in highway planning projects so that highway impacts on wetlands can be accurately determined and analyzed.

Highway construction in wetlands is regulated by federal and state laws. However, the unavoidable adverse impact on wetlands by a proposed highway construction activity may be permitted provided that such construction is judged to be in the public interest and an acceptable plan to mitigate wetland losses is implemented. A central component of the mitigation plan is compensating or offsetting unavoidable wetland losses. The objectives are basically of two kinds: the mitigation of adverse impacts and the enhancement of wetlands.

Highway professionals realize that accurate assessment of impacts on wetlands and appropriate mitigation and enhancement measures are integral to sound highway planning, design, and operation. It is hoped that this trend will continue and that highway professionals will use their planning, engineering, and management skills to implement highway projects that are compatible with natural ecosystems in general and wetlands in particular.

REFERENCES

1. Water-Related Activities of Highway Projects. Office of Environmental Policy, FHWA, 1980, pp. III-1 to III-36.
2. Our Nation's Wetlands: An Interagency Task Force Report. Council on Environmental Quality, Washington, D.C., 1978.
3. L.M. Cowardin, F.C. Golet, and E.T. LaRoe. Classification of Wetlands and Deepwater Habitats of the United States. Fish and Wildlife Service, U.S. Department of the Interior, 1979.
4. Highways and Wetlands: Volume 2--Impact Assessment, Mitigation and Enhancement Measures. FHWA, 1980.
5. Highways and Ecology: Impact Assessment and Mitigation. FHWA, Rept. FHWA-RWE-OEP-78-2, 1978.
6. P.W. Shuldiner and D.F. Cope. Ecological Effects of Highway Fills on Wetlands: Examples from the Field. Transportation Research Record 736, 1979, pp. 29-37.
7. Highways and Wetlands: Compensating Wetland Losses. FHWA, 1982.

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