# CLASSIFICATION, MAPPING AND DATA BASE DEVELOPMENT FOR COASTAL WETLANDS OF THE UNITED STATES

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## INTRODUCTION

Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life (Niering 1986). Wetlands include marshes, swamps, bogs, potholes, wet meadows, river overflow areas and other lowlands that are waterlogged or covered with standing water. Scientists recognize wetlands as areas of transition between upland and aquatic environments where the water table is at or near the surface or where the land is covered by shallow water that may be up to six feet deep (Cowardin et al. 1979).

The wetlands of the United States are vital areas that constitute a productive and invaluable public resource. Wetlands are among the most biologically productive ecosystems in the world and are crucial as habitats for many fish and wildlife species. Numerous species of invertebrates, fish, amphibians, reptiles, birds and mammals frequent marshes and swamps for feeding. Wetlands also provide essential nesting, migration, and wintering habitats for many species of migratory birds. The wetlands in the United States are also important in maintaining groundwater supplies and water quality, protecting shorelines from erosion, storing floodwaters, and trapping sediments which can pollute waterways. Wetlands help maintain good water quality or improve degraded water in several ways: (1) removing nutrients, (2) processing chemical and organic wastes and (3) reducing sediment loads. Wetlands are especially good water filters. They can serve as nutrient traps, chemical sinks and in erosion and sediment control. Additionally, cash crops such as timber, marsh hay, wild rice, blueberries, cranberries, and peat moss are all commercially important products of wetlands.

The United States possesses a wide variety of wetland types. Wetlands occur in every state in the Nation and, due to climate, vegetation, soils, and hydrologic conditions, they range in size, shape and type. Estuarine wetlands are found scattered along the entire coastline of the United States. They are associated with brackish tidal waters. These wetlands develop behind barrier islands and beaches or form along coastal rivers. A variety of wetlands develop in estuaries largely because of differences in salinity and duration and frequency of tidal flooding. Major types of

estuarine wetlands include: emergent wetlands, intertidal flats, and brackish shrub wetlands. Marine wetlands and deepwater habitats generally occupy the oceanic side of the system and can be represented by underwater reefs, shoals or kelp beds. Riverine and palustrine wetlands can also occur in coastal areas.

Wetlands are dynamic systems which are subject to both human and natural alterations that may affect their abundance as well as their quality. Natural events, including subsidence, rise in sea level, sedimentation and succession can impact the number and type of wetlands found in any given region of the country. Human activities have mainly tended to reduce wetlands by drainage for agriculture, channelizing waterways, dredging for navigation, harbors and marinas, filling for urban or industrial development, or disposal of waste materials.

Within the United States, the loss of coastal marshes and other wetlands is a serious problem. There is evidence to indicate that as of the 1970's over half of the coastal wetlands in the contiguous United States had been destroyed. In some areas of the country, losses of coastal wetland resources continue at a staggering rate (Frayer et al. 1983).

The reasons for the decline in coastal wetlands vary from region to region, but recent studies have indicated that between 70 to 90 percent of coastal wetland losses are directly related to population density, i.e. urbanization of the coastal zone (Gosselink and Baumann 1980). Pressure on wetland resources brought on by population shifts to coastal areas and associated industrial and municipal expansion will probably continue to erode coastal wetland resources. These land-use changes can adversely impact fishery resources, migratory bird habitat, shoreline stability and other coastal resources.

The United States of America continually faces the challenge of identifying and reconciling physical and environmental limits with the development of its natural resources. To meet the demand for resource development, the United States, like other countries, has developed laws, regulations and policies to increase the benefits of development while protecting fish and wildlife, environmental quality and socio-economic resource values. These values are often misunderstood or frequently overlooked in the marketplace and there is growing awareness that a better understanding of the environmental and ecological consequences of all types of resource development will lend to better solutions to potential conflicts between development and environmental protection.

One of the avenues that the United States has pursued to minimize these conflicts is to develop and disseminate sound information on the characteristics and extent of wetlands. The purpose of this information is to provide data for making informed decisions regarding the wetland resources. Decisionmakers anywhere in the world cannot make informed judgements about wetlands without knowing how many wetlands there are, what type of wetlands are within their territory's borders and where these resources are located.

## NATIONAL WETLANDS INVENTORY

The National Wetlands Inventory Project was established in 1975 by the U.S. Fish and Wildlife Service, an agency of the Government of the United States, to generate scientific information on the characteristics and extent of the Nation's wetlands. This information is developed in two stages: (1) the creation of detailed wetland maps, and (2) research on historical status and trends.

The objectives of the National Wetlands Inventory are to develop and disseminate information on the characteristics of the wetlands and to produce topical wetland maps that accurately represent these valuable resources. To accomplish these objectives, the National Wetlands Inventory is producing wetland maps for the United States, special map products, status and trend reports and a National digital database.

## CLASSIFICATION SYSTEM

Prior to beginning wetlands mapping, the National Wetlands Inventory initiated a pre-operational effort to determine the best way to inventory wetlands. During this pre-operational phase, the National Wetlands Inventory reviewed existing state and local wetlands inventories and existing classification systems, and then selected a remote sensing technique for the inventory.

The wetland classification system that is widely used by federal agencies in the United States (Cowardin et al. 1979) was developed by a team of wetland ecologists, with the assistance of local, state and federal agencies, as well as many private groups and individuals. Four major revisions were made and extensive field testing was done prior to the system's official adoption on October 1, 1980.

The purpose of the classification system is (1) to describe ecological units having certain common natural attributes; (2) to arrange these units in a system that will facilitate resource management decisions; (3) to furnish units for inventory and mapping; and (4) to provide nationwide uniformity in wetlands concepts and terminology.

A wetland must have enough water at some time during the growing season to cause physiological problems for plants and/or animals not adapted to life in water or in saturated soils. The most precise definition would be based on hydrology, but that would require detailed measurements over periods of time to determine if an area was, indeed, a wetland. Plants and soils furnish a record of the hydrology of a site. Both wetland plants and wetland soils are usually, but not always, present in most wetlands. Plants are not found in wetlands that are subject to drastic fluctuations in water level, wave acton, turbidity, or high concentrations of salts. Wetland soils are not found on rocky shores, rock bottoms, streambeds, etc. For these reasons, The U.S. Fish and Wildlife Service defines wetlands as:

> "Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification, wetlands must have one or more of the following

three attributes: (1) at least periodically, the land supports predominately hydrophytes, (2) the substrate is predominately undrained hydric soil, and (3) the substrate is saturated with water or covered by shallow water at some time during the growing season of each year."

The classification system itself is hierarchical. Wetlands are divided among five major systems at the broadest level: Marine, Estuarine, Riverine, Lacustrine and Palustmine. Each system is further subdivided into subsystems which reflect hydrologic conditions, e.g., subtidal vs. intertidal, in the Marine and Estuarine Systems. Below the subsystem level is the class level, which describes the appearance of the wetland in terms of vegetation (e.g. Emergent, Aquatic Bed, Forested) or substrate, where vegetation is inconspicuous or absent (e.g., Unconsolidated Shore, Rocky Shore, Streambed.) Each class is further subdivided into subclasses. The classification also includes modifiers to describe hydrology (water regime), water chemistry (pH, salinity and halinity) and special modifiers relating to man's activities (e.g., impounded, partly drained, farmed, artificial).

Use of this hierarchial system allows inventory to:

- Perform general reconnaissance surveys or detailed inventories using the same terms within the same classification system.
- Aggregate information at various levels for decisionmakers (Figure 1).
- Tailor the level of the inventory to answer the questions that need to be answered.
- The top of the hierarchy does not have to be repeated when the inventory is intensified.

The universal appeal of such a classification scheme has already been evidenced by adaptation and expressions of interest by a number of other countries. With some tailoring, the basic structure of the system can transcend continental differences and has already been used by some nations, such as India and Costa Rica, as a basis for common approach for naming classes of wetlands for conservation programs. The marine and estuarine components of the system seem especially suited to transcontinental application of coastal zone resources (Figure 2).

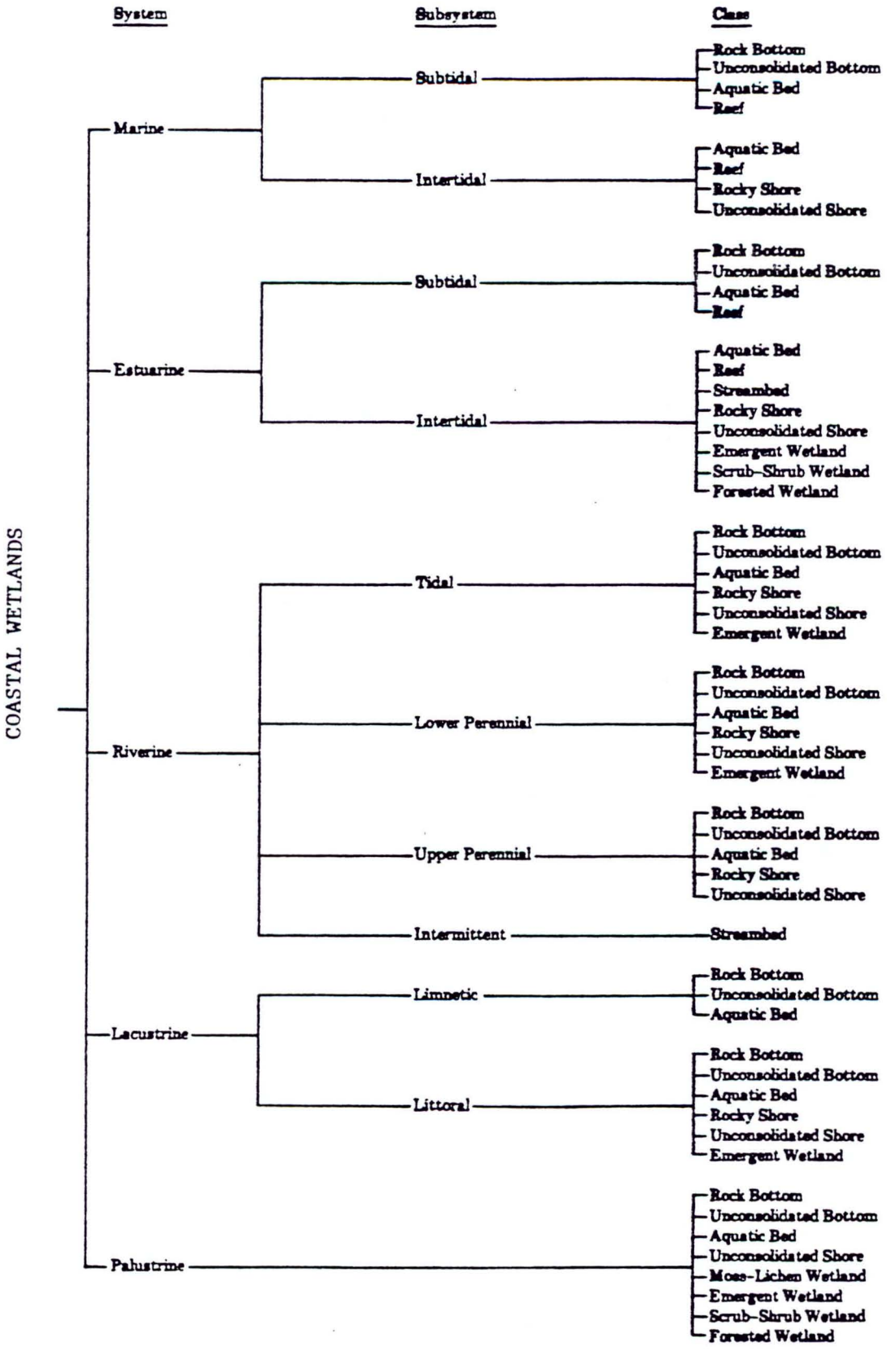



FIGURE 2.

Classification hierarchy of coastal wetlands and deepwater habitats, showing systems, subsystems and classes (Cowardin et al. 1979).

## MAPPING PROCEDURES

In the United States wetlands are being mapped primarily by the use of high altitude aerial photography. High quality and resolution photos taken in either the spring (April-May) or fall (October-November) when trees have no leaves are preferred. Biologists then photointerpret the wetland habitats using soils data, topographic maps or other regional studies to help ensure completeness.

Many large wetland inventories that attempt to map or statistically sample wetlands do so utilizing remote sensing imagery of one kind or another. Tailoring the use of remote sensing technology applicable to wetlands inventory work can be done to suit the needs, objectives and budget of the sponsoring entity. Aerial photography was the best choice for inventorying the wetlands of the United States since it was important to consistently identify and classify wetlands .5 hectares and larger. In parts of the world where needs and objectives are different, satellite imagery may be the preferred tool. LANDSAT or SPOT imagery may be very useful to those inventorying larger wetlands or wetland complexes.

Two series of wetland maps are being prepared by the National Wetlands Inventory: (1) small-scale (1:100,000 or 1:250,000) and (2) large-scale (1:24,000, or 1:63,360). The 1:100,000 scale maps each cover approximately 656 square kilometers. They are used chiefly for watershed and regional planning. The primary map product is the large-scale maps that shows the location, shape, and characteristic of wetlands and deepwater habitats overlaid on a 7.5 minute or 15 minute topographic base map. These deatailed maps are excellent for site-specific project evaluation and are the most sought-after map product.

National Wetlands Inventory map production began operationally in 1980. To produce National Wetlands Inventory maps, 7 major steps must be completed:

1. Field investigations
2. Photointerpretation of high altitude aerial photographs
3. Review of collateral wetland information
4. Quality control of interpreted photographs
5. Draft map production
6. Interagency review of draft maps
7. Final map production

Field investigations are conducted prior to beginning photointerpretation of a particular area. This step allows the photointerpretor to become familiar with the particular wetland communities, plant species and soil conditions in the area to be mapped. Photointerpretation is performed on high altitude aerial photography obtained from the United States National High Altitude Photography Program. Wetlands are delineated on the photography according to the Classification of Wetlands and Deepwater Habitats of the United States (Cowardin et al. 1979). Collateral wetland information such as soil surveys, topographic maps and local and regional studies are utilized during this step to help ensure accuracy and completeness.

To ensure that the maps are as accurate as possible, the U.S. Fish and Wildlife Service conducts regional and national quality control reviews of the wetland delineations and classifications on the aerial photography. A small percentage of the wetlands are checked in the field and cartographic quality control steps are built into the process. Draft wetland maps are prepared by transferring the data from the interpreted aerial photographs to an overlay on a U.S. Geological Survey topographic base map. This step is accomplished using a zoom transfer scope. This instrument enables the cartographer to superimpose the image of the interpreted photography onto the base map, and then transfer the wetland delineations to the base map.

The result of this work is a large-scale (1:24,000) wetland map that shows the locations, shape, and characteristics of wetlands and deepwater habitats overlaid on a United States Geological Survey topographic base map (copies on display). These maps are then distributed for review and comment to any federal, state, local, or private organization which wishes to receive them, or anyone who may have an opportunity to field check the wetland delineations. These users have an opportunity to make field observations and provide comments, suggestions or changes prior to compilations of map revisions and production of revised wetland maps.

The multi-agency input that the U.S. Fish and Wildlife Service receives on the draft maps contributes significantly to the quality and overall acceptance of the wetland maps. Accuracy is important since the maps are used by local, state and federal agencies as well as by private industry and organizations for many purposes including comprehensive resources management plans, environmental impact assessments, preliminary permit reviews, facility and corridor siting, oil spill contingency plans, natural resource inventories, and wildlife surveys.

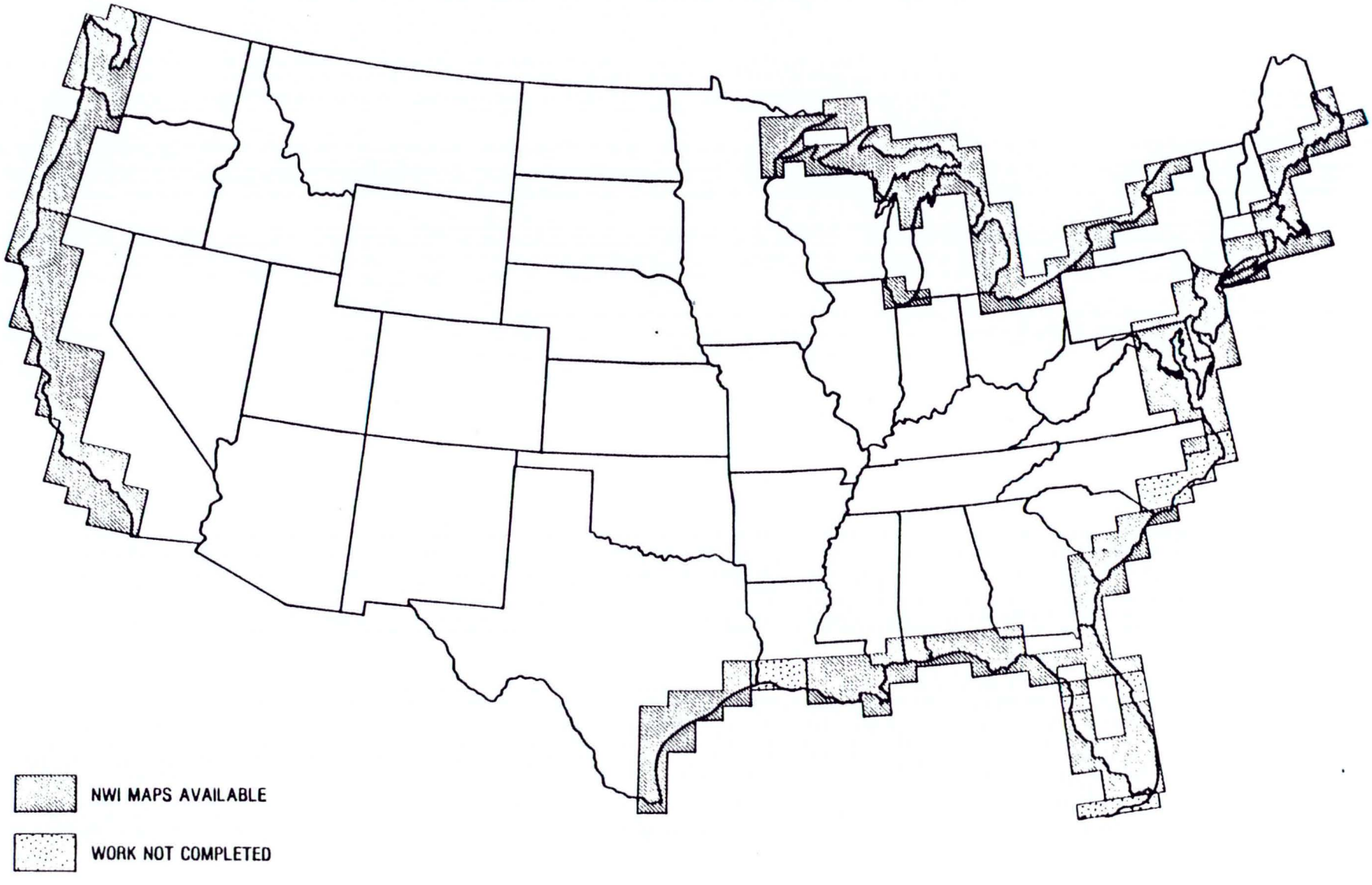
Final map production involves the incorporation of the review comments and corrections onto the original wetland map. Upon incorporation of these changes, the final map is reproduced for widespread distribution.

Utilizing these techniques, the National Wetlands Inventory has completed mapping for 95 percent of the coastal zone in the contiguous United States including the shorelines of the Great Lakes. Hawaii, Guam, Puerto Rico and portions of Alaska's coastal zone have also been mapped (Figure 3).

This information is proving to be very useful to coastal resource managers. Some of the applications for coastal wetlands data in the United States are listed in Table 1.

FIGURE 3.

## STATUS OF THE NATIONAL WETLANDS INVENTORY IN THE COASTAL ZONE




October 1987

TABLE 1

Uses of Wetlands and Trends Information by Coastal Managers

- Determining areal extent of aquatic and vegetated wetlands by type and by geographic location
- Determining length in miles of coastal wetlands by type and by geographic location
- Determining frequency of occurrence of wetlands by type, by size and by location (relative abundance and scarcity)
- Quantifying interface between wetland types
- Serving as a baseline for monitoring changes
- Quantifying wetland loss, gain and modification by type, size, geographic location, proximity, frequency of occurrence, contributing activity, etc.
- Determining the effectiveness of regulatory programs in preventing wetland loss and modification (measured as a function of change over time)
- Permit Review (e.g., examining, modifying, improving or denying application for permits for activities)
- Advanced Identification (e.g., identifying wetlands by type, location, size, etc. that are unsuitable for dredge and fill activities and other activities that alter wetlands)
- Special Areas Designation (e.g., identifying, quantifying and evaluating critical areas, preservation areas, Estuarine sanctuaries, acquisition areas)
- Mitigation (e.g., identifying, quantifying and evaluating wetlands suitable for restoration, enhancement or creation)
- Environmental Impact Assessment (e.g., recent and unbiased resource inventory and evaluation; identifying wetland by type, size, location, etc. that will be impacted by the proposed activity)
- Risk Analysis (e.g., oil spill sensitivity indexing - risk to wetlands)
- Facility Siting (e.g., proximity of hazardous waste site to wetland)
- Corridor Siting (e.g., determining best routes with minimal impacts on wetland for highways, pipelines, powerlines, underground cable, etc)
- Property Acquisition (e.g., identifying wetlands by type, size, location, etc. on parcels being evaluated for purchase and possible development)
- Energy Development (e.g., identifying areas suitable or unsuitable for hydroelectric, nuclear, or fossil fuel power plants)

## WETLAND TREND ANALYSIS IN THE UNITED STATES

As part of the United States' effort to monitor wetland trends, a statistical analysis was undertaken to develop national estimates on the status of United States wetland and deepwater habitats (in the lower 48 states) from the mid-1950s to the mid-1970s. The study was designed and conducted by an interagency group of statisticians, with data acquisition and generation provided by the National Wetlands Inventory. The findings of this study show that wetlands now represent only about 5 percent of the total land surface of the United States. Annual wetlands losses averaged 185,000 hectares: 178,000 hectares of inland wetlands and 7,300 hectares of estuarine wetlands. This annual loss equals an area about one half the size of the State of Rhode Island.

The trend analysis study found 19 states with significant net losses in wetlands: (1) in the Northeast-Delaware, Maryland, and New Jersey; (2) in the Midwest-Illinois, North Dakota, South Dakota, Minnesota, Nebraska and Wisconsin; (3) in the Southeast-all states, except Virginia, Tennessee and Kentucky; (4) Texas in the Southwest; and (5) California on the West Coast. The report discusses the causes of wetland conversions and identifies which wetlands of the country are in the greatest jeopardy.

Other major findings of this trend analysis included pertinent information on the following:

- o Status of coastal waters and bay bottoms
- o Status of coastal marshlands and mangroves
- o Recent changes in inland vegetated wetlands
- o Recent changes in Lacustrine deepwater habitats
- o Status of Estuarine vegetated and nonvegetated wetlands
- o Estimates of current annual wetland losses
- o Estimates of wetland losses by waterfowl flyway corridors
- o Indicators of developmental pressures on wetland resources and causes of wetland losses
- o States with significant changes in wetland resources

The U.S. Fish and Wildlife Service produced a popular report entitled "Wetlands of the United States: Current Status and Recent Trends" (March, 1984), to inform the general public, government agencies, private industry and others about the present status of United States wetlands. This publication is used extensively and represents the most comprehensive wetland status report available. In light of this information on wetland losses, the United States recognizes that more vigorous efforts are needed to protect and manage these valuable resources.

## DIGITAL DATABASE DEVELOPMENT

Concurrent with the mapping effort, the National Wetlands Inventory is applying geographic information system technology in its construction of a National georeferenced wetland database. Three major systems comprise the Geographic Information System: (1) The Wetlands Analytical Mapping System (WAMS), (2) The Map Overlay and Statistical System (MOSS), and (3) The Cartographic Output System (COS).

WAMS is a digitizing, editing, and database management system used to extract ground information for any size area from aerial photographs or map sheets and store it in a digital data base. Digitizing is done in arc-node format with attributes assigned to the left, center, and right sides of each arc. As digitization occurs, all points are converted to latitude/longitude coordinates in near real time. As a result, all map data in WAMS is in a common ground based, geographic reference system. WAMS has a rigorous on-line verification and editing capability that reports errors as they are encountered. The verification system ensures topological validity by requiring that error corrections and edge ties between maps or aerial photographs be completed before the files can be moved to the data base.

MOSS is a geographic analysis system. WAMS database files are imported to the MOSS database and can be projected in one of 20 available map projections. MOSS is designed to allow users to retrieve, analyze, and display maps and other spatial data. Map data may be stored in two formats: vector and raster (cell). All data processing functions in MOSS are command driven.

Commands can be classified into five functional groups: (1) Program Control, (2) Data Manipulation, (3) Data Display, (4) Data Description, and (5) Data Analysis. Program Control commands provide an interface between MOSS and the computer operating system and provide information about MOSS. Data manipulation commands provide the capability to add, access, and manipulate the map database. Data Display commands provide the capability to produce user-oriented output in the form of data set displays. Displays may be on a graphic cathode ray tube (CRT), an alphanumeric CRT, a line printer, or a plotting device. Data Description commands produce user-oriented output in the form of data set parameter reports and tables. These commands can calculate area, distance, perimeter, length, frequency, descriptive statistics such as mean and range, and location coordinates. Data Analysis commands provide for descriptive analysis of map data set and for the generation of new map data sets by transformation of existing maps. These commands function to reclassify maps, overlay and characterize cartographic maps, and measure cartographic distances, and characterize cartographic neighborhoods.

COS is a cartographic display system. It allows for the entry and manipulation of WAMS and MOSS map files as well as the generation of graphic display files such as legends, bar scales, map collars, titles, and other related text and graphics. COS is used to produce high-quality graphic and geographic outputs in the form of color thematic maps, diagrams, index maps, and graphs.

Geographic Information System applications in the National Wetlands Inventory include cooperative agreements with state and federal agencies. With these cooperators supplying all or part of the funding, statewide and local databases are being built using the WAMS-MOSS-COS system. To date, statewide databases for three states have been produced. Work in progress to complete statewide databases in several other states, and local databases in parts of 14 other states. Digital data files from either WAMS or MOSS are reformatted

and supplied to state agencies for use in their geographic information systems. Acreage statistics by map, county, state and/or project area, as well as color-coded wetland maps from COS are also provided (copies on display).

The National Wetlands Inventory digital database can be used to provide wetland information in map or statistical form or merged with other data within a geographic information system. These capabilities permit a wide range of uses for environmental impact analysis and land planning and management decisionmaking.

Acreage statistics on wetland types are invaluable to resource managers. For example, coastal zone managers require information on tidal wetlands for guiding economic development along the coast, while preserving environmental values. Fish and game managers need to know the status of wetlands important to fish and wildlife species.

The main advantages of a georeferenced wetland database include its storage capacity and its flexibility for producing information in a variety of forms to meet user needs. The flexibility of data manipulation and retrieval is especially important for environmental impact assessments, facility siting, and wetland management. A statewide wetland database will allow users to: (1) determine the areal extent of wetlands for the state, counties and major watersheds, (2) identify the relative abundance and scarcity of different wetland types, (3) produce color-coded wetland maps at a variety of scales for specific areas, (4) better analyze the cumulative impacts of wetland development, (5) quickly review site characteristics for facility planning and (6) improve wetlands management decisionmaking through providing additional resource information. Moreover, it will facilitate the monitoring of both natural and man-induced wetland changes and updating of National Wetlands Inventory maps as new information is acquired in the future.

Transfer of National Wetlands Inventory digital data files to federal and state agencies and other interested organizations is important. By transferring the wetland database to these agencies, wetland information is made more readily available for use in project and environmental planning.

## CONCLUSION

The application of the techniques being used to map wetlands in the United States is not necessarily desirable in other parts of the world. However, there are probably elements of the inventory process which can be adapted to meet the needs of similar resource mapping efforts in other countries.

The inventory of wetlands usually includes some form of these techniques:

- Mapping
- Sampling/Statistics
- Measurement

These three elements take wetland data and transform it into wetland information that is presented in map and/or report form. The gathering and analysis of wetland data can be accomplished in great detail by very sophisticated technical methodologies or can be gathered very simply and presented on rudimentary base maps and in report form. Both levels of effort and/or detail represent useful wetland information and both will be of utility to the resource manager attempting to make wide natural resource management decisions.

Additional information on the procedures and status of the National Wetlands Inventory can be obtained by writing:

U.S. Fish and Wildlife Service (FWE)
National Wetlands Inventory
Department of the Interior
18th & C Streets, N.W.
Washington, DC 20240 U.S.A.
Telephone: (202) 235-2760

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