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CREATING A NATIONAL GEOREFERENCED WETLAND DATA BASE FOR MANAGING WETLANDS IN THE UNITED STATES

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1. INTRODUCTION

Increasing public awareness of wetland values and concern for accelerating habitat losses during the 1960's and 1970's led to the adoption of wetland protection laws by numerous states and to expanded Federal jurisdiction through Section 404 of the Clean Water Act of 1977. Consequently, information on the characteristics and extent of U.S. wetlands was needed by government agencies and others to promote wise management of this valuable natural resource. In 1974, the U.S. Fish and Wildlife Service created the National Wetlands Inventory (NWI) Project to collect and disseminate this needed information to appropriate government and private organizations. Decisionmakers cannot make informed land-use decisions about wetlands without knowing the location and extent of different types.

The NWI Project is inventorying the Nation's wetlands through conventional aerial photointerpretation techniques. A variety of products are being produced, including wetland maps and status and trends reports (Wilen and Pywell 1981). To date, maps have been prepared for approximately 30% of the lower 48 states, 6% of Alaska and all of Hawaii. By 1988, the Service plans to have detailed wetlands mapping completed for about 55% of the conterminous U.S. and 16% of Alaska. NWI maps are available to the public through the U.S. Geological Survey's mapping centers and various state-run map distribution outlets.

Concurrent with the mapping effort, the Service has had an ongoing research and development operation in computer mapping technology. The capability to establish a national georeferenced wetland data base now exists. As funding permits, the NWI is creating georeferenced wetland data bases largely through digitizing large-

scale (1:24,000) wetland maps. The first statewide wetland data base has been recently constructed for New Jersey, while another for Delaware will be completed by the end of 1983. Both states financially supported this work. Other areas where wetland data bases are being prepared include portions of Minnesota, Nebraska, North Dakota, Oregon, South Dakota, Utah and Washington. This paper will focus on the NWI wetland data base - its components and applications. The New Jersey data base will serve as the subject for most of this discussion.

2. CONSTRUCTION OF THE NEW JERSEY WETLAND DATA BASE

The NWI large-scale (1:24,000) maps represent the foundation of the New Jersey wetland data base. Mapping techniques and data base components and construction are discussed below.

2.1 National Wetlands Inventory Mapping Techniques

Due to the magnitude of a national inventory, remote sensing was the obvious technique for inventorying the Nation's wetlands. In 1974, the basic choice was between high-altitude photography and satellite imagery (i.e., Landsat). After comparing Landsat's capabilities with the Service's and other agencies' needs for wetland information, it was evident that Landsat could not sufficiently detect or classify wetlands to the level of detail required. In fact, an attempt by NASA's Jet Propulsion Laboratory to map Alaskan wetlands for NWI was unsuccessful. Coarse resolution of satellite imagery has limited its uses (Woodhouse, et al. 1983). By contrast, use of aerial photography has proven effective for mapping wetlands in different parts of the country (Anderson 1968; Anderson and Wobber 1973; Cowardin and Myers 1974; Bartlett, et al. 1976; Miller, et al. 1976; Shima, et al. 1976; Tiner 1977; Roller 1977; Gammon and Carter 1979; Kennard, et al. 1980; Lovvorn and Kirkpatrick 1982; and others). Numerous states have inventoried wetlands through photointerpretation techniques (U.S. Fish and Wildlife Service 1976). Consequently, high-altitude photography (with 1:60,000 to 1:80,000 preferred) was selected as the imagery source for the NWI. Since 1980, the Service has participated in the Joint Federal High-Altitude Photography Program which plans to acquire 1:60,000 color infrared photography for the entire country on a periodic basis. Since this imagery is available for many areas, it is the primary data source for the NWI.

To produce final NWI maps, seven major steps were completed: (1) preliminary field investigations, (2) photointerpretation of high-altitude photography, (3) review of existing wetland information (4) quality control review of interpreted photos, (5) draft map production, (6) interagency review of draft maps, and (7) final map production. For New Jersey, 1:80,000 black and white transparencies

were the best available photography when the inventory commenced in 1978. They were viewed in stereo by specially-trained biologists who identified wetlands from uplands and classified each wetland according to the Service's operational draft classification system (Cowardin, et al. 1977). This system was later modified slightly (Cowardin, et al. 1979) and adopted as the Service's official wetland classification system. The New Jersey inventory alone required about six weeks of field investigations. A recent evaluation of NWI maps in Massachusetts determined that mapping accuracy was greater than 95% (Swartwout, et al. 1981). This high accuracy was achieved because of the exacting NWI mapping techniques.

2.2 Components of the National Wetland Data Base

Three major systems comprise the Service's geoprocessing capability for constructing the national wetland data base: (1) the Wetland Analytical Mapping System (WAMS), (2) the Map Overlay and Statistical System (MOSS) and (3) the Cartographic Output System (COS). All systems presently run on Data General's Eclipse and MV series minicomputers.

WAMS is the digitizing system which converts map data to a computer compatible form (Pywell and Niedzwiadek 1980). Digitizing can be performed in two ways: (1) on a standard X-Y digitizing table or (2) using the APPS-IV analytical stereo plotter. Information can be input directly from aerial photographs through the APPS-IV (Greve, et al. 1981). All digitizing is done in a arc-mode format with a left, center, and right attribute assigned to each arc. WAMS includes a rigorous on-line data verification and editing capability which notifies the operator of errors as they are encountered and ensures topological validity of the data. All map data is stored in a "geounit" which represents a predefined portion of the earth's surface. For the NWI data, the "geounit" is a 7.5' map quadrangle. Other standard geounits are 15', 1^{o} by 30', and 2^{o} by 1^{o}. All digital data must be tied between geounits during digitizing or else it cannot be databased. All data is entered in geographic coordinates, i.e., latitude and longitude. NWI map data can be converted to any map projection through use of U.S. Geological Survey's map projection package.

MOSS represents the geographic information system which allows input of digital geographic data, construction of a data base of one or more themes or planes, and manipulation and analysis of the data. Geoprocessing functions include area, length, frequency, overlay, proximity and buffer, plus many others (Reed 1981). The NWI uses MOSS to determine wetland area by type for each map, county, state or other project area. For county wetland acreages, MOSS overlays digital NWI data with digitized county boundaries. This can also be

done for watersheds or any sized areas.

Hardcopy products are produced through COS which allows users to select data from WAMS or MOSS. For computer maps, scale, rotation, shading symbology and map projection may be defined. COS also permits construction of a map collar, e.g., title, legend, bar scales, and other related text and graphics. A wide selection of typefaces and line styles is offered.

NWI digital map data is available on tape for limited areas. The digital map data contain polygon boundaries and their associated attributes, i.e., wetland types. Each 7.5' NWI map is stored as a separate file. Within the file, there is a header record for each polygon containing the polygon number, wetland type, and the number of coordinate pairs comprising the polygon boundary. The header record is followed by a string of X-Y coordinates. Users may specify map projection and whether the tape is written in ASCII or EBCDIC. Most users familiar with geoprocessing can reformat these data to their systems. In other cases, the Service can produce digital data in specialized formats at cost to users.

2.3 The New Jersey Wetland Data Base

Upon completion of the final NWI maps in late 1981, construction of the New Jersey wetland data base commenced. A total of 175 NWI maps were digitized through WAMS using an X-Y digitizing table. One map area was digitized directly from interpreted aerial photographs through APPS-IV. Boundaries of all 21 counties were digitized directly from U.S. Geological Survey 7.5' topographic maps. The data base was constructed by late 1982.

3. RESULTS OF THE NEW JERSEY WETLAND DATA BASE

The New Jersey wetland data base itself represents a geographic information system in that wetlands are referenced according to latitude and longitude. When wetland data is overlaid with county boundaries in the data base, wetland maps and acreage summaries can be produced.

3.1 Computer-generated Maps

Color-coded wetland maps at varying scales (e.g., 1:24,000 and 1:100,000) can be produced from the wetland data base through COS. For demonstration purposes, a county wetland map at 1:50,000 was prepared for Cape May County. This county was a high priority area for the New Jersey Department of Environmental Protection. A portion

of this map is shown as Figure 1. This type of map presents an excellent visual display of the relative abundance and scarcity of wetland types. One can easily see the concentration and extent of wetlands and can readily detect different wetland types by color.

3.2 Wetland Acreage Statistics

Wetland acreage summaries have been generated for all New Jersey counties. This combined with the availability of final NWI maps and other information collected during the inventory allows the Service to prepare its first state wetland report. This report will present the findings of the NWI for New Jersey and should be available by mid-1984.

A total of 915,969 acres of wetlands and 757,783 acres of deepwater habitats were inventoried in New Jersey. Palustrine or freshwater wetlands represented 67% of the State's wetlands, while nearly all of the remainder were estuarine or coastal wetlands. County wetland acreage summaries are listed below (Table 1). In general, coastal counties, i.e., Cape May, Atlantic, Ocean, Cumberland, Burlington, and Salem, had more wetland acreage than non-coastal counties. This was attributed to the vast estuarine marshes in those counties. More detailed statistics, such as individual wetland type acreages can be generated for each county.

Table 1. Wetland acreage summaries for New Jersey counties.

County	Wetland Acreage	% of County	County	Wetland Acreage	% of County
Atlantic	148,149	40.7	Mercer	11,819	8.1
Berger	10,084	6.7	Middlesex	24,026	12.0
Burlington	136,297	26.0	Monmouth	32,700	10.7
Camden	20,922	14.8	Morris	40,264	13.4
Cape May	89,581	52.4	Ocean	128,531	31.3
Cumberland	98,950	30.9	Passaic	5,042	4.1
Essex	6,833	8.2	Salem	58,987	25.3
Gloucester	36,844	17.5	Somerset	11,132	5.7
Hudson	3,894	13.0	Sussex	30,771	9.1
Hunterdon	5,450	2.0	Union	3,053	4.6
			Warren	12,637	5.5

4. APPLICATIONS OF THE WETLAND DATA BASE

The NWI wetland data base can be used separately to provide wetland information in map or statistical form or merged with other data bases within a geographic information system. These capabilities permit a wide range of uses for environmental impact analysis and

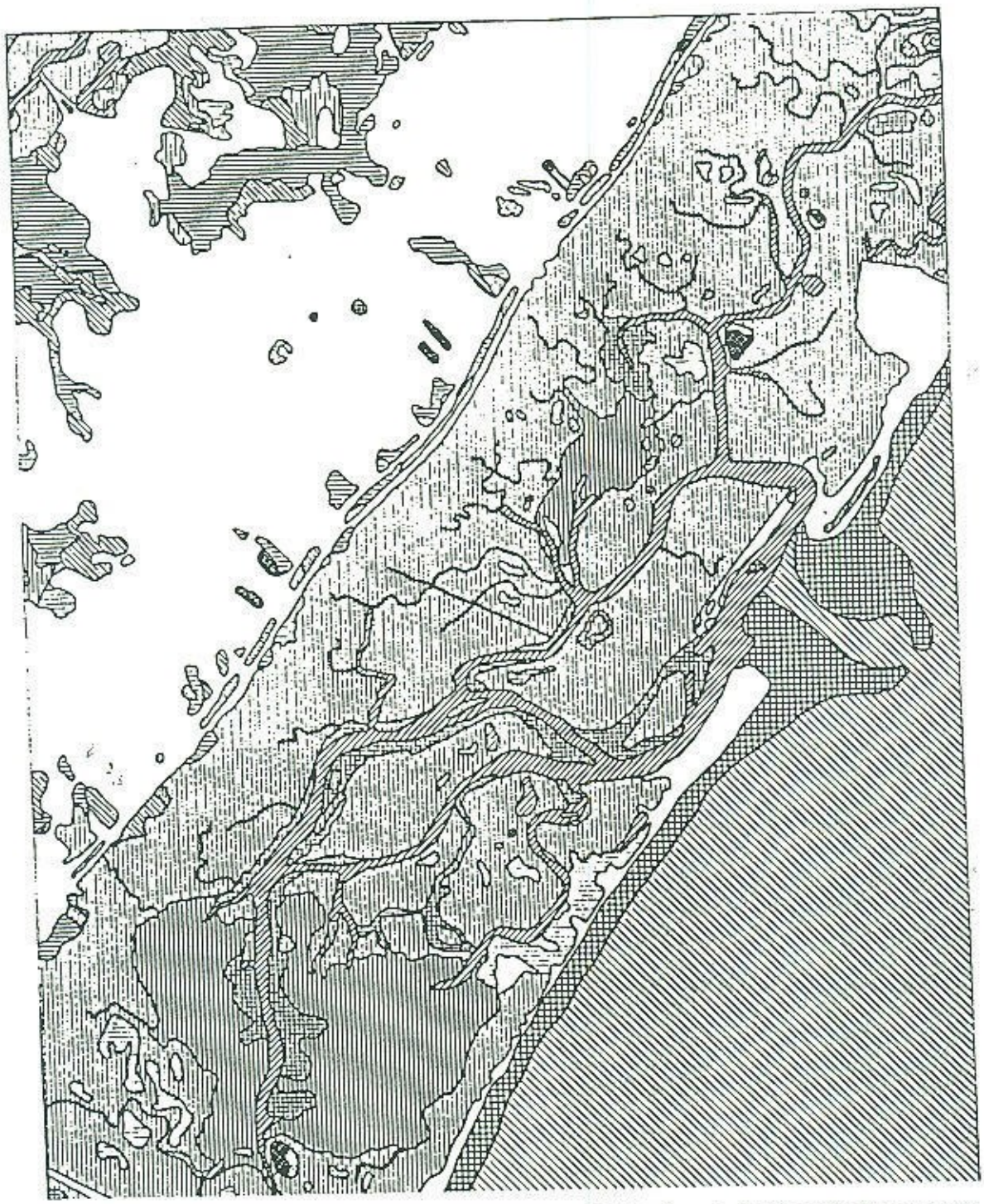

FIGURE 1. Example of computer-generated National Wetlands Inventory map showing wetlands in part of Cape May County, New Jersey. Major wetlands mapped include salt marshes (light green), intertidal flats (dark blue), freshwater marshes (red), deciduous forested wetlands (brown), and ponds (aqua blue).

land planning and management decisionmaking.

4.1 Computer-generated Maps and Statistics

The two hardcopy products of the data base, i.e., detailed wetland maps and acreage statistics, can be custom-tailored to meet the needs of resource managers and planners. Currently for New Jersey, county wetland maps and acreage summaries can be readily produced. County planners should find these products particularly valuable in assessing the current status of their wetland resources and in guiding future land-use decisions in light of wetland values. The data base has the capacity to produce wetland maps and statistics for variable sized areas, such as municipalities and watersheds. To accomplish this, political, hydrologic unit or other boundaries must first be entered into the data base. For demonstration purposes, the Service is preparing a town wetland inventory package, i.e., map and acreage statistics, for the town of Ringwood, New Jersey. This information will serve as a tool for the town to help administer its wetland zoning ordinance. If a bill (Assembly No. 3757) to strengthen protection of New Jersey's wetlands becomes law, all towns will need such information to help make local wetland protection and use decisions. The bill specifically identifies the National Wetlands Inventory maps as the primary data source for identifying and locating New Jersey wetlands.

In general, wetland maps, either hand-drafted by cartographers or computer-generated, have a wide range of uses varying from site-specific project evaluation to regional and statewide planning. More significant uses include environmental assessments and preparation of environmental impact statements; Federal and State permit reviews for construction in or near wetlands; siting studies for energy and transportation corridors and facilities, dredged material and hazardous waste disposal, and industrial and commercial developments; flood protection and watershed planning; oil spill contingency plans; natural resource inventories; natural areas acquisition programs; tax assessments; and fish and wildlife resource planning, management and research studies. Wetland maps are needed by Federal, State and local authorities for identifying areas that may be subject to their jurisdiction. The Adirondack Park Agency of New York State has stated this need and has worked closely with the NWI over the past three years to inventory their wetlands (Hughes 1981). Moreover, they intend to add NWI data to their geographic information system. Similarly, other states, including Pennsylvania, Maryland, Michigan, and New Hampshire, are using NWI maps to help administer state wetland protection programs. In New Jersey, wetland maps as well as the wetland data base will be useful for several programs, including coastal wetland protection, coastal area facility review, floodplain management and stream encroachment, and management of the Pinelands (a nationally important natural resource area). When wetland maps are used early in project planning, developers and construction

agencies can readily identify potential problem areas to avoid in planning construction of buildings, roads, and other structures. This leads to significant cost and time savings and minimizes wetland impacts.

While maps provide information on the location and characteristics of wetlands, the actual abundance and scarcity of wetlands throughout a project area, watershed, county or state can only be assessed through generating acreage statistics. Maps are the graphic display, but the acreage summaries represent the actual accounting of wetlands. The wetland data base facilities compilation of these figures and permits manipulation in various ways. This is useful for both public policy analysis and natural resource management.

The scope of existing and proposed land-use regulations, policies and programs can be evaluated relative to wetlands through this data base. In New Jersey, a comprehensive program of wetland protection could impact as much as 19% of the State, while similar programs in other states may affect a higher or lower proportion depending on wetland abundance. Statistical data for counties and municipalities would be useful for program impact analysis at the local level.

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 N.J. Fish, Game, and Shellfisheries Division is interested in wetland statistics for managing muskrat populations. The wetland data base may identify the extent and location of potential muskrat wetlands in each county and thereby help improve management of this furbearer. Similar assessments can be done for other wetland-dependent animals, such as beaver and waterfowl.

Wetland acreage summaries and the inventory itself represent the standard from which past and future use trends can be measured and predicted. Gains and losses in wetlands can be determined by comparing current survey results with figures generated from older inventories or by interpreting older aerial photography. The Service recently did the latter at the national level through a statistical sampling study which estimated a net loss of wetlands in excess of 450,000 acres per year from the mid-1950's to the mid-1970's (Frayer, et al. 1983).

The wetland data base also facilitates updating of NWI maps at considerable cost and time savings. The APPS-IV, which allows data

from interpreted photographs to be input directly into the computer, has shown great promise for map production.

4.2 Merging With Other Data Bases

The New Jersey wetland data base constitutes a geographic information system (GIS), since wetland data is referenced geographically by latitude and longitude. County and state boundaries are also part of the data base. These data can be combined with other thematic data bases, e.g., soil and land-use, for land planning and management decisionmaking. For example, in selecting alternative sites for an industrial complex, many locational criteria must be examined, including soil properties, adjacent land-use, current zoning, presence of environmentally sensitive resources (e.g. wetlands, endangered species, and water supplies), transportation routes and numerous others. All of this information can be analyzed either manually by a planner or automatically through use of a GIS. The GIS allows simultaneous overlay and analysis of numerous data sets to identify the best sites for proposed developments. This can also be applied to natural resource management. Woodcock and others (1983) have identified "ecological modeling" as a potential use of a GIS. First, a mathematical model is constructed to predict an outcome, like land capability for agriculture. Measureable variables, such as slope, soil texture, and water availability, are divided into three categories and given a rating from one to three based on increasing value to agricultural use. Land areas with the higher total number have the greatest potential for agriculture. Similar analyses can be done for fish and wildlife management. Knowledge gained from the wetland data base is extremely useful for ecological modeling.

The N.J. Department of Environmental Protection (DEP) is developing a GIS for environmental management purposes. At present, data sets include political boundaries, i.e., counties and municipalities, and special project areas for the Green Acres Program and Coastal Area Facility Review Act. The current effort is to expand the data set for soils to cover the entire State. The DEP is working closely with the U.S. Soil Conservation Service on this. The acquisition of the New Jersey wetland data base will give the DEP the ability to produce wetland maps and statistics for all municipalities. Also, if the boundaries of State-owned lands are entered into the GIS, information on the extent of New Jersey's wetlands in State ownership can be determined for the first time. This could be very important for identifying the need for new acquisition initiatives. Integrating various data sets with the wetland data base will provide a powerful management tool for guiding the future of New Jersey's wetlands and fish and wildlife resources.

5. CONCLUSION

The main advantages of a georeferenced wetland data base include its storage capacity and its flexibility for producing information in a variety of forms to meet user needs. The 176 NWI maps for New Jersey are stored on just ten computer tapes, one for each of the 1:100,000 mapping units covering the State. The flexibility of data manipulation and retrieval is especially important for environmental impact assessments, facility siting, and wetland management. A statewide wetland data base 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 NWI maps as new information is acquired in the future.

One major drawback of the wetland data base is that its construction is a very time consuming process. The polygon file method used is presently a relatively cumbersome and expensive technology (Woodcock, et al. 1983). However, cartographic map production is also labor intensive. The Service's capability to digitize directly from interpreted aerial photographs through the APPS-IV saves the redundant step of retracing mapped polygon boundaries for computer input. At present, the costs of data base construction relative to mapping costs are favorable. Future technological advances should further narrow time and cost constraints.

The high initial costs for system hardware plus the lack of trained operators also limit widespread development of wetland data bases. Largely due to the success of the New Jersey data base and the need for wetland acreage statistics in other areas, the Service plans to purchase additional hardware for sole use by the NWI Group in St. Petersburg, Florida. Presently, the NWI Project shares computer equipment and time with the Service's Western Energy and Land Use Team at Ft. Collins, Colorado.

Transfer of computer technology and data bases to Federal and State agencies and other interested organizations is crucial. By transferring the wetland data base to the states, in particular, wetland information should be more readily available for use in project and environmental planning and management by State and local authorities. For users without in-house data processing capability, the Service will process data at user cost as time permits.

The Service's NWI Project has moved from a research and development phase to an operational mode with the creation of the first statewide wetland data base for New Jersey. A second statewide data base will soon be completed for Delaware. Wetland data bases are also being prepared for selected areas in Minnesota, Nebraska, North Dakota, Oregon, South Dakota, Utah and Washington. A major step has been taken towards creating a national wetland data base that should greatly enhance our ability to wisely manage the Nation's wetland resource.

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