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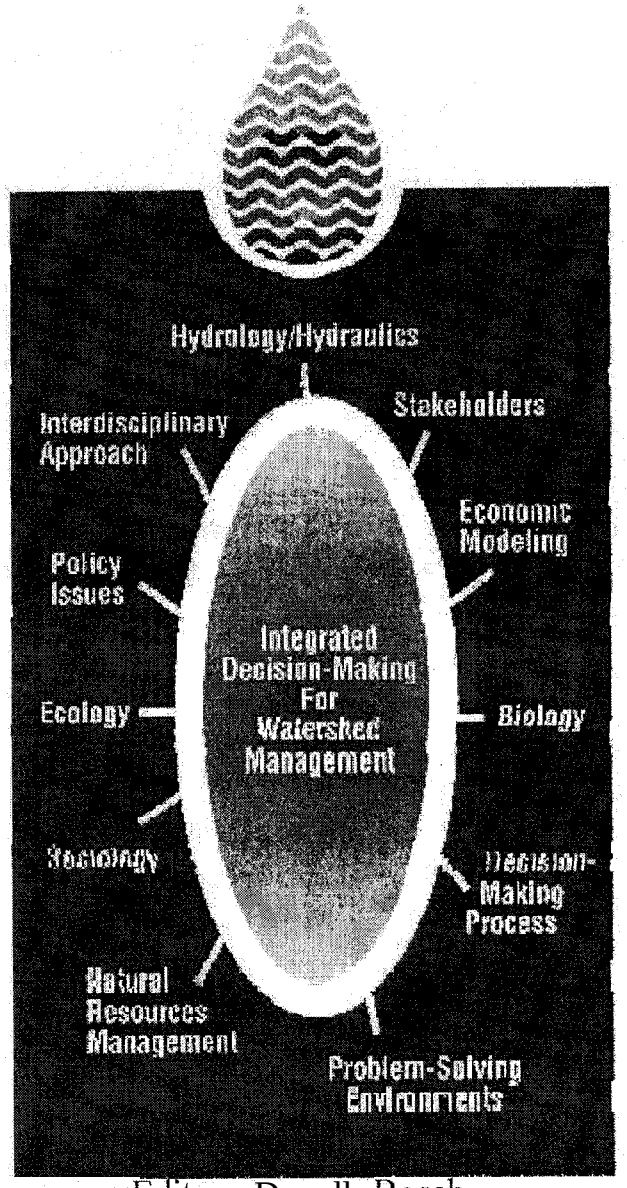

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Digital Meadowlands: A Web-based Decision Support System for an Urban, Estuarine Watershed

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Abstract

The Hackensack Meadowlands District (District) is a 32-square mile degraded, urban, estuarine watershed, located six miles west of New York City. The Hackensack Meadowlands Development Commission (HMDC) is a state agency with comprehensive land use planning and permitting authority for the District. The Rutgers University Center for Information Management Integration and Connectivity in collaboration with the HMDC have developed a web-based system called "Digital Meadowlands" to access detailed information about the District in support of environmental management and research (http://cimic.rutgers.edu/digitalmeadowlands).

The application presently has five major modules each one with its own search engine and query procedures:
1) Image module with satellite images of the District;
2) Reports module with an electronic catalog of research and engineering reports that can be searched via a text-based query or by using an interactive map;
3) Monitoring data module with continually updated datasets on weather and air and water quality, and static datasets from discrete monitoring projects;
4) Interactive maps of zoning, parcel and land use; and
5) Videos of virtual fly-bys and TV news clips about the District.

Digital Meadowlands provides a wealth of information to scientists. With time it will become the repository of the collective environmental memory for the HMDC District. The staff from HMDC likely to benefit the most are those revising development proposals, drafting environmental impact forms, and involved in environmental impact. studies, in outreach and in education. Short formal and hands on training sessions are being provided to staff on the use of the system.

Background

The Hackensack Meadowlands District, created in 1969 by an act of the New Jersey legislature, encompasses 32-square miles including parts of 14 municipalities in northeastern New Jersey. The District is a complex, heavily impacted and ecologically important area comprising much of the Hackensack River estuary, just a few miles from Manhattan. In addition to the River, the District is crisscrossed with numerous tidal creeks and channels and contains 3400 hectares of wetlands. Some sediments are contaminated with pollutants such as lead, mercury and chromium as a consequence of industrial dumping directly into the tidal creeks that took place before modern environmental laws (USACE, 1995; Berman and Bartha, 1986; Konsevick, 1993).

Land use and vegetation cover have changed dramatically in the past 100 years. Today, most open spaces including wetlands are dominated by a low diversity plant community (mainly a monoculture of *Phragmites australis*) that has replaced the original white cedar forests and historically dominant salt-marsh grasses *(e. g., Spartina alterniflora*). The HMDC has an active wetland restoration/enhancement program, affecting several hundred hectares. Researchers are working with engineers and scientists to evaluate and document vegetation establishment and ecological change at restoration sites.

The District is crossed by several major highways and railroads leading in and out of the New York Metropolitan area. Given the location of District within the New York metropolitan area, there is great pressure to develop remaining open space.

There are approximately 535 hectares of closed and active landfills sitting at low elevation that have the potential to leak contaminants into the marsh ecosystem. Construction of cut-off walls and extensive monitoring of landfill effluents are common activities in the District. Researchers have been and continue to conduct comprehensive studies to characterize sediment and water pollution at many locations and are establishing a continuous water monitoring system.

Since 1995, approximately 36 million cubic meters of methane gas have been collected from more than 80 hectares of landfills and sold to a public utility company. However, there is little information regarding the amount of methane gas that escapes the collection system and is released into the atmosphere. Researchers are starting to continuously monitor air quality, as well as developing new technologies to measure air pollution from satellite-based remote sensors.

Much of the research, planning and development done in the District over the past 30 years and beyond has been carefully documented through engineering, planning, permitting and scientific reports. Many of these documents are not widely published, thus constituting a body of "gray literature" which has not been readily accessible to the public. HMDC staff and associated researchers have been cataloging this body of literature and migrating document metadata to a digital library environment (Barrett et. al, 1999).

The many activities and transformations taking place in the District stem from the need to conserve and reclaim areas as well as from the opportunities that exist to develop the valuable real state properties. These forces generate a continuous demand for information about the District.

Justification

One hundred and twenty people make up the mainly professional staff of the HMDC. The staff requires rapid and reliable access to information and resources when evaluating permits and environmental impacts from numerous, simultaneously occurring multi-million dollar projects. Staff also need to respond to public concerns on a range of small and big issues where HMDC may or may not have, at any given time, someone assigned to properly follow up.

The shortage of permanent staff members, the amount and complexity of the information being handled and the need to rapidly and effectively respond to inquiries and make decisions that may affect the environment led HMDC to initiate development of an environmental decision support system.

Objectives

The objective was to develop a worldwide-web enabled state-of-the-art enviromnental decision support system that will organize, integrate and provide visualization tools for a wide variety of District information. The tools should enable HMDC staff and the general public to quickly obtain relevant information on the District's past and current environmental condition, infrastructure and ongoing

projects. The role of the decision support system, which came to be called Digital Meadowlands, is to capture and offer information to all users while creating and managing an ever-growing repository of reference environmental information.

Procedures

Two limiting factors were identified at the onset of the program: funding and technical expertise. The first step was to establish strategic alliances with government and university research centers that would provide the technology and the slkills necessary to build the system. Concurrently, HMDC began to search for and acquire state and federal funds.

HMDC established an alliance with NASA and Rutgers University Center for Information Management Integration and Connectivity (CIMIC). This collaboration was designed to help operate a NASA Regional Application Center (RAC). This specific NASA program is aimed at fostering the self-supporting use of environmental and earth resource: data from satellites and other sources by regional institutions including state and local government. The program offered access to relevant technology being developed at NASA to manage environmental information but no funding.

HMDC identified state funds that were used to acquired the initial hardware and staff the operation with Ph.D. level scientists and developers at Rutgers CIMIC. Later, the HMDC-Rutgers/CIMIC collaboration further expanded to include the creation of the Meadowlands Environmental Research Institute (MERI). The Institute provided an additional way to attract sponsors and to promote research and data collection on specific areas of interest, such as water quality and ecological restoration techniques.

The next step was to create a web-based interface that would provide a sole point of entry to access the environmental information. This portal, which became Digital Meadowlands, would provide powerful tools for searching documents, water chemical and physical measurements, images, animations, and interactive maps.

Two types of data were identified: relatively static data sources and continuous data sources. Relatively static data sources contain data that are not replaced or extended by new collections in a systematic way. Some records within relatively static databases need to be updated from time to time. Examples of these include parcel boundaries, parcel 'tax information, land use, zoning regulations, permitting information and animal and vegetation inventories. Continuous data sources, on the other hand, are collections of data that are augmented over time in a systematic way-- for example, surface water, ground water and sediment chemistry, remote sensing images and technical reports and documents.

The system in its present state has five major modules, each with its own search engine and query procedures:

1. The image module is a database that contains NOAA, Landsat and hyperspectral remote sensing images of the District. New NOAA images are downloaded daily from over-passing NOAA satellites. Image ingest, geo-registration and classification routines (presence or absence of clouds) were developed by CIMIC researchers in collaboration with NASA scientists and NEC researchers. The user can find and view raw image bands or look at and download raw or post-processed products for a given time period.

2. The reports module is an electronic catalog of research and engineering reports about the District from the early 1970's to the present. The database can be searched via a text-based query or by using an interactive map. The user can click on a specific location to view a list of all reports that have

information related to that specific location (Figure 1). The user can also view a map that highlights all of the locations sampled in a particular report.

3. The monitoring data module contains different environmental monitoring datasets. One set is surface water quality data collected from 1993 to 1999 at 14 stations throughout the District. There is information on 25 parameters that range from cadmium concentration to pH and salinity. This information is accessed through a text-based or map-based query (Figure 2). This module also includes real-time data from continuous water, air and weather monitoring stations that are being installed at strategic locations in the Meadowlands. Water and sediment chemistry information for specific areas currently being assessed for restoration and remediation can also be accessed through this module. Static data from past studies that are available in electronic format, such as a fish population census and a study on chromium in crabs, will be added to this module.

4. In the map module, users can access various interactive maps of the District. Zoom in, zoom out, pan and query capabilities are supported. The present maps available are zoning, parcel and land use. Users can learn about the zoning designations of a specific parcel, the parcel block and lot numbers, land value, land use, total tax paid, etc. (Figure 3). The user can also access detail descriptions (metadata) of all digital maps available for the District.

5. Finally, the video module contains visualization products (virtual fly-bys) for property visualization and to help place future development sites and sites to be preserved in the context of their topography and surroundings. This module also has access to a collection of educational videos and TV news clips about the HMDC.

System Construction

Digital Meadowlands is constructed using a combination of database, geographical information systems (GIS) and traditional web design. The initial page contains links to the 5 major applications. The satellite imaging application is built using a collection of off -the-shelf and custom software developed in conjunction with NASA. Raw satellite data from each pass is processed on a UNIX server to geo-rectify the image and to extract metadata such as the date and time of the satellite pass, the bands recorded, and the sensor and satellite (e.g., NOAA 12). The metadata is stored in an IBM DB2 relational database on a UNIX server and can be queried using an HTML form. The software IBM Net.Data is used to format the user's query specification as an SQL query and to display the query results as an HTML page. Thumbnail sized images are also generated to facilitate browsing over the web.

The reporting application was initially built using a Microsoft Access relational database. For the web implementation, the metadata describing each publication (titles, authors, publication date, study areas, land use and other parameters) are stored in an Oracle relational database running on a Windows NT server. Oracle WebDB is used to gather user query specification from an HTML form, query the Oracle database and present the results as HTML pages. Hyperlinks on the result page facilitate browsing the metadata by author, publication date and area of study. Additional links are provided to highlight study areas on a map generated by an application using MapObjects (a software tool from the company ESRI). A second map-based interface is also available that allows users to click on a region within the District to retrieve all reports that studied the selected area. The MapObjects application runs on a second Windows NT server.

The monitoring application is supported by an Oracle relational database that maintains the water quality data for the 14 different sampling locations within the District. Users can specify search criteria via an HTML form to facilitate retrieval by sample date or location. An additional map-based interface can be

used to retrieve specific data sets by clicking on the appropriate location on the map. Java applets are used to submit the appropriate query to the database.

The mapping module is implemented using ESRI MapObjects, an object-oriented software library with methods to accept input from a web browser and to manipulate map coverages developed by GIS. Each application provides the capability to pan and zoom a map. Clicking on the map on a particular region produces additional information about that region. For example, in the zoning map, clicking on a specific parcel in the District activates a query that is sent to the Oracle database that provides details about the particular parcel (for example, its zoning type).

Findings to Date

Digital Meadowlands began development in 1998 and was placed on-line in I999 (http://cimic.rutgers.edu/digitalmeadowlands). The system, effectively a "beta release" at this point, is still (and will continue to be) evolving and its capabilities have not yet been fully exploited. It has been targeted to a small number of internal users at HMDC and is being revised based upon their feedback.

One interesting finding is that demonstrating the application's abilities to other state and federal agencies has opened the door for new funding opportunities and is promoting strategic alliances with government and private institutions.

Automation has extended the value of HMDC's environmental monitoring. Continuous monitoring, with real-time reporting, is possible only through computerized data collection and processing systems. Continuous, real-time monitoring will allow HMDC to more effectively manage and assess natural resources. For example, it has allowed detection of significant events that occur at unpredictable or inopportune times or places, (such as minimum dissolved oxygen levels which often occur at dawn) that probably would not have been detected by discrete, manual monitoring.

Automation has also begun to change the perspective of the technical staff. Staff will be use advanced computing tools to analyze and manage large amounts of data from continuous monitoring. In doing so, they will learn and apply new skills and technologies.

As the system became operational, a demand emerged for qualified human resources to maintain and upgrade the applications. This proved once again that any significant transfer of technology has to occur along with some level of reorganization within the organization that receives the technology. A web master position was created and staffed, followed by a PC-user help position. Job descriptions in other positions related to environmental information will be revised to include responsibilities for updating and editing the content of databases and web pages.

Finally, as with any group of people there were the innovators that made an effort to understand and use the new technology and the ones that made no efforts and received no gains, Short, formal and hands-on courses and tutorials are being planned to introduce the functions of the system to all staff. This will increase the number of users and the overall productivity of staff.

Future Developments

One of the most significant challenges ahead is to devise ways in which the different databases that make up Digital Meadowlands are populated and updated with minimal human intervention. Management of continuous, regular digital data streams can be captured by a database over networks automatically, indexed, and linked to a URL for further query. A greater challenge is with relative static data bases that get their updates from distributed sources which exist in different media types: hard copies, CD's and

Internet downloads. In terms of documents, for example, there will be a need for individuals to catalog new documents and incorporate them into the database until something such as XML becomes the generalized standard for formatting and storing documents.

Other steps ahead are to develop web-based tools to effectively integrate diverse information types and formats to address specific information needs. One need is a tool to automate information needs of specific, common procedures, such as preparing site modification permit applications and environmental impact forms. Various "nuggets" of information need to be input into specific places on paper or electronic forms. For example, environmental impact forms typically have a section where the area under investigation needs to be described. By typing the name of a location or entering geographic coordinates, the information system would produce text that describes the area such as topography, land use, soils, geology, biodiversity, infrastructure and social demographics. To accomplish this automation, all the databases containing pertinent information need to be capable of being queried from a single interface.

Another demand for technical implementation has to do with predictive modeling. We need models that operate with real world variables and where these variables can be changed interactively to simulate a development, mitigation or conservation scenario. For example, a development project may propose a 400-car parking lot for a store. The predictive model would evaluate the impacts of increased runoff and decreased recharge on water quality, stream flow and biodiversity. We would be able to predict positive and negative consequences before any landscape alteration is realized.

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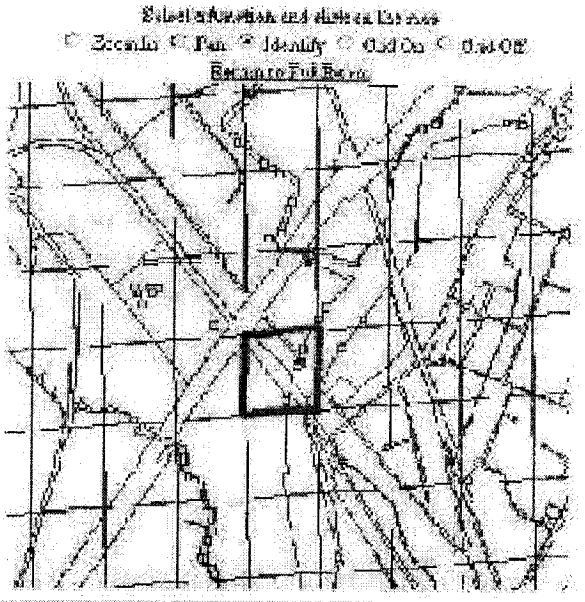

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Report Title:	Hackensack Meadowlands Estuary Wide Water Quality Monitoring Project Summary
Publication Date:	08-JUL-94

Figure 1: Results of Querying for Reports that Sampled in a Particular Grid Cell

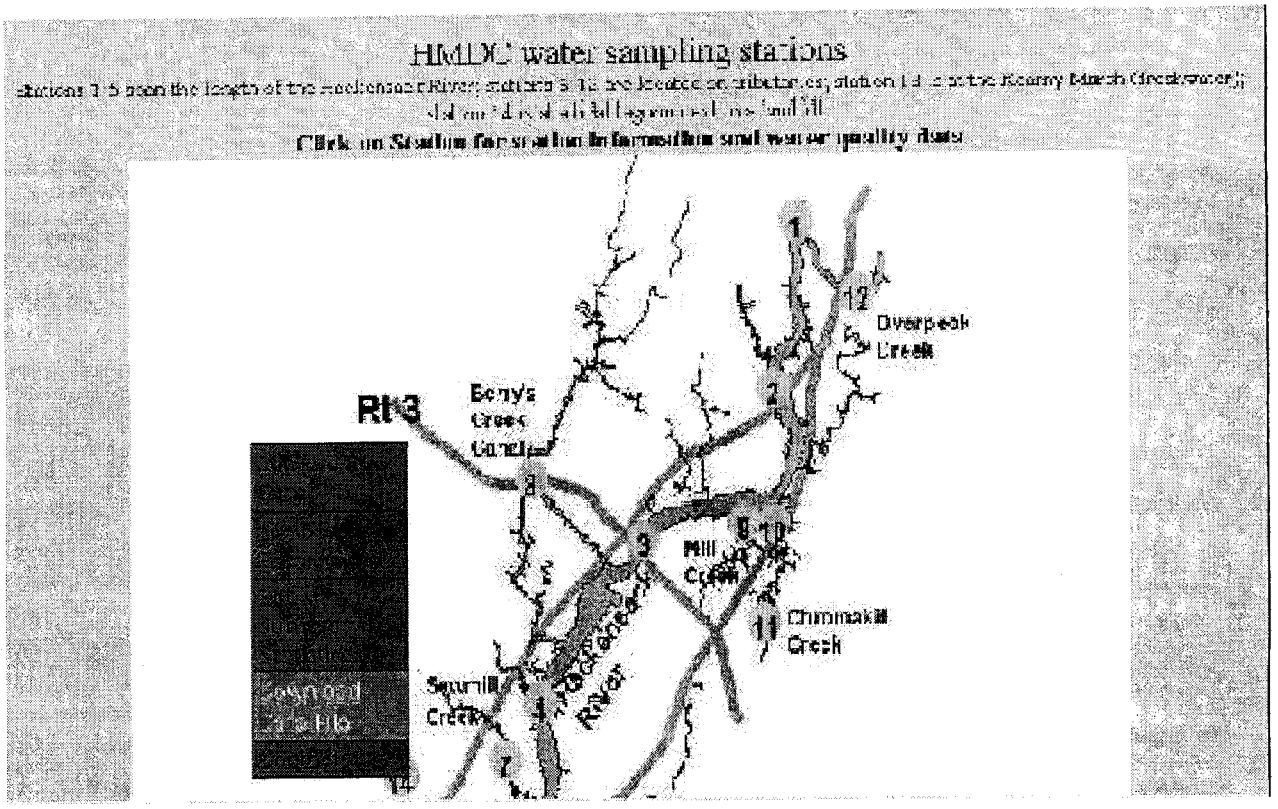
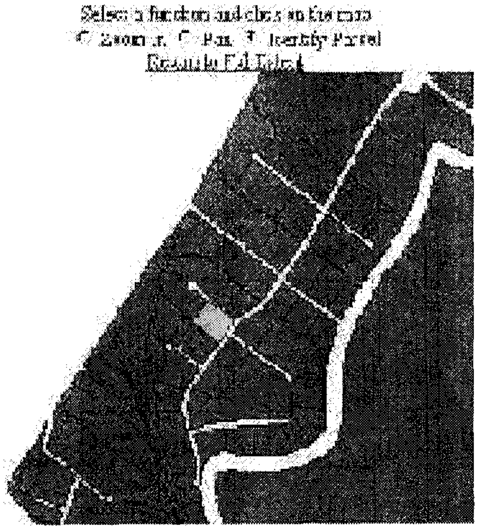


Figure 2: Map Interface to Quarterly Water Monitoring Data



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Owner	MILLMASTER ONYX INC	Old Block:	106i	Old Lot:		Land Value:	1541300
HMDC Use:	warehouse	Total Tax Paid:	$2,680.00	Total Value:	2200000	APN:	12-00106-0001-00003

Figure 3: Results of a Query of the Parcel Map