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National wetland database and information system: A step towards integrated planning for conservation of wetlands in India

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Abstract: Wetlands provide immense environmental, economic, and social benefits. Some of the wetland functions are surface water storage, groundwater recharge, storm water retention, flood control, shoreline stabilization, erosion control, and retention of carbon, nutrients, sediments and pollutants. According to the IPCC second assessment report, changes in climate will lead to an alteration of the hydrological cycle and could have major impacts on regional water resources. This warrants 'wise use' of wetlands based on 'holistic and sustainable use' approach, which presupposes the availability of comprehensive and reliable information on wetlands in the form of spatial database. This necessitates the creation of a database to generate information on the temporal behavior of wetlands biophysical parameters. Mapping and database creation is the first step in achieving the above aim where remote sensing with its multispectral and temporal nature provide ample tools to fulfill the aim. The spatial database is prepared on 1: 50,000 scale with each wetland bearing a unique code and comprising 8 wetland theme layers and 9 reference layers based on NNRMS standards. The database comprises spatial layers of open-water, qualitative turbidity and vegetation characteristic of wetlands in both post- and pre-monsoon as well as image database for both the seasons. The information system provides tools for query and retrieval of information from database at Country/State/District level and/or bio-geographic-zone/Agro-climatic-region/River-basin wise. Further, information on wetland-based National Parks/Sanctuaries forms a part of the database.

Keywords: Spatial database, GIS, Database design, Remote sensing, Spatial query

1. Introduction

Wetlands are among the most productive ecosystems besides having a significant role in hydrology, carbon sequestration, and biodiversity repository (Maltby and Turner, 1983, Aselman and Crutzen, 1989). To conserve and manage wetland resources, it is important to have scientific inventory and periodic monitoring. India harbours a large number of wetlands (Gopal and Sah, 1995). The diverse eco-climatic regimes in the country resulted in a variety of wetland systems ranging from high altitude mountainous lakes in the Himalayan region to the coastal wetlands like mangrove swamps, creeks and inter-tidal mudflats. During the past few years attention has been focused to conserve these wetlands, particularly the natural ones to arrest the rapid loss of these natural resources (Foote et al., 1996). Prasad et al. (2002) reviewed the status and distribution of wetlands, the causes and consequences of the wetland losses and suggested to have an information system as a means of integrated planning of wetland conservation in the country. Remote sensing technology is emerging as the most optimised tool for inventory and monitoring of wetlands world over. Aerial photography served the purpose of identification, delineation and measurement of spatial extent of wetland successfully for small geographic areas. Satellite remote sensing is now widely used especially for large geographic areas. Over the past few decades, satellite remote sensing technology has progressed significantly in terms of type of data as well as classification algorithms. Multi spectral, multi temporal and multi spatial resolution satellite remote sensing data is now used to map the wetland extent as well as its characteristics at various scales (Stacy and Bauer, 2002). The first scientific inventory of wetlands of India was carried out by Space Applications Centre (SAC), ISRO, Ahmedabad on the behest of Ministry of Environment and Forests, Govt. of India using Indian Remote Sensing –IRS-1A LISS II (36 m) data of 1992-93 timeframe. Mapping was done by visual interpretation of images at 1: 250,000 scaleput the wetland extent at 8.26 million ha (Garg et al., 1998). This was further updated using Indian Remote Sensing –IRS 1D- AWiFS (56 m) data of 2004-5 using digital classification at 1:250, 000 scale (Patel et al., 2009).

Realizing the importance of small wetlands, an inventory of wetlands at 1:50,000 scale was initiated under the project "National Wetland Inventory and Assessment" (NWIA) sponsored by Ministry of Environment and Forests, Govt. of India (Garg and Patel, 2007). The project aim were i) Wetland mapping and inventory on 1: 50 000 scale by using of digital IRS LISS-III data of post- and pre-monsoon seasons of 2006-08, ii) Creation of digital database in Geographic Information System (GIS) environment, iii) Preparation of state-wise wetland atlases and iv) Development of information system for query and data retrieval. Spectral indices based advanced digital classification has been used to map the wetlands and their characteristics in terms of spread of open water, aquatic vegetation and qualitative turbidity of open water both in pre and post monsoon. The work was completed by 2011 and state level and national atlases

were finalized (Panigrahy et al., 2011). All the state/UT atlases are available for viewing in the MoEF website (www.moef.nic.in). This paper highlights the last objective of the project in terms of centralized database design and information system for data retrieval entitled NWIS (National Wetland Information System).

2. Objectives

The main objectives of NWIS were:

- Identification, preparation and collection of the input data sets
- Design, creation and organization of GIS database.
- Design and implementation of functional, explicit and user-friendly information system for information retrieval/query and database maintenance both in spatial and tabular form, facilitating query/information retrieval by users/decision makers.

3. Input data

The input data base is drawn from the NWIA project outputs. The classification system based on Ramsar convention definition of wetlands, and is amenable to remote sensor data, has been used for inventory of wetlands under the NWIA project. Total 19 classes of wetlands under a three tier hierarchal classification system has been used to map the wetlands in India. Each wetland was given a unique code (Table-1). The results showed that the total wetland area in India as per 2006-08 data stands at 15.26 mha, which is 4.63% geographic area of the country. Category-wise wetland distribution is shown in Fig. 1.

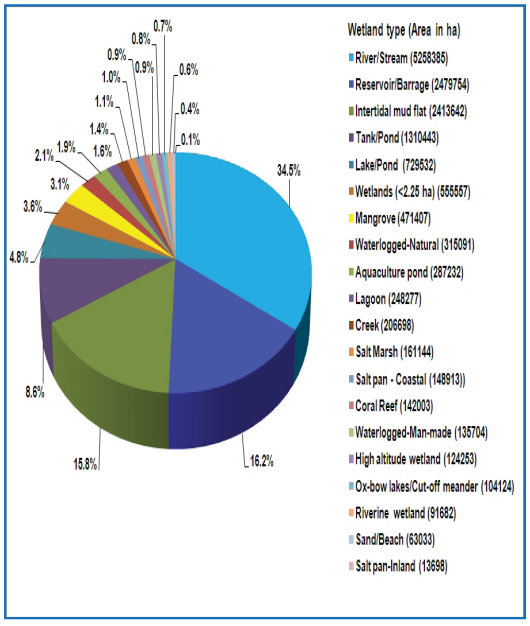

Figure 1: Category-wise wetland distribution of India

Table 1: Wetland classification system and coding used in NWIA project

Wettcode	Level I	Level II	Level III
1000	Inland Wetlands	Natural	
1100			
1101			Lake
1102			Ox-Bow Lake/ Cut-Off Meander
1103			High Altitude Wetland
1104			Riverine Wetland
1105			Waterlogged
1106			River/stream
1200		Man-made	
1201			Reservoir/ Barrage
1202			Tank/Pond
1203			Waterlogged
1204			Salt pan
2000	Coastal Wetlands	Natural	
2100			
2101			Lagoon
2102			Creek
2103			Sand/Beach
2104			Intertidal mud flat
2105			Salt Marsh
2106			Mangrove
2107			Coral Reef
2200		Man-made	
2201			Salt pan
2202			Aquaculture pond

Source: (Garg and Patel, 2007)

3.1 Spatial frame work

The spatial frame work is the first step for database organization. This was based on the Survey of India map-sheet schemes, 4 level graticules (1^o x 1^o, 30' x 30', 15' x 15' and 5' x 5') have been generated for entire country. India having about 32,29,000 km^2 geographic area is covered in 5112 (15' x 15' grid) maps of 1:50,000 scale. The national and state level spatial frame works at 1:50, 000 scale have been used (Anon., 2005). The database standards suggested by NNRMS guidelines was followed as given in Table-2.

The GIS database consisting of wetland layers viz, extent of wetland, open water-spread, aquatic vegetation and qualitative turbidity of open water. These layers were available for two seasons viz., pre-monsoon (April-May) and post-monsoon seasons (October-November). The other spatial layers created aremajor roads, railways, settlements, drainage, canal etc, and district, state administrative boundaries.

The non-spatial data included the field observations in terms of photographs, description data sheets of water quality, aquatic vegetation etc. The satellite images of LISS III used for mapping are also put into the database. The conceptual model of NWIS data base is

shown in Fig. 2. List of data, its naming conventions, sources etc. are given in Table 3.

Table 2: Database design specifications: Parameters and values

Sl. No.	Contents	Specifications (1:50 000)
	GIS DATABASE STANDARDS	
1.	Spatial Framework	Seamless-National
2.	Tie-Point Intervals for Spatial Framework	5' X 5'
3.	Coordinate units for Precision	Decimal-Seconds
4.	Projection	Geographic, LCC/TM
5.	Datum	WGS 84
6.	Coordinate Precision	Single
7.	Minimum Frame size	15' x 15'
8.	GIS DB Tic Registration Accuracy (0.25 mm of scale) (RMS) in m	12.5
9.	Position (Planimetric) Accuracy (1mm of scale) in m	50
10.	Coordinate Movement Tolerance(CMT)(0.125 mm of scale) in m	6.25
11.	Weed Tolerance (WT) (0.125 mm of scale) in m	6.25
12.	Sliver Polygon Tolerance (SPT) (less than MMU) in m	<22500
13.	Grid Size (for Image/Raster/DEM Layers) (0.5 mm of scale) in m	25

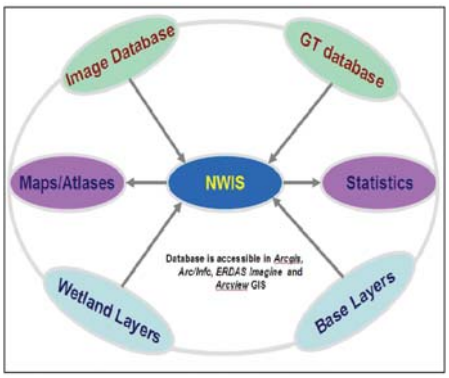

Figure 2: A conceptual model of NWIS database

In addition to the database layers, wetland maps generated at district and topographic map level at 1:50,000 scale also forms the part of data base. A typical topographic sheet level wetland map generated with all the layers integrated is shown in Fig. 3.

4. National Wetland Information System (NWIS)

In the present study ArcGIS and Arcview software have been employed as the main tools for design, organization, retrieval, analysis and generation of cartographic outputs.

4. 1 Coding scheme

Nation-wide administrative hierarchy (state-district-taluka) structure has been used for coding of spatial database. All the data elements are given a unique name, which are self explanatory with short forms. This has a feature attribute table and a link-code. A wetland attribute table is created for WETBND (Table-4). Two feature attribute tables namely wetcode.dbf which describes wetland codes, its description (table-4.1) and wettcode.dbf contains wetland type code and descriptions were linked to WETBND.

4.2 Database organisation

Organisation of the spatial database recognizes the fact that the system has to support information retrieval in terms of spatial units, which are generally used by the planners at country/state/district level. These units are invariably the administrative units like state, district, taluka and / or other boundaries like agro-climatic regions, bio-geographic zones, river basins and watershed boundaries. Furthermore, the information presentation has to be categorized into functional components, for various planning sectors.

The input data is in the form of maps, where administrative unit may include, partially or fully, more than one map-sheet. Spatial database has been created and organized in GIS at four levels (i.e. country level, state level, district level and map-sheet level). Fig. 4 shows NWIS database organisation and Fig. 5 shows NWIS database file structure

4.3 NWIS - query shell

The Graphical User Interface (GUI) provided by Arcview GIS has been used for development and customization of NWIS.

Avenue macro language has been used for customization and development of NWIS. Instead of selection of different menus/choices, pop-up menus with different readymade views for various selections have been provided. Accordingly the menu system has been designed and developed which covers all the above points. The menu system is based upon appropriate database design worked out specifically for query and information retrieval of wetland resources data. These database/tables provide a mechanism for translation of internal database organisation into different user views. Apart from these, theme-wise legend files (.avl) have been created which simulate the legend for the purpose of facilitating the display and query

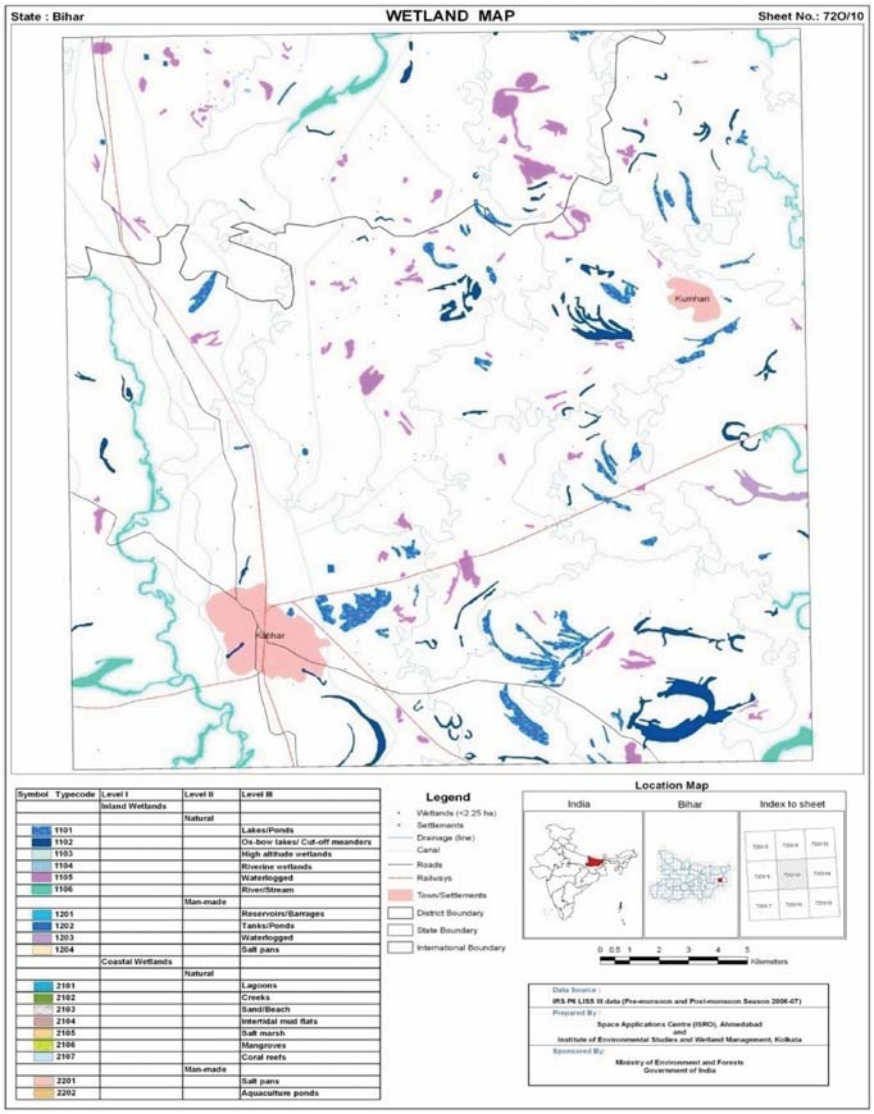

Figure 3: Typical integrated wetland map at 1:50,000 scale generated at topographic mapsheet level using NWIS

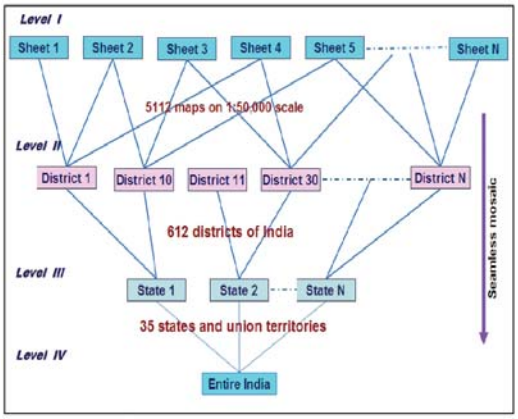

Figure 4: NWIS database organisation

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Table 3: List of data used, source and naming conventions

Sr. No.	Theme/Layer	Layer name	Key field	Source
1	Wetland boundary	wetbnd	wetcode&wettcode	Remote Sensing(RS) data-NWIA
2	Wetland pre-monsoon water spread	wetprbnd	-do-	RS data-NWIA
3	Wetland post-monsoon water spread	wetpobnd	-do-	RS data- NWIA
4	Aquatic vegetation (post-monsoon)	aqvegpost	-do-	RS data- NWIA
5	Aquatic vegetation (pre-monsoon)	aqvegpre	-do-	RS data- NWIA
6	Turbidity (post-monsoon)	turbiditypo	-do-	RS data- NWIA
7	Turbidity (pre-monsoon)	turbiditypr	-do-	RS data-NWIA
8	Wetlands (<2.25ha)	wetpnt	-do-	RS data-NWIA
9	Drainage lines	drainl	Key field codes are as per NNRMS Standards	RS data – NWIA and/or other sources available on 1:50000 scale.
10	Drainage polys	drainp		
11	Road network	roads		
12	Rail network	rails		
13	Settlements (points)	settlep		
14	Settlements (area)	settlea		
15	Canal	canal		
16	Country boundary	country	ccode	Natural Resources Database (NRDB) database
17	State boundary	state	scode	
18	District boundary	district	dcode	
19	Lat-long grid 15’ x 15’	soi	sheetno	Using graticultes of latitude and longitudes
20	Lat-long grid 30’ x 30’	soi30		
21	Lat-long grid 1^o x 1^o	soi1deg		
22	Lat-long grid5’ x 5’	soi5		
23	Bio-geographic zones	biozone	biozone	Wildlife Institute of India, 2000
24	Agro-Climatic regions	acregion	acrzone	Planning commission, 1988
25	River Basins	riverbasin	basincode	Survey of India, 1971

(Source: Garg and Patel, 2007)

Table 4: Attribute Table of WETBND

Sl. No,	Field Name	Field Type	Remarks
1	Wetcode	16, 16, C	Unique identifier for each wetland
2.	Wettcode	4, 4, I	Wetland type code based on wetland classification scheme
3.	Wetname	50,50,C	Wetland name if any
4.	Aqveg	2,2, C	Status of Aquatic vegetation (Y – Present, N – Absent)
5.	Turbidity	2,2,C	Status of Turbidity (H – High, M – Moderate,L–Low)

Table 4.1: Database structure of Wetcode.dbf

Field name	Field type	Key field	Remarks
Wetcode	16,16,C	Y	16 digit code (explained below) **
State	2,2,C	N	Coding scheme as per NNRMS/NRDB standards
District	2,2,C	N	Coding scheme as per NNRMS/NRDB standards
Taluka/Tehsil	2,2,C	N	Coding scheme as per NNRMS/NRDB standards
Toposheet	6,6,C	N	Ex. 46E/12 = 460512, 46A/16 = 460116
Wetnumber	4,4,C	N	Unique code for each wetland in a Map sheet

**** Coding scheme for wetcode**:

Wetcode for each wetland is ‘AABBCCDDDDDDEEEE’ (16 digits) map-sheet wise.

where AA – State code, BB – District code, CC – Taluka code, DDDDDD – Map Sheet number
EEEE – Wetland number

The menu system is aimed at facilitating information retrieval and data input functions both in spatial as well as in tabular form. The system gets activated via selection of ‘project file (nwis.apr)’. All further user responses / interactions are limited to mouse clicking / keyboard for selection of appropriate choices in the menu offered on graphic screen. A ‘project’ is a file in which one organises information elements and data required by planners/decision makers. A ‘project’ contains all the views, tables, graphs/charts, maps/layouts and scripts that one uses for a particular GIS application or set of related applications. When

the project opens, it displays a welcome screen for NWIS.

The project window gives access to all the components contained in the project file. It also enables to create new components. Project contains various views. A view is an interactive map that lets you display, explore, query, and analyse geographic data. One has to select view of interest for exploring NWIS. The Opening menu of view offers choices on selection of various types of further operations (Table-5).

The function of each menu and their sub-menus is as below:

Select Area Of Interest (AOI): This pop-up menu provides choices for selection of area of interest. User can select AOI based on eight different items. For selection of special areas like mangrove, coral reef and high altitude lake, ready-made windows/boxes are provided in GUI. User can select one of the boxes for query and information retrieval. NWIS also provides tools to display satellite images. User can display satellite images of AOI and perform query on active theme.

Overlay_Spatial layers: After selection of AOI user can select/click Overlay_Wetland_DB menu. This menu provides access to display wetland information and overlay different base layers like roads, railway, and settlements etc using Overylay_Reference_DB menu (Fig.6).

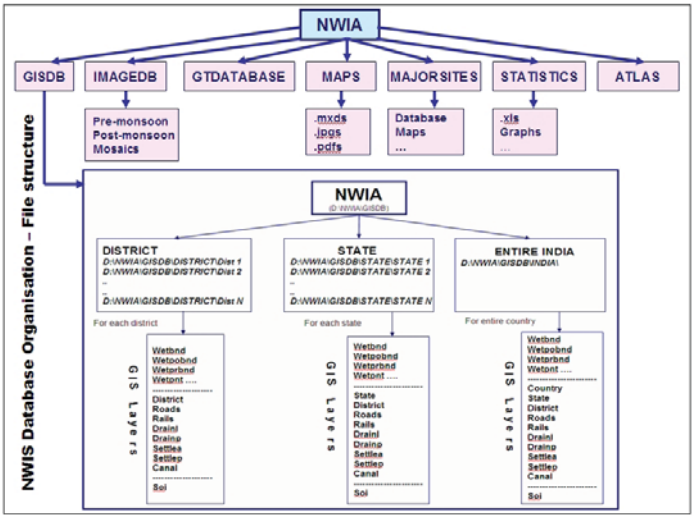

Figure 5: NWIS database file structure

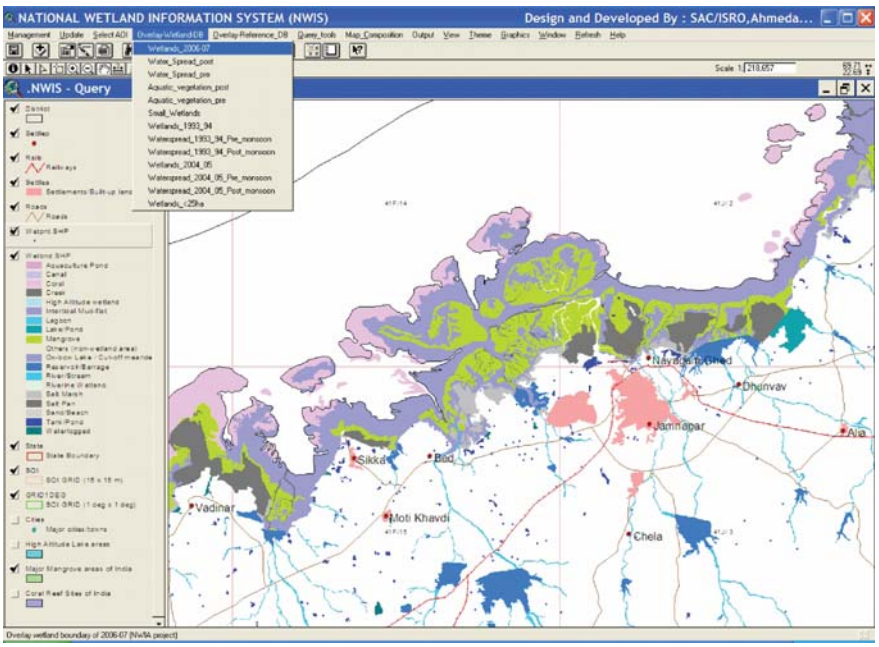

Figure 6: Example of overlay of spatial layers (Southern part of Gulf of Kachchh, Gujarat)

Table 5: NWIS menu tool

Menu/tool	Description	Sub-menu
Management	Provides tools for view management	Open Close Save Save as ….
Update	Provides tools for delete/copy/cut themes	Copy Cut Delete …
Select AOI	Enable to select area of interest for performing query and information retrieval from NWIA project database.	SOI Grid State River_Basin Bio-geographic_zones Agro_Climatic_Regions …..
Overlay_Wetland_DB	Pop-up menu for overlay of wetland resources layers of 1993-94, 2004-05 and 2006-07 timeframe.	Wetland_2006-07 Water_spread_post Water_spread_pre Aquatic_vegetation_post Aquatic_vegetation_pre Wetlands_<2.25ha Wetlands_1993-94 Wetlands_2004-05 …
Overlay_Reference_DB	Pop-up menu for overlay of base layers like major roads, railway, settlements and drainage etc.	Roads Raiways Drainage Settlements ….
Query_tools	Display the query builder to select features with a logical expression (spatial query (where lies…, What lies..), tabular query) Select features in the active themes using another theme's features (select by theme).	Query Select by theme Tables …..
Map composition	Display map composition tools	Layout
Output	Provides print and export options	Print Export ..
Refresh	Refresh screen/display as and when required	

Query tools

This menu facilitates various kinds of query tools. These tools are useful for querying on wetland resources data and baseline information of surrounding area. Query_tools are divided into three parts such as spatial query, tabular query and select by theme.

Tabular query: Tabular query from attribute databases can be performed using query builder. User can form logical and conditional query. It also provides analytical tools like join, relate, sort and edit. For example, one can check how many 'Inland-natural-ox bow /cut-off meanders' having area > 100 ha exists in Nadia district of West Bengal state.

Spatial query: Finding features by building a query expression

A query expression is a precise definition of what you want to select. Building a query expression is a powerful way to select features because an expression can include multiple attributes, operators and calculations. Firstly, user has to select the name of theme containing the features one wants to find, in this case Wetlands, to make active. Now query can be form using Query Builder menu. For example, one can check how many 'Inland-natural-waterlogged type' wetlands having area > 50 ha exist in the surrounding area of NalSarover in Gujarat state.

The ability to query data according to spatial relationships and tabular attributes is one of the key benefits of using this query shell

Spatial query using 'are completely within' buffer area One can find features in more than one active theme when you use the 'Select By Theme' option. Apart from this user can find following

- Features within a specified distance of a point
- Features adjacent to other features
- Nearest features to other features using spatial join
- Features that fall inside polygons
- Features that intersect other features

For example, one can select a wetland complex, create buffer of 1 km around wetland complex, using buffer area select all the settlements within buffer area

Charts and statistics

When one wants to communicate numeric values and their relationships, charts provide immediate visual impact and take less effort to understand than a table or a verbal explanation. Charts can show additional information about the features on the maps or show the same information in a different way. Charts in arcview are dynamically linked to maps and tables.

Chart tools provides options for

- Create a chart
- Change chart styles and colors
- Add or delete information

Statistics tools provide options for

- Derive statistics about attributes
- Derive summary statistics

Map composition

NWIS also provides map composition tools. This tool provides choices to compose a map of query results and/or AOI. It has all the facilities to add a title, scale bar, legend, north arrow, descriptive text etc. To do this with NWIS you can use layout menu.
It offers tools for

- Create a new layout
- Control how view are displayed on a layout
- Add text and other graphics to a layout
- Edit and rearrange what's on a layout
- Print and export layouts
- Save a layout as a layout template

As a part of NWIS, ready-made wetland maps of entire country at topographic map sheet level (5112), district level (618), state level (35) and wetland maps of important wetland sites (150) have been prepared and made available as .jpg and .pdf file. User can view/print these maps as and when required using NWIS.

5. Conclusion

A large number of information on wetlands is being gathered through various projects/programmes in the country. Archival of these database and development of an information system for easy access of this data is essential for judicious use of such data. National Wetland Information System (NWIS) is the first such step towards this. The national wetland database has been organised in a seamless manner on 1:50,000 scale at district level, state level and country level. One can access the prepared maps or generate maps of any area of interest at various scales. Ancillary information on settlements, drainage, canal, road and railway are also in the database that will facilitate understanding locational set up of wetlands. Thus, it can be very effectively used to assess the impact of any developmental activity on wetlands and aid in environmental clearance process. The NWIS also contains wetland database of 1992-93 and 2004-05 period done at 1:250,000 scale. Further strengthening information on flora and fauna details of major wetlands, socio-economic data, catchment information is envisaged in future. The NWIS with database and user manual was handed over to Ministry of Environment and Forest.

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