Article

# GIS and Remote Sensing in Water Resource Engineering

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**Abstract**

Water is one of the most important natural resources for preserving ecosystems and human life. Unequal spatial and temporal distribution of water resources, as well as pollution, put increasing pressures on water resources and disaster management, which is partly attributed to our lack of knowledge about water resource distribution and poor management of their use. Geographic Information Systems (GIS) provide the best tools for water resources, watershed modelling, drought and flood risk management, while Remote Sensing (RS) provides vital data for water resources mapping, hydrological flux measurement, watershed modelling, and modelling. It provides drought and flood monitoring. The role of GIS in watershed models and water resource decision support systems, as well as the role of GIS in the production, management, and delivery of spatially distributed data, are discussed. Understanding and managing water resource issues require understanding the complex processes and interactions that occur at the surface and subsurface of the basin. The application of Maximum Daily Load Limits (TMDL) to pollution inflows into a basin has led to significant demand for new assessment technologies. As the need for and development of watershed modelling capabilities has increased, GIS and remote sensing technologies have played an important role in helping to collect and analyze data. It is expected that the deployment of these technologies will reduce significant pressures on water resources and enable better mitigation and response to drought and flood disasters.

**Keywords:** GIS, RS, Water Resource, Watershed Modeling, Data Types

## Introduction

Mountain glaciers, snow, and surface water bodies (lakes, rivers, and reservoirs), as well as soil moisture and groundwater, are all human-accessible freshwater resources. Pressures on water resources are increasing globally due to their unequal geographical and temporal distribution. People, on the other hand, may not be aware of where and how much water is available in their location, particularly for isolated alpine glaciers/snow and deep constrained groundwater. Severe drought and torrent flooding can occur in extreme circumstances where there is too little or too much water within a specific period and location, often resulting in catastrophic impacts and damage to local and regional infrastructure.

Water resource mapping relies heavily on remote sensing data (Table 2). Satellite remote sensing systems, depending on their orbital properties, can make continuous and up-to-date measurements with global coverage, but they rely on ground observations for algorithm development and validation (Tang et al, 2009). The ideal river transverse sections for building dams to generate reservoirs were selected using Geographical Information Systems (GIS) approaches. GIS is a quick method of determining the optimum places while taking into account the environmental effects of flooding. They described how GIS and stochastic hydrology were combined to decide the location and size of water reservoirs in the Brazilian period (Mendonca and Rezende, 1999).

In an arid region in Jordan, researchers employed geographic information systems (GIS) technologies and remote sensing data to generate and evaluate digital layers of lithology, geological structure, drainage, and topography in order to find the most potential sites for groundwater excavation. Existing well maps and produced maps were intersected to calculate the proportion of wells in each density interval and the number of wells in each interval. The final map for the most potential groundwater research sites was created using several GIS intersections and spatial query methods. The study found that remote sensing and geographic information systems (GIS) were effective methods for mapping viable groundwater exploration areas. Groundwater well data, on the other hand, would help refine the final selection of the most promising site (Jawad and Yahya, 2013).

The importance of GIS in hydrologic models and water resource decision support systems is discussed, as its contribution to the collection, management, and distribution of geographically dispersed data, the introduction of new GIS tools, and the role of GIS in the development of new GIS tools. There are some critical research requirements as well as recent achievements identified. If geographic information science (GIS science) is to help solve water resource challenges in the future, the next section presents four sets of innovations required for enhanced water resource management and identifies priority areas for research and instruction. The final section includes some closing remarks as well as a summary of the most noteworthy results and issues.

## 2. Definition of GIS

"GIS" stands for Geographic Information System, which is a system for efficiently capturing, storing, manipulating, analysing, and displaying spatial data. It is a software application that efficiently connects graphical information to attribute data contained in a database and vice versa (Raju, 2006). A geographic information system (GIS) is a tool that allows users to create interactive queries, analyse spatial data, and change data (Johnson, 2009). A GIS is a geographic information system (GIS) that is used to collect, store, and analyze objects and phenomena when their geographic location is an important property or vital to the study. GIS distinguishing features include spatial searching and layer overlaying (map) layers. Crop potential maps and ground/surface water conditions maps, for example, can be combined in a GIS to create a temporal map of crop/land suitability (Knox and Weatherfield, 1999).

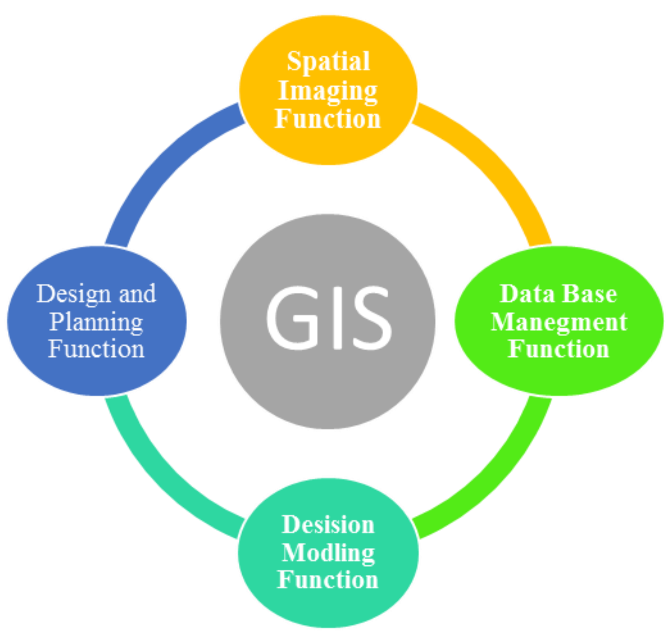
### 2.1. Major Task in GIS

While GIS software may vary in capabilities, most contain the following components (Marble *et al.*, 1984; Neteler and Mitasova et al., 2013). The necessary components are:

- Input: paper map digitization, scanning, vector processing, image classification
- Manipulation: All of the data must be translated to the same resolution scale before it can be combined.
- Administration of Geographic and Attribute Databases: Administration of Geographic and Attribute Databases
- Query and viewing: Once the database has been created, the user can use GIS to do any query on the data. For example, where are the soils with land types like MHL and clay-textured soils?
- Analysis: GIS offers a variety of strong tools for creating "what if" scenarios. Is there a drought in a specific area? What is the level of commitment? What is the magnitude of the crop yield loss, and how much will it cost?
- Visualization and printing: Creating maps, legends, symbols, and other associated features, as well as enabling printer access.

## 2.2 Uses of Geographic Information Systems (GIS)

A lot of companies depend on information for one or more of the major uses mentioned below. Internal management and control, transaction processing, operations, inventory management, planning and decision-making. Because they have functionalities that are common to other types of information systems, GIS can be implemented for these and other applications. GIS, on the other hand, has several distinctive features that set it apart from other information systems. (Mennecke et al., 1996) proposed a framework for defining the links between GIS functionalities and the commercial applications for which GIS can be employed (see Figure 1).



## 3. Uses of Remote Sensing

Different satellite sensors were utilised to examine a number of aspects of Lake Trasimeno (water quality, coastline vegetation, land use and land cover) (Table 2). As indicated in the next paragraphs, the photos were processed according to the object of inquiry. As a result, employing cutting-edge technology such as remote sensing, geographic information systems (GIS), geo-statistics, and hydrologic models, it is critical to precisely monitor and manage water resources, drought, and flooding risk.

**Table 1: Latest remote sensing technology and sensors used for water resources, hydrological fluxes (Tang et al, 2009)**

| Application Fields | Specific Contents | Examples of Sensors or Satellites |
|---|---|---|
| Water resources | Snow | AVHRR, Terra/Aqua MODIS, Landsat, SSM/I, AMSR-E, Cryosat etc. |
| | Glaciers<br>Soil moisture<br>Groundwater<br>Lakes, reservoirs, rivers, and wetlands | Landsat, ASTER, SPOT, ICESat, SRTM, etc. SSM/I, AMSR-E, SMAP, SMOS, etc. GRACE MODIS, Landsat, SPOT, ICESat, GRACE, SRTM etc. |
| Hydrological fluxes | Precipitation<br>Evapotranspiration<br>River, reservoir or lake discharge | NEXRAD, TRMM, GPM, etc.<br>MODIS, Landsat, GRACE, etc.<br>MODIS, ENVISAT, Landsat, SRTM, ICESat, etc. |

### 3.1 Surface Temperature from MODIS

At the National Aeronautics and Space Administration Land Processes Distributed Active Archive Centre, MODIS surface temperature data (MOD11A) with a nominal resolution of 1 km was provided. Between 2005 and 2008, all accessible clear-sky MODIS Terra imagery was used, yielding a total of 497 cloud-free pictures for analysis. The ST of Lake Trasimeno is calculated directly using the MOD11A swath data, which has been cropped and regridded to a 1-km equirectangular grid and projected to the Gauss Boaga (Monte Mario) national plane coordinate system (Doerffer et al., 2008).

### 3.2 Water Quality Parameters from MERIS

The ESA-Eolisa catalogue provided MERIS FR top-of-atmosphere radiance level-1, 300-m nominal FR data (v. 6.0.1). Between 2005 and 2008, a total of 118 clear-sky MERIS pictures were used. Each year had roughly 20 scenes, with the exception of 2008, when the number of photographs (55) was over double that of prior years due to increased focus on our project activities in 2008. The ESA Basic Envisat/ERS ATSR and MERIS (BEAM v. 3.6.1) toolboxes were used to process the photos (Brockmann Consult, Geesthacht, Germany). The Improved Contrast between Land and Ocean (ICOL) plug-in was used to rectify level-1 data for adjacency effects before being translated into water quality products. Three plug-in algorithms based on the MERIS Case-2 Core Module are available for this purpose: Case-2 Regional (C2R), Eutrophic Lakes, and Boreal Lakes (Doerffer et al., 2008). All of them put in place a specialised atmospheric correction (Doerffer et al., 2008). The C2R processor was chosen for this study because it is more suited to analysing the optical features of Lake Trasimeno (Giardino et al. 2008). The recovery of water constituents by C2R yields a variety of results, including Chl-a, TSM, and YS, as well as the lowest irradiance attenuation coefficient and the signal depth z90, which was thought to be comparable to SD depths. The Gauss Boaga national plane coordinate system was used to geolocate the image-derived goods.

Table 2 presents the nominal spatial resolution of the satellite data used in this investigation. The number of photos processed and the time of acquisition are also listed, as well as the reason for their investigation (Doerffer et al., 2008).

**Table 2: Nominal spatial resolution of the satellite data**

| Sensor | Spatial Resolution | Temporal Window | Number of Image | Object of Investigation |
|---|---|---|---|---|
| MERIS (Envisat-1, ESA) | 300 m | 2005–2008 | 118 | Water quality (Chl-*a*, TSM, SD) |
| MODIS (Terra, NASA)<br>TM (Landsat-5, NASA) | km<br>30 m | 2005–2008<br>07/08/1988 | 497<br>2 | Water quality (ST)<br>Land use/cover |
| MSS (Landsat-4, NASA)<br>AVNIR-2 (ALOS, ESA-JAXA) | 80m<br>10m | 22/05/1979<br>08/07/2007<br>23/06/2008 | 1<br>2 | Land use/cover<br>Land use/cover<br>aquatic vegetation |
| ASTER (Terra, NASA) | 15m[a] | 22/06/2003 | 1 | Land use/cover<br>aquatic vegetation |

### 3.3 Land Use/Cover and Macrophytes

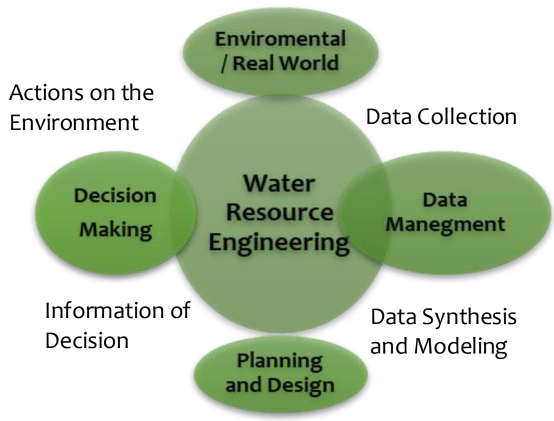
We used Landsat Multispectral Scanner (MSS)/Thematic Mapper (TM), Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), and Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) imagery acquired between 1979 and 2008 to investigate recent changes in land use and cover types in the Lake Trasimeno basin (Table 3). The summer seasons of 1979 (Landsat MSS, 1988; Landsat TM, 1998; Landsat TM, 2003; Terra ASTER, and 2008; Landsat TM) were used to collect remotely sensed multispectral images (ALOS AVNIR-2). Radiometric normalisation based on the selection of pseudo-invariant features and the transformation of linear regression was used to preprocess satellite data. After that, dark pixels were subtracted from normalised data to adjust for atmospheric influences (Chavez, 1988). Finally, the Gauss Boaga national plane coordinate system was dereferenced and co-registered.

## 4. Water Resources

Water resources engineering is concerned with the analysis and design of systems for managing water quantity, quality, timeliness, and distribution to fulfil the needs of human societies and the natural environment (Marothia., 2003).

**Figure 2** presents the water resources planning and design processes start with data gathering in the field and go through data management and modelling to provide information for making decisions about alternative plans and designs.

**Figure 2: Water resources planning and design processes**




### 4.1 Water Resource in GIS

Water resources and environmental information are essentially geographical. When surveyor John Wesley Powell visited the Colorado River and the Grand Canyon in 1869, he made a map of the area as part of his contribution (Figure 1). As a result, he laid a cartographic foundation on which others might obtain a better understanding of the region and devise plans for additional exploration and development. Powell later began attempts to examine the water supply and to recognise the land's natural limits to settlement (Colwell, 2010).

Powell created the first river gauge station in the country along a portion of the Rio Grande in New Mexico in 1889, kicking off programmes for resource surveys throughout the western United States. The word was coined by Powell and his colleagues (deBuys, 2001).

The primary science of hydrology, which deals with the occurrence, distribution, flow, and qualities of water on the Earth's surface and beneath, is the foundation for water resources engineering. A GIS is used to organise all of this data. It gives a complete method for handling data that would be impossible to do manually. Because of the vast amount of data involved, a GIS is required. The GIS allows you to capture and archive this data, as well as browse and evaluate it in colour-coded map forms. This data-review feature aids quality control by allowing faults to be spotted more easily. In addition, the user can acquire a deeper understanding of patterns and trends in the data through visualization, which is not feasible if the data is just in tabular format. In addition, the GIS has an analysis feature. Computer software can access the information, which can then be used as an input to various modelling techniques to develop derived products (Marothia, 2003).

- Defining the watershed and its hydrologic and hydraulic features so that models of rainfall-runoff processes can be applied to analyse the implications of land-use changes in a river basin, for example,
- Mapping land use and population demographics to aid in the estimate of water and wastewater demand,
- Estimating snowpack amounts in ungauged areas based on data received at gauged locations guided by elevation and exposure parameters or interpolating groundwater pollutant concentrations given sampled data from observation wells distributed across an aquifer,
- Managing public infrastructure, such as scheduling maintenance on a sewage collection system,
- Identifying locations of probable low pressure during fire-response planning scenarios, telling residents of water-pipe repair work, or notifying residents of water-pipe rehabilitation work,
- Identifying elements that coincide, such as erosion-prone locations with a specific mix of soil type, land cover, and slope,
- Keeping track of the frequency and severity of severe thunderstorms, as well as providing a means to alert those in danger,
- Providing a logical network structure for simulation and optimization models that arrange interactions between basin water supply, reservoirs, diversions, and demands.

GIS has a wide range of applications, including geographical analysis, modelling, visualization, data processing, and management. GIS works courageously behind the scenes most of the time, such as in this special issue. Almost every study in this special issue uses a geographic information system (GIS) for data pre-treatment, spatial analysis, or creating result maps (Table 3).

With unparalleled data resources, managing so much data in risk management and, particularly, disaster response, such as the aforementioned 2015 Texas flooding occurrence, is highly challenging (Schumann et al., 2016).

Table 3 shows how the 12 publications in this special issue used the most up-to-date geographic information systems (GIS), remote sensing technologies, and hydrologic models (Schumann et al, 2016).

**Table 3: Publications using geographic information systems (GIS), remote sensing technologies, and hydrologic models**

| Application Fields | Specific Contents | GIS, Algorithm, Model, Sensor or Satellites | Reference |
|---|---|---|---|
| Water resources mapping and management | Glaciers mapping | Landsat, ASTER GDEM, GIS, TIN 3D model. | Wang, X et al, 2017 |
| | Soil moisture | GPR, CMP, FO, GIS spatial | Lu, Y et al, |

| | | | |
|---|---|---|---|
| | detection | analysis | 2017 |
| | Groundwater and subsidence analysis | GIS spatial analysis, GPS | Li, Y et al, 2017 |
| | Irrigation planning | UAV, HTM for video image classification, GIS visualization | Perea-Moreno et al, 2016 |
| Rainfall measurements and design storm | Rainfall measurements | TRMM, GPM, GIS spatial analysis and visualization | Wang, R et al, 2017 |
| | Design storm and urban flood modeling | Huff curve, SWMM, GIS data preprocess and visualization | Pan, C et al, 2017 |
| Rainfall runoff prediction and flood forecasting | Flood modeling | GSSHA model, GPM IMERG, GIS visualization | Sharif, H.O et al, 2017 |
| | Rainfall Runoff simulation | RCM, LSM, CoLM, CoLM+LF, GIS data preprocess | Lee, J.S et al, 2017 |
| | Flood inundation forecast | ARX regressor, MOGA algorithm, GIS visualization | Ouyang, H.T et al, 2017 |
| Water body and flood mapping | Flash flood detection | TMPA real time 3B2RT, CT, CDFs, JFI, GIS spatial analysis | Tekeli, A.E, 2017 |
| | Urban water body mapping | ZY-3 images, AUWEM, GIS spatial analysis | Yang, F et al, 2017 |
| | Flood inundation mapping | ENVISAT, ASAR, GIS spatial analysis | Frappart, F et al, 2017 |

## 5. Watershed Modeling

The spatial and/or temporal scales employed, the methods used to solve the equations, and how the underlying hydrologic processes are depicted are all factors that can be used to classify watershed models (Melone et al., 2005). When it comes to spatial representation, the lumped modelling technique treats a watershed as a single unit for computations, averaging the watershed parameters and variables over this unit. The single unit is believed to have homogeneous attributes (climatic conditions, topography, geology, land use, and soil characteristics) (Arabi et al., 2004). Many of these models are now widely used in a wide range of applications (Einfalt, 2004). Aquifer vulnerability mapping, surface water and groundwater quality remediation, floodplain studies, assessment of surface water impact from groundwater withdrawal, water supply design, river basin management and planning, assessment of catchment changes due to land-use changes and irrigation, and runoff predictions in ungauged watersheds are just a few examples of typical applications (Graham, Butts, 2006).

### 5.1 Watershed Modeling and GIS

The trend in watershed modelling has been driven by advances in GIS and remote sensing techniques. Remote sensing techniques (e.g., radar and satellite imaging) can be used to gather spatial data on land use and soil type at regular grid intervals with repeating coverage, for example. The contribution of GIS technology to hydrologists has been critical in this advancement, as it has provided additional capabilities for reducing computation times, efficiently handling and analysing large databases describing heterogeneities in land surface characteristics, and improving model result display (Jain et al., 2004).

Watershed modelling has surely moved to a more dispersed representation by accounting for the geographical and temporal fluctuations in characteristics such as soil, land use, and precipitation, thanks to the increasing availability of fairly comprehensive spatial datasets and adaptable GIS capabilities. As a result, distributed models are finding their way into a wide range of applications (Noto, Loggia, 2007). Early GIS software packages were standalone applications with simple user interfaces and limited processing capabilities (Steiniger, 2013).

Table 3 shows a collection of GIS software applications for desktop and professional use in the water resource modelling community. The majority of these GIS tools use a Windows®-like interface with standard pop-up and pull-down menus. They also provide basic GIS features for capturing, storing, retrieving, managing, analysing, and displaying vector and raster data. Some GIS software packages additionally include tools for translating this information into a format that may be used by water resource models (Arc Hydro, WMS). The Internet or web-based GIS has evolved as an appealing platform for effectively delivering GIS data and applications to a wider audience as an extension of desktop GIS (Peng, Tsou, 2003).

### 5.2 GIS Watershed Functionality

The use of GIS technology is helping to advance the use of watershed models. Hydrologic assessment, model setup, parameter determination, and modelling within GIS are four separate areas where GIS is used in watershed modelling (Garbrecht et al., 2001; Ogden et al., 2001; Eldho et al., 2007).

**Table 4: Leading GIS Software Packages**

| Vendor | Desktop/Professional GIS Product | Internet GIS Products |
|---|---|---|
| Environment Research Systems | ArcView 3x, ArcGIS 9.x (ArcView, ArcEditor, ArcInfo) | ArcIMS, ArcServer |

| | | |
|---|---|---|
| Institute (ESRI) | | |
| Auto Desk | Autodesk Map | MapGuide Open Source |
| U.S. Army Construction Engineering Research Laboratories (CERL) | Geographic Resources Analysis Support System (GRASS) | |
| Caliper Corporation | Maptitude, TransCAD | Maptitude/TransCAD for the Web |
| Intergraph Corporation | GeoMedia, GeoMedia Professional | GeoMedia WebMap |
| Clark University | IDRISI | |
| MapInfo Corporation | MapInfo | MapExtreme |
| Microsoft® | MapPoint | MS Virtual Earth |
| ERDAS, Inc. | ERDAS IMAGINE | |
| Open Source | Map Window | MapServer |
| | Quantum GIS | |
| | Integrated Land and Water Information System (ILWIS) | |

### 6. GIS Data Sources

The Geodatabase acts as a "container" for a collection of datasets used to represent GIS features. Tables and raster pictures are used to store the features of GIS systems. Table 4 lists the various GIS datasets available, along with their descriptions (Addison, 2006).

**Table 5: GIS Data Sources**

| Data Source | Site | Description |
|---|---|---|
| Yahoo! BOSS | http://www.yahooapis.com | BOSS (Build your Own Search Service). Provides a facility of Place finder & Place Spotter to make location aware. |
| CityGrid | http://developer.citygridmedia.com http://docs.citygridmedia.com/displ | Incorporates local content into web and mobile applications. |

| | | |
|---|---|---|
| | ay/citygridv2/ Getting+Started | |
| Geocoder.us | http://geocoder.us | Provides latitude & longitude of any US address , Geocoding for incomplete address ,Bulk Geocoding and Calculates distances |
| GeoNames | http://www.geonames.org | It contains geographical names, populated places and alternate Names. All categorized into one out of nine feature classes. |
| US Census | http://www.census.gov http://www.census.gov/geo/www/tiger | Offers several file types for mapping geographic data based on data found in our MAF/TIGER database. MAF-Master Address File. TIGER -- Topologically Integrated Geographic Encoding. |
| Zillow | http://www.zillow.com | Zillow is a home and real estate marketplace. |
| Natural Earth | http://www.naturalearthdata.com | Natural Earth is a public domain map dataset available at 1:10m, 1:50m, and 1:110 million scales. |
| OpenStreet Map | http://www.openstreetmap.org | OpenStreetMap is a free worldwide map, created by many people |
| MaxMind | http://www.maxmind.com | GeoIP - IP Intelligence databases and web services minFraudtransaction fraud detection database |
| ArcGis, MapGis. | http://www.esri.com/software/arcgis | Helps to organize and analyze geographic data |
| OpenEarthquake Data | http://earthquake.usgs.gov/earthquakes/map | Gives the databases related to earthquake |

### 6.1 Data Representation in GIS

GIS Systems takes data from a wide range of communication devices from a variety of heterogeneous data sources. The data from the communicating devices is available in a variety of formats and representations. The data representation from these devices is divided into two groups in GIS: raster and vector data. The visual representation of the GIS data type is shown in Figure 3. Raster is a two-dimensional data type that records the value of raster picture pixel colours in a cell, with attribute values that are continuous. Information from sources such as air pictures, scanned maps, elevation layers, and remote sensing data is represented by the raster data type. In GIS, vector data types are used to describe discrete features using a layered architecture that includes points, lines, and polygons. With a stacked hierarchy, vector data types are utilised to represent information from sources such as highways, rivers, cities, lakes, and park boundaries. Figure 4 depicts the GIS data model (Addison, 2006).

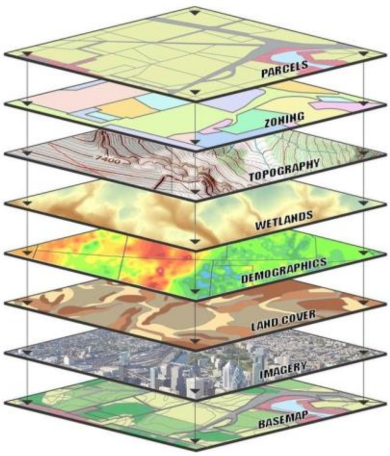



Fig. 3. Visual representation of GIS data type

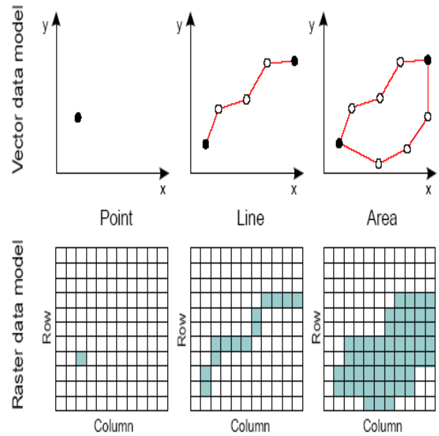



Fig.4. Data Model of GIS

**Table 6: File Formats in GIS**

| Raster Data | | Vector Data | |
|---|---|---|---|
| **Description** | **File Format** | **Description** | **File Format** |
| Arc/Info ASCII Grid, Binary Grid, | prj, adf | ESRI Generate Line, shapefile | arc, shp |
| ADRG/ARC Digitilized Raster Graphics | gen,thf, gen, jpeg, tif | MicroStation Design Files | Dgn |
| Magellan BLX Topo | blx, xlb | Digital Line Graphs | Dlg |
| Bathymetry Attributed Grid | Bag | Autodesk Drawing, eXchange Files | dwg,dxf |
| Microsoft Windows Device Independent Bitmap | Bmp | ARC/INFO interchange file | e00 |
| BSB Nautical Chart Format | Kap | Geography Markup | Gml |

| | | | |
|---|---|---|---|
| | | Language | |
| VTP Binary Terrain Format | Bt | ISOK | kf85 |
| Spot DIMAP (metadata.dim) | dim | MapInfo Interchange Format | mif,mid |
| First Generation , New Labelled USGS DOQ | doq | Spatial Data Transfer System | Sdts |
| Military Elevation Data (.dt0, .dt1, .dt2) | dt0, dt1, dt2 | Scalable Vector Graphics | Svg |
| Arc/Info Export E00 GRID | adf ,shx | Topologically Integrated Geographic Encoding and Referencing Files | Tiger |
| ECRG Table Of Contents (TOC.xml) | xml | Vector Product Format | Vpf |
| ERDAS Compressed Wavelets (.ecw) | ecw | Idrisi32 ASCII vector export format | Vxp |
| Eir – erdas imagine raw | bl,raw | Microsoft Windows Metafile | Wmf |

### 6.2 GIS Data Formats

Due to the various formats, representations, and data sources, analysing GIS databases that contain spatial information is difficult. Table 6 shows a collection of file formats in GIS (Addison, 2006). The following are the different issues that require spatial data from geodatabases (Addison, 2006).

- Domain specialists' assistance is required to relate and comprehend spatial and non-spatial data.
- Due to the vast diversity of file formats, it is difficult to select and represent data for mining from geodatabases.
- Recognizing the information contained in image files (raster data).
- Spatial attribute selection and transformation from non-spatial attributes.

### 6.3 Geographic Information System (GIS) Data for Water Resource Engineering

Water resource management necessitates a diverse set of spatial data, ranging from hydrography and water distribution and collection systems, which describe the state of water resources, to terrain, climate, soils, and land use, which influence the quality and movement of water.

#### 6.3.1 Hydrologic and Water Quality Data

GIS has enabled government agencies and business companies to extend the transmission of their data beyond numerical tables to maps, as well as to facilitate other forms of spatial data searches. The Environmental Protection Agency's "Surf Your Watershed" service, for example, allows users to acquire water quality data in the form of maps and tables (see http://www.epa.gov/surfyourwatershed). Similarly, the National Wetlands Inventory of the US Fish and Wildlife Service (http://www.nwi.fws.gov/) provides information on wetlands, and the National Weather Service's Hydrologic Information Center provides information on river and streamflow conditions, floods, and droughts (http://www.nws.noaa.gov/oh/hic/). The Illinois Stream Information System (see http://www.gis.uiuc.edu/research/info systems/ISIS/isis.html for details) and the Montana Water Information System (see http://nris.state.mt.us/wis/wis1.html for details) are two state agencies that provide state or regional data. The University of Arizona has created a collection of about 300 land-surface hydrology data connections (for more information, visit http://www.hwr.arizona.edu/hydrolink.html). The spatial content of numerous special-purpose hydrologic data sets has also increased gradually but steadily (Graham et al. (1999)).

### 6.3.2 Models of Digital Elevation

Topographic data in the form of digital elevation models (DEMs) has had a significant impact on GIS-based water resource applications, spurring research and development of distributed hydrologic and nonpoint source pollution models as well as their integration with GIS. New terrain mapping technologies such as IFSAR (interferometry synthetic-aperture radar), LIDAR (light detection and ranging), and real-time kinetic surveys (based on the mobile global positioning system (GPS)) are delivering higher degrees of detail and vertical accuracy (i.e., resolutions of 1-2 m, with 15-cm vertical accuracy). These new data sources will significantly improve our ability to assess and predict water and related pollutants' flows in natural and anthropogenic landscapes. Radar is a type of radar that detects objects. For example, data from a recent National Aeronautics and Space Administration/Department of Defense shuttle flight was utilised to create a new 30-m resolution global DEM, allowing hydrologic research at the continental/global scale at a level of detail previously only feasible at regional scales (Huang et al., 2003).

### 6.3.3.Climatic data

The Internet has also improved access to and distribution choices for national climate station data (see http://weather.ncdc.noaa.gov/for more information), and the spatial content of special-purpose climatic data sets has steadily increased. For example, the production and distribution of a gridded topography and mean monthly climate database for the African continent was presented. Fitted thin-plate splines were applied to the new Africa DEM to create monthly mean precipitation and temperature grids. The final surfaces interpolate monthly mean temperatures and precipitation to within 0.5 oC standard errors (Hutchinson et al. 1996).

### 6.3.4.Soil Data

State Soil Geographic (STATSGO) and Soil Survey Geographic (SSURGO) database packages, respectively, provide soil data for states and counties (Bliss and Reybold 1989; Reybold and TeSelle 1989). In each mapping unit, the STATSGO database depicts generalised soil mapping units and stores properties by soil layer for 1–21 soil series. Several researchers have contributed to this study (Foussereau et al. 1993; Maclean et al. 1993; Rogowski and Hoover 1996; Rogowski 1997).

They have developed methods for merging these data with other data sets in order to forecast continuous changes in soil water characteristics that may differ significantly throughout the terrain (Wilson 1999a, b).

### 6.3.5. Land-cover Data

Meteorological satellite data has been used in the majority of recent attempts to compile LandCover evaluations over vast areas (e.g., numerous counties, states, or continents) (Loveland et al. (1995). For example, using statistical analysis of mutilated Advanced Very High Resolution Radiometer satellite data for the continental United States, researchers created a multilayer land-cover database that serves as a prototype for a global land-cover database now in preparation. The Gap Analysis Program (Scott, Jennings, 1998) uses comparable source data to create state-by-state biodiversity maps (for more information on these products and their availability, visit http://www.gap.uidaho.edu/).New multispectral sensors, satellite platforms, and digital remote sensing data archives from the last two decades have shifted this study from a spatial to a spatiotemporal level, resulting in a powerful new tool (Wilkinson, 1996). The primary obstacles and problems that must be overcome in order to more effectively employ new forms of satellite data were recently highlighted (Gahegan, Flack, 1999). This shows how current computing technologies could be utilised to solve some of the difficulties uncovered using these and other GIS data topics.

## 7. Conclusion

Assessment and management of water resources are essentially geographical tasks that necessitate the use of a variety of spatial data types. During the last decade, GIS and watershed models have aided in the identification and evaluation of viable solutions to water resource concerns. Many of the most popular spatially distributed data sets may now be accessed via the Internet, thanks to GIS, which has increased the number of ways information can be displayed and thus increased its accessibility. Similarly, the amount and diversity of functionalities incorporated into GISs that are suitable for water resource applications has steadily increased. At numerous levels, GIS science has influenced the development and implementation of hydrologic models. By splitting entire watersheds into sub-watersheds in both site-specific and lumped parameter models, GIS has offered tools to compute averaged values more efficiently and to include at least some level of spatial effects.

The use of watershed-scale modelling is an important part of watershed management. The capacity to assist with a range of applications, such as future sediment loading and runoff, evaluation and construction of TMDLs, flood hazard mapping, and estimating peak flows, is one of the advantages of employing these models. To comprehend and portray these processes, major developments in watershed modelling rely on spatial datasets (e.g., DEMs, LULC), GIS, and remote sensing technologies (e.g., NEXRAD, LiDAR). Watershed modelling efforts have significantly benefited from GIS technology by providing the essential tools for hydrologic evaluations, model setup tasks, parameter extraction, user-friendly interactivity, and the transmission of watershed and associated information to diverse stakeholders over the Internet. According to future trends, GIS will continue to affect watershed modelling in the future by providing flexible platforms to facilitate hybrid watershed modelling systems development, real-time data gathering, and the deployment of web-based watershed modelling applications.

In its study proposing options for delivering deliberate, long-term solutions to water resource concerns and sustainable access to water resources in the United States, the National Research Council (1999) shares this particular vision of the future. Their final study reveals significant flaws and weaknesses in our current water resource GIS, simulation models, and decision support systems. If we are to build easy-to-use simulation models and decision support systems that help identify and solve real-world water resource challenges, we will need to make steady progress in each of these areas.

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