सत्यमेव जयते

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जल संसाधन, नदी विकास
और गंगा संरक्षण मंत्रालय
केन्द्रीय जल आयोग
राष्ट्रीय जल अकादमी

Training Program on

APPLICATION OF REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM IN WATER RESOURCE SECTOR

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कार्यक्रम समन्वयक

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पुणे

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BASIC CONCEPTS OF GIS

Introduction

Geographic Information System (GIS) is a computer based system designed to accept large volume of spatial data derived from a variety of sources and to store, retrieve, analyse, manipulate and display these data according to use specifications. Geographical objects include natural phenomena such as railways, canals, roads, rivers, soil type etc. Geographical data describe objects from the real world in terms of their position with respect to known co-ordinate system, their attributes that are unrelated to position and their spatial interrelations with each other, which describe how they are linked together. Conventionally, mapping map analysis, measurements were done manually. With the advent of computer technology software were written to handle geographic data on the computers. This has resulted in GIS which represents now rapidly developing field lying at the intersection of many disciplines namely cartography, computing, geography, photogrammetry, remote sensing, statistics, surveying and other branches concerned with handling and analysing spatially referenced data.

Basics of GIS

Mapping Concepts, Features

A map represents geographic features or other spatial phenomena by graphically conveying information about locations and attributes. Locational information describes the position of particular geographic features on the Earth's surface, as well as the spatial relationship between features, such as the shortest path from a fire station to a library, the proximity of competing businesses, and so on. Attribute information describes characteristics of the geographic features represented, such as the feature type, its name or number and quantitative information such as its area or length. Thus the basic objective of mapping is to provide

- descriptions of geographic phenomenon
- spatial and non spatial information
- map features like Point, Line, & Polygon.

Map Features

Locational information is usually represented by points for features such as wells and telephone pole locations, lines for features such as streams, pipelines and contour lines and areas for features such as lakes, counties and census tracts.

Point feature A point feature represents as single location. It defines a map object too small to show as a line or area feature. A special symbol of label usually depicts a point location.

Line feature A line feature is a set of connected, ordered coordinates representing the linear shape of a map object that may be too narrow to display as an area such as a road or feature with no width such as a contour line.

- Points (cities, wells, villages)
- Line (rails, roads, canals)
- Area (reservoir, watersheds, land use class)

Data Model

Geographic data are represented in GIS in a particular manner and the approach is called model. There are two models- raster and vector

Raster: The geographic data are divided in grid cells
Data Structure-run length encoding, chain coding and quad tree

Vector: represented by points and lines
Data Structure -spaghetti & topological

To know why and how a GIS can help us, we must know what a GIS is and what it can be used for

What is a GIS?

–*Questions a GIS can answer*
– *Applications of GIS*
–*The elements of GIS*

What Is a GIS

- An organised collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information
- A programme is a GIS only if it permits spatial operations on the data
- A GIS typically links data from different sets. A GIS can perform this operations because it uses geographic or space as the common key between the data sets

Questions A GIS Can Answer

- Location (What is at particular location?)
- Condition (where is it…..?)
- Trends (What has changed since….?.)
- Patterns (What spatial patterns exist ?)
- Modelling (What if…….?)

Application Areas

- Water resources planning
- Land use planning
- Geodesic mapping
- Environmental applications
- Cadastral mapping
- Urban and regional planning
- Route selection of highways
- Mineral exploration
- Census and related statistical mapping
- Automatic cartography
- Natural resources mapping
- Surveying

Components of GIS

- Data encoding and input processing - (Digitizer, scanner, computer files)
- Data manipulation
- Data management

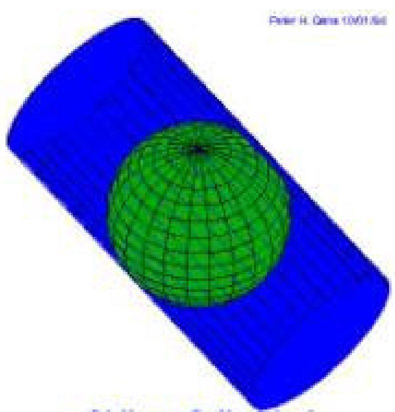
- Data retrieval
- Data analysis, modelling and cartographic manipulations
  (Overlay, intersection, identity, union, search, neighbourhood, distance, dissolve, classification reclassification, query etc)
- Data output(maps, graphs, photographs)

Map projection-

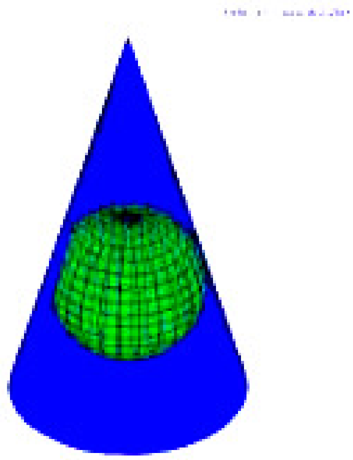
Map Projection is a systematic drawing of parallels of latitude and meridians of longitude on a plane surface for the whole earth or part of it on a certain scale so that any point on the earth surface may correspond to that on the drawing. A network of latitude and longitude is called ***graticule.***

- Map Projection is preparation of *graticule* on a flat surface.
- *Projection* means the determination of points on the plane as viewed from a fixed point.
- A flat surface will touch globe <u>only at one point</u> and other sectors will be projected over the plane in a distorted form. The amount of distortion increases with the distance from tangential point.

- Equal area or *homolographical* Projections
  (In this case graticule is prepared in such a way that every quadrilateral on it may appear proportionately equal to in area to the corresponding spherical quadrilateral.)
- Correct shape or *orthomorphic or Conformal* Projections
- True bearing or *azimuthal* Projections



Oblique Cylindrical Projection Surface



Conical Projection Surface

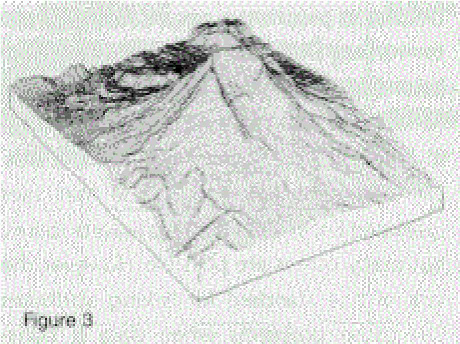
Polyconic, UTM etc.

Geometric rectification/ geo-referencing

Statistics- measurement, summary

DEM and Visualisation

Contouring, Hill shading, Perspective viewing, Fly through
Slope and aspect, extracting drainage



DEM

GIS packages

ARC/INFO (1969-ESRI Redlands California, USA), PAMAP GIS, SPANS (spatial analysis System- TYDAC Tech, USA,)

Modular GIS Environment (MGE)

IDRISI, GRASS, MAP/INFO, PROGIS

Indigenous GIS Packages- ISROGIS (12 modules) such as
Create, Edit, Make, Analyse, Attr-DB, Layout, Query, Map mosaic, 3D Module, Symbol Manager, Graphic User Interface (GUI)
GRAM^{++}, GEO-SPACE – RRSSC

Geographic Database

- A GIS does not hold maps or picture-it holds a database
- If one has to go beyond making pictures, one need to know three things about every feature stored in the computer; what it is, where it is, and how it relates to other features
- GIS gives the ability to associate information with a feature on a map and to create new relationships

Hardware and Software Resources

- The rapidly increasing power and the relative affordability of workstations now provide the user access to powerful machines for GIS operation dealing with large and complex data set and other decision-support tools such as hydrologic models, statistical packages, and optimisation programs
- With advancement in software development relating to GIS application more and more features are getting available on PC version of GIS packages
- Commercial GIS packages like Arc-Info, MapInfo, Intergraph, Spans etc. available in the market
- Most of the packages function under open GIS system
- Before a GIS package or peripheral is acquired, inter-compatibility should be confirmed.

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Issues Pertinent to WRD&M

- Critical role of water in human and natural environment. Role of GIS is important in management of the precious resource
- Water related data can have high precision (canal location) or can be Fuzzy (wetland perimeter)
- surface representation by DEM using GRID, TIN or contours required for hydro-geologic application of GIS
- Length, area and quantity computation, overlay of thematic layers and buffer zone generation important for WRD application

Application in Water Resources

1. Hydrologic/hydraulic modelling for basin Planning
2. WR and Irrigation potential assessment
3. Identification of WRD project sites
4. EIA studies and environmental monitoring
5. Command area monitoring
6. Disaster management

Network Analysis

Network models are based on interconnecting logical components, of which the most important are:

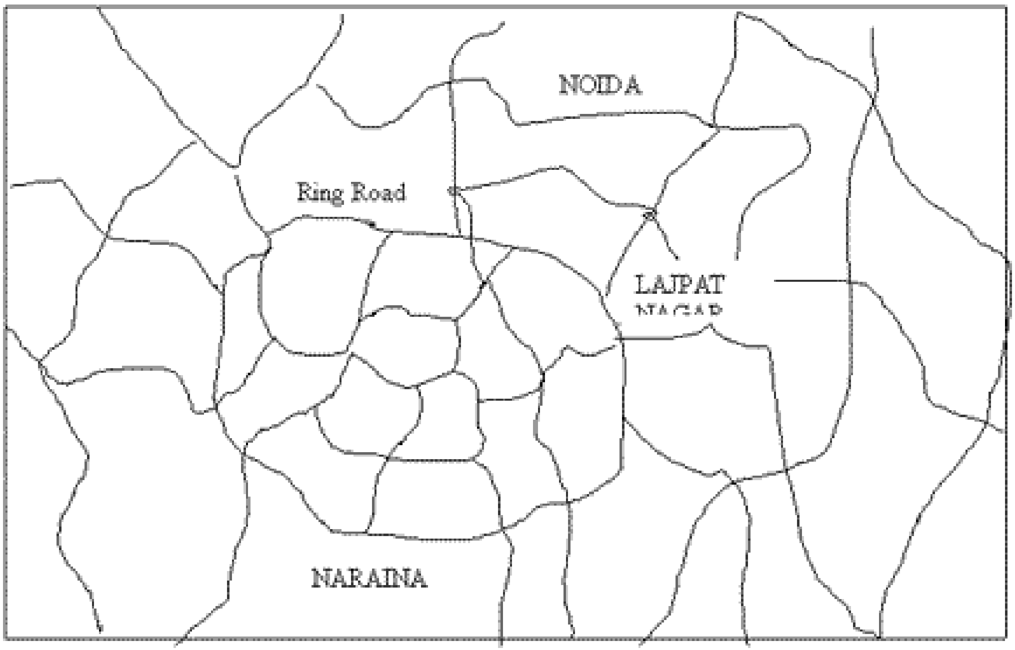
1. "Nodes" define start, end, and intersections
2. "Chains" are line features joining nodes
3. "Links" join together points making up a chain.

This network can be analyzed using GIS.A simple and most apparent network analysis applications are:

- Street network analysis,
- Traffic flow modelling,
- Telephone cable networking,
- Pipelines etc.

The other obvious applications would be service centre locations based on travel distance.

Basic forms of network analysis simply extract information from a network. More complex analysis, process information in the network model to derive new information. One example of this is the classic shortest-path between two points. The vector mode is more suited to network analysis than the raster model.



A Road Network *Image*

Capabilities of GIS

- Presentation Graphics
- Data Query
- Spatial Query
- Routing and Minimum path
- Buffering
- Overlay
- Distance, Adjacency and Proximity analysis
- Misc. analysis likes neighbour analysis, network analysis, 3D Analysis etc.

Presentation Graphics

- Thematic mapping is a means offered by GIS to draw map elements using patterns or colour based on a particular attribute
- Thematic mapping can be classified as
  - Polygon thematic
  - Line thematic
  - Point thematic
- Thematic maps usually involve only a few map layers and limited amounts of data

Data Query

- Much of the data collected by businesses are spatially referenced
- Non GIS user querying such a data base are limited to tabular views of the results of query
- A GIS user can view the results on a map apart from the regular tabular view
- Most important benefit is that the GIS user can see the spatial distribution which is hidden for the non GIS user
- Thus the GIS user is offered a "*powerful lens*" which makes hidden data visible to him
- This type of data base query is also called the "*show-me*" query
- Most available GIS packages are designed to effortlessly perform data queries
-

Spatial Query

- In this form of a query the user relies on the map as a querying tool
- Typically the data base is accessed by pointing to specific map feature
- GIS will then search the data base, and find those records that qualify, for presentation
- Spatial queries can be through
  - Pointing a feature
  - Spatial windows (Circular/Rectangular)
- Spatial queries are also called "tell-me" queries

Routing and Minimum Path

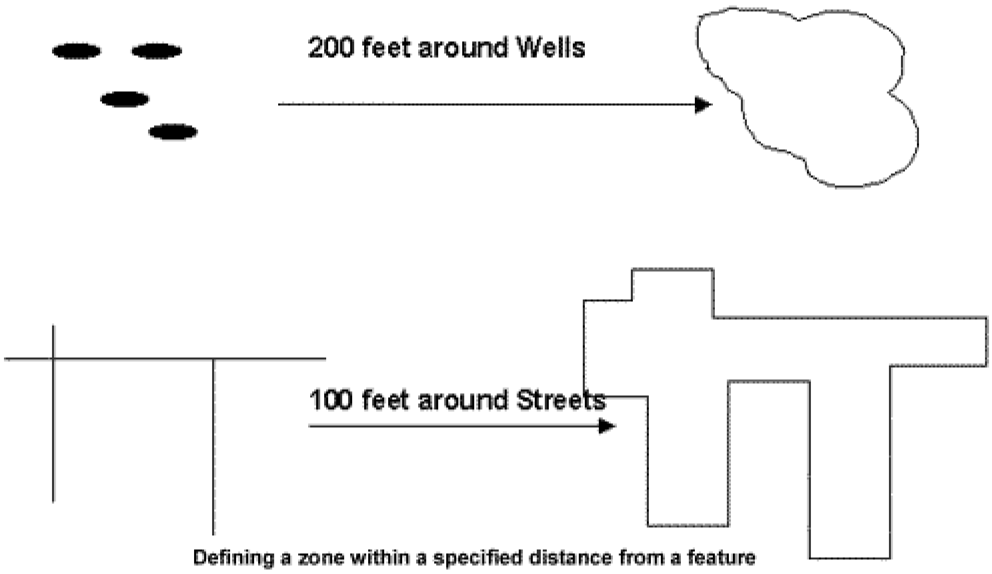
- Answer lies in the ability to find the shortest-path along a transportation network
- Routing involves "legal" travel from one point to another along a designated network
- Minimum path analysis involves finding out the shortest, fastest or most appropriate route

Buffering

- A buffer is a zone of fixed width around a map feature
- Buffer around a point takes the shape of a circle
- Buffer around a line takes the form of a corridor
- Buffer around a polygon taken the form of a bigger polygon
- Most of the GIS packages can buffer points, lines and polygons
- Very few packages are capable of handling concave polygons

Using these operations, the characteristics of an area surrounding in a specified location are evaluated. This kind of analysis is called proximity analysis and is used whenever analysis is required to identify surrounding geographic features. The buffer operation will generate polygon feature types irrespective of geographic features and delineates spatial proximity. For example, what are the effects on urban areas if the road is expanded by a hundred meters to delineate a five-kilometer buffer zone around the national park to protect it from grazing.

Using Buffer



Defining a zone within a specified distance from a feature

Overlay Operations

The hallmark of GIS is overlay operations. Using these operations, new spatial elements are created by the overlaying of maps. There are basically two different types of overlay operations depending upon data structures:

Raster overlay It is a relatively straightforward operation and often many data sets can be combined and displayed at once.

Vector overlay The vector overlay, however is far more difficult and complex and involves more processing.

Logical Operators The concept of map logic can be applied during overlay. The logical operators are Boolean functions. There are basically four types of Boolean Operators: viz., OR, AND, NOT, and XOR.With the use of logical, or Boolean, operators spatial elements / or attributes are selected that fulfill certain condition, depending on two or more spatial elements or attributes.

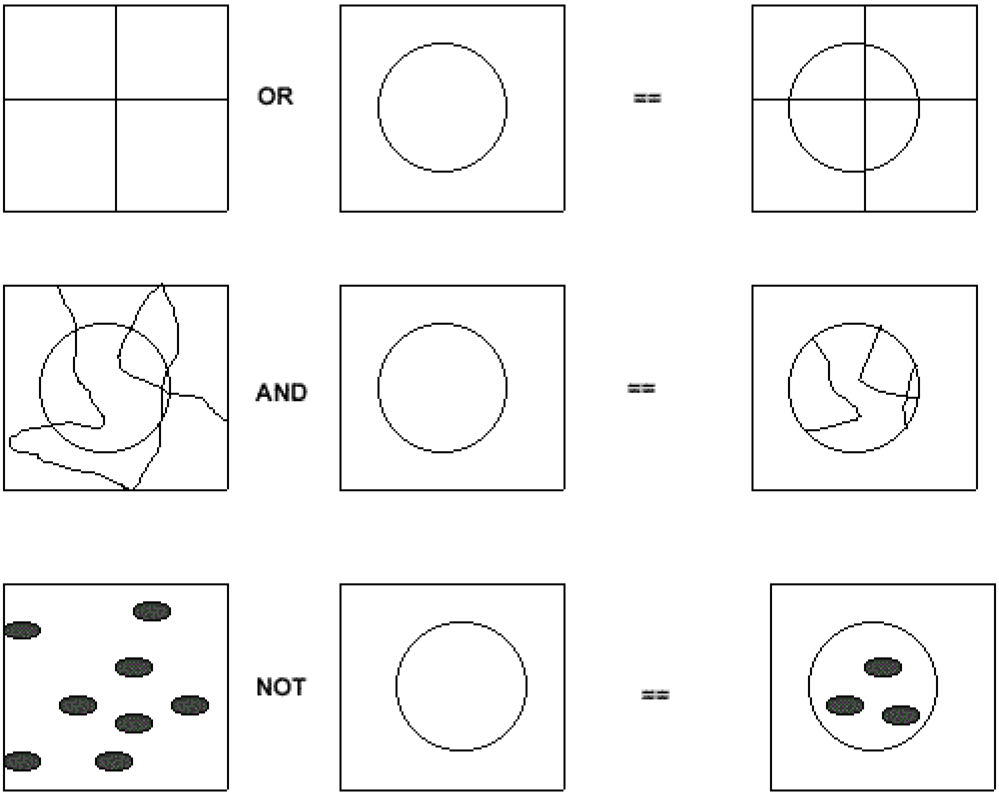
Vector Overlay During vector overlay, map features and the associated attributes are integrated to produce new composite maps. Logical rules can be applied to how the maps are combined. Vector overlay can be performed on different types of map features: viz., Polygon-on-polygon overlay

Line-in-polygon overlay

Point-on-polygon overlay.

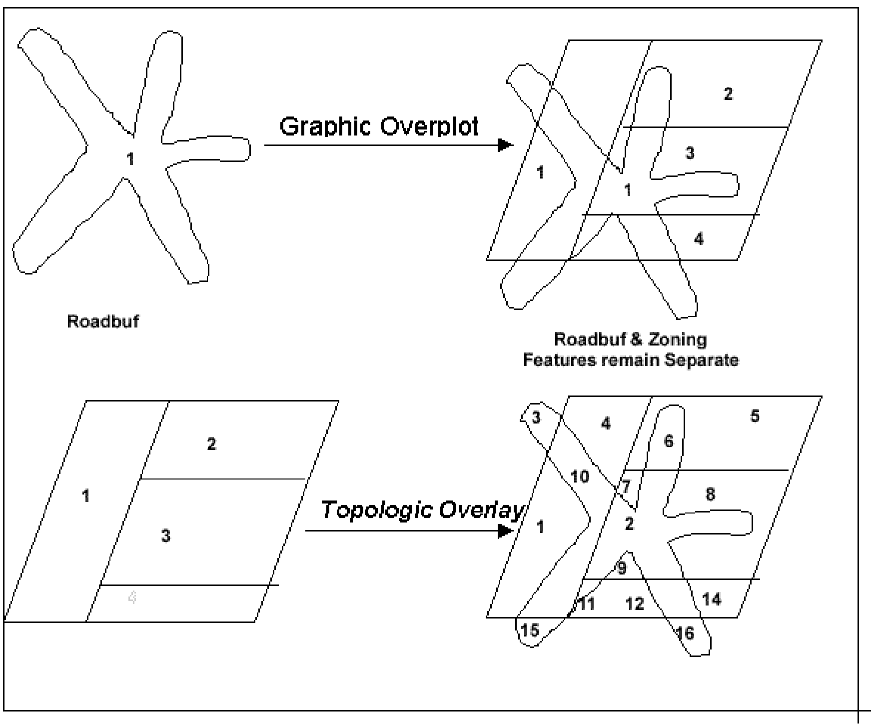
During the process of overlay, the attribute data associated with each feature type id merged. The resulting table will contain both the attribute data. The process of overlay will depend upon the modelling approach the user needs. One might need to carry out a series of overlay procedures to arrive at the conclusion, which depends upon the criterion.

Polygon-on-Polygon Overlay



Polygon-on-Polygon Overlay

Difference between a Topologic Overlay and a Graphic Over plot



Distance, Adjacency and Proximity Analysis

- Distance analysis refers to the ability to calculate *distances* from a map or along a transportation network
- Adjacency analysis refers to the ability to determine which of the map features TOUCH or are adjacent to other map features
- Proximity analysis refers to the ability to determine which of the map features are NEAR or in the neighbourhood of the referred map features
- All available GIS packages can estimate aerial distances
- A more limited set can estimate distances along road network
- Very few GIS packages can "*directly*" perform adjacency/ proximity analysis

Analysis of Geographic Data

ANALYSIS - What? & Why? The heart of GIS is the analytical capabilities of the system. What distinguish the GIS system from other information system are its spatial analysis functions. Although the data input is, in general, the most time consuming part, it is for data analysis that GIS is used. The analysis functions use the spatial and non-spatial attributes in the database to answer questions about the real world. Geographic analysis facilitates the study of real-world processes by developing and applying models. Such models illuminate the underlying trends in geographic data and thus make new information available. Results of geographic analysis can be communicated with the help of maps, or both. The organization of database into map layers is not simply for reasons of organizational clarity, rather it is to provide rapid access to data elements required for geographic analysis. The objective of geographic analysis is to transform data into useful information to satisfy the requirements or objectives of decision-makers at all levels in terms of detail. An important use of the analysis is the possibility of predicting events in the another location or at another point in time.

ANALYSIS - How? Before commencing geographic analysis, one needs to assess the problem and establish an objective. The analysis requires step-by-step procedures to arrive at the conclusions. The range of geographical analysis procedures can be subdivided into the following categories.

- Database Query.
- Overlay.
- Proximity analysis.
- Network analysis.
- Digital Terrain Model.
- Statistical and Tabular Analysis.

Spatial Analysis

It helps us to:

- Identify trends on the data.
- Create new relationships from the data.
- View complex relationships between data sets.
- Make better decisions.

Geographic Analysis

Analysis of problems with some Geographic Aspects.

- Alternatives are geographic locations or areas.
- Decisions would affect locations or areas.

- Geographic relationships are important in decision-making or modelling.

Some examples of its application:

- Nearest Neighbour.
- Network distances.

Planar distances

Tabular Statistical Analysis

If in the above road network we have categorised the streets then in such a case the statistical analysis answers questions like

- What unique categories do I have for streets?
- How many features do I have for each unique category?
- Summarize by using any attribute?

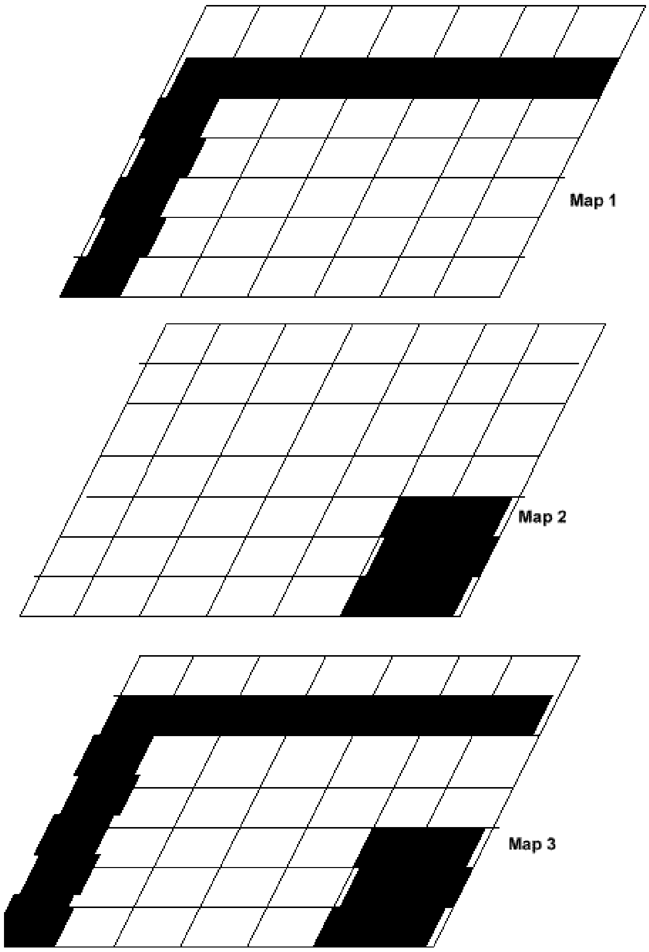
Database Query The selective display and retrieval of information from a database are among the fundamental requirements of GIS. The ability to selectively retrieve information from GIS is an important facility. Database query simply asks to see already stored information. Basically there are two types of query most general GIS allow: viz., Query by attribute,

Query by geometry. Map features can be retrieved on the basis of attributes, For example, show all the urban areas having the population density greater than 1,000 per square kilometer, Many GIS include a sophisticated function of RDBMS known as Standard Query Language (SQL), to search a GIS database. The attribute database, in general, is stored in a table (relational database mode.) with a unique code linked to the geometric data. This database can be searched with specific characteristics. However, more complex queries can be made with the help of SQL. GIS can carry out a number of geometric queries. The simplest application, for example, is to show the attributes of displayed objects by identifying them with a graphical cursor. There are five forms of primitive geometric query: viz., Query by point, Query by rectangle, Query by circle, Query by line, Query by polygon, A more complex query still is one that uses both geometric and attributes search criteria together. Many GIS force the separation of the two different types of query. However, some GIS, using databases to store both geometric and attribute data, allow true hybrid spatial queries.

Conditional Operators

Conditional operators were already used in the examples given above. The all evaluate whether a certain condition has been met.

= eq 'equal' operator<> ne 'non-equal' operator< lt 'less than' operator<= le 'less than or equal' operator> gt 'greater than' operator>= ge 'greater than or equal' operator. Many systems now can handle both vector and raster data. The vector maps can be easily draped on to the raster maps.



Raster Overlay

Current and Future Role of GIS

- Users should periodically examine the requirement for GIS and whether their system continues to meet those needs
- GIS is yet to be used in a large way for terrain visualisation, 3-D analysis, resource information and organisation planning.

Reference

Sankhua, R N (1999 to 2010), Lecture notes on GIS training courses, NWA

REMOTE SENSING: SATELLITES AND SENSORS

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1.0 REMOTE SENSING

Remote sensing is the science and the art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object (Lillesand and Kiefer, 1987). Remote sensing can be thought of as a reading process. Using various sensors, the data can be collected remotely and analysed to obtain information. The remotely sensed data can be of many forms, including acoustic wave distributions, or electromagnetic wave distributions. Commonly, the remote sensing is referred to the collection and analysis of data regarding earth using electromagnetic sensors, which are operated from airborne and space borne platforms. These sensors acquire data on the way the various earth surface features emit and reflect electromagnetic energy and these data are analysed to provide information about the resources under investigations.

The two basic processes involved in electromagnetic remote sensing are data acquisition and data analysis. The elements of data acquisition process are energy sources, propagation of energy through the atmosphere, energy interaction with the earth surface features, re-transmission of energy through the atmosphere, airborne and/or space-borne sensors, resulting in the generation of sensor data in pictorial and/or digital form. In short, we use sensors to record variations in the way earth surface features reflect and emit electromagnetic energy. The data analysis process involves examining the data using various viewing and interpretation devices to analyse pictorial data, and/or a computer to analyse digital sensor data. Reference data about the resources being studied are used when and where available to assist in the data analysis. The information is then compiled, generally in the form of hard copy maps and tables, or as computer files that can be merged with the other 'layers' of information in a Geographical Information System (GIS).

1.1 Energy Sources and Radiation Principles

Visible light is only one of many forms of electromagnetic wave energy. Radio waves, heat, ultraviolet rays and X-rays are other familiar forms. All this energy is inherently similar and radiates in accordance with basic wave theory. The wave theory describes electromagnetic energy as traveling in a harmonic, sinusoidal fashion at the 'velocity of light' c. The distance from one wave peak to the next is the wavelength λ and the number of peaks passing a fixed point in space per unit time is the wave frequency ν From basic physics, wave obey the general equation

$$c = \nu\lambda$$

In remote sensing, it is most common to categories electromagnetic waves by their wavelength location within the electromagnetic spectrum (Figure 1). The most prevalent unit used to measure wavelength along the spectrum is the micrometer (μm). Although names are generally assigned to regions of electromagnetic spectrum for convenience (such as ultraviolet and microwave), there is no clear-cut dividing line between one nominal region and the next. The visible portion of the electromagnetic spectrum is small, since the spectral sensitivity of the human eye extends only from about 0.4 μm to 0.7 μm. The color blue is ascribed to the approximate range of 0.4 to 0.5 μm, green to 0.5 to 0.6 μm, and red to 0.6 to 0.7 μm. Ultraviolet energy adjoins the blue end of the visible portion of the spectrum. Adjoining the red end of the visible portion are three different categories of infrared (IR) waves: near-IR (from 0.7 to 1.3 μm), mid-IR (1.3 to 3 μm) and thermal IR (beyond 3 μm). At much longer wavelengths (1mm to 1m) is the microwave portion of the spectrum.

Most common sensing systems operate in one or several of the visible, IR, or microwave portions of the spectrum. Within the IR portion of the spectrum, only thermal IR energy is directly related to the sensation of heat.

According to the quantum theory, the electromagnetic radiation is composed of many discrete units called photons or quanta and the energy of quantum is inversely proportional to its wavelength. The longer the wavelength involved the lower its energy content. This has important implications in remote sensing from the standpoint that naturally emitted long wavelength radiation, such as microwave emission, is more difficult to sense than radiation of shorter wavelengths, such as emitted thermal IR energy.

The sun is the most obvious source of electromagnetic radiation for remote sensing. However, all matter at temperatures above absolute zero continuously emits electromagnetic radiation. The energy emitted from an object is a function of its temperature. The earth radiates the maximum energy at a wavelength of about 9.7 μm. Because this radiation correlates with terrestrial heat; it is termed as 'thermal infrared' energy. This energy can neither seen or photographed, but can be sensed with radiometers. The sun emits maximum energy at about 0.5 μm. Our eyes are sensitive to energy of this magnitude and wavelength. Thus, when the sun is present, we can observe earth features by virtue of reflected solar energy. The general dividing line between reflected and emitted IR wavelength is about 3 μm. Below this wavelength, reflected energy predominates; above it emitted energy prevails.

Certain sensors, such as radar systems, supply their own source of energy to illuminate features of interest. These systems are termed as 'active' systems, in contrast to 'passive' systems that sense naturally available energy.

1.2 Data Acquisition and Interpretation

The detection of electromagnetic energy can be performed either photographically or electronically. In remote sensing, the term photograph is reserved exclusively for that are detected as well as recorded on film. The more generic term image is used for any pictorial representation of image data. Because the term image relates to any pictorial product, all photographs are images. Not all images however are photographs.

The data interpretation aspects of remote sensing can involve analysis of pictorial and/or digital data. Visual interpretation of pictorial image data has long been the workhorse of remote sensing. Visual interpretation techniques have certain disadvantages. They require extensive training. Spectral characteristics are not always fully evaluated in visual interpretation efforts. In applications where spectral patterns are highly informative, it is preferable to analyse digital, rather than pictorial, image data.

The digital image data is composed of a two dimensional array of discrete 'picture elements' or 'pixels'. The intensity of each pixel corresponds to the average brightness or radiance measured electronically over the ground area corresponding to each pixel. In the digital image data each pixel in a grid stores a Digital Number (DN). The DN values are positive integers that result from quantizing the original electrical signal from the sensor into positive integer values using a process called as analog-to-digital signal conversion. Typically the DN values of digital image range between 0 to 255, the range representing the set of integers that can be recorded using 8-bit binary computer coding scale.

The use of computer assisted analysis permits the spectral patterns in remote sensing data to be more fully examined. However, visual and numerical techniques are complimentary.

1.3 Digital Image Data

Remotely sensed image data are digital representation of objects on the earth. Image data are stored in data files, called as image files, on a magnetic tape, computer disks or other media. The data consists of only numbers, which are called as pixels. Each pixel represents an area of the earth at a specific location. The location of a pixel in a file is expressed using a two-dimensional co-ordinate system formed of rows and columns. Image data organised into such a grid are known as raster data. Image data may include several bands of information sometimes called as layers.

Image data can be arranged in several ways on a tape or other media. The most common storage formats are:

a) BIL (Band Interleaved by Line)
b) BSQ (Band Sequential)
c) BIP (Band Interleaved by Pixel)

Band interleaved by line (BIL) BIL is one of three primary methods for encoding image data for multiband raster images in the geospatial domain, such as images obtained from satellites. BIL is not in itself an image format, but is a scheme for storing the actual pixel values of an image in a file band by band for each line, or row, of the image. For example, given a three-band image, all three bands of data are written for row one, all three bands of data are written for row two, and so on. The BIL encoding is a compromise format, allowing fairly easy access to both spatial and spectral information. The BIL data organization can handle any number of bands, and thus accommodates black and white, grayscale, pseudocolor, true color, and multi-spectral image data. In BIL format, each record in the file contains a scan line (row) of data for one band. All bands of data for a given line are stored consecutively.

Band Sequential BSQ format is a very simple format, where each line of the data is followed immediately by the next line in the same spectral band. This format is optimal for spatial (x,y) access of any part of a single spectral band. The BSQ data organization can handle any number of bands, and thus accommodates black and white, grayscale, pseudo-colour, true color, and multi-spectral image data. In BSQ format, each band is contained in a separate file. This format is advantageous because one band can be read and viewed easily and multiple bands can be loaded in any order.

Band Interleaved by Pixel (BIP) Images stored in BIP format have the first pixel for all bands in sequential order, followed by the second pixel for all bands, followed by the third pixel for all bands, etc., interleaved up to the number of pixels. In BIP format, the values of each band are ordered within a given pixel. The pixels are arranged sequentially on the tape. For a single band of data, all formats (BIL, BSQ, and BIP) are identical.

2.0 SATELLITES AND SENSORS

Launching of a Landsat 1 satellite, originally known, as Earth Resource Technology satellite (ERTS) by NASA on 23 July 1972 was the beginning of a modern remote sensing application for earth resource studies. It was followed by Landsat-2, 3, 4 and 5 in the subsequent years. Three different types of sensors were flown in various combinations of these missions. These are the Return Beam Vidicon (RBV) camera systems, The Multispectral Scanner (MSS) systems and the Thematic Mapper (TM). In latter years, SPOT satellites were launched with different sensors for various applications.

2.1 Indian Earth Resources Satellites

During the 1970's and 80's, India's remote sensing data needs were being addressed by foreign satellites like LANDSAT, NOAA, SPOT etc., where NRSC procured the satellite data products from foreign agencies and supplied it to the users. With the setting up of an Earth Station at Hyderabad in 1979, satellite data reception started, first from USA's LANDSAT satellite.

The launch of India's first civilian remote sensing satellite IRS-1A in March 1988, marked the beginning of a successful journey in the course of the Indian Space Programme. The two LISS sensors aboard IRS-1A beamed down valuable data that aided in large scale mapping applications. Subsequently, IRS-1B, having similar sensors, was launched in August 1991, and together, they provided better repetivity. The LISS-III, PAN and WiFS sensors on IRS-1C (December 1995) and IRS-1D (September 1997) further strengthened the scope of remote sensing, with increased coverage and foray into application areas like resources survey and management, urban planning, forest studies, disaster monitoring and environmental studies.

IRS-P5 (Cartosat-1), launched on May 5, 2005, catapulted the Indian Remote Sensing program into the world of large-scale mapping and terrain modeling applications.

Foreign Satellites

Apart from the Indian Remote Sensing Satellites, NRSC acquires and distributes data from a number of foreign satellites. Currently, NRSC is acquiring data from NOAA-17, NOAA-18, TERRA, AQUA and ERS. Apart from acquiring NRSC also distributes data collected by RADARSAT, IKONOS, QUICKBIRD , ORBIMAGE and ENVISAT.

2.2 IRS-1A and IRS-1B

These are the operational first generation Indian Remote Sensing Satellites launched in March 1988 and August 1991 respectively. They have been put into a polar sun-synchronous orbit at an altitude of 904 km. In the sun-synchronous orbit, the orbit plane rotates at the same speed as the speed of rotation of earth around the sun (0.986 deg/day). Thus, the satellite passes over particular latitude at the same local time. It enables study of the earth surface at various seasons under the same illumination conditions. Both of these satellites carry two Linear Imaging Self-Scanning Sensors (LISS), one with a spatial resolution of 72.5m (LISS-I) and the other with a spatial resolution of 36.25m (LISS II). The swath (ground coverage) is 148 km. The repeativity of scanning is 22 days. LISS-I and II sensors provide multispectral data collected in four bands of visible and near IR region (0.45 to 0.86 μm). The details of these bands are given in Table – 1.

Table – 1 : LISS-I and LISS-II Bands and Applications

Band Number	Spectral Range	Application Area
B1	0.45 – 0.52 μm	Designed for water body penetration, making it useful for coastal water mapping. Also useful for soil/vegetation, forest type mapping and cultural feature identification.
B2	0.52 – 0.59 μm	Designed to measure green reflectance peak of vegetation. Useful for vegetation discrimination, cultural feature identification and turbidity of water.
B3	0.62 – 0.68 μm	Discrimination of plant species and cultural feature identification.
B4	0.77 – 0.86 μm	Delineation of water bodies, vegetation type, soil moisture and land form studies

Although the design life was three years, IRS-IA was in service until October 1992 and IRS-1B is still in service providing good quality data.

2.3 IRS-1C

IRS-1C is the first of the second generation, operational, multi-sensor satellite with improved sensor and coverage characteristics besides having an On Board Tape Recorder (OBTR) for obtaining data outside the visibility of receiving stations. IRS-1C was launched on 26 December 1995. The three sensors on-board IRS-1C Satellite are:

a) Panchromatic (PAN) sensor with a resolution of 5.8m in one band in the visual region with a swath of 70 km with 26 deg across track tilt capability,
b) LISS-III multispectral sensor with a resolution of 23.5 m in three spectral ranges viz. visible, near infrared and Shortwave Infra-Red (SWIR) bands with swath of 141 km.
c) Wide Field Sensor (WiFS) with a resolution of 188 m in two bands in the visible\near infra-red region with a swath of 810 km.

2.4 IRS-1D

IRS-1D is identical to the IRS-1C satellite with a continuous data supply. IRS-1D was launched in September 1997 by Polar Satellite Launching Vehicle (PSLV). The IRS-1D has a sun synchronous orbit at height of 817 km with repeativity of 24 days (341 orbits). The payload consists of three sensors, the details of which are given in Table – 2.

Table – 2 : IRS-1D Sensor Characteristics

	LISS-III	PAN	WiFS
Spectral Bands	B2) 0.52 - 0.59 μm B3) 0.62 - 0.68 μm B4) 0.77 - 0.86 μm B5) 1.55 - 1.70 μm	0.50 - 0.75 μm	B3) 0.62-0.68 μm B4) 0.77-0.86μm
Ground Resolution	23.5m (B2, B3 & B4) 70.5m (B5)	5.8 m	188.3 m
Swath	141 km (B2, B3 & B4) 148 km (B5)	70 km	810 km

2.5 IRS P5

The CARTOSAT-1 (IRS-P5) is envisaged as a mission to meet the stereo data requirements of the user community. The objectives of the mission was to design, develop, launch and operate an advanced space based mission with enhanced spatial resolution (2.5m) with along track stereo viewing capability for large scale mapping applications (up to 1:5000 scale) . To further stimulate newer areas of cartographic applications, urban management, disaster assessment, relief planning and management, environmental impact assessment and GIS applications. CARTOSAT-1 is a global mission. The nominal life of the mission is planned to be five years. The satellite was launched by the indigenously built Polar Satellite Launch Vehicle on May 05, 2005.

2.6 IRS P6

The RESOURCESAT-1 (IRS-P6) is envisaged as the continuity mission to IRS-1C/1D, with enhanced capabilities both in the payload and the platform, to meet the increasing demands of the user community. The objectives of the mission are to provide continued remote sensing data services on an operational basis for integrated land and water resources management at micro level, with enhanced spectral and spatial coverage and stereo imaging. Carry out studies in advanced areas of user applications like improved crop discrimination, crop yield, crop stress, pest/disease surveillance, disaster management etc.,.

The payload system of IRS-P6 consists of three solid state cameras :
1. A high resolution multispectral sensor - LISS-IV
2. A medium resolution multispectral sensor - LISS-III
3. An Advanced Wide Field Sensor – AWiFS

2.7 IKONUS

Ikonus satellite is launched in 1999.
Resolution: 0.82 meters Panchromatic.
3.2 meters Multi-spectra

Spectral Range: Blue: 445-516 nm
Green: 506-595 nm
Red 632-698 nm
NIR: 757-853 nm
Pan: 450-900 nm

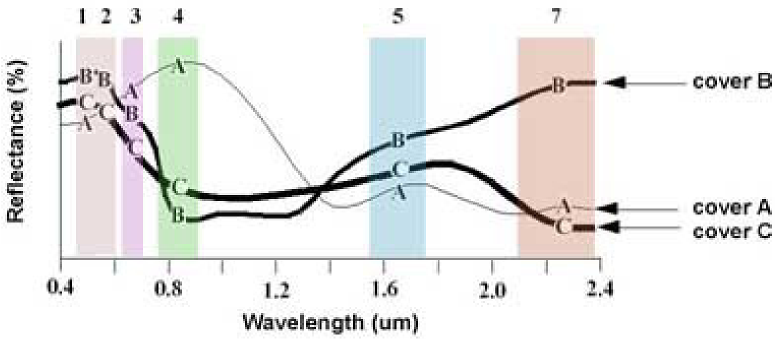
3.0 DIGITAL IMAGE PROCESSING

Digital image processing involves the manipulation and interpretation of digital image with the aid of a computer. The central idea behind digital image processing is simple. The digital image is fed into a computer. The computer is programmed to insert these data into an equation, or series of equations, and then store results of the computation for each pixel. These results form a new digital image that may be displayed or recorded in pictorial format or may be manipulated by additional programs. Thus, Image processing is a technique for improving image quality for interpretation. The image processing procedures may be categorised into one of the following three broad types of computer assisted operations:

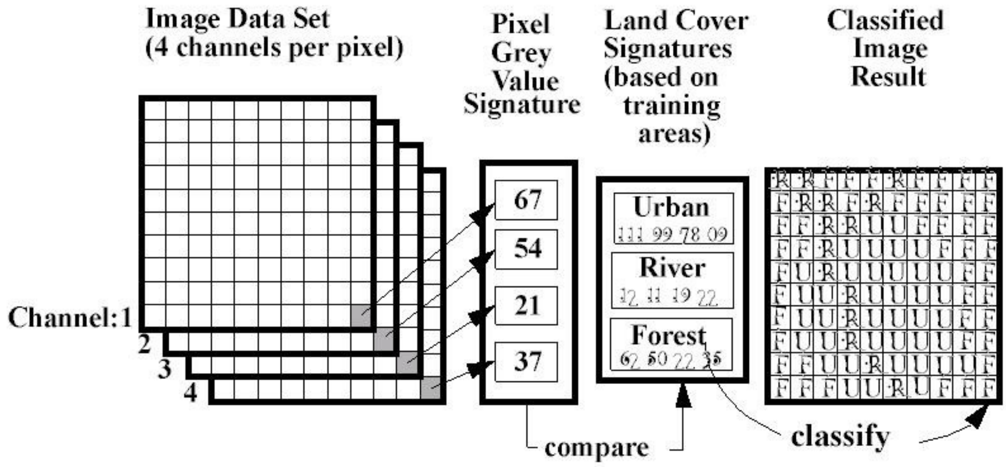
3.1 Pre-processing (Image rectification and restoration): Image rectification is a transformation process used to project two-or-more images onto a common image plane. It corrects image distortion by transforming the image into a standard coordinate system. Image rectification in GIS converts images to a standard map coordinate system. This is done by matching ground control points (GCP) in the mapping system to points in the image. These GCPs calculate necessary image transforms.

3.2 Image enchantement : the process of improving the quality of a digitally stored image by manipulating / enhancing the image with software. It is quite easy, for example, to make an image lighter or darker, or to increase or decrease contrast. Advanced image enhancement software also supports many filters for altering images in various ways. Programs specialized for image enhancement are sometimes called image editors.

3.3 Image classification : The intent of the classification process is to categorize all pixels in a digital image into one of several land cover classes, or *"themes"*. This categorized data may then be used to produce thematic maps of the land cover present in an image. Normally, multispectral data are used to perform the classification and, indeed, the spectral pattern present within the data for each pixel is used as the numerical basis for categorization (Lillesand and Kiefer, 1994). The objective of image classification is to identify and portray, as a unique gray level (or color), the features occurring in an image in terms of the object or type of land cover these features actually represent on the ground.



3.3.1 **Supervised Classification** With supervised classification, we identify examples of the Information classes (i.e., land cover type) of interest in the image. These are called *"training sites"*. The image processing software system is then used to develop a statistical characterization of the reflectance for each information class. This stage is often called "*signature analysis"* and may involve developing a characterization as simple as the mean or the rage of reflectance on each bands, or as complex as detailed analyses of the mean, variances and covariance over all bands. Once a statistical characterization has been achieved for each information class, the image is then classified by examining the reflectance for each pixel and making a decision about which of the signatures it resembles most.

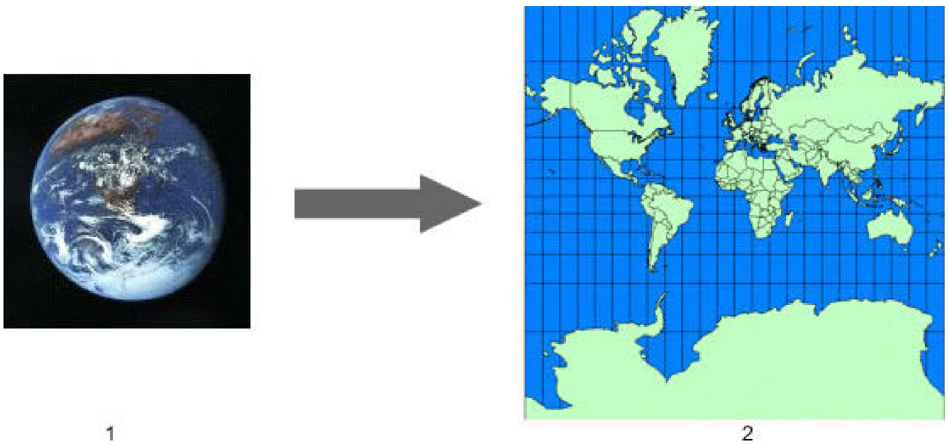


3.3.2 **Unsupervised Classification:** Unsupervised classification is a method which examines a large number of unknown pixels and divides into a number of classed based on natural groupings present in the image values. unlike supervised classification, unsupervised classification does not require analyst-specified training data. The basic premise is that values within a given cover type should be close together in the measurement space (i.e. have similar gray levels), whereas data in different classes should be comparatively well separated (i.e. have very different gray levels) The classes that result from unsupervised classification are spectral classed which based on natural groupings of the image values, the identity of the spectral class will not be initially known, must compare classified data to some from of reference data (such as larger scale imagery, maps, or site visits) to determine the identity and informational values of the spectral classes. Thus, in the supervised approach, to define useful information categories and then examine their spectral separability; in the unsupervised approach the computer determines spectrally separable class, and then define their information value.

3.3.3 **Sub-setting:** Many images used in IMAGINE cover a large area, while the actual area being studied can only cover a small portion of the image. To save on disk space and processing time, you can make new images out of a subset of the entire data set.

3.3.4 **Mosaicing:** Mosaicing is the seamless joining or stitching of adjacent imagery. Joining Landsat / IRS imagery that was collected along the same satellite path (one image taken after the other) is straightforward with very little time elapsing between imagery collection, the atmosphere and sensor properties do not change (that much). However, when joining adjacent imagery from different paths, several days to a couple of weeks can pass. As such, here is a need to adjust the radiometric differences between the images in an effort to make the join appear seamless.

3.3.5 **Map Projection:** A map projection is a mathematical expression that is used to represent the round, 3D surface of the earth on a flat, 2D map. In other terms. Map projection is a systematic transformation of the latitudes and longitudes of locations on the surface of a sphere or an ellipsoid into locations on a plane. Map projections are necessary for creating maps. All map projections distort the surface in some fashion. Depending on the purpose of the map, some distortions are acceptable and others are not; therefore different map projections exist in order to preserve some properties of the sphere-like body at the expense of other properties. There is no limit to the number of possible map projections.



1. 3D earth 2.Mercator Projection

This process always results in distortion to one or more map properties, such as area, scale, shape, or direction. Because of this, hundreds of projections have been developed in order to accurately represent a particular map element or to best suit a particular type of map.

Data sources for maps come in various projections depending upon which characteristic the cartographer chooses to represent more accurately (at the expense of other characteristics). In the example above, the Mercator projection preserves the right angles of the latitude and longitudinal lines at the expense of area, which is distorted at the poles, showing the land masses there to be larger than they actually are.

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GLOBAL NAVIGATION SATELLITE SYSTEM AND ITS APPLICATION

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ABSTRACT

This article is prepared to give a basic knowledge about the Global navigation satellite system (GNSS), which consists of Global Positioning System (GPS) System with a special emphasis to the applications on Geographical Information System (GIS) in water resources applications. The GPS has variety of applications and hence it is essential to understand the technology so that the required information of our choice is extracted. The advantages and the limitations of GPS, use of Differential GPS (DGPS) are explained. Role of GPS in GIS environment is also discussed. One case study to estimate siltation of reservoirs, where GPS system along with GIS software is used is also explained.

INTRODUCTION

Global Navigation Satellite Systems (GNSS) represent the satellite navigation systems that provide autonomous geo-spatial positioning with global coverage. The core satellite navigation systems currently are GPS, Galileo and GLONASS, three systems developed by three political and economic powers, which are in various states of maturity and robustness. The development of the NAVSTAR GPS took nearly 20 years and cost more than $10 billion. It is the first and currently the only fully operational GNSS, globally available since 1994, consisting on 32 medium Earth orbit satellites. Galileo and GLONASS are in development stages, with Galileo having 2 test bed satellites in orbit since 2005 and with the first two of four operational satellites to validate the system launched on October 2011. Full completion of the 30 satellites Galileo system (27 operational + 3 active spares) is expected by 2019. With the approval for development granted in 1970 by the Soviet Union, GLONASS reached full operation in 1995 by the hand of Russia Federation. After that there were no further launches until December 1999. By 2011, the full orbital constellation of 24 satellites was restored, enabling full global coverage. The GLONASS satellite designs have undergone several upgrades, with the latest version under implementation being GLONASS-K. With GNSS, availability of two or more constellations, more than doubling the total number of available satellites in the sky, will enhance service quality, increasing the number of potential users and applications. Traditional GNSS receivers designs are based on closed hardware implementations and signal processing. In an effort to take advantage of the rapid innovation of this technology, turning to open-architecture systems and software defined radios (SDRs) is the alternative to traditional receiver closed system designs. Compared with traditional receivers, the SDR has much more flexibility, especially in the GNSS receiver area. This makes SDRs an ideal platform for development, test of algorithms and integration with other devices without the need of hardware replacement. This would likely be impractical to be done in traditional receivers and is one key element to keep pace with the changing technology without the cost of a complete redesign. A SDR consists of two components, the hardware front-end implementation and the software signal processing, both presented and described throughout this document. A well-designed hardware ensures a proper functioning and a good foundation capable of being updated, extending the life-time of the product. This document will introduce the design of a GNSS single frequency L1 band (civilian-use signal) SDR receiver, for the GPS, Galileo and GLONASS signals from the hardware point-of-view, although validation will be accomplished through the use of open-source signal-processing software.

1.2 Goals, requirements and tasks

The main objective of this work is to develop an open-architecture sampler for the combined GPS/Galileo/GLONASS L1 signals. As it will be shown along this document, this sampler will be a key component for accessing the potentialities offered by these systems. The main requirements for this project are:

1. Interoperability between GPS, Galileo and GLONASS systems;
2. Use of a flexible and efficient configurable front-end chipset;
3. Data transmission through an IP interface, optimized for maximum throughput to enable maximum acquisition rate performance;
4. The developed system should be platform independent, intended for all types of users;
5. Easy-to-use graphical user interface (GUI).

In order to achieve these objectives, the following set of key tasks were established and met:

1. Study GNSS characteristics and interoperability;
2. Research about current SDR implementations, algorithms and currently active projects;
3. Study of Ethernet Protocols and implementations;
4. Study hardware components characteristics and implementations to guarantee the best trade-off between price, efficiency and performance;
5. Implement glue logic Serial-in to Parallel-out (SIPO)/Parallel-in to Parallel-out (PIPO) by means of HDL language and map it into a Complex Programmable Logic Device (CPLD);
6. Research about best implementations and develop an application to interface with the receiver.
7. Design, develop and test the system printed circuit board (PCB);
8. Test and experimental characterize the developed system.

1.3 Outline

What follows is a brief summary of this document organization. Section 2 provides an overview of satellite navigation fundamentals and GNSS signal standards. Working frequencies and their modulations are presented as well as the navigation message format. The interoperability between the targeted systems is also discussed. In section 3, the basis of a GNSS receiver is presented with the hardware and software briefly described. Also in this section, existing SDRs and their conception are presented, namely the first complete SDR-GPS implementation, as well as other current implementations. Section 4 introduces the embedded system architecture. All the considered hardware is explained in detail along with the developed software. Fabrication concerns are described and the complete developed system is presented. In section 5, the user interfaces are demonstrated and described. Once the design and fabrication of the receiver has been carried out, validation is required. Section 6 deals with the characterization of the system and validation. Finally, some conclusions and future work suggestions are presented in section 7.

2 GNSS Fundamentals and Systems Overview

2.1 Introduction

In order to design a software-defined single frequency GNSS receiver, firstly the fundamentals of satellite navigation and its principles must be analysed. This section deals with the systems overview, also the characteristics of the signal and data transmitted from the satellites and received by the Radio Frequency (RF) front-end. These characteristics will impose steps to take in the course of the system development.

2.2 Satellite navigation principles

Satellite navigation systems are comprised of three functional segments: The *space segment*, corresponding to the operating satellites constellation; the *control segment*, corresponding to the ground stations involved in the monitoring of the system; and the *user segment*, represented by the receivers for the civilian and military use. All satellite navigation systems determine coordinates using the same basic principles. Consider the simple model shown in Figure 2.1, where a transmitter and a receiver with synchronized clocks are located in a one dimensional plane. Knowing that a radio wave propagates at the speed of light of around 300000 km/s, by measuring the delay from when the signal is transmitted to when it is received, it is possible to assess the receiver distance from the transmitter. However, there can be a discrepancy between the clocks of the transmitter and the receiver, leading to a large error in the calculated distance.

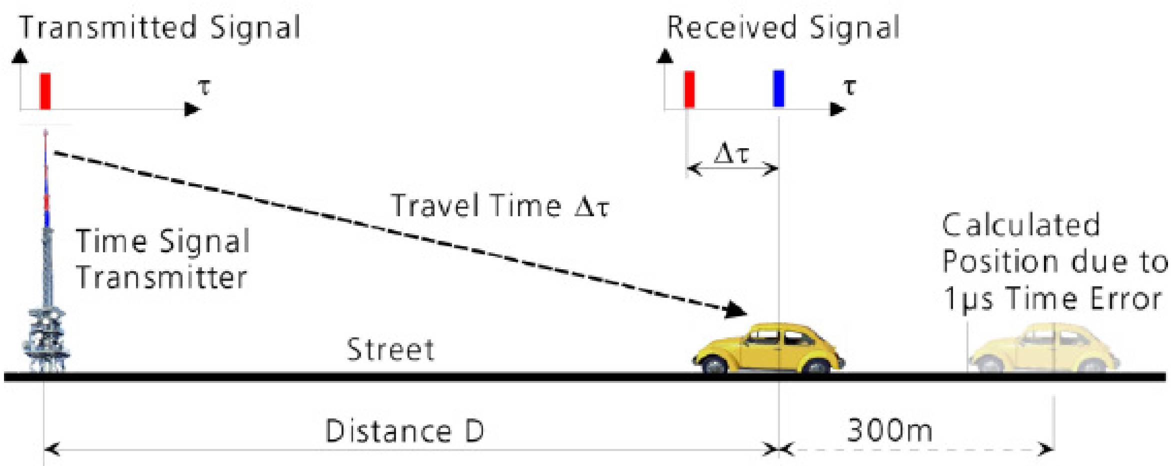


Figure 2.1 – 1D simple model navigation principle [3].

To overcome the local clock synchronization discrepancy, a second synchronized time signal transmitter where the separation to the first transmitter is known, can be used to outfit the exact same clocks, as shown in Figure 2.2 – 1D simple model with two transmitter. From this model a conclusion can be drawn: in order to exactly determine the position and time along a one dimension plane, at least two time signal transmitters are required. Now, this conclusion can be extrapolated to more dimensions. It is then possible to say that when an unsynchronized receiver clock is employed in calculating position, it is necessary that the number of time signal transmitters exceed the number of unknown dimensions by a value of one. Satellite navigation systems use satellites as time-signal transmitters. In order for a GNSS receiver to determine its position, it must receive time signals from at least four separate satellites, represented in Figure 2.3, to calculate the signal travel times Δt1 to Δt4.

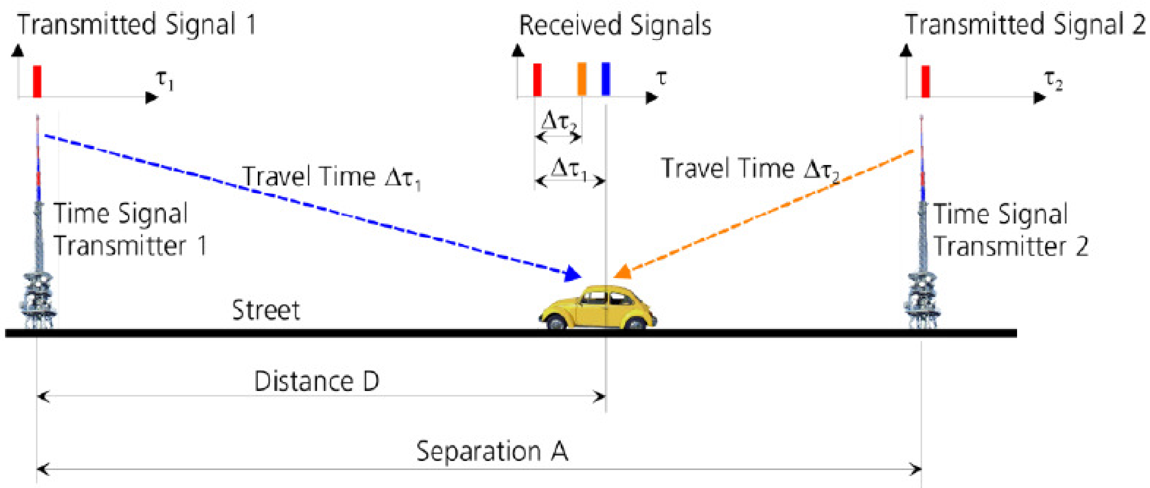


Figure 2.2 – 1D simple model with two transmitter [3].-

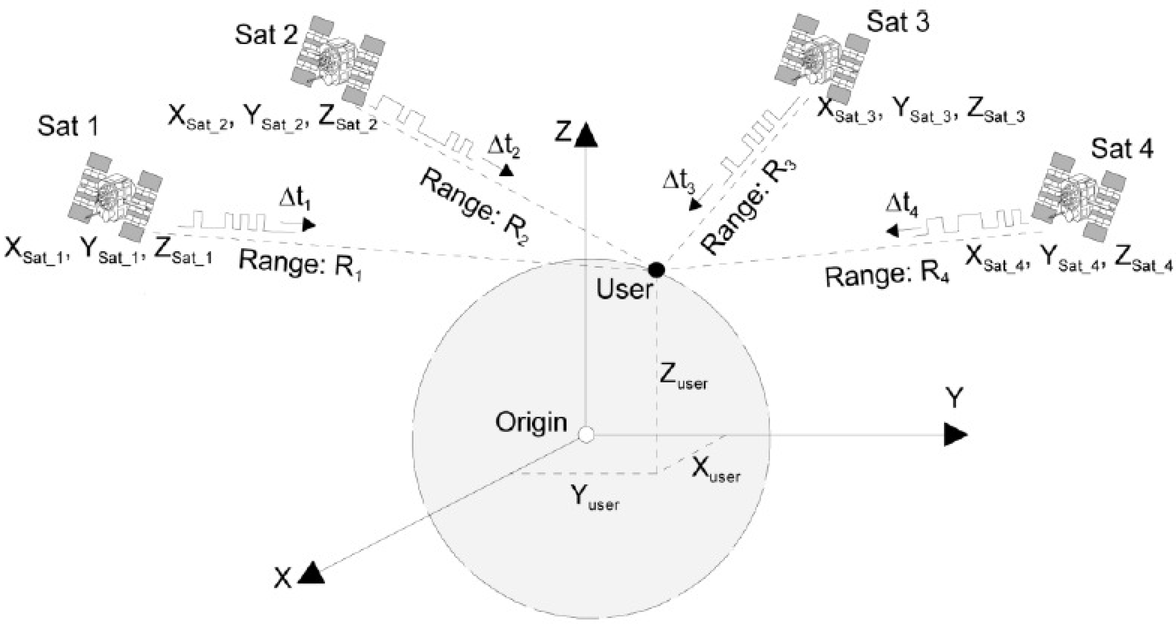


Figure 2.3 – Four satellites are required to determine a position in 3-D space.

Calculations are effected in a Cartesian, three-dimensional coordinate system with a geocentric origin. The range of the user from each of the four satellites, R1 to R4, can be determined with the help of the calculated signal travel times between the satellites and the receiver. As the locations XSat, YSat and ZSat of the four satellites are known, the user coordinates can be calculated.

2.3 Global Navigation Satellite Systems

Having the satellite navigation principles briefly studied. In this sub-section, the GPS and Galileo and GLONASS standards are explained in more detail.

2.3.1 GPS

The NAVSTAR GPS is a continuously available, satellite-based RF positioning system providing highly accurate position, velocity and time (PVT). The baseline system is specified for 24 satellites, however the system currently employs 28-31 satellites, in a constellation of 6 orbital planes inclined 55 degrees to the equator, at 20,183 Km from the mean surface of the Earth. Each plane contains 4-7 active satellites. Although other signals are being planned and studied for future implementation, the GPS, at present, transmits only on two carrier radio frequencies in the UHF band, referred to as L1 and L2 frequencies. Table 2.1 contains current and planned GPS carrier radio frequencies. As stated in, three signals are transmitted at the moment by GPS in L1: C/A Code and P(Y) Code. In the future, an additional new civil signal, known as L1C and military M-Code, will also be transmitted.

Table 2.1 – GPS Frequency plan. Band	**Frequency [MHz]**	**Bandwidth [MHz]**	**Description**
L1	1575.420	~ 12	Coarse-acquisition (C/A) & encrypted precision P(Y) codes + L1 civilian (L1C) & military (M) codes on future Block III satellites.
[L1C/A	**1575.420**	**2.046]**	**Coarse-acquisition (C/A)**
L2	1227.600	~ 12	P(Y) code + L2C & military codes on the Block IIR-M.
L3	1381.050	Used for nuclear detonation (NUDET) detection.	
L4	1379.913	Being studied for additional ionospheric correction.	
L5	1176.460	~ 12	Proposed for use as a civilian safety-of-life (SoL) signal.

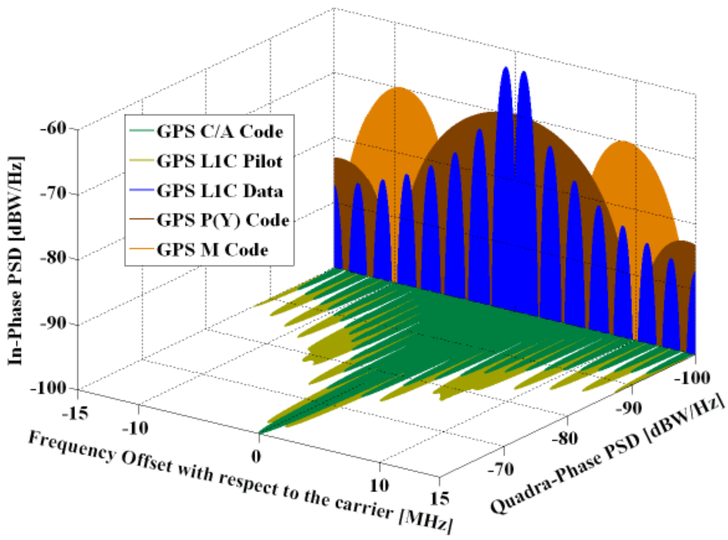


Figure 2.5 – Spectra of GPS Signals in L1 [1].

2.3.2 Galileo

The Galileo space segment constellation will comprise a constellation of a total of 30 Medium Earth Orbit satellites, of which 3 are spares. The Galileo satellite constellation has been optimised to have three equally spaced orbital planes, at an altitude of 23,222 km with an inclination of 56°. Each orbital plane would have 9 operational satellites, equally spaced and 1 spare satellite (also transmitting). Each Galileo satellite will broadcast 10 different navigation signals in the frequency ranges 1164–1215 MHz (E5 band), 1260–1300 MHz (E6 band), and 1559–1592 MHz (E2-L1-E1 band), making it possible for Galileo to offer an open service (OS), safety-of-life service (SoL), commercial service (CS) and public regulated service (PRS). All satellites will make use of the same carrier frequencies with different ranging codes again through CDMA transmission. Six signals [1], including three data-less channels, so-called pilot tones (ranging codes not modulated by data), are accessible to all Galileo users on the E5a, E5b and L1 carrier frequencies for Open Services and Safety-of-life Services and their accessibility are free of direct charge. Two signals on E6 with encrypted ranging codes, including one dataless channel are accessible only to some dedicated users that gain access through a given Commercial Service provider. Finally, two signals, one in E6 band and one in E2-L1-E1 band, with encrypted ranging codes and data are accessible to authorized users of the Public Regulated Service.

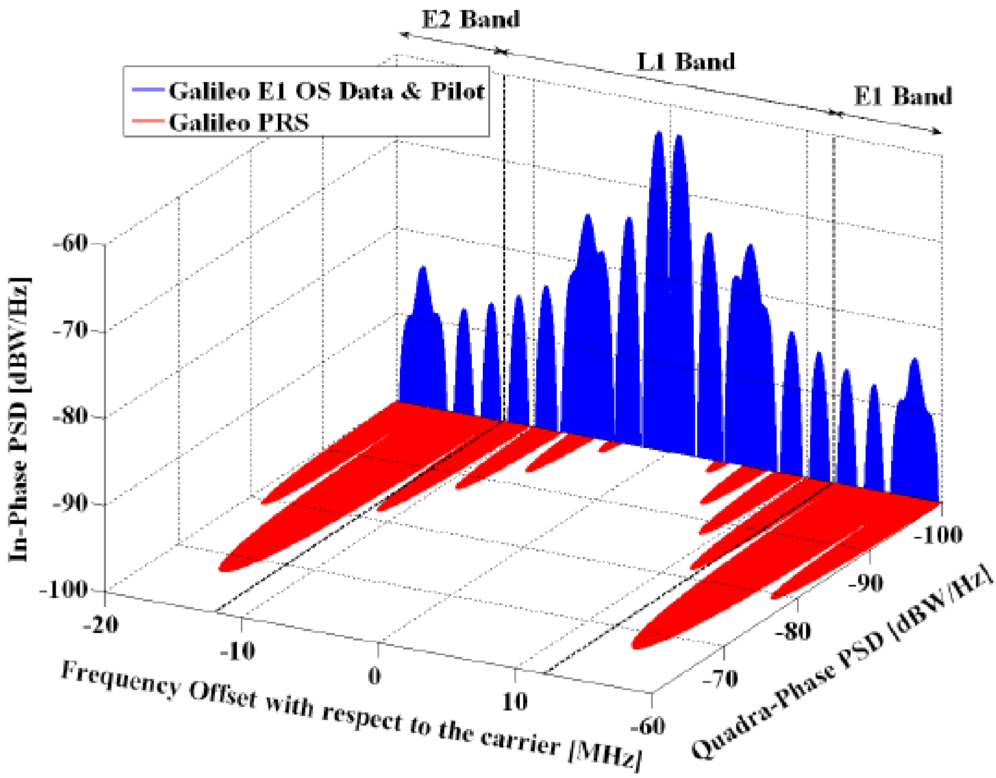


Figure 2.6 – Spectra of Galileo Signals in E2-L1-E1 [1].

Moreover, several combinations for the open services provided by Galileo are also possible, such as a dual frequency service based on using L1 and E5a, for best ionospheres (atmospheric electricity) error cancellation, to single frequency services, at L1, E5a, E5b or E5a and E5b together, on which case the ionosphere error is removed using a model, and even triple frequency services using all the signal together which can be exploited for very precise centimetric type of applications. In GPS only one signal is available, which does not allow the kind of optimisation performed for Galileo. This will be overcome by the GPS modernization programme, where more GPS signals will be made available. However, the signal of interest for this work is the L1F-d (data), a signal transmitted in the E2-L1-E1 band as part of the Galileo open service (OS). The advantage of this signal in this work is that the L1 band of GPS signal is centered in the same carrier, making this signal a non-hardware changing signal to process in a GPS common SDR, as it can be seen in the spectra of Galileo signals in E2-L1-E1 Band.

2.3.3 GLONASS

Similarly to GPS, GLONASS satellites transmit signals centered on two discrete L-band carrier frequencies and have a program under development which will introduce new signals that will make its service more available, accurate, reliable and robust. The space segment constellation is composed by 31 satellites of which 24 are operational plus 1 in flight test for the GLONASS modernization, located in middle circular orbit at 19,100 km altitude with a 64.8 degree inclination. The signals use similar DSSS encoding and BPSK modulation as in GPS signals. However, the signal access scheme of this signal is Frequency Division Multiple Access (FDMA) where each satellite transmits the same PRN sequence on a different frequency using a 14-channel spanning either side from 1602.0 MHz, also known as the L1 band. The center frequency is 1602 MHz + $n \times 0.5625$ MHz, where n is the satellite frequency channel number shared by two antipodal satellites. A representation of the spectra where the PSDs of the GLONASS signals in the L1 band is shown in Figure 2.7.

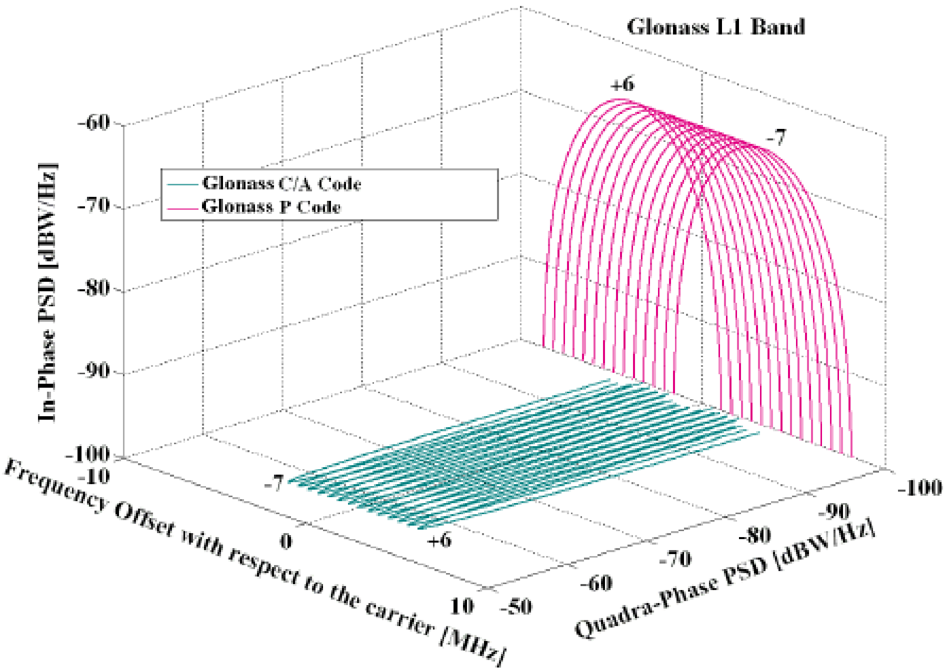


Figure 2.7 – Spectra of GLONASS signals in L1 [1].

In the figure above, each of the channels is filtered to only transmit the main lobe of the BPSK, thus the 14-channel spanning of the C/A code can be observed. The choice of FDMA over CDMA is one of the design trade-offs for this work, more details on sub-section 2.3.5. FDMA typically leads to more expensive receivers because of the front-end components required to process multiple frequencies or a wider bandwidth, capable of acquiring them. This issue will be surpassed with the future of the GLONASS modernization program. Such an arrangement will allow easier and cheaper implementation of multi-standard GNSS receivers.

2.3.4 NAVIGATION MESSAGE

The Navigation Message provides all the necessary information to allow the user to perform the positioning service. It includes the Ephemeris parameters, this parameters are needed to compute the satellite coordinates with enough accuracy, the Time parameters and Clock Corrections, to compute satellite clock offsets and time conversions, the Service Parameters with satellite health information (used to identify the navigation data set), Ionospheric parameters model needed for single frequency receivers, and the Almanacs, allowing the computation of the position of ”all satellites in the constellation”, with a reduced accuracy (1 – 2 km), which is needed for the acquisition of the signal by the receiver. The GPS current Navigation Message contains 25 frames of 30 seconds each, forming the master frame that takes 12.5 minutes to be transmitted, as shown in Figure 2.8. Every frame is subdivided into 5 sub-frames of 6 seconds each consisting of 10 words, with 30 bits per word. The last 6 bits in each word of the navigation message are used for parity checking to provide the user equipment with a capability to detect bit errors during demodulation. This subframes always starts with the telemetry word (TLM) to assist the user equipment in locating the beginning of each subframe. Next, the transference word (HOW) appears. This word provides time information, allowing the receiver to acquire the week-long P(Y)-code segment.

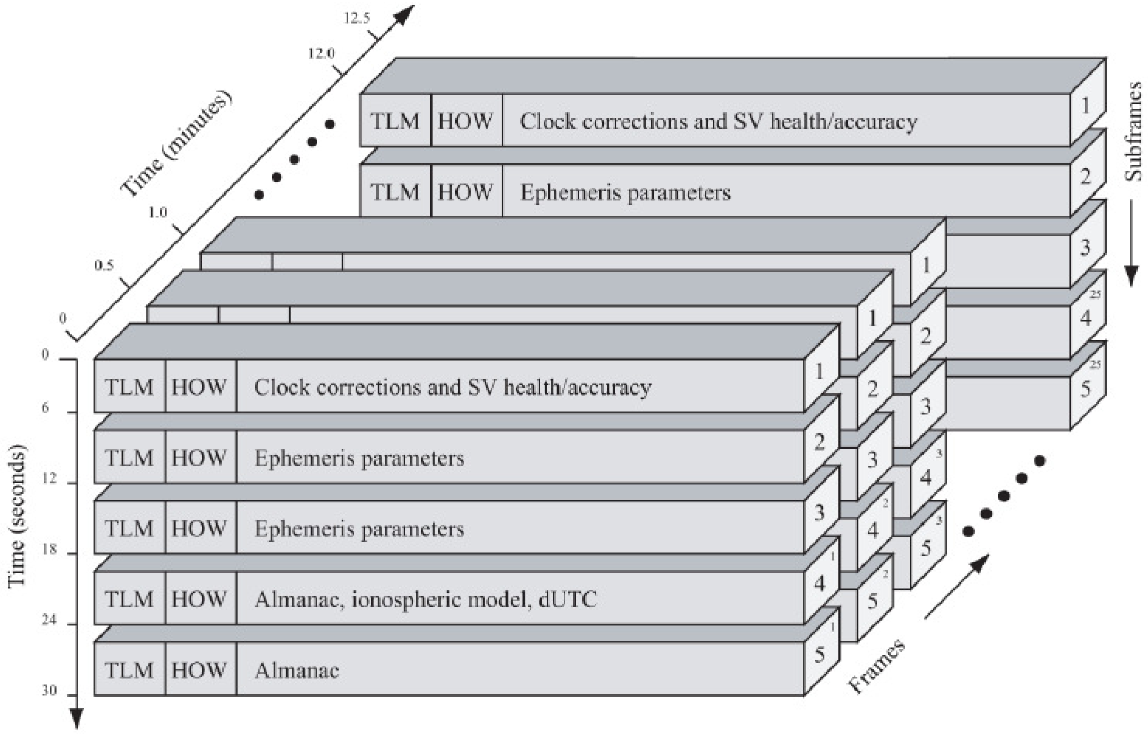


Figure 2.8 - GPS navigation data structure [2].

GPS modernization introduces four new data messages; three civilian messages, and one military message. They provide more accurate and frequent message data than the legacy navigation message. The Galileo satellites will broadcast five types of data (services) in four navigation messages: a freely accessible, an Integrity, the Commercial and the Governmental Navigation Messages. The Galileo ephemeris parameters are *Keplerian*-like orbital elements as in GPS. The Almanac is also similar to the GPS and GLONASS ones.
Figure 2.9 shows the all GNSS frequency allocation.

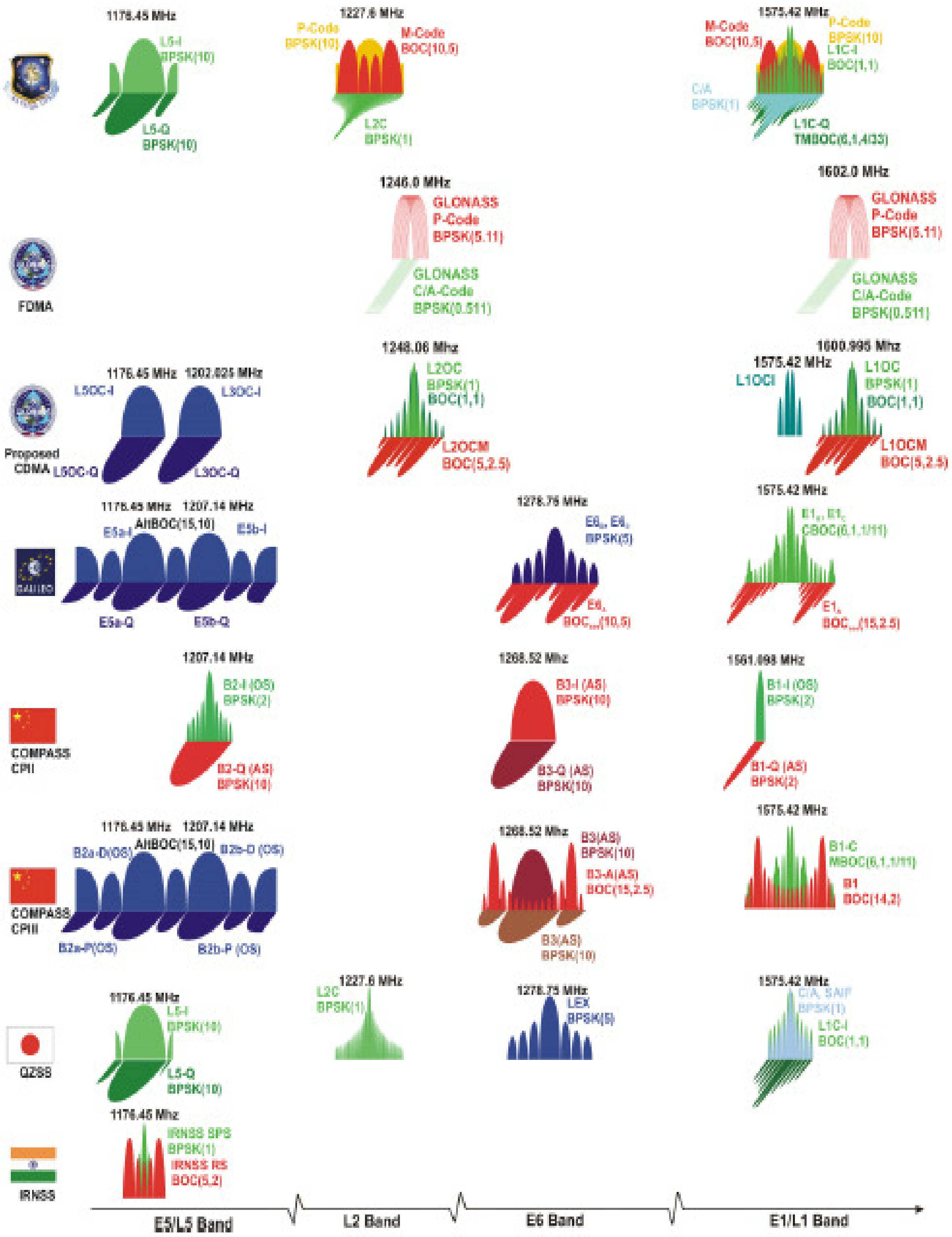


Figure 2.10 – All GNSS frequency bands [1].

Though many satellite system are in service GPS is wide spread and available in affordable cost. The following chapters will concentrate on GPS and its role in GIS applications.

3.0 GPS SATELLITE CONSTELLATION

Constellation of Satellites

Uncorrected positions determined from GPS satellite signals produce accuracies in the range of 50 to 100 meters. When using a technique called differential correction, users can get positions accurate to within 5 meters or less. With some consideration for error, GPS can provide any point on earth with a unique address (its precise location). Each satellite transmits on three frequencies. Civilian GPS uses the 'L1' frequency of 1575.42 MHz. Each satellite is expected to last approximately 10 years. Replacements are constantly being built and launched into orbit.

A GIS is basically a descriptive database of the earth (or a specific part of the earth). GPS tells you that you are at point X,Y,Z while GIS tells you that X,Y,Z is a paddy field, or a spot in the ocean where a oil berth is located. GPS tells us the "where". GIS tells us the "what". GPS/GIS is reshaping the way we locate, organize, analyze and map our resources.

3.1 COMPONENTS OF GPS

The GPS system consists of three segments

1.**Space Segment**: Space segment (SS) is composed of the orbiting GPS satellites, or Space Vehicles (SV) in GPS parlance.

2. **Control Segment:** The ground facilities carrying out the task of satellite tracking, orbit computations, telemetry and supervision necessary for the daily control of the space segment. The control segment is composed of

1. A master control station (MCS),
2. An alternate master control station,
3. Four dedicated ground antennas and
4. Six dedicated monitor stations.

3. **User Segment:** The entire spectrum of applications equipment and computational techniques that are available to the users. GPS receivers may include an input for differential corrections, using the RTCM SC-104 format. This is typically in the form of an RS-232 port at 4,800 bit/s speed. Data is actually sent at a much lower rate, which limits the accuracy of the signal sent using RTCM. Receivers with internal DGPS receivers can outperform those using external RTCM data. As of 2006, even low-cost units commonly include Wide Area Augmentation System (WAAS) receivers, which is detailed in the later section. Figure 2 shows a typical receiver unit.

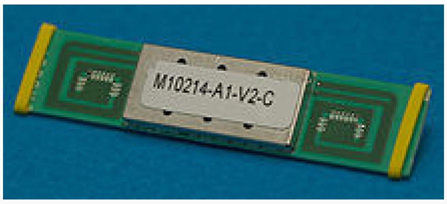


Fig 2. A typical GPS receiver with integrated antenna.

Many GPS receivers can relay position data to a PC or other device using the NMEA 0183 protocol, or the newer and less widely used NMEA 2000.[54] Although these protocols are officially defined by the National Marine Electronics Association (NMEA),[55]references to these protocols have been compiled from public records, allowing open source tools like gpsd to read the protocol without violating intellectual property laws. Other proprietary protocols exist as well, such as the SiRF and MTK protocols. Receivers can interface with other devices using methods including a serial connection, USB, or Bluetooth.

3.2 DETERMINATION OF A LOCATION ON EARTH

GPS is based on satellite ranging - calculating the distances between the receiver and the position of 3 or more satellites (4 or more if elevation is desired) and then applying some calculations based on the geodesy. Assuming the positions of the satellites are known, the location of the receiver can be calculated by determining the distance from each of the satellites to the receiver. GPS takes these 3 or more known references and measured distances and "triangulates" an additional position. Triangulation does not involve the measurement of angles. More generally, GPS used trilateration methods, which involves the determination of absolute or relative locations of points by measurement of distances, using the geometry of spheres or triangles. The principle is shown in figure 3 below.

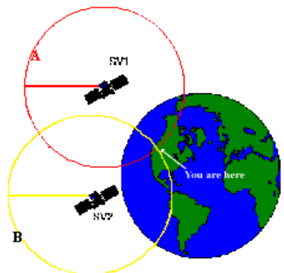


Fig.3 Locating a position on earth using GPS

3.3 DETERMINING THE SATELLITE LOCATIONS

The DOD can predict the paths of the satellites vs. time with great accuracy. Furthermore, the satellites can be periodically adjusted by huge land-based radar systems. Therefore, the orbits, and thus the locations of the satellites, are known in advance. Today's GPS receivers store this orbit information for all of the GPS satellites in what is known as an **almanac,** which is nothing but the time schedule of satellite positions. Each GPS satellite continually broadcasts the almanac. The GPS receiver will automatically collect this information and store it for future reference.

Any deviations in satellite path (caused by natural atmospheric phenomenon such as gravity), are known as **ephemeris** errors. When ephemeris errors are determined to exist for a satellite, the errors are sent back up to that satellite, which in turn broadcasts the errors as part of the standard message, supplying this information to the GPS receivers. By using the information from the almanac in conjunction with the ephemeris error data, the position of a GPS satellite can be very precisely determined for a given time.

3.4 COMPUTING THE DISTANCE

GPS determines distance between a satellite and a GPS receiver by measuring the amount of time it takes a radio signal (the GPS signal) to travel from the satellite to the receiver. Radio waves travel at the speed of light, which is about 186,000 miles per second. So, if the amount of time it takes for the signal to travel from the satellite to the receiver is known, the distance from the satellite to the receiver (distance = speed x time) can be determined. If the exact time when the signal was transmitted and the exact time when it was received are known, the signal's travel time can be determined. In order to do this, the satellites and the receivers use very accurate clocks which are synchronized so that they generate the same code at exactly the same time. The code received from the satellite can be compared with the code generated by the receiver. By comparing the codes, the time difference between when the satellite generated the code and when the receiver generated the code can be determined. This interval is the travel time of the code. Multiplying this travel time, in seconds, by 186,000 miles per second gives the distance from the receiver position to the satellite in miles.

3.5 DETERMINATION OF A 3D POSITION

Three measurements can be used to locate a point, assuming the GPS receiver and satellite clocks are precisely and continually synchronized, thereby allowing the distance calculations to be accurately determined. Practically, it is impossible to synchronize these two clocks, since the clocks in GPS receivers are not as accurate as the very precise and expensive atomic clocks in the satellites. The GPS signals travel from the satellite to the receiver very fast, so if the two clocks are off by only a small fraction, the determined position data may be considerably distorted. The atomic clocks aboard the satellites maintain their time to a very high degree of accuracy. However, there will always be a slight variation in clock rates from satellite to satellite. Close monitoring of the clock of each satellite from the ground permits the control station to insert a message in the signal of each satellite which precisely describes the drift rate of that satellite's clock. The insertion of the drift rate effectively synchronizes all of the GPS satellite clocks. The same procedure cannot be applied to the clock in a GPS receiver. Therefore, a fourth variable (in addition to x, y and z), time, must be determined in order to calculate a precise location. Mathematically, to solve for four unknowns (x,y,z, and t), there must be four equations. In determining GPS positions, the four equations are represented by signals from four different satellites.

3.6 POSITION ACCURACY AND ERRORS

The GPS system has been designed to be as nearly accurate as possible. However, there are still errors. Added together, these errors can cause a deviation of **+/- 50 -100** meters from the actual GPS receiver position. There are several sources for these errors, the most significant of which are discussed below:

a. The ionosphere and troposphere both refract the GPS signals. This causes the speed of the GPS signal in the ionosphere and troposphere to be different from the speed of the GPS signal in space. Therefore, the distance calculated from "Signal Speed x Time" will be different for the portion of the GPS signal path that passes through the ionosphere and troposphere and for the portion that passes through space.
b. Ephemeris Errors/Clock Drift/Measurement Noise: GPS signals contain information about ephemeris (orbital position) errors, and about the rate of clock drift for the broadcasting satellite. The data concerning ephemeris errors may not exactly

model the true satellite motion or the exact rate of clock drift. Distortion of the signal by measurement noise can further increase positional error. The disparity in ephemeris data can introduce 1-5 meters of positional error, clock drift disparity can introduce 0-1.5 meters of positional error and measurement noise can introduce 0-10 meters of positional error.

c. Selective Availability: Ephemeris errors should not be confused with Selective Availability (SA), which is the intentional alteration of the time and epherimis signal by the Department of Defense. SA can introduce 0-70 meters of positional error. Fortunately, positional errors caused by SA can be removed by differential correction.
d. Multipath: A GPS signal bouncing off a reflective surface prior to reaching the GPS receiver antenna is referred to as multipath. Because it is difficult to completely correct multipath error, even in high precision GPS units, multipath error is a serious concern to the GPS user.
e. Satellite constellation errors: The geometry of the constellation is evaluated for several factors, all of which fall into the category of Dilution Of Precision, or DOP. A greater angle between the satellites lowers the DOP, and provides a better measurement. A higher DOP indicates poor satellite geometry, and an inferior measurement configuration.

3.7 POSITION CORRECTION:

Some GPS receivers can analyze the positions of the satellites available, based upon the almanac, and choose those satellites with the best geometry in order to make the DOP as low as possible. Another important GPS receiver feature is to be able to ignore or eliminate GPS readings with DOP values that exceed user-defined limits. Other GPS receivers may have the ability to use all of the satellites in view, thus minimizing the DOP as much as possible.

A technique called **differential correction** is necessary to get accuracies within 1 -5 meters, or even better, with advanced equipment. Differential correction requires a second GPS receiver, a *base station,* collecting data at a stationary position on a precisely known point (typically it is a surveyed benchmark). Because the physical location of the base station is known, a correction factor can be computed by comparing the known location with the GPS location determined by using the satellites. The differential correction process takes this correction factor and applies it to the GPS data collected by a GPS receiver in the field. Differential correction eliminates most of the errors listed above.

3.8 TYPES OF GPS RECEIVERS:

There are three types of GPS receivers, namely Coarse Acquisition (C/A code) GPS receivers, Carrier Phase receivers and Dual Frequency receivers each having different levels of accuracy, and has different requirements to obtain those accuracies.

3.8.1 C/A Code receivers

C/A Code receivers typically GPS position accuracy with differential correction. C/A Code GPS receivers provide a sufficient degree of accuracy (1-5 meter) to make them useful in most GIS applications. Recent advances in GPS receiver design will now allow a C/A Code receiver to provide sub-meter accuracy, down to 30 cm.

3.8.2 Carrier Phase receivers

Carrier Phase receivers measure the distance from the receiver to the satellites by counting the number of waves that carry the C/A Code signal. This method of determining position is much more accurate; however, it does require a substatially higher occupation time to attain 10-30 cm accuracy. Initializing a Carrier Phase GPS job on a known point requires an occupation time of about 5 minutes. Initializing a Carrier Phase GPS job on an unknown point requires an occupation time of about 30-40 minutes.

3.8.3 Dual-Frequency receivers

Dual-Frequency receivers are capable of providing sub-centimeter GPS position accuracy with differential correction. Dual-Frequency receivers provide "survey grade" accuracies not often required for GIS applications. Dual-Frequency receivers receive signals from the satellites on two frequencies simultaneously. Receiving GPS signals on two frequencies simultaneously allows the receiver to determine very precise positions.

3.9 SATELLITE SIGNAL PATH

GPS receivers require a line of sight to the satellites in order to obtain a signal representative of the true distance from the satellite to the receiver. Therefore, any object in the path of the signal has the potential to interfere with the reception of that signal. Objects which can block a GPS signal include tree canopy, buildings and terrain features. Further, reflective surfaces can cause the GPS signals to bounce before arriving at a receiver, thus causing an error in the distance calculation. This problem, known as multipath, can be caused by a variety of materials including water, glass and metal. The water contained in the leaves of vegatation can produce multipath error. In some instances, operating under heavy, wet forest canopy can degrade the ability of a GPS receiver to track satellites.

4.0 MAP DATUM:

A map datum is a mathematical description of the earth or a part of the earth, and is based on the ellipsoid or the arc of an ellipsoid that most closely represents the area being described. In addition, the datum is centered at a specific location know as the datum origin. A datum may describe a small part of the earth, such as WGS84, depending on which ellipsoid or ellipsoidal arc is selected and where the datum origin is. Since datum’s use different ellipsoids and have different origins, the Latitude and Longitude coordinates of the same position differs from one datum to another. The difference may be slight or great, depending on the datum involved, but will affect the apparent accuracy of the positioning information provided by a GPS receiver. This is one of the important specification while selecting a GPS.

4.1 WAAS GPS

WAAS (Wide Area Augmentation System) was developed by the Federal Aviation Administration to augment the Global Positioning System to improve its accuracy.WAAS consists of approximately 25 ground reference stations positioned across the United States that monitor GPS satellite data. Two master stations, located on either coast, collect data from the reference stations and create a GPS correction message. This correction accounts for GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere. The corrected differential message is then broadcast through one of two geostationary satellites, or satellites with a fixed position over the equator. The information is compatible with the basic GPS signal structure, which means any WAAS-enabled GPS receiver can read the signal. The accuracy comparison is shown graphically in Figure 4.

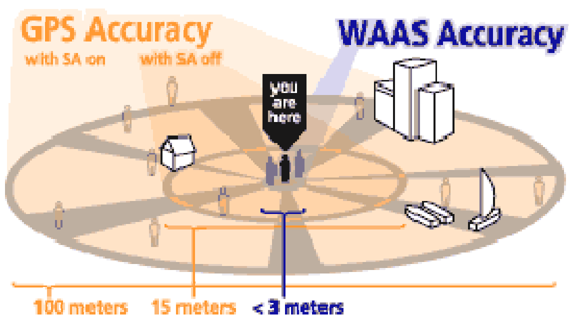


Fig. 4. WAAS enabled GPS accuracy plot

5.0 GPS IN GIS APPLICATIONS

Once the location on the surface of the Earth is determined it is informative to know what is at the location. The "what" is the object or objects which will be mapped. These objects are referred to as "Features", and are used to build a GIS. It is the power of GPS to precisely locate these Features which adds so much to the utility of the GIS system. On the other hand, without Feature data, a coordinate location is of little value.

5.1 Feature Types

There are three types of Feature which can be mapped: Points, Lines and Areas. A Point Feature is a single GPS coordinate position which is identified with a specific Object. A Line Feature is a collection of GPS positions which are identified with the same Object and linked together to form a line. An Area Feature is very similar to a Line Feature, except that the ends of the line are tied to each other to form a closed area. The catagories of descriptions for a Feature are know as Attributes. Attributes can be thought of as questions which are asked about the Feature. The answers to the questions posed by the Attributes are called Values. By collecting the same type of data for each house which is mapped, a database is created. Tying this database to position information is the core philosophy underlying any GIS system.

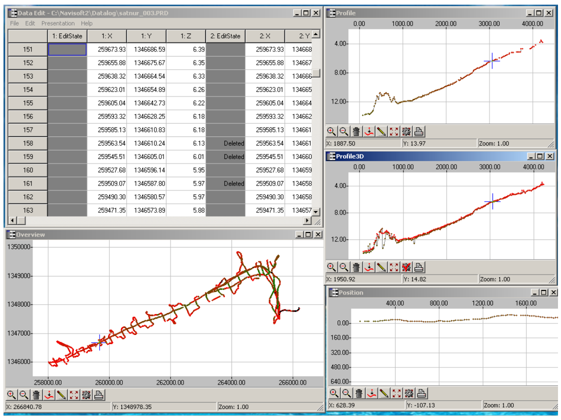
5.2 Exporting to a GIS System

The final step in incorporating GPS data with a GIS system is to export the GPS and Feature data into the GIS system. During this process, a GIS "layer" is created for each Feature in the GPS job. For example, the process of exporting a GPS job which contains data for House, Road and Lot Features would create a House layer, a Road layer and a Lot layer in the GIS system. These layers can then be incorporated with existing GIS data. Once the GPS job has been exported, the full power of the GIS system can be used to classify and evaluate the data.

6.0 ROLE OF GPS IN A HYDROGRAPHIC SURVEY

A GPS based survey system requires ahighily precise position (i.e DGPS) , an high resolution echosounder along with a sophisticated data logging software with facility to log position and depth data. Figure 5 shows the survey boat, logged data along with the equipments used for hydrographic survey work. Once the equipments are setup in the boat, survey lines are drawn according to the site conditions (normally across the flow) are drawn with reasonable grid interval. Data is collected and analysed with sophisticated software like Hypack, Surfer, Navisoft etc in order to get the area elevation, bed profile, surface plots.

Fig 5a the survey Boat with GPS & echo system



5b. Depth & position plot acquired online

7.0 OTHER APPLICATIONS

- Automobiles can be equipped with GNSS receivers at the factory or as aftermarket equipment. Units often display moving maps and information about location, speed, direction, and nearby streets and points of interest.
- Aircraft navigation systems usually display a "moving map" and are often connected to the autopilot for en-route navigation. Cockpit-mounted GNSS receivers and glass cockpits are appearing in general aviation aircraft of all sizes, using technologies such as WAAS or LAAS to increase accuracy. Glider pilots use GNSS Flight Recorders to log GNSS data verifying their arrival at turn points in gliding competitions. Flight computers installed in many gliders also use GNSS to compute wind speed aloft, and glide paths to waypoints such as alternate airports or mountain passes, to aid en route decision making for cross-country soaring.
- Boats and ships can use GNSS to navigate all of the world's lakes, seas and oceans. Maritime GNSS units include functions useful on water, such as “man overboard” (MOB) functions that allow instantly marking the location where a person has fallen overboard, which simplifies rescue efforts. GNSS may be connected to the ships self-steering gear and Chartplotters using the NMEA 0183 interface. GNSS can also improve the security of shipping traffic by enabling AIS.
- Heavy Equipment can use GNSS in construction, mining and precision agriculture. The blades and buckets of construction equipment are controlled automatically in GNSS-based machine guidance systems. Agricultural equipment may use GNSS to steer automatically, or as a visual aid displayed on a screen for the driver. This is very useful for controlled traffic and row crop operations and when spraying.
- Bicycles often use GNSS in racing and touring.

- Hikers, climbers, and even ordinary pedestrians in urban or rural environments can use GNSS to determine their position, with or without reference to separate maps. In isolated areas, the ability of GNSS to provide a precise position can greatly enhance the chances of rescue when climbers or hikers are disabled or lost (if they have a means of communication with rescue workers).
- GNSS equipment for the visually impaired is available.
- Surveying — Survey-Grade GNSS receivers can be used to position survey markers, buildings, and road construction. These units use the signal from both the L1 and L2 GPS frequencies. These dual-frequency GPS receivers typically cost more, but can have positioning errors on the order of one centimeter or less when used in carrier phase differential GPS mode.
- Mapping and geographic information systems (GIS) — Most mapping grade GNSS receivers use the carrier wave data from only the L1 frequency, but have a precise crystal oscillator which reduces errors related to receiver clock jitter. This allows positioning errors on the order of one meter or less in real-time, with a differential GNSS signal received using a separate radio receiver.
- Geophysics and geology — High precision measurements of crustal strain can be made with differential GNSS by finding the relative displacement between GNSS sensors. Multiple stations situated around an actively deforming area (such as a volcano or fault zone) can be used to find strain and ground movement. These measurements can then be used to interpret the cause of the deformation, such as a dike or sill beneath the surface of an active volcano.
- Archeology — As archaeologists excavate a site, they generally make a three-dimensional map of the site, detailing where each artifact is found.
- Precise time reference — Many systems that must be accurately synchronized use GNSS as a source of accurate time. Sensors (for seismology or other monitoring application), can use GNSS as a precise time source, so events may be timed accurately. Time division multiple access (TDMA) communications networks often rely on this precise timing to synchronize RF generating equipment, network equipment, and multiplexers.
- Mobile Satellite Communications — Satellite communications systems use a directional antenna (usually a "dish") pointed at a satellite. The antenna on a moving ship or train, for example, must be pointed based on its current location. Modern antenna controllers usually incorporate a GNSS receiver to provide this information.
- Location-based games — The availability of hand-held GNSS receivers has led to games such as Geocaching, which involves using a hand-held GNSS unit to travel to a specific longitude and latitude to search for objects hidden by other geocachers. This

popular activity often includes walking or hiking to natural locations. Geodashing is an outdoor sport using waypoints.

- Aircraft passengers — Most airlines allow passenger use of GNSS units on their flights, except during landing and take-off when other electronic devices are also restricted. Even though consumer GNSS receivers have a minimal risk of interference, a few airlines disallow use of hand-held receivers during flight. Other airlines integrate aircraft tracking into the seat-back television entertainment system, available to all passengers even during takeoff and landing.[2]
- Heading information — The GNSS system can be used to determine heading information, even though it was not designed for this purpose. A "GNSS compass" uses a pair of antennas separated by about 50 cm to detect the phase difference in the carrier signal from a particular GNSS satellite. Given the positions of the satellite, the position of the antenna, and the phase difference, the orientation of the two antennas can be computed.
- GPS tracking systems use GNSS to determine the location of a vehicle, person, pet or freight, and to record the position at regular intervals in order to create a log of movements. The data can be stored inside the unit, or sent to a remote computer by radio or cellular modem. Some systems allow the location to be viewed in real-time on the Internet with a web-browser.
- GNSS Road Pricing systems charge of road users using data from GNSS sensors inside vehicles. Advocates argue that road pricing using GNSS permits a number of policies such as tolling by distance on urban roads and can be used for many other applications in parking, insurance and vehicle emissions. Critics argue that GNSS could lead to an invasion of people's privacy
- Weather Prediction Improvements — Measurement of atmospheric bending of GNSS satellite signals by specialized GNSS receivers in orbital satellites can be used to determine atmospheric conditions such as air density, temperature, moisture and electron density. Such information from a set of six micro-satellites, launched in April 2006, called the Constellation of Observing System for Meteorology, Ionosphere and Climate COSMIC has been proven to improve the accuracy of weather prediction models.
- Photographic Geocoding — Combining GNSS position data with photographs taken with a (typically digital) camera, allows one to view the photographs on a map or to lookup the locations where they were taken in a gazeteer. It's possible to automatically annotate the photographs with the location they depict by integrating a GNSS device into the camera so that co-ordinates are embedded into photographs as Exif metadata.

- Skydiving — Most commercial drop zones use a GNSS to aid the pilot to "spot" the plane to the correct position relative to the drop zone that will allow all skydivers on the load to be able to fly their canopies back to the landing area.

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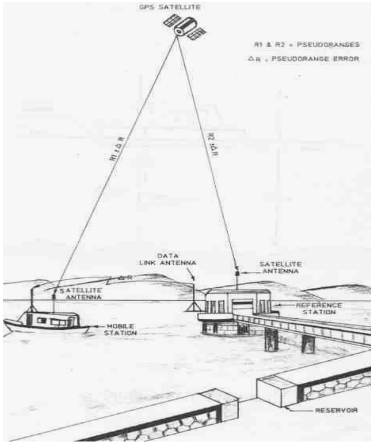

Fig. 1a. DGPS Setup

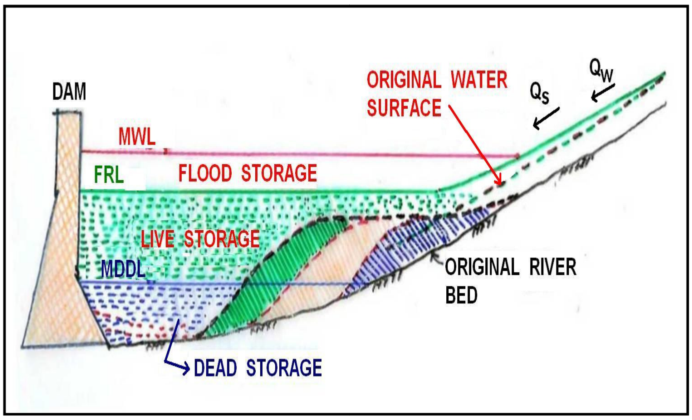

Fig 1b. Process of Sedimentation

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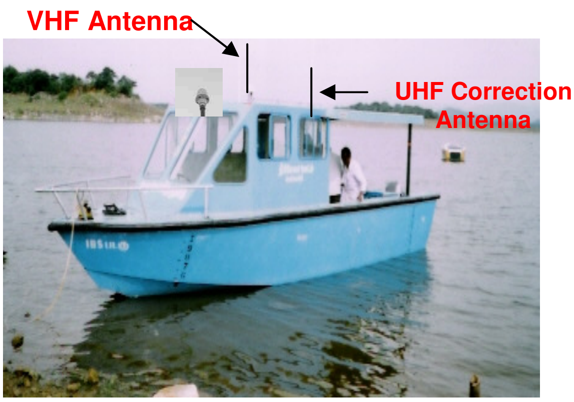

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Fig 2. Typical survey boat along with the survey equipments

MONITORING OF IRRIGATION PROJECTS USING BHUVAN WEB SERVICES

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INTRODUCTION

Monitoring and evaluation of irrigation projects must play a more important role in the future if the irrigation management process is to be improved. The process is complex, since a large number of regular, specific tasks must be performed, both concurrently and sequentially, and coordinated by a variety of professionals within available time and resource constraints. For any evaluation to be used, it must be credible- objective, accurate, and fair. Reports should be clear, unambiguous, balanced in terms of strengths and weaknesses, and contain justifiable conclusions and recommendations. For monitoring and evaluation to succeed, irrigation managers need to develop a new evaluative mind-set that enables them to appraise their projects' performance objectively, reflect on what has been learned for future use, and adjust policies on the basis of that knowledge whenever necessary.

The gainful use of high resolution **CARTOSAT** satellite data for inventory of Irrigation Infrastructure (canal network, conveyance & distribution system), assessment of progress of Irrigation works, closer visualization of spatial irrigation utilization patterns, assessing the impact of irrigation developmental programme on the performance of irrigation command and to address the performance at Water Users level in the participatory irrigation management approach.

DEFINITION OF MONITORING AS PER CWC

Monitoring is the process of collecting information about the actual execution of planned tasks and factors, which might affect their execution; analyzing these in relation to the plan and exercising control, so that the deviations from the plan are minimal. This helps the central authorities to assess the real work done up to a time, so that necessary advises can be given to project authorities.

OBJECTIVES OF THIS TRAINING PROGRAMME

i.) Monitoring of Priyadarshini Jurala Project, Andhra Pradesh through spatial technique

ii.) Digital Image processing involved in the process of monitoring of irrigation projects through Remote Sensing and GIS

iii.) Assessment of irrigation potential created up to April 2007 using Cartosat high resolution satellite data and Identification of gap / critical areas in I.P creation

iv.) Inventory and Mapping of Irrigation Infrastructure consisting of canal network, cross drainage and other irrigation structures

v.) Assessment of Irrigation Potential (I.P) created as on April, 2007 as the data corresponds to April 2007.

Details of Methodology

Basic approach involved in the study consists of inventory and mapping of existing irrigation infrastructure viz. canal network, irrigation and other related structures from the Cartosat satellite data in a irrigation project and comparing with proposed irrigation infrastructure. Based on the completed irrigation infrastructure derived from the cartosat-1 satellite data and considering the hydraulic connectivity, the Irrigation Potential created in the project command is assessed. Brief description of methodological steps involved in the study area given below:

(a) Overview of Methodology

1. Field data collection: Collection of preliminary and detailed field data consisting of map(s) showing proposed canal network and canal wise CCA/ICA, I.P proposed, I.P created as on March 2009 or any other date as required by the project .

2.Cartosat data acquisition planning and procurement : Preparation of AIBP component polygon shape file(s) using the field maps to plan for acquisition of fresh Cartosat satellite data during April 2010 - June 2010 for all the projects (both completed / ongoing) . In case atellite data is not available, either for total project during the above period, the time window will be extended beyond Jun, 2011 till it is covered for completely ongoing projects. For completed projects, in addition to the above, the archived Cartosat data from April 2008 onwards will also be utilized.

3. Field database creation: Preparation of field database on irrigation infrastructure and Irrigation Potential information

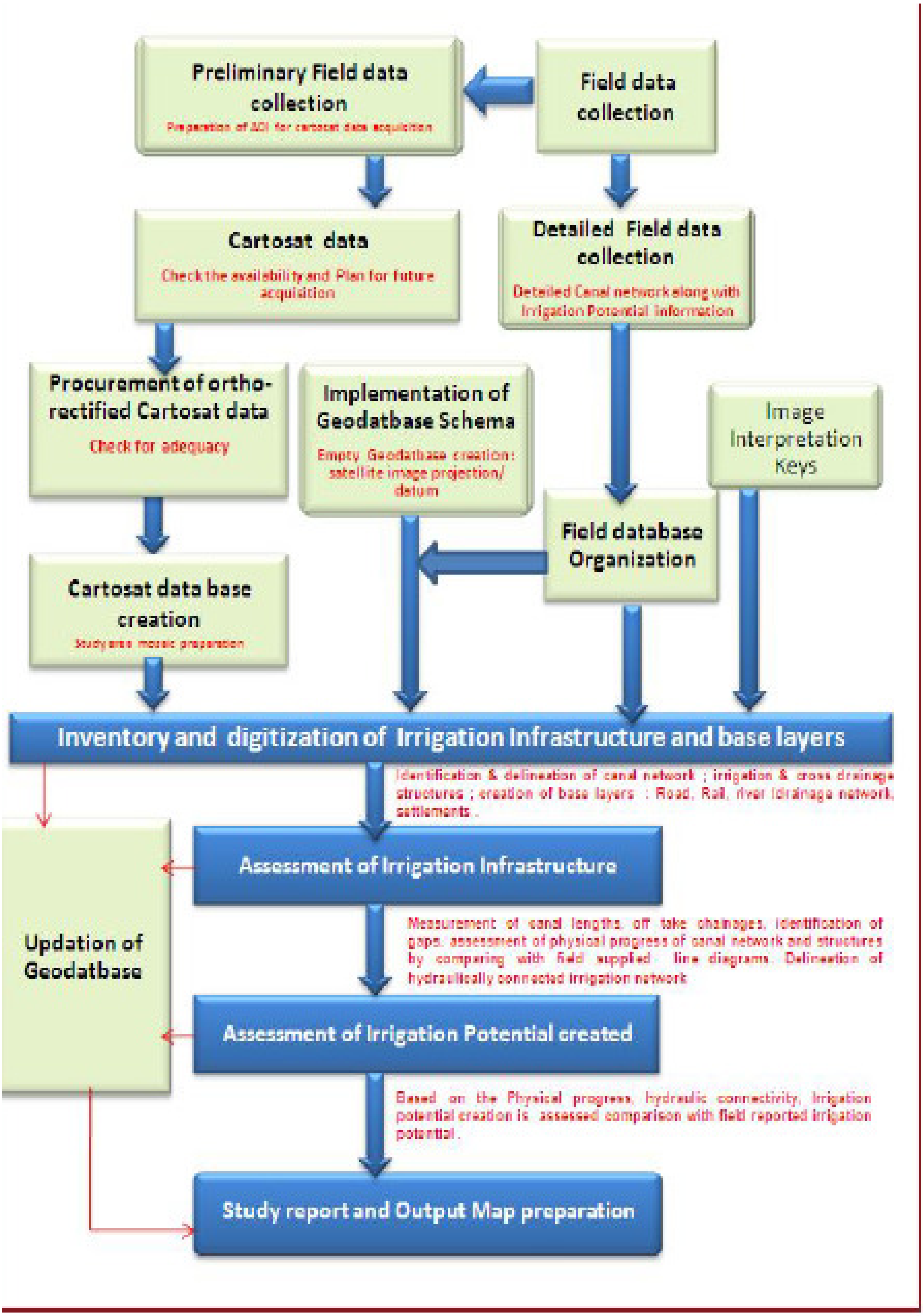
4. Cartosat database creation: Edge matching and mosaic of Cartosat satellite data tiles and preparation of satellite database.
5. Geo-database creation: All the vector layers (Irrigation Infrastructure and base layers) along with attribute information will be developed in GIS environment using geo-database schema developed for the project.

6. Inventory and mapping of Irrigation Infrastructure and base layers : Identification and mapping of existing Irrigation Infrastructure consisting of Irrigation canal network up to Minor /Sub-Minor level, Cross drainage, Irrigation and other structures as on the date of satellite overpass date. Identification and mapping of base layers consisting of study area boundary, rivers, streams, roads, railway lines, settlements, balance I.P polygons etc.

7. Assessment of Irrigation Infrastructure and Irrigation Potential created: Comparison of satellite derived information with proposed Irrigation infrastructure to create planned I.P under AIBP. Assessment of Irrigation Potential (I.P) created based on the extent of accomplishment in irrigation canal network creation with hydraulic flow continuity as on the satellite data acquisition date. Finalization of assessment of I.P created.

8. Ground truth field visit: Conduct of random field visits to check for satellite data interpretation.

9. Preparations of Outputs: Preparation of output map along with study report; Preparation of digital data backup for supply to user. Flow chart showing the over view of the methodology is provided here.



Process flow chart for the Irrigation Potential assessment

The **Inputs / Parameters** required from the **field data** and **satellite data derived irrigation infrastructure** information are:

1. **Proposed length** of canal.
2. **Satellite derived Lengths** ; Physical progress of canal construction for the corresponding canal.
3. Irrigation potential proposed under each canal .
4. **Gaps** existing in different stretches of the canal network,
- Number of gaps and gap lengths, their chainages – derived hydraulically connected length of a particular canal .
5. Number of **DPOs**, their contribution to the **irrigation potential** as per field data; their **chainages** – to assess the hydraulic connectivity .

The **steps to be followed** for the satellite based assessment of irrigation potential creation: Irrigation potential assessment is made based on physical status of canal and its hydraulic connectivity to the source of irrigation. As explained earlier, canal network hierarchy consists of Main canal – Branch canal-Distributary-Lateral-sub lateral , etc and may vary from one project to another project. In addition to this, irrigation potential is also created through the Direct Pipe Outlets (DPOs) from Main canal /Distributary, etc. Various scenarios that one would come across in different irrigation projects are briefly explained.

(Details of methodology has been described in NRSC manual).

GROUND TRUTH

The ground truth photographs have been taken from the actual site and have been compared with the corresponding images to have a clear visualization.

CONCLUSION

The endeavour of bringing together the this monitoring of Irrigation projects using online monitoring, the direction and decisions in this domain will shape our future in monitoring real time scenario of any irrigation projects with no software cost. The free plug ins can be loaded to the G-GIS to have a smart way of analyzing things.

WEB BASED WATER RESOURCES INFORMATION SYSTEM (INDIA-WRIS)

1.1 *India-WARIS* VISION

The National Water Policy (2012) recognizes that development and management of water resources need to be governed by national perspectives and aims to develop and conserve the scarce water resources in an integrated and environmentally sound basis. The National Water Policy 2002 Para 14.0 on Information System reads as -

All hydrological data, other than those classified on national security consideration, should be in public domain. However, a periodic review for further declassification of data may be carried out. A National Water Informatics Center should be established to collect, collate and process hydrologic data regularly from all over the country, conduct the preliminary processing, and maintain in open and transparent manner on a GIS platform.

In view of the likely climate change, much more data about snow and glaciers, evaporation, tidal hydrology and hydraulics, river geometry changes, erosion, sedimentation, etc. needs to be collected. A programme of such data collection needs to be developed and implemented.

All water related data, like rainfall, snowfall, geo-morphological, climatic, geological, surface water, ground water, water quality, ecological, water extraction and use, irrigated area, glaciers, etc., should be integrated with well defined procedures and formats to ensure online updation and transfer of data to facilitate development of database for informed decision making in the management of water.

The proposed India-Water Resources Information System (*India-WRIS*) is envisaged with following vision –

THE VISION

India–WARIS aims to provide a
'Single Window solution' for all water resources
data and information in a
standardized national GIS framework.

It will allow users to
Search, Access, Visualize, Understand and Analyze
comprehensive and contextual water resources data
for assessment, monitoring, planning, development
and finally IWRM.

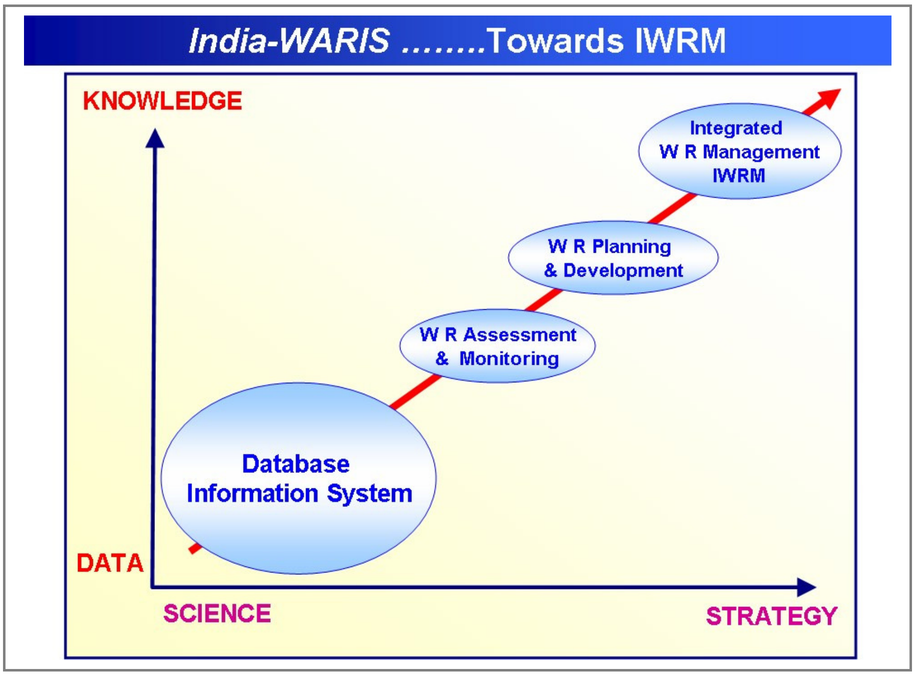
1.2 *India-WARIS* OBJECTIVES

1. To **collate** available data from varied sources, **generate** new databases of country's water resources, **organize** in standardized GIS format and **provide** a thin client scalable web-enabled information system.

2. To provide **easier and faster access** and **sharing** of nationally consistent and authentic water resources data **through a centralized database** and application server to all water resources departments, organizations, professionals and other stake holders for IWRM.

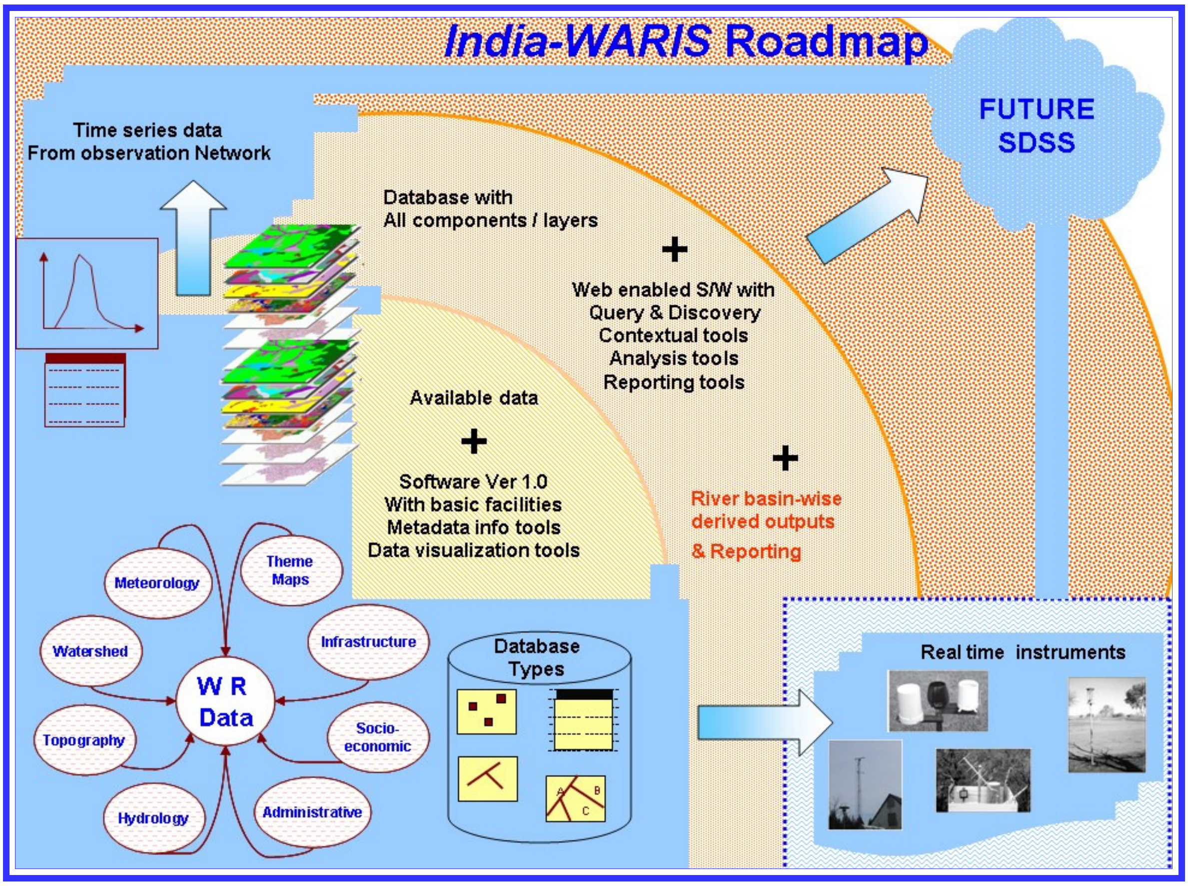
3. To **provide tools** to create value added maps by way of multi-layer stacking of GIS databases so as to **provide integrated view** to the water resources issues.

4. To provide **foundation** for advanced modeling purposes and future SDSS including automated data collection system.



Spatial Decision Support Systems specially targeted towards near real time problem solving demands require large amount of dynamic data at higher scale, which becomes increasingly complex in the initial stage. However, once the all the resources are pulled together and a centralized data repository is established the initial information system could be slowly further developed towards SDSS with application specific models. Hence, efforts right now will be to put Web Enabled Information System in place with centralized server.

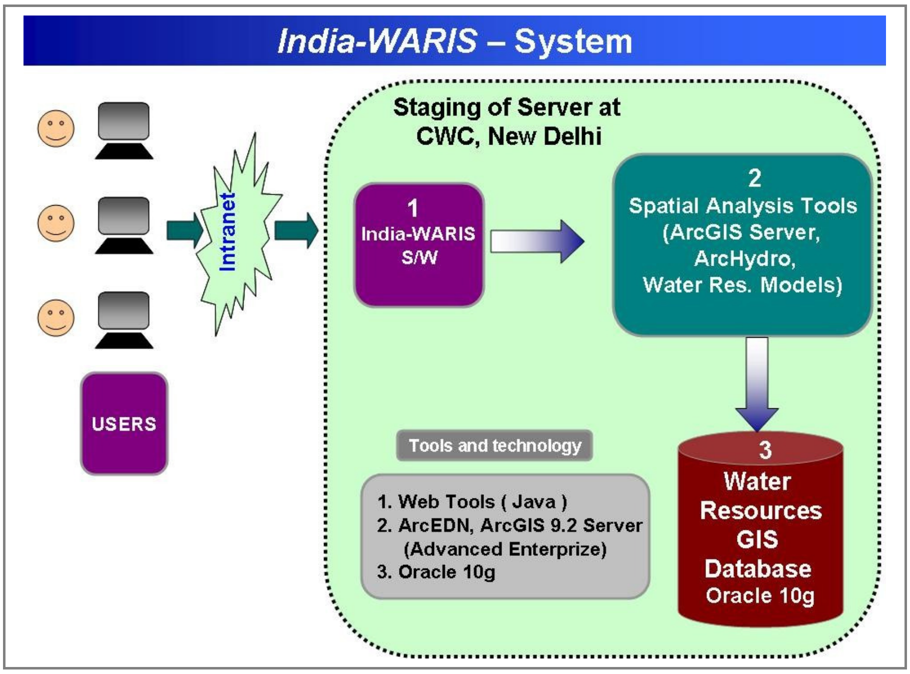
The system will be primarily aimed at organizing the varied databases on common platform with standards defined for each of the database layer and further providing the user friendly interface to Geo-Visualize the diversified data. The system will employ Geo-visualization strategy to view data at user specified scale and also in automated fashion to match the View as per the scale requirements. As the viewing scale changes the viewer contents will also change as per scale. The system will allow to stack multiple GIS layers and will provide flexible switching operations to the user for desired layer selection. System will provide ways to generate value added maps and will allow to have insight into the databases. Information system hence will allow to aesthetic display, layer stacking, query, pan/zoom operations and area of interest operations, basic report generation, printing etc.



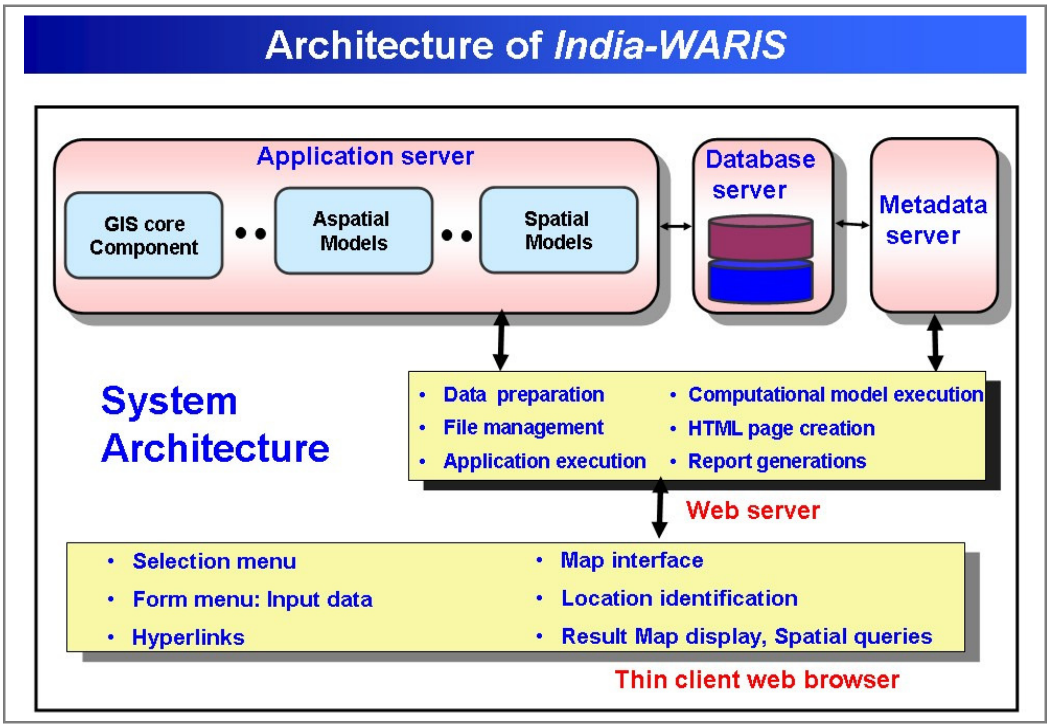
1.3 SYSTEM ARHITECTURE OF *India-WARIS*

As decided by CWC, *India-WARIS* will be a client server system with server side processing. The server-side approach uses a thin client and most of the processing, including spatial data access and manipulation is performed on the server side. The resulting information and image objects are then sent to the clients to be rendered. The server-side Web enabled information system requires only a browser installed on the client machine to carryout tasks. However, every user action requires communication between the client and the server.

The server side environment typically will include a web server (Apache, IIS etc.) and a map server (ArcGIS Server) that will provide GIS services. The map server software establishes a common platform for the exchange of web-enabled GIS data and services. The web server transfers spatial and non-spatial data between the client side (Web browser) and the map server through sockets. The client side user interface will be developed using Industry Standard Languages and web technologies provided by ArcGIS server Application Development Framework (ADF).



ArcGIS Server is an open, flexible, and scalable technology that runs on industry-standard IT infrastructure and supports geospatial Service-Oriented Architecture (SOA) initiatives. ArcGIS Desktop software complements ArcGIS Server by acting as a means of authoring, configuring, and maintaining data, models, and applications. This authored content can be published via ArcGIS Server, which provides the technology foundation for organizations to build and implement GIS-based Web services.



1.4 SCOPE OF THE PROJECT

The project envisages 30 Major spatial layers (Annexure – I) grouped under 5 heads & the report generation.

1. Watershed atlas (Basin maps – Basin, sub-basin, catchment, Watershed, River network, Digital Elevation Map)

2. **Administrative layers (**International, State, District, Tehsil / taluk, Village Boundary, Town / Villages location and extent, Infrastructure layers, Major Tourist Stations on River banks, Major water sanctuaries, Major Waterfalls & other environmental issues)

3. **Water resources projects (**Location of Major & Medium, Location of Hydroelectric projects, Location of Multipurpose projects, Major and medium Irrigation project command boundaries, Canal network, Waterlogged and salt affected area, soil sample)

4. **Thematic layers** (Water bodies, Landuse landcover, snow cover area, Groundwater well and its analyses, litholog data, land degradation, wasteland map, Drought prone area, Flood inundation map, Interbasin transfer links, inland navigation)

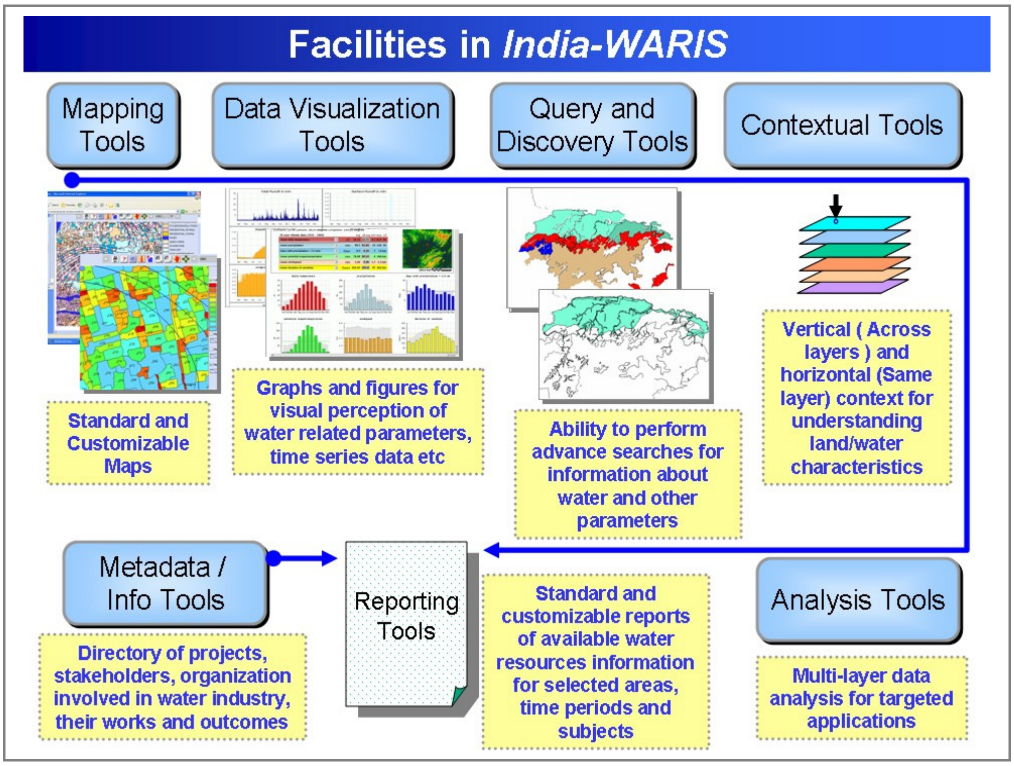
5. **Environment data** (Rainfall station, G&D station, Water quality station, climatic layer)

1.5 WEB ENABLED *India-WARIS* – PROPOSED FACILITIES

The user requirements, data types and required tools for decision support have been arrived through discussions and as of now, following facilities are proposed in India-WARIS:

Table 4: Facilities in *India-WARIS*

S N	Broad level facilities
1.	Mapping tools
	• Rendering of static styled maps with roaming, zoom-in and zoon-out facilities. Map tips to get information about any spatial unit on display on available database fields. • Multi-layer visual overlays for value added maps generation • Annotation on the maps through a database field and as graphic tools for map creation.
2.	Data visualization tools
	• Non-spatial data visualization for viewing spatial patterns • Visualization of non-spatial data in various ways to create environment for visual analysis of data and trigger decisions. • Generation of bar chart / pie chart from tabular data for data
3.	Query and discovery tools
	• Aim and shoot query to provide user required results through a single or stack of layers on the display. • Logical query through 'software provided forms' on thematic and other layers • Provide querying on single database layer • Stacking of query outputs with for visual analysis • Provide ways to discover the data
4.	Contextual tools
	• Vertical context by multi-layer stacking and identification tools and with layer transparency management
5.	Analysis tools
	• Multi-layer logical queries and unit-wise area / length statistics generation • Tools to facilitate analysis in other suitable packages providing open format inputs. • Multi-theme based analysis based on intra-theme and inter-theme weight-ages as desired by CWC
6.	Metadata / info tools
	• Metadata for the all the available data in central server • Information on projects / works of the stakeholders as provided by CEC
7.	Reporting tools
	• Generation of printable maps using standard map layout with various map elements. • Creation of area statistics report.



1.6 DATABASE STANDARDS

The Database Standards for Spatial and Non-Spatial Data: Standards are fundamental requirement for the GIS based information system. These standards enable technologies – imaging, GIS, GPS and applications – thematic mapping, services and outputs etc to work together. Standards are important not only to facilitate data sharing and increase interoperability, as is understood from many international efforts, but also to bring a systematization and "automation" into the total process of mapping and GIS itself. ISRO / DOS has put enormous amount of efforts and prepared the NNRMS standards for most of the thematic data. However all the new elements, which are not covered in earlier standards, will be standardized on the same guidelines as NNRMS standards. With regard to non-spatial data, this project will have enormous amount of such data, which will be standardized. Database table names and their linkage with corresponding spatial layer, database field type and structure of non-spatial database will be addressed by the small working level group of CWC and ISRO scientists.

Metadata Standards: The Metadata standards contain a set of relational tables that standardize the layer Metadata, the geographic search metadata, the access metadata etc. The NNRMS Metadata Standards will be followed for each of the database components.

Datum and projection: The project envisages WGS-84 datum and UTM projection for individual states and WGS-84 datum and LCC projection for entire country mosaic data.

Scale: All database creation under *India-WRIS* is proposed at 1:50,000 scale.

1.7 User of India-WRIS:

There could be three categories of users and datasets, namely -

General user : Public domain fast track system – all users will be able to the visit website and get the snapshots of the outcome of the project on reduced scale with limited access to the database.

Registered user : Public domain user registered with Login and Password. Registered user can download the data and create customize maps.

Premium user : This category of user will be able to get the access to the India-WRIS web application with the visualization of selected database and tools.

1.8 Status of Development of WRIS:

Central Water Commission (CWC), MoWR, initiated the project 'Generation of Database and Implementation of Web enabled Water Resources Information System named as **India –WRIS in XI plan.** WRIS has been jointly formulated by CWC and ISRO to generate nationally consistent water resources database to be completed by December 2012. The MOU was signed with ISRO in December 2008. Hon'ble Minister for Water Resources launched the first version during December 2010. The URL of the website is www.india-wris.nrsc.gov.in. The current version is 4.0, which contains around 95 GIS layers and is on 1:250K scale (Public domain).

Annexure – I

S.No	Name of GIS layer
1	Basin, sub basin, catchment, water shed
2	River network
3	Digital Elevation model
4	Administrative boundary like International, state, district & block boundary
5	Village boundary
6	Town/village location and extent
7	Road network
8	Major tourist station
9	Location of major & medium irrigation projects
10	Location of Hydroelectric project
11	Location of multipurpose projects
12	Major & medium irrigation command boundary
13	Waterlogged and salt affected area in major & medium command
14	Soil samples of major & medium irrigation project command
15	Canal network
16	Surface water bodies
17	Ground water observation well location & data
18	Litholog data with aquifer data
19	Landuse/land cover
20	Land degradation
21	Wasteland map
22	Snow cover area
23	Flood inundation map
24	Drought prone area map
25	Inland navigation waterways
26	Inter-basin transfer link as per NWDA
27	Hydro-meteorological (Gauge & Discharge) sites of CWC
28	Meteorological station of IMD & CWC
29	Climate related data
30	Pollution monitoring station/water quality station of CWC

INTEGRATED FLOOD FORECAST MODELLING

Sunil Kumar
Director, NWA, Pune

1.0 Introduction

All major ancient civilisations were developed in the river valleys because river served as source of water, food, transportation and protection to the mankind. On contrary, now days even a small, slow-flowing stream or gentle river could cause severe damage to the people and their businesses by flooding. With the changing patterns of rainfall and global climate, floods are matter of greater concern now as it has enhanced damage potentials. Not only river plains are vulnerable to riverine or fluvial flooding but also places far away from river are prone to surface water flooding due to heavy rainfall. Some time immemorial, floods have been responsible for loss of crops andvaluable property and untold human misery in the world, India has been no exception. Anarea of more than 40 million ha in India has been identified as flood prone. Indiais traversed by a large number of river systems, experiences seasonal floods. It has beenthe experience that floods occur almost every year in one part or the other of the country.The rivers of North and Central India are prone to frequent floods during the south-westmonsoon season, particularly in the month of July, August and September. In the Brahmaputra river basin, floods have often been experiences as early as in late May while in Southern rivers floods continue till November. Floods have been affecting millions of people throughout the country. There is every possibility that figure may increase due to population growth,urbanizationin the flood plains& probable impact of climate change.The real time flood forecasting is one of the most effective non- structural measures for flood management. For formulating the flood forecast in the real time, the observed meteorological and flow data are transmitted to the forecasting station through the different means of data communication which include telephone, wireless and network of telemetry stations etc. The collected meteorological and flow data in real time are then used into the calibrated & validated real time flood forecasting model to forecast the flood flow and corresponding water levels for different lead periods varying from few hours to few days depending on the size of catchment and purpose of the forecast. The structure of the model should be simple and it should not have excessive input requirements, but at the same time the forecasted flood must be as accurate as possible.

2.0 Existing Flood Forecasting System

Central Water Commission (CWC) is the national agency entrusted with the responsibility to provide flood forecasting services to all major flood prone inter-state river basins of India. CWC accomplishes this task through a network of 175 flood forecasting stations which include 147 level & 28 inflow forecasting station. On the basis on long term observed data, gauge-to-gauge correlation chart has been developed. Therefore, once discharge/water level at base station (upstream) is observed, discharge/water level at forecast station (downstream) is forecasted. Selection of base station was made is such a way that it may give long lead for the forecast station. [Lead is the time period between issue of forecast till actual arrival of the forecasted event]. Locations vulnerable for flooding historically have been selected as forecasting stations.

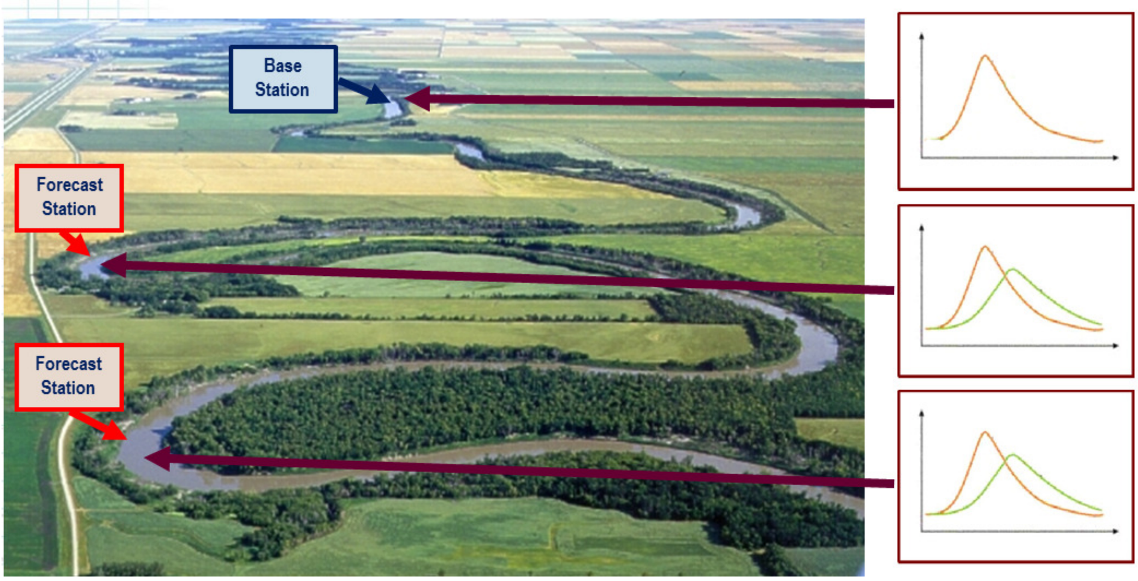


Figure 1: Base Station and Forecast Station

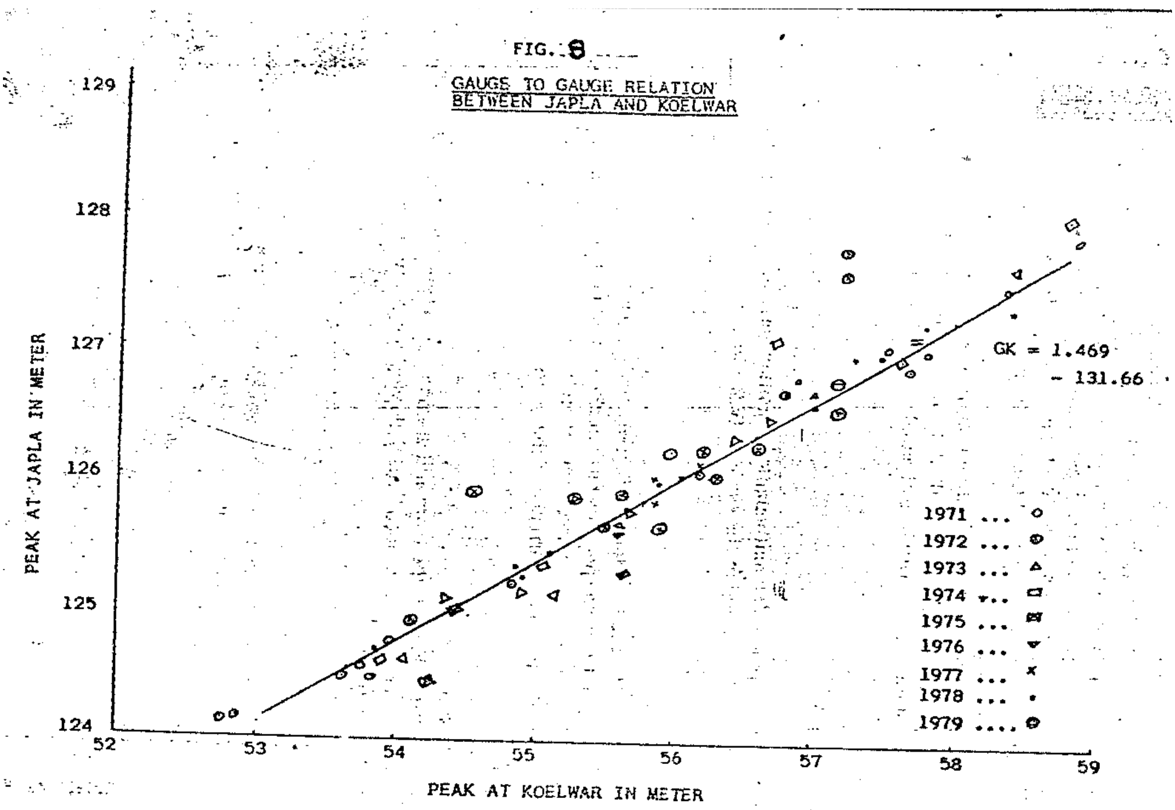


Figure 2: Gauge to Gauge Co-relation Chart

Though fairly accurate, the flood forecast issued on the basis of Gauge to Gauge correlation has following limitations:

1. Forecast is issued only after measurement at base station, therefore lead time is insufficient for appropriate disaster preparedness.
2. Since rainfall is not incorporated, lead time can't be enhanced by including duration of rainfall forecast.

   For eg. If rainfall forecast issued in 5 days advance, Time of concentration is 1 day and travel time of flow from base station to forecast station is 14 hours. In present scenario, lead time is just 14 hours and it could have been enhanced upto 6 days 14 hours (5days + 1 day + 14 hours).
3. Locations other than forecast station prone to flooding are not under consideration. Since selection of these locations took place long ago, there may be other locations in the river reach which are prone to flooding in changing climatic and other conditions.
4. Generally water level forecasts are issued at forecast station in terms of earmarked danger line. No information is given in terms of movement of water in flood plain viz. depth, extent, duration of flooding.
5. Only riverine flooding is taken into consideration. However, surface water of pluvial flooding which is common nowdays in urban areas are not considered.

Figure 3: Flood Forecast Shorcomings

3.0 Urban Flooding

Urban Flooding is extremely complex phenomena and affected by various factors. It can be caused by excessive precipitation in small duration, flash floods, coastal floods, or riverinefloods.Urban floods are a great disturbance of daily life in the city. The economic damages are high as well as number of casualties.The main problem with urban flooding is the fact that they occur in highly populated areas. If the area would have not been urbanized, the waters that flood the area would be more likely to infiltrate into the ground or move to nearby streams, therefore adding up to surface or ground water. For analysis of urban flooding, variety of data is required which is not generally available in Indian scenario. In the urban area accurate information of buildings, roads, fences, kerbsneed to be incorporated as it affects the flooding substantially.

Figure 4: Urban Flooding

For developing an integrated flood forecasting model for urban catchments, following are required:

- Flow data in the river reach (in case of riverine flooding)
- Drainage model of the project area.
- Flood data for calibration & validation of the stream & drainage network.
- Flood-flow/ flood-depth data.
- Finer grid DTM.
- Clear methodology.

4.0 Integrated Flood Forecasting Model

An integrated modeling approach need to be followed which includes rainfall-runoff model of upstream catchment, hydraulic model of the river & drainage network of the urban area and a coupled 2-D flow simulation model for flood analysis. Only such integrated state-of-the-art flood forecasting model may be capable of giving fairly accurate information of the extent and duration of flooding at any location in the project area corresponding to a rain event. Since rainfall time series is the main input to the flood forecasting model, correctness of model-outcome is largely dependent on the correctness of rainfall forecast by Meteorological Office.

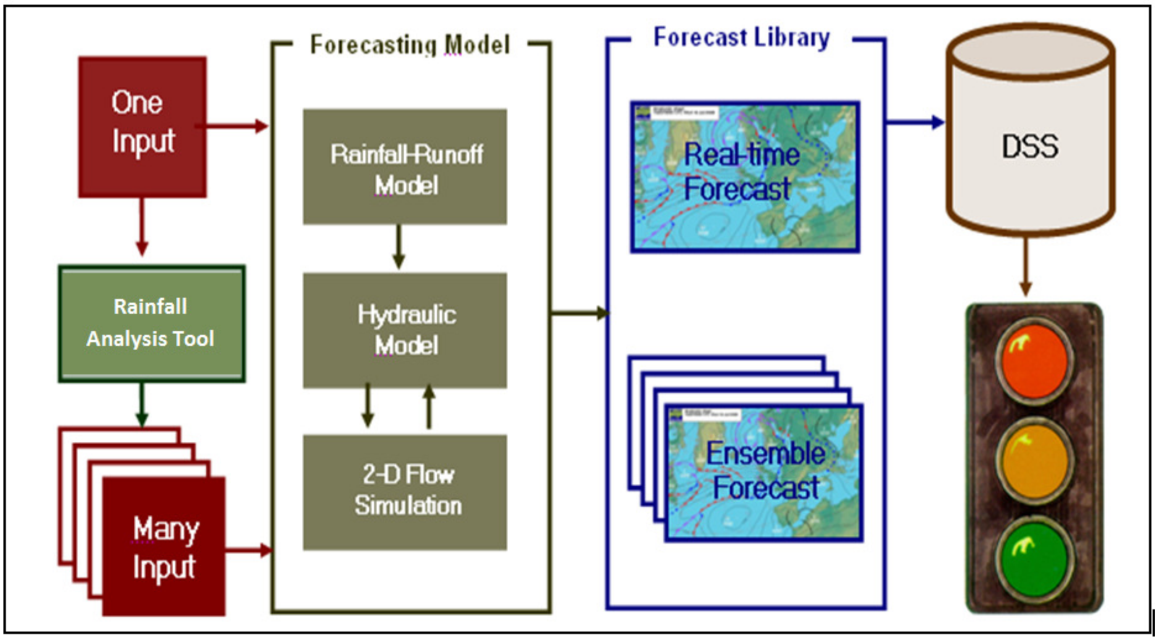


Figure 5: Integrated Flood Forecasting Model

4.1 Rainfall Analysis

The meteorological data is collected from land, sea& air and fed into the dedicated super computers, which, by solving a number of complex mathematical equations gives a variety of weather solutions up to a week or so ahead. The Super computers provide one solution to the evolution of weather is called a 'deterministic forecast' and it gives very little information about the probability of the occurrence of the event. Where, a new evolving technique known as ‘ensemble forecasting’ shows the probability of the occurrence of certain weather events. In this method, the deterministic forecast is run several times with a slightly different starting point and several possible events are generated. Therefore, rather than solely relying on a single event, probabilistic forecasting provides several possible scenario and hence an idea of possible extremities. This enables a better risk based approach to decision making in case of flooding and which in turn facilitate a better allocation of emergency services, flood control measures. Considering, numerous benefit the flood forecasting approach is shifting from deterministic to probabilistic. However, the lead time is the limiting factor for the ensemble forecasting as quick analysis of several scenarios is not feasible.

Fig 6: Rainfall Analysis: Ensemble rainfall

Considering above advantages and limitations of both deterministic and ensemble forecasting system, the best methodology is one which is intended to harness the benefit of both. It envisages an elaborate rainfall analysis which consists of generating several ensemble rainfall scenarios from deterministic one (*Fig 5*). Further, the single deterministic and few extreme ensemble rainfalls are fed into the flood forecasting model. The main purpose is to maintain a small model run time and hence longer lead time in order to facilitate an advance flood warning system. Though all rainfall inputs are later fed to the flood forecasting model and the results are stored into the forecast library. For generating many ensemble rainfalls from a single deterministic rainfall, several tools may be used.

4.2 Forecasting Model

A holistic approach is to be adopted using integrated state-of-the art model for simulating the river & drainage network along with two-dimensional flow. Forecasting model has 3 main components and output of one is used as input of subsequent model:

[1]. Rainfall-Runoff Model

Rainfall-runoff modeling of upstream catchment is the starting point of forecasting model. This approach specifically enhances the lead time substantially. If rainfall forecast is available in 4-5 days advance, the corresponding runoff may be estimated immediately by running this rainfall-runoff model. Commonly used softwares for rainfall-runoff modeling are HEC-HMS, SWAT, Infoworks, Mike SHE etc.

[2]. Hydraulic Model

Hydraulic model includes the river-reach under consideration, hydraulic structure (if any) in the reach, drainage (storm water/ foul water) network of the area of concern, any other abstraction / lateral inflow to/from the river reach.Commonly used softwares for Hydraulic modeling are HEC-RAS, Mike 11, Mike Flood, ISIS, Inforworks RS/CS etc.

[3]. 2-D Flow Simulation Model

Further, the hydraulic model is to be well coupled with the two dimensional flow zone. Two-dimensional zone is to be well represented by accurately incorporating roads, buildings, fence, kerbs, soil-type, culvert features etc. Two-way interaction between hydraulic and 2-D models signifies the fact that when river breaks its bank or drain overflows, water flows into 2D-zones (*Fig 6*). But subsequently after few hours/days water drains back to river/drainage network when flood recedes. Commonly used softwares for 2-D flow simulations are Infoworks 2D, Mike Flood, ISIS, Mike 21 etc.

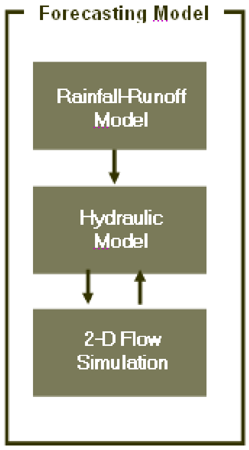


Fig7: Flood Forecasting

4.3 Forecast Library

All flooding scenario corresponding to various rainfall input will be stored into the forecast library. Considering the lead time constraints, all rainfall inputs can not be fed into above flood forecasting model in the real time. Rather the deterministic rainfall along with few extreme ensemble rainfalls will be fed into model for real-time forecast. However the forecast library will be enriched later by model results corresponding to all other ensemble rainfall events. This may be proved highly beneficial in case a particular rain event shows resemblance to any previous rain event against which the flood forecast is available in the forecast library. Therefore, it will enable a quick flood forecast even without running the model and will facilitate a long lead time.

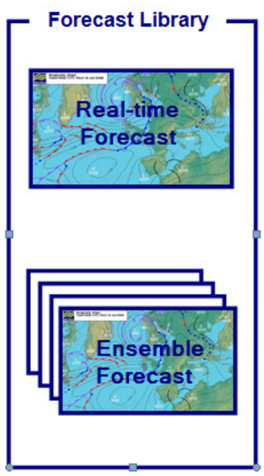


Fig8: Forecast Library

4.4 Decision Support System

There could be several components of flood forecasting & warning decision making but the forecast library is definitely the most important one. However, the decision making may also be assisted by previous actual rainfall record and measured flow data. The ultimate aim of the project is to device a simple traffic-light type flood warning system. The low, medium and high extent of flooding may be defined by the stakeholder and researchers altogether for their clear understanding.

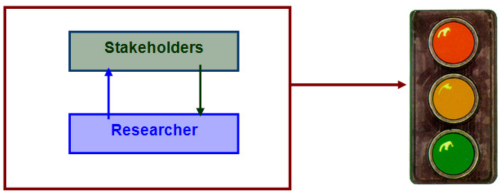


Fig9: Estimation of Flood Warning signals

HYDROLOGICAL ANALYSIS USING HEC-HMS

1.0 Introduction

All major ancient civilisations were developed in the river valleys because river served as source of water, food, transportation and protection to the mankind. On contrary, nowadays even a small, slow-flowing stream or gentle river could cause severe damage to the people and their businesses by flooding. With the changing patterns of rainfall and global climate, floods are matter of greater concern now as it has enhanced damage potentials. Not only river plains are vulnerable to riverine or fluvial flooding but also places far away from the river are prone to surface water flooding due to heavy rainfall. Hydrological processes are extremely complex phenomena so as its accurate understanding & its quantification. However, with the advent of many hydroinformatics tools & technology, a fairly accurate rainfall-runoff analysis of a catchment is possible nowadays. Despite rapid advancement in computer processing technology, 2-dimensional flood flow simulation is not in practice on large scale catchment because of its massive computational requirements. Especially long computational time is the greatest limitation and therefore, 2-D models cannot be effectively utilised for the water assessment and especially for flood forecasting purpose where information is desired to be conveyed in much advance to reduce the impact of the flooding event. Considering this inherent fact of 2D modeling, a comparatively smaller zone is delineated for 2D flow simulation, if required. Therefore, 2D models are incapacitated for rainfall-runoff analysis or flood flow simulation of entire catchment and software like HEC-HMS is quite useful for this purpose. Rainfall-runoff analysis & flow-simulation of an urban catchment remains a challenge as it consists of building, roads, footpath, fences, hedges etc which affects the flow substantially. There is an urgent need to adopt a holistic modeling approach to address urban flooding problems.

2.0 Integrated Water Modeling

A holistic modeling approach is essentially needed to be followed which includes rainfall-runoff model of upstream catchment, hydraulic model of the river & drainage network of the urban catchment and a coupled 2-D flow simulation model for flood analysis (Fig.1). The output of rainfall-runoff analysis of the upstream catchment serves as the input for the hydraulic model. Further, the drainage/sewage component also constitutes as the part of urban hydraulic model. In case of riverine or pluvial flooding, the water overflows out of river or drainage system is represented by the 2-dimensional flow simulation.

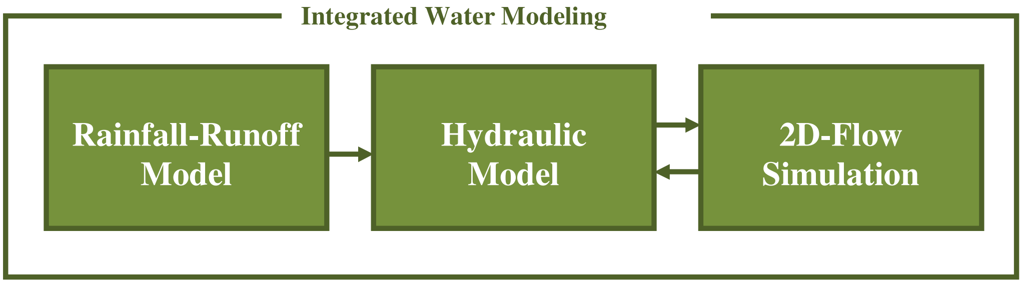


Fig 1: Schematic Diagram

The two arrows (incoming & outgoing, in Fig.1) between hydraulic and 2-D models signifies the flood wave in the flood plain and receding flood wave respectively. At the time of flooding water break the bank of river or urban drainage is insufficient to intake storm water. When flood recedes the water from flood plain drains back to river or drainage system.

3.0 Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS)

The Hydrologic Engineering Center (HEC) is the appex Center of Expertise for the US Army Corps of Engineers and works under the Institute for Water Resources. Its working domain include surface and groundwater hydrology, river hydraulics and sediment transport, hydrologic statistics and risk analysis, reservoir system analysis, planning analysis, real-time water control management and a number of other closely associated technical subjects. HEC-HMS is designed to simulate the rainfall-runoff processes of watershed systems. It is designed to be applicable in a wide range of geographic areas for solving a broad range of problems. This includes large river basin water supply and flood hydrology to small urban or natural watershed runoff. Hydrographs produced by the program can be used directly or in conjunction with other software for studies of water availability, urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, wetlands hydrology, and systems operation.

3.1 Runoff Processes in HEC-HMS

The hydrological processes incorporated for Rainfall-Runoff analysis in HEC-HMS is shown below:

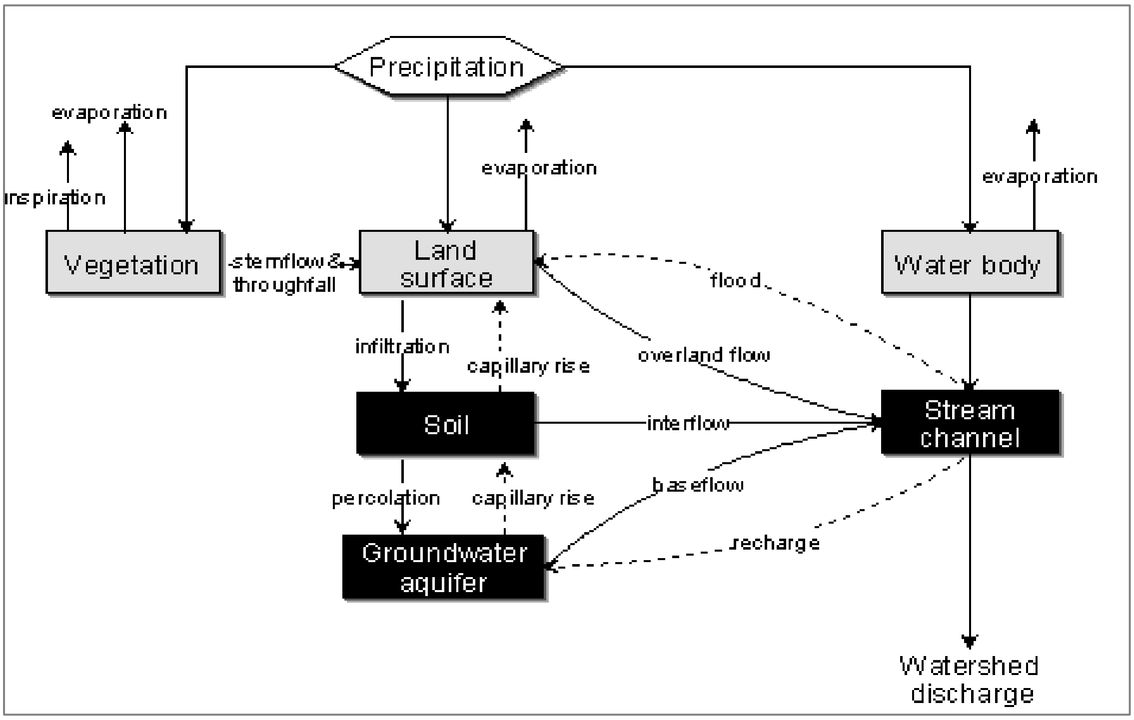


Fig 2: Natural Hydrologic Process

In the hydrological system, runoff depends on many factors such as soil type, ground cover, antecedent moisture, infiltration, evaporation from vegetation and other watershed properties. This infiltrated water is stored temporarily in the upper, partially saturated layers of soil. From there, it rises to the surface again by capillary action, moves horizontally as interflow just beneath the surface, or it percolates vertically to the groundwater aquifer beneath the watershed. The interflow eventually moves into the stream channel. Water in the aquifer moves slowly, but eventually, some returns to the channels as baseflow. Water that does not pond or infiltrate moves by overland flow to a stream channel. The stream channel is the combination point for the overland flow, the precipitation that falls directly on water bodies in the watershed, and the interflow and baseflow. Thus, resultant streamflow is the total watershed outflow.

3.2 Constituents of HEC-HMS

3.2.1 State Variables

These terms in the model's equations represent the state of the hydrologic system at a particular time and location. For example, the deficit and constant-rate loss model that is described in next section tracks the mean volume of water in natural storage in the watershed. This volume is represented by a state variable in the deficit and constant-rate loss model's equations. Likewise, in the detention model, the pond storage at any time is a state variable; the variable describes the state of the engineered storage system.

3.2.2 Parameters

These are numerical measures of the properties of the real-world system. They control the relationship of the system input to system output. Parameters are generally used as turning knobs of a model. The parameters are adjusted to accurately match the real life physical process. For example, the Snyder unit hydrograph model has two parameters, the basin lag, *tp*, and peaking coefficient, *Cp*. The values of these parameters can be adjusted to "fit" the model to a particular physical system. Different methods have different parameters used to calibrate the outcome of model vis-à-vis a measured data.

3.2.3 Boundary Conditions

Boundary conditions are the input/output of a model and these are the forces that act on the hydrologic system and cause it to change. The most common boundary condition in the HEC-HMS program is precipitation; applying this boundary condition causes runoff from a watershed. Another example is the upstream (inflow) flow hydrograph to a channel reach; this is the boundary condition for a routing model.

3.2.4 Initial Conditions

Initial conditions are the set of information describe the state before running a particular model. It affects significantly the initial time period of simulation but eventually its impact is comparatively less in the later time period of simulation.

3.3 Fundamentals of HEC-HMS Modeling

The program underneath HEC-HMS considers that all land and water in a watershed can be categorized as either:

- Directly-connected impervious surface

- Pervious surface

Directly-connected impervious surface in a watershed is that portion of the watershed for which all rainfall converted to runoff with no infiltration, evaporation, or other hydrological losses. Precipitation on the pervious surfaces is subject to losses. The following alternative models are included to account for the cumulative losses:

- The initial and constant-rate loss model
- The deficit and constant-rate model
- The SCS curve number (CN) loss model
- The Green and Ampt loss model

With each model, precipitation loss is found for each computation time interval, and is subtracted from the Mean Areal Precipitation (MAP) depth for that interval. The remaining depth is referred to as precipitation excess. This depth is considered uniformly distributed over a watershed area, so it represents a volume of runoff.

3.3.1 Initial and constant-rate loss model

The underlying concept of the initial and constant-rate loss model is that the maximum potential rate of precipitation loss, f_c, is constant throughout an event. Thus, if p_t is the MAP depth during a time interval t to $t+\Delta t$, the excess, pe_t, during the interval is given by:

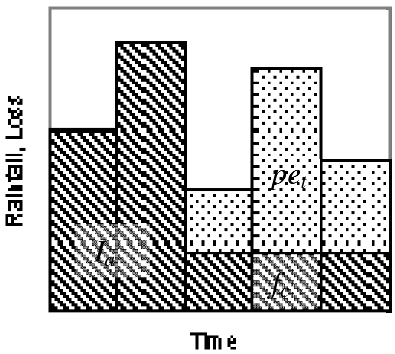


Fig 3: Initial & Constant rate loss

$$pe_t = \begin{cases} p_t - f_c & if\ p_t > f_c \\ 0 & otherwise \end{cases} \quad (1)$$

An initial loss, I_a, is added to the model to represent interception and depression storage. Interception storage is a consequence of absorption of precipitation by surface cover, including plants in the watershed. Depression storage is a consequence of depressions in the watershed topography; water is stored in these and eventually infiltrates or evaporates. This loss occurs prior to the onset of runoff. Until the accumulated precipitation on the pervious area exceeds the initial loss volume, no runoff occurs. Thus, the excess is given by:

$$pe_t = \begin{cases} 0 & if \sum p_i < I_a \\ p_t - f_c & if \sum p_i > I_a \text{ and } p_t > f_c \\ 0 & if \sum p_i > I_a \text{ and } p_t < f_c \end{cases} \quad (2)$$

The initial losses are computed in HEC-HMS as per following table:

Table 1: SCS soil groups and infiltration (loss) rates (SCS, 1986; Skaggs and Khaleel, 1982)

Soil Group	Description	Range of Loss Rates (in/hr)
A	Deep sand, deep loess, aggregated silts	0.30-0.45
B	Shallow loess, sandy loam	0.15-0.30
C	Clay loams, shallow sandy loam, soils low in organic content, and soils usually high in clay	0.05-0.15
D	Soils that swell significantly when wet, heavy plastic clays, and certain saline soils	0.00-0.05

3.3.2 The deficit and constant-rate model

The HEC-HMS program also includes a quasi-continuous variation on the initial and constant model of precipitation losses; this is known as the deficit and constant loss model. This model is different from the initial and constant loss model as the initial loss can "recover" after a prolonged period of no rainfall. This model is similar to the loss model included in computer program HEC-IFH (HEC, 1992). To use this model, the initial loss and constant rate plus the recovery rate must be specified. The moisture deficit is tracked continuously, computed as the initial abstraction volume less precipitation volume plus recovery volume during precipitation-free periods. The recovery rate could be estimated as the sum of the evaporation rate and percolation rate, or some fraction thereof.

3.3.3 SCS curve number (CN) loss model

The Soil Conservation Service (SCS) Curve Number (CN) model estimates precipitation excess as a function of cumulative precipitation, soil cover, land use, and antecedent moisture, using the following equation:

$$P_e = \frac{(P - I_a)^2}{P - I_a + S} \quad (3)$$

where P_e = accumulated precipitation excess at time t; P = accumulated rainfall depth at time t; I_a = the initial abstraction (initial loss); and S = potential maximum retention, a measure of the ability of a watershed to abstract and retain storm precipitation. Runoff is zero until the accumulated rainfall exceeds the initial abstraction.

Through analysis of results from many small experimental watersheds, the SCS developed an empirical relationship of I_a and S:

$$I_a = 0.2\,S \tag{4}$$

Therefore, the cumulative excess at time t is:

$$P_e = \frac{(P - 0.2\,S)^2}{P + 0.8\,S} \tag{5}$$

Incremental excess for a time interval is computed as the difference between the accumulated excess at the end and the beginning of the period. The maximum retention, S, and watershed characteristics are related through an intermediate parameter, the curve number (commonly abbreviated CN) as:

$$S = \begin{cases} \dfrac{1000 - 10\,CN}{CN} & \text{(foot - pound system)} \\ \dfrac{25400 - 254\,CN}{CN} & \text{(SI)} \end{cases} \tag{6}$$

CN values range from 100 (for water bodies) to approximately 30 for permeable soils with high infiltration rates. A table (called TR-55) is developed by SCS for obtaining CN according to the soil type, land use etc.

3.3.4 Green and Ampt loss model

The Green and Ampt infiltration model included in the program is a conceptual model of infiltration of precipitation in a watershed. The model computes the precipitation loss on the pervious area in a time interval as:

$$f_t = K\left[\frac{1 + (\phi - \theta_i)S_f}{F_t}\right] \tag{7}$$

Where f_t = loss during period t; K = saturated hydraulic conductivity; (ϕ - θ_i) = volume moisture deficit; S_f = wetting front suction; and F_t = cumulative loss at time t. Same as other models, the Green and Ampt model also includes an initial abstraction and computed in same manner.

3.4 HEC-HMS: Direct Runoff

HEC-HMS simulates the process of direct runoff of excess precipitation on a watershed using following two methods:

3.4.1 Empirical models (also referred to as system theoretic models)

These are the traditional unit hydrograph (UH) models. The system theoretic models attempt to establish a causal linkage between runoff and excess precipitation without detailed consideration of the internal processes. The equations and the parameters of the model have limited physical significance. Instead, they are selected through optimization of some goodness-of-fit criterion.

3.4.2 Conceptual model

The conceptual model included in the program is a kinematic-wave model of overland flow. It represents, to the extent possible, all physical mechanisms that govern the movement of the excess precipitation over the watershed land surface and in small collector channels in the watershed.

3.5 HEC-HMS: Modeling Channel flow, Routing

HEC-HMS routing models are based on the fundamental equations of open channel flow: continuity and momentum equation. Together the two equations are known as the St. Venant equations or the dynamic wave equations.

The continuity equation accounts for the volume of water in a reach of an open channel, including that flowing into the reach, that flowing out of the reach, and that stored in the reach. In one-dimension, the equation is:

$$A\frac{\partial V}{\partial x} + VB\frac{\partial y}{\partial x} + B\frac{\partial y}{\partial t} = q \qquad \textbf{(8)}$$

where B = water surface width; and q = lateral inflow per unit length of channel. Each of the terms in this equation describes inflow to, outflow from, or storage in a reach of channel, a lake or pond, or a reservoir. Henderson (1966) described the terms as $A(\partial V/\partial x)$ = prism storage; $VB(\partial y/\partial x)$ = wedge storage; and $B(\partial y/\partial t)$ = rate of rise.

The momentum equation accounts for forces that act on a body of water in an open channel. In simple terms, it equates the sum of gravitational force, pressure force, and friction force to the product of fluid mass and acceleration. In one dimension, the equation is written as:

$$S_f = S_0 - \frac{\partial y}{\partial x} - \frac{V}{g}\frac{\partial V}{\partial x} - \frac{1}{g}\frac{\partial V}{\partial t} \tag{9}$$

where S_f = energy gradient (also known as the friction slope); S_0 = bottom slope; V = velocity; y = hydraulic depth; x = distance along the flow path; t = time; g = acceleration due to gravity; $\partial y/\partial x$ = pressure gradient; $(V/g)(\partial V/\partial x)$ = convective acceleration; and $(1/g)(\partial V/\partial t)$ = local acceleration.

- The momentum and continuity equations are derived from basic principles, assuming:
- Velocity is constant, and the water surface is horizontal across any channel section.
- All flow is gradually varied, with hydrostatic pressure prevailing at all points in the flow. Thus vertical accelerations can be neglected.
- No lateral, secondary circulation occurs.
- Channel boundaries are fixed; erosion and deposition do not alter the shape of a channel cross section.

Water is of uniform density, and resistance to flow can be described by empirical formulas, such as Manning's and Chezy's equation. The channel flow or routing models available in HEC-HMS include:

- Lag
- Muskingum
- Modified Puls
- Kinematic-wave, etc.

Each of these models computes a downstream hydrograph, given an upstream hydrograph as a boundary condition. This is obtained by solving the continuity and momentum equations.

3.5.1 Lag Model

This is the simplest of the included routing models. With it, the outflow hydrograph is simply the inflow hydrograph, but with all ordinates translated (lagged in time) by a specified duration. The flows are not attenuated, so the shape is not changed. This model is widely used, especially in urban drainage channels (Pilgrim and Cordery, 1993).

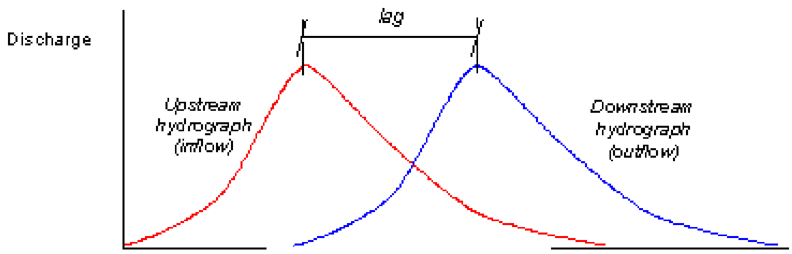


Fig 4: Lag Model

3.5.2 Muskingum Model

Storage in the channel-reach is modeled as the sum of prism storage and wedge storage. As shown in Fig.5, prism storage is the volume defined by a steady-flow water surface profile, while wedge storage is the additional volume under the profile of the flood wave. During rising stages of the flood, wedge storage is positive and is added to the prism storage. During the falling stages of a flood, the wedge storage is negative and is subtracted from the prism storage.

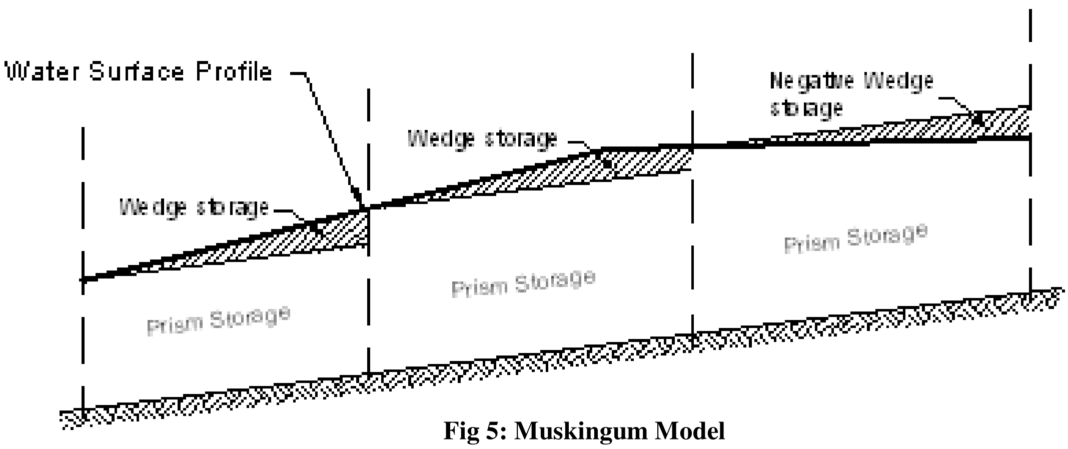


Fig 5: Muskingum Model

3.5.3 Modified Puls Model

The Modified Puls routing method, also known as storage routing or level-pool routing, is based upon a finite difference approximation of the continuity equation, coupled with an empirical representation of the momentum equation (Chow, 1964; Henderson, 1966). For the Modified Puls model, the continuity equation is written as

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0$$

This simplification assumes that the lateral inflow is insignificant, and it allows width to change with respect to location. Rearranging this equation and incorporating a finite-difference approximation for the partial derivatives yields:

$$\overline{I_t} - \overline{O_t} = \frac{\Delta S_t}{\Delta t}$$

Where, I_t= average upstream flow (inflow to reach) during a period Δt; O_t= average downstream flow (outflow from reach) during the same period; and ΔS_t = change in storage in the reach during the period.

3.5.4 Kinematic Wave Model

Kinematic wave routing, the watershed and its channels are conceptualized as shown in Fig.6 below. This represents the watershed as two plane surfaces over which water runs until it reaches the channel. The water then flows down the channel to further downstream. At a cross section, the system would resemble an open book, with the water running parallel to the text on the page (down the shaded planes) and then into the channel that follows the book's center binding.

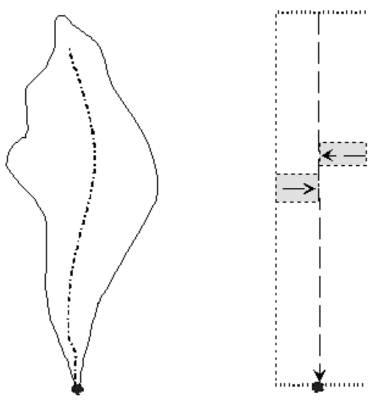


Fig 6: Muskingum Model

4.0 Conclusion

Rainfall- runoff analysis is a key component of urban flood analysis and HEC-HMS is an effective software tool for this purpose. However, accuracy will be definitely improved once 2-D models are employed for the same purpose. It'll also indicate fairly accurate pour-points of the runoff generated over the catchment. But huge computational requirement and availability fine grid-size GIS data remains a challenge for application 2-D modeling for rainfall-runoff analysis.

DYNAMIC WAVE ROUTING AND FLOOD MODELLING WITH HEC-RAS

Abstract

The present lecture focuses on the theoretical concepts of hydraulic flood routing model with time-varying roughness updating to simulate flows through natural channels based on the quasi-steady dynamic wave and full dynamic wave theory emphasizing the solving of the intricate Saint Venant's equations (continuity & momentum equation). In the later phase of the lecture, a real case study of unsteady flood modelling through HEC-RAS has been dealt with for a reach in Krishna river (Karad - Kurundwad reach, chainage 140 km to 260 km. Lateral inflows to the main river on the corresponding dates have been considered at Sangam, where river Panchganga contributes to the Krishna flow. The technique provides a reliable initialization of stage/discharge profile for the forecast. The examinations including the initialization of stage profile, conservation of mass, iteration convergence, Manning's N, effectiveness evaluation, and convergence with optimum theta (implicit weighing factor) values are conducted to verify the forecast capability and in validating the model. The forecasting results show that the stage recalculated by updating the Manning ***N*** in current time has a good agreement with the observed stage. Also, RAS mapper procedure has been covered in brief for a flood scenario conceptualization.

Introduction

Hydraulic routing employs the full dynamic wave (St. Venant) equations. These are the continuity equation and the momentum equation, which takes the place of the storage-discharge relationship used in hydrologic routing. The equations describe flood wave propagation with respect to distance and time. Henderson (1966) rewrites the momentum equation as follows:

$$S_f = S_0 - (\frac{\partial y}{\partial x}) - (\frac{V\partial V}{g\partial x}) - \frac{1}{g}\frac{\partial V}{\partial t}$$

Where,

S_f = friction slope (frictional forces), in m/m;

S_o = channel bed slope (gravity forces), in m/m;

2nd term = pressure differential;

3rd term = convective acceleration, in m/sec^2;

Last term = local acceleration, in m/sec^2

$$q = A(\frac{\partial V}{\partial x}) - (VB\frac{\partial y}{\partial x}) - B\frac{\partial y}{\partial t}$$

The description of each term:

A(.V/.x) = prism storage

VB(.y/.x) = wedge storage

B(.y/.x) = rate of rise

Q = lateral inflow

The full dynamic wave equations are considered to be the most accurate solution to unsteady, one dimensional flow but are based on the following assumptions used to derive the equations (Henderson, 1966):

1. Velocity is constant and the water surface is horizontal across any channel section.

2. Flows are gradually varied with hydrostatic pressure prevailing such that vertical acceleration can be neglected.

3. No lateral circulation occurs.

4. Channel boundaries are considered fixed and therefore not susceptible to erosion or deposition.

5. Water density is uniform and flow resistance can be described by empirical formulae (Manning, Chezy) Solution to the dynamic wave equations can be divided into two categories: approximations of the full dynamic wave equations, and the complete solution.

The three most common approximations or simplifications to the full dynamic equations are referred to as *Kinematic*, *Diffusion*, and *Quasi-steady models*. They assume certain terms of the momentum equation can be neglected due to their relative orders of magnitude. The full momentum equation is

$$S_f = S_0 - (\frac{\partial y}{\partial x}) - (\frac{V \partial V}{g \partial x}) - \frac{1}{g}\frac{\partial V}{\partial t}$$

Kinematic and diffusion models have found wide application and acceptance in the engineering community (Bedient and Huber, 1988). This acceptance can be attributed to their application to mild and steep slopes with slow rising flood waves (Ponce et al., 1978). Henderson (1966) supported this by computing values for each term in the. momentum equation. He found that the last three terms of the momentum equation are two orders of magnitude less than the channel bed slope value and therefore are negligible for steep slopes.

Quasi-Steady Dynamic Wave Routing

Description

The quasi-steady dynamic wave approximation method incorporates the convective acceleration term but not the local acceleration term, as indicated below:

$$S_f = S_0 - (\frac{\partial y}{\partial x}) - (\frac{V \partial V}{g \partial x})$$

In channel routing calculations, the convective acceleration term and local acceleration term are opposite in sign and thus tend to negate each other. If only one term is used, an error result which is greater in magnitude than the error created if both terms were excluded (Brunner, 1992). Therefore, the quasi-steady approximation is not used in channel routing.

Fully Dynamic Wave Routing

Description

Complete hydraulic models solve the full Saint Venant equations simultaneously for unsteady flow along the length of a channel. They provide the most accurate solutions available for calculating an outflow hydrograph while considering the effects of channel storage and wave shape (Bedient and Huber, 1988). The models are categorized by their numerical solution schemes which include characteristic, finite difference, and finite element methods.

Characteristic methods were used for early numerical flood routing solutions based on the characteristic form of the governing equations. The two partial differential equations are replaced with four ordinary differential equations and solved along the characteristic curves (Henderson, 1966). The four equations are commonly solved using explicit or implicit finite difference techniques (Amein, 1966; Liggett and Woolhiser, 1967; Baltzer and Lai, 1968; Ellis, 1970; Strelkoff, 1970). Bed ient and Huber (1988) state that characteristic methods incorporate cumbersome interpolations with no added accuracy compared to the finite difference techniques.

The finite difference method describes each point on a finite grid by the two partial differential equations and solves them using either an explicit or implicit numerical solution technique. Explicit methods solve the equations point by point in space and time along one time line until all the unknowns are evaluated then advance to the next time line (Fread, 1985). Much research has been performed on this topic (Garrison et al., 1969; Liggett and Woolhiser, 1967). Implicit methods simultaneously solve the set of equations for all points along a time line and then proceed to the next time line (Liggett and Cunge, 1975). Again, this topic has been well researched by Amein and Chu (1975), Amein and Fang (1970), and Fread (1973a and 1973b), among others. The implicit method has fewer stability problems and can use larger time steps than the explicit method. Finite element methods can be used to solve the Saint Venant equations (Cooley and Mom, 1976). The method is commonly applied to two-dimensional models.

Assumptions

The assumptions given above for all hydraulic models (one-dimensional flow, fixed channel, constant density, and resistance described by empirical coefficients) apply to dynamic routing. It is also assumed that the cross sections used in the model fully describe the river's geometry, storage, and flow resistance.

Limitations

The major drawback to fully dynamic routing models is that they are time-consuming and data intensive, and the numerical solutions often fail to converge when rapid changes (in time or space) are being modeled. This can be addressed by adjusting the time and distance steps used in the model; sometimes, however, memory or computational time limits the number of time and distance steps that may be used. Additionally, fully dynamic one-dimensional routing models do not describe situations (such as lakes and major confluences) where lateral velocities and forces are important.

Data Requirements

The accuracy of the model depends on the detail and accuracy of the river geometry that is input to the model (as well as the choice of appropriate time and distance steps). Input data for each cross section must describe channel slope and geometry; over bank storage; natural and man-made constrictions (such as bridges); channel and over bank roughness coefficients, and lateral inflows or outflows. In addition each model needs upstream and downstream "boundary conditions" – usually a flow hydrograph at the upstream end and some form of stage-discharge relationship at the downstream end.

Development of Equations

Dynamic routing models use finite-difference versions of the full St. Venant equations. This produces a set of simultaneous equations for each distance and time step, which are solved by a variety of techniques in different models.

Use and Estimation of Parameters

The hydraulic input data needed in a dynamic routing model is usually determined from a topographic map or surveyed river/valley cross sections. Any other special hydraulic conditions (u/s, d/s, or internal boundary conditions such as dams or waterfalls) must also be identified and described as a rating curve or fixed stage or flow hydrograph. The selection of computational time and distance steps is critical to the accurate solution of the equations and to the numerical stability of the solution technique. A commonly cited guideline is that the wave celerity ***c*** should be greater than the ratio of model distance step to time step.

MODELLING WITH HEC-RAS

HEC-RAS is based on the U.S. Army Corps of Engineers' water surface profile model used for modeling both steady and unsteady, one-dimensional, gradually varied flow in both natural and man-made river channels. It also allows sediment transport/mobile bed computations and water quality modeling. The capabilities of RAS are:

- Steady and unsteady flow modeling
- Mixed flow regime analysis, allowing analysis of both subcritical and supercritical flow regimes in a single computer run
- Bridge and culvert analysis and design, including culvert routines for elliptical, arch, and semi-circular culverts
- Multiple bridge and culvert openings of different types and sizes at a roadway crossing
- Bridge scour computations
- Bridge design editor and graphical cross section editor
- Floodplain and floodway encroachment modeling
- Multiple profile computations
- Lateral flow, split flow, over bank dendritic networks
- Sediment Transport/Movable Bed Modeling
- Sediment Impact Analysis Methods (SIAM)
- Water Quality Capabilities (Temperature Modeling)
- Tidal boundary conditions
- Reservoir and spillway analysis
- Levee overtopping
- User Defined Rules for Controlling Gate Operations
- Pumping of flooded areas
- Modeling Pressurized Pipe Flow
- Geometric model schematic can be placed over background maps and incorporate clickable scanned images of structures
- Inline weirs and gated spillways analysis, including both radial and sluice type gates and Ogee, broad and sharp crested weirs
- Tributary/diversion flow network capabilities, allowing for fully looped river system analysis in which reaches can be subdivided and combined
- Quasi 2-D velocity distributions
- X-Y-Z (pseudo 3-D) graphics of the river system

Theoretical Calculations for One-dimensional Flow

The following paragraphs describe the methodologies used in performing the 1-D flow calculations within HEC-RAS. The basic equations are presented along with discussions of the various terms. Solution schemes for the various equations are described. Discussions are provided as to how the equations should be applied, as well as applicable limitations.

- ♦ Steady Flow Water Surface Profiles
- ♦ Unsteady Flow Routing

Steady Flow Water Surface Profiles

HEC-RAS is currently capable of performing one-dimensional water surface profile calculations for steady gradually varied flow in natural or constructed channels. Subcritical, supercritical, and mixed flow regime water surface profiles can be calculated. Topics discussed in this section include: equations for basic profile calculations; cross section subdivision for conveyance calculations; composite Manning's n for the main channel; velocity weighting coefficient alpha; friction loss evaluation; contraction and expansion losses; computational procedure; critical depth determination; applications of the momentum equation; and limitations of the steady flow model. Figure- 1 depicts the terms of the energy equation representation.

Equations for Basic Profile Calculations

Water surface profiles are computed from one cross section to the next by solving the Energy equation with an iterative procedure called the standard step method. The Energy equation is written as follows:

$$Z_2 + Y_2 + \frac{a_2 V^2}{2g} = Z_2 + Y_2 + \frac{a_2 V^2}{2g} + he$$

Z_1, Z_2= elevation of the main channel inverts

Y_1, Y_2= depth of water at cross sections

V_1,V_2= average velocities (total discharge/ total flow area)

a_1,a_2= velocity weighting coefficients

g = gravitational acceleration, h_e=energy head loss

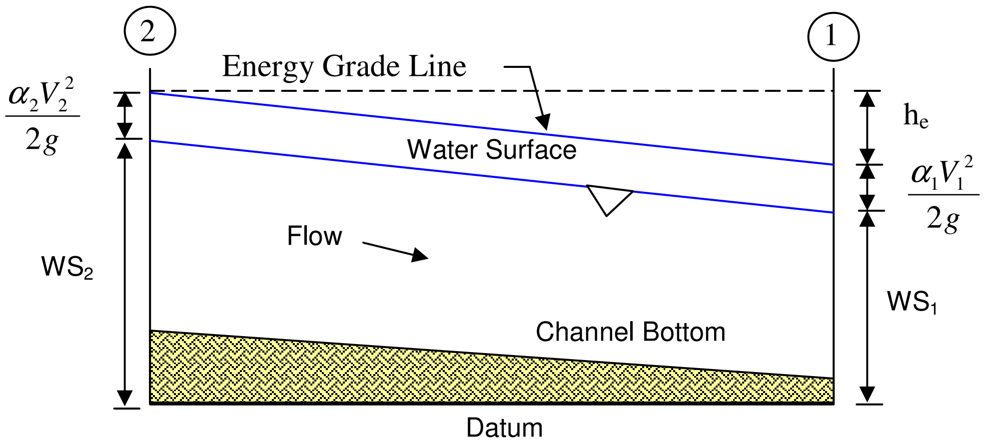


Fig. 1 Representation of terms in energy equation

Friction losses

The energy loss term h_e in equation 1 is composed of friction loss $\boldsymbol{h_f}$ and form loss $\boldsymbol{h_o}$. Only contraction and expansion losses are considered in the geometric form loss term.

$$h_e = h_f + h_o \qquad (2)$$

To approximate the transverse distribution of flow of the river is divided into strips having similar hydraulic properties in the direction of flow. Each cross section is sub divided into portions that are referred to as subsections. Friction loss is calculated as shown below:

$$h_f = \left(\frac{Q}{K^1}\right)^2 \qquad (3)$$

Where, $$K^1 = \sum_{j=1}^{J}\left[\frac{1.49}{n_j}\right]\frac{\frac{(A_2 + A_1)}{2}\left[\frac{R_2 + R_1}{2}\right]_j^{1/2}}{L_j^{1/2}} \quad (4)$$

A_1, A_2 = downstream and upstream area, respectively of the cross sectional flow normal to the flow direction

J = total number of subsections

L_j = length of the j^{th} strip between subsections

n = Manning's roughness coefficient

Q = water discharge

R_1, R_2 = down stream and upstream hydraulic radius

Other losses

Energy losses due to contractions and expansions are computed by the following equation:

$$h_0 = C_L\left|\frac{\alpha_2 V_2^2}{2g} - \frac{\alpha_1 V_1^2}{2g}\right| \quad (5)$$

Where, C_L = loss coefficient for contraction and expansion. If the quantity within the absolute value notation is negative, flow is contracting, C_L is the coefficient for contraction; if is positive, flow is expanding and C_L is the coefficient of expansion. In the standard step method for water surface profile computations, calculations proceed from the d/s to u/s based upon the reach's downstream boundary conditions and starting water surface elevation.

Exercise for you

The primary thrust of this exercise is to introduce you to channel flow using the HEC River Analysis System (HEC-RAS). By the end of this exercise, you should be able to:

- Import and edit cross-sectional geometry data
- Perform a unsteady flow simulation for flood forecasting
- View and analyze HEC-RAS output and use RAS mapper for flood delineation.

HEC-RAS Hydraulics

HEC-RAS is a one-dimensional flow hydraulic model designed to aid hydraulic engineers in channel flow analysis and floodplain determination. The results of the model can be applied in floodplain management studies. If you recall from hydraulics, unsteady flow describes conditions in which depth and velocity at a given channel location changes with time. Gradually varied flow is characterized by minor changes in water depth and velocity from cross-section to cross-section. The primary procedure used by HEC-RAS to compute water surface profiles assumes a steady, gradually varied flow scenario, and is called the *direct step method*. The basic computational procedure is based on an iterative solution of the energy equation: $H = Z + Y + \frac{\alpha V^2}{2g}$, which states that the total energy (H) at any given location along the stream is the sum of potential energy (Z + Y) and kinetic energy ($V^2/2g$). The change in energy between two cross-sections is called head loss (h_L). The energy equation parameters are illustrated in the following graphic:

Given the flow and water surface elevation at one cross-section, the goal of the direct step method is to compute the water surface elevation at the adjacent cross-section. Whether the computations proceed from upstream to downstream or vice versa, depend on the flow regime. The dimensionless Froude number (Fr) is used to characterize flow regime, where:

- Fr < 1 denotes Subcritical flow
- Fr > 1 denotes Supercritical flow
- Fr = 1 denotes Critical flow

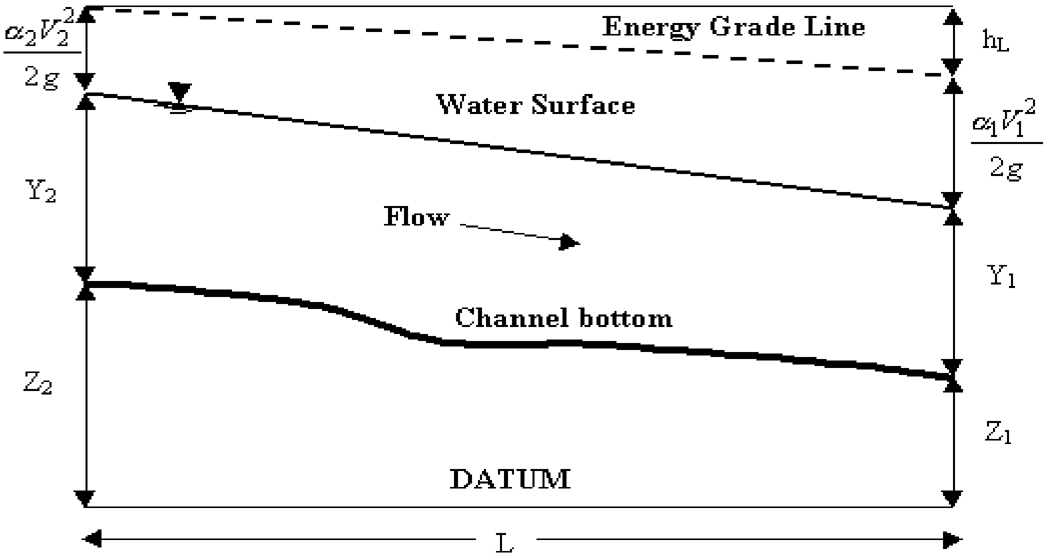


Figure 2

For a subcritical flow scenario, which is very common in natural and man-made channels, direct step computations would begin at the downstream end of the reach, and progress upstream between adjacent cross-sections. For supercritical flow, the computations would begin at the upstream end of the reach and proceed downstream.

Starting a Project

Start the HEC-RAS 4.1.0 program. The following window should subsequently appear:

Figure- 1

Henceforth, this window will be referred to as the main project window. A **Project** in RAS refers to all of the data sets associated with a particular river system. To define a new project, select **File/New Project** to bring up the main project window:

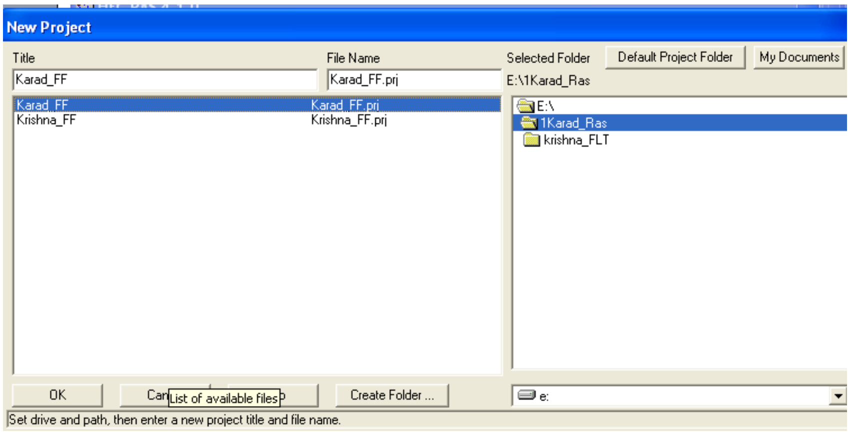


Figure- 2

You first need to select your working directory, and then a title (say Karad), and file name (Karad.prj). All project filenames for HEC-RAS are assigned the extension ".prj". Click on the **OK** button and a window will open confirming the information you just entered. Again click the **OK** button. The project line in your main project window should now be filled in. The **Project Description** line at the bottom of the main project window allows you to type a detailed name for the actual short **Project** name. If desired, you may click on the ellipsis to the right of the **Description** bar, and additional space for you to type a lengthy **Description** will appear. Any time you see an ellipsis in a window in HEC-RAS, it means you may access additional space for writing descriptive text.

For each HEC-RAS project, there are three required components-

Geometry data- The **Geometry** data, for instance, consists of a description of the size, shape, and connectivity of stream cross-sections.

Flow data- **Flow** data contains discharge rates.

Plan data- **Plan** data contains information pertinent to the run specifications of the model, including a description of the flow regime.

Each of these components is explored below individually. The schematic picture in **Figure 3** depicts the Krishna -Koyna river confluence at Karad and we will be analyzing a reach Karad - Kurundwad.

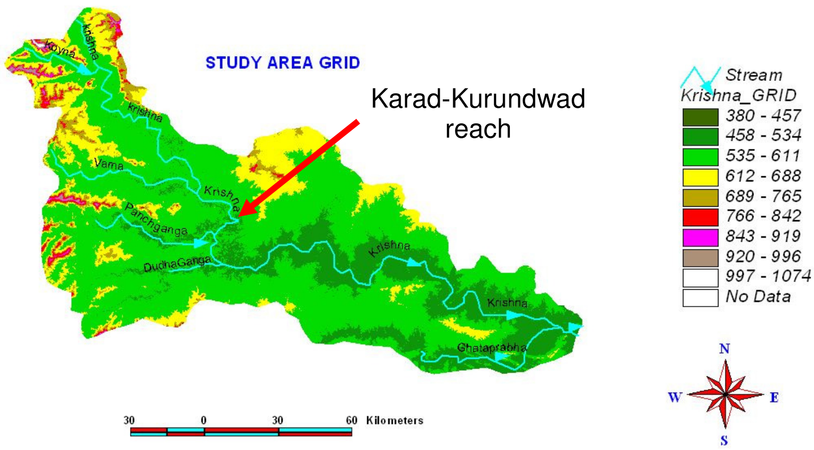


Figure 3

Importing and Editing Geometric Data

The first of the components we will consider is the channel geometry. To analyze stream flow, HEC-RAS represents a stream channel and floodplain as a series of cross-sections along the channel. To create our geometric model, we can do it by three ways.

i) From HMS DSS files

ii) From Geo-RAS (derived from DEM/TIN)

iii) By manual entry of Geometric data

This HEC-RAS geometry file contains physical parameters describing cross-sections. To view the data, select **Edit/Geometric Data** from the project window. The cross sections of Krishna are obtained from Upper Krishna Division topographic survey record.

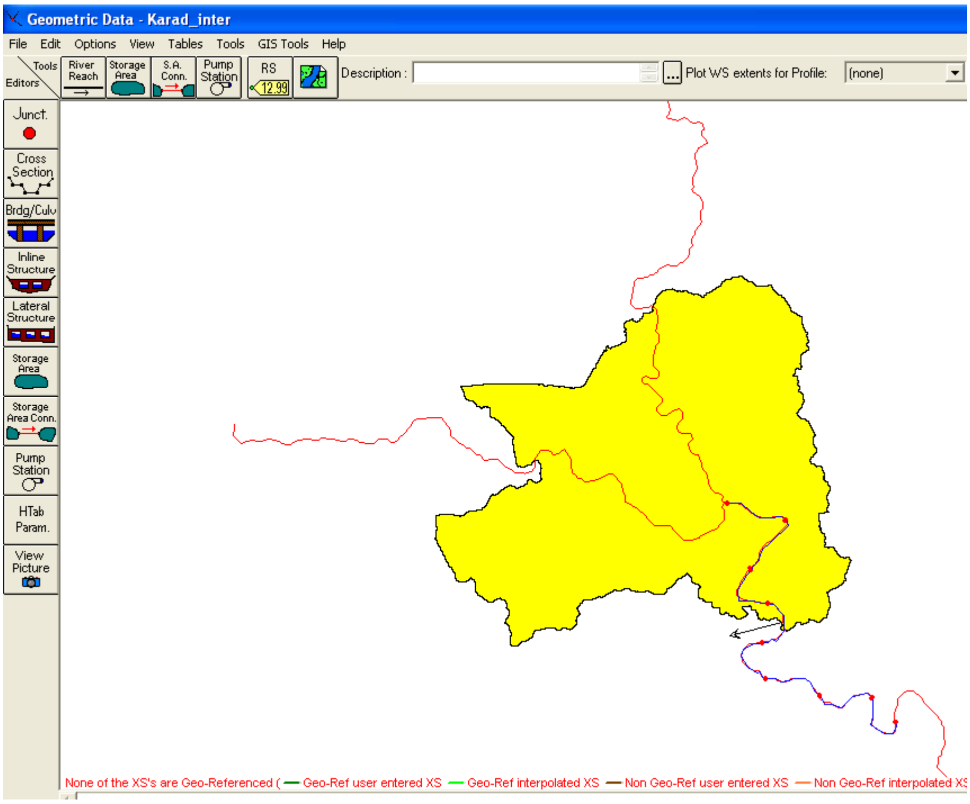
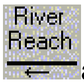
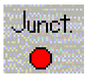
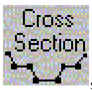
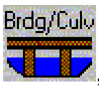


Figure 4

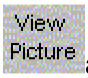
The resulting view shows a schematic of Krishna & its tributary Koyna river with the area of study. This is the main geometric data editing window. The red tick marks and corresponding numbers denote individual cross-sections. Choices under the **View** menu provide for zoom and pan tools. The six buttons on the left side of the screen are used to input and edit geometric data. The 

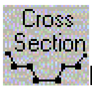
and 

buttons are used to create the reach schematic. A reach is simply a subsection of a river, and a junction occurs at the confluence of two rivers. Since our reach schematic is already defined, we have no need to use these buttons. The 

, 

, and 

buttons are used to input and edit geometric descriptions for cross-sections, and hydraulic structures such as bridges, culverts, and weirs. The 

allows you to associate an image file (photograph) with a particular cross-section. Click on the 

button to open the cross-section data window:

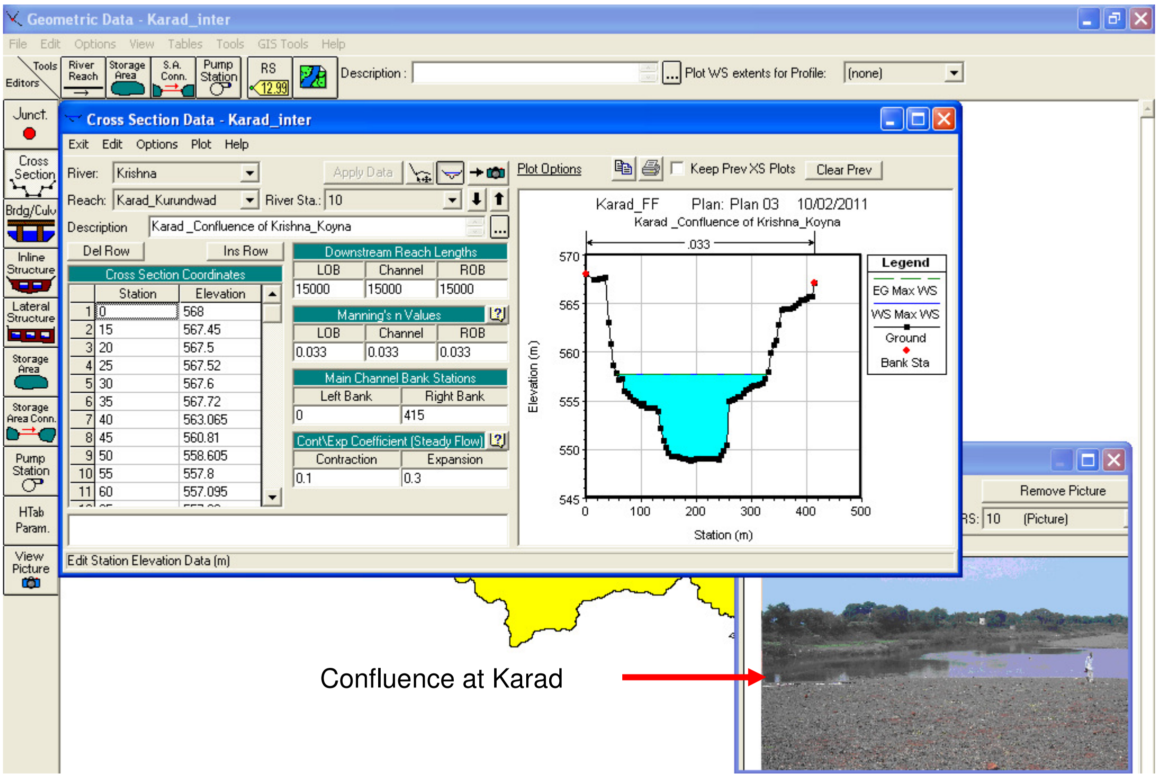
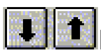


Figure 5

The data used to describe the cross-sections include the river station/XS number, lateral and elevation coordinates for each terrain point (station & elevation columns), Manning's roughness coefficients (n), reach lengths between adjacent cross-sections, left and right bank station, and channel contraction and expansion coefficients (here 0.1 & 0.3 have been taken for smooth transitions) (refer page 87 of Ref Manual). These data are obtained by field surveys.

X-section No & Name	***Manning's N** (as from computed from discharge)*
10-Karad	0.033
7-Narasingpur	0.033
6-Khed	0.032
5-Arjunwad	0.031
1-Kurundwad	0.054

The  buttons can be used to toggle between different cross-sections. To edit data, simply double-click on the field of interest. You may notice that this action caused all of the data fields to turn red and it enabled the "Apply Data" button. Whenever you see input data colored **red** in HEC-RAS, it means that you are in edit mode. There are two ways to leave the edit mode:

1. Click the "***Apply Data***" button. The data fields will turn black, indicating you're out of edit mode, and the data changes are applied.
2. Select **Edit/Undo Editing**. You'll leave the edit mode without changing any of the data.
3. To actually see what the ***Kurundwad*** X-section looks like, select the **Plot/Plot Cross-Section** menu item.

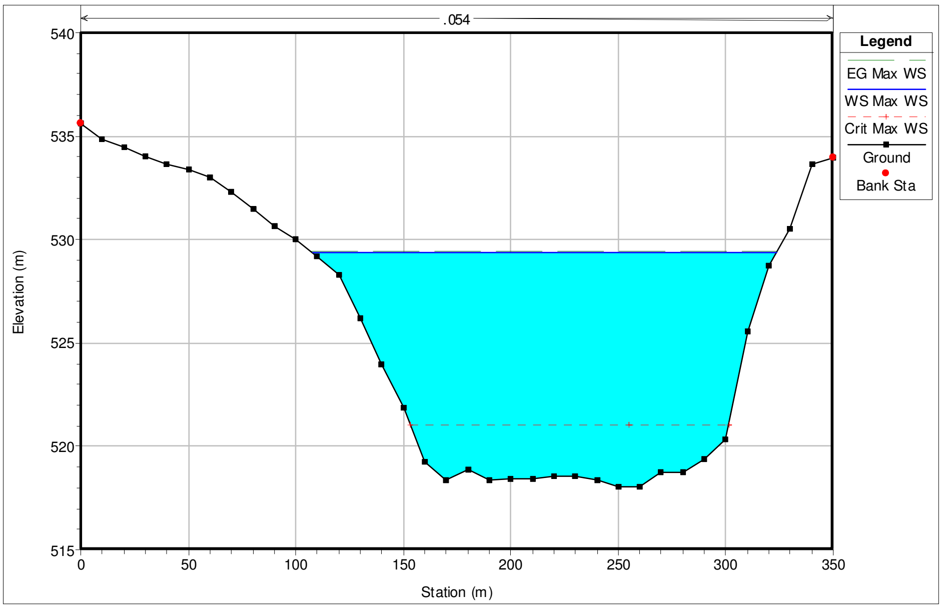
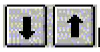
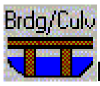


Figure 6

The cross-section points appear black and bank stations are denoted with red. Manning roughness coefficients appear across the top of the plot. Again, the buttons can be used to maneuver between different cross-sections. Any solid black areas occurring in a cross-section represent blocked obstructions. These are areas in the cross-section through which no flow can occur. Some cross-sections contain ***green arrows and gray areas***. This symbolism is indicative of the presence of a bridge or culvert. Input data and plots specifically associated with bridges and culverts can be accessed from the main geometric data editor window by clicking on the 

button. Take a little time to familiarize yourself with the geometric data by flipping through some different cross-sections and bridges/culverts. When you are finished, return to the geometric editor window and select **File/Save Geometric Data**. Return to the main project window using **File/Exit Geometry Data Editor**.

Importing and Editing Flow Data

Enter the flow editor using **Edit/Unsteady Flow Data** from the main project window. Instead of importing an existing HEC-RAS flow file, you can use stream flow output from an HEC-HMS model run.

The coordinates of the cursor (time, flow rate) are displayed in the bottom right corner of the plot. Gridlines can be shown by invoking the **Options/Grid** menu item.

The direct step method uses a known water surface elevation (and several hydraulic parameters) to calculate the water surface elevation at an adjacent cross-section. For a sub-critical flow regime, computations begin at the d/s end. The present data set corresponds to1st & 2nd July, 2006 flood. (Figure 7). The ***Flood Hydrograph*** at Karad (July 1 & 2, 2006) and ***Rating Curve*** at Kurundwad are entered as per the actual available dataset. Click on the ***Initial conditions*** and enter the value of initial flow at Karad. The initial flow of 888.04 m^3/s at Karad on the day 1 at 0100 hrs is put. Click on **OK**. The flood hydrograph and rating curve plots along with data view can be seen in **Figures 8 & 9.**

All of the required flow parameters have now been entered into the model. From the file menu, select **Save unsteady Flow Data** and save the flow data under the name "Karad flows."

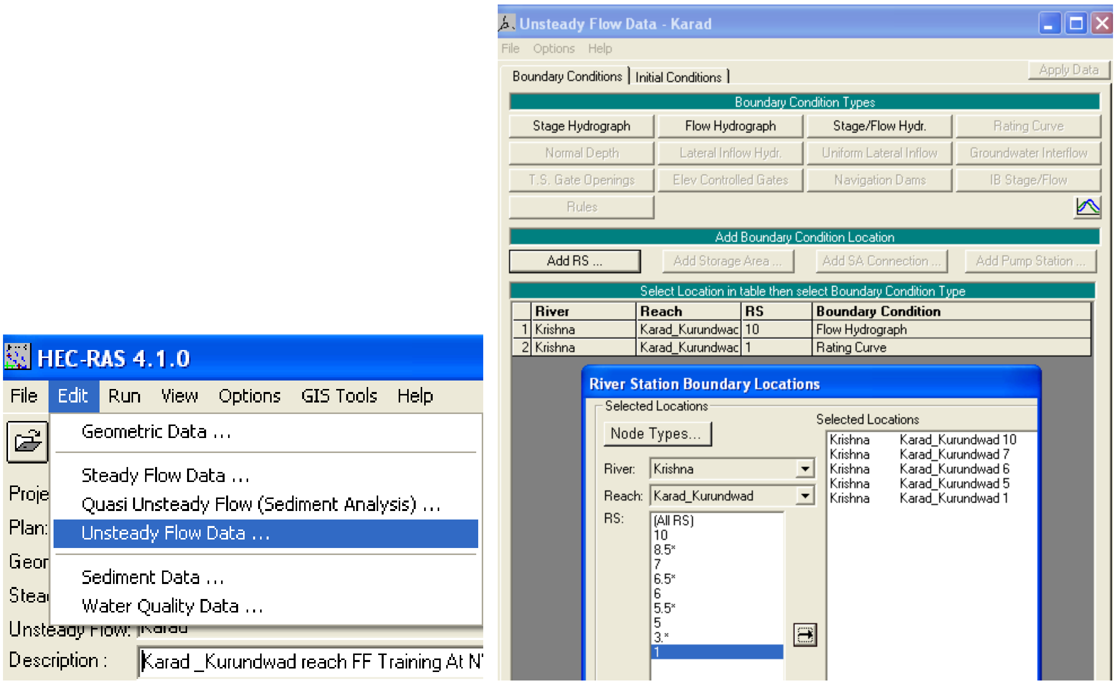


Figure 7

Click on the button from the unsteady flow data window. HEC-RAS allows the user to set the ***boundary conditions*** and **Initial conditions** at the points (u/s, d/s or internal locations) or as shown in figure. The boundary conditions and initial flow conditions are filled in as per the actual data.

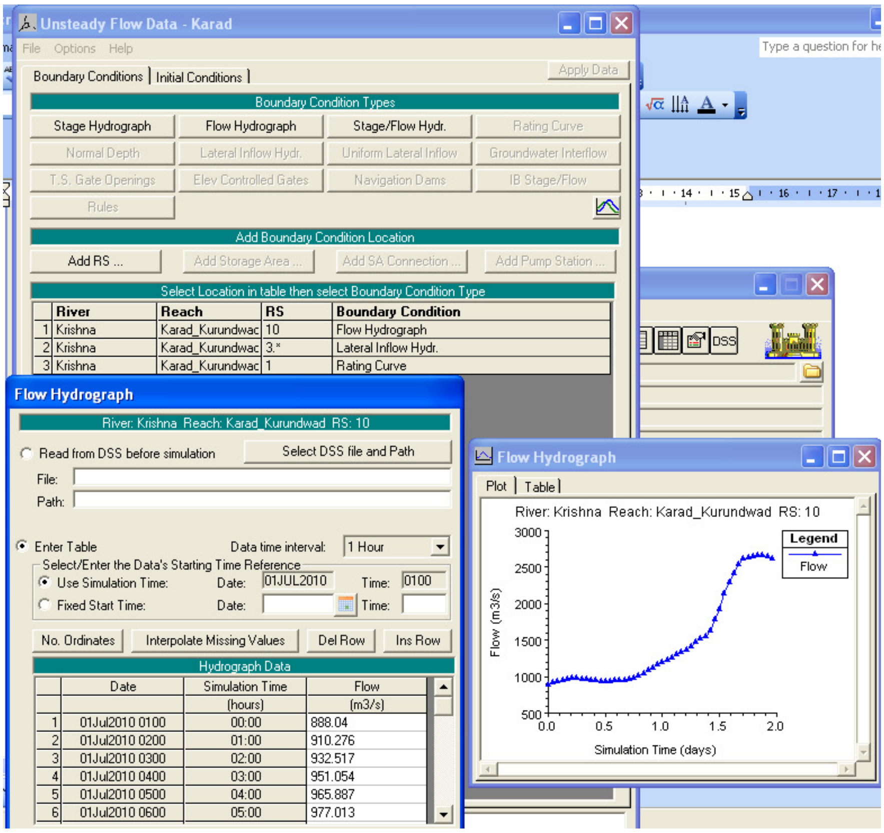


Figure 8

Similarly, enter the values for Kurundwad after clicking on the rating curve button and see the curve by pressing the Plot data option.

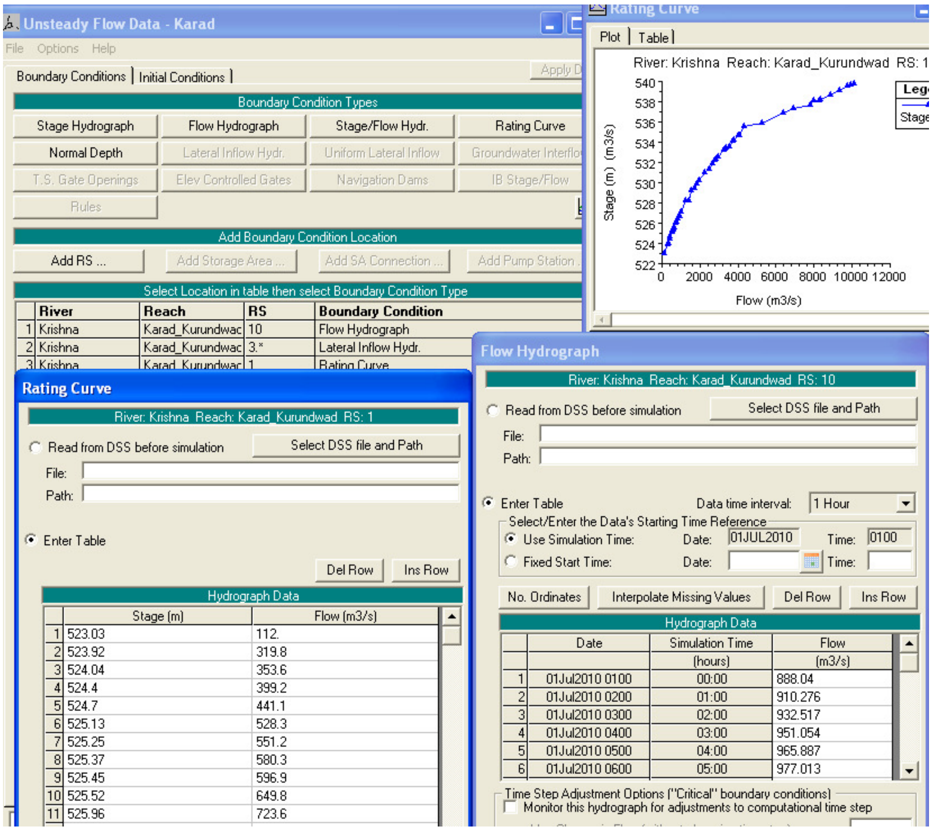


Figure 9

If you want to some rating curve at known site, then you can enter it by clicking on Options> ***Observed (measured) data> rating curves (gages)***

To leave the flow data editor and return to the HEC-RAS project window, choose **File/Exit Flow Data Editor**.

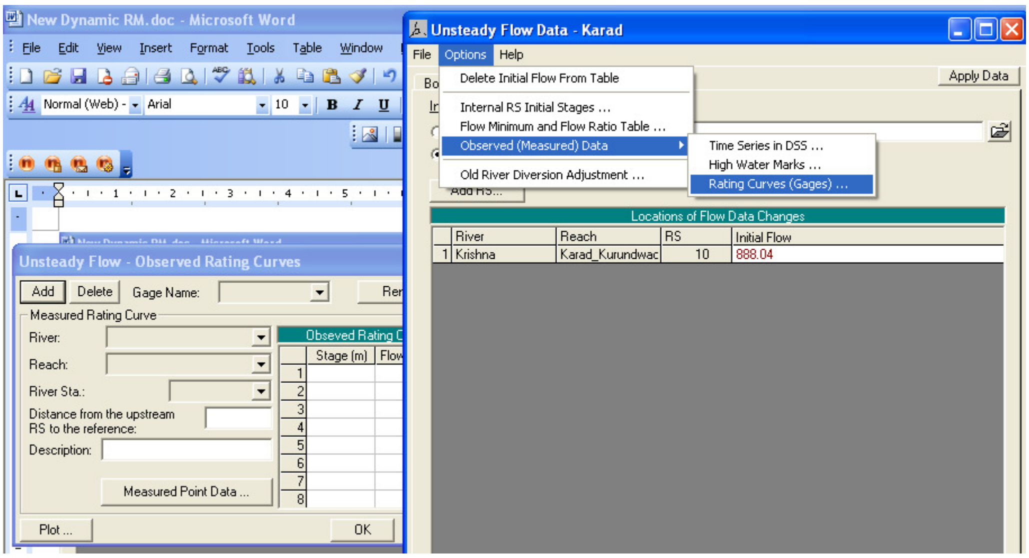


Figure 8

Executing the Model

With the geometry and flow files established, select **Run**/ **Unsteady Flow Analysis** from the project window. But before running the model, one final step is required: definition of a plan. The plan specifies the geometry and flow files to be used in the simulation. To define a plan, select **File**/**New Plan** and You'll be subsequently asked to provide a plan title and a 12 character identifier as depicted in the figure 9.

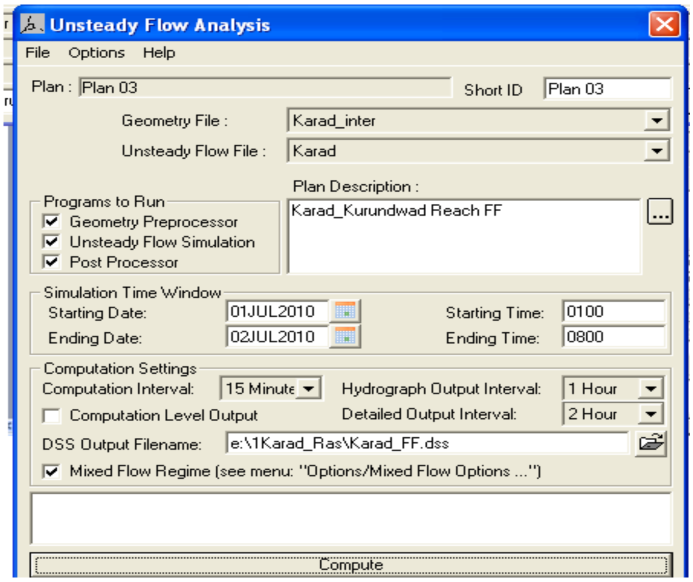


Figure 9

To execute the model, ensure that the flow model parameters set properly, and click ***compute*** button.

Viewing the Results

There are several methods available with which to view HEC-RAS output, including cross-section profiles, perspective plots, and data tables. From the project window, select **View/Cross-Sections**.

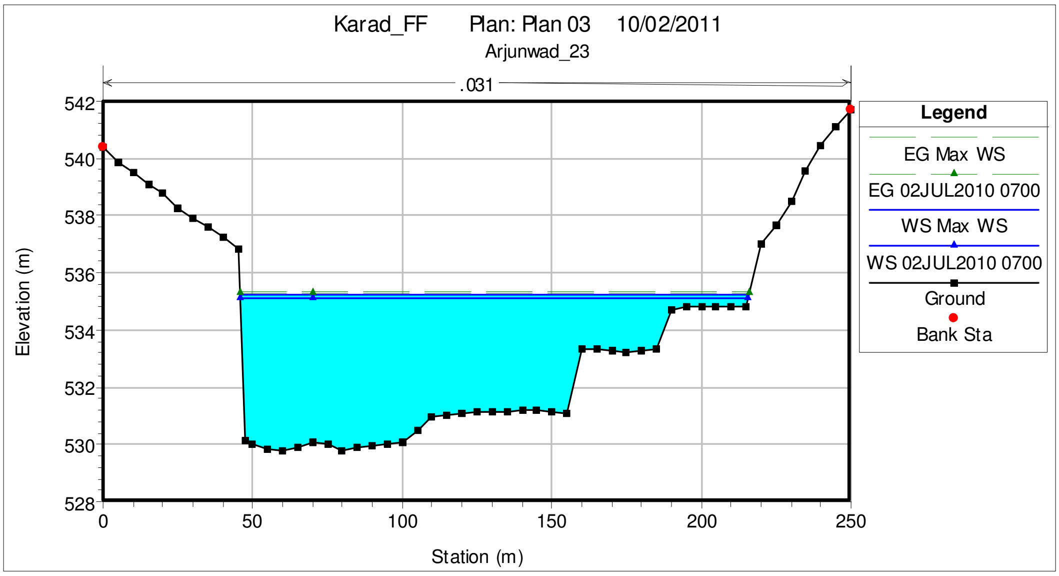


Figure 10

The cross-section view is similar to the one shown when we edited the cross-section data. However, the output view also shows the elevation of the total energy head line (shown in the legend as "EG 02Jul2010 0700"), the water surface ("WS 02Jul2010 0700"). As with the cross-section geometry editor, you can use the  to scroll to other cross-sections. For a profile of the entire reach, select **View/Water Surface Profiles** from the project window.

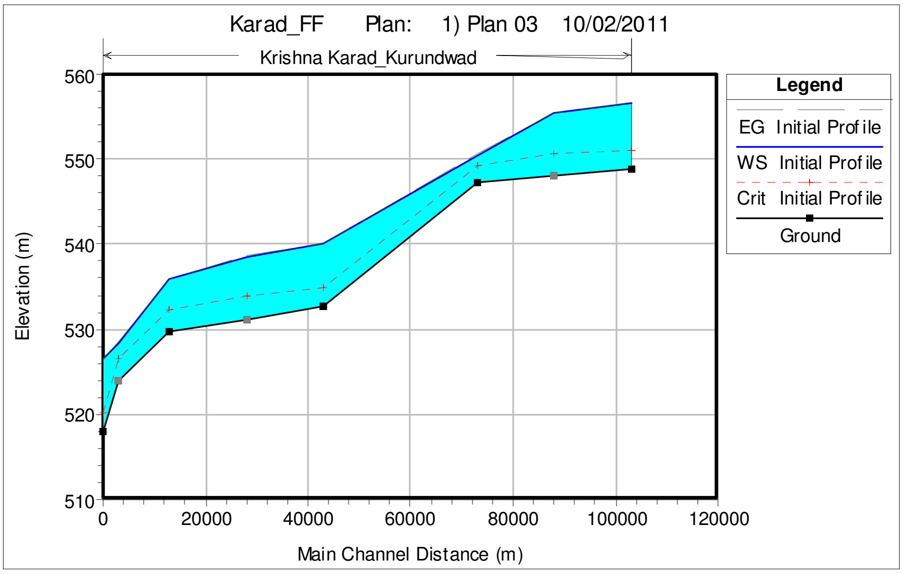
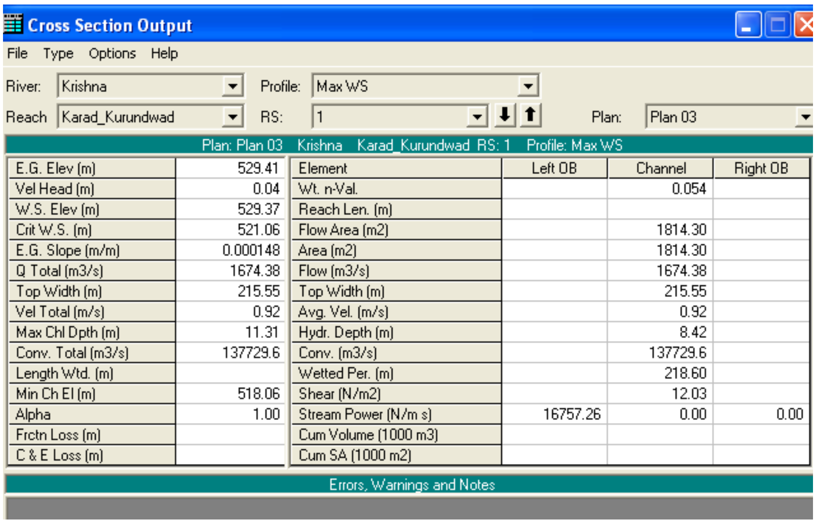


Figure 11

Using the **Options/Zoom In** menu option, you can focus on a particular stretch of reach to see how the water surface relates to structures in the channel such as bridges. Other available options for graphical display of output data include plots of velocity distribution (**View/Cross-Sections/Options/Velocity Distribution**) and pseudo 3D plots (**View/X-Y-Z Perspective Plots**). Spend a little time playing around with some of the display options.

For hydraulic design, it is often useful to know the calculated values of various hydraulic parameters. HEC-RAS offers numerous options for tabular output data display. From project window, choose **View/ Detailed Output Table**. It is to note that the simulated value is ***1674.38*** m^3/s against the actual observed value of ***1674.34*** m^3/s at Kurundwad (X-section_1)(0800 hrs on 2nd July, 2006, i.e, end of simulation period). The simulated water level is ***529.37m*** against observed value of ***529.145*** m.

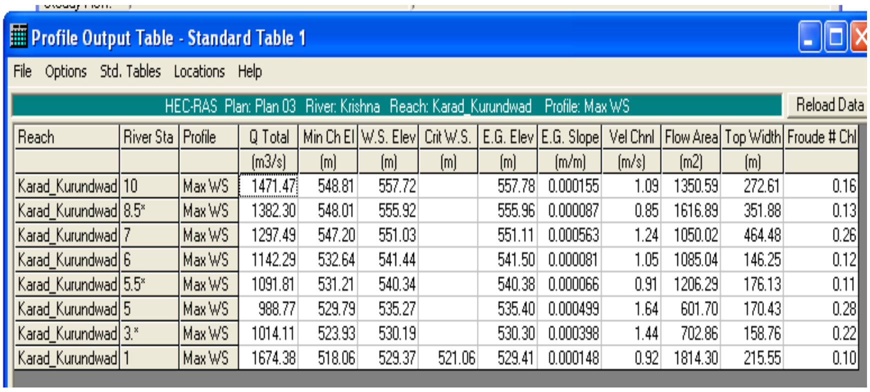


E.G. Elev (m)	529.41
Vel Head (m)	0.04
W.S. Elev (m)	529.37
Crit W.S. (m)	521.06
E.G. Slope (m/m)	0.000148
Q Total (m3/s)	1674.38
Top Width (m)	215.55
Vel Total (m/s)	0.92
Max Chl Dpth (m)	11.31
Conv. Total (m3/s)	137729.6
Length Wtd. (m)	
Min Ch El (m)	518.06
Alpha	1.00
Frctn Loss (m)	
C & E Loss (m)	

Element	Left OB	Channel	Right OB
Wt. n-Val.		0.054	
Reach Len. (m)			
Flow Area (m2)		1814.30	
Area (m2)		1814.30	
Flow (m3/s)		1674.38	
Top Width (m)		215.55	
Avg. Vel. (m/s)		0.92	
Hydr. Depth (m)		8.42	
Conv. (m3/s)		137729.6	
Wetted Per. (m)		218.60	
Shear (N/m2)		12.03	
Stream Power (N/m s)	16757.26	0.00	0.00
Cum Volume (1000 m3)			
Cum SA (1000 m2)			

Figure 12

Additional tabular output data can be accessed from the invoking **View/Profile Output Table** from the main project window. Numerous formats and data types can be viewed by selecting different tables from the **Std. Tables** menu.



Profile Output Table - Standard Table 1

File Options Std. Tables Locations Help

HEC-RAS Plan: Plan 03 River: Krishna Reach: Karad_Kurundwad Profile: Max WS

Reload Data

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl
			(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Karad_Kurundwad	10	Max WS	1471.47	548.81	557.72		557.78	0.000155	1.09	1350.59	272.61	0.16
Karad_Kurundwad	8.5*	Max WS	1382.30	548.01	555.92		555.96	0.000087	0.85	1616.89	351.88	0.13
Karad_Kurundwad	7	Max WS	1297.49	547.20	551.03		551.11	0.000563	1.24	1050.02	464.48	0.26
Karad_Kurundwad	6	Max WS	1142.29	532.64	541.44		541.50	0.000081	1.05	1085.04	146.25	0.12
Karad_Kurundwad	5.5*	Max WS	1091.81	531.21	540.34		540.38	0.000066	0.91	1206.29	176.13	0.11
Karad_Kurundwad	5	Max WS	988.77	529.79	535.27		535.40	0.000499	1.64	601.70	170.43	0.28
Karad_Kurundwad	3.*	Max WS	1014.11	523.93	530.19		530.30	0.000398	1.44	702.86	158.76	0.22
Karad_Kurundwad	1	Max WS	1674.38	518.06	529.37	521.06	529.41	0.000148	0.92	1814.30	215.55	0.10

Figure 13

The resulting table includes a number of hydraulic parameters, including water surface elevation, head losses, and cross-sectional area. At the bottom of the window, error and notes (if any) resulting from the steady flow computations are shown. As you scroll through the cross-sections, take a look at some of the error messages. For this model, some X-sections have been added as the warning it showed to interpolate cross section.

Calibration of the Model

The model can be calibrated by changing the hydraulic parameters. Open ***Unsteady flow analysis***> ***Options***> ***Calculation options and tolerances***. The ***theta*** (implicit weighing factor) value as shown in figure can be changed from 0.6 to 1 and repeated simulations can be run with changed iterations and Changed Manning's ***N*** to validate the actual results (**Figure 14**). Some Manning's ***N*** values have been cited from the literature (**Figure 15**), but the actual values are to be calibrated to have the model match with the real conditions. (Page 81 of Reference Manual)

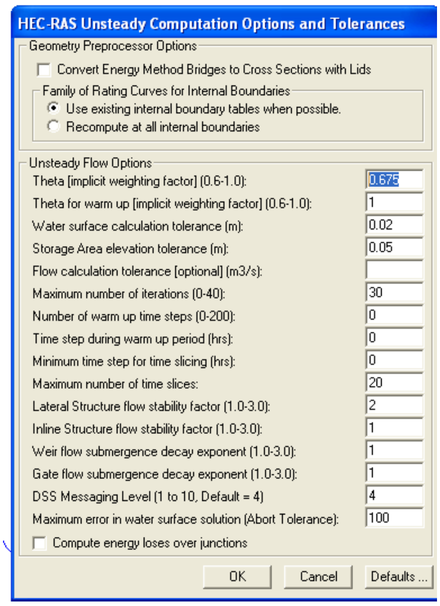


Figure 14

Type of Channel and Description	Minimum	Normal	Maximum
A. *Natural Streams*			
1. **Main Channels**			
a. Clean, straight, full, no rifts or deep pools	0.025	0.030	0.033
b. Same as above, but more stones and weeds	0.030	0.035	0.040
c. Clean, winding, some pools and shoals	0.033	0.040	0.045
d. Same as above, but some weeds and stones	0.035	0.045	0.050
e. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
f. Same as "d" but more stones	0.045	0.050	0.060
g. Sluggish reaches, weedy. deep pools	0.050	0.070	0.080
h. Very weedy reaches, deep pools, or floodways with heavy stands of timber and brush	0.070	0.100	0.150
2. **Flood Plains**			
a. Pasture no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
2. Same as above, but heavy sprouts	0.050	0.060	0.080
3. Heavy stand of timber, few down trees, little undergrowth, flow below branches	0.080	0.100	0.120
4. Same as above, but with flow into branches	0.100	0.120	0.160
5. Dense willows, summer, straight	0.110	0.150	0.200
3. **Mountain Streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged**			
a. Bottom: gravels, cobbles, and few boulders	0.030	0.040	0.050

Figure 15 (*Source- HEC_RAS Tech Reference Manual*)

RAS Mapper

The flood mapping can be done using RAS mapper. Open RAS mapper and Click on ***tools***> ***flood*** **delineation**. It would ask you to input the files as shown in figure 16. Input the ***floating raster*** file as ***Karad.flt***, which is converted from the ***grid*** file in any GIS software. Input the files as desired and fill in the parameters like profiles as Maximum Water surface and variables as water surface elevation. For better visualization, you can change the properties by R_clicking the layer. Also, raster/vector layers can be added to the map thus generated.

The final step is to generate the delineation map by clicking on ***generate layer*** button. ***Save*** your project. Now you are done.

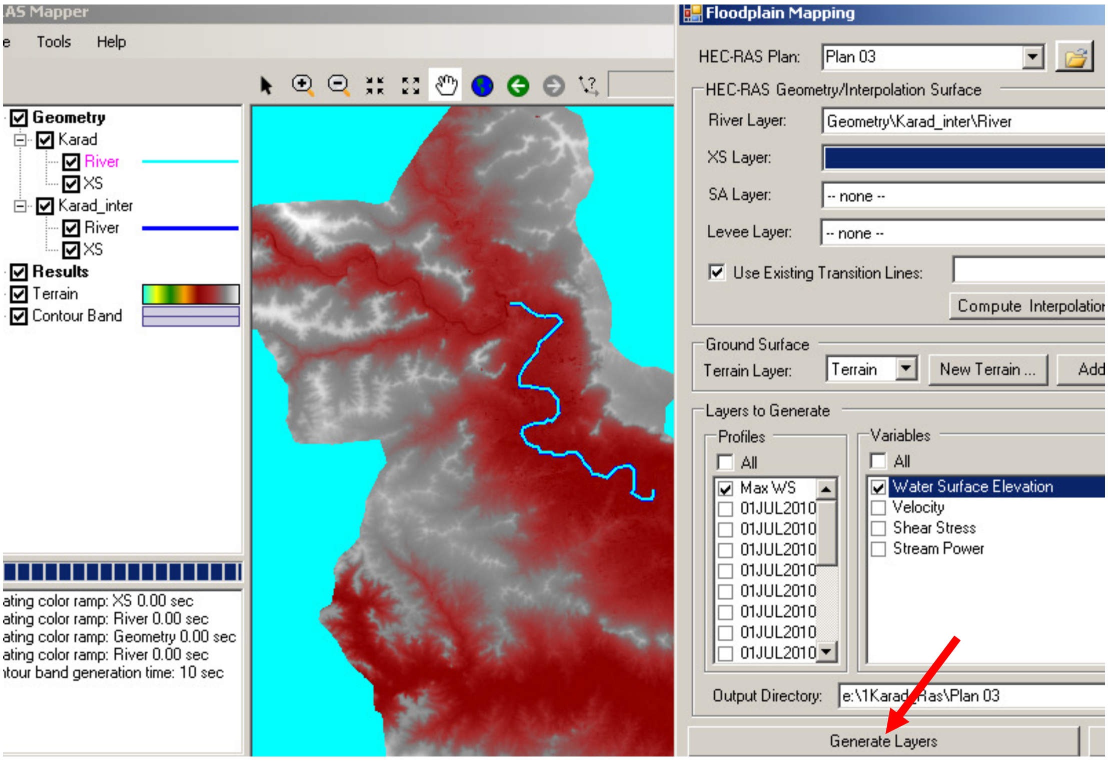


Figure 16

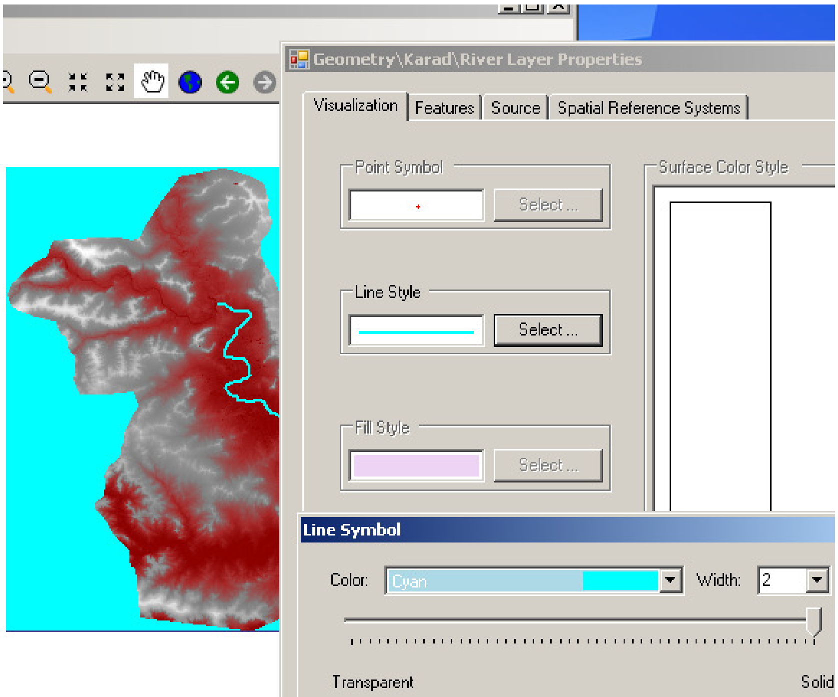


Figure 17

References:

1. Sankhua, R N, (2008 & 2009), Lecture on Hydraulic modelling, 23rd ITP, NWA Pune
2. HEC-RAS technical reference guide

Using Quantum GIS

Pradeep Kumar
Director, NWA

Introduction

The purpose of this write-up is to introduce one to the use of key aspects of quantum GIS (QGIS). This material is structured with the content to suit novice, intermediate and advance users. Each step is designed to instruct in one and more of these aspects, so that one can use it for extracting necessary information from the CARTOSAT satellites image for monitoring of the any irrigation projects. In the following write-up, one will have an idea how to use this open source Q-GIS, where many GIS capabilities are inbuilt. The write-up is based on the Quantum GIS training manual designed and provided by Linfiniti consulting CC for QGIS version 2.8. However, in this training course, the QGIS version 2.10 (Pisa) has been used.

Exercise Data

The sample data used throughout this write-up can be downloaded here:
http://qgis.org/downloads/data/training_manual_exercise_d

Table of Contents

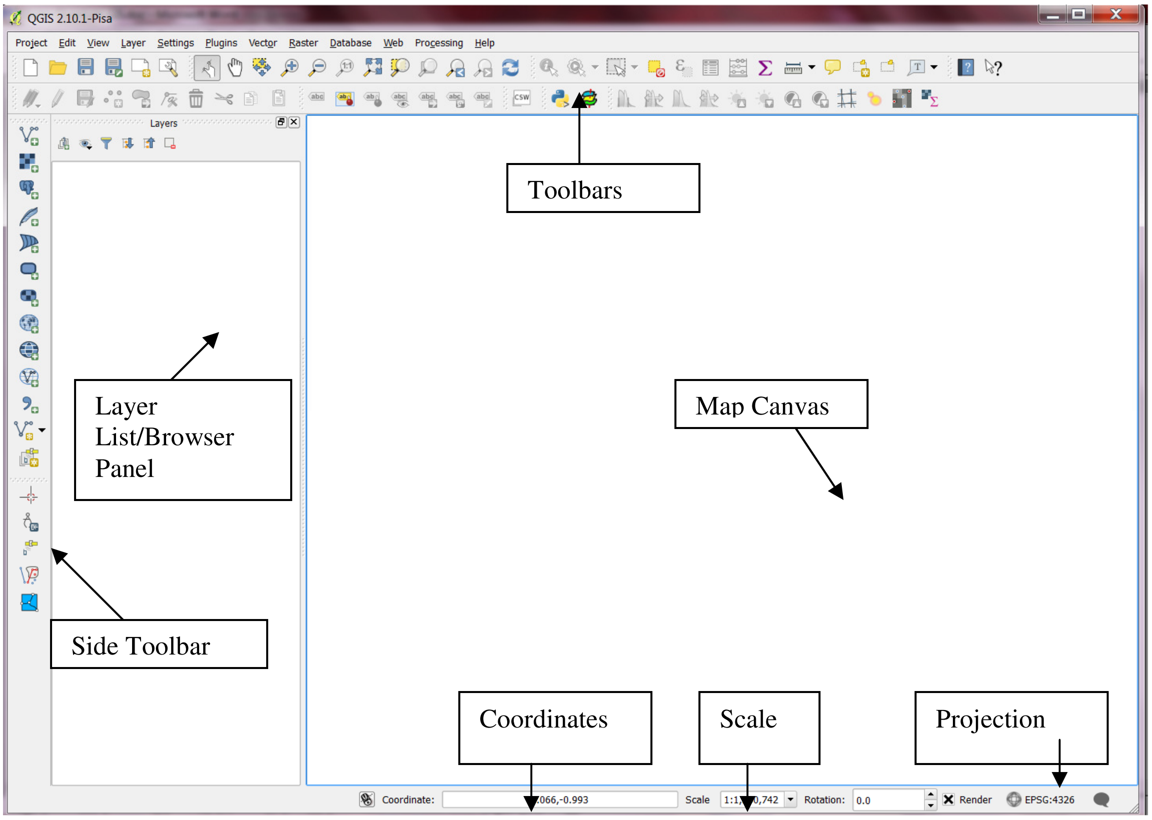
Following key aspects or functions of Q-GIS will be described in this write-up:

a) Overview of Interface of QGIS
b) Toolbar
c) Adding Layer
d) Changing names of layer, layer color
e) Working with vector data
f) Symbology
g) Attribute Data
h) The label tool
i) Classification
j) Creating New GIS Data
k) Query Builder
l) Using map composer
m) Creating a basic map and printing a map

This Training course assumes that one have some knowledge of working with Computers and knows some about theoretical GIS knowledge or the operation of a GIS program. However, a Limited theoretical background will be provided to explain the purpose of an action you will be performing in the program, but the emphasis is on learning by doing. When you complete the course, you will have a better concept of the possibilities of GIS, and how to harness their power via QGIS.

The Interface

Open QGIS by Double Clicking **[QGIS desktop]** icon on desktop or by going to **Start > All Programs > Quantum GIS > Quantum GIS Desktop.** Following window will open:



This is how QGIS 2.10 looks when you open it. How many tools/icons you see might be different from this screen capture. Using QGIS we are able to use data layers in the form of **Shapefiles** and **Images**

Shapefiles (.shp) are geospatial data files that hold vector-based data. Vector data layers are **points**, **lines** (arcs, polylines), and **polygons** (closed shapes with defined area).

Images(.img, .tiff etc) are raster-based datasets that are made up of cells, organized in columns and rows, which contain data. Raster imagery includes digital USGS topographic maps, aerial photography (Ortho-photography), and satellite imagery.

Layer List

In the Layers list, you can see a list, at any time, of all the layers available to you.

Toolbars

Your most oft-used sets of tools can be turned into toolbars for basic access. For example, the File toolbar allows you to save, load, print, and start a new project. You can easily **customize** the interface to see only the tools youuse most often, adding or removing toolbars as necessary via the **View→Toolbars** menu. Even if they are not visible in a toolbar, all of your tools will remain accessible via the menus. For example, if you remove the File toolbar (which contains the Save button), you can still save your map by clicking on the File menu and then clicking on Save.

The Map Canvas
This is where the map itself is displayed.

The Status Bar
Shows you information about the current map. Also allows you to adjust the map scale and see the mouse cursor's coordinates on the map.

Adding a Layer

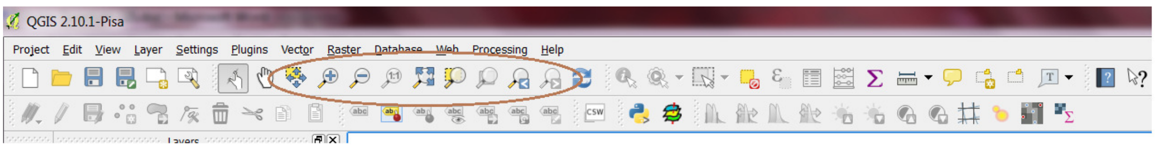
A common function of GIS Applications is to display **map layers** or simply layer. Map layers are stored as files(**.shp** files) on a disk or as records in a database. Normally each map layer will represent something in the real world- a roads layer for example will have data about the street network.

- *Look for the Add Vector Layer button:* 
- *Select "**File**" as the "Source type". The encoding is "**System**".*
- *Click **Browse** and Navigate to your PM_GIS\shapefiles folder. Load a shape file. (say **Canal network.shp** file)*

Congratulations! You now have a basic map. Now would be a good time to save your work.

- Click on the Save As button:
- Save the map under \exercise_data and call it basic_map.qgs.

Now please experiment with the map navigation toolbar and use the zoom and pan functions



Working with Vector Data

Vector data is arguably the most common kind of data you will find in the daily use of GIS. It describes geographic data in terms of points, that may be connected into lines and polygons. Every object in a vector dataset is called a feature, and is associated with data that describes that feature.

It's important to know that the data you will be working with does not only represent where objects are in space, but also tells you what those objects are.

Please note that please try to include following aspect of Qgis.

1. **Enable the labels for settlement, river, canal_network, reservoir layer with suitable font, size, placement etc.**
2. **Classify and symbolize the canal_network layers according to the type of canal.**
3. **Classify and symbolize the Structure layers according to the type of structure.**
4. **Using MAP composer, create a map of 1:70000 scale and A0 size paper size with suitable titles and details, border, scale bar, and Legend.**
5. **Export the map into PDF file jurala_map.pdf**

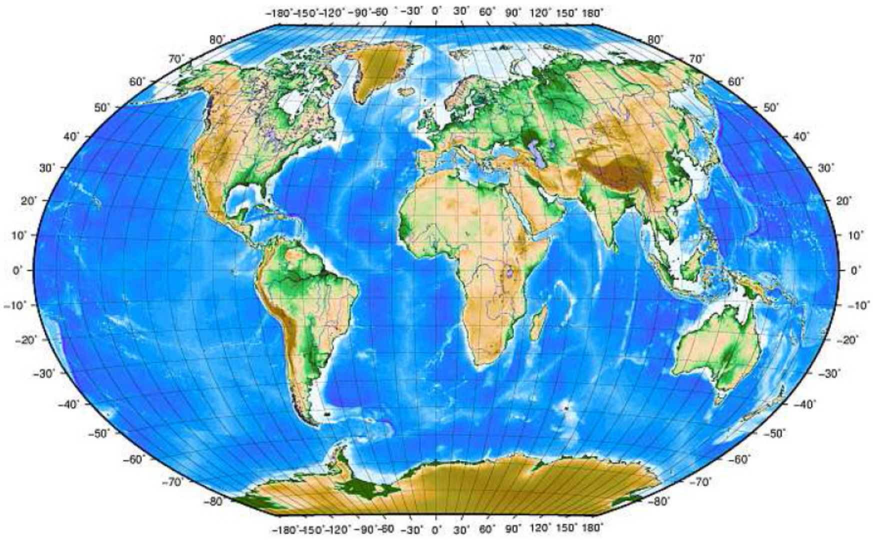
Map Projections

Coordinate reference system (CRS)

You have learnt about shape files which contain vector data in form of spatial data as well as attribute date of specific geographical feature of earth. The data that you use has to come from somewhere. For most common applications, the data exists already; but the more particular and specialized the project, the less likely it is that the data will already be available. In such cases, you'll need to create your own new data. But before going on creating new data set (shape file) let's discuss about the Map projections and world Coordinate reference system

Geographic Coordinate Systems

The use of Geographic Coordinate Reference Systems is very common. They use degrees of latitude and longitude and sometimes also a height value to describe a location on the earth's surface.



Lines of latitude run parallel to the equator and divide the earth into 180 equally spaced sections from North to South (or South to North). The reference line for latitude is the equator and each **hemisphere** is divided into ninety sections, each representing one degree of latitude. In the northern hemisphere, degrees of latitude are measured from zero at the equator to ninety at the North Pole. In the southern hemisphere, degrees of latitude are measured from zero at the equator to ninety degrees at the South Pole. To simplify the digitization of maps, degrees of latitude in the southern hemisphere are often assigned negative values (0 to -90◦). Wherever you are on the earth's surface, the distance between the lines of latitude is the same (60 nautical miles).
Lines of longitude, on the other hand, do not stand up so well to the standard of uniformity. Lines of longitude run perpendicular to the equator and converge at the poles. The reference line for longitude (the prime meridian) runs from the North pole to the South pole through Greenwich, England. Subsequent lines of longitude are measured from zero to 180 degrees East or West of the prime meridian. Note that values West of the prime meridian are assigned negative values for use in digital mapping applications.

Rectangular coordinate system
Most of the spatial data available by means of remote sensing system or any other sources of data for the use in GIS are in two-dimensional form. This coordinate reference system to locate any object point is called rectangular coordinate system.

In order to determine the true earth locations of these (remote sensing data or any other sources data) digitized entities, it is necessary to devise a mathematical transformation formula to covert these rectangular coordinates/map units into the positions (latitude and longitude) on the curved surface of earth as represented on map.

Map projections

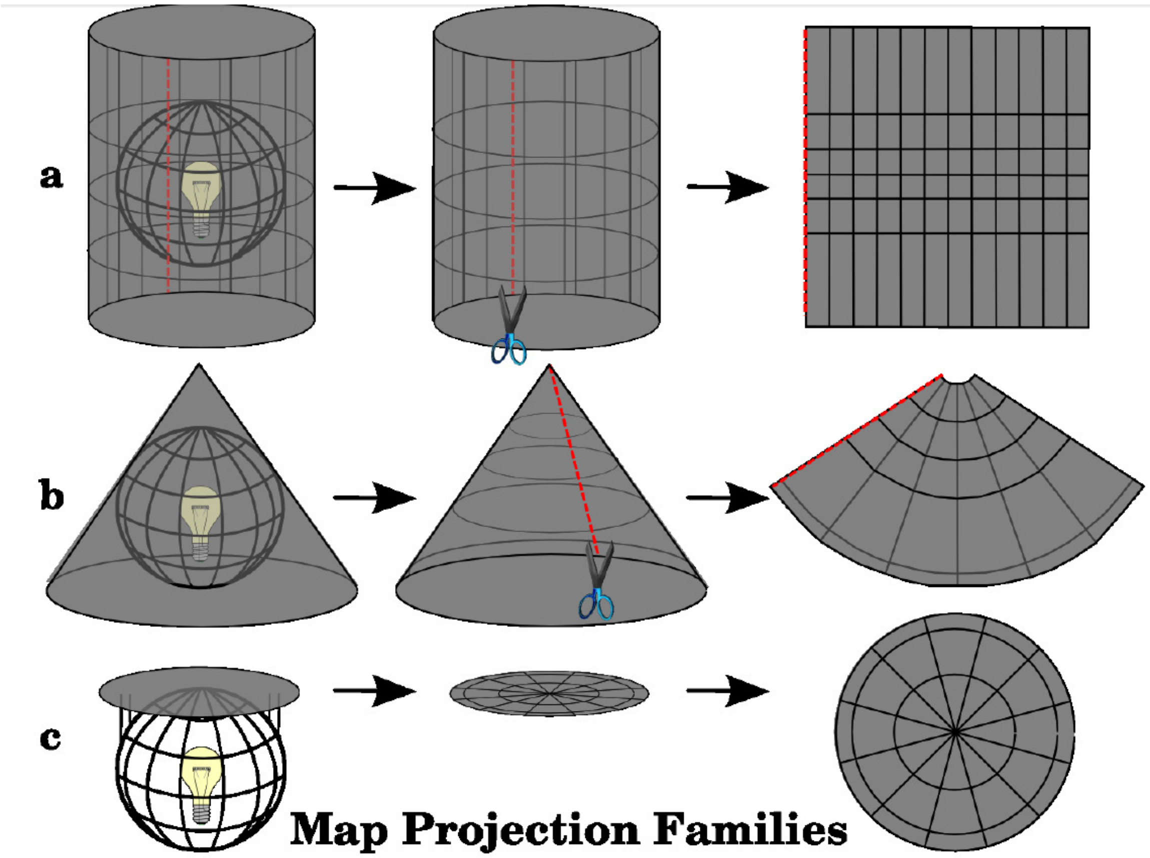
It is to portray the surface of the earth or a portion of the earth on a flat piece of paper or computer screen. To transfer the image of the earth and its irregularities on the plane surface of a map or computer screen, three factors are involved, namely, a geoid, an ellipsoid or a datum with ellipsoid and a projection.

Geoid is a irregular spheroidal shape which representation of the surface of the **earth** that it would assume if the sea covered the **earth**, also known as surface of equal gravitational potential.

ellipsoid the observations made on the geoid are then transferred to a hypothetical regular geometric reference surface for the mathematical computations of geodetic data reduction, also called 'Geodetic Datum' or 'Map datum'. The accuracy of such computations and mapping is directly affected by the suitability of the datum used. Several hundred local geodetic datums are in use in different parts of the world, and many of these have been / are being redefined to meet the ever-increasing accuracy requirements. The GPS yields positions of survey points on a global reference surface called ***World Geodetic Sysetm 84 (WGS 84).*** It is most popular geometric reference surface system. This geodetic datum is geocentric, and defined to high accuracy by the Defense Mapping Agency, USA (DMA). In order to correlate the coordinates obtained by using GPS, on this datum, to the coordinates of the point on Survey of India topographical maps, the relationship between the WGS 84 and Indian map datum must be defined.

Map Projection

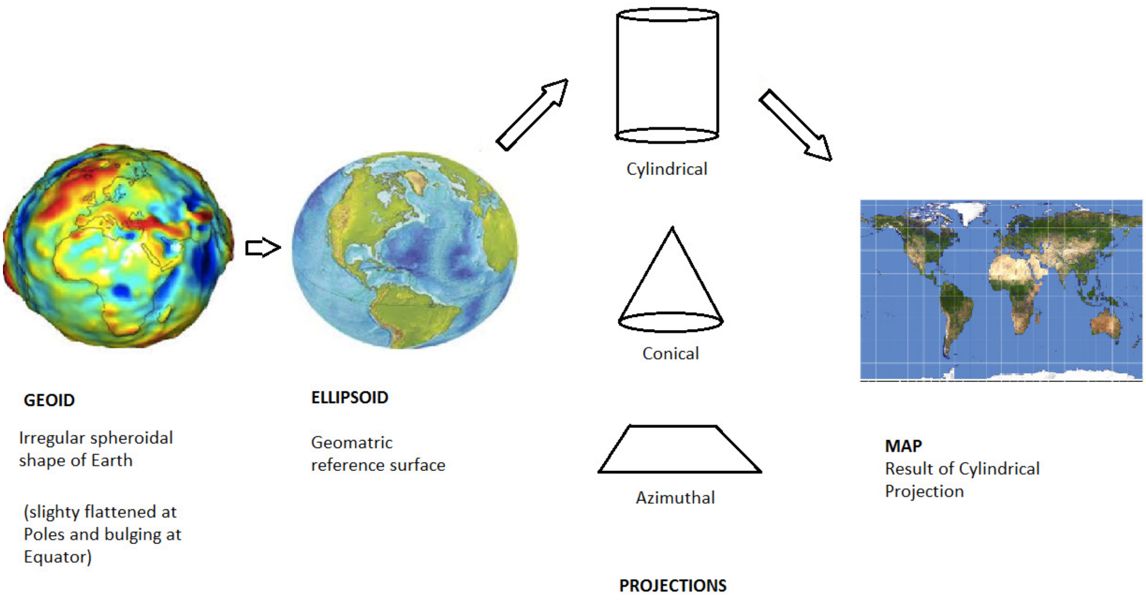
The process of creating map projections can be visualized by positioning a light source inside a transparent globe on which opaque earth features are placed. Then project the feature outlines onto a two-dimensional flat piece of paper. Different ways of projecting can be produced by surrounding the globe in a ***cylindrical*** fashion, as a **cone**, or even as a **flat surface**. Each of these methods produces what is called a map ***projection family***. Therefore, there is a family of **planar projections**, a family of ***cylindrical projections***, and another called **conical projections**



a) Cylindrical projection b) conical projection c) planer projection

Each map projection has **advantages** and **disadvantages**. The best projection for a map depends on the scale of the map, and on the purposes for which it will be used. For example, a projection may have unacceptable distortions if used to map the entire African continent, but may be an excellent choice for a **large-scale (detailed) map** of your country. The properties of a map projection may also influence some of the design features of the map. Some projections are good for small areas, some are good for mapping areas with a large East-West extent, and some are better for mapping areas with a large North-South extent. Map projections are never absolutely accurate representations of the spherical earth. As a result of the map projection process, every map shows **distortions of angular conformity, distance and area**. A map

projection may combine several of these characteristics, or may be a compromise that distorts all the properties of area, distance and angular conformity, within some acceptable limit.
It is usually impossible to preserve all characteristics at the same time in a map projection. This means that when you want to carry out accurate analytical operations, you need to use a map projection that provides the best characteristics for your analyses. For example, if you need to measure distances on your map, you should try to use a map projection for your data that provides high accuracy for distances.



Angular conformal or orthomorphic projection: The projections that retains the property of maintaining correct angular correspondence (i.e East will always occur at a 90 degree angle to North). These projections are used when the **preservation of angular relationships** is important. They are commonly used for navigational or meteorological tasks. It is important to remember that maintaining true angles on a map is difficult for large areas and should be attempted only for small portions of the earth. The conformal type of projection results in distortions of areas, meaning that if area measurements are made on the map, they will be incorrect. The larger the area the less accurate the area measurements will be. Examples are ***UTM*** and ***lalmbert comformal conic projection.***

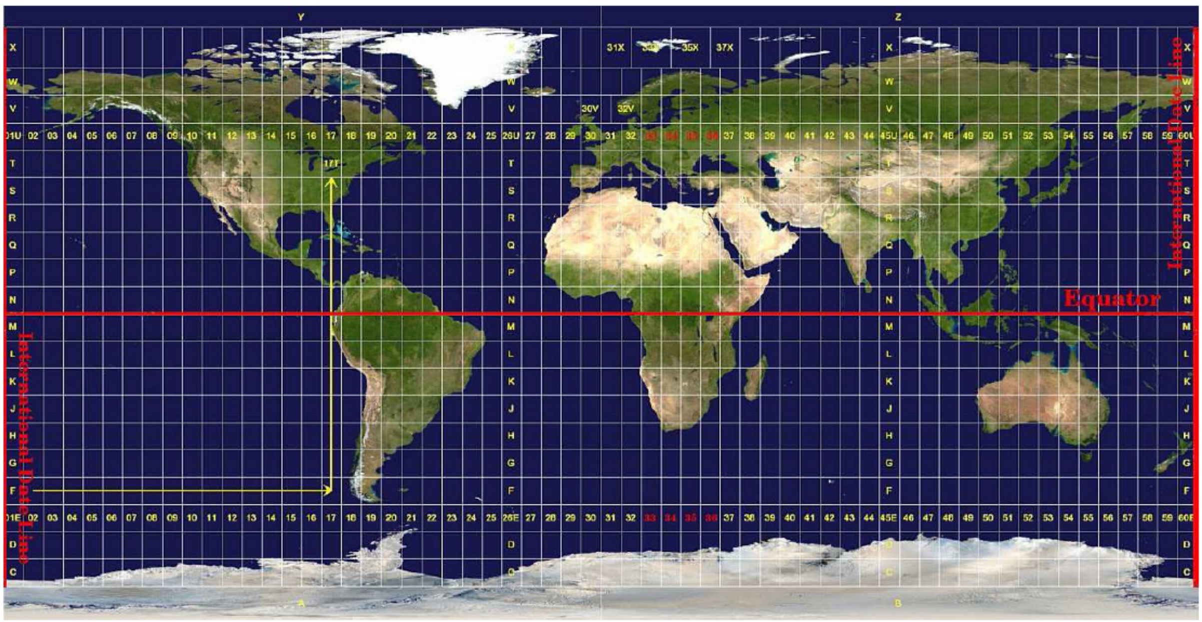
Equidistant projections: The projections by which the distances are preserved are known as equidistance projection. It maintains accurate distances from the centre of the projection or along given lines. These projections are used for radio and seismic mapping, and for navigation.

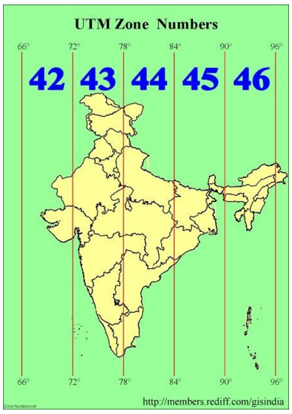
Equal area projections: When a map portrays areas over the entire map, so that all mapped areas have the same proportional relationship to the areas on the Earth that they represent, the map is an **equal area map**. These maps are best used when calculations of area are the dominant calculations you will perform. If, for example, you are trying to analyse a particular area in your town to find out whether it is large enough for a new shopping mall, equal area projections are the best choice. an equal area projection results in **distortions of angular conformity** when dealing with large areas.

Keep in mind that map projection is a very complex topic. There are hundreds of different projections available worldwide each trying to portray a certain portion of the earth's surface as faithfully as possible on a flat piece of paper. In reality, the choice of which projection to use, will often be made for you. Most countries have commonly used projections and when data is exchanged people will follow the national trend. The National Spatial Framework for India uses Datum WGS84 with a LCC projection and is a recommended NNRMS standard. Each state has its own set of reference parameters given in the standard.

Universal Transverse Mercator (UTM) CRS in detail

The Mercator projection is a typical cylindrical projection with the equator tangent to the cylinder. The Universal Transverse Mercator (UTM) is also an internationally popular map projection. The Universal Transverse Mercator (UTM) coordinate reference system has its origin on the **equator** at a specific **Longitude**. Now the Y-values increase Southwards and the X-values increase to the West. The UTM CRS is a global map projection. This means, it is generally used all over the world. But as already described in the section 'accuracy of map projections' above, the larger the area (for example South Africa) the more distortion of angular conformity, distance and area occur. To avoid too much distortion, the world is divided into **60 equal zones** that are all **6 degrees** wide in longitude from East to West. The **UTM zones** are numbered **1 to 60**, starting at the **International Date Line** (**zone 1** at 180 degrees West longitude) and progressing East back to the **International Date Line** (**zone 60** at 180 degrees East longitude)





As you can see in above two Figures, INDIA is covered by six **UTM zones** to minimize distortion. The **zones** are called **UTM 42N, UTM 43N, UTM 44N,UTM 45N,UTM 46N and small area in UTM47N**. The **N** after the zone means that the UTM zones are located **North of the equator** and **S** for UTM zones are located **south of the equator.**

The position of a coordinate in UTM south of the equator must be indicated with the **zone number** (44) and with its ***northing (y) value*** and ***easting (x) value*** in meters. The **northing value** is the distance of the position from the **equator** in meters toward north. The **easting value** is the distance from the **central meridian** (longitude) of the used UTM zone toward east. The ***northing*** (y) value and easting (x) value is taken negative for south of equators and west of **central meridian.** However, in the UTM coordinate reference system, negative values are not allowed therefore, we have to add a so called **false northing value** of 10,000,000m to the northing (y) value and a false easting value of 500,000m to the easting (x) value.

This sounds difficult, so, we will do an example that shows you how to find the correct **UTM 35S** coordinate for the **Area of Interest in South Africa**.

The northing (y) value

The place we are looking for is 3,550,000 meters south of the equator, so the northing (y) value gets a **negative sign** and is -3,550,000m. According to the UTM definitions we have to add a **false northing value** of 10,000,000m. This means the northing (y) value of our coordinate is 6,450,000m (-3,550,000m + 10,000,000m).

The easting (x) value

The place we are looking for is **85,000 meters West** from the central meridian. Just like the northing value, the easting (x) value gets a negative sign, giving a result of **-85,000m**. According to the UTM definitions we have to add a **false easting value** of 500,000m. This means the easting (x) value of our coordinate is 415,000m (-85,000m + 500,000m). Finally, we have to add the **zone number** to the easting value to get the correct value. As a result, the coordinate for our **Point of Interest**, projected in **UTM zone 35S** would be written as: **35 415,000mE / 6,450,000mN**. In some GIS, when the correct UTM zone 35S is defined and the units are set to meters within the system, the coordinate could also simply appear as **415,000   6,450,000**.

Reprojecting and Transforming Data

Let us understand How to reproject and transforming data into Quantum GIS: