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MAPPING OF WATER DISTRIBUTION NETWORK THROUGH GEOGRAPHICAL INFORMATION SYSTEM (GIS)

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ABSTRACT

Design of surface water supply system concerns the locations and capacities of diversion works and storage, as well as the operations of these to meet multiple purposes and objectives. Therefore, in order to ensure the availability of sufficient quantity of good quality of water, it becomes almost imperative in a modern society, to plan and build suitable water supply schemes, which may provide potable water to the various section of the community in accordance with their demand and requirements.

Due to the advent of Geographical Information Systems (GIS), it possible to visualize, and model the entire cycle of water supply network from source to household .There has been a significant interest in the application of GIS to address the special need of water distribution department during the past several years.

This paper describes GIS has created a technology with considerable potential for achieving dramatic gains in efficiency and productivity for innovative Water Management application.

KEYWORDS: Geographical Information System (GIS), Water, Water Management

INTRODUCTION

GIS provides the hub technology for planning, deploying, operating and optimizing water distribution systems. Any large water distribution system requires a team of technical professionals and programme administrators.

GIS helps coordinate this team across functional areas and geographic divisions by sharing information. GIS technology is familiar to leading system integrators and its use has been fuelled by an increase in the abundance and quality of data.

This increase is due to cheaper and faster data collection tools and availability of high quality commercial data sets. In this Paper, how to map water distribution network through develop GIS in the standard GIS tools.

METHODOLOGY FLOWCHART

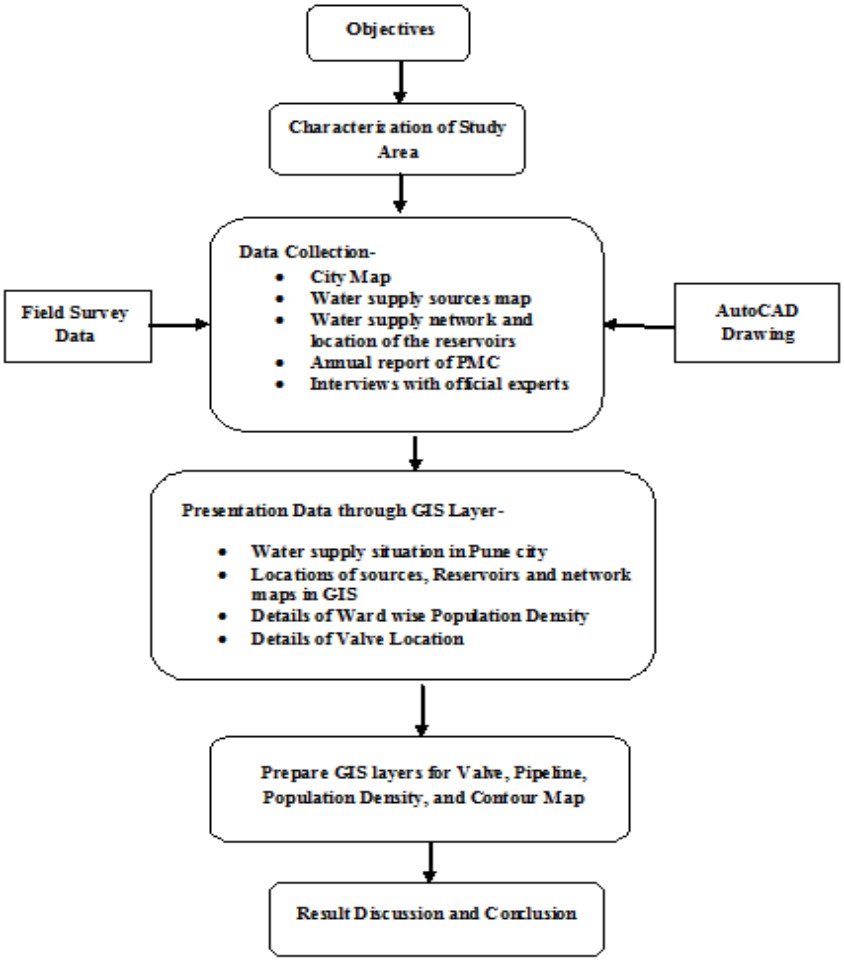

Figure 1: Methodology Chart

- **Research Objective:** To design or prepare Geographical Layers for Water distribution network.
- **Study Area:** Define study area
- Preparation of Geo-referenced water distribution network zone maps

A base map displays the fundamental data set (key physical features such as, roads, railway network, rivers, neighborhood ward boundaries, schools, other landmarks etc.) that is used to render sector data more meaningful. The content of a base map depends on the user of the map and its intended use. These guidelines are for water distribution base maps that capture water and related features that are significant in planning for equitality water distribution system for Municipal Corporation.

Thus, it shall aid planners in preparing 24 hours water supply for city. It is important for the mapmaker and also the target custodians of this data to understand the procedural steps in the production of base maps, the hierarchy of the sources of data and the nature of the data, in addition to actual usage of the data itself.

Major Components of Base Map

Content of an Appropriate Base Map: This includes a list of the base map features needed to be captured like, ticks/ geographic coordinates, boundaries, natural features like prominent streams, major manmade features like transport network, bridges, important landmarks/ locations.

Procedure for Base Map Preparation Using Existing Maps/Data: This would cover general steps involved in preparing base maps from existing analogue map data.

This shall guide where to look for input data, what to do with such data, and important steps involved in preparation of base map through GIS systems. This will include:

- Preparation of base maps at coarser levels using SOI (Survey of India) maps (1:50,000) and finer scale (1: 2000 or 1:5,000 and 1:500) respectively.
- Procurement of appropriate high resolution satellite images of water distribution network of city.
- Digitization, image rectification, ground truthing and preparation of city level water distribution network.
- Listing of all water distribution network and all water entities and locating them on the base map

Base Map Preparation (Internal or by Outsourcing): The Urban Local Body (ULB) shall have to make a self-assessment on their capability to produce the first version of a ULB base map. When it is determined that ULBs do not have in-house capacity to produce base map, help from government /private agencies to prepare base map may be obtained

Base Map Features

The basic requirement to start the water distribution network survey is to have a base map at reasonable scale for the city. In this regard, the scale of the base map for the city is recommended to be at 1: 2000, 1:5000 and 1: 10000 scale based on the availability.

However, preference will be given to the available base maps larger than 1:10000 scales.

Table 1: Comparison of Maps of Different Scales

Scale	Application and Utility of the Map	Features that Can Be Captured	Benefits & Required Resources
1:500	Micro planning (including layout plans of the water distribution network and utilitymapping)	All tenements/building/pipeline network and utility information with accuracy can be captured	Ideal for micro level planning -where detailed plans can be prepared using micro details Spatial data at this scale not easily available so has to be generated through large scale Mapping exercises. As this takes longer and dedicated manpower, the mapping of Slums in the city may be done in phases.
1:2000	All functions beginning from water network planning, area planning	Settlement boundary and Water infrastructure networks can be Captured. Tenement boundaries or building footprints are not very clearly visible at this Scale.	Detailed information can be captured required for area level mapping. Satellite maps may not be available at this scale. Maps need to be generated particularly for the utilities by superimposing the spatial information available in various forms such as paper maps and /or soft copies.
1:10000	Regional planning (city planning can be done but with limited information as at this scale many spatial features are not	Lanes and service roads may not be visible but arterial roads and settlement blocks, regional land use /land cover information would be visible	This scale is appropriate for regional planning but for city level planning the information available might not be adequate. Spatial maps /remote sensing images at this scale are

In building the GIS for water distribution network for city, there would be two forms of base maps; first one in the digital form composed of different layers of digital files for each feature of the base map and other one will be the printed

version of the same. The layout of the printed base map should have standard map features such as scale, north arrow, title, legend etc. Both forms of the base map (digital and printed versions) should have same features. The base map features vary with scale of mapping and hence, care should be taken to define the base map features in accordance with the scale of mapping.

The following broad features are recommended to be included in the base map. The potential source of the data will be from Survey of India (SOI), State Remote Sensing Application Centers (SRSACs), Urban Local Bodies (ULBs)/ Municipalities, etc.

For illustrative list of data layers, codes and attributes required from them are as follows in Table No.2

Table 2: Base Map Features & Potential Sources

Base Map Feature	Potential Source of Data
Administrative Boundary	
State Administrative boundary	Survey of India (SOI), Open Series of maps
Municipal and ward boundary	ULBs
Water distribution boundaries	ULBs/Municipalities, generate using satellite data, GPS based field data
Natural Features	
Natural landmarks	SRSAC, ULBs, SOI, generate using satellite data ,GPS based field data
Stream, creek	SRSAC; ULBs, SOI, generate using satellite data ,GPS based field data
Man-Made Features	
Roads: National; City/Municipal/Slum (line segment)	SRSAC, ULBs, SOI, generate using satellite data satellite data
Railway (line features)	SRSAC, ULBs, SOI, generate using satellite data
Airport (line features)	SRSAC, ULBs or Directorate of Economics & Statistics, SOI, generate using satellite data , GPS based field data
Built-up area of slums in a generalized manner	Satellite imagery, aerial photograph, GPS based field data
Contour lines	SOI, Ground Survey
Cadastral maps	ULBs, land records and survey (LRS)

Prepare GIS Based Water Distribution (Network) Base Map

Hands on Description of Preparation of Base Map Using Existing Data

Obtain paper prints (heavy paper) of the base map, preferably without topography. The base map print can be a blue line or black line copy with plenty of extra space for notations. Hard copy of the latest high resolution satellite image or print of the land use map of the municipality. The following information should be shown on this map:

- Water Distribution Pipeline network
- Land use
- Ward Name , number, boundaries, Population, Population Density
- Valve Details such as Valve number and timings ward wise
- Water tank Location along with all technical specification
- Water Treatment Plant along with name, specification

Steps for Preparing Base Map Using GIS Software

The following broad steps show the generic procedure in the preparation of a base map showing the various data types which the ULB should acquire under GIS environment. Data may be in two forms, the technical description and the

paper map. The capture of data from the technical description involves a more direct step of encoding the numerical data into the computer, which is further converted to points or shapes. The capture of data from paper maps involves three steps as described below:

Figure 2: Process of Digitization

Administrative Boundaries of the Water Zones

Data for administrative boundaries especially for water zone boundaries may come in two forms, technical descriptions and paper maps. It is critical to identify the source of administrative boundaries of such water distribution zone. Sources available with ULBs like topo maps, water distribution department and city Planning Department. Boundary conflicts if any, should be captured and saved in a separate layer and should be consulted with water distribution employees.

Create the Boundary Using Technical Description/ Coordinates

ULBs, municipalities and municipal corporations usually keep records and technical descriptions of water zone boundaries. In cases, where geographic coordinates / grids are available, it is better to use these data and maps. When such data or descriptions are not available, field methods like Total Station Survey or GPS points needs to be used to identify legal boundaries of water distribution zone.

Capture the Boundary Using the Paper Maps

This procedure refers to paper maps with plotted water zone boundaries. They are the plotted paper maps of the boundaries from surveys. If the map also includes technical description or coordinates, digitization of paper maps becomes easy. These maps need to be scanned, geo-referenced and digitized in order to convert them into the digital map. The procedure is as follows:

- Review and inspect the map. Make sure that it contains tick marks with coordinates. There should be at least 4 tick marks with coordinates, but it is often seen that they do not produce accurate results.
- Get familiarized with the projection and datum of the maps.
- Prepare maps for scanning. Smooth all folds and crumpling. Fix and align torn out portions, if any.
- Scan and save images in .jpeg/ .tiff format.
- Check for image distortions and clarity of map features and make sure that the tick marks or reference points to be used are clearly visible on the scanned image. Rescan, if necessary
- The process of defining the position of geographical objects relative to a standard reference grid is known as Geo referencing. It is a system that links information to a position on earth's surface. It is done by assigning map coordinates to image data for making the data amenable to GIS analysis

- Crop the image. Remove areas outside the neat lines of the map with the soft-ware, if possible.
- Load the geo-referenced image using the GIS software for digitizing and perform on-screen digitization.
- Geo referencing and creation of a universally compatible file, like shape file format.
- Create the municipal, zonal and ward boundaries layer as a polygon. Digitize the boundaries from the geo-referenced image. Save the file using standard file naming convention.
- Create the water zone boundaries, from the same source, for the municipal boundaries. Use tools to split or append polygon if available with the software.
- Label or encode the feature name while digitization process. Ward names should be labeled as attributes. Make sure to save the slum layer, created as a different file, and do not overwrite the municipal boundary file which is used as a base layer

Geo-Referencing of Paper Maps

Once a paper map containing information in present scenario, water pipeline network zone, is scanned, save it as a digitized image. The image that is imported can be geo-referenced using any Geo referencing tool. Geo referencing of raster maps (images) involves various steps which are illustrated as an example using one of the software tools.

Data Collection of Water Zone Details Using Global Positioning System (GPS)

- GPS is a simple device using which necessary field data could be collected as needed. Appropriate projection parameters as decided need to be used for mapping purpose.
- For each of the features needed, create a corresponding layer with appropriate feature type. Label or encode the feature name while it is digitized. Create metadata for each feature type created.

Digitization

The final step of digital image formation is the digitization. This means sampling the gray values at a discrete set of points, which can be represented by a matrix. Each layer of the map is geo referenced with respect to the road network, that is. Whether it is slums or canals or whatever it may be, they are geo-referenced along with road network, since the known points are taken on the road network. Hence to have a particular identity of each layer, it is to be digitized, excluding the road network. A feature on a map can be identified either by a shape of a polygon, or a line, or a point. Two types of files are available to generate such shapes.

- Shape file
- Personal Geo Data Base (PGDB)

Shape File

The shape file format is used commonly in Geographic Information Systems (GIS). The format was developed by Environmental Systems Research Institute (ESRI), and is tied to their Arc View GIS 3.2 products; Shape files are simple because they store primitive geometrical data type of points, lines, and polygons. Therefore, table of records will store properties/attributes for each primitive shape in the Shape files. Shapes (points/lines/polygons) together with data attributes can create infinitely many representations about geographical data, and depiction provides the ability for powerful and accurate computations.

Personal Geo Database (PGDB)

Geo database is the latest spatial data format commonly used, with all map data stored in relational database format. The personal geo data base is built into Arc View GIS.

Geographical Information Systems (GIS)

Geographic Information Systems [3] are utilized to improve efficiency, decision-making and communication by integrating various multiple and complex sets of information. The systems provide a framework for management, analysis and display of geographic information. There are three major components of a GIS: the data sets and models which represent the raw information, the maps and globes in which this information is placed, and the processing and manipulation that can be applied.

For this project, the data sets are largely comprised of the home, tap stand and other important locations within the water distribution system. The maps and globes allow the 3-D setting to be more easily understood in a 2-D space, and geo processing can create new data and representations to interpret. One hope is to create intuitive and cognitive tools that will help people across cultures and disciplines work efficiently together. [1]

Important features for the GIS [4] related to this project are flexibility and availability of data manipulation tools and multiple scales. Tools are necessary to understand more about the available data. For example, if the population nearest to a particular tap stand is defined, a next valuable piece of information would be the percentage of this population that actually utilizes this tap and the frequency of use. As a result of the depth and extensive nature of geographical data, it is important for collaboration especially regarding the creation and maintenance of data sets.GIS provides powerful and cost-effective tools for creating intelligent maps for water.

Mapping Basics

The basic concepts essential for understanding GIS mapping are summarized in the following subsections.

Map Types

There are two major types of GIS maps [8]: vector and raster. In vector format, objects are represented as points, lines, and polygons. Examples of the vector format are maps of water mains, hydrants, and valves. Scanned maps, images, or aerial photographs are examples of raster format. Raster data is also referred to as grid, cell, or grid–cell data. In raster format, objects are represented as an image consisting of a regular grid of uniform size cells called pixels, each with an associated data value. Many complex spatial analyses, such as automatic land-use change detection, require raster maps. Raster's maps are also commonly used as base maps. Existing paper maps that are used to create GIS maps are called source maps.

Topology

Topology is defined as a mathematical procedure for explicitly defining spatial relationships between features. A topological GIS [7] can determine conditions of adjacency, containment, and proximity. Topological relationships allow spatial analysis functions, such as network tracing, that can be used to facilitate development of hydraulic models for water and sewer systems.

Because the Earth is round and maps are flat, transferring locations from a curved surface to a flat surface requires some coordinate conversion. A map projection is a mathematical model that transforms (or projects) locations from the curved surface of the Earth onto a flat sheet or 2D surface in accordance with certain rules. Small-scale

(1:24,000 to 1:250,000). The origin of each zone is the equator and its central meridian. X and Y coordinates are stored in meters. Large-scale local GIS data are usually projected using a State Plane Coordinate (SPC) projection in the United States.

Coordinate Systems

A coordinate system is a reference system used to measure horizontal and vertical distances on a map. A coordinate system is usually defined by a map projection. The GIS and mapping industries use either latitude/longitude- or geodetic-based coordinate grid projections. Surface location is defined by the angle from the center of the Earth between a given location and the plane of the equator (latitude) or Prime Meridian (longitude). Latitude and longitude coordinates can be described using two main notations:

Degree: Minute: Second (DMS) and Decimal Degree (DD). For DMS, each degree is divided into 60 parts (minutes) and each minute is further divided into 60 seconds. For DD, the minutes and seconds are represented by digits (typically four) following the major degree and a decimal.

Map Scale

Map design addresses two fundamental map characteristics such as accuracy and depicted feature types. Both characteristics vary with map scale. Generally, larger scale maps are more accurate and depict more detailed feature types. Smaller scale maps, such as U.S. Geographical Survey (USGS) quadrangle maps, generally show only selected or generalized features.

Map Accuracy

A primary factor in the cost of data conversion is the level of positional accuracy. Required map accuracy and resolution depend on the application in which the maps will be used. A 2000 survey conducted by the Geospatial Information and Technology Association (GITA) [2] indicated that the water utilities were seeking more land base accuracy of 5-ft compared with other utilities, such as the 50-ft accuracy sought by the gas companies.

MAP TYPES

The map layers are registered to a coordinate system geodetic control framework and a set of base information often referred to as a base map. The foundation for a successful GIS mapping project is an appropriately designed base map. The base map is the underlying common geographic reference for all other map layers. Because the base map serves as the reference layer for other layers, its accuracy can affect the accuracy of other layers. Selection of an appropriate base-map scale is largely determined by the earlier choice of GIS applications.

GIS Mapping Steps

GIS mapping consists of five typical steps as following in Figure 3.

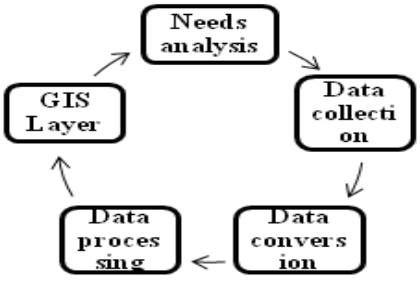

Figure 3: GIS Mapping Steps

These steps are intended for GIS technicians who work in a GIS lab equipped with map - making equipment such as digitizers, scanners, and plotters.

Needs Analysis

The needs analysis study describes the features that should be captured during the data conversion step, mapping specifications (accuracy, resolution, scale, etc.), and source documents. For example, the needs analysis determines whether or not the customer meters should be mapped

Data Collection

When existing maps do not exist or are inadequate, mapping data should be collected using a field survey with or without GPS.

Capturing Attributes

The annotations (labels) shown on the source map are the most common source of attributes. The source document ID (e.g., drawing number) is one of the most important attributes that should always be captured during data conversion. Features such as valves and hydrants have unique IDs, which can be easily captured from labels (annotations) on source maps.

Capturing Graphics

The data conversion methodology for capturing graphics depends on database design, source materials, and project digitization and scanning are the two most common data conversion methods.

Data Conversion (Digitization)

Digitization is a process of converting a paper map into a vector file by a computer using a digitizer or digitizing table (or tablet). The source map should be registered (or calibrated) to control points. Conventional table digitization is a laborious process. For easy identification, certain utility assets that are difficult to see on the aerial photographs (e.g., valves, hydrants, manholes) can be pre-marked. Pre-marking is done by placing (or painting) targets with special symbols and colors over or adjacent to the asset to be captured. Scanning is a process of converting a paper map into a raster file (or image) by a computer using a map-size scanner.

Data Conversion Software

Data conversion requires GIS development software that draws objects as points, lines, or polygons or represents them as pixels. ESRI's ArcGIS® [6]For large projects, data conversion application programmes are very useful. The water editing tool was developed in several versions for different users. The ArcView version was developed using Avenue and ESRI's Dialogue Designer Extension to support water system and sewer system map-ping needs of the ArcView 3.x users. Data conversion is started by drawing and attributing the points. After the points are attributed, the connecting lines are added from point to point. Data conversion applications like the water editing tool increase the speed, efficiency, and accuracy of data conversion for water, wastewater, and storm water systems.

Data Processing

This task makes the raw data from source maps or field/GPS surveys available for GIS use or GIS ready. Typical activities include post-processing of captured data, changing data formats (e.g., from DXF to Shapefile), applying map projections, geo referencing the image data, and/or clipping the aerial photos.

Post processing of captured data is warranted, if the source maps and the base map have different accuracy, and captured data do not align with the base map. In this case, captured data is edited (moved, stretched, or resized) to fit the base map.GIS data are stored in various file formats.

Preparation of GIS Layers-Pipes

Pipe layer is drawn in poly line and contains the following attribute fields: Unique ID for each pipe segment, diameter of the pipe in milli meters, material of the pipe, depth of the pipe (if known), calculated length of the pipe, pressure zone of the pipe, address information and information about the installation of the pipe. The following figure 4 shows GIS layers or Shape file of water distribution pipe network.

These attribute fields are filled from project values and field staff's knowledge but they may contain important mistakes (mostly wrong diameter and wrong ict with the reality on the field. In this figure show various different diameter pipeline with different color.

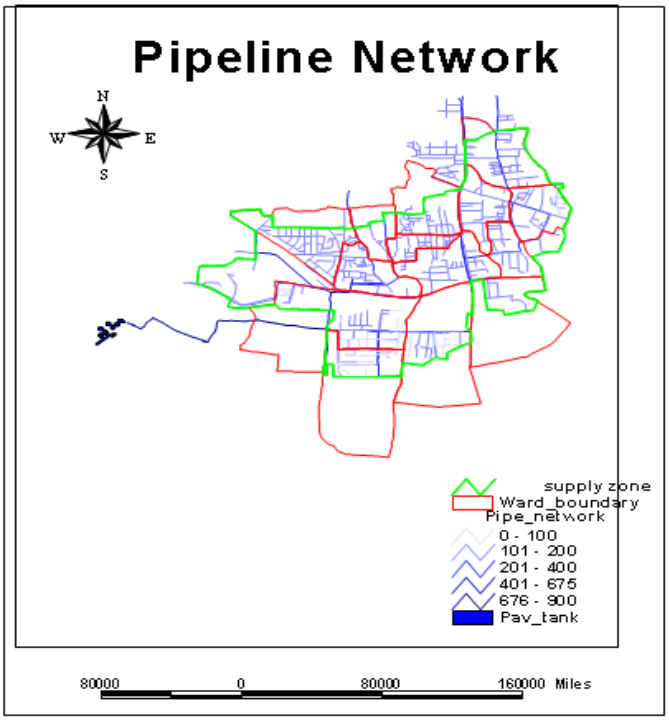

Figure 4: Pipeline Network for Water Distribution Zone Developed Using Arc View GIS

CONCLUSIONS

Geographic Information System which links computerized maps i.e. location data to computerized data base which describes attributes of a particular location. By this linkage, one can easily access location and data simultaneously. Further, maps and other data may be updated quickly and accurately with the help of GIS. The spatial data of GIS can provide information to support modelling. The strength of GIS is that it is possible to process the data sets using any type of numerical analysis procedure.

The digital procedure of storing and processing spatial or image data is a very much useful to analyzing the data.GIS has a wide range of use. Water Supply can use GIS in conjunction with the source water assessments to help protect the various water supply system. With an adequate database, Geographic Information Systems (GIS) can serve as a powerful analytic and decision making tool for water supply system. Furthermore, it can also be used for management and to test consequences of development**.**

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