



## Managing Urban Water-Supply Using GIS

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### Introduction

Geographic Information Systems (GIS) have been proposed as a means of making information about the systems used to provide urban services more accessible and useful. Urban services that appear to be particularly suitable for GIS include the networks for distribution of water, electricity and natural gas as well as collection of sewage (Borrough, 1986; Taylor, 1991; Jacobs et al., 1993; Douglas, 1995; Brebbia and Pascolo, 1998).

In the present study, a geographic information system has been developed for water supply management in urban areas in a user-friendly environment. The basic aim of proposed Water Supply Management System (WSMS) is to facilitate the water works management by helping maintain the records of leaks and repairs; provide customer information service; automatic billing of monthly charges; provide inputs for accounts section; generate contracts, work orders and daily work schedules for crews; and assist in many more regular and advanced decisions.

### Water Supply Management System

As WSMS is data driven, its development methodology has been illustrated by implementing it for the Bidanasi area of Cuttack city (Orissa). India. The study area, GIS development and development of a user-friendly interface have been described below.

### Description of study area

Cuttack is a coastal city situated in the state of Orissa at longitude of  $21^{\circ}15'$  and latitude of  $81^{\circ}15'$ . Because of the increase in population, the Cuttack Development Authority is developing residential sectors and related infrastructure on the outskirts of Cuttack at Bidanasi area. The Bidanasi area is about 8 km west of the old city and is located between Mahanadi river and its tributary Kathjuri. Till now, eleven sectors have been developed with water distribution system, sewerage system and road network. This study is concerned with 18.485 km long water distribution system, supplying drinking water to 1572 houses of sector 9 spread over an area of about 71.5 hectares.

### Implementation of WSMS

The present study was carried out on an IBM RISC

6000 workstation using ARC/INFO GIS software running in UNIX environment (ESRI, 1995a, 1995b). The layout map of the Bidanasi project site was scanned into a personal computer using FSS 8000 full-scale scanner. The scanned image was transferred to the IBM workstation. The scanned image file was converted to raster format using ARC/INFO and the coordinates of the four corners of the study area were digitized in that coverage. The following main coverages required were created.

*Street layout coverage:* Street layout coverage was created keeping layout as background and digitizing streets using mouse. The digitized coverage was cleaned twice to correct errors etc.

*House coverage:* House coverage was digitized from layout of the study area. Using the options available in the software, the *House\_number* were allocated to each of 1572 individual houses of the study area. In the point attribute table, *Type\_of\_house*, *Supply\_pipe\_id*, *Water\_consumption*, and *Water\_charge* items were added. The *Type\_of\_house* and *Supply\_pipe\_id* were recorded using the data obtained from project area map. The third item was calculated by assuming the consumption variation depending on the *Type\_of\_house* and referring to water supply manual. Finally knowing the unit water charge and *Water\_consumption*, *Water\_charge* was calculated using ARC/INFO software features.

*Water supply network coverage:* This was digitized taking the digitized street layout coverage as background. The water supply network consisted of 35 pipe segments. During the digitization of the network, *Pipe\_id* was assigned to each pipe segment in the network. The arc attribute table of network coverage was appended with two new items viz. *Pipe\_length* and *Pipe\_dia*. The values of *Pipe\_length* and *Pipe\_dia* were entered manually for all pipe segments as per the water distribution network map of the study area. After this, two more items named as *Frequency* and *Population* were added to the same table. *Frequency* and *Population* meant how many houses and how many persons, respectively a pipe segment was serving. *Frequency* and *Population* were generated automatically from HOUSE.PAT knowing the average number of members per household for a *Type\_of\_house*.

*Valve coverage:* Valve coverage was created and the valve positions were digitized taking digitized water

supply network coverage as background. Here different identifiers were given to distinguish sluice valves from the air relief valves. The network had 189 sluice valves and 7 air relief valves. The location of pump house was also digitized in this coverage.

Now, the GIS database for the water supply system of the study area was ready. A macro language program was written to utilize the developed GIS database and present it in user friendly manner so that managerial staff can assess and use WSMS without having to learn about the intricacies of GIS software.

**Practical Applications**

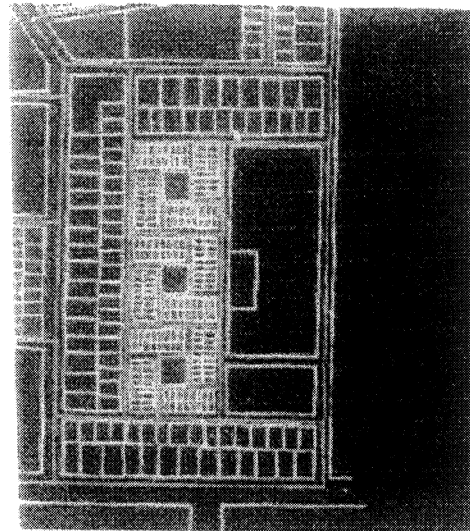
The WSMS developed above can be used an on-line information system of the operation and maintenance of the water distribution network. The main advantage of the system is that the detailed records of water distribution can be maintained and updated easily. Search for any specific query is also possible. For example, Fig. 1 displays all pipes serving more than 100 person each. Table 1 is the result of the query-list the house getting water from pipe number 213.

The presentation and preparation of maps is the major advantage of WSMS. Figs 2, 3, 4 and 5 show the street layout, house arrangements, water supply network and position of valves, respectively. Thus one is not forced to work with only one detailed map containing all information about the area. Rather, if one is interested to know about property rights and ownership etc., he should limit his work to map as displayed in Fig 3. The municipality can use this map to maintain records of ownership and for automatic billing of house tax, water tax, sewer tax etc., while at the same time maintaining the records of payment made by residents and credit or due amount, if any. Capacity determination, optimization, or upgradation of network will require only information on network as shown in Fig. 4.

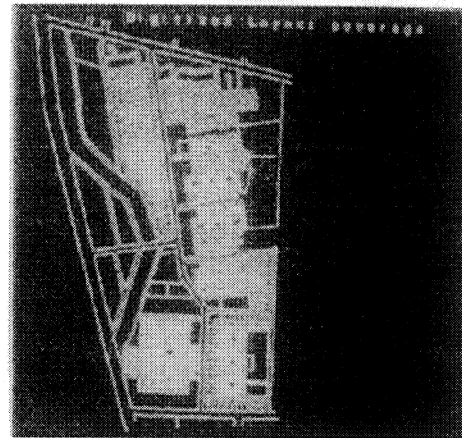
If any repair is to be done for a particular pipe, the crew is not required to take the whole distribution network map. The details of that particular pipe segment are sufficient for them. For this, they may be given the

**Table 1. List of houses getting water from pipe number 213.**

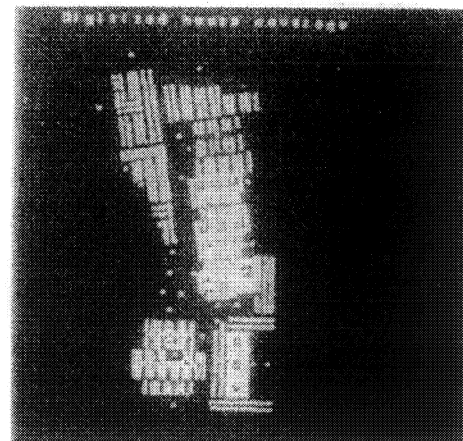
Record number	House number	Type	Water consumed (combic metres)	Water charge (Rs.)
662	882	4	24	53
663	883	4	24	53
664	884	4	25	55
665	885	4	25	55
666	886	4	24	53
667	887	4	25	55



**Figure -1**



**Figure -2**



**Figure -3**

enlarged view of the damaged pipe area containing network and steel layout information as shown in Figure 6. This is not possible with conventional approach.

For automating the generation of monthly water bills,

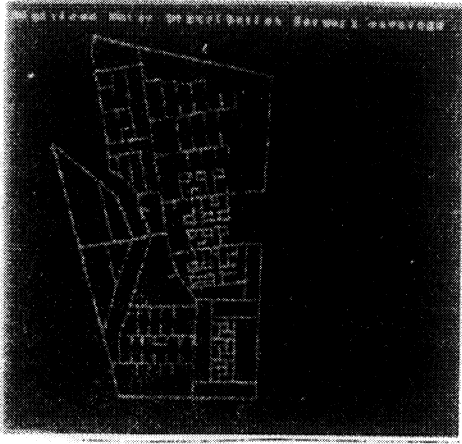


Figure -4

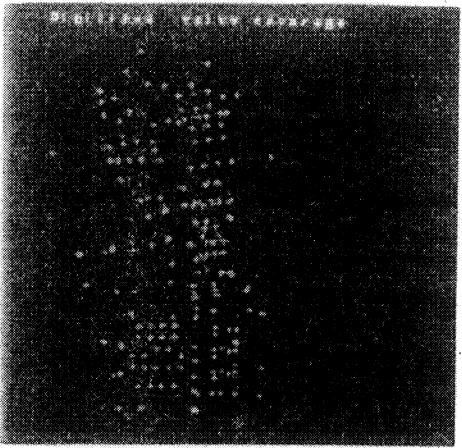


Figure -5

the developed system is well suited. A computer file will be used to maintain the readings on monthly water consumption for different houses. Once this information is known, the systems will generate individual bills of water charges. The account section of water works may use this data to accept the amount paid and to calculate the amount due till that month for each consumer. It is also very easy to issue notice to those consumers whose dues are outstanding for significant period of time. The billing system may be also refined to contain as much information as required by Billing and Audit unit of water works.

Many potential uses of WSMS are possible. A few of them are being discussed here. (1) WSMS can be used to fix the schedule of water supply and for this the management of the water works can divide the area into number of supply zones. (2) Maintaining the information regarding the conditions of various valves, the date of last maintenance or replacement etc. is extremely easy.

(3) The records of daily water quality can be stored and may serve as the basis of monitoring the performance of water treatment plant. It is also possible to identify the contamination of water at the earliest and auto alarm system may also be invoked to draw attention of the management. (4) For planning future augmentation and improvements of water works operations, the long term records of daily supply over the year, the number of connections of various sizes, the total revenue collected from the consumers are required. All these can be easily assembled by the WSMS. To this, the repair done, the date of repair, the cost of the repair etc. can also be added. These types of cost estimates are useful for performing the benefit-cost analysis of the water distribution system. Thus, the management can fix water charge to make the water works economically stable and self-sufficient. (5) The water main replacement programme can be planned using WSMS. The following data will be needed – the date of installation of the pipe, leaks occurred through the pipe, the type of repair carried on the pipe, date of repair and cost of the repair. The management can take the decision, which pipes are to be replaced depending on their condition for example, pipes older than 30 years or pipes having more than 3 leaks etc. Then the management can find the location of such pipes and calculate the cost of each replacement. The process of issue of contract documents for repair/replacement can also be automated. (6) WSMS can be used to carry out the risk assessment of the water distribution system. With the availability of the data such as how many persons are served by a pipe, how much water a pipe can transmit, valve condition of the system, it is easy to perform a risk assessment study. Alternatively, the risk may also be calculated by computing the revenue loss to the management and the number of person affected due to break in a water main. (7) The management can take the decisions on how to repair the system, how many persons are required to perform the repair operation and at what time the repair may be carried out. (8) The management can also use WSMS for making decision such as how to temporarily supply water to the houses affected by the damaged pipe from other mains.

### Conclusions

A GIS based general methodology for developing urban water supply management system has been proposed which uses street layout coverage, house arrangement coverage, water distribution network coverage and valve position coverage. It has been shown with the aid of demonstration application developed for a part of Cuttack city that WSMS can serve as the tool for effective operation and maintenance of water

distribution network. It provides for the automatic billing of the water charges. With some modifications, it can be upgraded for generating contracts, developing work schedules for the crew, developing service zones, detecting leaks and wastage in the system, maintaining records of leaks, carrying water budgeting, fixing water charges, developing pipe replacement programme, carrying out risk assessment and making decisions in emergency situations etc.

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