GIS enabled Information and Management System for a Sewage Treatment Plant

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ABSTRACT

A sewage treatment plant is one of the essentials provided by the municipality to the society. A complete treatment of wastewater involves many unit operations and processes. Since the treatment of wastewater is a vital and continuous activity, the sewage treatment plant must be managed and functioned judiciously.

This paper deals with the use of GIS to expedite the concerned authorities at the treatment plant with the evaluation of the various treatment alternatives and processes considering the plant state, influent sewage conditions and various other influential factors.

A pilot project was undertaken involving development of package using AutoCAD Map 2000i (a GIS package) and VBA at Punjab Engineering College for a fictitious city of which the entire wastewater collection system and the Sewage Treatment Plant was evaluated for optimal treatment scheme for changing conditions. In addition, the package functions as an information system for the complete Sewage Treatment Plant and the Sewage Collection System.

INTRODUCTION

A sewage treatment plant (STP) can be described as a water pollution control plant consisting of an arrangement of pipes, equipments, devices, tanks, structures etc., for treating wastewater and industrial wastes. The various components (units and processes) of a Sewage Treatment Plant are provided with main emphasis on the influent sewage quality and quantity (expressed as discharge)

Domestic sewage experiences large variation in flow rate which hampers the optimal performance of the Sewage Treatment Plant. Generally, the sewage treatment plant is designed for peak flow and a number of parallel units or processes are provided which are put into use with the increase in influent discharge. A lower value of influent discharge necessitates the shutting of redundant units or processes.

The nature treatment to be provided also depends upon the quality of the influent sewage. Depending upon the quality of influent sewage (in terms of BOD_5, Suspended Solids, Settleable Solids etc.), the treatment scheme is varied.

Hence, the various units and processes in a Sewage Treatment Plant function in accordance to the influent sewage quality and quantity.

The detention time, quantity of chemicals required, use of mechanical equipment are few of the various Sewage Treatment Plant issues that are to be addressed properly. Heavy expenditure is incurred every year on Sewage Treatment Plant activities due to mismanagement. Apart from the quality and quantity of the influent sewage, the decision relating to such issues are based on the condition of plant components, climatic factors (temperature, precipitation, etc), manpower availability, degree of treatment desired, outfall requirements, sewage hydraulics, process cost, process time, etc. An improper functioning plant component may cause to compromise on the quality of sewage treatment, which may ultimately result in the pollution of the environment. Moreover, improper management of treatment activities escalates the total cost of treatment, which is otherwise avoidable.

Therefore, to arrive at the best possible combination of the various components of the plant for a particular condition, it is important for the concerned plant incharge to have immediate access to information related to the following:

- Condition of plant components
- Features/requirements of the plant components (chemicals, mechanical equipment, detention time, etc.)
- Strength and qualification of the manpower available to handle the various plant components
- Possible variation in influent discharge due to a breach in a sewer line, closing of a valve or penstock gate, etc.
- Spatial location of the faulting sewer or plant component
- Quality of the influent sewage
- Other physical factors
- Related past records

Thus, the selection of the best possible combination of the plant components commensurate with the over all performance of the treatment plant becomes a tedious task.

This necessitates the development of a computer tool which can collect, manage and display Sewage Treatment Plant specific data, evaluate various wastewater flow configurations through the treatment plant and generate the result in spatial and non-spatial form. GIS can provide the mechanism by which the management of the Sewage Treatment Plant can become more efficient and cost effective at multiple levels.

GIS APPLICATION

In the recent years, there has been an enormous change in the way information is collected, stored, retrieved, manipulated, analyzed and displayed. The development in Information Technology (IT) has prompted both government and the non-government organizations to rethink their operational aspects. With the

progress in information generation and dissemination technology, it is now possible to have spatial and non-spatial databases on digital domain. By suitably designing the analysis and query system, it becomes very easy to make accurate assessment and take decisions efficiently.

GIS is a systematic integration of computer hardware, software and data (spatial and non-spatial), for collecting, storing, displaying, manipulating and analyzing purpose, which can be used for solving management related issues. A GIS stores both spatial and non-spatial data in a database system which links the two types of data to provide flexible and powerful ways of querying.

GIS is a powerful tool, which can be used for the management and process planning of Wastewater Treatment Plant with the following advantages:

- Display of sewer network layout in the city and the various treatment plant components.
- Efficient planning and optimization of the complete sewage treatment process based on factors relating to influent sewage and the condition of the sewage treatment plant units and processes
- Detection of redundant units or processes and the spatial display of the same
- Easy and exhaustive information retrieval with respect to the spatial and non-spatial data relating to the sewer network and the sewage treatment plant
- Easy determination of variation in influent discharge (at Sewage Treatment Plant) due to breach in sewer, closing or opening of valve, etc. in the city sewer network
- Overcome of delay in decision making at various levels related to treatment process
- Network analysis of the flow of sewage in the Sewage Treatment Plant through various units and processes on the basis of the plant component condition, environmental factors (temperature, rainfall and humidity), manpower availability, degree of treatment desired, outfall requirements, sewage hydraulic flow characteristics, process cost, process time, etc.

- The expected sewage quality and hydraulic flow characteristic for a particular scheme of treatment involving a specific combination of plant components
- Various queries made possible which help in decision making related to the proper functioning of the Sewage Treatment Unit
- Keeping a log of plant operations and other related records for future consideration

STUDY AND DEVELOPMENT OF SOFTWARE PACKAGE

A pilot project was undertaken at Punjab Engineering College to study the various possibilities of GIS application in effective management of STP. This led to the development of a GIS enabled Information and Management System for STP catering to a fictitious city (having similarity to Chandigarh).

Project Objectives

- To develop a comprehensive GIS based Sewage Treatment Plant Management System.
- To generate a comprehensive and exhaustive display of sewer networks and other related features.
- To generate a comprehensive and exhaustive display of Sewage Treatment
- To create comprehensive GIS ready Database to supplement the STP Management System
- To perform various queries on spatial and non-spatial databases relating to Sewage Treatment Plan.

Methodology

The study and the package development was done using AutoCAD Map 2000i as GIS tool and MS Access was used for database creation. Visual Basic for Applications (VBA) was used to facilitate specific queries.

Since the project was organized for a fictitious city, mock data was used which was generated on the lines of the Chandigarh Sewage Treatment Plant.

Spatial database was prepared on the basis of the arrangement of sectors in the city, the provided sewer layout and the Sewage Treatment Plant layout. The same were generated in digital format using Auto CAD Map 2000i.

The following features were created in digital format:

- City map upto sector level
- Sewer network (location and spatial arrangement of sewers)
- Drain network (location and spatial arrangement of drains)
- Sewage Treatment Plant Layout (location and spatial arrangement of various plant components including interconnecting pipes and channels)

Non-spatial database was created using MS access for wastewater collection system and for the various plant components. The Database created was in accordance to the third RDBMS (Relational Database Management System) normalization.

The non-spatial data included the following

- Sewer dimensions
- Sewage Flow characteristics in sewers
- Dimension of storm drains
- Storm Flow characteristics in storm drains
- Dimensions of various components of sewage treatment plant
- Flow characteristics of various components of sewage treatment plant
- Sewage characteristics (BOD, SS etc.) in various plant units and processes
- Performance / efficiency of treatment units
- Information related to manpower deployed at sewage treatment plant

Object Data was also attached to respective spatial features (objects) to facilitate relational querying.

Queries

The various queries were generated as per the objectives of the project. They are listed as follows:

1. Show
    a) The whole Sewer Network

b) Sewers / Sections

On the basis of

a) Their type (mains, trunk etc.)

b) Their Physical parameters (diameter, gradient, length, etc.)

c) Their Flow characteristics (discharge, velocity, etc.)

d) Location

c) Various sewer appurtenances

On the basis of

e) Their name

f) Their Physical parameters

g) Location

d) The whole Drain Network

e) Drains / Sections

On the basis of

h) Their type (mains, trunk etc.)

i) Their Physical parameters (gradient, length, width, etc.)

j) Their Flow characteristics (discharge, etc.)

k) Location

f) Sewage Treatment Plant Components

On the basis of

l) Name

m) Their Physical parameters

n) Their Flow characteristics (discharge, head loss)

o) Sewage characteristics (BOD, Suspended Solids, etc.)

p) Location

2. On account of variation in sewage discharge

a) Show the best combination of treatment units and processes

b) Show the penstock gates to be closed

On the basis of the condition of the plant components

a) Show defective units

b) Show alternative treatment combinations

3. Complete non-spatial information of

a) Selected Sewer(s)
b) Selected Drain(s)
c) Appurtenance(s)
d) Pump(s)
e) Plant components(s)

A combination of the above queries was also made possible.

Results

Various query results were obtained and subsequently evaluated for accuracy and consistency.

Fig-1 exhibits the result of the query for best combination of treatment components for a given influent discharge. The pipes highlighted in green give the flow of sewage and sludge in the plant for the given discharge. Hence, for the given discharge, only the displayed components are required to function for optimal performance of the Sewage Treatment Plant's

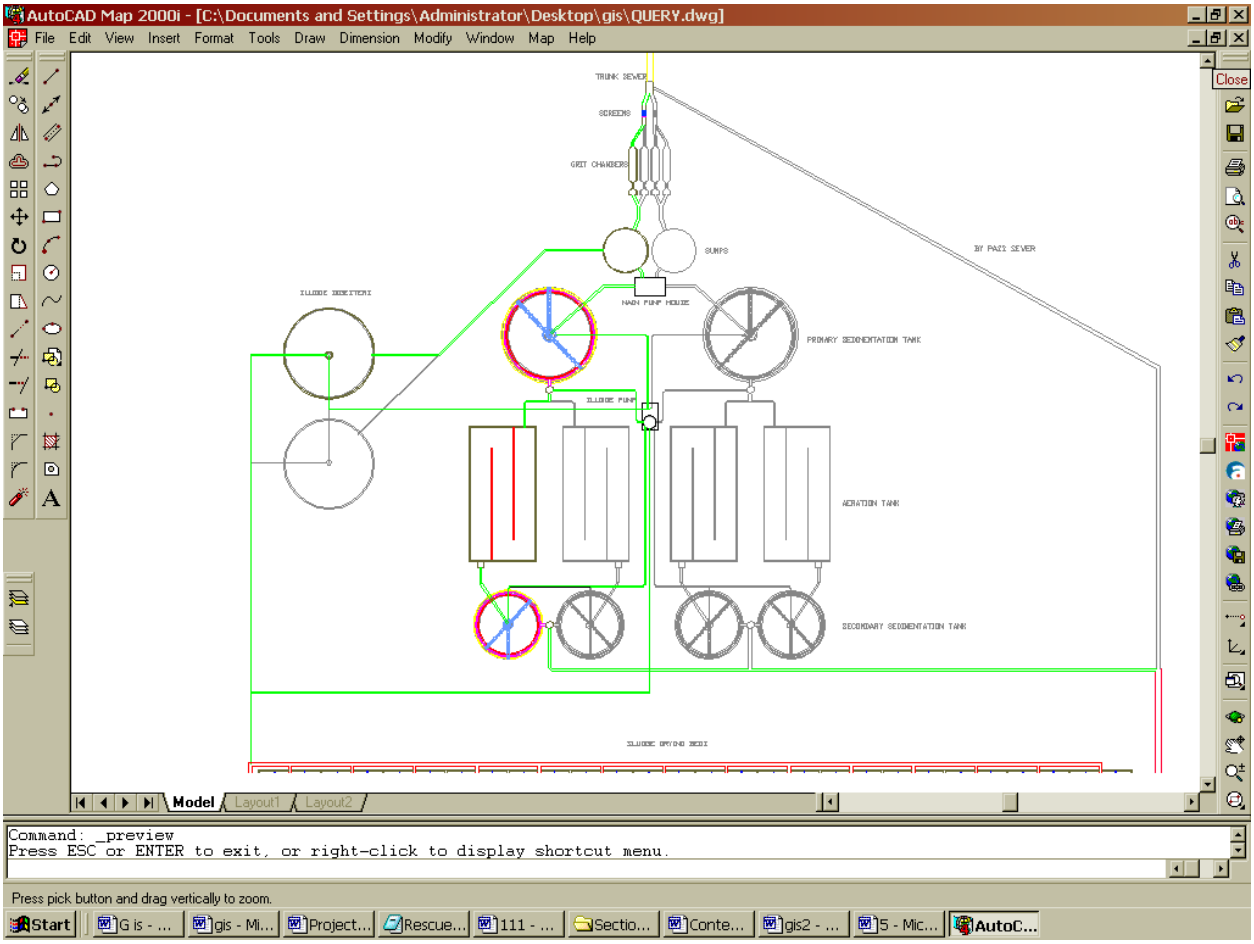

Fig-1: Query result for best combination of treatment components as per flow rate

Fig-2 exhibits the result of the query for display of all the pipes carrying sewage in the treatment plant. The pipes highlighted in green colour carry sewage while the rest are sludge carrying pipes. Similarly, result may be obtained for the display of other components and the related appurtenances in the Sewage Treatment Plant.

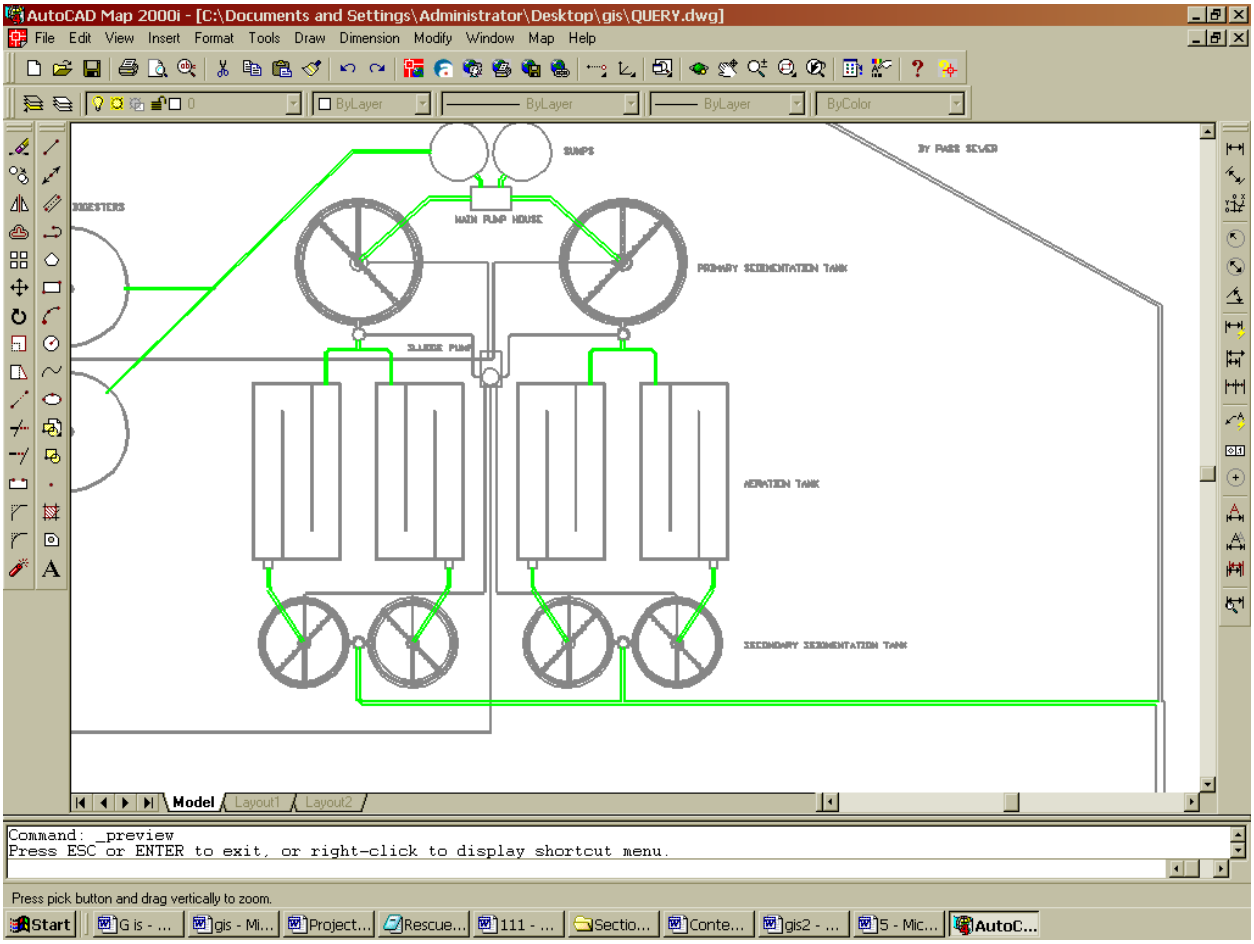

Fig-2: Query result for display of pipes carrying sewage in the treatment plant

CONCLUSION

The GIS enabled Information and Management System for a Sewage Treatment Plant can prove to be of great importance to the municipal department engaged in facility management. With exhaustive thematic display and customized query utilities, the GIS package will serve as a decision support tool designed to aid in efficient management of the Sewage Treatment Plant. This will also set the pace to the complete computerization of the municipal department.