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Using Arc/Info GIS to help implement the National Pollutant Discharge Elimination System (NPDES) Stormwater Permit for Los Angeles County

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ABSTRACT

One of Los Angeles County Department of Public Works' many responsibilities is to manage non-point pollution that enters the storm drain network within Los Angeles County. The management of this non-point source pollution is mandated by the NPDES guidelines under the Federal Clean Water Act. These guidelines require the County to monitor the drainage network and the storm water and urban runoff flowing through it. The County covers over 3,117 square miles, with the NPDES Permit covering over 3,100 square miles and over 2500 miles of storm drains. A proposed solution to monitor and manage this vast geographic area is centered upon an Arc/Info GIS. Some of the many concerns which need to be addressed include the administration and evaluation of Best Management Practices (BMP's), storm drain inspection for illegal connections and illicit discharges, and pollutant load assessment and modeling. The storm drain network and other coverages will be related to external data bases currently used for facility management and planning. This system would be used for query purposes to perform spatial modeling and "what if" scenarios needed to create maps and reports required by the permit and to evaluate various BMP implementation strategies.

Overview

Los Angeles County Department of Public Works

One of Los Angeles County Department of Public Works' many responsibilities is to manage non-point source pollution that enters the storm drain network within Los Angeles County. This is a non-trivial task due to the size of Los Angeles County, its large population, and the potential for pollutants entering the system. Los Angeles County covers over 3,117 square miles and is home to over 11.4 million people who place a large demand upon the system. The network of over 2,000 miles of closed storm drains and 500 miles of open channels drains 6 major watersheds into the Pacific Ocean.

NPDES Permit

The California Regional Water Quality Control Board, Los Angeles Region, under authority of the Federal Clean Water Act and the National Pollutant Discharge Elimination System (NPDES), issues and regulates NPDES permits. A new permit was issued to the county in July 1996 for the management of storm water and urban runoff. The Los Angeles County Department of Public Works' (DPW) Water Quality Section (WQS) is responsible for implementing the new permit

requirements including coordinating reporting for 85 cities within the County limits.

The new permit's requirements place significant new information management demands on WQS staff for data management and analysis capabilities in the following areas:

- identification and elimination of illicit connections and discharges,
- tracking and evaluation of best management practices (BMPs),
- water quality monitoring, and
- reporting.

Conceptual Solutions

The LACDPW sought help in preparing a solution for the permit requirements. Using a Cooperative Research and Development Agreement (CRADA), a team from the Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee, was tasked with examining LACDPW resources and the permit requirements, and creating a Conceptual Solutions Report (CSR)(Sale et.al., 1997). The CSR contains a list of the actions necessary to satisfy the County's need for an information system to manage and analyze data associated with the permit. This list is shown in table 1. In order to efficiently perform these actions, the CSR recommends a GIS-based Environmental Data Management System (EDMS) which interrelates tabular and geographic data .

Current Situation

The Environmental Programs Division (EPD), of which the WQS is an organizational unit, is responsible for meeting the permit requirements. Several other EPD sections provide information to WQS, especially the Industrial Waste/Underground Tanks Section that operates the Hazardous Materials System (HMS). Other divisions which capture and maintain relevant information are the Information Technologies Division, the Mapping and Property Management Division, and the Hydraulics/Water Conservation Division (HWCD).

The DPW information technologies infrastructure includes a number of different database management systems, mainframe computers, and distributed workstations/servers, as well as very good capabilities in mapping and computer modeling. Most of these existing facilities are in organizational units outside the WQS. The new EDMS must fit efficiently within these existing systems, taking full advantage of available capabilities and data while also providing for the specialized needs of the WQS staff who have storm water management responsibilities.

The divisions within the DPW collect and maintain a rich set of GIS databases which can be used within the EDMS. These data are in various formats and spatial resolutions depending upon the their intended use. These GIS layers include: the storm drain network, catch basins, manholes, natural drains and streams, lakes and reservoirs, land use, soils, political boundaries, Standard

Industrial Classification (SIC) codes, census tracts, water quality monitoring sites, hydrological monitoring sites and county facilities.

The data in the current condition cannot be effectively used. It can be difficult to ascertain which data exist, the characteristics of the data, and how to use the data. The GIS data are in disparate formats and in various degrees of spatial accuracy. While GIS data is shared among divisions, some coverages are maintained by more than one division. Similarly, the tabular data is maintained by different divisions in different formats on different computer platforms. These data have not, as a rule, been related and therefore have not been used to maximum advantage. There have been some independent efforts to combine datasets for specific applications, but currently there are few applications other than database query. The EDMS is a proposed solution to these problems and will relate these datasets together and create an easy to use, efficient system which takes advantage of the natural synergies between datasets.

Arc/Info-based Solution

Hardware

The proposed hardware required for the EDMS consists of two interconnected workstations, two uninterruptable power supplies, a switching hub, a large color plotter, a black and white Postscript printer, a color PostScript printer, and several network-compatible PCs as shown in figure 1. Such a system should support five concurrent users with acceptable response times.

Software

Commercial off-the-shelf software is recommended for the EDMS. UNIX is the recommended operating system. Oracle is the recommended relational DBMS which will be used to manage the tabular data described in earlier sections of this report. ARC/INFO and ArcView are the recommended GIS systems and will be used to manage the geographic data. Spatial analyses tools will be written in AML and/or Avenue. Statistical analysis may be performed using PC-based software packages such as Excel or Statistica. Users will access the workstations using Hummingbird or an equivalent X-terminal emulator. The user interface to the EDMS will be ArcView, customized with its Avenue language and dBASE 5.0 using ODBC.

Undocumented Connections and Illicit Discharges

The NPDES permit requires that the DPW identify and eliminate illicit connections and discharges

into the storm drainage system. Illicit connection are discovered either through planned inspections of the storm drain network or by public support, usually through the telephone hotline. Data collected from these sources are stored in a database and used as historical evidence.

There are existing dBase tabular data sets that support the illicit connections and discharge elimination activities. These data sets include storm drain name and number, stationing of event (how far from a drain line starting point the connection/discharge is located), and the permittee or the responsible party. Each of these data tables need to be related to the GIS storm drain coverage through the use of common fields: the drain identification number and the start and end stationing of each drain segment.

The geographic database to be constructed for use in the illicit connections and discharge elimination activities consists of a base coverage of the storm drain network, the location of manholes and catch basins, links to inspection and land use types, and hydraulically connected subbasins.

Integrate Upstream Watershed Data

An ArcView project will be developed that has access to all the necessary GIS data and has appropriate links to the tabular data to meet the needs of the Illegal Connections/Illicit Discharge program. Once the user chooses to use this particular project, it will load a working version from the project template. Next the user will be asked to choose a starting point by entering a feature name, pointing and clicking on a base map, or loading an existing study area. The text entry could be by drain name, subbasin name, or watershed name. The base map displayed would include the watersheds, storm drain network, and subbasins.

The user will then be asked if he or she wants to a) retrieve data associated with that particular storm drain segment, b) identify all upstream storm drain segments, or c) define interactively an area of interest based on the geocoded location. If the latter, the user could also use this information to highlight all upstream subbasins. This selected set of subbasins could then be used to geographically query the other GIS themes and their data tables.

Once the area of interest is defined, the application will allow the user to interactively query the spatial and tabular data within the defined area. For example, the user may want to plot all storm drain connections (permitted or illicit) along the selected storm drain and generate a mailing list. Most analyses will require interaction with other database tables. Additionally, the user may want to get a plot of all locations of businesses, color-coded by SIC code, within the drainage area. The user should then be able to create a report based upon the analysis.

The GIS output capabilities include tables, figures, and paper-based maps. The GIS has built-in

functionality to create maps along with marginalia such as titles, legends, scale, lineage, coordinates, etc. The cartographic components are then transformed into a plot file which can then be output to an electrostatic plotter or color printer. The plot file can also be converted into a form that is compatible with other software tools such as word processors and drawing packages. In this fashion, hardcopy maps can be generated easily for distribution to field crews.

Best Management Practices

Best Management Practices (BMPs) are guidelines created by the county which reduce the possibility of pollutants jeopardizing the storm drain system for many types of activities. There are two categories of BMP tabular data. The first category consists of the data from the source identification component of the industrial/commercial education program. These tables use the Standard Industrial Classification (SIC) coding system to characterize the potential storm water impacts associated with industrial and commercial facilities. The second category consists of the data from the educational site visits. These tables can be used to manage the detailed data resulting from the County's facility visits and the summary data provided by the other Permittees to the County.

The geographic data needed to support evaluations of BMPs relate to land uses and land use practices that affect storm water quality. A number of tasks required by the permit make it necessary to have a good database, including a GIS coverage of the SICs of commercial and industrial facilities throughout the county.

There are several other GIS coverages that need to be developed or improved to provide a spatial interface to the BMP data. The WQS is affected by several BMP tasks such as: catch basin cleanup, street sweeping, county facility inspections, and construction site inspections, which are managed by other divisions. While having a GIS link to the data associated with these activities is not required by the permit, having the link will make the data more useful for reporting and evaluating BMP activities and may provide insight into results from water quality sampling and analysis activities. Furthermore, because of the needs of the other major tasks, the GIS and tabular functionality necessary to provide the utilities described in this section will already be available.

Programming applications needed for the BMP evaluations include data input screens, geographic displays to support ad hoc analyses, and report generators. A query system must be developed to allow the user to easily query the data tables from the GIS coverages. This will allow the user to locate and obtain data for all sites with one or more specific SIC codes, or a set of activities associated with selected SIC codes.

Water Quality

Monitoring and managing the water quality data in the EDMS, such as performing the loads assessment, consists of two major components. The first is the water quality monitoring component, which contains the tables necessary to store and manage the water quality measurements. The second component consists of tables containing the watershed and land-use characteristics data.

The tabular water quality data tables are the monitoring station table, flow measurements, station events, field samples, field sample analytical results, laboratory quality control samples, station event mean concentrations, subbasin event runoff, subbasin landuse characteristics, and land use event mean concentration . The data for these tables reside in disparate databases and will be linked in the proposed EDMS.

Both the EPD and HWCD collect water quality and quantity measurements throughout the county. The locations of sample sites have changed over the last few years and will likely continue to change. Therefore both the samples and the sample sites change through time and need to be captured within the database. Three comprehensive GIS coverages need to be created from existing coverages. In the case of the first two coverages, water quality and quantity sampling sites, the coverages must be of sufficient accuracy to place the sampling sites within (or on top of) the topology of the hydrologic features from which samples are collected. The third coverage, precipitation sampling locations, must also be developed. All of these coverages must have the appropriate attributes for each site to be linked to tabular data.

The WQS requires a suite of models and ad hoc statistical analysis functions to understand and report water quality results. These analyses will be performed on tabular data residing on EDMS as well as output data from spatial analyses. Additionally, some results from statistical procedures will be incorporated into the GIS spatial analyses and/or map results.

The GIS model which predicts water quality will be implemented on a subbasin-by-subbasin basis. The modeling results will be aggregated to the watershed level for reporting watershed totals as required by the permit. The GIS implementation of the model should be able to provide a map of the distribution of the source of loads of particular chemicals within a watershed or subbasin. This will aid tremendously in targeting critical management areas.

An ArcView project will be developed to provide for spatial display of water quality results and comparisons. This would require that as a minimum the sampling locations, watersheds, and subbasin coverages have a direct link to the water quality and hydrologic data tables. Additional coverages should be available for adding base map type reference information. Graphical displays of water quality and hydrologic data should be in the form of color-ramp coding of results to each watershed or subbasin polygon coverages, creating time series or chemical series bar charts and pie charts at each sampling location, and plotting summary data tables at each sampling location.

The user interface with the GIS model should provide a mechanism for the user to define a study

area. This would be accomplished by asking the user to a) enter a storm drain project name, subbasin name, or watershed name; b) graphically select one of these features from the GIS files displayed on the screen; or c) define the area of interest by drawing a polygon on the screen using the digitizing function of the GIS.

Once the study area is selected the system will display tables of input parameters that the user can then edit. The user will be able to edit the following parameters from the user interface.

- **Chemical:** Users will have the option of selecting which chemical to model.
- **Average flow-weighted concentration:** Users will have the option to change this value for any or all of the land uses.

The model will calculate a total event of seasonal load from each watershed based on the breakdown of land use types, imperviousness, and rainfall totals. The results will be in the form of a total loading for each subbasin within the study area and a total loading for the entire study area.

In addition to characterizing watersheds by geographic and hydrologic characteristics, it will be useful to characterize them by chemical signature. By comparing water quality data from different storm events within a single watershed as well as from different watersheds for a single storm event, it may be possible to elicit significant variations between watersheds. The determination of chemical signatures for different watersheds and events will be important in evaluating the effectiveness of BMPs, selecting critical source and land use monitoring stations, and examining changes over time in mass emissions. In general terms, the signatures would be identified by comparing concentrations of a limited suite of indicator properties and chemicals. This would be done best by using the EDMS to convert the raw water quality tabular data into a graphical format, such as a bar chart, for each station event.

Reporting

The WQS requires a suite of modeling and ad hoc statistical analysis tools to understand and report water quality, BMP effectiveness, and simple tracking and status reporting on all programs related to NPDES. These analyses will be performed on tabular data residing in the EDMS as well as output data from spatial analyses. Additionally, some results from statistical procedures will need to be incorporated into the GIS to map results spatially or to enhance spatial analyses. All the ad hoc mapping capabilities of the GIS components of the EDMS are likely to be needed in the annual report writing associated with the county's storm water permit.

The tabular data sets for the reporting module include Questionnaire Responses, Questionnaire Definitions, and Question Definitions.

An ArcView Project will be created as part of the EDMS to allow summaries of the reporting

data from permittees to be viewed in a geographical context. The specific parameters displayed in such an application will need to be confirmed in the implementation phase, but an example would be to display annual expenditures on storm water management by color coding the polygon of the political boundary for each respective permittee.

Conclusions

The CRADA successfully analyzed the requirements of the NPDES permit, the LACDPW resources, and recommended a practical solution. This solution is the EDMS which is built around Arc/Info GIS and Oracle data tables. This tightly linked combination provides the data capture, analyses and reporting needed to manage the storm drain system.

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AUTHOR INFORMATION

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Table 1. Summary of the information management needs for compliance with the 1996 municipal NPDES storm water permit. (Source: Sale et al., 1997)

Illicit Connections and Discharges:

- Integrate databases that support the illicit discharge programs.
- Track status of incident and complaint resolution.
- Integrate analytical water quality results with field inspections.
- Maintain and update data on land uses (e.g., Standard Industrial Classification codes).
- Identify upstream areas and facilities contributing to an illicit discharge.*
- Predict downstream distribution of contaminants from illicit/accidental discharges.*
- Support ad hoc analyses as needed.*

Best Management Practices:

- Track public educational activities.
- Document site inspections and training.
- Track BMPs for construction and inspections.
- Integrate maintenance records with BMP evaluations.
- Provide data exchange with other permittees.
- Design monitoring for critical BMPs.*
- Support ad hoc analyses as needed.*

Water Quality Monitoring:

- Document quality assurance/quality control (QA/QC) results.
- Associate land use types with nonpoint-source pollutant discharges.*
- Evaluate BMP effectiveness for critical sources.
- Estimate mass emissions for large watersheds.*

Reporting:

- Provide data for annual Program and Monitoring reports.
- Provide data and analyses for the Program Evaluation Report.
- Provide data and analyses for the Integrated Receiving Water Impacts Report.*
- Support ad hoc analyses as needed.*

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* GIS-based activities.

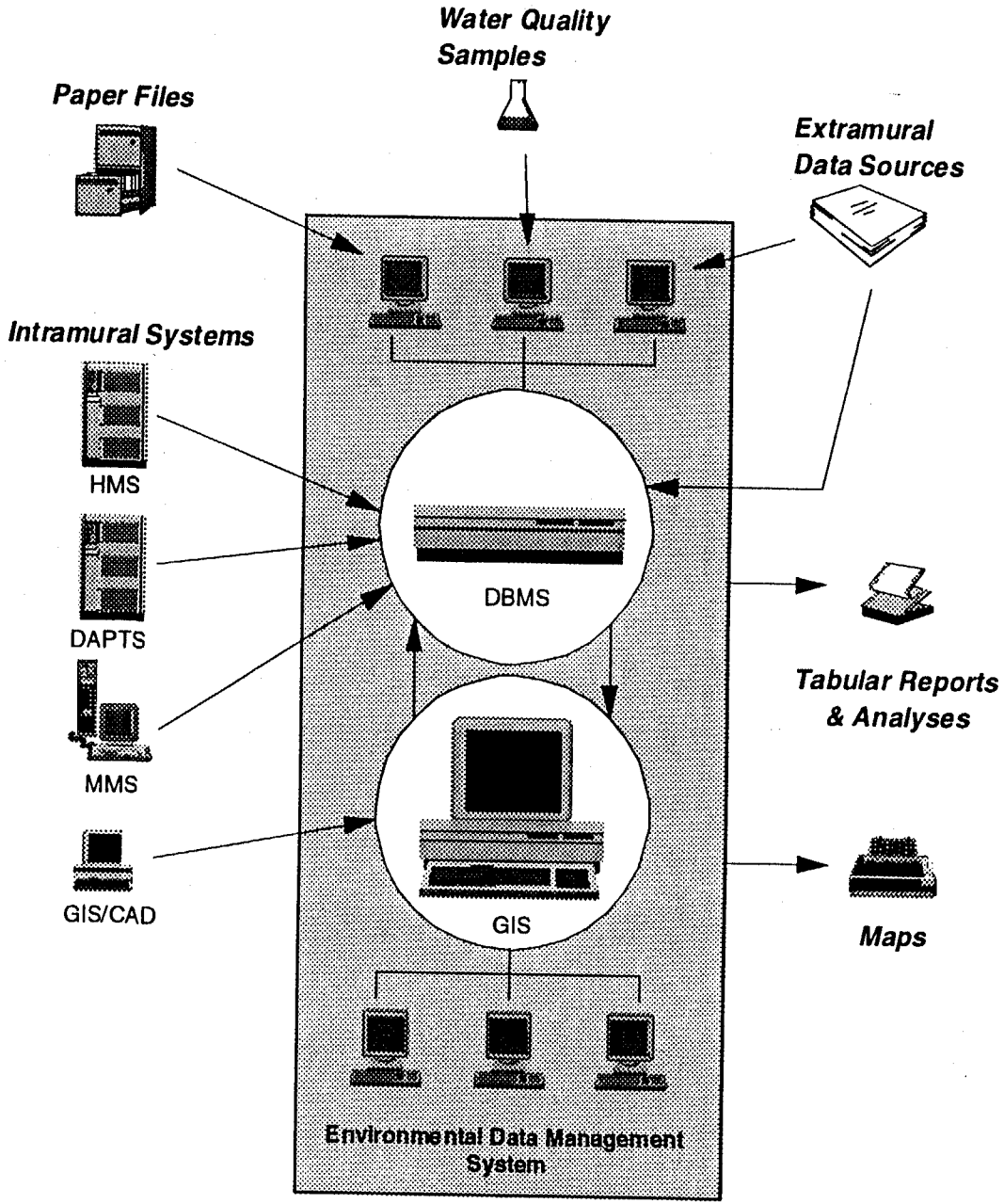
Water Quality Samples
Paper Files
Extramural Data Sources
Intramural Systems
HMS
DAPTS
MMS
GIS/CAD
DBMS
GIS
Tabular Reports & Analyses
Maps
Environmental Data Management System

Figure 1.