

**ROUGE RIVER WATERSHED
ILLCIT SEWER CONNECTION
DETECTION PROGRAM: A GIS APPLICATION**

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ABSTRACT

The Rouge River National Wet Weather Demonstration Project (Rouge Project) is a comprehensive approach to watershed management. The mission of the Rouge Project is to restore the water quality in the Rouge River to a safe and healthy environment for ourselves and future generations. Detailed research and analysis of the entire river system is being conducted for innovative, watershed-based solutions to control the wet weather problems in the Rouge River Watershed.

Several key objectives of the Rouge Project address the sources of nonpoint source pollution. One objective is the detection and elimination of improper discharges to the sewer systems of the watershed. An illicit connection is the inappropriate connection that allows discharge of contaminated water to the storm sewer, e.g. plumbing fixtures discharging to the storm sewer. Wayne County (MI) has implemented what is known as the Illicit Connection Detection Program as a component of the Rouge Project.

Field strategies and target area selection are enhanced through the analysis capabilities of an interactive Geographic Information System (GIS). The Rouge GIS allows program managers to examine the entire watershed according to selection criteria for prioritization. Business and industrial facilities are evaluated for relative risks to water quality based on the Standard Industrial Classification (SIC) codes. The GIS system ranks drainage areas based on frequency of priority facilities.

This paper discusses how GIS provides a reliable routine that eliminates labor intensive planning and coordination, once required in former procedures for detecting illicit sewer connections. The GIS application increases staff efficiency with well organized materials for field operations. It allows staff to plan and document field activity with spatial analysis and graphic displays which previously were not possible. Combined with substantial savings in time and costs, these enhancements have transformed a complex program into one of effective, sustainable Non Point Source Pollution Control.

KEYWORDS

Rouge River, GIS, Geographic Information System, Nonpoint Source Control, Water Quality, Watershed Management.

INTRODUCTION

The Great Lakes Basin is the largest fresh water system in the world. Water quality within the Great Lakes and tributary watersheds has been a concern of local, state, federal and Canadian officials in the wake of the industrial revolution. Past practices have used the waterways and the adjacent land areas for industrial and commercial purposes without regard for the limitations of the resources. The impacts are now evident in the Rouge as we encounter severely restricted use of the river. The Clean Water Act of 1972 mandates action to eliminate sources of water pollution and provide for conservation of the resource for the future. In the later part of the 1980s Watershed Management has evolved as means to confront a number of complex issues that impede the effort to clean-up and protect the Rouge River.

The Rouge Project represents a significant commitment on the part of the Federal Government, the State of Michigan, Wayne County and the local communities of the watershed to implement specific action-oriented strategies. Guided by the recommendations of the Rouge River Remedial Action Plan (RAP), this unique partnership is planning, implementing, and evaluating these strategies watershed-wide to reduce or eliminate current sources of pollution and remediate serious problems from previous contamination. The Wayne County Illicit Connections Detection Program (ICD) is one of several endeavors aimed at controlling Nonpoint Source Pollution to the Rouge Watershed. The ICD is an extensive effort to identify and correct improper connections to storm sewer systems. The Rouge GIS has substantially enhanced that effort by automating the priority analysis and generating field planning materials necessary for conducting site investigation visits.

The purpose of this paper is to describe the use of the Rouge Watershed Geographic Information System (GIS) as a tool in spatial analysis and watershed management. Though currently under full implementation, and showing positive results, the ICD program is

extremely ambitious and difficult to administer. This paper presents the background of the existing Wayne County Illicit Connections Program administration and its relationship to the Rouge River National Wet Weather Demonstration Project. The emphasis is on the value of GIS from an administrative perspective in a practical application. As such, the GIS enhancements to the ICD are discussed in terms of time and cost efficiency, the resulting program effectiveness, and the implications with regard to long-term program support.

Geography

The Rouge River is located in the southeast region of lower Michigan. The Rouge Watershed is a highly urbanized system extending over an area of about 467 square miles. Approximately 1.5 million residents of 48 municipalities live and work in the watershed. Portions of the watershed reach into the counties of Oakland and Washtenaw, while about 60 percent of watershed (276 square miles) is within Wayne County. More than 120 linear miles of stream channel and 11 subwatersheds make up the four main branches known as the Main, Upper, Middle and the Lower Rouge Drainage Areas. Generally the flow is southeast from the hill upland area of the glacial moraine, across the flat lake bottom deposits into the Detroit River, which is a natural boundary between the United States and Canada.

Background

The International Joint Commission (IJC), established by the United States and Canadian International Boundaries agreement, is a bi-national agency authorized to oversee the entire Great Lakes Basin. The IJC is charged with evaluating the condition of these water bodies and prioritizing problem areas. In its 1981 water quality study, the IJC identified 43 areas of concern within the Great Lakes from Lake Superior to the St. Lawrence River. The area of Southeast Michigan that flows into the Detroit River, including the Rouge River Watershed, was identified as one of 14 areas of concern in Michigan with severe water quality problems.

In response to these findings, and the demands of local residents, the Michigan Department of Natural Resources (MDNR) developed a series of Remedial Action Plans (RAP) that address specific sources of pollution to the surface waters of the state.

The Rouge River Remedial Action Plan (RAP) is an ambitious 20-year plan to clean up and restore the river to a fishable and swimmable state. Developed in 1989, the plan identified action necessary for the protection of public health through a phased process of planning, implementation and evaluation. The focus of the RAP was on the sources of pollution including Combined Sewer Overflows (CSO), Industrial Pollutant Discharges, and Nonpoint Source Pollution.

In 1992 Wayne County was awarded a federal grant from the United States Environmental Protection Agency (EPA) to conduct the Rouge River Wet Weather Demonstration Project (Rouge Project). In addition to confronting the many complex issues related to CSO control, the Rouge Project is developing strategies to control Nonpoint Source Pollution and creating the institutional structure for comprehensive watershed management. Using the Rouge River RAP as a guide, the Rouge Project is assisting in the implementation of the county's Illicit Connections Program.

Wayne County Illicit Sewer Connections Detections Program

Under the Nonpoint Source Pollution component of the RAP, the Wayne County Illicit Connections program was developed and implemented to reduce pollution to the Rouge through detection and elimination of improper/illegal connections to the storm sewers or surface waters within Wayne County. The County has broadened this "classical" definition to include overland discharges/runoff to storm sewers, surface waters, and the ground. The program takes a proactive approach by conducting on-site investigations and using dye testing and sampling protocols to determine pathways to the drainage system.

The program has been notably successful over the last two years, inspecting more than 730 facilities and finding 13 percent to have illicit connections in 5 drainage subareas of the Rouge Watershed. Approximately 8,564 pounds of pollutants per year have been diverted from the river.

Methodology

To implement the ICD program county-wide, the County agent must determine, for each facility, the pathways of flow to the river. With four major watersheds in Wayne County, finding the flow path for each facility is cost prohibitive unless sites are clustered into logical areas and identified as groups and subgroups. Even before the shift toward watershed management, it made sense to approach the challenge based on the natural or man-made drainage areas and subareas of surface water collection.

The strategy for implementing field investigation in Wayne County consists of four elements of operation: selection of target area, inventory of facilities, site examination, and follow-up. The key to the operation of the ICD program is in compiling and processing the necessary information to determine high priority target areas, generate a comprehensive list of addresses for each area, and maintain the inventory of facilities for follow-up correspondence or subsequent visits.

Target areas: Given the enormity of each task, discrete areas for investigation must be delineated and prioritized for effective field investigations. Natural and man-made drainage patterns are derived from maps and engineering plans of various size and scales. Areas are selected for investigation based on a number of criteria including:

- Land Use
- The potential for handling hazardous materials
- Outfall size (volumes)
- Complaint histories
- Personal knowledge
- Acreage of drainage area
- Business/addresses within drainage areas as determined by field survey

Inventory: Within each area, an address list must be compiled to both notify facilities of the upcoming visit and to provide the staff with an organized plan for field work. This requires a combination of commercial mailing lists and windshield surveys.

Site investigation: Sanitarians combine education with investigation. Dye is placed into the plumbing, floor drains, and catch basins, and visual observations for open pathways are noted. Infractions are pointed out for correction and relayed to the community for follow-up.

Follow-up: The local zoning and building code enforcement agencies are notified to provide assistance or enforcement in correcting the situations. Here again, education is reinforced by policy which in turn promotes long term program effectiveness.

Limitations

Complex: The **paper-based** system was stored in a number of different files, cabinets, and formats. It was obtained from a number of **different sources**, at various scales and geographic extent. There was no guarantee that the same routine or sources would yield the same information and detail for other drainage areas. Data sources were each created for differing purposes and at various scales and scope.

Because of the variable nature of the data, updating or refining the process with additional information is unlikely. Conventional methods of collecting, storing and retrieving the necessary information in the existing state was an extremely complex and time consuming procedure. As program managers learned what type of information was important for management and reporting, it was found to be to time consuming to update previously developed information. Therefore, progress reporting was inconsistent over time.

The system was dependent on a high degree of coordination and personal knowledge. To estimate relative risks of contamination to the river, the sanitarian went to Southeast Michigan Council of Governments (SEMCOG), the regional planning agency, to obtain the land use data in hardcopy, maps or aerial photo materials. In addition, field reports, engineering designs, and as-built plans for sanitary and storm sewers were consulted for the location and dimensions of the outfalls and drainage areas. If these materials were insufficient or unavailable, the areas were delineated based on the field investigation by the staff.

Prior to automation, the effectiveness of the program was vulnerable to staff turnover. Normal attrition rates account for numerous technical staff being assigned to a project of this type and magnitude. A few become especially well trained and stay with the program only to grow more valuable to management or other projects requiring experience. New staff are dependant on others for on-the-job training. Procedures for data management and analysis become subject to the effectiveness of training and individual interpretations. Coupled with data that is already difficult to compile and manage, this type of discontinuity leads to long-term inefficiencies and inconsistency in how the program is administered. Consequently, the process for data collection and analysis varies significantly.

GIS APPLICATION DESCRIPTION

The Illicit Connection Application (ICA) is a computer-automated technique for determining priority drainage areas and sites for field investigations. The application uses the Rouge Geographic Information System to analyze thousands of address records for the entire watershed in preparation for, and facilitation of field investigations work. Using the enhancements of spatial analysis and data management, on-site visits across 467 square miles are scheduled such that commercial and industrial activities within the watershed bearing relatively greater potential for contamination can be targeted first. The systematic routine of the ICA provides a standardized method of prioritizing thousands of individual sites within hundreds of subareas of the watershed for field investigations.

The Procedure

The automated application program is designed to process the information required for; selecting the target areas, compiling the list of sites within those areas, and printing the mailing lists for notification and follow-up. Later enhancements will build on these initial capabilities and provide for tracking and illustration as well. The primary and most significant enhancement rendered by the GIS application is in the type and format of the data.

The Data

The GIS uses data captured in the most basic form and stored in digital formats. Geographic data for the base map themes, obtained from the Michigan Resource Information System (MIRIS), were digitized from 1:24,000 scale United States Geological Survey (USGS) Topographic Quadrangle maps. The base map is composed of the road and highway layers; lakes, shorelines and waterways; public land survey and political boundaries; and utility easements and rights of way. The Rouge Watershed drainage was delineated by the Rouge Program Office also using the USGS maps as the standard for quality data entry. Combined with the site locations, these data provides the foundation on which the analysis was developed.

Site Locations

The role of the computer in the ICA analysis was instrumental in the reduction of the data to that of a simple business list purchased from a national vendor. Typically used for mailing and marketing purposes, this list included the Standard Industrial Classification (SIC) code which along with several additional fields provided the essential information for characterization of each business within the watershed.

The business list was assigned geographic coordinates, through a process called address matching, to place each site on the digital base map of the Rouge GIS. Registering the business data to map coordinates eliminated the need for windshield surveys. The

comparisons with existing field-verified facilities lists found the vendor list to be greater than 94 percent accurate in terms of locations and counts. Moreover, the data covers the entire watershed. Therefore, each of 335 individual subareas of drainage are simply combined with more than 40,000 business and industry addresses to provide a mailing list and field investigation printout - specific to each area.

The Analysis

Ironically, the most significant enhancement, yet the least explicit, is the relationship established between the type of industry and its spatial location. Each drainage area can be characterized by the commerce and industry located within the drainage boundary. Land use maps and outfall dimensions are no longer necessary for selecting the areas for investigation. Simplifying the data has, consequently, simplified the data processing to a weighted frequency analysis.

For each of 43,520 industrial, commercial and institutional facilities within the watershed, a ranking value is assigned based on the contaminant risks to the river through inappropriate discharges. They are ranked on a scale of I through IV. *Table A* illustrates priority groups of facilities based on field experience (personal knowledge) of the registered sanitarian. Each SIC code was given a ranking based on the likelihood of storing, generating, or handling materials that may be hazardous to water quality. This ranking is, therefore, an important tool in directing the field work.

Table B is a frequency of priority types within the watershed. Priority III has the largest number of facilities. Therefore, simply prioritizing the subareas based on the number of facilities is not appropriate. The numerous Priority III Facilities would be the driving force in prioritizing the subareas, not the more important Priority I and II sites. Therefore, it was decided that a weighing factor should be applied to the number of Priority Facilities to remove bias from the numerous Priority III Facilities.

A weighing factor of 1 was given to Priority III Facilities. By simply dividing the total number of Priority III Facilities by the total number of Priority I Facilities basin-wide a weighing factor of 9.9 was found and was rounded to 10. This weighing factor was found to remove the bias from the numerous Priority III Facilities. Priority II weighing factor was chosen to be one half of the value for Priority 1.

Priority IV Facilities were given 0.5 weighing factor because they are associated with agricultural production. Therefore, it was desired to reduce their importance in the prioritization process.

TABLE A

PRIORITY CHARACTERIZATION OF FACILITIES

- Priority I: Automobile Related Businesses/Facilities and Heavy Manufacturing.
- Priority II: Printers, Dry Cleaners/Laundries, Photo Processors, Utilities, Paint Stores, Water Conditioners, Chemical Laboratories, Construction Companies and Medium-Light Manufacturing.
- Priority III: Institutional Facilities, Private Service Agencies, Retail Establishments, and Schools.
- Priority IV: Agriculture Production, Forestry, and Fishing , Hunting , and Trapping.

TABLE B

	<u>Frequency</u>	<u>Percent</u>	<u>Mtg. Factor</u>
Priority I:	3,876	8.0	10.0
Priority II:	1,081	2.5	5.0
Priority III:	38,469	88.4	1.0
Priority IV:	94	0.2	0.5

$\Sigma = 43,520$

Subarea Ranking = the Sum of: (# of priority I facilities X 10.0) +
 (# of priority II facilities X 5.0) +
 (# of priority III facilities X 1.0) +
 (# of priority IV facilities X 0.5)

DISCUSSION

The ICA was built on the SUN™ workstation running the ARC/INFO ver 6.1.1 GIS software. The entire application is written in Arc Macro Language (AML), and requires very little GIS expertise to run. It is operated from the opening display screen composed of six windows, three of which are menus that lead the user to a variety of options for the display, analysis and output of the data.

The Coverages Menu provides the user limited access to the coverages of the Rouge GIS. These coverages can be displayed or turned off with the toggle switch in the menu. The advantage of this menu is that it can be expanded to accommodate future applications with relatively minimal development.

The Zooming Tools are pretty basic options geared primarily for the infrequent user that must not be hindered by the software. These are self explanatory and have been thoroughly adequate in the application to date.

The Main Menu offers the six major functions of the application. The DISPLAY BUSINESSES option provides three additional options to display either by color coded point locations, or by drainage areas which is also color coded, based on the ranking analysis and user input, or clear the display.

The SELECT AREA option allows the user to define the geographic area for analysis. If the subarea is known, it can be identified by its ID number. Otherwise, it can be selected interactively by the mouse or it can be defined by a user digitized boundary. Digitizing allows the user to diverge from the subarea boundaries for more unique queries of the data.

Once the area has been selected, the remaining options of the main menu can be performed on that geographic-specific subset of the data. QUERY DATA is the option of the main menu that allows the user to build various statements that further explores the information with a great deal of refinement. For instance, QUERY DATA can identify select automotive industries within the area, and which ones are permitted to discharge. Depending on the data in the database these refinements can be extremely explicit. The query option is thoroughly developed with a number of menu and prompt displays that help the user to build and save, if desirable, the specifics of any query statement.

FREQUENCY REPORTS is a useful function in both the analysis and the output. Often it will provide the user the simple statistic necessary to round out the various queries made of the data. It will operate on the data subset of the selected area, or if the query option has generated a refined subset, it will perform the count on those records. The data results can be sent to the screen, printer, or an ASCII file can be created for import into another software.

The remaining two options are output selections that assist the user in preparation of the field materials and mailing correspondence. Similar to the frequency report option, the BUSINESS LISTING REPORT will generate the printouts on the data set identified by the area selected,

or the refined data set resulting from the query analysis. The feature of particular value to the field staff is the MAILING LIST capability which can index the address list according to street order (alphabetically) and by address (chronologically). This allows them to conduct their visits much more efficiently going up one side of the street and down the other.

ADVANTAGES OF THE NEW SYSTEM

A comparison of both techniques was conducted in two of the five previously surveyed drainage areas. The following was found to be directly attributable to the use of the Rouge GIS in selecting these areas through the automated process.

Efficient

The revised strategy, as the result of the alternative data, has displaced the use of maps and graphics from disparate reports and sources. Time and effort once spent on the research, duplication, acquisition and interpretation of these materials is no longer necessary. Furthermore, the business list was more comprehensive when compared to the list derived by the staff. Therefore, the time spent in the field to compile and/or verify address and facility information has been eliminated from the operation. Field staff can, however, upgrade the database with information obtained from the field work. Overall it was found that, for each subarea, approximately six to eight staff weeks of preparation time was reduced from the operation; time which now is applied to the focus on investigations and reporting.

Effective

Greater efficiency has translated into greater effectiveness. In addition to being able to investigate more sites at a faster rate, the entire watershed is now being evaluated. Natural drainage areas that once were presumed to be of low risk can be examined to reveal exceptional circumstances. These areas can be highlighted individually in a matter of moments, if desirable, through interactive user analysis that did not exist previously. Individual sites can also be flagged for investigation in low priority areas.

The data are available in a fraction of the time it took in the former procedure. This means that any question in the operation can be quickly reviewed by accessing the data and rerunning the analysis to be sure of the results. Any flaws can be corrected immediately and the entire process can be run for all or any part of the watershed. Upgrades or corrections in the data or the criteria for evaluation further increases the effectiveness.

Comparisons can be made over time to show effectiveness of the field work by regenerating the analysis for the same area and checking to see if reconnection may have occurred through redevelopment. Unless the macro commands or the data have been altered, the program will produce consistent results any number of times.

Sustainable

The Wayne County Illicit Connections Detection Program is now in its fourth year of operation. To often programs that are truly valuable become too complex, time consuming, and costly to become fully institutionalized. Though purely speculation, it is conceivable that the Illicit Connections program, as conducted according to the former methods could follow the all-to-familiar pattern and terminate prematurely. Quantifying the work and the results in terms of progress rates, pollutant load reductions, change in conditions or human behavior, etc. can help to justify continued program funding. As a planning tool, the Rouge GIS has taken the Illicit Connections program a significant step forward toward a sustainable operation. The current application now serves as a platform upon which future enhancements could provide additional modules that might simplify other county programs; or promote new programs that were once unimaginable.

FUTURE DEVELOPMENTS OF THE GIS APPLICATION

To secure and maintain more certain long term support necessary for success, the application must go beyond the achievements of a planning tool. With this objective in mind, users/investigators must clearly demonstrate program effectiveness and document the progress toward full realization of the goals.

Plans for the future include expanding the development of the GIS application to generate map products for reports and presentations. Illustrating progress in testing more than 54,000 locations in 335 drainage areas can be extremely persuasive. With the right information and a few macros, the maps could be used show the change in relative risks of pollution for each subarea.

Diversifying the utility of the application to address a broader range of issues is also planned. Modifications of the existing AMLs can be made to include:

Illicit Connection Analysis Refinements

Electronic data transfer is being considered to provide additional data and information in future analyses. Since SIC codes are available, it would be possible to compare frequency of violation with SIC codes. The user could determine if there is a relationship between violations and specific SIC codes. If so, these SIC codes could be specifically targeted for site inspections illicit connection violations and era of development. Former building codes (reflected in era of development) could be examined for any association with the frequency of illicit connections.

Scoring Procedures

This application could be expanded to use the scoring procedure detailed in the United States Environmental Protection Agency's (EPA) "Urban Targeting Manual" on a watershed-wide approach in an efficient and effective manner for prioritizing areas for a Nonpoint Source Control Program.

Stormwater Discharge Permit Programs

By selecting the appropriate SIC codes or ranges, a list can be created for facilities regulated under the current federal STORMWATER regulations. With this list, it can then be determined, which of these facilities must apply for stormwater discharge permits.

Air Pollution Regulation

Combining the inspections for local air pollution control may be possible using the ICA to and SIC codes to sort, and list facilities, that may require a permit for toxic emissions. An example might be automotive repair shops with solvents and emissions from the paint shop operations. The application supplies the ability to sort the repair shops by SIC codes, produce a list with addresses, employee size, etc.

Spill Response

The Michigan Department of Natural Resources might wish to use the application in spill responses.

Economic Development

A person or entity might wish to go to the Environmental Services Agency and identify a point within that jurisdiction and receive a map, generated by the application detailing sites of environmental concern; examples being 307, landfills, and leaking underground storage tanks within a predetermined radius.

CONCLUSION

Throughout the next year on the Rouge project, Nonpoint Source Control activities will evaluate the Wayne County Illicit Connections Program for application in the Oakland County jurisdiction of the watershed.

Environmental management and protection in Michigan is swiftly broadening to the local level of stewardship where programs appear to be more effective. Continued evolution of Geographic Information Systems is now making it possible to implement complex administrative and technical programs with limited budgets. The GIS tool is capable of enhancing existing programs as well as documenting, by illustration, these enhancements. Programs that were once presumed impossible at the local level can now be explored with a greater sense of optimism.

Time and experience with the GIS conventions will only improve the efficiency and effectiveness. With greater accountability for long term funding there is truly the potential for a number of programs similar to the Wayne County Illicit Connections Program to be conducted at the local level.

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