RECEIVING WATER QUALITY INDICATORS FOR JUDGING STREAM IMPROVEMENT

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ABSTRACT

Most regulatory programs for pollution control and water quality protection in the United States are based on numeric water quality standards for chemical constituents, although the standards development process does have provision for using chemical, physical, and biological criteria. The need to consider other factors such physical and biological conditions in addition to chemical factors when making decisions regarding management of surface waters has been recognized by many but implementation of a more holistic system for monitoring water quality and ecosystem health has been slow. This paper describes a public use indicator system, based on a combination of condition quality indicators and multi-factor indexes, developed for the Rouge River in southeast Michigan.

Wayne County's Rouge River National Wet Weather Demonstration Project (Rouge Project) is a comprehensive program to restore the water quality and beneficial uses of the Rouge River, a tributary to the Detroit River in southeast Michigan which has been designated as a significant source of pollution to the Great Lakes system along the border between the United States and Canada. The Rouge River Watershed is largely urbanized, spans approximately 113,442 hectares (438 square miles), and is home to over 1.5 million people in 48 communities and 3 counties. Sources of pollution to the river include industrial and municipal point sources, storm water runoff, combined sewer overflows (CSOs), interflow from abandoned dumps, and resuspension of contaminated sediment.

A critical element of the multi-year Rouge River restoration effort has been the collection and analysis of information about the causes of impairment in the river in order to prioritize potential pollution controls by source and by river segment. A comprehensive instream water quality monitoring program was initiated in 1993 and has expanded to sampling of biological communities, habitat, aesthetics, and the effectiveness of individual pollution controls. The Rouge Project indicator system presented in this paper arose from the need to translate the wealth of technical data about the Rouge River and options for its management and restoration to the 48 community governments, 3 county governments, state and federal government, industries, environmental and community groups, and private citizens involved in this river restoration effort. The Rouge Project indicator system, along with other watershed management tools developed by the Rouge Project, has aided decision-makers and the general public in evaluating options for preventing, reducing, and minimizing pollution loading impacts on the river under a watershed approach to wet weather pollution management.

INTRODUCTION

Environmental quality within a water body depends on many factors including chemical, physical, biological, and aesthetic conditions. Measurements of each factor defines some aspect of quality, but each represents quality in a different way and to a different degree. In the United States, water quality standards are adopted by States and Tribes to protect water quality within each state. Water quality standards include designated uses for each water body and criteria to protect those uses. Most regulatory programs for pollution control and water quality protection are based on numeric water quality standards for chemical constituents, although the standards development process does have provision for using chemical, physical, and biological criteria. The need to consider other factors such physical and biological conditions in addition to chemical factors when making decisions regarding management of surface waters has been recognized by many but implementation of a more holistic system for monitoring water quality and ecosystem health has been slow.

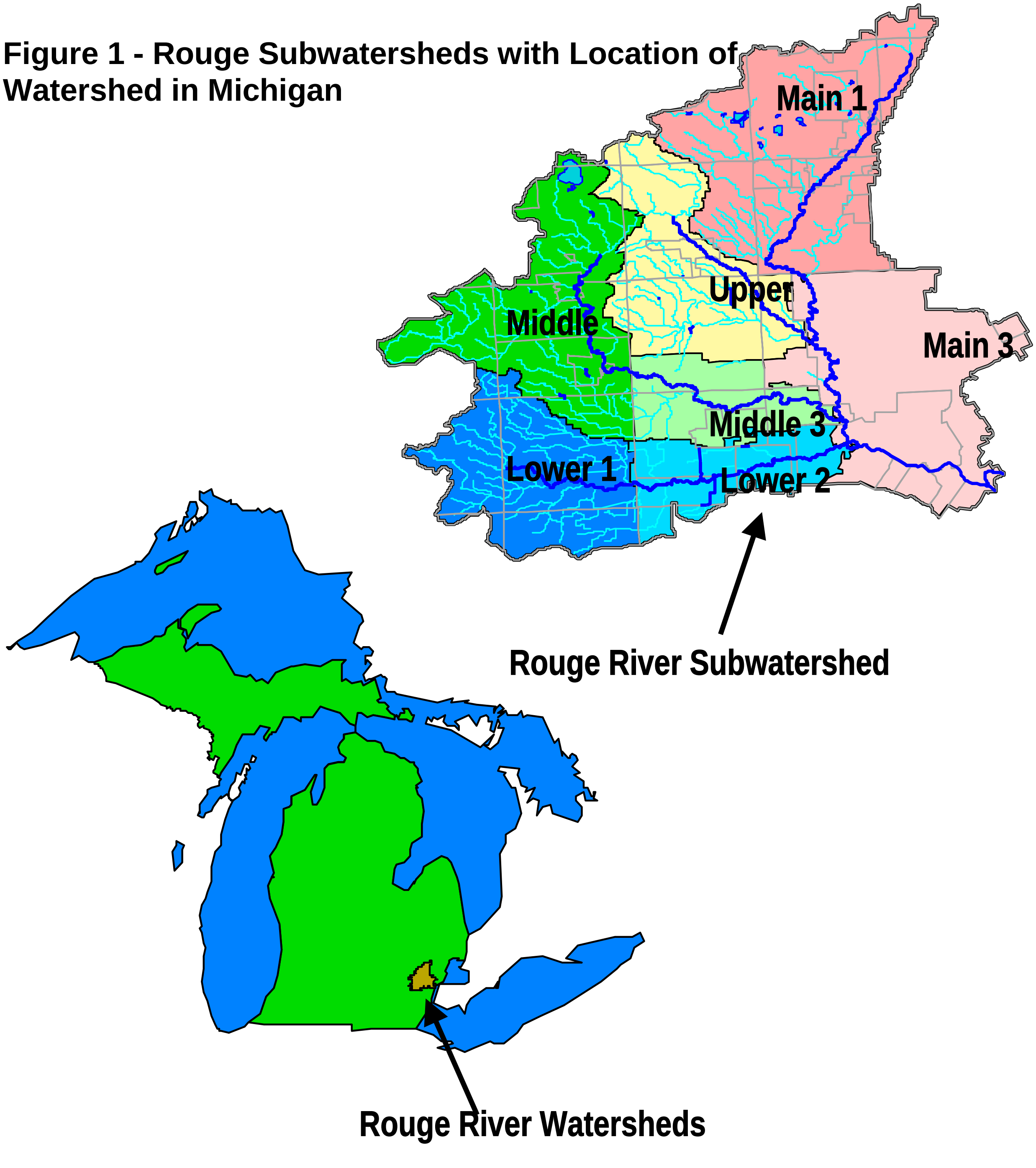
In order to achieve and maintain a healthy ecosystem and associated designated uses within surface waters, it has become clear that pollution management must be addressed through a watershed approach. The watershed approach is a holistic approach that considers the impacts from all sources of pollution and use impairment in a receiving water. The challenge is to develop of innovative solutions to achieve water quality objectives that may: 1) be more cost-effective, 2) be implemented in a more timely fashion and 3) be better able meet local needs. It has also become clear that water resources management must have the support of the general public in order to be effective and to become self-sustaining. A locally-driven watershed approach to pollution management as a means to achieve management goals is an exciting concept which has been discussed by many but for which there is limited practical experience. This is particularly true in urban situations where there are multiple sources of impairment to a water body and stiff competition for limited local resources to address the pollution sources. The Rouge River National Wet Weather Demonstration Project (Rouge Project) in southeastern Michigan (see Figure 1) has provided an unique opportunity for a watershed-wide approach to restoring and protecting an urban river system by using a cooperative, locally-based approach to pollution control.

A comprehensive water quality and ecosystem health monitoring program, implemented watershed-wide, has been the technical backbone of the Rouge River restoration efforts. The watershed monitoring program has provided information necessary to define and track instream conditions, support water quality model development, assist in defining the most cost-effective controls, evaluate the effectiveness of individual control measure, assist in enforcement of water quality regulations, and support watershed recreational and educational uses. A wealth of information has been collected to date about the Rouge River, sources and locations of impairment within each branch and tributary, and options for restoring and protecting the Rouge as a valuable community asset. A number of tools had been developed for analysis of this information but a framework for integrating chemical, physical, biological and descriptive data was missing. A mechanism for presenting both the data and the analyses of solutions for restoring the river to non-technical stakeholders was also needed. This paper describes an indicator system, based on a combination of condition quality indicators and multi-factor indexes, for public uses of the Rouge River developed as part of the Rouge Project. The Rouge indicator system, along with other watershed management tools developed by the Rouge Project, has aided decision-makers and the general public in evaluating options for preventing, reducing, and minimizing pollution loading impacts on the Rouge River under a watershed approach to wet weather pollution management.

BACKGROUND

The City of Detroit and 47 other communities are located wholly or partially within the 113,442 hectare (438 square miles) Rouge River watershed that is home to 1.5 million people and encompasses parts of three counties in southeast Michigan (see Figure 1). The eastern side of the watershed consists of much of the older industrial areas in southeast Michigan. The western side of the watershed consists of newer suburban development and areas under heavy development pressure. The Rouge River consists of 4 main branches totaling approximately 209 km (130 miles). All sanitary and

Figure 1 - Rouge Subwatersheds with Location of Watershed in Michigan



combined sewers in the watershed are connected to the Detroit Wastewater Treatment Plant that discharges outside of the watershed into the Detroit River. Twenty percent of the watershed is served by combined sewers. Separate sanitary and storm sewers serve most of the remaining areas of the watershed with the exception of isolated pockets and rural areas in the headwaters that still have on-site septic systems. Historically, the major sources of pollution to the river were industrial and municipal point sources, wet weather sanitary sewer bypasses, and combined sewer overflows (CSOs). The point sources and sanitary sewer overflows have been successfully controlled by an aggressive National Pollutant Discharge Elimination System (NPDES) permitting process administered by the state regulatory agency (Michigan Department of Environmental Quality (MDEQ)). However, the river still fails to meet water quality standards due to a wide range of sources such as CSOs, storm water runoff, illicit connections, failing septic systems, interflow from abandoned dumps, and resuspension of contaminated bottom sediment. The Rouge Project was born out of a desire and critical need to manage the multiple sources of pollution in this large, urban watershed in a prioritized, comprehensive manner. The U.S. federal government began sponsoring this effort in 1992 to develop and demonstrate technical, institutional, and regulatory options and processes to protect and restore a large, multi-jurisdictional, urban watershed.

The Rouge River National Wet Weather Demonstration Project is a working example of how a systematic watershed approach to pollution management can result in cost-effective and ultimately greater and faster achievement of designated uses in a water body. In 1992, the project began developing demonstration projects for combined sewer overflow (CSO) control to determine optimal sizing for long-term control projects. Data from full-scale construction projects in pilot areas are being generated in 1997. Storm water management plans based on a locally-directed watershed approach are currently under development. Over 60 pilot storm water best management practices (BMP) projects are currently being implemented to support the decision-making for attainment of desired uses of the river. A variety of other activities important to use attainability are being explored such as creation of wetlands, a presumptive approach for clean-up of abandoned dumps, remediation of contaminated sediments, lake restoration, protection and restoration of habitat, involving the public in watershed decision-making, and management of on-site sewage disposal systems. The Rouge Project has also had success in the ongoing efforts to build institutional and regulatory frameworks necessary to accommodate a watershed approach to wet weather pollution management, as documented by a new watershed-based regulatory program for storm water discharges recently enacted by the State of Michigan and based on Rouge Project efforts, Murray, et. al. (1). Consensus building strategies continue to be critical to the success of this effort and include activities used to engage numerous stakeholders, gain their support, provide them opportunities to influence decisions, and participate in actions to restore and sustain the Rouge River as a valuable community asset. The Rouge watershed assessment tools, described below, have proved to be critical in garnering public support for the river restoration efforts and have provided the general public, local decision-makers, and regulatory agencies with information to prioritize and tailor pollution control solutions to specific river reaches while coordinating efforts throughout the watershed.

ROUGE MONITORING PROGRAMS

One of the first activities of the Rouge Project was to initiate a comprehensive data collection effort which included gathering information about watershed features and characterizing existing water quality and ecosystem health. The first water quality sampling under the project began in 1993 and by the end of 1994 a supporting geographic information system and watershed modeling effort was in full operation with baseline, automated water quality monitoring sites located throughout the watershed, Mullett, et. al. (2). The watershed monitoring program is based on evaluating numerous indicators of ecosystem health including chemical, physical, biological, and aesthetic factors. Data from the monitoring programs is used to define and track instream conditions, support water quality model development, assist in defining the most cost-effective controls, evaluate the effectiveness of individual control measure, assist in enforcement of water quality regulations, and support watershed recreational and educational uses. This section provides an overview of the Rouge Project monitoring programs which provide data for the Rouge water quality indicator system described later in this paper.

Baseline Monitoring Program

This program was initiated in 1993 The initial effort included water quality monitoring stations located on all four branches of the river where dissolved oxygen, temperature, pH, and conductivity were measured continuously. River stage recording stations were installed at 18 locations in the watershed with rating curves developed by the U.S. Geological Survey (USGS). Automatic samplers were installed at 16 locations supplemented by 21 grab sampling locations. The samples from these locations were analyzed for oxygen demand, solids, nutrients, and metals. A network of 22 tipping bucket rain gages was installed within the watershed. This baseline system was also supplemented by periodic watershed-wide sampling events. To date, over 50,000 water quality samples have been analyzed. Over 4,000,000 measurements of continuous water quality, flow, and rain have also been recorded from the baseline monitoring program.

Special Studies

The baseline monitoring program provided information about instream conditions throughout the four branches of the river. A number of special studies have been implemented to provide specialized information for specific purposes. One of the special studies was an outfall monitoring program which has also been in operation since 1993. This program is targeted at combined sewer overflow outfalls and storm water outfalls to aid in the characterization of those sources of pollution. The storm water outfall sampling program has been supplemented by sampling programs to target other sources of pollution such as failing septic systems and improper connections of sanitary sewers to storm water systems.

The effectiveness of the various storm water best management practices (over 60 projects) and CSO controls (20 projects) which are being pilot-tested is being quantified, in part, by an extensive sampling and monitoring program. For structural storm water controls (e.g., detention ponds, wetlands), water quality and flow samples are taken of the influent and effluent from the control and the results compared. Samples from this program are analyzed for oxygen demand, solids, nutrients, and metals. For storm water source controls, the evaluation includes before and after monitoring and paired watershed monitoring. The parameters monitored to characterize the effectiveness of source controls varies by the pollutant targeted in the source control efforts. Similar to the pilot structural storm water controls, the influent and effluent from the CSO control facilities is also being sampled and the results compared. Instream water quality sampling is also performed upstream and downstream of the CSO control facility. In addition to sampling for chemical constituents, other monitoring techniques (e.g., biological) are being utilized to assess the benefits of all Rouge pilot pollution control projects.

A number of field studies were developed and conducted by the Rouge Project to assist in the development of input variables for the water quality models developed for the river. These field studies include sediment oxygen demand, stream reaeration, time of travel, and impoundment limnology.

An assessment of toxic contaminants was also performed throughout the Rouge River watershed. The focus of this effort was to investigate the occurrence and impacts of toxic contaminants on human health and aquatic ecological health, Mikesell (3). The human health effects sampling included testing of sediment, water, fish tissue, and semipermeable membrane devices (plastic tubes containing triolein, a fish fat) for bioaccumulative chemicals of concern. Sampling for aquatic health effects was conducted during both dry weather and wet weather conditions and included analysis of water and sediment for bioaccumulative chemicals of concern, metals, volatile organic compounds, semivolatile organic compounds. Toxicity testing was also performed.

Biological and Habitat Assessment

A three-phased biological survey of the Rouge River was initiated to provide information about the ecological integrity of the river prior to implementation of any watershed management activities and pollution controls. In addition, the survey was used to assess the relationship between aquatic habitat and existing fish communities, to identify habitat factors limiting the development of healthy aquatic communities, and to target areas for specific restoration work. This study was an effort to demonstrate that other factors, such as habitat, must be considered in addition to traditional chemical water quality indicators when evaluating and implementing a management program for water body.

The habitat survey was conducted at 83 sites along over 200 miles of waterway. Three transects across the stream were taken at each site to represent each stream segment. Measurements and observations were made at three points (25 percent, 50 percent and 75 percent of the stream width) along each transect, as well as along the overall transect and on adjacent streambanks. Procedures and habitat assessment techniques were developed by Rouge Project staff from both the Great Lakes and Environmental Assessment Section (GLEAS) Procedure #51 aquatic habitat assessment procedure developed by the Michigan Department of Natural Resources (MDNR) and the U.S. Geological Survey (USGS) National Water Quality Assessment Program (NAWQA), Adaniya, et. al. (4). Chemical and physical evaluations were made on the instream habitat at each site location and included in-situ measurements for pH, dissolved oxygen, turbidity, temperature, salinity, conductivity, bottom substrate and available cover, embeddedness, and flow velocity and depth. Channel morphology parameters noted included flow stability, deposition/sedimentation, and pools-riffles-bends. Each site was designated a Rosgen stream type, Adaniya, et. al. (4). Riparian and bank characteristics were also noted. Rouge Project staff classified each site (good, fair, poor) using the MDNR GLEAS Procedure #51 aquatic habitat assessment procedure. In addition, limiting factors to the health of fish populations and other aquatic life were identified using both GLEAS Procedure # 51 and the U.S. Fish and Wildlife Service Habitat Suitability Index (HSI) models, Adaniya, et. al. (4)

The second phase of the biological survey was an algal diversity assessment. Three classes of periphyton, macroalgae, microalgae and aquatic mosses, were collected at 1 km intervals throughout the Rouge River system. Three subsamples were obtained at each site during dry weather conditions (no rain 72 hours prior to sampling event). Procedures and assessment techniques were developed by Rouge Project staff from the USGS National Water Quality Assessment Program, Zimmerman, et. al. (5). The species diversity index used assess community structure and complexity between various segments of the river. Significant site variation serves as one indicator of water quality, either by the relative presence of algal diversity or the specific extant taxa.

The third phase of the biological survey was a benthic macroinvertebrate assessment. Macroinvertebrates have historically been sampled as a means of assessing the relative quality of a river habitat. Benthic community organisms are an important group to study because they are exposed to potential contaminants in both sediment and in the water column. To provide compatibility with the other phases of biological assessment, samples were collected at 1 km intervals throughout the river system. Procedures and assessment techniques were developed by the USGS National Water Quality Assessment Program, Nesmith, et. al. (6). Three replicate samples were obtained at each site using a kick-sampling technique during dry weather conditions (no rain 72 hours prior to sampling event). Shannon (H') diversity index, Hilsenhoff's 1987 biotic index, and percent oligochaetes were calculated for samples from each site. GLEAS 51 scores were also developed for each site. This information was used in conjunction with other biological sampling to characterize water quality and habitat for other aquatic life (e.g., fish).

A comprehensive fisheries survey was also completed throughout the river system. Electrofishing was conducted at 36 locations along the main river branches and tributaries. A total of 53 species were identified, Beam, et. al. (7). This data was related to the 16 species associations for the most common riverine species in Michigan. Each of the 16 species associations for Michigan has a characteristic drainage area and base flow conditions. Regional reference models were used to develop summer temperature regimes used as benchmarks of thermal integrity; target temperatures represent average thermal regimes found where a species association currently flourishes in southern Michigan. This analysis was used to project potential fish communities by specific Rouge River reach and has been helpful in demonstrating what benefits will be realized by the overall Rouge watershed management effort, Wiley, et. al. (8).

WATERSHED AND RIVERINE COMPUTER MODELS

A suite of computer models was also developed by the Rouge Project to simulate the water quantity and quality response of the Rouge River in response to wet weather events for existing and future conditions in the watershed and under various CSO and storm water runoff management alternatives. The flow and water quality conditions in the river projected by the models under various management alternatives provides the technical basis for developing corresponding quality and use indicators for each alternative, as discussed in an upcoming section of this paper.

The approach to simulating the Rouge watershed with computer models has three tiers. This multi-level approach allows the project to examine and understand in detail the various pollutant generation, removal, and treatment processes on a small scale and translate the findings to a watershedwide level.

Small Area Models (Tier 1): The purposes of the small area analyses are to: 1) examine the physical processes of pollution accumulation and transport through simulation and analysis of flows and pollutant loads and concentrations from pilot areas, 2) examine the processes associated with pollution treatment technologies through simulation and analysis of flows and pollutant loads through pilot pollution control projects, and 3) develop methodologies for extrapolating the results to the subarea analysis (Tier II). A suite of models are used and include various blocks of the USEPA Storm Water Management Model (SWMM), US Army Corps of Engineers Storage, Treatment, Overflow, Runoff Model (STORM), and the P8 Urban Catchment Model. A variety of CSO and storm water control practices are analyzed and include CSO basins, wetlands, swales, detention ponds, and sand filters.

Subarea Models (Tier II): The subarea analysis has two components: 1) A simple pollutant loading model [CDM - Watershed Management Model (WMM)] is used to perform load allocation analysis and 2) a complex subarea model (RUNOFF block of SWMM) is used to develop flows and loads for input into the riverine water quality model. The Rouge watershed is subdivided into 335 subareas (0.6 sq. mi. average size) for the Tier II modeling effort. With the WMM, up to 12 pollutants and multiple management alternatives are simulated with the pollutant loading model. Up to 10 pollutants and multiple management alternatives are simulated with the Rouge RUNOFF model.

Riverine Models (Tier III): The TRANSPORT block of SWMM is used to define river hydraulics to determine river flow, depth, velocity, and volume during wet weather events. The USEPA Water

Quality Analysis Simulation Program (WASP) model is used to determine river water quality and the fate of pollutants in the river during wet weather events. The four major branches of the 126-mile Rouge River are segmented into 181 river segments of average 0.5 mile length for simulation of hydraulics in the TRANSPORT model and simulation of water quality of the river with the WASP model.

The Tier II and III models have been calibrated to instream characterization data collected during 1994. Data collected during 1995 was used to verify these models. The Tier I models were also calibrated to pollution source characterization and control effectiveness data collected during 1994 and 1995.

OTHER WATERSHED ASSESSMENT TOOLS

A comprehensive geographic information system (GIS) and relational databases were designed and implemented to manage and to provide spatial analysis of the wealth of data collected about the Rouge River and its watershed. The Rouge GIS platform is Arc/Info® running on a three-node SUN® work station network with ArcView® on the Windows®-based personal computers attached through a NOVELL® network. The primary database for the project is Oracle®. Existing and projected future land use, soils, political boundaries, hydrologic boundaries, sampling locations, pilot BMP locations, abandoned dump locations, and outfall locations are a few of the many data coverages available. Various applications have been developed to facilitate easy access and use of the information in the Rouge Project GIS and databases.

A special data exploration tool, DataView, was developed to support routine analysis of large time series data sets such as that generated by the 17 continuous water quality monitors installed in the Rouge River. DataView is a user-friendly system developed to spatially display sampling sites and data, view data in tabular or graphical format, spatially associate and display non-numeric (e.g., photographs and text files) data. DataView also provides summary statistics based on data sets created using a variety of selectors (e.g., time, minimum values, etc.). Similar to DataView, Rouge Information Manager was developed as a user-friendly tool for accessing multi-media information about the Rouge River restoration effort. The applications serves as an “electronic file cabinet” which can be used by watershed stakeholders to display Rouge Project information such as reports, maps, data, photographs, construction plans, and videos.

DEVELOPMENT OF ROUGE WATER QUALITY AND USE INDICATORS

A wealth of information has been collected to date about the Rouge River, sources and locations of impairment within each branch and tributary, and options for restoring and protecting the Rouge as a valuable community asset. As described above, a number of tools had been developed for analysis of this information a framework for integrating chemical, physical, biological and descriptive data and computer model projections was missing. A mechanism for presenting both the data and the analyses of solutions for restoring the river to non-technical stakeholders was also needed. This section describes an indicator system, based on a combination of condition quality indicators and multi-factor indexes, for public uses of the Rouge River.

The need to consider other factors such physical and biological conditions in addition to chemical factors when making decisions regarding management of surface waters has been recognized by many but implementation of a more holistic system for monitoring water quality and ecosystem health has been slow. In 1996, the USEPA issued the first in a series of reports on the “Environmental Indicators of Water Quality in the United States”, USEPA, (9). This report defines 18 indicators and the national water quality objectives they support. The USEPA report makes the important point that these and other indicators are still imperfect tools for characterizing the whole realm of water quality. However, they do provide a useful way to simplify large amounts of technical information and convey the essential meaning of it to all concerned. Besides the USEPA report, there is other precedent for use of quality indicators to gauge the success of watershed management programs such as those described in a comprehensive review of indicators used to evaluate storm water control programs, USEPA, (10).

As evidenced by the comprehensive monitoring program described in a previous section, the Rouge Project has been committed to a holistic approach to restoring both human and aquatic uses of the river. Rouge Project staff began considering use of an indicators approach for integrating the myriad of data and condensing the information for use by non-technical stakeholders in 1995. In the original Rouge Remedial Action Plan prepared by the MDNR, sixteen use impairments in the Rouge River were associated in a general way with five broad categories of public use: water contact recreation, warm water fisheries, general aesthetic, industrial/agricultural water supply, and navigation, Bean, et. al. (11). Data for approximately 35 river quality factors indicators were being collected as part of the Rouge Project monitoring program. Staff initially proposed using four water quality indexes, scored as good, fair, or poor, composed of multiple factors:

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- aesthetic: odor (30%), clarity (20%), color (20%), visible debris (30%)
- biological: habitat (33.3%), fish (33.3%), macroinvertebrates (33.3%)
- chemistry: total suspended solids, (16%), dissolved oxygen (17%), ammonia (10%), nitrate (10%), total phosphorus (10%), temperature (10%), 5-day biochemical oxygen demand (10%), E. Coli (17%)
- health: E. Coli (30%), fish consumption (70%).

It was then proposed to change the four water quality indexes into five river use indexes in order to show the effects of management options on uses of the river. The five indexes were water contact recreation, warm water fisheries, general aesthetic, industrial/agricultural water supply, navigation. During discussion of this approach, it was suggested that a fifth index, physical, be added to the four and that seven use categories would then relate to certain combinations of condition quality (five indexes).

None of these approaches was acceptable to the reviewers of this work effort, particularly to the Michigan Department of Environmental Quality who is responsible for water quality protection for the entire state, Smith, (12). The relationship between indexes or indicators and water quality standards was a frequent comment on use of the proposed index system; for example, there was concern that the indexes provide comparative rank rather than absolute determination of acceptability (e.g., water quality standards compliance). It was questioned whether a multi-parameter rating was sensitive enough for single-parameter problems or if indexes represent important phenomena. It was also noted that indexes can obscure data for certain key factors which individually may have an important impact on public use or ecosystem health.

After considerable discussion and various proposals, it was determined that the best approach for an water quality and ecological health indicator system for the Rouge River was to use four condition quality indicators in conjunction with three multi-factor indexes to rate three categories of public uses as “good, fair, poor”.

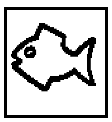
Condition quality indicators are defined as follows:

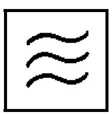
Dissolved Oxygen (DO). Water concentrations (mg/L) and saturation (%) values, both of which are ecologically important; no distinction made between wet (high flow) and dry conditions.

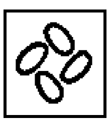
*Fish Consumption Advisory***.** The Michigan Department of Public Health has identified portions of the Rouge where fish consumption is not advised based on tissue concentrations of certain contaminants.

River Flow. Flow velocities in ft./sec. Ratings to be used are pending MDNR determination of flow significance to aquatic habitats and fish communities.

Bacterial Count (E. coli). Colony counts per 100 ml in culture; ratings are based on Michigan Water Quality Standards; distinction between wet and dry conditions.





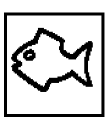


Multi-Factor Indexes (Indices) are defined as follows:

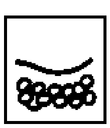
Aquatic Biology Index. Index ratings are based on GLEAS Procedure #51 fish community assessment, MDEQ (13), based on both fish and macroinvertebrates, and the Index of Biotic Integrity (IBI) which accounts for the condition of both populations and individual fish.

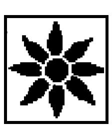
Aquatic Habitat Index. Index ratings are based on Rouge Project data analyzed GLEAS Procedure # 51 and the U.S. Fish and Wildlife Service Habitat Suitability Index (HSI) models, Adaniya, et. al. (4). The aquatic habitat index is based on substrate, cover, channel morphology, riparian/bank condition, and water quality.

Aesthetic Index. Index ratings are based on Rouge River Aesthetic Index system using clarity, color, odor and visible debris, Heidtke, et. al. (14).



These seven indicators represent some 30 physical, chemical and biological conditions which have some direct impact on public use quality, either singly or in combination. Use quality indicators are defined as follows:





Water Contact. Health hazard to humans of external contact with Rouge water; relates mainly to the Bacterial (E. Coli) factor above.

Warmwater Fishery. Suitability of Rouge waters for fish populations and recreational fishing, relates mainly to DO, Consumption and Flow factors, and to the Aquatic Biology and Habitat Indexes above.

General Aesthetics. Desirability of Rouge environment for any personal enjoyment; relates mainly to the Aesthetic Index above.

Navigation (and boating) was originally listed as a fourth use quality indicator. However, much of the Rouge River system has insufficient depth for anything other than a canoe, with the exception of the most downstream section of the river which has been channelized for use by ships. Thus, the boating use would be coded “poor” throughout the majority of the river system based on the lack of flow.

Because it would be confusing to explain that the river is rated “poor” for boating from a flow perspective alone, regardless of water quality conditions, it was decided to delete navigation and boating from the list of use quality indicators. The issue of how to represent “naturally occurring” poor conditions from anthropogenically impaired conditions has been a recurring difficulty overcome on a case-by-case basis.

The numerical ratings to be used for ranking the quality of these Rouge factors and indexes are shown with select references in Table 1 (located at the end of this paper due to its length).

APPLICATION OF INDICATOR SYSTEM TO LOWER ROUGE SUBWATERSHED

Rouge Project staff initially produced nine status reports called “Rouge River “Rouge River Quality for Public Use”. These 12-page reports describe conditions and use quality for each of the principal subwatershed of the Rouge River in a largely graphical format with limited text. The content and layout are designed to summarize existing conditions (1994-95) of river quality using selected indicators, represented on maps by color-coded icons. The probable impact of these conditions on the quality of common uses is represented on the maps by color-coded river segments. Other supporting information is included in the reports, as described below.

The brief descriptions of Public Uses and River Conditions in the reports highlights the significance of each and notes features which can influence quality ratings. In the Subwatershed Overview section, a base map of the subwatershed shows all tributaries, major roads and communities. Locations of all monitoring stations by type are plotted on the map. An overview table summarizes basic information about the subwatershed: sanitary service, development, land use and environmental features.

The body of the report consists of graphical summaries of condition and use quality for each of the four categories of use: Fishing, Wading/Swimming, and Aesthetics. Figure 2 represents shows example condition and use summaries for the Lower Rouge River under existing conditions. Within the subwatershed Public Uses and River Conditions reports, each use is described on a separate page, with a description of how certain condition factors affect river quality for this activity. Other use quality considerations are noted as well. Legend boxes where condition and use quality ratings are defined are also provided; Figure 3 shows the legend box for the Fishing Conditions map shown in Figure 2. Icons in the first legend represent those condition indicators which are most relevant to fishing in the particular way defined. Color codings with the icons represent three ranges of quality: good (green); fair (yellow); poor (red). As described in the previous section, all of the indicator ratings are based on

Figure 2: Existing Conditions in the Lower Rouge Subwatershed

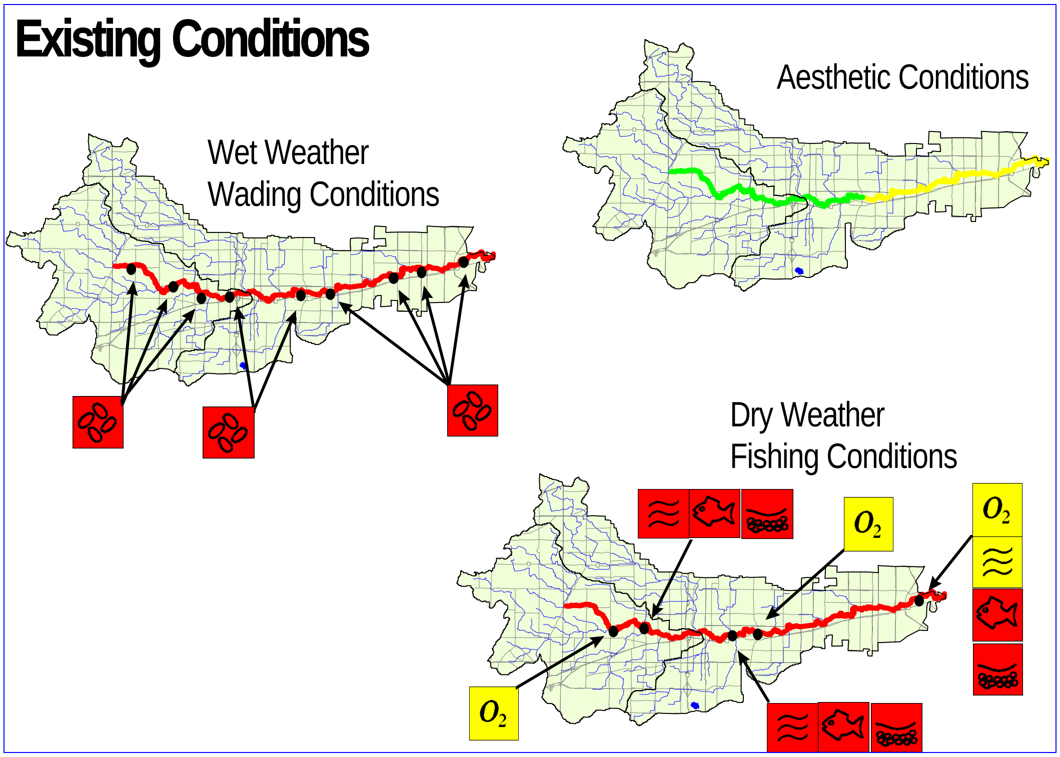
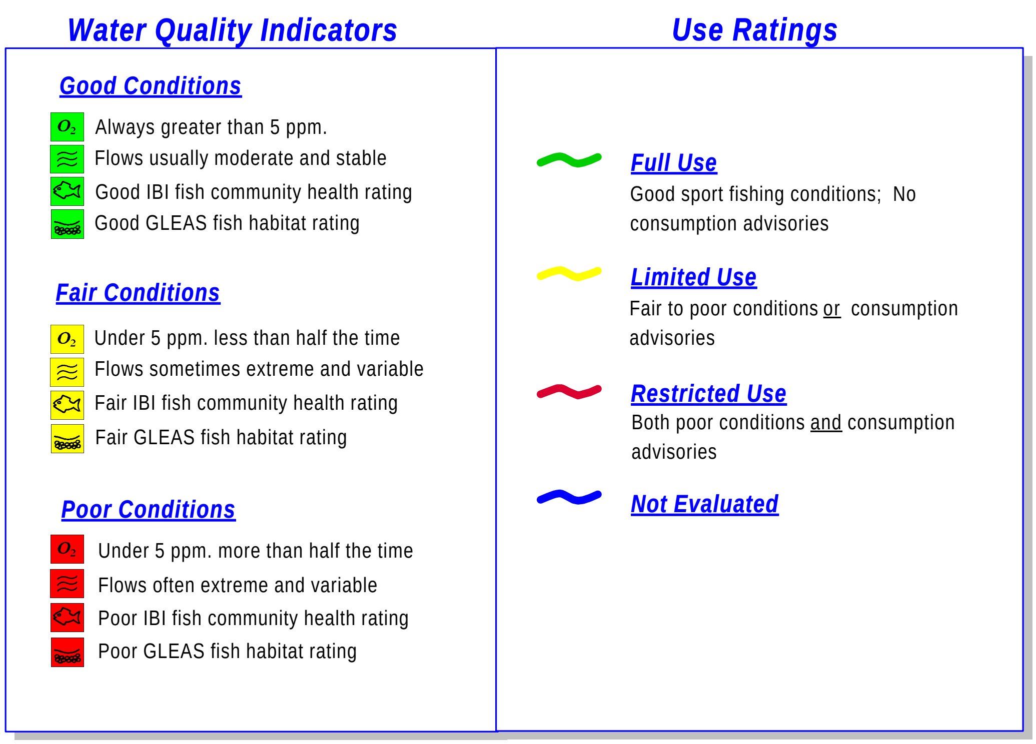


Figure 3: Legend for Fishing Conditions



one of two things: (1) a numerical value and a frequency of measurements above or below that value; (2) a division of the whole range of values into three sub-ranges.

In the second legend box (see Figure 3) the color-coded lines represent three ratings of use quality with respect to Fishing, etc: Full use (green) where fishing potential is good; Limited Use (yellow); Restricted Use (red); and Not Evaluated (blue). These ratings are defined differently for each use category. Within the subwatershed use books, each use is defined by subwatershed maps representing both the wet weather (high river flow) and dry weather (low river flow) situations. Color-coded icons representing condition quality ratings are linked to monitoring station points on the maps. The icons reflect data that are appropriate to fishing quality and available at each site. In addition to data from these primary sites, more information pertinent to fishing may be available from other sampling sites as indicated on the base maps. Depending on the subwatershed, this may include biological, sediment and water quality information, either from Rouge Project studies or other sources. For example, a Rouge Project reconnaissance survey during 1994 resulted in data on sediment containments at nearly 200 additional sites. All pertinent data, whether or not it represented the five indicators, was considered by Rouge Project staff as they evaluated each public use quality in the Rouge River.

In addition to the condition ratings (icons) for sites, the river lines on the map are color-coded to represent zones of different public use or potential. These zone ratings are necessarily based on both evaluations of the condition quality data for specific points and on the best professional judgement of Rouge Project staff who have personal knowledge of the Rouge. Since the use ratings are inherently more subjective, they are more likely to be refined with more data and observations in the field.

Aesthetic Quality is a special case, in that different indicators of the observational type were used to rate condition and use quality. Aesthetic enjoyment of the Rouge by the public represents a wide range of activities in the river environment. Some of these like nature walks involve human perceptions of beauty or quality that are difficult to rate objectively. For example, natural debris (log jams) in the river may not appeal to hikers or canoeists, but may provide important shelter for fish communities during flow extremes. Standards of use quality may conflict in that sense. Nonetheless, condition ratings for aesthetics are currently based on observations of four river properties: water clarity, color, odor and debris, as described previously.

Attached to each subwatershed report are a number of site summary sheets. Each sheet summarizes information about one of the monitoring or sampling sites in the subwatershed, and provides a statistical summary of water quality data collected at the site over a period of record (1994-1995). All together, these summaries represent the main body of technical information on which the subwatershed reports are based and have been useful tools for communicating with those watershed stakeholder who desire more technical information than is provided in the public use reports.

The Rouge water quality indicator system has also been utilized to provide information to watershed decision-makers and the general public about management options for river restoration efforts. For the Lower Rouge subwatershed, existing conditions (shown in Figure 2) and four sequential management options have been analyzed to date. These options can be summarized as:

- Step 1: Effluent from a new wastewater treatment plant is discharged into the Lower Rouge system near the upstream end of the system.
- Step 2: Control of all combined sewer overflows by the year 2005, using a combination of sewer separation projects and detention basins sized to provide 30 minute detention of the 1 year, 1 hour storm

- C Step 3: Implementation of a moderate municipal and industrial storm water control program which includes public education, catch basin cleaning, street sweeping, aggressive illicit connection and failing septic system detection and elimination program, BMPs for all new and redevelopment.
- C Step 4: Final activities to restore the Lower Rouge, including construction of regional storm water impoundments at key locations to reduce peak flows, implement habitat restoration/creation projects along select reaches, stabilize stream banks along select reaches, and other activities.

Figure 4 shows the estimated water quality indicators and public use opportunities under the combination of Steps 1, 2, and 3 (note: results of Steps 1 - 3 not shown individually). Because the key objectives of Steps 1, 2 and 3 are to prevent pollution (especially raw sewage) from entering the river, wading potential increases substantially from existing conditions. Because the Lower Rouge has a very mild slope, increasing baseflow conditions due to a new treatment plant outfall under Step 1 is beneficial for flow conditions and dissolved oxygen levels. Figure 5 presents a summary of the projected water quality indicators and public use opportunities under each management step for analyzed for the Lower Rouge subwatershed.

The Rouge water quality and public use indicators, based on rigorous technical analysis and coupled with cost estimates for each proposed management option, has provided a framework for discussions among local communities, regulatory agencies, and others about options and priorities for restoring or protecting different segments of the Rouge River. It should be noted that the indicator system is one of many tools utilized during the development and implementation of subwatershed management plans. As more detail is required in the subwatershed planning effort, the indicator system is supplemented by more rigorous technical analysis.

SUMMARY AND CONCLUSIONS

The Rouge River National Wet Weather Demonstration Project in southeastern Michigan is a working demonstration of a watershed-wide approach to restoring and protecting an urban river system by using a cooperative, locally-based approach to pollution control. The Rouge water quality and use indicator system, along with other watershed management tools developed by the Rouge Project, has aided decision-makers and the general public in evaluating options for preventing, reducing, and minimizing pollution loading impacts on the Rouge River. The Rouge watershed management tools such as the indicator system facilitate the prioritization and tailoring of pollution control and ecosystem restoration solutions to specific river reaches while coordinating efforts throughout the watershed.

The use of water quality indicators, which is already established in the realm of water quality reporting, is not only a useful but necessary means of distilling a large variety and quantity of technical data into simpler expressions of quality. An important concept demonstrated by the Rouge system is that of linking condition quality status to its likely impact on uses of the river. This linkage has proven critical to educate the watershed stakeholders about the consequences of conditions in the river and potential management activities to restore and protect the river. The graphical presentation utilized by the Rouge indicator system has been successful in aiding public understanding of technical information. Use of an icon-based, color-coded approach has also proven to be a simple way to express quantitative information without numbers. It has also become clear from river restoration efforts such as the Rouge Project that water resources management efforts must have the support of the general public in order to be effective and to become self-sustaining. Use of the Rouge indicator system has been effective in garnering public support for the river restoration efforts.

Figure 4: Projected Water Quality Conditions and Public Use Potential Under Step 3, Storm Water Program, for Lower Rouge Subwatershed

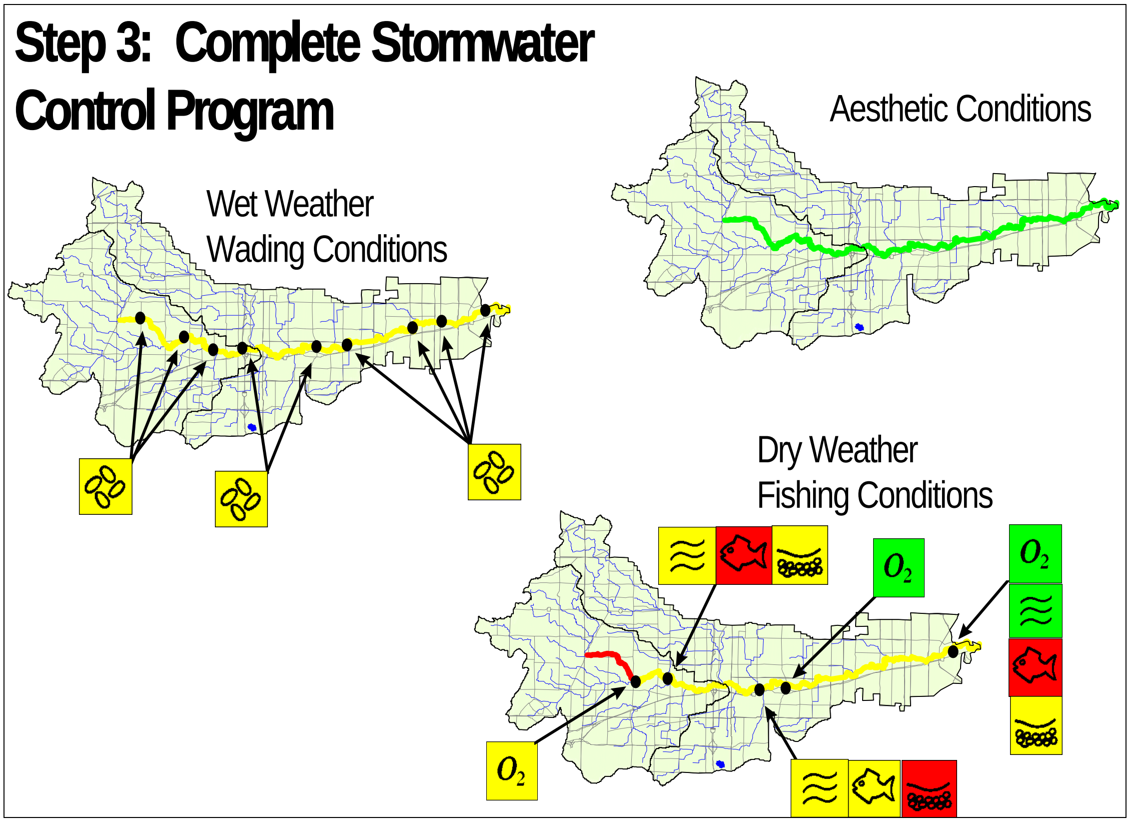
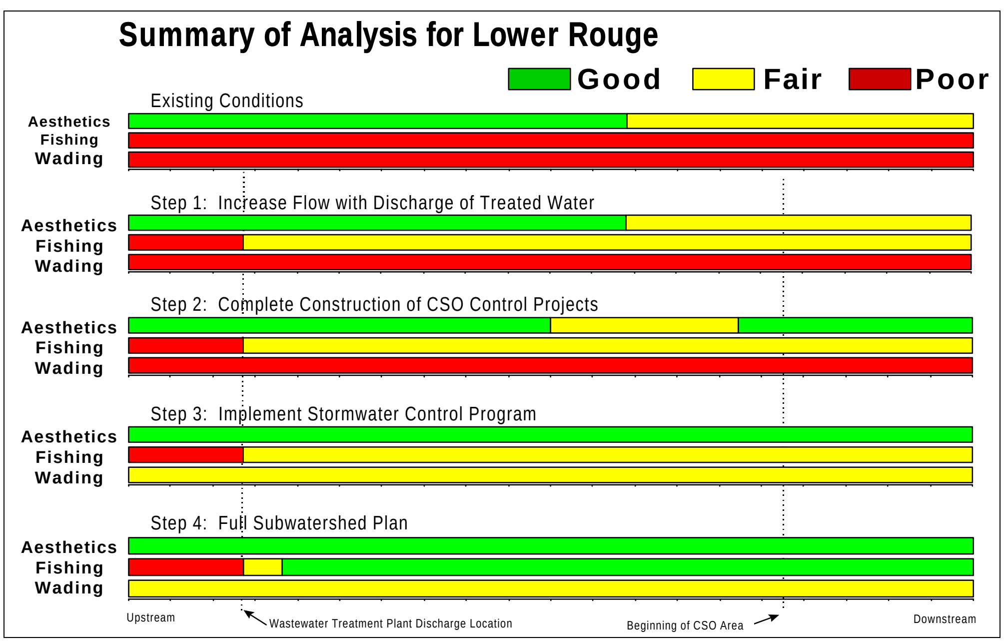


Figure 5: Summary of Analysis for Lower Rouge Subwatershed



A caveat of the indicator approach is that water quality indicators and indexes such as those used in the Rouge indicator system are general markers but not substitutes for other data or rigorous analysis. It is therefore important to also summarize the technical basis for the indicator ratings of river quality in an easy to use format. At best, indicator values can never perfectly represent other data in every situation. The four condition quality indicators used in conjunction with three multi-factor indexes to rate three categories of public uses as “good, fair, poor” were the best surrogates for the wealth of data for approximately 30 environmental indicators contained in the Rouge Project database. As the Rouge River restoration efforts continue, other quality indicators may also prove to be useful for tracking certain conditions.

It is clear from comprehensive water resources management efforts such as the Rouge Project that multiple environmental factors such chemical, physical, and biological conditions needs to be evaluated when making decisions regarding management of surface waters. Progress of any surface water management efforts should also be monitoring using a variety of indicators of ecosystem health because each factor defines some aspect of quality, but each represents quality in a different way and to a different degree. Successful and cost-effective water resources stewardship is based on a holistic approach to resource restoration and management.

ACKNOWLEDGMENT

This paper represents a summary of select elements from the ongoing efforts of many individuals and organizations who are involved in the restoration of the Rouge River. The work of V. Elliott Smith, Colleen Hughes, Karen Snyder, Tom Heidtke, Eric Tauriainen, Barry Johnson, Charlie Bristol, Noel Mullett, and others to develop the Rouge Quality Indicator system is especially noted. Special thanks to Chris O’Meara and Karen Snyder for assisting with the graphics and slides for this paper.

The Rouge River National Wet Weather Demonstration Project is funded, in part, by the U.S. Environmental Protection Agency, Grant #X995743-01. The material in this report has not been subject to U.S. Environmental Protection Agency (EPA) technical and policy review. The views expressed by the author is her own and do not necessarily reflect those of EPA.

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TABLE 1
SUMMARY OF QUALITY INDICATORS FOR ROUGE RIVER

INDEX/FACTOR DESCRIPTOR	QUAL. RANK	RATING RANGE (units)	IND. WT.	RATIONALE FOR RANGE AND WEIGHTING OF RANK
DISSOLVED OXYGEN (DO) Dry or Wet	Good Fair Poor	$5 mg/L instant., $60% to #100% sat. <u>and</u> instant. >4 mg/L 4.0 -4.9 mg/L instant. <u>and</u> 50% to 59% sat. or 100% to 110% sat. <4.0 mg/L instant. <u>and</u> <50% sat. or >110% sat. *(Concentration alone used when saturation is not available.)*		<u>Ref:</u> *Neponset River Basin Survey, 1994, Aquatic Life Support guideline*-- Support: $5.0 mg/L Partial Support: 4.0-4.9 mg/L Non Support: #4.0 mg/L <u>Ref:</u> *Michigan DNR General Rules, 1994, Part 4, Water Quality Standards R 323.1064 Rule 64* Warmwater fish and aquatic life: DO $6 mg/L daily average, and $5 mg/L instantaneous Coldwater fish: DO $6 mg/L (warm weather) and $7 mg/L (design flow)
RIVER FLOW Water Velocity ***(ON HOLD PENDING MDEQ STUDY RESULTS)*** Flow Stability	Good Fair Poor Good Fair Poor	11-20 Score 6-10 Score 0-5 Score 8-15 Score 4-7 Score 0-3 Score		<u>Ref:</u> *Qualitative Biological and Habitat Survey Protocols for Wadable Streams and Rivers: Revised GLEAS Procedure #51, 1991, Michigan Department of Natural Resources, Lansing.*
FISH CONSUMPTION	Good Fair Poor	No restriction #1 fish meal/week No consumption		<u>Ref:</u> *Fish Consumption Advisory, 1995, Michigan Department of Public Health, Division of Health Risk Assessment, Lansing.*

TABLE 1 (Continued)

INDEX/FACTOR DESCRIPTOR	**QUAL. RANK**	**RATING RANGE (units)**	**IND. WT.***	**RATIONALE FOR RANGE AND WEIGHTING OF RANK**
BACTERIA ***(E. coli)*** Dry or Wet	Good Fair Poor	#130 / 100mL** 131-1000 / 100 mL >1,000 / 100 mL		Ref: *Michigan DNR General Rules, 1994, Part 4, Water Quality Standards R 323.1062 Rule 62* Good - Full body contact** Fair - Partial body contact Poor - No body contact * *30-day geom. mean; max. 300/100mL/sample
AQUATIC BIOLOGY INDEX Fish	Good Fair Poor	28-50 Score 20-27 Score <20 Score	0.5	Ref: *Qualitative Biological and Habitat Survey Protocols for Wadable Streams and Rivers: Revised GLEAS Procedure #51, 1991, Michigan Department of Natural Resources, Lansing.*
Macro-invertebrates	Good Fair Poor	30-54 Score 10-29 Score <10 Score	0.5	
AQUATIC HABITAT INDEX Substrate/Cover Channel Morph. Riparian/Bank Water Quality	Good Fair Poor	>50% 25-50% <25%	 0.30 0.25 0.15 0.30	Ref: *Qualitative Biological and Habitat Survey Protocols for Wadable Streams and Rivers: Revised GLEAS Procedure #51, 1991, Michigan Department of Natural Resources, Lansing.* Ref: *Habitat Suitability Index Models, 1982-1983, Biological Services Program, Fish and Wildlife Service, U. S. Department of the Interior.*

* Best professional judgment

TABLE 1 (Continued)

INDEX/FACTOR DESCRIPTOR	QUAL. RANK	RATING RANGE (units)	IND. WT.*	RATIONALE FOR RANGE AND WEIGHTING OF RANK
AESTHETIC INDEX				Ref: *A Review of Water Quality and Related Indices (C.*
Clarity				*Steinhart, L. Schierow and G. Chesters), 981, Environmental*
	Good	8-10	0.2	*Planning Study Contrib. No. 38, Water Resources Ctr., Univ.*
	Fair	6-8		*of Wisc.-Madison.*
	Poor	<6		Ref: *Heidtke, 1996. Summarized as:*
Color				**Clarity**
	Good	8-10	0.2	Clear 10 Muddy/Highly Turbid 2
	Fair	6-8		Slightly Turbid 8 Opaque 0
	Poor	<6		Cloudy 5
Odor				
	Good	8-10	0.3	**Color**
	Fair	6-8		Clear 10 Medium Brown 5
	Poor	<6		Green 9 Dark Brown 2
Debris				Light Brown 8 Milky/White 0
	Good	8-10	0.3	
	Fair	6-8		**Odor**.
	Poor	<6		None/Natural 10 Harsh (sewage, fishy)
				Musty-Faint 8 -Faint 4
				Musty-Strong 6 -Strong 2
				Anaerobic (rotten eggs) 0
				Debris/Obvious Pollution
				None 10 Floating Scum 2
				Natural (leaves, limbs) 9 Oil Film 1
				Foam 7 Sewage Solids-Floating 0
				Trash -Floating 4 -Fixed 0
				-Fixed 4

KEY WORDS

aquatic habitat, biological monitoring, habitat monitoring, river use indicators, water quality indicators, aesthetic monitoring, storm water, watershed management, Rouge River National Wet Weather Demonstration Project, public involvement, water quality and ecosystem health monitoring