A Comparative Analysis of Indianapolis' Approach to Combined Sewer Overflows

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I. <u>Introduction</u>

History of Combined Sewer Overflows

Throughout the ages, every city and town has had to manage two problems that have become tied together, which are human waste and excessive storm water. Drainage systems were used for many centuries to carry storm water run-off away from streets and parking lots. Municipalities prevented the flooding of streets so that business could continue during times of heavy rainfall. During this time period, wastes of all kinds were simply piled nearby offices and homes, or were transported by means of privies and cesspools. This resulted in odorous, unsanitary and unpleasant living conditions (Water Environment Federation, 1999).

To reduce the problem of the raw sewage accumulation, United States communities started combining both the water drainage and sewage into one system of pipes; these became known as combined sewage (CS) pipes. Scientists of the day believed this CS system would provide ample, long-term dilution; therefore these CS pipes were funneled to nearby water bodies such as creeks and rivers. What resulted was an overload of pollution to the receiving water bodies (Moffa, 1997, Water Environment Federation, 1999).

To clear up the unhealthy water a number of interceptors were built to transport the water in CS pipes to either Water Treatment Plants or to larger bodies of water. These interceptor pipes were designed for two to four times the average wet weather overflow rates; which became inadequate over time. The projected rain-event capacity was not included in this system because of the increased costs, both in the size of the piping and the volume of treatment plant inflow. To assure this inadequate system did not back-up during rain events it became essential to install devices that could relieve the pipes; these become known as Combined Sewer Overflows (CSOs) (Moffa, 1997).

As of 1997 there were approximately 15,000-20,000 CSOs and 1,300 communities with CSOs nationwide. In many urban areas these CSOs present more of a detriment to the water quality than do all of the upstream agricultural and urban runoff as is described in subsequent water quality and human health sections. The Federal Government has attempted to address the problem by signing many pieces of legislation that now guide this area of policy making. Despite many these pollution abatement programs and policies, these problems still remain (Moffa, 1997, Water Environment Federation, 1999).

Laws Pertaining to Combined Sewer Overflows

History and Purpose of the Clean Water Act

The amended Federal Water Pollution Act of 1972 (known as the Clean Water Act or CWA) contained a framework for setting enforceable effluent standards for industry, water quality standards, and the National Pollutant Discharge Elimination System

(NPDES) permit program. The goal of the act was to restore all waterways in the U.S. to "fishable and swimmable" by 1983 and eliminate the discharge of pollution into navigable waters by 1985. As of 1997, it was estimated that less than 45% of waterways (40% rivers and 44% of lakes) were designated as fishable and swimmable (Ferrey, 1997).

The CWA was amended in 1977, setting deadlines for compliance of best conventional pollutant control technology (BCT) for conventional pollutants such as biological oxygen demand (BOD), fecal coliform, suspended solids, pH, and oil and grease. It also added best available technology (BAT) limitations for priority toxic pollutants (toxic or priority pollutants) to the conventional pollutants enumerated in the 1972 Act.

The CWA was again amended in 1987. The amendments of 1987 in part established a program to deal with waterways with continuing toxic pollutant problems, provided a timeline for regulation of storm water discharges, created a revolving loan fund for publicly owned treatment works (POTWs) construction, and increased enforcement options available to the EPA (Gallagher, 1997).

Basic Provisions of the Clean Water Act Regarding POTW Discharges

POTWs are treatment facilities for municipal sewage from residential homes, businesses, industry (considered sanitary sewage), and in some communities, water from storm water and surface runoff. The combination of sanitary sewage and storm water/surface runoff is called "combined sewage." POTWs are required to obtain an NPDES permit to eliminate the discharge of pollutants into navigable waters of the United States in compliance with the technology and water quality requirements of the CWA. The NPDES permit turns technology and water quality standards into enforceable limits on discharges by the POTW. Technology based and water quality based effluent limitations are set to provide enforceable mechanisms to achieve this overarching goal.
The scope of the NPDES program depends on what is considered a pollutant, from a point source and into navigable water. Pollutants covered under NPDES permits are categorized in Table 1 (USEPA, 1994).

Conventional	Toxic or priority	Unconventional (any other parameters not contained in the above two categories including):
BOD Ph Suspended solids (SS) Fecal coliforms Oil and grease	Those contained in Section 307of the CWA (including metals and manmade organic compounds	Ammonia Nitrogen Phosphorus Chemical oxygen demand (COD) Whole effluent toxicity (WET)

Table 1. Pollutants Covered Under NPDES Permits

For the purposes of defining a pollutant discharge, it is important to distinguish between the two sources of discharge, point and nonpoint. Discharges from POTWs are normally considered point sources. Point sources are defined according to Section 502 of the federal Clean Water Act (CWA) as:

> "any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged (FWPA, 1977, Section 502)."

Section 319 of the Act does not specifically define a "nonpoint source", but it is considered any other discharge of pollutants not conveyed in or characterized by a discrete site of pollutant discharge, but including agricultural runoff and seepage into groundwater. Although the CWA recognizes nonpoint sources as important to water pollution, problems identifying the initial sources and how control of them, as well as, lack of federal enforcement action over them (Section 309) has meant that control of nonpoint sources has been left largely to the states (Malone, 1997; USFWPA, Section 309).

Discharges from POTWs are governed as point source discharges under the CWA and are subject to effluent limits of point sources based on the requirement for secondary treatment of sewage. Direct discharges from POTWs are subject to a permitting system under NPDES (Section 301 of the CWA), which regulates the amount and concentration of pollutants discharged into streams, lakes, or marine environments. During events, such as rain events, in which the capacity of the POTW is exceeded, combined sewage can bypass the treatment facility and discharge directly to a receiving waterway via a channel, pipe, or tunnel. These discharge points are called outfalls or combined sewer overflows (CSOs). CSOs are not subject to secondary treatment requirements applicable to POTWs (USEPA, 1994).

NPDES Permits Under CWA

NPDES permitting is designed to identify and limit the most harmful pollutants and ensure compliance with the CWA as a condition to issuance and renewal of the permit. Municipal facility NPDES permits are issued by the EPA or more usually by the state if it has been granted permitting authority from the EPA. The state requirements must be at least as stringent as the federal standards and all permits are ultimately reviewable by the EPA.

States submit general or individual facility permit applications to the permitting agency after which a draft permit will be issued and public notice published. The draft permit allows at least 30 days for public comments, and/or public hearings. If no issues are raised within the notice and comment period, the permit is issued and administrative proceedings cannot be raised until renewal of the permit takes place. Permits last five years and are subject to review and approval by either the state court system (in state issued permits), or adjudication by EPA (in EPA administered permits). Appeals to the draft permit must be written and include all legal and factual issues to address. If review is granted, there is an on-the-record evidentiary hearing by an administrative law judge (ALJ). The decision of the ALJ or the denial of hearing can be further appealed to the EPA Environmental Appeals Board (EAB) whose decision is the final agency action (Barnes, 1999).

Permitting agencies include in the NPDES permit effluent limits, monitoring and reporting requirements, and other conditions specific to the permitted facility. Permitting agencies analyze the application and other sources and determine both technology and water quality based effluent limits. The more stringent of the two, water quality or technology based limitations, are applied. Occasionally, this will mean different effluent limit standards for individual pollutants.

Pollutant dischargers are not required to use specific technology control methods as long as they can satisfy the requirements of the CWA and their NPDES permit. Technology based standards for conventional pollutants are based on Best Conventional Control Technology (BCT), which includes a cost-reasonableness test. Toxics and non-conventional pollutants must be controlled through Best Achievable Technology (BAT). BAT is the most stringent of the control methods and while there is no requirement for cost-benefit analysis as in BCT, there is a requirement that standards are "economically feasible," and the BAT for toxics is health based (Ferrey, 1997).

Most states, including Indiana, retain authority (granted by the federal EPA) to promulgate their own water quality standards. States designate uses of each water body in the state but are not allowed to downgrade designated uses from "fishable/swimmable" unless this status is unobtainable due to natural causes, irremediable conditions, or where attainment would cause "substantial and widespread economic and social impact." In addition, states must conduct use attainability analysis (UAA) to describe and quantify the chemical, biological, physical and economic factors that influence achieving the fishable/swimmable goal. Based on the results of the previous factors, states must also develop anti-degradation policies to protect existing water quality (Malone, 1997). Violations of the NPDES permit are subject to enforcement by the EPA and the states although EPA retains the primary enforcement authority. Enforcement options include administrative orders for compliance and/or penalties, and civil penalties and/or injunctions, or criminal penalties. The EPA can consider the nature, extent, and gravity of the violations, the degree of fault of the violator, and the ability of the violator to pay among other things, when dispensing administrative penalties. Civil penalties do not have to show that the violator was negligent or at fault. Gravity, here, is determined by looking at the significance of the action, actual or potential harm to humans or the environment, and the number of violations and length of time the violator was in noncompliance. In addition, the CWA has citizen suit provisions for any person, withstanding, to sue violators for permit violations (Malone, 1997).

CSO Control Policy

Because of the aging of municipal POTW systems and the increase in system needs, the problem of POTW discharges to waterways is increasing, particularly for combined systems. In response, the EPA formulated the National CSO Control Strategy in 1989 that was revised as the CSO Control Policy in 1994 (40 CFR Part 122) by a negotiated dialogue with stakeholders. The purpose of the CSO Control Strategy is to expedite and provide a consistent approach in eliminating CSO discharges to waterways through compliance with the NPDES permitting requirements (USEPA, 1994). While implementation of the 1989 Strategy has resulted in progress controlling CSOs, the presence of CSOs and the resulting releases of raw or partially treated sewage continues to pose a significant public health and water quality concern. In December of 2000, the CWA Section 402 was amended requiring that all permits, orders, and decrees issued after the date of enactment conform to the CSO Control Policy.

The CSO Control Policy endeavors to engage the agencies, municipal governments, scientists, and the public in formulating a comprehensive but site-specific and cost-effective strategy to eliminate CSO discharges that violate the technology-based and water quality-based requirements of the CWA, including protection of designated uses. The CSO Control Policy recognizes the need for site-specific flexibility and the social and financial impacts on localities when formulating CSO reduction/elimination strategies. The Policy provides guidance to NPDES permittees with CSOs in their communities. The Policy provides assistance on coordinating the planning, selection, and implementation of CSO controls that meet the requirements of the CWA and involve the public during the decision-making process. The Policy also includes guidance to assist in developing suitable site-specific NPDES permit specifications for combined sewer systems that overflow because of insufficient capacity resulting in wet weather events. The Policy requires the immediate elimination of dry weather overflows in compliance with the provisions of the CWA (USEPA, 1994).

There was a 1997 deadline for the implementation of phase I of the Control Policy. CSO permittees were to characterize their CSO discharges and demonstrate implementation of the nine minimum technology-based controls (NMC) identified in the Policy. The NMC are measures that can reduce the frequency and effects of CSOs while not requiring major construction or other significant expenditures. The NMC are as follows (USEPA, 1995):

1. Proper operation and regular maintenance programs for the sewer system and the CSOs
2. Maximum use of the collection system for storage
3. Review and modification of pretreatment requirements to assure CSO impacts are minimized
4. Maximization of flow to the publicly owned treatment works for treatment
5. Prohibition of CSOs during dry weather
6. Control of solid and floatable materials in CSOs
7. Pollution prevention
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts
9. Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls

Phase II of the Policy develops Long Term CSO Control Plans (LTCPs) that evaluate alternatives for attaining compliance with the CWA and implementation of the LTCP for attainment of water quality standards in impacted waters.

The nine minimum technology-based controls in Phase I of the CSO Control Policy are determined on a site-specific basis by the NPDES authority and all CSO communities are responsible for implementing their approved plan. The NPDES permitting authority (either state, if authorized, or the EPA) determines whether the NMC satisfy the technology-based requirements of the CWA based on factors in the NPDES regulations.

The Policy lays out two approaches for development of control alternatives in the LTCP, the "demonstration" approach and the "presumption" approach. The demonstration alternative bases success on a LTCP that allows the municipality to reduce discharges to meet water quality standards. The presumption approach consists of developing performance criteria that reduces outfall events by a given amount (number of events per time period) or reduce the volume of the outfall by a set amount (percent reduction in volume over time). Both approaches require post-modification monitoring to demonstrate compliance of the permit conditions and attainment of water quality standards.

Once the LTCPs are completed, permittees are responsible for implementing the plan as soon as practicable according to the fixed timeline established in the permittee's LTCP, but generally within two years of permit issuance. By law, discharges that remain after implementation of the LTCP must not interfere with attainment of water quality or pollution reduction goals. The involvement of state authorities in formulating water quality standards helps assure that development of the permittee's LTCP is coordinated with the permitting authorities. The Policy also includes enforcement provisions incorporating an appropriate timeline for implementation of the LTCP goals and compliance with provisions of the CWA. These implementation goals may be introduced gradually based on the relative importance of adverse impacts upon water quality standards and designated uses, and on a permittee's financial capability (USEPA, 1995).

During the development of the LTCP, the permittee is expected to give high priority to development of controls for sensitive areas, which include designated Outstanding National Resource Waters, National Marine Sanctuaries, waters with threatened or endangered species and their habitat, waters with primary contact recreation, public drinking water intakes or their designated protection areas, and shellfish beds. In addition, during development of the LTCP, the permittee must encourage active public participation in the process of selecting long-term controls (USEPA, 1994). Following implementation of the LTCP, communities and states must monitor CSO and water quality data to evaluate the effectiveness of the LTCP as a measure of compliance in improving water quality and supporting designated or existing uses.

Upon completion and approval of the LTCP, NPDES authorities can issue, reissue, or reopen and modify permits (if CSO controls fail to meet water quality or designated uses) to require compliance with the technology and water quality-based requirements of the CWA.

Use Attainability Analysis

EPA regulation 40 CFR 131requires that states specify use categories for state water bodies (designated or existing). The regulation distinguishes between existing and designated uses and sets out specific requirements to ensure achievement and protection of these two broad use categories. Designated uses are defined as those uses specified in water quality standards for each water body, whether or not they are being attained. The EPA interprets existing uses as those uses actually attained in the water body on or after promulgation of the initial EPA water quality standards in 1975, whether or not they are included in water quality standards. Designated uses focus on the attainable condition while existing uses focus on the past or present condition of use. A state must conduct a UAA (that can be part of the LTCP) in order to make any changes in state water quality standards or to temporarily suspend a designated use. If the water quality goals stated by the EPA are not going to be met in a state’s particular water body, regulations require that such a determination be based upon a credible UAA. Under 40 CFR 131.1, regulations promulgated by the EPA requiring fishable/swimmable conditions in the nations waterways does not restrict the states discretion to determine that the uses of a particular waterway are not attainable as long as a credible UAA is conducted (USEPA, 1998).

Additional Factors Influencing CSO Control in Indiana

The Senate Enrolled Act 431 (SEA 431) was signed into Indiana law on 17 March 2000. SEA 431 allows state facilities some level of liability protection during the development and implementation of the LTCP and includes procedures for measuring the cost-effectiveness (knee of the curve) of pollutant control alternatives in the LTCP. SEA 431 requires implementation of NMC, additional characterization of waterways (particularly those designated as outstanding state resource waters), implementation of the LTCP, and cost-effectiveness analysis (State of Indiana, 2000).

Public Health Implications of Combined Sewer Overflows

The human health risks associated with CSO discharges are the result of contact with bacterial and viral pathogens and chemicals found in wastewater. Pathogens are microscopic organisms that can infect people and may result in disease (King County Department of Natural Resources, 1999). The symptoms associated with bacterial and viral pathogens include, nausea, diarrhea, chills, fever, stomach and intestinal cramps, and jaundice (King County Department of Natural Resources, 1999). Fecal-oral transmission is the most common method by which people are infected by these viruses (Fort Wayne, IN City Utilities, 2002). Fecal-oral transmission can occur through both direct and indirect means. Direct contact with sewage or touching an object that was in direct contact with sewage followed by touching the mouth, eyes, ears, and nose can result in infection. There are four major types of organisms associated with potential human health risks from pathogens in wastewater, which are bacteria, viruses, parasitic worms, and protozoa (King County Department of Natural Resources, 1999).

Bacteria

Bacterial pathogens are single celled disease causing organisms lacking a distinct nuclear membrane. Most bacterial pathogens reproduce inside of the host by means of binary fission (King County Department of Natural Resources, 1999). The consequences of bacterial infections can vary from mild to fatal and are often treated successfully with antibiotics. The bacteria most commonly found in wastewater are listed in Table 2.

Bacterial Pathogens	Diseases & Symptoms
Salmonellae sp.	Salmonellosis
Yersinia enterocolitica	Diarrhea, reactive arthritis, erythema nodosum and Reiter's syndrome, can cause Enterocolitis in young children
Shigellae sp.	Shigellosis
Escherichia coli	Diarrhea, vomiting, fever, abdominal cramps
Staphyloccous sp.	*Staphylococcus aureus*
Enteroccus sp.	Haemolysis
Camplylobacter	Gastrointestinal disease-diarrhea, abdominal cramps, severe cases can lead to Septicaemia, meningitis, reactive arthritis, and haemolytic uraemic syndrome
Vibrio cholerae	Cholera-watery diarrhea and dehydration

Table 2. Bacterial Pathogens with Associated Diseases & Symptoms

Viruses

There are more than 100 enteric intestinal viruses found in human feces thus, these viruses can be expected to be present in waters following CSO discharges (King County

Department of Natural Resources, 1999). Viruses are non-cellular infectious agents that are only able to replicate after its genetic material enters a host cell causing the host to produce viral proteins and nucleic acids (Starr & Taggart, 1989). Rotoviruses, a viral pathogen, are the vector for the most common waterborne illness in the U.S. and are spread through direct contact with infected individuals, contaminated water, and/or other materials (Awwa Research Foundation Webpage, 2002). Common viral pathogens and their associated diseases and symptoms are shown in Table 3.

Viral Pathogen	**Diseases & Symptoms**
Norwalk-like viruses small round viruses (SRV's)	Nausea, profuse diarrhea and projectile vomiting
Enteric non-A, non-B hepatitis	Most cases are Hepatitis C
Hepatitis A	Viral Hepatitis A-jaundice, abdominal pain, loss of appetite, nauseas and diarrhea
Rotavirus	Gastroenteritis
Meningitis	Meningitis-inflammation of the meninges
Poliovirus	Polio
Encephalitis	Encephaltis- inflammation of the brain
Gastroenteritis	Viral Diarrhea-Nausea, vomiting, diarrhea, abdominal pain, myalgia, malaise, low grade fever

Table 3. Viral Pathogens with Associated Diseases & Symptoms

Parasitic Worms

Infestations with helminths, i.e. tapeworms (platyhelminthes) or roundworms (nematodes) can result in severe tissue and organ damage, vomiting, diarrhea, malnutrition, and anemia (King County Department of Natural Resources, 1999). Helminths, otherwise known parasitic worms, can enter the human body through the consumption of raw fish and many other ways, including direct contact with damaged skin. There are numerous types of helminths found in fish and shellfish with most being relatively harmless to humans. Sewage related helminths are typically not a problem in developed countries because of enforced water quality standards, effective water treatment processes, and lower risks of human exposure, i.e. indoor plumbing versus common wells and latrines (King County Department of Natural Resources, 1999). As a result, in this country parasitic worms are considered to be a minor source of sewage related illnesses in comparison to bacteria or viruses.

Organism	Diseases & Symptoms
Parasitic Worms	▪ Abdominal pain ▪ Vomiting ▪ Diarrhea ▪ Anemia ▪ Fever ▪ Anorexia ▪ Hookworm disease ▪ Taeniasis ▪ Coughing ▪ Chest pain ▪ Nutritional imbalances

Table 4. Parasitic Worms with Associated Diseases and Symptoms

Protozoa

Protozoan pathogens are typically motile parasites and predators including flagellated and amoeboid protozoa's (Starr & Taggart, 1989). Protozoan pathogens are disease-causing agents found in wastewater, treated wastewater, CSO discharges, and improperly treated drinking water (USEPA, 2002). Protozoa colonize the digestive tract resulting in severe diarrhea, which can ultimately lead to serious dehydration and nutritional imbalances (King County Department of Natural Resources, 1999). The most common types of protozoan pathogens are found in drinking water and sewage mainly because they are resistant to chlorine treatment are *Giardia* spp. and *Cryptosporidium* spp. Typically, people become infected by these organisms through improperly treated drinking water. The consequences of these illnesses are often debilitating but can be fatal to susceptible populations, i.e. the elderly, infants, people with suppressed immune disorders, or those who have been weakened by other illnesses (King County Department of Natural Resources, 1999).

Organism	Diseases & Symptoms
Protozoa	▪ Gastroenteritis ▪ Acute entertitis ▪ Giardiasis ▪ Dysentery ▪ Toxoplasmosis, ▪ Crypotosporidiosis

Table 5. ProtozoanPpathogens with Associated Diseases & Symptoms

CSOs pose a significant threat to human health. Sewage contains high concentrations of bacteria and viral pathogens in addition to protozoa and parasitic worms, and can lead to illnesses ranging from mild gastroenteritis to life threatening diseases such as dysentery (USEPA, 2002). People can become exposed to these pathogens through direct contact with sewage via recreational water bodies containing CSO outfalls, contaminated drinking water sources, shellfish and other fish harvested from areas contaminated by raw sewage (USEPA, 2002). Therefore, in order to protect the general population and from these potentially life threatening illnesses it is in our best interest to reduce and/or eliminate discharges from CSOs into our local water bodies.

Environmental Health Implications of Combined Sewer Overflows

CSO discharges adversely affect water quality. Excessive nutrient inputs from CSO wastewater can lead to the eutrophication of surface water bodies which negatively impacts dissolved oxygen concentrations and consequently impairs macroinvertebrate and fish communities (City of Indianapolis, 2001). In addition, CSO wastewater can contain metals and toxic organics, byproducts of industrial waste, which seriously threaten aquatic life (MMSD, 2002).

II. Indianapolis, Indiana

History of Indianapolis Combined Sewer Overflows

Around the turn of the last century, many of the city sewers that were constructed were combined sewers. Indianapolis was a growing city during this time and, therefore, much of the older portion of the city, the center of Indianapolis, relies upon a combined sewer system. As the city has grown to its current population of 860,454 people, the wet weather capacity of the combined sewers has decreased in order to accommodate the increase in population that has resulted in an increase in sewage water (U.S. Census Bureau, 2002). In addition, as the city continues to grow, there is an increase in the amount of impervious surfaces, which decreases the amount of rainfall that can be absorbed by the land surface. This decline in absorption of wet weather in combination with the reduced wet weather capacity means that when even small rain events occur, the sewers overflow. There are currently 135 combined sewer outfall points in the Indianapolis region (City of Indianapolis, 2001). Each of these outfalls overflow into the White River basin approximately 60 times per year (City of Indianapolis, 2001). The White River basin drains 11,349 square miles of central and southern Indiana and the city of Indianapolis makes up approximately 60 percent of the population living in this drainage basin (City of Indianapolis, 2001). According to a study done in 1998 by the United States Geological Survey, the degradation of Indianapolis streams was primarily due to pollution from urban areas. The 800 billion gallons of overflow per year due to combined sewers greatly contributes to the stream degradation, as well as, causing potential human health hazards. There are five streams that have overflow points on them. The streams are Pleasant Run, Pogues Run, Eagle Creek, Fall Creek, which all flow into the White River.

In order to address the CSO issues in Indianapolis, the city, along with consultants, have studied the affects of the overflows and developed a Long Term Control Plan (LTCP). The studies found that the streams in Indianapolis are not safe for full-body human contact. The streams have reduced oxygen levels, high fecal bacteria content, and elevated toxic and organic concentrations. The water quality degradation also affects the biotic communities and has even caused fish kills (City of Indianapolis, 2001). Another issue is the smell that the sewer overflows cause in the associated communities. The LTCP goal is to minimize water quality impacts, meet state and national requirements, and control solids and 'floatables' caused by CSOs.

Historical Public Health Issues Relating to Combined Sewer Overflows

The potential for transmission of gastrointestinal diseases exists from direct water contact in areas such as gravel pits, excavated drainage ponds, farm ponds, rivers, and streams, where they have been contaminated by untreated sewage. Specific examples of diseases associated with swimming in sewage-contaminated waters are below (Center for Disease Control and Prevention, 2002).

Disease	**Vector**
Cryptosporidiosis	*Cryptosporidium*
E-Coli-0157:H7	Escherichia coli
Leptospirosis	Leptospira
Primary Amoebic Meningoencephalitis	*Naegleria fowleri*
Shigellosis	*Shigella*
Dermatitis (Swimmer's Itch)	*Schistosoma*
Typhoid Fever and Salmonellosis	*Samonella typhi* and *Salmonella enteritidis*
Viral Gastroenteropathy	
Viral Hepatitis A	*Hepatitis A virus*

Table 6. Diseases Assoicated with Sewage-Contaminated Water

Indiana State Department of Health investigated a total of 32 cases in the Communicable Disease Program (CDP) in 2000. There was an increase of 146% over 1999. Two of these outbreaks were respiratory, while 30 were gastrointestinal. Of the gastrointestinal outbreaks, 12 were food borne, 12 were spread by person-to-person contact, and 6 outbreaks did not have a conclusive transmission route (Pontones, 2001).

Example of a gastrointestinal outbreak in Indianapolis is Shigellosis. In the first half of 2000, Shigella cases began to increase. There were 1315 cases in 2000, compared to 23 cases in 1999, and a median of 22 cases in 5 years (The Health and Hospital Corporation of Marion County, 2002). The Shigella Task Force was created to formulate plans for pubic education and Shigellosis outbreak tracking.

There was evidence of gastrointestinal infections associated with contaminated water in Hendricks County. Several cases of gastrointestinal infections were reported among residents of a mobile home park in July 2000. Many cases indicated that they had experienced plumbing problems or had been exposed to contaminated water within the park prior to illness. The Indiana Department of Environmental Management (IDEM) collected water samples from several sites throughout the park. All tested negative for fecal coliforms; however, some tested positive for total coliforms. This could have been the result of environmental contamination such as leaking sewer pipes into the drinking water system. IDEM noted that the park's water system was deteriorating, and provided alternate water sources to residents (Pontones, 2001).

Out of concern for the health and safety of the public, the Marion County Health Department (MCHD) has started an Ambient Sampling Program. The program collects samples five times per month, with geometric means calculated for each site's E.coli data. Sampling locations include nine sites along Fall Creek, 21 sites on Pleasant Run, 21 sites along Bean Creek and six sites on Pogues Run. Under the Public Access Sampling Program, MCHD has also collected monthly grab samples for E.coli from major waterways during the recreational season over the last ten years. Warning signs are then posted where E.coli levels are found to exceed the 235/100ml State Water Quality Standard. There are approximately 80 signs posted along 60 sampling sites (MCHD, 2002).

Long Term Control Plan

Indianapolis is required by the EPA's CSO Control Policy to assess the current CSO situation, implement minimum controls to reduce the impact of CSOs, and to create a Long Term Control Plan. The plan was created by the Indianapolis CSO project team, which consists of staff from the Department of Public Works working with three consulting firms, with input from the mayor's CSO Advisory Committee and the Wet Weather Technical Advisory Group. The resulting proposed LTCP is controversial. Members of the Sierra Club have testified against it at public meetings and Improving Kids' Environment has filed a civil rights complaint with the EPA for the disproportionate impacts of the LTCP on African American communities in Indianapolis (Miles, 2001, IKE 1 2002). The complaint has been accepted by the EPA and is currently being examined.

Indianapolis must meet a number of challenges in order to effectively manage its watershed. Along with having problems with CSOs, the city's sewers operate at close to their full capacity during heavy rain events, while there are additional pollution problems from damaged and leaking septic systems and pollution from upstream of the city. In addition to the existing problems, the city's current rate of growth ensures that its existing sewer system will not have enough capacity to serve all of Marion County in the future unless large-scale improvements are made. The CSO problem has resulted in dissolved oxygen (DO) levels in the White River low enough to cause fish kills, bacterial contamination, and impaired biotic communities in both the White River and its tributaries.

The proposed Indianapolis Long Term Control Plan (LTCP) aims to control CSOs and improve the sewer system by making use of a number of policy initiatives and technologies. First, the city proposes to put sewers in unsewered areas and connect these neighborhoods to the sewer system, taking them off their septic systems. The plan also includes measures to further utilize the existing capacity of Indianapolis' system, such as real-time controls governing inflatable dams and gates. These systems will close off overflow pipes in wet weather, storing water that would normally overflow into creeks and canals. A proposed stream bank restoration to revegetate areas close to CSO outflows will improve the water quality of CSO-affected streams. Measures are also proposed to control water moving into the system by implementing controls on large paved areas, such as at the campus of Indiana University-Purdue University Indianapolis and local hospitals, as well as the cleaning of storm basins and increased street sweeping. The plan also outlines sediment removal in the White River and tributaries to improve DO levels. A storage tunnel may be built along Fall Creek that will be able to capture 51 million gallons from a consolidating sewer that will collect outflows from the CSOs along Fall Creek, while a 15MGD dry/60MGD wet weather Fall Creek Water Reclamation Facility may be built to drain the storage tunnel. The proposed LTCP further outlines how dams and aeration systems could be installed at various points along Fall Creek in order to improve flow along the creek and increase DO levels. Adding in-line storage to sewers along Fall Creek to prevent overflows at seven CSO locations has also been discussed. At Pleasant Run, a relief interceptor could be constructed in order to divert flow to the Belmont WWTP. Along Pogues Run, a number of storage tanks and inflatable dams are proposed to improve in-line storage. A Pogues Run wetland will possibly be constructed south of I-70 to reduce the pollutant load from CSOs and non-point sources. The proposed LTCP also proposes expansions to the Belmont Wastewater Treatment Plant, including the addition of 125 MGD Bioroughing Solids Clarification and 125 MGD of additional treatment capacity, while the Southport treatment plant could be upgraded with a 150 MGD secondary treatment addition. If the proposed interplant sewer is constructed, it will allow 70MGD to be diverted from Belmont to Southport, which traditionally experiences lower wet weather flows than Belmont. The plan also includes the construction of an underground storage facility, which would allow for 27MG of storage. Along Eagle Creek, a relief interceptor to divert flow to Belmont WWTP is also proposed for construction. A number of other dams and aeration projects may be built at other areas to improve flow and DO levels, as well as two more storage tanks to hold sewage. Mars Hill is the only area in the plan, targeted to undergo sewer separation (LTCP, pp7-12—7-15, 2001).

The Indianapolis LTCP is estimated to cost over a billion dollars, and it is likely that it will cost more. The WWTP expansion, including the interplant connection, will cost over $200 million and the Fall Creek Water Reclamation Facility, Storage Tunnel, and sewer improvements will cost more than $250 million (LTCP, p7-6, 2001). The cost of converting septic sewer homes to city sewer service is not factored into the plan, and will entail a large cost burden on the proprietors of these homes. Critics of the LTCP note that the plan does not take into account population growth in Indianapolis. If the plan is implemented as it currently stands, the system’s capacity will be overburdened again in a decade or so. Marion County grew around 8% between 1990 and 2000 (United States Census Bureau 3, 2001). Loading of the system will continue to increase as Indianapolis’ population increases. One of the priorities of Indianapolis’ government is to draw new citizens in, if the LTCP is implemented as it stands, the sewer improvements in it may not be enough to support the wastewater burden of Indianapolis’ new inhabitants.

In 2000, Senate Enrolled Act 431was signed into law. SEA 431 institutes statutory CSO controls, including deadlines for action. SEA calls for the complete implementation of the nine minimum controls and conforms to existing national and state CSO policies. It further requires some classification of streams and canals to determine their usage and risk to the public, as well as what organisms may be found there. While the determination is being made, the Act suspends designated uses rules used to determine water quality criteria, effectively suspending water quality rules. A number of conditions must be fulfilled before the water quality rules are suspended. A system to notify the public during outflow events will be implemented. The Act also mandates an analysis of costs to the city. SEA 431 does not require elimination of CSOs and is intended to curb the expense of the LTCP (SEA 431, 2000). Critics of the act propose that the reclassification of streams and canals is a means of suspending water quality standards indefinitely (Great Lakes Aquatic Habitat News, 2000).

Initiative	Cost (millions)
System-wide: sewering unsewered areas, real-time controls, streambank restoration, source control, sediment removal, and LTCP updates	$58.9
Fall Creek: storage tunnel, water reclamation facility, consolidation sewer, dam modification, aeration, and in-line storage	$261.2
Pleasant Run: Relief Interceptors to Belmont WWTP	$51.0
Pogues Run: storage tank, consolidation sewer, storage in Pogues Run box, wetlands	$56.2
White River: WWTP improvements, storage & conveyance tunnel, relief interceptor, aeration, dam modification, and in-line storage	$402.1
Non-construction and contingency cost (35% of capital cost)	$212.7
Total	$1042.1

Table 7. Table of Initiatives and Costs by Location

Environmental Justice Implications of Combined Sewer Overflows

On October 20, 1999, an environmental organization called Improving Kids' Environment (IKE) filed an unprecedented civil rights complaint with the Environmental Protection Agency (EPA) against the City of Indianapolis for environmental injustices that result from combined sewage overflows (CSO). IKE claimed that the city's policies and procedures had discriminatory effects on the residents of neighborhoods along Fall Creek and White river on the north and near-west sides of Indianapolis (IKE 2, 2002).

The complaint states that the city encourages continued degradation of CSOs by encouraging development on the North and northeast sides of the City. By constructing roads and providing tax abatements, the city is inviting new hook-ups to a sewer system that is already strained (IKE 1, 2002). Although these new developments separate the sewer and stormwater flow, their sewage is still conveyed through the Lower Fall Creek and Middle White River neighborhoods as it makes its way to the treatment plants. Because residents of these new housing developments on the outskirts of the city are predominantly white higher income individuals, racial injustice from increased flow feeding CSOs in minority neighborhoods may have indeed occurred. While the complaint does not allege intent to discriminate, it seeks to leverage federal funding to eliminate the disproportionate impact of CSOs on minority communities while requiring the "right-to-know" for these communities when overflow events occur.

After receiving the complaint on November 9, 1999, the EPA had the discretion to accept or reject it. This process normally triggers a 20-day review period for the EPA to make its decision. However, the EPA claimed it is overloaded with pending cases and lacked the resources to review the complaint in a timely fashion (IKE 2, 2002). The Hoosier Environmental Council, Sierra Club and the Concerned Clergy of Indianapolis all added their signature to the complaint.

On October 12, 2001, the EPA accepted the complaint for investigation. IKE has agreed to suspend further action on the investigation pending the results of regular meetings between the EPA, Indiana Department of Environmental Management (IDEM) and the City of Indianapolis (Neltner, 2002). These discussions are still ongoing. In the meantime, the residents of the Lower Fall Creek and Middle White River neighborhoods must endure potential pathogen exposure and offensive odors from the effects of raw sewage at close proximity to their homes and parks. Despite posted signs warning of contamination danger, graffiti and well-worn trails provide evidence that children play in and along the streams.

Social Implications of Combined Sewer Overflows

Indianapolis' combined sewer overflows; located within the old city limits and within residential areas, create sources of water pollution and hazards to human and environmental health. As discussed in previous sections of this report, the sewage overflows contain raw sewage, bacteria, viruses, industrial chemicals, "floatable" items flushed down toilets, and other pollutants making these streams unsuitable for recreational activities such as fishing and swimming. Residents living, working, and attending school next to or downstream from combined sewer overflows suffer from foul smells and hazardous pollution in their neighboring waterways. Although the Marion County Health Department has posted warning signs on stream banks at combined sewer overflow locations, people, especially children, continue to use the polluted waterways for recreation. The Monroe County Health Department places at least one combined sewer overflow warning sign at each outfall location, with additional signage at heavily frequented locations (Personal Communication, Pam Thevenow April 2002). However, the warning signs are located approximately six feet off of the ground without bilingual notices, making it difficult for children and Spanish-speaking citizens to read and understand the warnings.

The city of Indianapolis has created a combined sewer overflow education and outreach program to inform citizens of the dangers of sewage overflow events and the steps the city is taking to control these events to improve water quality in area streams. The Department of Public Works (DPW) is charged with maintaining public infrastructure (including streets, sewers, bridges, and traffic systems) and with managing municipal solid waste collection and disposal. DPW also ensures a healthy, safe, and natural environment (air, land, and water), which includes monitoring and controlling combined sewer overflows within Indianapolis (DPW, 2002). The DPW has created a web site entitled Improving Our Indianapolis Waterways: City of Indianapolis Planning to Control Sewage Overflows (DPW, 2002). This website was formed to educate the public on sewage overflow planning and public participation. It includes an overview of the issue as well as links to the CSO related documents, including the proposed Long Term Control Plan and the CSO Report. The CSO Report was written in June of 2000 as a report on options for controlling sewage overflows. The report outlines all of the options the city has to control CSOs as well as the reasons why some options were chosen over others. This document is located at all Marion County Libraries and an abbreviated form is handed out at public meetings. Indianapolis has held public meetings throughout the city in locations such as churches, the city-county building, public schools, and libraries to increase public participation. Notices of the meetings are posted in local newspapers and advertised by citizens' groups. Furthermore, the city has extensively used the Internet as a means of educating the public on combined sewer overflows and encouraging public participation.

A further education and outreach program created by the city of Indianapolis is called the WaterWise Initiative, which strives to make the public aware of ways they can help clean up waterways and become more aware of the sources of pollutants that affect rivers and streams. A link to combined sewer overflow information is located on this web site and encourages the public to participate in public meetings concerning combined sewer overflows (WaterWise, 2002). Additional information can also be found on the IndyEcology web page, which has links to numerous water related Indianapolis issues and information (IndyEcology, 2002).

The combined sewer overflow issue affects Indianapolis residents not only from an ecological and health aspect, but from monetary aspects as well. The city has imposed a $1.94-per-month sewer bill increase, effective in 2001, to help pay for treatment plant upgrades and for future design and engineering work on sewage overflow control alternatives (City of Indianapolis, 2000). Additional sewer bill increases are anticipated for the future once the sewage overflow control alternatives are chosen, but the city claims the increases will stay within a reasonable and affordable range. Currently, Indianapolis residents pay approximately $10.91 per 7,000 gallons, which is a relatively low fee when compared with other cities reviewed in this report (City of Indianapolis, 2000). The city claims that in order to control combined sewer overflows in an affordable manner, they need public input and participation on the rate of increases for sewer bills. Furthermore, the city is attempting to provide sewer service to areas with septic systems to reduce the occurrence of failing septic systems. There are approximately 18,000 homes within the city limits with septic systems. These residents will be required under the Barrett Law to pay a contractor to connect their homes to the city's sewage, pay to have their septic tank disconnected and filled, and pay approximately 10% of the assessed value of their home to have the city put in sanitation sewers in the city-county streets (Personal Communication with Glenn Pratt January, 2002). Citizens groups are working with the city-county government to have this payment process changed, with the city paying more of a share of the cost. The fear is that many homeowners will not be able to pay the high expenses and have to foreclose on their homes. The expense of converting septic systems to city sewers and the potential of an increased sewer bill is the cause of concern of local citizens groups such as Improving Kids' Environment (IKE), the Sierra Club, the Hoosier Environmental Council (HEC), and area neighborhood groups which have been actively involved with the Indianapolis combined sewer overflow issue. Indianapolis environmental and social justice groups such as these and others have banded together through lobbying and community outreach to bring public awareness to combined sewer overflows and their implication on human health and the environment. Specifically, IKE has created an Indiana CSO Scoring system for Indiana citizens to score their communities based on combined sewer overflow issues (IKE 3, 2002). The organization has also written articles about Indianapolis' combined sewer overflows to educate and mobilize area citizens.

Future Implications of Human Health Issues

Indianapolis is currently working towards controlling combine sewer overflows by utilizing in-line storage with real-time control, expansion of the wastewater treatment plants, and partial sewer separation. This means that Indianapolis will be able to control about 85% of combined sewer overflows, causing the risk for raw sewage exposure to the citizens of Indianapolis to become greatly reduced, but not eliminated. Consequently, outbreaks of shigellosis, Hepatitis A, and cryptosporidious will still be possible for children and adults playing near Indianapolis's streams and rivers (IKE 3, 2002). All of the previously mention diseases will continue to be a problem for the city until CSOs are contained and the water can be properly treated. Essentially, Indianapolis is taking great strides to reduce the occurrences of these diseases, but they will always be a part of the human health landscape as long as combine sewer overflows continue to dump raw sewage into the streams and rivers. Smaller communities such as Lansing, MI, will eliminate a route of exposure to shigellosis, Hepatitis A, and cryptosporidious, by completely separating their sewer system and thus will eliminate CSOs.

CSOs also create a problem for the river or stream ecosystem that they are discharged into. The high organic content of the raw sewage reduces the amount of dissolved oxygen available for wildlife, which can make the water body more prone to anoxia (Schwarzenbach, 1993). An anoxic event can cause massive fish kills in rivers and streams, which reduces the health of the environment. Indianapolis has had several fish kills in its streams in past years and can continue to expect to have them until the city can contain all of its CSO discharges. Additionally, CSO discharges contribute to nutrient loading and increased turbidity, which can affect the aquatic vegetation in the water body. The rivers and streams in Indianapolis may always feel the impact of CSOs, because the proposed Long Term Control Plan only calls for an 85% capture of discharges.

III. Using GIS to Evaluate Environmental Justice in Marion County

Political leaders continue to reaffirm citizens' right to know about possible health hazards from combined sewage overflows (CSO) located in their neighborhood. Yet, due to the complexity of risk characterizations, it is extremely difficult for the average citizen to discern the relative risk posed by CSOs. This independent study will shed light on the social structures of risk by developing a graphical representation based on E.coli levels found at water quality monitoring sites in the CSO area for Indianapolis, Indiana.

Using a geographic information system (ArcGIS version 8.1), this study will look at the extent of the spatial coincidence between the location of CSOs and minority/low-income residence. Utilizing data from the Indianapolis Department of Public Works (DPW), the Marion County Health Department and the U.S. Census of Population and Housing, the paper will address the following questions:

- Do minority and low-income communities in Indianapolis/Marion County bare a disproportionate share of combined sewage overflow sites?

- What are the areas at risk for potential E.coli exposure in Marion County?

The results of this study are not intended to describe individual risk. Instead, this approach serves as an initial screening tool to be used by municipal and county governments, as well as community organizations, for the purpose of identifying potential at-risk communities and prioritizing projects for CSO abatement.

Injustices based on proximity to CSOs will be evaluated at the following scales:

- County to CSO area
- County to CSO point (where pipe meets the stream) buffers
- CSO area to CSO point buffers
- County to census tracts with CSOs
- CSO area to census tracts with CSOs

E.coli is measured in colony forming units (cfu) per 100ml sample. The Marion County Health Department recognizes a level above 235 cfu to be a potential human health risk. A map of hot spots (highest levels of E.coli) will provide incite into which areas of Marion County have higher potential exposure to harmful E.coli bacteria.

Data Sources

Water quality data has been obtained from the Marion County Health Department. This data has latitude/longitude coordinates (State Plane projection, NAD_83) for a quarter of their monitoring sites. The rest of the health department's monitoring sites are given by crossing street to stream.

Combined Sewer Overflow sites are given as point coordinates by the DPW in a shapefile (Transverse Mercator projection, NAD_83). Information on streams and streets has also been provided by the DPW. Demographics and boundary files for census tracts were obtained from the1990 TIGER files of the U.S. Census of Population and Housing through the Social Assets and Vulnerabilities Indicators (SAVI) website and the Environmental Systems Research Institute (ESRI) Geography Network.

Methods

The lat/long coordinates for the water sampling points were given in degrees, minutes, and seconds. These points were converted to decimal degrees and a spatial database was built in ArcInfo Workstation. This coverage was defined in State Plane projection (Indiana East) for North American Datum (NAD) 1983. The Health Department's data were converted to the Transverse Mercator and the units set to feet. The remaining E.coli water sampling points were placed manually by looking up crossing street to stream in ArcMap using the Editor tool.

Referring to Excel spreadsheets on water quality provided by the Health Department, a separate spreadsheet was created for all water-sampling points with annual averages of E.coli amounts. Averages were not included for years with less than 5 months of sampling data. E.coli annual averages were averaged together by site to provide consistency for sporadic sampling among sites occurring from 1996 to 2001. This spreadsheet was saved in database4 format and converted to an Info Table in ArcToolbox. This table was then joined to the water sampling points by the "Feature ID" field.

Census data taken from the SAVI website included information on other counties besides Marion County. The Editor tool was used to delete census tract polygons for areas outside Marion County for both income and race shapefiles. Buffers were created around the CSO points at 1 mile, .5 mile and .25 mile. These buffers were used to clip census tract data on income and race at various distances. The CSO area shapefile was used to clip census tracts from the Marion County data to provide a different perspective on the effects of scale in this analysis.

All data for the clipped census tracts (income and race) were exported to an Excel spreadsheet were duplicate tracts could be removed and averages taken. Z-tests at the 95% confidence level were run for all comparisons to determine if there were significant differences between the populations (Marion county or CSO area) and samples (buffers).

Results

Monitored water quality sites were ranked by the amount of E.coli found during sampling efforts across a 6-year time frame. E.coli levels were averaged by year and averaged across years per site to obtain an estimate of the potential exposure at a certain location. The top 20 worst locations are listed below with the first row being the site with the highest temporal average of E.coli and decreasing by row.

Pogues Run was listed 10 times in the top 20 worst E.coli sites. Gadsden Street on the State Ditch is located outside the CSO area but it had the highest E.coli site average. This site is located just south of a major industrial area - Park Fletcher Industrial Park to the west, Reilly Tar and Chemical Industries to the north and the Indianapolis Disposal Plant to the east. The sites with the lowest levels of E.coli that are not considered a health risk were all found on the Upper White River. See Table below for an estimate of the range of total E.coli levels per year.

	1996	1997	1998	1999	2000	2001
Minimum	80	64	104.29	71.43	57.14	100
Maximum	38040	140000	16650	14657	43235	37767.14
# of sites sampled	29	45	45	36	42	47

Table8. E.coli Results by Year

Ethnicity was determined by percentage of white population. For example, an 87% white population in a census tract means there is a 13% minority. Minority populations include: African American, Asian, American Indian, and Hispanic. For Marion County there was a 26% minority population while the CSO area contained a 36% minority. Average household income was $29,039 for Marion County and $23,740 for the CSO area.
To determine the coincidence of CSO location in census tracts with low income or minority populations, a hypothesis was designed to test the assumption that there was no difference between the mean compressive strength of the Marion County census tracts and the mean compressive strength of the census tracts captured by the buffer(s). The alternative hypothesis was the rejection of the null, indicating a significant difference between population and sample means. The rejection of the null hypothesis may indicate the potential for environmental injustice related to the location of CSOs by income or race. Results of the z-tests and corresponding p values are contained in the following table.

Test at 95% confidence level	Race	Income
County to CSO area	yes	Yes
County to census tracts with CSOs	no	Yes
CSO area to census tracts with CSOs	no	No
County to 1mi buffer	yes	Yes
County to .5mi buffer	no	Yes
County to .25mi buffer	no *	Yes
CSO area to 1mi buffer	no *	No
CSO area to .5mi buffer	no	No
CSO area to .25mi buffer	no	No
*p value outside of confidence range (Null Hypothesis may not be true)		

Table9. Significant Difference Found

Many CSOs are present in census tracts with a high percentage of white population, up to 99% in some areas. Although there are some census tracts with CSOs having a large minority population, the wide range of racial proportions balanced out any correlation that might indicate bias. However, on the county level, racial and income bias was statistically present. The income characteristic had a stronger correlation toward environment injustice than race. Income bias was seen at all buffer zones around CSO points. However, bias was not seen when comparing the CSO buffers to CSO area.

Conclusions

Environmental Justice implications depend of the analysis of scale for the study area. In general, the larger geographic units of analysis tend to generate a greater potential for bias recognition. Marion County has a ring of predominant white, higher income census tracts on the outskirts of Indianapolis. This may be due to urban sprawl and the ability of some ethic groups to escape pollution and crime often see in the inner city by moving to the city's edge. Inner city residents are often limited to residential options and have less resources to spend on environmental factors (Burke, 1993). When comparing CSO tracts to the county level, it is not surprising to see that bias was found for both income and race.

This study serves as an opportunity to investigate several methods of viewing environmental justice. As you can see from the results, the study area boundaries have a significant effect on the decision of injustice. For this reason, comparing CSO census tract demographics to the CSO area may be a more accurate representation of actual bias. The problem with CSOs does not occur on the county's edge. It occurs in the inner city where old pipes and infrastructure exist. Comparing CSO census tracks to other tracks in this same inner city region provides a more defined picture of where the problem areas are located.

The mapping of high E.coli levels reveals Pogues Run and the State Ditch to be two areas of particular risk of exposure to E.coli. The State Ditch is dry during most of the year.

When water is present, it is usually due to rain events and the combined sewer overflows that follow. Sampling during or after a significant rain event may be the cause of such extreme levels of E.coli found in this area.

Pogues Run, especially, is an at-risk community due the number of schools and concentration of residential neighborhoods around the stream. Of the 10 water quality sampling points on Pogues Run, five had site averages of 7600 cfu and above. Researchers and policy makers should understand the dynamics that may have produced a particular pattern of bias so they can separate those factors that are amenable to change from those that are not (Wagener, 1993). Prioritizing areas of potential high risk to human contact with E.coli can lead to a more comprehensive CSO abatement program that seeks to correct injustices in an efficient and timely manner.

Limitations of Study

This analysis was based on 1990 census data because 2000 data on demographics has not yet been released. This outdated data invites error in showing realistic representation of current minority and low-income groups for Indianapolis. As accuracy of data becomes dated, the variables for evaluating risk become less significant (McMaster, 1997).

Because CSO points and water quality data were not in the same spatial context (site for site match), correlations of E.coli levels and their direct cause from outfalls can only be assumed. In a perfect world, it would be best to have water quality data above, at and below all CSO outfalls in regular time intervals over the course of several years. However, limited Health Department staff and the need for new information at other sites dictates where and to what extent sampling will occur. Some sampling sites that consistently gave similar data along the same stream course were consolidated to key areas for sampling efficiency.

Although the Health Department was geometric mean in many of their records on E.coli, this study aggregated annual and site specific data by the method of averaging. This may have lead to a bias in analysis results. Future studies of at-risk communities should include geometric mean as a data-aggregating tool. In addition, risk should be evaluated by individual stream for years with the most conclusive data. Breaking up the site analysis by year could show deterioration or improvement of specific combined sewer overflow areas.

IV. <u>City Comparison Indices</u>

Introduction and Goals of Indices

The control and eradication of combined sewer overflows has recently gained national attention with the §402 amendment to the Clean Water Act in 2000. This amendment requires that all subsequent policy associated with water quality must comply with the Combined Sewer Overflow Control Policy. Cities are required to establish Long Term Control Plans that directly address combined sewer overflows. Indianapolis is currently developing and refining their Long Term Control plan as well as the technology to control overflow events. Other cities in the United States, particularly in the Midwest and East, also have numerous combined sewer overflows and are currently addressing this policy enforced by the EPA.

The purpose of this study is to compare Indianapolis' Long Term Control Plan as well as relevant combined sewer overflow control technology and policy with other United States cities' Long Term Control Plans and related combined sewer overflow control methods and policy. Nine additional cities were chosen to evaluate with four indices. The cities selected were Cincinnati, Cleveland, Columbus, Detroit, Louisville, Milwaukee, Pittsburgh, St. Louis, and Seattle. The indices were broken down into four categories, Financial, Social, Technology, and Water Quality. The information gathered for each city index came primarily from contacts within the specific city departments that address combined sewer overflows and their related issues. Information was also received from regional Environmental Protection Agency staff and related web sites. Each city was then scored based on the presence or absence of specific criteria used to address combined sewer overflows. Indianapolis was also scored using the same index so that we could rank the cities based on the evaluated criteria to determine how Indianapolis compares to other cities with combined sewer overflows. We also utilized information from our research and indices scoring system to produce recommendations for Indianapolis as to how they may improve certain aspects of their Long Term Control Plan.

Methods for City Selection

The selection of cities for this project was difficult because every city varies in geography, population, extent of CSO problem, and political situations. Consequently, several categories were used to make the city selection. These categories included: city and county population, number of combined sewer overflow outfalls, proximity to Indianapolis, type of receiving water body and many other categories. St. Louis, Columbus, Cincinnati, Louisville and Cleveland were all chosen because of their proximity to Indianapolis, their similar size and their number of outfalls. Detroit, Seattle, Milwaukee and Pittsburgh were chosen because of their number of outfalls and county populations. All of the cities except Cleveland, Seattle, and Milwaukee discharge into rivers and streams. The river volumes, however, vary greatly between cities, for instance St. Louis discharges into the Mississippi River while Indianapolis discharges into Fall Creek. Cleveland and Milwaukee discharge into Lake Erie and Lake Michigan, respectively. Seattle discharges into Puget Sound. These cities provided a good mix of characteristics that were useful to help determine how Indianapolis is performing on the combined sewer overflow issue.

City Descriptions

Cincinnati, OH

The Metropolitan Sewer District of Greater Cincinnati (MSD) was created by an inter-government agreement in 1968 that consolidated most of the wastewater collection and treatment systems in 33 municipalities in Hamilton County, Ohio, serving 800,000 customers (MSDGC, 2002). MSD is owned by the county and managed by the City of Cincinnati. The wastewater collection system includes over 3,000 miles of combined and separate sanitary sewers and 165 pump stations (Cincinnati Water Works, 2002). Cincinnati has 251 combined sewer overflows that average an annual discharge of 6.2 billion gallons. The management of a flood wall protection system consisting of 14 removable sections (or gates) in conjunction with the operation of a large flood barrier dam and pump station that protect Cincinnati from the Ohio River are also the responsibility of MSD.

As common to older urban areas, some of the sewers date back to the 1820's. The sewer system delivers an average of 200 million gallons per day (MGD) to twenty-three treatment plants ranging in capacity and complexity from 130 MGD to small "package plants" serving a few dozen homes (Minges, 2002). Working to eliminate sanitary sewer overflows, the MSD is evaluating the construction of a large, deep tunnel that would hold storm water until it could be properly treated.

In accordance with the comprehensive capital improvement program, MSD is making an extensive effort to protect and enhance the quality of its receiving waters. Flow monitors have been set up throughout the sewer system to record the depth and velocity of flow in the pipes (MSDGC, 2002). This data will provide information to a computer model for the purpose of responding to storm events. Along with GIS, new technology is playing a critical role in the control of combined sewer overflows by providing cost-effective tools and information for managers.

Cleveland, OH

Cleveland, Ohio, located in Cuyahoga County, is 77.6 square miles and has a population of 478,403 people (U.S. Census Bureau, 2000). The Northeast Ohio Regional Sewer District (NEORSD) is charged with providing efficient and environmentally responsible management of the area's waste and storm water (NEORSD, 2002). The NEORSD serves about one million customers in a total area of 355 square miles. About half of the service area is on combined sewer drainage and the rest is on separate sewer drainage. The first combined sewer system was established in the 1870's. There are about five billion gallons of CSO discharges per year from 126 outfalls in nine communities (Greenland, 2002).

Currently, NEORSD is on the second phase of LTCP, which has been approved by the Ohio Environmental Protection Agency (OEPA) in March 2002. Total estimated expenditures are $1.2 billion. Approximately $268 million spent to date on CSO control.

$54 million of that were from the USEPA grants. Approximately $1 to $1.1 billion of remaining CSO control is for construction which finances by State of Ohio revolving loan. Thus far the city has constructed major separate sanitary interceptors to route separate sanitary sewage from suburban areas directly to WWTPs. It reduces CSO volume by approximately 400 million gallons annually. Recent construction includes underground tunnel of 20 to 24-foot-diameter to hold untreated overflow and expanding Easterly WWTP capacity resulted from stress test. Present controls include 29 auto regulators, inflatable dames, and hydraulic structure for inline storage. The NEORSD has started real time monitoring since early 1970s. The CSO operation and maintenance revenues come from user fees (Greenland, 2002).

The NEORSD has three WWTPs under its jurisdiction that serve the Cleveland metropolitan area; Easterly, Westerly, and Southerly. They discharge to Lake Erie, Rocky River, and Cuyahoga River, including Big Creek and Mill Creek. The three WWTPS treat a total average of 363 million gallons of wastewater per day and has a maximum wet-weather capacity of 830 million gallons per day. In addition, Southerly can provide primary treatment for a maximum of 735 million gallon per day during wet weather (NEORSD, 2002). The city of Cleveland has demonstrated an effort to control combined sewer overflows. The current goal is to limit number of overflows to 4 events per year.

Columbus, OH

The city of Columbus, Ohio, located in Franklin County, is 212.6 square miles with a population of 711,470 people (U.S. Census Bureau, 2000). The Columbus Division of Sewerage and Drainage (DOSD) is charged with providing efficient and environmentally responsible management of the area's waste and storm water (DOSD, 2002). The DOSD services a total area of approximately 100,000 acres within Columbus and a large portion of Franklin County. The service area includes 5,286 acres of combined sewer drainage, which represents 5.2 percent of the current service area (OEPA, 1999). Columbus has a relatively small number of combined sewer overflows (31) and combined sewer overflow events (10-12 per year) when compared to the other cities in this report. Although the city has not yet submitted a LTCP to the Ohio Environmental Protection Agency (OEPA), Columbus updated their Metropolitan Facilities Plan in 2000, which was submitted to the OPEA for incorporation into their 208 area wide plan. The plan addresses regional wastewater planning through 2020 and includes combined sewer overflow control and elimination (Mohr, 2000). Columbus is currently working with the OEPA to finalize a LTCP and has been issued a new storm water NPDES permit by the agency on July 1, 2000. Monthly effluent reports are submitted to the OEPA by all NPDES permitted discharging entities such as the city of Columbus (OEPA, 1999). The city has controlled and eliminated combined sewer overflows primarily through a capital improvement project with a budget of over $100,000,000, begun in 2000, which incorporates such technology as sewer separation, sewer rehabilitation, and trenchless technologies. The DOSD operates innovative programs such as Industrial Pre-Treatment Program, Surveillance Laboratory services, Stormwater Management's Erosion and Sediment Control program, and a compost facility, as well as, public outreach and education programs.

The DOSD has two WWTPs under its jurisdiction that serve the Columbus metropolitan area, Jackson Pike and Southerly, that discharge to the Scioto River. The two City of Columbus WWTPs treat a total average of 151 million gallons of wastewater per day. This is generated not only by Columbus households and businesses, but most of Franklin County. Over 20 other municipalities contract with Columbus for wastewater treatment facilities (DOSD, 2002). The plants have each been awarded with Gold Awards by the Association of Metropolitan Sewerage Agencies for achieving 100 percent compliance with NPDES permits from the OEPA. Less than one dozen plants in the nation have received this honor or status (Mohr, 2000). Beginning in 1989, both the Jackson Pike WWTP and the Southerly WWTP began upgrading their facilities with such cost saving improvements as centrifuge fume hoods to reduce maintenance costs and methane gas capture for reuse in the plant. In addition, a large interconnector sewer was constructed connecting the Jackson Pike WWTP with the Southerly WWTP thus enabling some sewage flow to be diverted to the Columbus Southerly WWTP for treatment and allowing the Jackson Pike WWTP to maintain a high degree of treatment. The city of Columbus has demonstrated innovative technologies to control combined sewer overflows as well as storm water and wastewater management and could be used as a model for similarly sized cities in these areas.

Detroit, MI

The City of Detroit is involved in the Rouge River National Wet Weather Demonstration Project that started in 1992 (Wayne County Department of Environment, 2002). The project encompasses 438 square miles and 1.5 million people. This area includes 48 communities spread across three counties. Prior to the implementation of the project 127 miles of rivers and streams were impacted by combined sewer overflows. This project was started to eliminate the major source of pollution for the Rouge River, combined sewer overflows. The Rouge River and its tributaries were not meeting the Michigan dissolved oxygen standard of 5 mg/L.

The LTCP developed to help combat this problem in the Metro Detroit Area included three phases (Wayne County Department of Environment, 2002). The goal for phase one was to eliminate raw sewage and protect the public health for 40% of the combined sewer area. Phase two's goal consisted of protecting the public health for the remaining combined sewer area. Phase three will be complete when the Rouge River meets Michigan Water Quality standards. Currently, the project is somewhere between Phase One and Phase Two.

Detroit receives funding for this project from several different sources. The Federal and State Government's have provided grants to the Rouge River project that do not have to be paid back. Additionally, bonds have been issued to help pay for some of the infrastructure needed in this project. The estimated cost of this project is around 3 billion dollars.

Louisville, KY

Louisville is a unigovernment or a city-county government system. The Louisville/Jefferson County Metropolitan Sewer District (MSD) was created in 1946 as a non-governmental, non-public agency and considers itself a "public body corporate and subdivision of the Commonwealth of Kentucky" (LVMSD: 2001 Financial Report, 2001, p.2). As of 2000, the Louisville MSD has served a population of 693,600. According to the MSD's 2000 Strategic Plan there are seven factors which must be met to achieve success and excellence in customer service: customers first, environment, employees, performance, economic growth, public awareness/involvement and financial resources (LVMSD: 2001 Financial Report, 2001). There are a total of 6 main treatment plants and 28 smaller plants within the entire sewer system. The six main plants are Morris Forman, West County, Hite Creek, Cedar Creek, Jefferstown, and Floyds Fork. The total wastewater treatment system's average daily flow is 122 million gallons (mg), while the design capacity is 158mg, and the eventual capacity is 179mg (MSD: WWTP, 2001)

The district has approximately 122 CSOs, which contribute to the pollution of Beargrass Creek and the Ohio River. Many of these sewer lines date back 125 to pre-civil war and are made of only brick and stone (LVMSD: Inside, 2001). They are constantly up-dating their system with new technological advances to reduce the impact of CSOs on water quality. Some of the most recent advances include the construction of the new Floyds Fork Wastewater Treatment Plant in 2001, with a capacity of 3.25 million gallons per day. This Treatment Plant includes an environmental education center, which was planned in conjunction with the Jefferson County School Corporation. Also in the year 2001, the MSD installed 45 rain gauges, 11 of which have been connected to a radio telemetry system. This system allows real-time data retrieval via Internet every 5 minutes (LVMSD: 2001 Financial Report, 2001). The MSD has implemented a variety of other measures to reduce CSOs that include dams, sewer separation, in-line storage, and net bags for solids and floatables. The MSD considers the Long-term Control Plan as an on-going project and has no specific date of completion (CSO Program History, 2002).

One of the most impressive of the MSD's achievement is it participation in the US Environmental Protection Agency's Project XL (eXcellence and Leadership) Program. The Louisville MSD was chosen out of 5 sewer districts Nationwide. This program is administered as a pilot study that will determine what are the most cost-effective strategies can be used to reduce pollution from industrial sources. Both parties signed the final agreement for this project on September 2000 (MSD-News Release, 2000).

Milwaukee, WI

The Milwaukee Metropolitan Sewage District (MMSD) is a state-chartered governmental agency that provides wastewater services to 28 municipalities and approximately 1.2 million people (MMSD, 2002). The District encompasses 420 square miles and contains 2,220 miles of collector sewers and 310 miles of intercepting and main sewers. The MMSD was created in 1921 in an effort to improve water quality in Milwaukee's local rivers and Lake Michigan. The MMSD was given the task of designing and constructing a complete sewage treatment system because the city's original system, built in 1868, did not provide for any sewage treatment (WI Department of Natural Resources, 2001). MMSD operates two wastewater treatment facilities, the Jones Island and South Shore WWTP (WI DNR, 2001). Together these two wastewater treatment facilities collect and treat approximately 200 million gallons per day (MMSD, 2002).

In 1994, the MMSD began the operation of the Inline Storage System (ISS). The ISS, or Deep Tunnel, was built to combat the problem of CSOs by transporting and storing wastewater during excessive wet weather events (WI DNR, 2001). The ISS was determined to be the most cost effective abatement system for Milwaukee because it did not require the construction of a new sanitary sewer system but rather a large storage basin located 300 feet below ground (WI DNR, 2001). The ISS is capable of storing 400 million gallons, is more than 20 miles in length, contains tunnels ranging between 17-32 feet in diameter, 24 dropshafts where CSO and SSO (Sanitary Sewer Overflows) are able to enter the system, and has three dewatering pumps with 50 million gallon per day capacity (WI DNR, 2001). Since 1994, the ISS has reduced the number of CSOs from an average of 50 to 2.5 a year and has prevented roughly 40 million gallons of wastewater from entering surface waters in the Milwaukee area (MMSD website, 2002). Currently, the system is set up to handle 50% of wastewater from the combined sewer area with the remaining 50% reserved for water from the separated sewer area. However, system operators have the capability of changing these parameters to allow for high rainfall events (WI DNR, 2001).

Funding for the ISS has come from state and federal grants, state loans, sewer user fees, and a tax levy (MMSD, 2002). The total cost of the ISS project was estimated to be $1 billion. Operation costs are funded primarily from sewer user fees, which are based on a charge per unit volume. MMSD received matching funds for the ISS project from the Wisconsin Fund, the CSO, and the EPA (MMSD, 2002). The breakdown of the matching funds is as follows:

- Wisconsin Fund – 60 % grant, 40 % local
- CSO – 50 % grant, 50 % local
- EPA – 75 % grant, 25 % local

Pittsburgh, PA

The Allegheny County Sanitation Authority (ALCOSAN) serves Pittsburgh and many of the municipalities in Allegheny County. ALCOSAN serves 879,000 customers in Allegheny County in an area of 311 square miles. A single WWTP with a maximum capacity of 225 MGD processes sewage for the system. Approximately 61 square miles of the system are combined sanitary and storm water sewers (Water Environment Research Foundation, 2002). Pittsburgh's sewer system is over sixty years old, and there are 217 CSOs in the city (EPA, 2002). The CSOs empty into the Ohio, the Allegheny, and the Monongahela Rivers. ALCOSAN's service area has between 60 and 70 wet weather events a year, which create 16 billion gallons per year of discharge (Hopey, 2002). Within the service area, there are 553,094 households on public sewers and 26,163 on septic systems (Watershed Atlas, 2002). After wet weather events, river areas that are contaminated by CSOs are flagged with plastic warning markers (Three Rivers Second Nature, 2002). ALCOSAN completed its LTCP in 1999, and includes a storage tunnel and improvement of existing systems. The LTCP plans for $1 billion in plant and interceptor upgrades as well as a possible $2 billion in sewer improvements (Sustainable Pittsburgh, 2000). As part of its strategy to improve the sewer system, ALCOSAN has created an inter-jurisdictional program to disburse funds in grants. The Three Rivers Wet Weather Demonstration Program (TRWWDP) allocates funds to communities whose grant proposals the program deems worthwhile (TRWWDP, 2002). The TRWWDP's estimated cost is $120 million, with 55% federal participation and 45% coming from local and state sources. TRWWDP grants have been used for a number of different initiatives, including activities such as the Nine-Mile Run Restorative Redevelopment, which rebuilt a local park using materials and structures that minimize the amount of wet weather water that flowing into the combined system (Ferguson, Pinkham, and Collins, 2001). The TRWWP has helped fund a number of demonstration projects including manhole replacement, replacement of sewers, and a sewer-shed pilot program. The programs funded by the TRWWDP have shown innovation and may be quite adaptable to other applications (Water Environment Research Foundation, 2002). There is not a lot of material available on Pittsburgh's CSO problems, and ALCOSAN representatives are hard to contact. Comments on the plan include criticism of ALCOSAN's acceptance of sewage from other communities (no plans are made to include this extra demand on capacity), and that water quality sampling upstream of the CSOs found that bacterial levels were in excess of standards upstream of ALCOSAN's service area (Gadzik, 1999).

St. Louis, MO

The city of St. Louis is adjacent to the Mississippi River, located in central Missouri. The city consists of 62 acres with a population of 348,189 (U.S Census Bureau, 2000). The entire city is on a combined sewer system, as is an 18 additional acres in the county. Both the city and county sewer systems are regulated and maintained by the Metropolitan St. Louis Sewer District (MSD), which was established in 1954 (City of St. Louis, 1999). The city's wastewater is treated at two WWTPs, Bissell Point and Lemay (they also serve part of the county). These WWTP treat a combined total of approximately 211 MGD, with a combined capacity of 490 MGD (MSD, 1996). When rainfall events occur and the WWTP are unable to accommodate the volume of water, the combined sewer system overflows into eight streams at 207 outfall points. All of these streams are intermittent except the Mississippi River, which has a flow of 175 cfs (MSD, 1996). Overflows occur approximately 100 times per year (EPA, 2000). An additional concern for St. Louis is Mississippi River flooding that flows back through the combined sewer system and into citizen's basements (MSD, 1999).

The MSD began work in 1996 to develop a LTCP that would evaluate the CSO issues and provide technological solutions. The plan was submitted to the Missouri Department of Natural Resources in 1999 and is currently waiting approval (personal contact, 2002). Because the streams are not classified for body contact, the goal of the plan was to minimize aesthetic impacts of the CSOs on all streams. In one stream, however, the goal was to meet acute toxicity criteria during wet weather (MSD, 1999). The LTCP calls for an anti-litter campaign, more frequent street sweeping, new storage and treatment system near a pump station, limited sewer separation, additional screening structures, and River Des Peres beautification projects (MSD, 1999). The MSD is currently implementing some control and management practices, a few of which are an increased the capacity of the two WWTPs, disconnecting two large industries from the combined system, and providing additional water storage space through tunnels (MSD, 1999).

Seattle, WA

Management of wastewater collection and treatment in the Seattle area servicing approximately 1.3 million people in 420 square miles is coordinated between the City of Seattle and the King County Municipal government (Metro). The City is responsible for inspection, repair, and operation of the main lines and pumping stations while treatment is largely by the King County Wastewater Treatment Division of Natural Resources and Parks. Average treatment at three wastewater treatment facilities (a fourth in the citing process) is over 400 MGD. Two CSO treatment facilities (and a third under construction) perform primary treatment of CSO overflows.

In the 1960's, 20-30 billion gallons of overflow were discharged into Puget Sound, Lake Washington, Lake Union, Green Lake, and the Duwamish River. In the late 1960's separation projects began, and approximately one-third of the City's combined system was converted into a partially separated system. The County's first official control policy for CSOs was the 1979 CSO Control Program. In the 1980's the City developed and implemented its first comprehensive CSO reduction program. The "201 Facility Plan" focused primarily on constructing storage facilities that would temporarily hold combined overflows for later discharge to treatment plants. By 1998, the City had done a significant amount of work on all of its CSOs except for those overflowing to the Ship Canal. Current CSO discharges are approximately 1.5 BGY down from a 1983 baseline of 2.3 BGY.

King County and the City of Seattle conduct integrated management of permit compliance, and control and construction of CSO capital improvement projects. The City, representatives from King County's CSO program, the Seattle-King County Health Department, and the Citizens' Drainage and Wastewater Advisory Committee developed the 2001 CSO Reduction Plan. CSO discharges at 147 CSO locations are reported to the Washington State Department of Ecology who administers the CSO Control Policy including NPDES compliance, under Water Pollution Law RCW 90.48 requiring all municipalities with CSOs to develop plans for "the greatest reasonable reduction at the earliest possible date. RCW 90.48 defines "greatest reasonable reduction" as meaning "control of each CSO such that an average of one untreated discharge may occur per year."

Prioritization of future projects in the 2001 CSO Reduction program is based on protecting public health by limiting exposure and impacts on beneficial uses of receiving waters, rather than volume reduction. The Reduction program actively promotes a two-way communication strategy with the public, including all concerned groups of varying ethnic, economic, or social backgrounds, to gather meaningful input and support for the CSO Reduction program to meet the public health goals of the program.

Financial Index

A financial index was used to evaluate the financial status of each city with respect to how it is approaching the Combined Sewer Overflows. This index investigated the means by which each city funds the LTCP, the cost per outfall and budget for operation and maintenance normalized for population. The following is a break down of the scoring for each category (Grants are worth 2 points because cities do not have to pay them back):

2 points for Federal Grants that are used to fund projects associated with the LTCP

2 points for State Grants that are used to fund projects associated with the LTCP

1 point for any Bond used to fund projects associated with the LTCP

1 point for using a state revolving fund for LTCP

1 point for taxes

1 point for increased rates

2 points possible depending on rank for cost of LTCP per number of outfalls

2 points possible depending on rank for Operation and maintenance per number of people served

City	Information	Points
Federal Grants	Yes/No	2 or 0
State Grants	Yes/No	2 or 0
Bonds	Yes/No	1 or 0
Revolving Fund	Yes/No	1 or 0
Taxes	Yes/No	1 or 0
Increased Sewer Rate	Yes/No	1 or 0
Cost of LTCP / #outfalls	Rank highest 10 lowest 1	Rank/10 * 2.0
O&M / #people	Rank highest 10 lowest 1	Rank/10 * 2.0
Total		

Cleveland, OH	Information	Points
Federal Grants	Yes	2
State Grants	No	0
Bonds	No	0
Revolving Fund	Yes	1
Taxes	No	0
Increased Sewer Rate	Yes	1
Cost of LTCP / #outfalls	$9,500,000	Rank 5 → 1.0
O&M / #people	$69.80	Rank 4 → 0.8
Total		**5.8**

Columbus, OH	Information	Points
Federal Grants	Yes	2
State Grants	Yes	2
Bonds	No	0
Revolving Fund	No	0
Taxes	Yes	1
Increased Sewer Rate	No	0
Cost of LTCP / #outfalls	$3,225,806.45	Rank 3 → 0.6
O&M / #people	$116.03	Rank 10 → 2.0
Total		**7.6**

Detroit, MI	Information	Points
Federal Grants	Yes	2
State Grants	Yes	2
Bonds	Yes	1
Revolving Fund	No	0
Taxes	No	0
Increased Sewer Rate	No	0
Cost of LTCP / #outfalls	$37,179,487.18	Rank 9 → 1.8
O&M / #people	$76.59	Rank 6 → 1.2
Total		**8.0**

Indianapolis, IN	Information	Points
Federal Grants	No	0
State Grants	No	0
Bonds	Yes	1
Revolving Fund	Yes	1
Taxes	No	0
Increased Sewer Rate	Yes	1
Cost of LTCP / #outfalls	$11,940,298.51	Rank 7 → 1.4
O&M / #people	$30.47	Rank 1 → 0.2
Total		**4.6**

Louisville, KY	Information	Points
Federal Grants	No	0
State Grants	No	0
Bonds	Yes	1
Revolving Fund	No	0
Taxes	No	0
Increased Sewer Rate	Yes	1
Cost of LTCP / #outfalls	$10,325,203.25	Rank 6 → 1.2
O&M / #people	$74.68	Rank 5 → 1.0
Total		**4.2**

Milwaukee, WA	Information	Points
Federal Grants	Yes	2
State Grants	Yes	2
Bonds	Yes	1
Revolving Fund	No	0
Taxes	No	0
Increased Sewer Rate	Yes	1
Cost of LTCP / #outfalls	$23,333,333.33	Rank 8 → 1.6
O&M / #people	$60.54	Rank 2 → 0.4
Total		**6.0**

Pittsburgh, PA	Information	Points
Federal Grants	Yes	2
State Grants	Yes	2
Bonds	No	0
Revolving Fund	No	0
Taxes	No	0
Increased Sewer Rate	No	0
Cost of LTCP / #outfalls	$9,216,589.86	Rank 4 → 0.8
O&M / #people	$79.04	Rank 7 → 1.4
Total		**6.2**

St. Louis, MO	Information	Points
Federal Grants	No	0
State Grants	No	0
Bonds	No	0
Revolving Fund	No	0
Taxes	Yes	1
Increased Sewer Rate	Yes	1
Cost of LTCP / #outfalls	$1,789,565.22	Rank 1 → 0.2
O&M / #people	$112.46	Rank 9 → 1.8
Total		**4.0**

Seattle, WA	Information	Points
Federal Grants	Yes	2
State Grants	Yes	2
Bonds	Yes	1
Revolving Fund	Yes	1
Taxes	No	0
Increased Sewer Rate	Yes	1
Cost of LTCP / #outfalls	$324,324,324.43	Rank 10 → 2.0
O&M / #people	$63.08	Rank 3 → 0.6
Total		**9.6**

City	Score	Rank
Cincinnati, OH	5.0	7
Cleveland, OH	5.8	6
Columbus, OH	7.6	3
Detroit, MI	8.0	2
Indianapolis, IN	4.6	8
Louisville, KY	4.2	9
Milwaukee, WI	6.0	5
Pittsburgh, PA	6.2	4
St. Louis, MO	4.0	10
Seattle, WA	9.6	1

Social Index

The Social Index ranks cities based on the presence or absence of community outreach programs, such as education programs, web resources, public meetings, and warning signs, that specifically address CSOs. The index further compares standardized sewer bills across cities in order to infer any correlation between the cost of sewer bills and the current number of combined sewer overflows. The sewer bills are ranked from highest to lowest, divided by the total number of cities and then multiplied by 2 to get the final score.

Data for CSO location bias is from the Census Bureau "TIGER" map server that uses 1990 census data and 1998 government boundary data (U.S. Census Bureau 1, 2002) Census tract data was then compared against CSO location maps from the various communities to determine if there were a disparate number of outfalls in low-income areas compared to higher income areas. Data was not available from all communities to conduct a comparison of CSO volumes and frequencies against demographic areas. Lack of data from this kind of comparison makes real measures of spatial bias difficult as outfall volume and frequency is a determiner in how much nuisance, public health risk, property value diminishment, and local water quality problems there are.

This index uses census tract data on income, classified by quintiles and is broken down into the following income brackets (in dollars): 0-18, 494; 18, 494-24, 451; 24,451-

30,644; 30,644-39,987; and 39,987-150,000. Equivalent interval classification was used to compare if clarification of higher income areas was needed since higher income brackets are not discrete. The federal poverty level is currently $17,960 for a family of four with two children under the age of 18, based on money income before taxes (U.S. Census Bureau 2, 2002).

Comparisons across environmental justice (EJ) research are difficult based on how the data are compiled and what kinds of equity problems are examined (citing, compliance, or EPA remediation quality and quantity). Our index uses lower income levels as a predictor of the presence of environmental harm from CSO location instead of minority population or renter/owner status of household. Minority population is not necessarily indicative of income level as in the case with Seattle, but may be an indicator of environmental inequity nevertheless depending on how enfranchised people feel in their community.

We also examined the renter or owner status of households. A limitation to using renter/owner status is that median housing costs may determine the percentage of renters in area irrespective of income levels. Tracts in areas with a college or university generally have higher rental rates.

Scores will also be assigned for each city offering public assistance for sewer connections. Finally, the index ranks cities according to whether failing septic systems exist in the city limits and whether or not there is public assistance to replace or reconnect septic systems. Assistance can consist of low interest loans or direct aid in kind and are scored similarly. Septic systems are an additional public health hazard and their presence or absence may exacerbate the health risks associated with combined sewer overflows. Directly assessing quantity, quality, and fate of septic outflows is problematic. Assessment of failing septic system's contribution to overall human health/water quality problems is difficult in the context of the whole system so we chose to include septic financial assistance programs as a measure of a municipalities commitment to public education and welfare. The approximate total score for the Social Index is 18; the closer the city score is to 18, the more of the criteria they have implemented.

Scoring System

2 points for combined sewer overflow education programs

2 points for combined sewer overflow web resources

2 points for combined sewer overflow public meetings

2 points for combined sewer overflow warning signs

2 points for no combined sewer overflow location bias based on income

2 points for public assistance with sewer connections

2 points for no failing septic systems in city limits

2 points for public assistance with septic system conversion

City	Information	Points
CSO Education Program	Yes/No	2 or 0
CSO Web Resources	Yes/No	2 or 0
CSO Public Meetings	Yes/No	2 or 0
CSO Warning Signs	Yes/No	2 or 0
CSO Spatial Bias	No/Yes	2 or 0
Sewer Bill	Rank highest to lowest	Rank/10 *2
Public Assistance – Sewers	Yes/No	2 or 0
Failing Septics in City Limits	No/Yes	2 or 0
Public Assistance - Septics	Yes/No	2 or 0
Total		

Cincinnati, OH	Information	Points
CSO Education Program	Yes	2
CSO Web Resources	Yes	2
CSO Public Meetings	Yes	2
CSO Warning Signs	Yes	2
CSO Spatial Bias	Yes	0
Sewer Bill	$24.00	Rank 8 → 1.6
Public Assistance – Sewers	No	0
Failing Septics in City Limits	Yes	0
Public Assistance - Septics	Yes	2
Total		**11.6**

Cleveland, OH	Information	Points
CSO Education Program	Yes	2
CSO Web Resources	No	0
CSO Public Meetings	Yes	2
CSO Warning Signs	No	0
CSO Spatial Bias	Yes	0
Sewer Bill	$21.10	Rank 7 → 1.4
Public Assistance – Sewers	Yes	2
Failing Septics in City Limits	No	2
Public Assistance - Septics	Yes	2
Total		**11.4**

Columbus, OH	Information	Points
CSO Education Program	Yes	2
CSO Web Resources	No	0
CSO Public Meetings	Yes	2
CSO Warning Signs	Yes	2
CSO Spatial Bias	Yes	0
Sewer Bill	$20.18	Rank 6 → 1.2
Public Assistance – Sewers	Yes	2
Failing Septics in City Limits	Yes	0
Public Assistance - Septics	Yes	2
Total		**11.2**

Detroit, MI	Information	Points
CSO Education Program	Yes	2
CSO Web Resources	Yes	2
CSO Public Meetings	Yes	2
CSO Warning Signs	Yes	2
CSO Spatial Bias	No	2
Sewer Bill	$31.43	Rank 10 → 2
Public Assistance – Sewers	No	0
Failing Septics in City Limits	No	2
Public Assistance - Septics	No	0
Total		**14**

Indianapolis, IN	Information	Points
CSO Education Program	Yes	2
CSO Web Resources	Yes	2
CSO Public Meetings	Yes	2
CSO Warning Signs	Yes	2
CSO Spatial Bias	Yes	0
Sewer Bill	$10.91	Rank 2 → 0.4
Public Assistance – Sewers	Yes	2
Failing Septics in City Limits	Yes	0
Public Assistance - Septics	Yes	2
Total		**12.4**

Louisville, KY	Information	Points
CSO Education Program	Yes	2
CSO Web Resources	Yes	2
CSO Public Meetings	Yes	2
CSO Warning Signs	Yes	2
CSO Spatial Bias	Yes	0
Sewer Bill	$15.75	Rank 4 → 0.8
Public Assistance – Sewers	No	0
Failing Septics in City Limits	Yes	0
Public Assistance - Septics	No	0
Total		**8.8**

Milwaukee, WI	Information	Points
CSO Education Program	Yes	2
CSO Web Resources	Yes	2
CSO Public Meetings	Yes	2
CSO Warning Signs	No	0
CSO Spatial Bias	Yes	0
Sewer Bill	$5.96	Rank 1 → 0.2
Public Assistance – Sewers	No	0
Failing Septics in City Limits	Yes	0
Public Assistance - Septics	No	0
Total		**6.2**

Pittsburgh, PA	Information	Points
CSO Education Program	No	0
CSO Web Resources	No	0
CSO Public Meetings	Yes	2
CSO Warning Signs	Yes	2
CSO Spatial Bias	NA	0
Sewer Bill	$17.00	Rank 5 → 1
Public Assistance – Sewers	No	0
Failing Septics in City Limits	Yes	0
Public Assistance - Septics	No	0
Total		**5**

St. Louis, MO	Information	Points
CSO Education Program	Yes	2
CSO Web Resources	Yes	2
CSO Public Meetings	Yes	2
CSO Warning Signs	Yes	2
CSO Spatial Bias	No	2
Sewer Bill	$14.96	Rank 3 → 0.6
Public Assistance – Sewers	Yes	2
Failing Septics in City Limits	No	2
Public Assistance - Septics	No	0
Total		**14.6**

Seattle, WA	Information	Points
CSO Education Program	Yes	2
CSO Web Resources	Yes	2
CSO Public Meetings	Yes	2
CSO Warning Signs	Yes	2
CSO Spatial Bias	No	2
Sewer Bill	$31.14	Rank 9 → 1.8
Public Assistance – Sewers	Yes	2
Failing Septics in City Limits	Yes	0
Public Assistance - Septics	Yes	2
Total		**15.8**

City	Score	Rank
Cincinnati, OH	11.6	5
Cleveland, OH	11.4	6
Columbus, OH	11.2	7
Detroit, MI	14	3
Indianapolis, IN	12.4	4
Louisville, KY	8.8	8
Milwaukee, WI	6.2	9
Pittsburgh, PA	5	10
St. Louis, MO	14.6	2
Seattle, WA	15.8	1

Technology Index

To evaluate each city's technological approach to the CSO problem we decide to investigate technology included in the LTCP. A city can receive a maximum score of 65 points. The descriptions and table below contains a breakdown of the points:

Wastewater Treatment Plant Capacities, current and planned: found by dividing a city's average daily system load by the maximum capacity of the system, existing or planned.

Long Term Control Plan: the existence of a LTCP indicates the city's attitude towards changing its CSO situation and compliance with the EPA's regulations. Each city can earn 5 points for yes, zero for no.

CSO information: cities are ranked on the number of CSOs, the annual overflow volume, and the number of CSOs per square mile served by the system. Each of the rankings establishes a point value from one to ten.

Big Improvements: these indicate the existence of large-scale improvements to increase the capacity of the system, such as new WWTP's, basins, large capacity storage tunnels or mines, and the like. Two points are awarded for each measure currently implemented or in implementation: one point for planned measures, zero for no measure.

Small Improvements: these indicate initiatives to better use the existing capacity of the system. Measures include inflatable dams, some sort of real-time monitoring and/or control of flows, and in-line storage that increases capacity. One point for each measure currently implemented or in implementation, half a point for planned measures, zero for no measures.

Other Measures: these indicate other measures listed in the nine minimum controls. One point for each measure currently implemented or in implementation, half a point for planned measures, zero for no measures.

City	Information	Points
WWTP Percent Capacity		
50%-60% or below		5
61%-70%		4
71%-80%		3
81%-90%		2
91%-100%		1
WWTP Percent Planned Capacity		
50%-60% or below		5
61%-70%		4
71%-80%		3
81%-90%		2
91%-100%		1
Long-Term Control Plan	Yes/No	5
CSO outflow BG annually	#	10
# of CSO outfall		10
# of CSO outfalls/ sq. mile		10
Big Improvements		
Large-Scale Separation	Current/Future/No	2,1,0
New WWTP	Current/Future/No	2,1,0
Basins	Current/Future/No	2,1,0
Other	Current/Future/No	2,1,0
Small Improvements		
WWTP Expansions	Current/Future/No	1,0.5,0
Inflatable Dams	Current/Future/No	1,0.5,01
In-line Storage	Current/Future/No	1,0.5,01
Real-time Control	Current/Future/No	1,0.5,01
Flow Control	Current/Future/No	1,0.5,01
Other	Current/Future/No	1,0.5,01
Additional Controls		
Grids, Grates, and Catch Net	Current/Future/No	1,0.5,01
O&M	Current/Future/No	1,0.5,01
Storage of Excess Flows	Current/Future/No	1,0.5,01
Maximize Flows to the WWTP	Current/Future/No	1,0.5,01
Prohibition of Dry Weather Outflows	Current/Future/No	1,0.5,01
Total		**65**

LTCP- 85% of CSO Containment – No LTCP Records of WWTP

Cincinnati, OH	Information	Points
Percent Capacity		
50%-60% or below		
61%-70%	X	4
71%-80%		
81%-90%		
91%-100%		
Percent Planned Capacity		
50%-60% or below		
61%-70%		
71%-80%		
81%-90%	X	2
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow BG annually	6.2	4
# of CSO outfall	251	1
# of CSO outfalls/ sq. mile	.627	3
Big Improvements		
Large-Scale Separation	No	0
New WWTP	Future	1
Basins	Current	2
Other		
Small Improvements		
WWTP Expansions	Future	0.5
Inflatable Dams	Current	1
In-line Storage	Current	1
Real-time Control	Current	1
Flow Control	Current	1
Other		
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	Future	0.5
Maximize Flows to the WWTP	Future	0.5
Prohibition of Dry Weather Outflows	Future	0.5
Total		**30**

Cleveland, OH	Information	Points
Percent Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Percent Planned Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow BG annually	5	5
# of CSO outfall	126	6
# of CSO outfalls/ sq. mile	.35	4
Big Improvements		
Large-Scale Separation	Future	1
New WWTP	No	0
Basins	Current	2
Other		
Small Improvements		
WWTP Expansions	Current	1
Inflatable Dams	Current	1
In-line Storage	Current	1
Real-time Control	Current	1
Flow Control	Current	1
Other		
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	Current	1
Maximize Flows to the WWTP	Future	0.5
Prohibition of Dry Weather Outflows	Current	1
Total		**42.5**

Ave Daily Cap of WWTP= 242 MGD—Continually Trying to Fit to Population

Columbus, OH	Information	Points
Percent Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Percent Planned Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow BG annually	N/A	0
# of CSO outfalls	31	10
# of CSO outfalls/ sq. mile	.146	9
Big Improvements		
Large-Scale Separation	Current	2
New WWTP	Current	2
Basins	No	0
Other	---	0
Small Improvements		
WWTP Expansions	Current	1
Inflatable Dams	No	0
In-line Storage	Current	1
Real-time Control	Current	1
Real-time Monitoring	Current	1
Flow Control	Current	1
Other		
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	Current	1
Maximize Flows to the WWTP	Current	1
Prohibition of Dry Weather Outflows	Current	1
Total		**47**

Detroit, MI	Information	Points
Percent Capacity		
50%-60% or below		
61%-70%		
71%-80%		
81%-90%	X	2
91%-100%		
Percent Planned Capacity		
50%-60% or below		
61%-70%		
71%-80%		
81%-90%	X	2
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow BG annually	7.8	3
# of CSO outfall	83	9
# of CSO outfalls/ sq. mile	.13	10
Big Improvements		
Large-Scale Separation	Current	2
New WWTP	No	0
Basins	Current	2
Other		
Small Improvements		
WWTP Expansions	Future	0.5
Inflatable Dams	No	0
In-line Storage	No	0
Real-time Control	No	0
Flow Control	Current	1
Other		
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	Current	1
Maximize Flows to the WWTP	Current	1
Prohibition of Dry Weather Outflows	Current	1
Total		**41.5**

Indianapolis, IN	Information	Points
Percent Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Percent Planned Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow BG annually	4.75	6
# of CSO outfall	127	5
# of CSO outfalls/ sq. mile	.32	6
Big Improvements		
Large-Scale Separation	No	0
New WWTP	No	0
Basins	No	0
Other (Wetlands)	Future	1
Small Improvements		
WWTP Expansions	Future	.5
Inflatable Dams	Current	1
In-line Storage	Current	1
Real-time Control	Current	1
Flow Control	Future	.5
Other (Small Scale Separation)	Future	.5
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	Future	.5
Maximize Flows to the WWTP	No	0
Prohibition of Dry Weather Outflows	No	0
Total		**40**

Louisville, KY	Information	Points
Percent Capacity		
50%-60% or below		
61%-70%		
71%-80%	X	3
81%-90%		
91%-100%		
Percent Planned Capacity		
50%-60% or below		
61%-70%	X	4
71%-80%		
81%-90%		
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow BG annually	3.27	7
# of CSO outfall	122	7
# of CSO outfalls/ sq. mile	.316	7
Big Improvements		
Large-Scale Separation	Current	2
New WWTP	Current	2
Basins	Current	2
Other		
Small Improvements		
WWTP Expansions		
Inflatable Dams	Current	1
In-line Storage	Current	1
Real-time Control	Current	1
Flow Control	Current	1
Other-	Future	0.5
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	Current	1
Maximize Flows to the WWTP	Current	1
Prohibition of Dry Weather Outflows	No	0
Total		**47.5**

Milwaukee, WI	Information	Points
Percent Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Percent Planned Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow BG annually	1.8	8
# of CSO outfall	120	8
# of CSO outfalls/ sq. mile	1.2	2
Big Improvements		
Large-Scale Separation	No	0
New WWTP	Current	2
Basins	Current	2
Other	No	0
Small Improvements		
WWTP Expansions	Current	1
Inflatable Dams	No	0
In-line Storage	Current	1
Real-time Control	Current	1
Flow Control	Current	1
Other		
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	Current	1
Maximize Flows to the WWTP	Current	1
Prohibition of Dry Weather Outflows	Current	1
Total		**46**

Pittsburgh, PA	Information	Points
Percent Capacity		
50%-60% or below		
61%-70%		
71%-80%		
81%-90%	X	2
91%-100%		
Percent Planned Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow BG annually	16	2
# of CSO outfall	217	2
# of CSO outfalls/ sq. mile	.29	8
Big Improvements		
Large-Scale Separation	*No*	0
New WWTP	No	0
Basins	Current	2
Other (Nine-Mile Run Redevelopment)	Current	2
Small Improvements		
WWTP Expansions	No	0
Inflatable Dams	Future	.5
In-line Storage	Current	1
Real-time Control	No	0
Flow Control	No	0
Other		
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	No	0
Maximize Flows to the WWTP	No	0
Prohibition of Dry Weather Outflows	No	0
Total		**31.5**

St. Louis, MO	Information	Points
Percent Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Percent Planned Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow MG annually	25.9 BG/yr	1
# of CSO outfall	207	3
# of CSO outfalls/ sq. mile	3.34	1
Big Improvements		
Large-Scale Separation	No	0
New WWTP	No	0
Basins	No	0
Other	No	0
Small Improvements		
WWTP Expansions	Current	1
Inflatable Dams	No	0
In-line Storage	Current	1
Real-time Control	Current	1
Flow Control	Current	1
Other		
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	Current	1
Maximize Flows to the WWTP	Current	1
Prohibition of Dry Weather Outflows	No	0
Total		**28**

Seattle, WA	Information	Points
Percent Capacity		
50%-60% or below		
61%-70%	X	4
71%-80%		
81%-90%		
91%-100%		
Percent Planned Capacity		
50%-60% or below	X	5
61%-70%		
71%-80%		
81%-90%		
91%-100%		
Long-Term Control Plan	Yes	5
CSO outflow BG annually	1.5	9
# of CSO outfall	137	4
# of CSO outfalls/ sq. mile	.33	5
Big Improvements		
Large-Scale Separation	Current	2
New WWTP	Future	1
Basins	Current	2
Other		
Small Improvements		
WWTP Expansions	Current	1
Inflatable Dams	Current	1
In-line Storage	Current	1
Real-time Control	Current	1
Flow Control	Current	1
Other		
Additional Controls		
Grids, Grates, and Catch Net	Current	1
O&M	Current	1
Storage of Excess Flows	Current	1
Maximize Flows to the WWTP	Current	1
Prohibition of Dry Weather Outflows	Current	1
Total		**47**

CSO Annual Flow in Billions of Gallons

City	Information	Rank
Cincinnati, OH	6.2	4
Cleveland, OH	5	5
Columbus, OH	N/A	0
Detroit, MI	7.8	3
Indianapolis, IN	4.75	6
Louisville, KY	3.27	7
Milwaukee, WA	1.8	8
Pittsburgh, PA	16	2
St. Louis, MO	25.9	1
Seattle, WA	1.5	9

Number of CSO Outfalls

City	Information	Rank
Cincinnati, OH	251	1
Cleveland, OH	126	6
Columbus, OH	34	10
Detroit, MI	83	9
Indianapolis, IN	127	5
Louisville, KY	121	7
Milwaukee, WA	120	8
Pittsburgh, PA	217	2
St. Louis, MO	207	3
Seattle, WA	137	4

Number of Outfalls / Square Mile

City	Information	Rank
Cincinnati, OH	.627	3
Cleveland, OH	.35	4
Columbus, OH	.146	9
Detroit, MI	.13	10
Indianapolis, IN	.32	6
Louisville, KY	.316	7
Milwaukee, WA	1.2	2
Pittsburgh, PA	.29	8
St. Louis, MO	3.34	1
Seattle, WA	.33	5

City	Score	Rank
Cincinnati, OH	30	9
Cleveland, OH	42.5	5
Columbus, OH	47	2
Detroit, MI	41.5	6
Indianapolis, IN	40	7
Louisville, KY	47.5	1
Milwaukee, WA	46	4
Pittsburgh, PA	31.5	8
St. Louis, MO	28	10
Seattle, WA	47	2

Water Quality Index

The water quality index was developed to assess the detrimental affects of combined sewers on receiving streams in each city. The index accounts and gives credit for efforts to alleviate any water quality problems. The higher the city's index score, the better they are dealing with the effects of combined sewers on the water quality of their receiving waters.

One point of credit was given for each water parameter tested. These parameters all have a direct correlation to the health of the water body. The parameters are dissolved oxygen (DO), solids, phosphorus, nitrogen, fecal coliform, pH, and metals. By sampling these parameters, the cities show positive consideration for the overall health of the water body. If a city further evaluated the water health using biological indices, such as fish or macroinvertebrate indices, they received an additional two points. Two points were also given if water sampling and analysis is to continue after the LTCP is in place in order to evaluate the effectiveness of the plan.

The number of parameters that are exceeding the city / state water quality standards reduced the city's score by one for each parameter. The number of parameters exceeding was scored both before the LTCP and after the LTCP. If the city does not have a LTCP then it was assumed that the water quality parameters would remain as they are currently. If the city has a LTCP, but has not yet implemented the plan, the number of water quality parameters exceeding was assumed to be as determined in the plan.

If the water quality of the receiving streams was assessed during dry weather, the city received one point. If the city took additional measures and sampled specifically in wet weather, two points were rewarded. In order to evaluate the overall efforts of the city, two points were rewarded if the city, alone, took the initiative to measure water quality. If the city worked jointly with the state, it is assumed that the state felt the city was not doing sufficient work on the problem and one point was rewarded. If the city is not at all involved with the water quality testing and the state alone has taken the initiative, then zero points were rewarded to the city.

City	Information	Points
Dissolved Oxygen	Yes/No	1
Solids	Yes/No	1
Phosphorus	Yes/No	1
Nitrogen	Yes/No	1
Fecal coliform	Yes/No	1
pH	Yes/No	1
Metals	Yes/No	1
Biological Index	Yes/No	2
Future Testing	Yes/No	2
Number Exceeding Before	# Parameters * -1	
Number Exceeding After	# Parameters * -1	
Dry Weather Testing	Yes/No	1
Wet Weather Testing	Yes/No	2
Responsibility:	City, State or City and State	2, 1, or 0
Total		**16**

Cincinnati, OH	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	Yes	1
Nitrogen	Yes	1
Fecal coliform	Yes	1
PH	Yes	1
Metals	Yes	1
Biological Index	Yes	2
Future Testing	Yes	2
Number Exceeding Before	1	-1
Number Exceeding After	1	-1
Dry Weather Testing	Yes	1
Wet Weather Testing	Yes	2
Responsibility:	City	2
Total		**14**

Cleveland, OH	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	Yes	1
Nitrogen	Yes	1
Fecal coliform	Yes	1
PH	Yes	1
Metals	Yes	1
Biological Index	Yes	2
Future Testing	Yes	2
Number Exceeding Before		-2
Number Exceeding After		-2
Dry Weather Testing	Yes	1
Wet Weather Testing	Yes	2
Responsibility:	City	2
Total		**12**

Columbus, OH	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	Yes	1
Nitrogen	Yes	1
Fecal coliform	Yes	1
PH	Yes	1
Metals	Yes	1
Biological Index	Yes	2
Future Testing	Yes	2
Number Exceeding Before		-5
Number Exceeding After		
Dry Weather Testing	Yes	1
Wet Weather Testing	Yes	2
Responsibility:	City and State	1
Total		**10**

Detroit, MI	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	Yes	1
Nitrogen	Yes	1
Fecal coliform	Yes	1
PH	Yes	1
Metals	Yes	1
Biological Index	Yes	2
Future Testing	Yes	2
Number Exceeding Before		-3
Number Exceeding After		-2
Dry Weather Testing	Yes	1
Wet Weather Testing	Yes	2
Responsibility:	City and State	1
Total		**10**

Indianapolis, IN	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	Yes	1
Nitrogen	Yes	1
Fecal coliform	Yes	1
pH	Yes	1
Metals	Yes	1
Biological Index	Yes	2
Future Testing	Yes	2
Number Exceeding Before		-4
Number Exceeding After		-2
Dry Weather Testing	Yes	1
Wet Weather Testing	Yes	2
Responsibility:	City and State	1
Total		**9**

Louisville, KY	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	Yes	1
Nitrogen	Yes	1
Fecal coliform	Yes	1
PH	Yes	1
Metals	Yes	1
Biological Index	Yes	2
Future Testing	Yes	2
Number Exceeding Before		-3
Number Exceeding After		-3
Dry Weather Testing	Yes	1
Wet Weather Testing	Yes	2
Responsibility:	City	2
Total		**10**

Milwaukee, WI	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	Yes	1
Nitrogen	Yes	1
Fecal coliform	Yes	1
PH	Yes	1
Metals	Yes	1
Biological Index	Yes	2
Future Testing	Yes	2
Number Exceeding Before		-4
Number Exceeding After		-4
Dry Weather Testing	Yes	1
Wet Weather Testing	Yes	2
Responsibility:	City and State	1
Total		**7**

Pittsburgh, PA	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	No	0
Nitrogen	No	0
Fecal coliform	No	0
PH	Yes	1
Metals	No	0
Biological Index	No	0
Future Testing	Yes	2
Number Exceeding Before		0
Number Exceeding After		0
Dry Weather Testing	Yes	1
Wet Weather Testing	Yes	0
Responsibility:	City	2
Total		**8**

St. Louis, MO	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	No	0
Nitrogen	Yes	1
Fecal coliform	No	0
PH	Yes	1
Metals	Yes	1
Biological Index	No	0
Future Testing	No	0
Number Exceeding Before		-2
Number Exceeding After		-2
Dry Weather Testing	Yes	0
Wet Weather Testing	Yes	2
Responsibility:	City	2
Total		**5**

Seattle, WA	Information	Points
Dissolved Oxygen	Yes	1
Solids	Yes	1
Phosphorus	Yes	1
Nitrogen	Yes	1
Fecal coliform	Yes	1
PH	Yes	1
Metals	Yes	1
Biological Index	Yes	2
Future Testing	Yes	2
Number Exceeding Before		-4
Number Exceeding After		-4
Dry Weather Testing	Yes	1
Wet Weather Testing	Yes	2
Responsibility:	City	2
Total		**8**

City	Score	Rank
Cincinnati, OH	14	1
Cleveland, OH	12	2
Columbus, OH	10	Tied 3
Detroit, MI	10	Tied 3
Indianapolis, IN	9	6
Louisville, KY	10	3
Milwaukee, WI	7	9
Pittsburgh, PA	8	Tied 7
St. Louis, MO	8	Tied 7
Seattle, WA	5	10

Summary Index

	Financial	Technology	Social	Water Quality	Rank	Overall Score
Cincinnati	7	9	5	1	5.5	6
Cleveland	6	5	6	2	4.75	4
Columbus	3	2	7	6	4.5	3
Detroit	2	6	3	3	3.5	2
Indianapolis	8	7	4	5	6.5	7
Louisville	9	1	8	3	5.25	5
Milwaukee	5	4	9	9	6.75	8
Pittsburgh	4	8	10	6	7.0	9
St. Louis	10	10	2	10	8.0	10
Seattle	1	2	1	6	2.5	1

Results

Financial Index

From total score of 10, Seattle has the highest score of 9.6 since it is the only city that obtains funding from all the financial sources except taxes. Seattle plans to spend $324 million/CSO outfall, which is the most expensive LTCP. Detroit has the second highest score of 8.0. Detroit received both federal and state grants, along with bonds, without increasing sewer rate or taxes. Detroit plans to spend $37 million per CSO outfall, which is the second most expensive LTCP. Columbus has the third highest score of 7.6 since it obtains funding from both federal and state grant, besides taxes, without increasing sewer rate.

Pittsburgh and Milwaukee are the other two cities that receive both federal and state grants. Pittsburgh is the only city that uses only federal and state grants without increasing sewer rate and taxes. Milwaukee also funded by bonds and increasing sewer rate because it has the forth most expensive LTCP of $23 million/CSO outfall. Cleveland receives only federal grants and funding mainly is from revolving fund and sewer fee. Cincinnati, Louisville, and St. Louis are cities that do not receive neither federal nor state grants. Among these three cities, Louisville has high LTCP cost per outfalls that are funded mainly on bonds alone. Cincinnati and St. Louis plan to spend about the same on LTCP. While Cincinnati has bonds, St. Louis funding based on taxes and sewer fee only.

Social Index

Seattle ranked the highest in the social index with a score of 15.8. St. Louis and Detroit ranked second and third in the index with scores of 14.6 and 14, respectively. Seattle received such a high ranking because the city provides public assistance and outreach programs, no spatial biases were found, and the city has the second highest sewer bill rate in the index. St. Louis and Detroit were also high in the ranking because of the lack of spatial biases of CSOs, high sewer bill rates, and no failing septic systems within the city limits. Pittsburgh, Milwaukee, and Louisville ranked the lowest in the index, with scores of 5, 6.2, and 8.8, respectively. Pittsburgh fared so poorly in this index because the city does not offer CSO educational programs or CSO web resources, it has a relatively low sewer bill, and there are failing septics within the city limits with no public assistance programs. Milwaukee and Louisville did not receive high rankings because of low sewer bills, CSO spatial bias, and the lack of public assistance.

Comparing communities' CSO outreach programs, every city was found to have CSO public meetings. Every city except for Pittsburgh has some sort of public CSO educational program. Columbus, Pittsburgh, and Cleveland do not have web resources for CSOs, while Milwaukee and Cleveland do not have CSO signs at outfall locations. Cleveland plans to place CSO signs at outfalls in the bay area. However, it is currently unknown whether Milwaukee is planning to place CSO signs at outfalls. Detroit and Seattle were found to have the first and second highest sewer bill rates, while Milwaukee and Indianapolis ranked the first and second lowest for sewer bill rates, respectively. The index further displayed that Detroit, Pittsburgh, Milwaukee, Cincinnati, and St. Louis do not have public assistance for sewer bills. Detroit, Cleveland, and St. Louis were the only cities in the study to report not having failing septic systems within their city limits. However, Cleveland did report to offer public assistance for septic reclamation. Louisville, Milwaukee, and Pittsburgh all have failing septic systems within their city limits but do not provide public assistance for septic reclamation and subsequent city sewer hook-up. Finally, the spatial bias study showed that the cities of Cincinnati, Cleveland, Columbus, Indianapolis, Louisville, and Milwaukee all had CSO outfalls that were located in disproportionately high numbers within low-income neighborhoods.

Technology Index

The technology index was created to demonstrate the technological innovations cities are currently utilizing or plan on implementing to mitigate the effects of CSOs in these areas. According to this index Columbus has the most effective CSO abatement technological system while St. Louis is using the least effective approach. Columbus has the fewest number of outfalls in comparison to the other cities surveyed and is currently operating with a combination of large-scale sewer separation and a new WWTP. St. Louis has expanded the capacity of their WWTP's and is using various technologies including inline storage, real-time control, flow control, grids, etc. but has no plans for major improvements to the cities sewer infrastructure. As a result, despite its rank as 3rd in total number of CSOs St. Louis discharges roughly 25.9 billion gallons of CSO water each year into the surface waters in the region.

No particular pattern emerged to explain the differences in scores for the cities surveyed although there is a possible correlation between the number of CSO outfalls and technological scores. According to the data, Cincinnati, Pittsburgh, and St. Louis, have the highest number of CSO outfalls in the survey and received the lowest technological rankings. In addition, these cities are lacking many of the small CSO improvements listed. Furthermore, the WWTP's in Cincinnati and Pittsburgh are operating at a higher percent capacity, reducing their ability to capture flows during excessive wet weather events. On the other hand, cities receiving higher scores, i.e. Columbus, Louisville, and Seattle are currently utilizing a minimum of two small and two big improvements along with additional controls as opposed to having plans for the development and installation of these CSO abatement technologies.

Water Quality Index

The water quality index, as described previously, endeavors to quantify a city's efforts and concerns about the water quality of the CSO receiving water bodies. The health of our nations streams, lakes, and oceans has long been impacted by CSOs and other anthropogenic inputs. One of the goals of CSO abatement is remedy the harmful affects of their inputs. Improving our nations water quality is important for human health, biological health, aesthetics, and philosophical values.

All of the cities, except St. Louis and Pittsburgh sampled for all parameters.

This shows that most of the cities are taking the time and effort to analyze the health of their receiving water bodies. The chosen sample parameters, dissolved oxygen (DO), solids, phosphorus, nitrogen, fecal coliform, pH, and metals, are ones typically used for any type of water quality analysis. In addition, CSO inputs to water will affect all of these constituents. Raw sewage, because of its high organic content, will reduce the amount of oxygen present in a water body as it decomposes. The solids affect the light availability, as well as, the creating silt layers by its deposition to the bottom of water bodies. Both phosphorus and nitrogen are important nutrients that affect biological growth. When these nutrients are available, an increase in biological growth occurs, often causing unwanted algal blooms as well as generally disrupting the natural biological system. Fecal coliform is a bacterium that comes from fecal matter. It can be the cause of many human diseases. In addition, the presence of fecal coliform is indicative of other pathogens being present in the water. pH is another factor that greatly affects the biological and chemical constituents in a water body. Any change in pH can alter the populations of phytoplankton, macroinvertebrates, fish, and metal species. Metals are also important to measure in receiving water bodies because of their unfavorable human and biological affects.

Biological testing was done for all cities except St. Louis and Pittsburgh.
Analysis of the species of fish or macroinvertebrates present in a water body can be indicative of water quality. Different species of fish and macroinvertebrates have varying tolerance levels to water quality. By evaluating the presence or absence of the species, the overall health of the water can be established through the use of biological indices that have been developed. Biological testing of either fish or macroinvertebrates shows a city's commitment to the health of their waters, particularly because the increased time and cost associated with this type of testing and analysis typically makes it more difficult to execute.

Future tests of water quality for CSO receiving water bodies will be done by almost all of the cities. St. Louis and Columbus are the only cities that will not continue to perform water quality testing. Continuing water testing is important to ensure that the CSO abatement technologies are having the desired affect upon water quality.

The major difference between the city scores was due mainly to the number of parameters exceeding standards before and after implementation of the LTCP. Many of the cities were able to reduce the number of times per year that a parameter was in exceedance of the standard, but were unable to completely eliminate the detrimental affect of the CSOs on water quality. What should also be noted here is that the standards were particular to each city or state. This can affect the score because cities with higher standards may have more parameters exceeding those standards. But, in general, most of the standards were similar.

The city with the most parameters exceeding was Columbus with five. Milwaukee and Seattle both had four parameters exceeding before and after. Indianapolis also had four, but believes it can reduce that to two after implementation of the LTCP. Louisville had three both before and after the LTCP. Detroit had three exceeding the standards before, but now has been able to reduce that to two after. Cleveland and St. Louis both had two before and after implementation. And Cincinnati had only one parameter exceeding before and after the LTCP. Pittsburgh did not have any parameter exceeding, but they only sampled for DO, solids, and pH, so this may have attributed.

Dry and wet weather sampling was similar to almost all cities. All cities, except Pittsburgh and St. Louis did both dry and wet water quality sampling. Pittsburgh only did dry weather testing, which can then underestimate the effect of the CSOs on the receiving water body. St. Louis did only wet weather water sampling, although they did flow monitoring during dry weather in order to create an overall model of the system.

The responsibility section of index is to measure the efforts of the cities to deal with the CSO issues themselves. Most cities are taking full responsibility themselves. The only exceptions to this are Milwaukee, Detroit, and Indianapolis. These cities are all working jointly with the state.

V. Implications for Indianapolis

Comparison with Selected Cities

Financial

Indianapolis ranked eighth overall in the financial index. When compared to other cities, Indianapolis has the lowest operation and maintenance costs, with one of the most expensive LTCP. Financial sources for operation and maintenance costs are obtained from bonds, revolving funds, and from sewer rates but no funding is obtained from federal and state grants or taxes. Furthermore, the relatively low sewer bills do not make a large contribution to funding programs outlined in the LTCP and other operation and maintenance costs. The LTCP is funded mainly through repaid bonds and revolving funds. Other cities reviewed in the study received grants and increased sewer rates to fund LTCP programs and general operation and maintenance costs of combined sewer overflows, resulting in a low financial index score for Indianapolis.

Social

Indianapolis was ranked fourth in social index. Indianapolis implements all of the combined sewer overflow community outreach programs outlined in the index. Both educational programs and public meetings are held on a regular basis. Combined sewer overflow web resources are available through numerous city/county and federal government websites such as IDEM, the Marion County Health Department, and the City of Indianapolis. In addition, Indianapolis provides sewer bill and sewer connection public assistance for low-income families. Although Indianapolis provides public assistance for failing septic systems, there are still hundreds of septic systems within the city limits. The presence of failing septic systems within city limits and the spatial bias of CSO outfalls lowered the overall social score. However, when compared to other cities, Indianapolis is providing just as much if not more educational information to its citizens.

Technology

Indianapolis is ranked fifth in total number of CSOs, sixth in number of outfalls per square mile, sixth in annual volume of CSO discharges, and seventh in overall CSO technology. Approximately 4.75 billion gallons of CSO wastewater is discharged into Indianapolis area water bodies each year. One of the primary reasons for Indianapolis' relatively low technology score is the fact that there are no large-scale improvements scheduled for the city. In addition, many of the small improvements such as in-line storage with real-time control, the expansion of the wastewater plants and partial sewer separation, are planned for the city but contingent upon funding based on the city's LTCP. This technological analysis shows that Indianapolis should implement the planned technology measures and to make future preparations for major improvements to the city's sewer system. These implementations will improve the city's technology ranking and the quality of surface water in the Indianapolis area.

Water Quality

Indianapolis was ranked fifth overall for water quality effects and efforts. This was mainly due to their inability to reduce the concentrations of fecal bacteria and toxic metals to levels below required standards. The LTCP does decrease the level of dissolved oxygen to above standard levels. However, the human health implications associated with high fecal bacteria and toxins greatly endanger the citizens of Indianapolis. The high metal concentration also damages the health of the stream by altering the chemistry of the system. In order to ensure the public's safety and to improve the health of the streams, the level of these constituents must be reduced.

The other major difference between Indianapolis and the other cities is who is responsible for water quality testing and analysis. Many of the other cities with water quality scores exceeding Indianapolis' have taken the responsibility upon themselves to do the necessary testing. Indianapolis continues to share this responsibility with IDEM. However, this partnership may be beneficial in that additional water quality testing is occurring by IDEM that may not otherwise be done.

Recommendations

Financial Recommendations

Indianapolis was required to complete a comprehensive affordability analysis within the LTCP to determine the impact of the LTCP on both the current and future fiscal security of Indianapolis. The decision to consider a CSO project alternative was based on the ability of the community to finance it. The affordability analysis used the low median income (Center Township) as a baseline to determine a financial capability indicator. The financial capability analysis examined median family income, unemployment rates, tax collection rates, bond ratings, and property tax revenues as a proportion of market value.

Based on the results of the financial capability assessment, Indianapolis has decided that it wants to continue using primarily bond financing of CSO projects and money from the State Revolving Fund (SRF).

Our recommendations for Indianapolis include:

- Increase spending on plant operation and management: Indianapolis's spending on wastewater plant operation and maintenance per individual ninth among the communities that we studied.

- Grants: write more grant proposals trying new technologies. Indianapolis believes that it is too much effort to secure the few grants available but other cities have used them to good effect. Application of some may especially be helpful with the issue of water quality degradation due to failing septics.

- Sewer rates: The city looked at ability to pay for CSO projects based on the lowest median income neighborhoods (based on affordability). Perhaps increasing sewage rates over a shorter timeline while providing assistance to low income individuals would generate more needed capital for CSO projects.

- Taxes: Additional property taxation for wastewater and CSO improvement is constrained by political, legal, and equity issues. An argument is that taxation rates are tied to property value and not to "use" (creating equity concerns). However, higher value properties most likely receive better "service" by not having the CSO problem at their door.

- New development: Developers adding new additions to the existing wastewater system should pay a direct impact fee. If the LTCP goal of 85% reduction is to be successful, additional development must have charges for additional contributions that will require additional plant capacity and treatment.

- Public awareness: Other communities have been more effective at stating their case for appropriated funds from Congress. Indianapolis certainly has strong justification for receiving an appropriation based on the length and severity of the CSO problem, communities affected, and the impact on the water bodies discharged into. Encourage community participation during discussion of funding alternatives to invest community members in outcomes and to build consensus.

Social and Community Recommendations for Indianapolis

The problem of how to improve and build suitable wastewater infrastructure with constrained budgets is one that many CSO communities across the country are facing. Some of the problems cities with combined sewer overflows face are large expenditures to upgrade and improve the system, poor image of the city as a place to live and work, the threat of disease outbreaks, and legal liability. Citizens living in these cities have many of the same concerns such as human health risks from raw sewage, lowered property values, increases in sewer bills, taxes, or sewer hook-up fees. The municipal Indianapolis government, private firms, and the citizens residing in Indianapolis have a mutual interest in finding a solution to CSOs and adequate future wastewater capacity.

Although Indianapolis has made positive steps by increasing their commitment to resolving the CSO problem, a late start addressing CSOs and wastewater infrastructure shows Indianapolis compared unfavorably to some other regional cities competing for businesses and growth. Although Indianapolis has one of the most extensive CSO problems, reduction and elimination of CSOs can be budgeted for long periods of time while still working to improve the well being of its citizens in the short-term. Furthermore, allocating additional money to the budget is difficult since budget surpluses of the last few years have dissipated. While unpopular politically, and with equity concerns for poor citizens, revenue generation by increased wastewater charges and additional taxes on property have been effective in other cities.

Indianapolis has an additional problem with large numbers of failing septics in some of the neighborhoods. These failing septics create not just a health hazard and nuisance to those who must live in the area, but contribute to water quality problems and negative public images of Indianapolis as a place to live, raise a family, and conduct business. Indianapolis should consider failing septics not as a separate issue pertaining to some neighborhoods and with individual citizen liability, but as an integral part of the city's CSO problem. The failing septic issue affects all Indianapolis citizens in multiple ways. As conversions from septic systems to the city sanitary sewer increase, more capacity in the WWTP may be necessary to efficiently manage the additional flow. Failing septics also lead to human and environmental health concerns for area citizens such as sewage-related diseases and the potential for widespread water contamination. Environmental justice issues are also linked to the location of failing septics. Many Indianapolis citizen groups argue that a large portion of citizens with septic systems are bearing the financial burden of septic renovation and sewer connection disproportionate to the ability to pay.

The Indianapolis LTCP addresses ways in which to involve the public during planning and construction phases of CSO improvements. We agree with the city that citizen involvement in CSO issues is crucial and recommend that these measures continue. Both citizens and city/county government offices need to be informed and involved in the resolution of the CSO problem. Adequate information needs to be collected concerning areas of greatest CSO impact, areas of human contact, and the effects of other wastewater structural failures, including the impacts and fate of failing septics, in order to prioritize and adequately inform agencies and citizens.

Citizens and agencies need centralized, access to this information. Agencies, nonprofit organizations, community groups, and city/county departments benefit from a source of reliable, centralized, and continuously available data. Raising the consciousness and cooperation of the community will more effectively happen if there is interagency cooperation and coordination. Accessibility means more than just available information, it also means actively pursuing fair and consistent treatment in hearings, public meetings, and dissemination of information. Poorer residents often have neither the resources nor the time to actively pursue information that is hard to find and understand.

One effective feature in communities that are dealing more successfully with the CSO issue is appropriate, clear, and focused communication. Involvement of local community groups, nonprofit organizations, schools, and churches to assist in conveying information is a good way to involve, coordinate, and gain cooperation. The city should implement education of children and their parents about CSOs through school health classes, posters in neighborhoods, and community group action. Signage at CSO outfalls is important, but inadequate in communicating risk to children and gaining cooperation with communities.

To improve the image that Indianapolis has among its citizens, businesses, and people considering relocation to Indianapolis, citizens living within CSO areas need:

- For the City to continue gathering more information about CSOs and other wastewater infrastructure problems including health risk assessments, GIS studies to assist in prioritization of improvements, and local community health and social issues.

- Cooperation and coordination among governmental agencies and city/county departments to improve response efficiency and effectiveness in financing, construction, and public outreach missions.

- Consistency in city, agency, and departmental action. Reliable production of information and forthcoming interactions with the government generate trust and good working relationships

- For the city to continue public outreach based on the 2000 LTCP model. The city should inform the public and increase their knowledge of CSOs through the sharing of information in an appropriate, understandable language. Information should be communicated in languages that are understood in each neighborhood.

- Make information consistent, accurate, and available. Communicate at the community level using local citizens groups, nonprofit organizations, churches, television stations, door hangers, and representatives in schools. Warning of imminent CSO events in affected neighborhoods is also necessary through television or other means.

- Reexamine additional revenue generation by increasing wastewater treatment rates while providing the disadvantaged assistance with sewer bills and septic hookups. Although competitive and requiring more creative grant writing and planning, other CSO communities have taken advantage of federal grants to a larger effect than Indianapolis.

- Continue educational programs to inform all citizens about the CSO problem and associated risks. Citizen knowledge of what can and is being done will help generate citywide support for equitable improvements. Communication with the public must continue as long as CSO events occur.

The citizens of Indianapolis who have access to timely, accurate, and clear information about CSOs and what the city is doing to address the problem will more likely be part of the CSO solution in Indianapolis.

Technology Recommendations

All cities examined in this report use some form of technological measures to improve sewer systems. These technological measures may serve to reduce inputs to the system, improve the usage of existing system storage, or expand the system's capacity. Measures to reduce inputs to the system include mandating the use of porous materials instead of concrete and asphalt, rehabilitating soils to make them more porous, and creating infiltration basins that allow water to soak into the earth, as well as creating pipes which run directly from areas such as parking lots to creeks and streams, instead of into the sewer system. In order to improve the use of existing system capacity, Indianapolis and other cities have made use of controls that block overflow pipes with inflatable balloons or metal gates. Computers measure the amount of flow and close the gates or inflate the balloons to trap water and sewage and open again when maximum capacity has been reached or when the wet weather event is over. These systems require some sort of real-time monitoring to inform the system when a wet weather event is taking place and when the event is over. Other measures to better utilize existing system capacity include the creation of boxes and angles which control the sewer flows underground, and the improvement of WWTPs to increase their capacity. Measures that expand the systems capacity that cities are putting into place include links between WWTPs to send excess flows to plants with more capacity, digging catch basins that also have some primary treatment capacity, and the utilization of deep storage tunnels and mines, which add excess capacity to the system.

Indianapolis is planning to expand WWTPs and to make use of two inflatable dams and real-time monitoring systems. Indianapolis planners might also consider the creation of catch basins and diverting flows from parking lots and building roofs away from the sewer system and to canals and ditches. In the parks downtown, some of the measures mentioned above might be taken to improve the porosity of the soil and surfaces, as well as planting foliage to absorb extra rainwater. These measures will not improve the inner-city areas that have outflows, however. Alternatives that work well in these areas have yet to be developed.

Water Quality Recommendations for Indianapolis

Water quality problems associated with CSOs are difficult to remedy without a comprehensive CSO abatement plan with an extensive focus on water quality itself.

Even the cities that scored high in the water quality index have had difficulty improving the water quality of receiving water bodies to meet the applicable standards. The most common problem, and a significant one for Indianapolis, is fecal coliform concentrations. Indianapolis exceeds the standards for *E. coli* on a regular basis, and according to their LTCP, *E. coli* will continue to exceed the standards. The other water quality parameter Indianapolis needs to deal with specifically is toxic metal concentrations.

E. coli, bacteria associated with the intestine of warm blooded animals, has three primary sources in Indianapolis; CSOs, runoff, and failing septic systems. Metal contaminants come from stormwater runoff and industrial effluent. The LTCP shows that the *E. coli* and metals will not be reduced to below the standards with the only strategies provided in the plan. So, in order to deal with these issues, Indianapolis needs to propose a plan that directly deals with these issues in addition to the LTCP. Some recommendations are:

- Further reduce the number of overflows into the streams.

- Construct upgradeable holding basins for the overflows such that eventually all sewage will receive treatment.

- Provide incentives for local businesses and residential communities to increase pervious surfaces and decrease storm water runoff.

- Provide assistance to citizens to fix or remove failing septic systems.

- Build a new WWTP to relieve the CSO system.

- Consider river clean up of metals in sediments.

- Focus first on areas of high population and high fecal concentrations, such as Pogues Run area where there are many schools in proximity to the river.

Future Studies and Research

There is the significant potential for future studies within the area of combined sewer overflows. As a result, we have several recommendations for future research. One potential research focus would be determining whether there is a correlation between CSOs and known health outbreaks. A future study could assess the overflow periods with the number of health outbreaks in a community. Another potential area of study involves determining the effect, if any, the presence of CSO outfalls has on property values. Furthermore, measuring the implications CSOs have on economic growth, beautification and residents' quality of life would also better assess their impact. Research into the financial aspects or cost-benefit studies of CSOs could assist communities with the implementation of combined sewer overflow reduction plans that provide the lowest economic consequences. More specifically, less expensive CSO outfall-monitoring techniques, through software development, could greatly increase the assessment of the CSO impact as well as methods of monitoring and reducing overflow events. Through this study, we have found that the CSO problem is a politically and socially charged issue, involving a wide range of stakeholders. There are numerous future research applications including health, the environment, environmental justice, political actions, and social mobilization.

Report Limitations

There were several limitations to this graduate-level service-learning project. A primary limitation was due to the many facets of data retrieval and interpretation. The desired data was many times not available, not comparable between cities, and inconsistent between cities. The lack of data availability greatly limited our research and subsequent interpretations. The comparability between data was also a significant problem due to the fact that each city had specific methods for data collection and recording. This was especially a problem when interpreting water quality data, the associated instrumentation, frequency of data collection, and reporting. Inconsistent data was a result of the large number of sources contacted and contradicting information received. Moreover, there were significant difficulties obtaining data due to the inaccessibility of information via the Internet, city contacts, or other sources. An additional limitation involved the lack of time and researchers required for a project of this magnitude. Lack of monetary funding was also a significant barrier. Costs associated with the gathering of data, mailing and receiving important data, and personal meetings with city representatives were not permitted due to the lack of a travel allotment. Although our study had several limitations it was completed with a great deal of time and effort and to the best of our capabilities. We hope the research and indices presented in this report can be applied as a framework of comparison for cities with combined sewer overflows.

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VII. Appendices

Appendix A: Listing of Acronyms Cited

BAT - Best Available Technology
BCT -Best Conventional Technology
CSO - Combined Sewer Overflow
CWA - Clean Water Act otherwise known as the Federal Water Pollution Control Act
DO – Dissolved Oxygen
DOSD - Columbus Division of Sewerage and Drainage
DPW - Indianapolis Department of Public Works
EPA - Environmental Protection Agency
FWPCA - Federal Water Pollution Control Act
HEC - Hoosier Environmental Council
IKE - Improving Kids' Environment
LTCP - Long Term Control Plan
NMC - Nine Minimum Controls
NPDES - National Pollutant Discharge Elimination System
OEPA – Ohio Environmental Protection Agency
POTW - Publicly Owned Treatment Works
UAA - Use Attainability Analysis
WWTP – Waste Water Treatment Plant

Appendix B: Author Biographies

Kara Bush

Kara Bush will receive a Master's of Public Affairs degree in June of 2002 with concentrations in Natural Resource Management and Policy Analysis and Nonprofit Management from the Indiana University School of Public and Environmental Affairs. Kara received a Bachelor's of Science in Public Affairs degree with a major in Environmental Management and a minor in Spanish from the Indiana University School of Public and Environmental Affairs. Her interests include sustainable community development issues, restoration, and volunteerism. After graduation Kara will work as a seasonal land steward with Indianapolis Parks and Recreation and will then move to Mexico to work on sustainable community development projects.
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Steve Crider

Steve Crider will receive a Master's of Science in Environmental Science in May of 2002 with a concentration in Environmental Chemistry, Toxicology and Risk Assessment. After graduation Steve plans to work for a private consulting firm in Michigan where he will be part of the environmental redevelopment team.
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Erika Jensen

Erika Jensen is a Master's of Science student specializing in Water Resource Management at Indiana University's School of Public and Environmental Affairs. Erika received her B.S. in Natural Resource Management and Environmental Studies from the University of Wisconsin Madison. She has worked in environmental consulting, as an Americorps volunteer, and in the non-profit sector for the Seattle Aquarium. Erika recently spent a semester studying water management in The Netherlands.
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Richard Knepper

Richard Knepper is a master's student in a joint program between Indiana University's Russian and East European Institute and the School of Public and Environmental Affairs. His research interests include information systems design and implementation, IT for non-profit organizations, e-government initiatives, and development in Poland. He is currently working on an evaluation of Poland's Information Technology Infrastructure Development Plan. He is also an employee at IU's University Information Technology Services, working as a system administrator in the Unix Systems Support Group.
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Pinida Leelapanang

Pinida Leelapanang is a Master's of Science in Environmental Science candidate with a concentration in Environmental Chemistry, Toxicology, and Risk Assessment. She will graduate in December of 2002 from the Indiana University School of Public and Environmental Affairs. Her specific interests include water quality control and pollution prevention. She received Bachelor's of Science in Chemistry with a concentration in Analytical Chemistry in March of 2000 from Mahidol University, Bangkok, Thailand. Her undergraduate work was mainly on High Performance Liquid Chromatography.
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Angie Magner

Angie Magner will earn a Master's of Public Affairs degree in May of 2002, with a concentration in Natural Resource Management and Environmental Policy. She also completed her undergraduate degree at Indiana University and earned a Bachelor of Science degree in Park and Recreation Administration with a Minor in Environmental Management. Her previous work experiences include a variety of environmental education positions. Working as a Naturalist at McCormick's Creek State Park in Spencer, Indiana has been one of her most enjoyable work experiences.
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Debra Rose

Debra Rose has a Bachelor's degree in microbiology and graduate work in molecular biology. She currently works in a cell biology laboratory characterizing proteins that effect early cell division. Debra will graduate this spring with a Master's degree in Public Affairs and a specialized concentration focus of environmental policy and alternative dispute resolution. She is also interested in environmental equity.
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Stephanie Snider

Stephanie Snider is a native of Arkansas who graduated from Indiana University in 1996 with a Bachelor's of Science in Public Affairs concentrating in Environmental Science and Management. She has worked for the Sierra Student Coalition – the student branch of the Sierra Club - in Providence, Rhode Island and Second Nature (an environmental post secondary education organization) in Boston, Massachusetts. Stephanie was also employed as the Outreach Coordinator for Save The Bay in Providence where she facilitated campaigns and promoted legislation to protect and restore Narragansett Bay. As a volunteer, Stephanie served on the Executive Committee of the Rhode Island Chapter of the Sierra Club. Stephanie is currently pursuing a Master's of Public Affairs in Environmental Geographic Information Systems (GIS). She is currently an intern with the City of Bloomington as a GIS assistant for the Planning Department. Upon graduation, Stephanie plans to move west to use GIS as a tool for ecosystem management on public lands.
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Theresa Wilson is a Master's of Science in Environmental Science student at the School of Public and Environmental Affairs, Indiana University – Bloomington. She will graduate in December 2002 with a concentration is water resources. Theresa received her B.S degree in Biology from St. Louis University. Her work experience has included Leukemia research, California Gnatcatcher population and habitat studies, Ichthyological studies, and outdoor leadership positions. In addition to her coursework, Theresa also currently enjoys teaching 'Managing Resources for Learning' at Indiana University.
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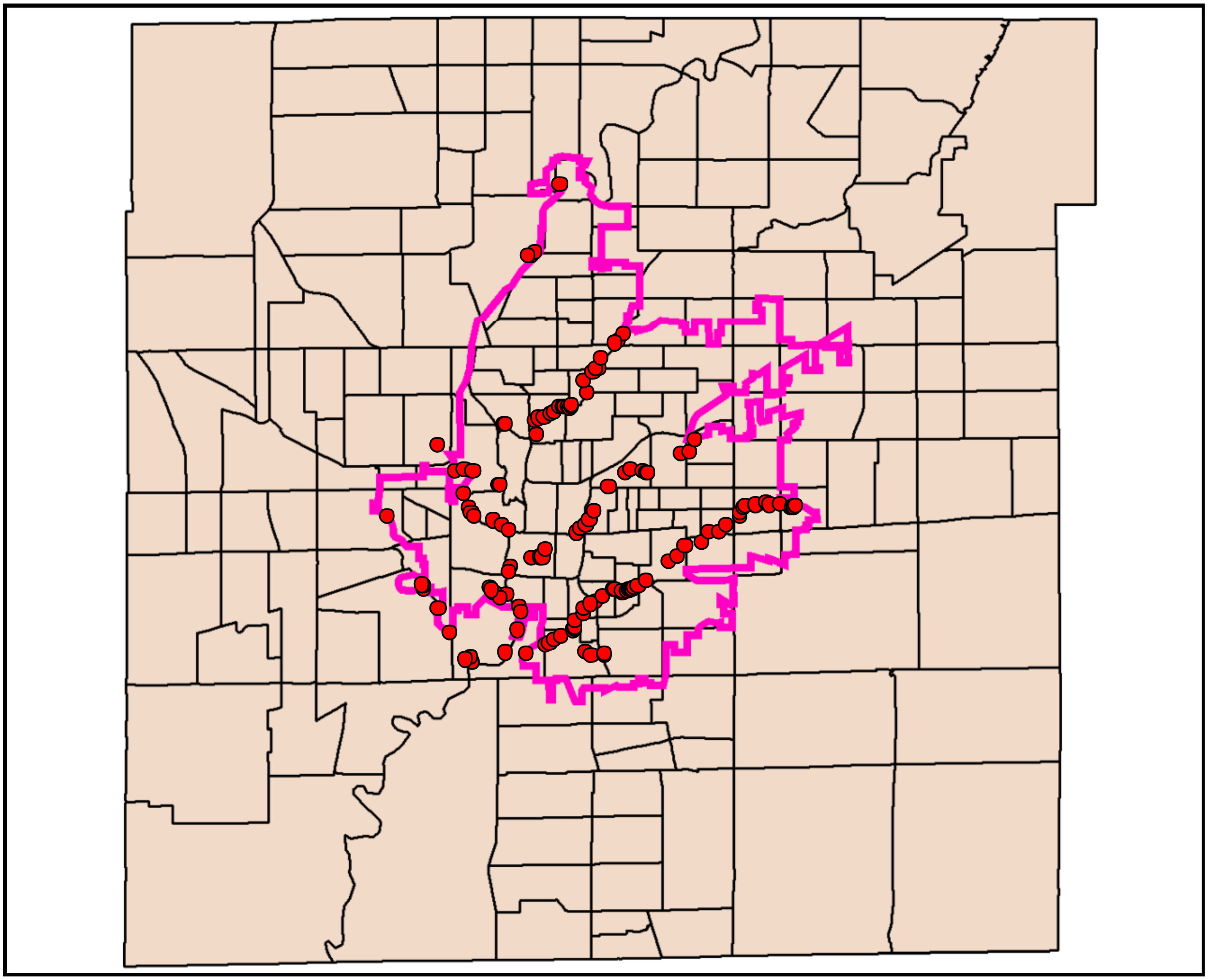
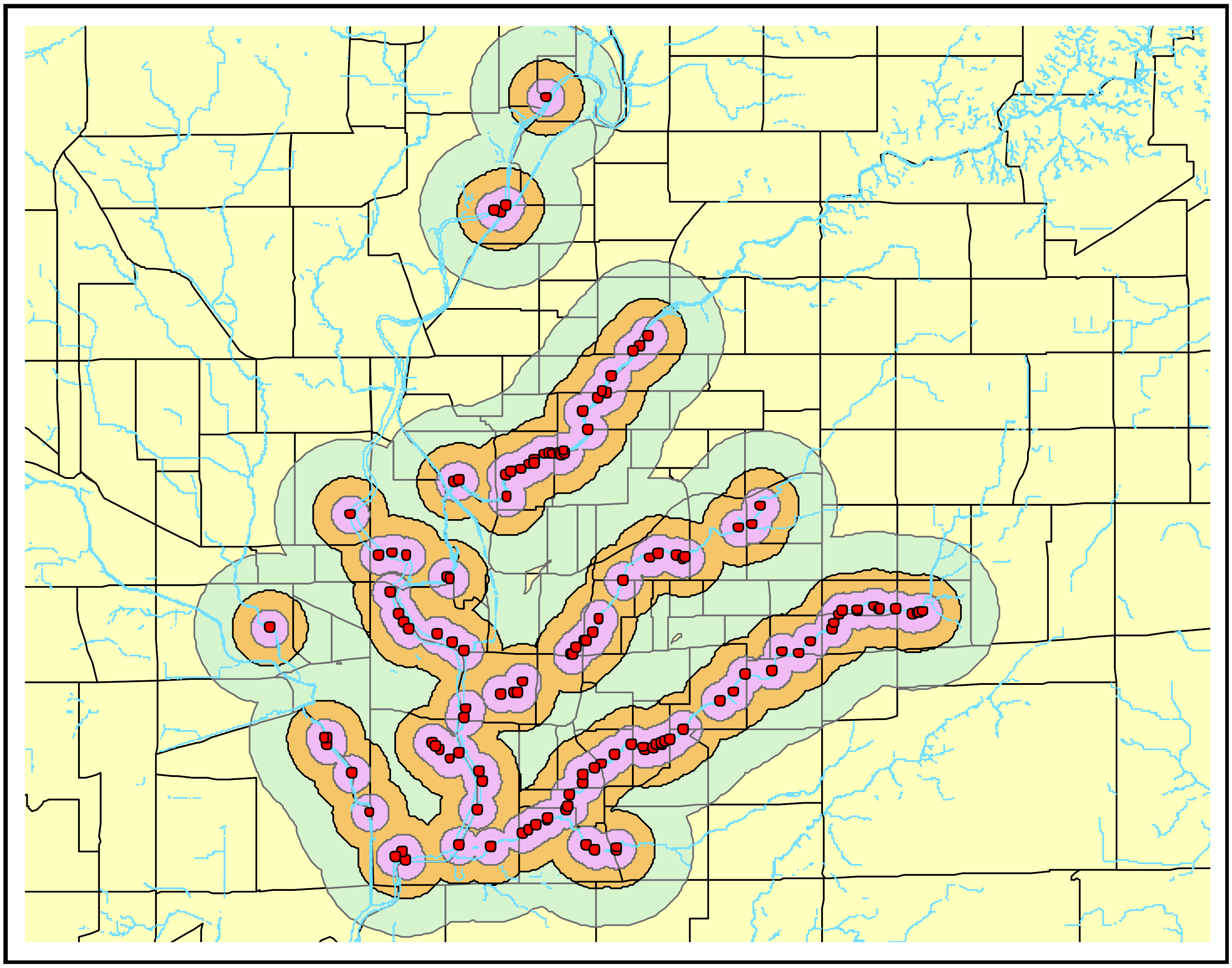
Appendix C: Environmental Justice GIS Maps for Indianapolis and Marion County

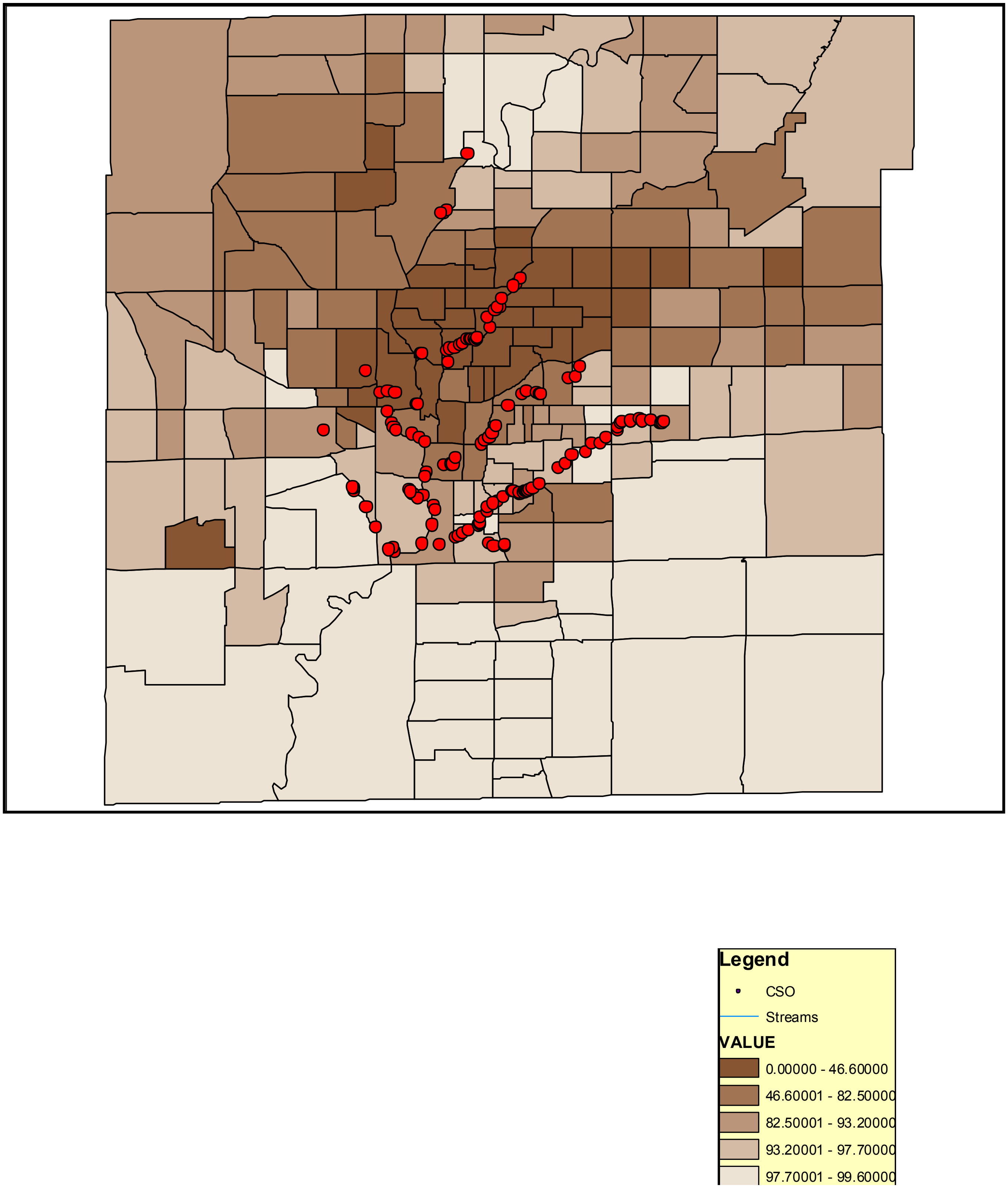
Map 1: Study Area – Marion County with CSO Area



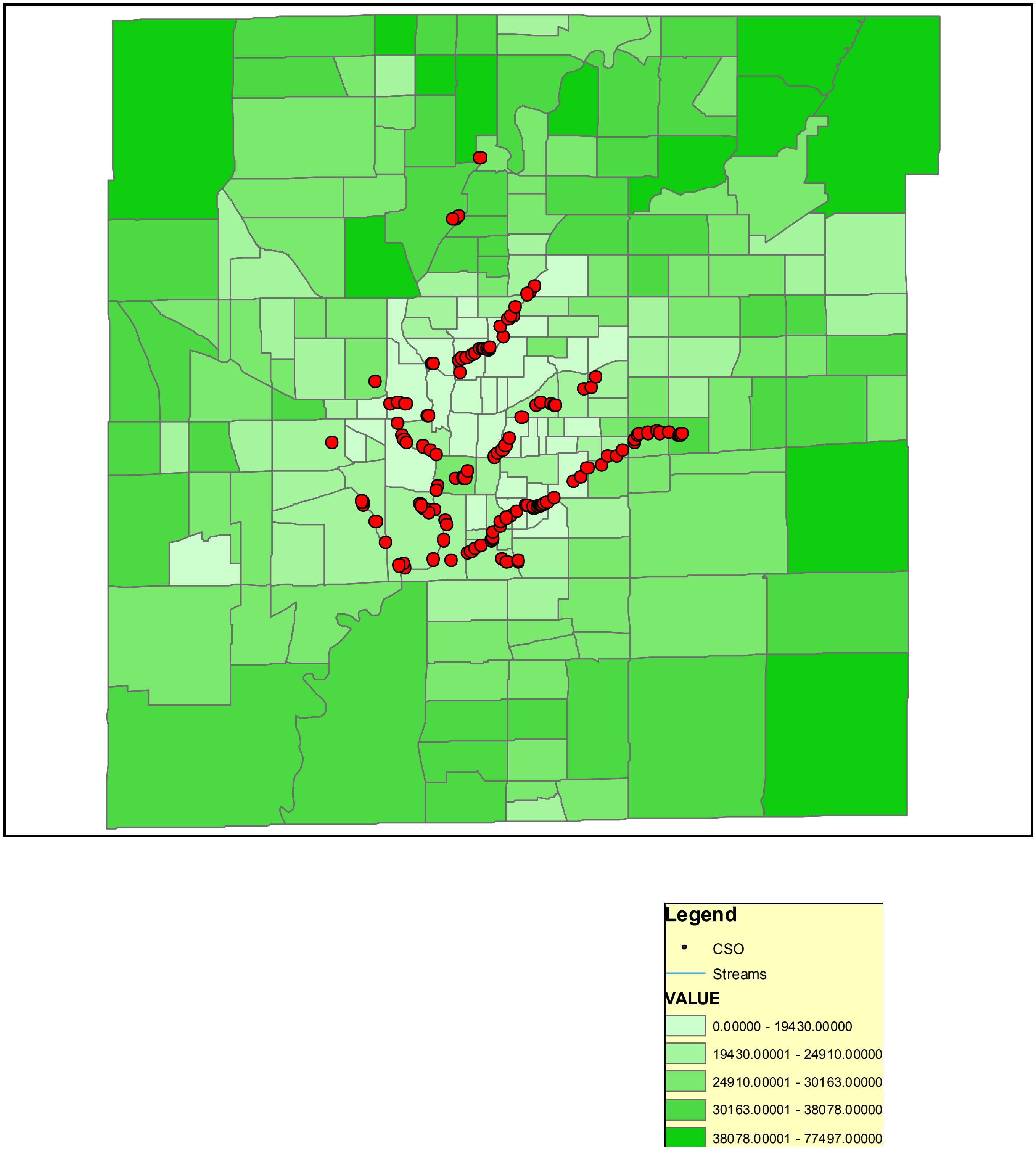
Map 2: Census Tracts and CSO buffers



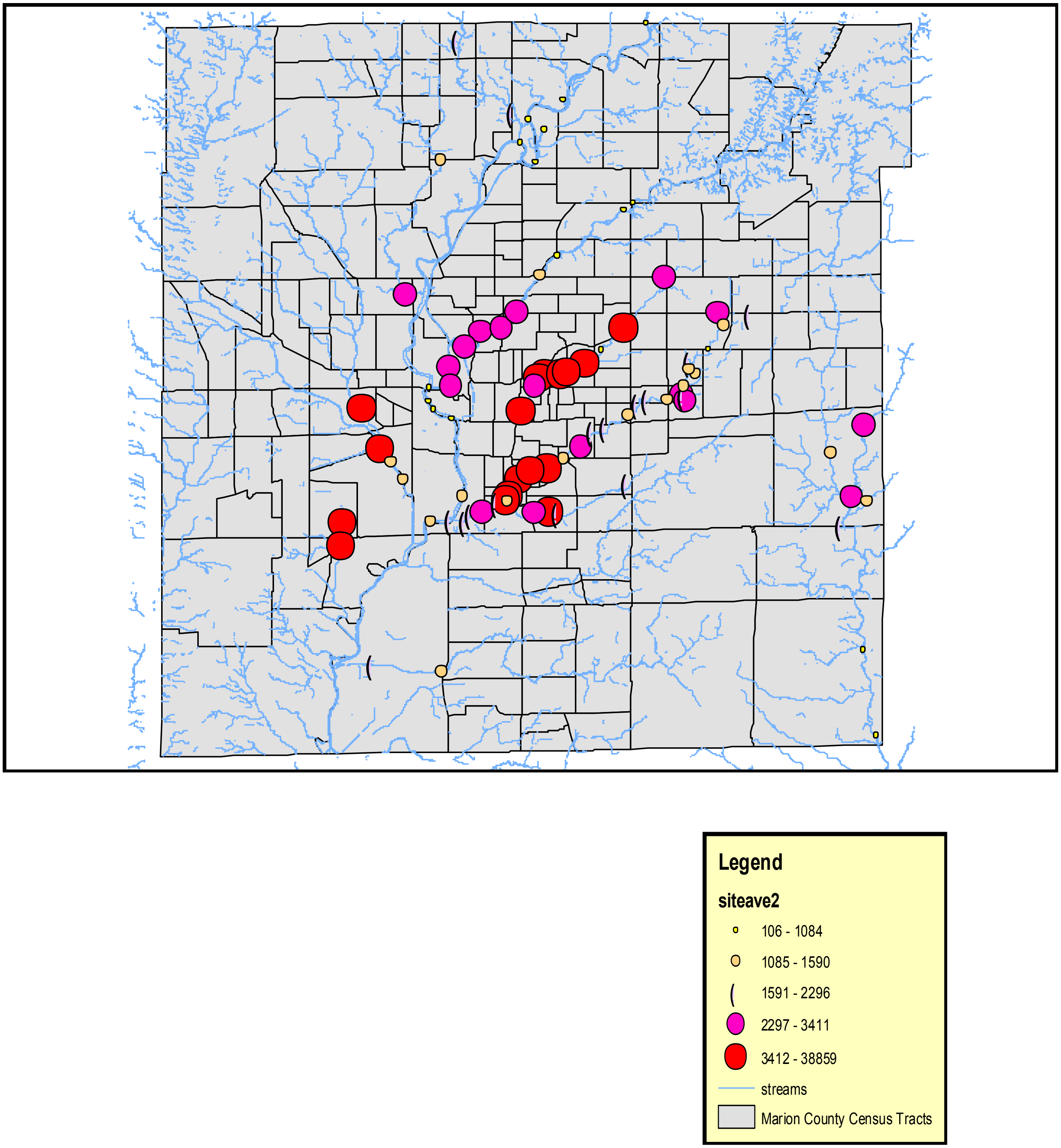
Map 3: Minority Census Tracts in Marion County (by Caucasian population percentage)



Map 4: Low Income Census Tracts in Marion County (by Household Income)



Map 5: E.coli Hot Zones (Extreme High Levels) for Water Quality Sampling Sites



Appendix D: Summary Table Of *E.coli* Sampling in Marion County for GIS Analysis

Location	Stream	Ecoli96	Ecoli97	Ecoli98	Ecoli99	Ecoli00	Ecoli01	Site Average
Gadsden St.	State Ditch	3150	140000	8653	14657	43235	23461	38859.33
Steel St.	Pogues Run	38040	1780	5283.33				15034.44
New York St.	Pogues Run				1603.49	1983.82	27474.72	10354.01
Vermont St.	Little Eagle Creek	980	8380	3350	6547.143	551.4286	37767.14	9595.95
Brookside Ave.	Pogues Run	6350	3302	16300				8650.67
Olney St.	Pogues Run	3460	5390	16650				8500
Tacoma St.	Pogues Run	6920	5360	10800				7693.33
Lyons St.	State Ditch					9351	5191	7271
McCarty St.	Big Eagle Creek					715.7143	12115.71	6415.71
Villa Ave.	Pleasant Run	5560	5730					5645
Barth Ave.	Pleasant Run					2818	7527	5172.5
Raymon d St.	Pleasant Run	7690	2630					5160
Rural St.	Pogues Run	5560	3367	15816.67	2173.59	1264	1394.83	4929.35
Garfield Park	Pleasant Run			4314	248	5206	7703	4367.75
Villa Ave.	Bean Creek			4036.33				4036.33
Cottage Ave.	Pleasant Run	5280	2630					3955
Emerson Ave.	Pogues Run				3633.8	4137.82	3668.28	3813.3
38th St.	Pogues Run				963.86	4214.68	5055.79	3411.44
10th St.	Pogues Run	3090	1215	7016.67	948.96	2940.36	4830.35	3340.22
Edmondson	Pleasant Run			3230.17				3230.17