CHAPTER 3: DEVELOPMENT AND EVALUATION OF ALTERNATIVES FOR CSO CONTROL

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CHAPTER 3: DEVELOPMENT AND EVALUATION OF ALTERNATIVES FOR CSO CONTROL

The Final Combined Sewer Overflow (CSO) Long-Term Control Plan (Final CSO LTCP) approach to reduction required by the 1994 CSO Control Policy is based on identifying the solutions that provide the greatest benefit-cost ratio and/or improves overall performance of the combined sewer system (CSS) in containing and treating pollutants. This chapter discusses the approach toward creating the Final CSO LTCP, the process toward development of CSO control alternatives, and the tools used to evaluate CSO control alternatives.

3.1 LONG-TERM CONTROL PLAN APPROACH

In this section, structured approaches to establish targets for CSO controls that will protect water quality and designated uses are addressed. The processes and tools used to create and convey solutions are discussed.

3.1.1 Demonstration Versus Presumption Approach

The CSO Policy identifies two methods, the "demonstration" and the "presumption" approaches, to establish targets for CSO controls that will protect water quality and designated uses (59 Code of Federal Regulations {CFR} 18688). In developing CSO alternatives, the Louisville and Jefferson County Metropolitan Sewer District (MSD) initially used a presumptive approach that was based on the number of overflows per year.

To establish the best technical solution for each of the 106 CSOs, a range of technical alternatives were developed to achieve an initial control level of four overflows per year. The costs and benefits of each technical alternative were developed, and a benefit-cost tool used to select the preferred technical approach for each CSO. The preferred alternative may be a project to control a single CSO outfall, or a project that consolidates control of a cluster of several CSO outfalls. Each of the preferred alternative solutions was then resized to achieve other levels of control, namely zero, two, and eight overflows per year. The benefit-cost evaluation was repeated for each level of control, and the optimal level of control then established for each solution.

Concurrently, water quality models were utilized to predict water quality effects of the various levels of control. The Beargrass Creek water quality simulation results demonstrated that reductions in CSOs did have an effect on water quality, but the differences between the levels of control were small. Similar to the Beargrass Creek water quality model results, the Ohio River water quality model demonstrated an improvement in water quality between baseline conditions and eight overflows per year, but no water quality benefits of CSO control are observed for the other levels of control.

Based on the water quality model results and benefit-cost evaluation results, MSD selected a system-wide solution which meets the criteria of the both presumptive and demonstrative approaches.

The selected plan exceeds the minimum presumptive approach of 85 percent capture of CSO (per the CSO Control Policy) and also successfully meets the criteria of demonstrative approach (per the CSO Control Policy) listed below:

- The planned program captures 96 percent of combined sewer overflow in a typical year, and water quality models for the Ohio River and Beargrass Creek predict that CSOs will not cause violations of the water quality standards with background pollutant loads from other sources removed.
- Benefit-cost evaluation and water quality modeling of the control plan demonstrate that the selected plan provides the maximum pollution reduction benefits reasonably attainable.
- The selected plan will be designed to allow for reasonable expansion or retrofitting of controls to meet water quality objectives based on post construction compliance monitoring. Additional options to modify the plan include expansion of the Green Infrastructure Program, if proven cost-effective, to reduce source runoff to the CSS.

MSD will monitor the reduction of other pollutant sources to Beargrass Creek and the Ohio River as it implements the Final CSO LTCP and its post-construction monitoring program. Monitoring will include application of the Beargrass Creek and Ohio River water quality models to assess attainment of water quality standards for bacteria in both water bodies plus dissolved oxygen in Beargrass Creek.

3.1.2 Decision Process

The risk management-based decision process that was applied to develop and evaluate CSO control alternatives for the Final CSO LTCP utilized institutional knowledge of the CSS, Water Environment Federation (WEF) Guidance documents, U. S. Environmental Protection Agency (EPA) Guidance documents, and tools developed by the MSD's program technical team. The process addressed benefit determination, cost analysis, and public participation. The risk management-based decision process is described in detail in Volume 1 of the Integrated Overflow Abatement Plan (IOAP).

An initial Final CSO LTCP project list was established by reviewing numerous documents compiled over the previous 20 years related to both CSS and associated watershed studies. Workshops were conducted March 2007 and May 2007 with a group comprised of MSD senior management and technical personnel from the engineering firms having historical experience with the CSS. The historical knowledge by personnel was applied to create an initial wide-range of control technologies resulting in 198 projects. A screening exercise reduced this list to 136 viable alternatives. These 136 projects were conceptually designed, followed by determination of related costs and benefits. These projects consisted of CSO-specific, CSO-consolidation, and CSO-regionalization projects across an array of control technologies, including storage, treatment, separation, etc. A matrix of the control technologies reviewed by CSO is listed in Table 3.1.1 located at the end of this chapter. In addition, a Green Infrastructure Program considered multiple solutions to reduce the volume of stormwater entering the CSS. This program is described in detail in Section 3.2.5.

There were other elements of the Final CSO LTCP that were not subject to the evaluation process, primarily because no alternatives were considered. These were related primarily to the U. S. Army Corp of Engineers (USACE) Flood Protection System Infrastructure, combined sewage pump-back to the CSS following a wet-weather event, and completion of downspout disconnection programs that are partially complete as of December 31, 2008.

Regarding Flood Pump Stations, physical modifications are recommended to five existing stations developed per the Consent Decree. Modifications involve new gates, actuators, and operating guidelines, therefore, there were no comparative alternatives.

In addition, during the optimization of alternatives, the need to off-load existing interceptors was realized to allow return of stored CSO to the CSS. This necessitated upsizing an existing pump station, therefore no alternatives exist for this project. Related to interceptor capacity, the final hydraulic model run indicated the need for additional capacity in Beargrass Creek South Fork corridor in order to empty recommended storage basins within 48 hours, therefore a parallel interceptor project is recommended.

Finally, downspout disconnection programs are in progress in two CSO drainage areas contributing to Beargrass Creek Middle Fork. Two other projects are recommended to complete the downspout disconnection programs under this Final CSO LTCP.

3.1.2.1 Cost Model

The "Wet Weather Plan Project Cost Estimating Reference Document" (May 2007, CH2M Hill) was used to prepare conceptual cost estimates of proposed projects. The cost model utilized standard construction cost estimating unit factors, based on the "Engineering News Record – Construction Cost Index" (ENR-CCI), and was calibrated to MSD's history of construction costs.

The cost model was used to generate capital and 20-year present worth costs for each project under consideration for consistent comparison between projects and technologies. In anticipation of construction initiation by 2010, an ENR-CCI of 8550 was applied to advance planning-level costs into 2010 dollars. Following selection of the final gray infrastructure project list, these project costs were recalculated at the 2008 ENR-CCI of 8136, plus project/site-specific cost data and allowances in order to create a present-day program cost. This allowed MSD to apply an escalation factor over the life of the program in order to establish cash flow and funding requirements.

3.1.2.2 Benefit-Cost Analysis

Following establishment of the initial project list and subsequent conceptual designs and cost estimates, the benefits of the CSO control were determined to generate ultimately, a benefit-cost ratio for eventual project ranking and recommendation. For instance, the project list included a variety of technologies and project sites, and addressed single-CSO vs. multiple-CSO project groupings. The discussion of the benefit determination process is discussed extensively in IOAP Volume 1, Chapter 2.5 and is only discussed in this section in terms of application to the Final CSO LTCP.

Eleven community-based, project-specific and programmatic values (benefits) were established by the Wet Weather Team (WWT), of which five were ultimately selected to calculate a project's array of impacts to the community. To enhance the benefit-cost ratio process, the WWT assigned weighting factors on a 0-10 scale to each of the five project values to reflect the degree of importance to the overall control plan impact to the community. The values and assigned weights that were used to score benefits were as follows:

- Asset Protection 6
- Eco-Friendly Solution 6
- Environmental Enhancement 8
- Public Health 10
- Regulatory Performance 8

Information and data utilized to score three performance values: Asset Protection, Public Health, and Regulatory Performance, were generated by the hydraulic model of the CSS. Additionally, to account for the significant magnitude of scale of receiving stream flow, separate scales were established for the Ohio River and Beargrass Creek.

Regulatory Performance and Public Health were scored on a 25-point severity-frequency matrix according to CSO discharge volume and frequency. The baseline characteristics of the CSS were initially scored, followed by scoring the remaining overflow/frequency resulting from the proposed control. The difference in these values was the benefit score, with a higher score indicating a higher reduction in risk, or higher value of benefit.

The Asset Protection value was also scored on a 25 point severity-frequency scale (design storm versus damage impact) to account for reduction in surface flooding conditions by a proposed CSO control. This value was scored using one of two methods. Method 1 utilized design storms versus basement backup potential (hydraulic grade line) of the CSS during precipitation events. Method 2 utilized design storm versus customer flooding complaints.

To score Method 1, the baseline condition was first established by the CSS model, followed by determination of the sewer hydraulic grade line during various precipitation scenarios. A basement backup was considered possible if the hydraulic grade line reached a level within six feet of a manhole rim. As with the Regulatory Performance and Public Health values, the benefit was the difference in the two scores, with a higher score indicating a greater benefit.

To score Method 2, MSD Customer Information System complaint data was compiled according to storm event. The level of damage (ranging from standing water to severe structural damage) was plotted against the storm frequency. Higher degrees of damage during high frequency storms were considered the worst-case outcome. The scores from the two methods were compared and the worst-case condition was applied to a project. In practice, it was found that the hydraulic condition score (Method 1) governed the outcome as Customer Information

System complaints were difficult to use to fully assess the nature of damage reported by the customer.

The Environmental Enhancement and Eco-Friendly Solution values were scored using several performance metrics that represent a variety of aspects related to the environment or ecosystems. Each of the aspects were scored on a 10-point negative-to-positive scale (-5 to +5). Environmental Enhancement primarily assesses aquatic impact, while Eco-Friendly Solutions assesses broader land/energy impacts of proposed CSO control alternatives. To score these subjective aspects, a diverse, objective group of professional engineers, certified ecologists, and aquatic biologists from different consultant entities were assembled. This group established methodologies of scoring, and then participated in scoring a majority of the alternatives.

3.1.2.3 Public Participation

In order to educate and engage the community in CSO control alternatives development, a series of public meetings were held throughout the Fall of 2007. The meetings were publicly advertised in the local newspaper, and an announcement was posted on the Project WIN (Waterway Improvements Now) website, www.msdlouky.org/projectwin.

MSD held a public meeting at the Girl Scouts of Kentuckiana offices. Attendees learned about Project WIN and the changes they could make to improve water quality.

The objectives of the public meetings were to provide an opportunity to review the in-progress draft IOAP, view maps of the sewer service area of affected neighborhoods, encourage dialogue between the public and MSD officials, and record and address questions regarding the planning process. Seven meetings were held, spatially distributed across the community. MSD staff conducted the presentations and communications, while IOAP technical team representatives attended to address the specifics of each solution. The meetings were conducted during evening hours to maximize the opportunity for attendance.

The public was also involved through the Stakeholder Group membership in the WWT. The WWT was extensively involved in CSO controls alternatives development and selection of the recommended plan. Their engagement, plus a list of meeting dates with associated agenda topics, is discussed fully in IOAP Volume 1, Chapter 3.2.

3.2 DEVELOPMENT OF ALTERNATIVES

In this section, the green and gray infrastructure technologies that control CSO discharges are discussed. Various alternatives exist in today's market; a brief description of the processes and performances of these technologies is presented. In addition, programmatic elements, such as source control/reduction and collection system storage are discussed.

MSD received a strong appeal from the WWT to integrate green technologies into the Final CSO LTCP to reduce the frequency and volume of CSO discharges. Because of this encouragement, plus commitment by MSD leadership to consider all solutions, a Green Infrastructure Program was evaluated for inclusion in the Final CSO LTCP. Along with the presentation of both technologies, this section also begins discussion of the initial CSO controls considered.

3.2.1 General Considerations and CSO Control Measures

Over the years, those involved with CSO abatement programs, such as consultants, equipment manufacturers, and CSO communities, have developed various practices and technologies for control and treatment of CSOs. The earliest technologies were in response to the nine minimum controls (NMC) requirements in the 1990s including technologies such as netting, screens, and trash racks for floatables control. As NMC technologies were implemented, the industry began to develop new technologies that represented the second generation of control strategies. Many of these next generation technologies are under consideration for application to MSD's CSS. The following Sections 3.2.2 through 3.2.4 review those technologies.

Each technology evaluated for applicability is grouped within one of three categories: Collection System Controls, Storage, and Supplemental Treatment. A detailed summary of each technology is presented along with examples of MSD's experience with applicable technologies.

3.2.2 Available Technologies - Collection System Controls

Collection system control technology is designed to increase the capacity of the sewer system and/or minimize extraneous flows into the system. The reasons behind the need for collection system modification or rehabilitation may include:

- Change in design philosophy, from a combined system to a separate system
- Inadequate capacity (e.g., land development exceeded expectations)
- Poor construction practices (e.g., improper bedding)
- Root intrusion (e.g., causing open joints)
- Chemical attack on the system (e.g., Hydrogen Sulfide)
- Normal aging and deterioration
- Damaged and leaking pipes
- Soil movement (e.g., causes joint separation)

Methods of collection system control include infiltration reduction, inflow reduction, and new sewer construction. The techniques are described in the following sections.

3.2.2.1 Infiltration Reduction

Infiltration is the introduction of groundwater into a sewer through defects in the sewer pipe or a manhole. Groundwater can enter a sewer through various sources such as defects or cracks in the pipe or manhole barrel, open joints caused by soil movement or root infiltration, or loose construction castings. As a result, groundwater utilizes the available capacity in the sewer that was intended for sanitary sewage and/or stormwater. Infiltration therefore results in loss of capacity to convey combined sewage flow. There are several rehabilitation methods of reducing groundwater infiltration.

Chemical Grouting

A quick-setting liquid is injected into defects in the pipe or manhole, open joints and/or minor cracks. Once set-up, the grout seals the joint and prevents groundwater from entering into the sewer at the point of repair.

Relining

If there are multiple defects in the sewer system, or if there is loss of structural integrity of the sewer or manhole, a liner can be installed over the entire length of the pipe/manhole. Relining can take the form of cured-in-place-pipe liners or prefabricated high-density polyethylene (liners (slip lining). The cured-in-place-pipe liners are easier to install within sewers since they do not require excavation but do require heated curing. On the other hand, slip lining requires some excavation to allow the installation of the high-density polyethylene pipe. The installation of a liner reduces the inside diameter of the sewer and, theoretically, the capacity of the sewer. However, the installation of the liner may reduce the resistance to flow (Manning's Roughness Coefficient) such that there is no net loss of, or even a slight increase in, capacity. Infiltration can still occur at service lateral connections, so a comprehensive assessment should be undertaken when considering relining as an infiltration reduction method. MSD has applied sewer-relining technology with some success within the sewer system. MSD has been very successful applying sewer relining using in-house resources on sanitary house sewer lines that connect to the main sewer.

Pipe Bursting

If the installation of a liner, as previously described, reduces the inside diameter of a sewer and adversely impacts the sewer's capacity, it may be possible to perform an in-situ replacement of the sewer with a new pipe of the same, or slightly larger, diameter. Pipe bursting uses a pneumatic, hydraulic or static busting tool to fracture the existing pipe. Concurrent with the shattering of the existing pipe, a polyethylene pipe is pulled into the void. The size of the new polyethylene pipe is dependent on the surrounding soil conditions and the ability for the bursting tool to create a void that is sufficiently large to accommodate the new pipe. This no-dig process is suitable for enlarging the size of utility pipes, existing sewers or other pipelines without excavation. MSD has applied pipe-bursting technology in limited applications with some success. Additional excavations are required to reconnect building lateral sewers.

3.2.2.2 Inflow Reduction

Inflow is water that enters into the sewer system through undesirable connections, such as downspouts and basement sump pumps. Inflow is generally a term that is associated with separate sanitary sewers, since stormwater is not supposed to be conveyed by a sanitary sewer. In relation to a combined sewer, stormwater flow from downspouts, surface runoff into catch basins and cross connections with storm sewers are sources that often can be disconnected and redirected to other natural drainage systems or, be allowed to soak into the ground. The reduction of the wet weather flow component of a CSS leads to a potential reduction in CSOs.

Green infrastructure techniques include the disconnection of downspouts from the combined sewer. Once disconnected, the discharge is allowed to drain across the lawn and stormwater infiltrates into the ground. Downspouts can be rerouted to rain barrels or cisterns. The rainwater can then be stored and used to water gardens during dry periods. Rain gardens can be planted to absorb stormwater runoff. Porous pavement also can reduce runoff rates to attenuate peak flow within the combined sewer system. MSD investigated several green infrastructure technologies to be implemented as part of the Final CSO LTCP, which are discussed later. MSD has conducted downspout disconnection programs, sump pump disconnection programs, as well as rain barrel, rain garden, and porous pavement pilot projects.

3.2.2.3 New Sewer Construction

Sewer separation is the conversion of a CSS into a system of separate sanitary and storm sewers. Sewer separation, in theory, eliminates a CSO and this alternative is most likely to prevent sanitary wastewater from being discharged to receiving waters. Additionally sewer separation advantages include increasing available plant capacity and reducing the public's exposure to raw sewage. Construction of new sewers may cost much more than other viable treatment technologies. In addition, when combined sewers are separated, storm sewer discharges potentially contribute more untreated pollutant load to the receiving waters. In addition, partial sewer separation may not eliminate the overflow, but actually cause the overflow to be redefined as a sanitary sewer overflow (SSO). Sewer separation is typically the most expensive CSO control measure. Because of the high cost and the negative impacts of major construction projects on local traffic, sewer separations are traditionally planned for small areas or as part of a greater infrastructure rehabilitation project.

In practice, there are two distinct approaches to sewer separation:

> **Full Separation** - new sanitary sewer lines are constructed and the existing CSS becomes a storm sewer system. This is probably the most widely used form of separation. Another option involves an entirely new storm sewer system is constructed with the existing CSS remaining as a sanitary sewer system. This form of separation is not often used because the capacity of the existing CSS was designed to accommodate stormwater runoff, which exceeds what is required to accommodate sanitary flows.

Partial Separation - a new storm sewer system is constructed for street drainage, but roof leaders and basement sump pumps remain connected to the existing CSS.

MSD has successfully implemented sewer separation projects as part of the CSO Program. However, as stated above, projects have typically been part of major redevelopment efforts in downtown Louisville Metro or implemented where circumstances made it cost effective. For example, the sewer systems for CSO206 and CSO209 already had separate pipe networks for both storm and sanitary sewage although these networks had common manholes. The scope of the projects, in these cases, consisted of separating the manholes, reconnecting some drainage basins, and correcting private property connections.

3.2.3 Available Technologies - Storage

The objective of storage is to reduce overflows by capturing combined sewage during wet weather for controlled release into wastewater treatment facilities after the storm flows subside. Storage technology has three major sub-groups: in-line, off-line and on-site. While the NMC requirements in the 1990s required the implementation of low-cost optimization of in-line storage such as raising an overflow dam, current storage technology is much larger in scale and more complex utilizing real-time controls (RTC) technology and flow control structures. A typical modern storage facility may include an RTC controlled diversion regulator and an open or covered storage unit, an RTC controlled return regulator and an emergency relief point. The emergency relief point may be equipped with netting, disinfection or other CSO control devices.

Storage facilities are widely used as CSO control because they effectively reduce the volume, frequency, and duration of CSO events. Storage facilities can provide a relatively constant flow into the treatment plant and thus reduce the size of required treatment facilities. A storage facility may be located at overflow points or near treatment facilities. A major factor determining the feasibility of using storage facilities is land availability. Operation and maintenance costs are generally small; requiring only collection and disposal cost for residual sludge solids, unless inlet or outlet pumping is required. The following sections outline the technologies that are important in regards to storage.

3.2.3.1 Real Time Control

RTC seeks to optimize sewer system performance during wet weather events. RTC is applicable in CSSs because these systems typically include large pipes for transport of wet weather flows. RTC uses system-wide dynamic controls to implement control tasks such as in-line storage flow maximization and flow diversion. There are two types of system-wide dynamic RTCs: reactive systems and predictive systems.

In reactive RTC, sewer level and flow data are measured in “real time” at key points in the sewer system. The collected data is transferred to a central computer where custom software applies feedback loops and optimization rules to operate system elements to maximize use of the existing sewer system and to limit overflows.

Predictive control goes one-step further by incorporating weather forecast data to allow for advanced planning of control tasks and control tasks sequencing. RTC technologies are capable of reducing the frequency, duration, and volume of CSOs through optimization of sewer system operations. CSSs use RTC technology to control system regulator elements such as weirs, gates, dams, valves and pumps in a real-time environment.

RTC may be more effective in areas with excess capacity and level terrain where it is more practical to store wastewater in existing sewers. RTC has proven useful to divert flows to and from storage systems during wet weather. Some other advantages of RTC include the ability to manage storage facilities in such a way as to minimize overflows; hydraulic models can be integrated into RTC control techniques to refine operational strategies; and, system response can be predicted through use of rainfall forecast and gauge data.

While the initial costs of enhanced RTC can be significant, the monitoring costs will likely be a fraction of the cost of large capital projects that would achieve similar levels of CSO reduction. MSD completed Phase I and II of a major CSO Predictive RTC program in 2006 and 2008, respectively. Future phases of the RTC program are a significant part of the Final CSO LTCP.

3.2.3.2 In-line Storage

In-line storage is the term used to describe storage of wet weather flows within the sewer system. Taking advantage of this type of storage may reduce the frequency and volume of CSOs without a large capital investment. The amount of potential storage available in the sewer system largely depends on the available capacity of the pipes that will be used for storage, the grade of the pipes, and on the availability of suitability sites for installing regulating devices. In-line storage techniques typically use RTC to control the use of flow regulators, in-line storage units or basins, and parallel relief sewers.

Storage units and basins constructed in-line are typically governed by flow regulators which optimize in-line storage during wet weather events by damming or limiting flow in specific areas of the sewer system. Dry weather flows pass directly through in-line storage facilities. In-line storage units and basins may be either tanks or open or closed basins and may include facilities to minimize their aesthetic and environmental impact. These may include odor control systems, washdown/solids removal systems, and access for cleaning and maintenance.

Closed tanks are constructed below grade such that the surface at grade can be used for parks, playgrounds, parking or other light uses. In-line capacity can also be created by installing relief sewers parallel to existing sewers or by replacing older sewers with larger diameter pipes. One factor that may limit the applicability of in-line storage is the possible increase in basement backups and street flooding (EPA 1999).

In-line storage may also slow flow, which allows solids to settle in the sewer. If allowed to accumulate, these solids can reduce available storage and conveyance capacity. Therefore, it is important to design the facility in such a way that adequate flow velocities are provided during dry weather service to move the solids to the Water Quality Treatment Center (WQTC).

To-date, MSD has constructed and installed inflatable dams as in-line storage controls at the Sneads Branch Relief Drain and in the Southwestern Outfall. These projects have been very successful as means to reduce the volume and frequency of CSOs. Additional in-line storage is included in this Final CSO LTCP document.

3.2.3.3 Off-line Storage

Off-line storage is the term used to describe facilities that store wet weather flows adjacent to the sewer system. Off-line storage facilities have broad applicability and are adapted to site-specific conditions by changing basin shape, size, inlet or outlet type, and disinfection mechanism. Off-line storage may consist of a large single unit or several smaller units operating in an “as-needed” parallel configuration. The multiple-unit configuration allows the first unit to capture the highly polluted first flush. Diversion devices are typically used to pass flow to the other units after the first unit has reached capacity. The use of off-line storage tends to be more expensive than inline storage and is usually considered in areas where in-line storage is insufficient or unavailable. Off-line storage units are an integral part of this Final CSO LTCP. Where feasible, off-line storage units have been optimized in size based on the efficient use of in-line storage and green technologies. The off-line storage units that are included in this Final CSO LTCP are generally located in vacant lots and below grade, which reduces the potential for odors and allows the land above the unit to be utilized for low impact recreation and other uses. MSD currently operates several open basins within the CSS.

Deep tunnel storage facilities are used where large storage volumes are required and opportunities for near-surface storage are unavailable. Deep tunnels are located 100-feet to 400-feet below ground. Tunnel diameters range from 10-feet to 50-feet and many are several miles in length. During dry weather, untreated wastewater is routed around, not through, these off-line storage facilities. In contrast, during wet weather, flows are diverted from the sewer system to the off-line storage facilities by gravity drainage or with pumps. The wastewater is detained in the storage facility and returned to the sewer system once downstream conveyance and treatment capacity become available.

Overflows can occur once the capacity of off-line storage structures is exceeded. Some treatment is provided through settling; however, the primary function of such facilities is storage and the capture of peak wet weather flows. Storage tunnels were evaluated for the control of CSOs, but were found to be cost prohibitive compared to in-line or off-line storage units.

3.2.3.4 On-site Storage

On-site storage is storage developed at the WQTC. It is most applicable in systems where conveyance capacity exceeds treatment capacity. On-site storage provides operators with the ability to manage and store excess flows. The methods of on-site storage may be either new construction or rehabilitation of under-utilized or abandoned equipment. The costs associated with the development of on-site storage are typically lower than for other storage facilities built outside the bounds of the WQTC. Utilizing abandoned treatment facilities may reduce costs even more. Much of the cost savings derive from siting storage facilities on land already owned by the utility. Sewer system conveyance capacity is a limiting factor with on-site storage and should be analyzed early in the design. In addition, availability of suitable land can be a barrier to on-site storage.

3.2.4 Available Technologies - Supplemental Treatment

The recent development of wet weather treatment systems presents an alternative to storing excess flows. Supplemental treatment technologies are end-of-pipe controls used to provide some level of physical, biological, or chemical treatment to excess wet weather flows immediately prior to discharge from a CSS. This level of treatment, while less than expected from a conventional WQTC, may significantly reduce the pollutant loads from a CSO. Specific treatment technologies can address different pollutants, such as floatables, settleable solids, and pathogens. However, a major factor determining the feasibility of using treatment facilities is land availability and adjacent landuse.

3.2.4.1 Primary Clarification

The objective of clarification is to produce an effluent treated by gravitational settling of the suspended particles. Sedimentation also provides storage capacity as well as an opportunity for disinfection. Clarification is adaptable to chemical additives, such as lime, alum, ferric chloride, and polymers, which provide higher rates of suspended solids and biochemical oxygen demand, or allow “equivalent primary clarification” to occur at higher loading rates than typically used for primary clarifier sizing.

3.2.4.2 Swirl Concentrators/Vortex Separators

Vortex separators (swirl concentrators) are designed to concentrate and remove suspended solids and floatables (S&F) from wastewater or stormwater. Flow enters the unit at a controlled tangential velocity and is directed around the perimeter of a cylindrical shell, creating a swirling, vortex pattern. Vortex separators use centrifugal force, inertia, and gravity to divide combined sewage into a smaller volume of concentrated sewage, solids, and floatables; and a large volume of more diluted sewage and surface runoff. The swirling action causes solids to move to the outside wall and fall toward the bottom, where the solids concentrated flow is conveyed through a sewer line to the WQTC. The overflow is discharged over a weir at the top of the unit. Various baffle arrangements capture floatables that are subsequently carried out in the underflow. Removal effectiveness is a function of the hydraulic loading rate with better performance observed at lower loading rates. These devices may be considered “equivalent primary treatment” in some cases, but the variable performance makes this questionable in many applications. Principal attributes of the swirl concentrator are the ability to treat high flows in a very small footprint, and a lack of mechanical components and moving parts, thereby making it less operational and maintenance intensive. This technology, when coupled with disinfection, may provide an acceptable level of supplemental treatment. However, the configuration of most of the CSO outfalls in MSD’s system is not conducive to the use of vortex separators, and consistent biochemical oxygen demand and total suspended solids (TSS) removals cannot be assured; therefore, they were not evaluated for selection.

3.2.4.3 High Rate Physical/Chemical Treatment

High rate physical/chemical treatment under this Final CSO LTCP considered two treatment technologies: Ballasted Flocculation and Retention Treatment Basin. Both are traditional gravity settling processes with enhanced flocculation and settling aids to increase loading rates and improve performance. The pretreatment processes for high rate physical/chemical treatment are screening and degritting.

In the first stage of ballasted flocculation a coagulant is added and rapidly mixed into solution. This is followed by a flocculation stage where polymer is added and mixed to form floc particles that will settle in the following stage. Finally, the wastewater enters the gravity settling. Sludge is collected at the bottom of the clarifier and either pumped back to the flocculation stage or removed periodically when sludge blanket depths become too high. Disinfection is applied downstream of clarification, followed by disinfectant residual neutralization. Performance varies with treatment rate and chemical dosages, but in general, removal rates of 80 - 95 percent for TSS and 60 - 80 percent for biochemical oxygen demand can be expected.

Retention treatment basin is considered equivalent primary treatment. For this treatment, polymer only is injected into the wastewater stream, followed by gravity sedimentation. Disinfection is applied downstream of clarification, followed by disinfectant residual neutralization. Performance varies with treatment rate and chemical dosages, but in general, removal rates of 50 percent of TSS and 30 percent of biochemical oxygen demand.

Removal efficiencies for each technology are also dependent on start-up time. In general, the start-up time for ballasted flocculation units, coupled with the high influent peak flow rates, require a substantial storage basin upstream of the treatment unit. There are several locations; however, where retention treatment basins could be effective due to the reduced land requirements of the technology, particularly the CSO015 and CSO191 common outfall, where substantial outfall storage is available to reduce peak inflow rate.

3.2.4.4 Disinfection

The objective of disinfection is the control of the discharge of pathogenic microorganisms into receiving waters. The disinfection methods considered for use in CSO treatment include chlorine gas, calcium or sodium hypochlorite, chloride dioxide, ozone, ultraviolet (UV) radiation, and electron beam irradiation. The chemicals are all oxidizing agents that are corrosive to equipment and in concentrated forms are highly toxic to both microorganisms and people. Each disinfection method is described below.

- Chlorine gas - Chlorine gas is effective, however, it is extremely toxic and its use and transportation are strictly controlled. In addition, it is a respiratory irritant and in high concentrations can be deadly.
- Calcium or Sodium Hypochlorite - Hypochlorite systems are common in wastewater treatment installations. For years, large, densely populated metropolitan areas have employed hypochlorite systems in lieu of chlorine gas for safety reasons. The hypochlorite system uses sodium hypochlorite in a liquid form much like household

bleach and is similarly effective as chlorine gas although more expensive. It can be delivered in tanker trucks and stored on-site.

- Chlorine Dioxide - Chlorine dioxide is an unstable and explosive gas and must be generated on site. The overall system is relatively complex to operate and maintain compared to more conventional chlorination.
- Ozone - Ozone is a strong oxidizer and must be applied as a gas. Due to the instability of ozone, it must also be generated on site. Ozone disinfection is relatively expensive with high primary capital cost and high power consumption during operation. Ozonation is also relatively complex to operate and maintain compared to chlorination.
- UV Disinfection – UV disinfection uses light with wavelengths between 40 and 400 nanometers for disinfection. Light of the correct wavelength can penetrate cells of pathogenic organisms, structurally altering DNA and preventing cell function and replication. Because UV light must penetrate the water to be effective, the TSS level of CSOs can affect the disinfection ability. UV disinfection is most applicable downstream of a settling technology.
- Electron Beam Irradiation - Electron Beam Irradiation uses a stream of high-energy electrons directed into a thin film of water. The electrons break apart water molecules and produce a number of reactive chemical species, which can kill pathogenic organisms.
- Emerging Technologies – Several other disinfection systems are being developed for use in CSO disinfection applications. For example, combinations of hydrogen peroxide and peracedic acid provide effective disinfection of wastewaters with less contact time required as compared to chlorination. MSD is evaluating this technology for potential application in CSO treatment and supplemental disinfection for both chlorination and UV systems during periods of high flow. MSD will continue to monitor the application of emerging technologies as part of the "adaptive management" process. If future developments in disinfection technology indicate that a change in direction in disinfection practice is warranted, MSD will consider modifying its approach to CSO and treatment plant effluent disinfection.

Disinfection reduces potential public health impacts from CSOs however, to protect aquatic life in the receiving waters, dechlorination facilities must be installed whenever chlorination is used as a disinfectant. Dechlorination is typically accomplished by injection of sodium bisulfite in the flow stream before discharge of treated CSO flow to waterways. Dechlorination with sodium bisulfite is rapid; hence, no contact chamber is required since the reaction with chlorine is immediate.

3.2.4.5 Deep Bed Filtration

A deep bed filter system consists of a series of large tanks filled with coarse medium; typically sand or anthracite. Excess wet weather flows are directed to the top of each tank and exit at the bottom of the tank. Pollutants either may attach to the filter media or become trapped in the interstitial space of the filter; the filter is later cleaned through backwashing. Chemical additives can be used to improve removal rates.

3.2.4.6 Trickling Filters

Trickling filters are biological treatment technology for treating excess wet weather flows. In a trickling filter system, microorganisms are maintained as a biological film attached to a fixed media. Supplemental treatment facilities with any biological process must operate continuously with a minimum flow rate to maintain the biomass necessary for treatment of wet weather flows. During dry weather, effluent from biological supplemental treatment facilities is typically returned to the sewer system for further treatment and discharged at the WQTC.

3.2.4.7 Constructed Wetlands

Constructed wetlands use natural biotic systems to treat wastewater. Aquatic plants and bacteria utilize the organic wastes, nutrients, greases and bacteriological pollution found in CSOs in much the same way as in a traditional WQTC. Constructed wetlands act as both storage and treatment for CSO flows. There are two types of constructed wetlands; subsurface flow and free water surface.

Subsurface flow wetlands consist of a series of planted cells. They are two feet to three feet deep basins filled with rock or other media and vegetated with aquatic plants. These plants hide the rock and feed off the sewage flowing below the surface. These wetlands are designed to not have any exposed sewage. This reduces odor and vector problems making them more acceptable to the public. The downside is that the wholly subsurface requirement greatly reduces the volume treated or stored per acre.

Free water surface wetlands consist of two types of cells. The first type is the open water cell that contains submerged aquatic vegetation. It has a design depth of four feet and cannot tolerate floating aquatic vegetation. The large air to water contact area and penetrating sunlight raise dissolved oxygen and allow for the release of nitrogen gas to the atmosphere. This cell has a high rate physical/chemical treatment of two - three days. Extending the high rate physical/chemical treatment beyond three days, especially in sunny conditions, may cause an algae bloom that would blanket the cell and prevent gas exchange.

The second cell type in a free water surface wetland is the fully vegetated cells. It is heavily vegetated with aquatic plants that either float or grow from the bed and break the surface of the water. Fully vegetated cells are approximately two feet deep. Up to 30 percent of the cell volume is taken up by the flora planted in it. The purpose of the vegetated cell is to prohibit sunlight, drop the dissolved oxygen level, allow anaerobic processes, and kill the algae.

Typically, free water surface wetlands are constructed as alternating open-water and vegetated cells with the first cell being vegetated to trap S&F and enhance settling. The high rate physical/chemical treatment for each cell is two - three days. The process is primarily settling in the first cell with nitrification-denitrification cycle processes beginning as well. The second cell is an open-water cell, which allows for sunlight, algae, and release of nitrogen gas. The cells continue in an alternating series to the point at which the design goals are met. The last cell will always be vegetated to kill any algae. Aeration and disinfection may be added prior to the outfall.

Little energy is required to maintain treatment processes. Typically, energy consumption is limited to pumping if required to deliver CSOs to the wetland area and clear water recirculation pumping during periods of low flow to maintain the health of the facility. Additionally, wetlands provide a storage component with the treatment component. A wetland will typically provide one-million gallons (MG) of storage per acre of wetland. They also provide sanctuary for aquatic flora and fauna. Drawbacks with constructed wetlands are (1) they require relatively large areas of land; (2) treatment processes are slow (especially in cold winter environments); and (3) CSO effluent is left open to the environment.

3.2.4.8 WQTC Modification

Excess wet weather flows cause sudden changes in the hydraulic and pollutant loads impacting the WQTC. Modifications to existing wastewater treatment facilities can increase their ability to handle wet weather flows. Modifications may involve changes to the physical configuration of various treatment processes and/or the operation of specific plant processes during wet weather. Most modifications require the active involvement of the treatment plant operator to ensure effective implementation. Example modifications that maximize the treatment of wet weather flows include:

- Baffles to protect clarifiers from hydraulic surges and ensure the even distribution of flow
- Using metal salts and polymers to increase suspended solids removal
- Switching the mode of delivering flow from the primary to the secondary treatment units
- Switching from “series” operation to “parallel” operation during wet weather flows

Performance evaluations are required to determine whether additional capacity can be obtained from existing facilities. While facility modifications are generally more cost effective than new construction, some modifications that improve wet weather performance may result in increased concentrations of pollutants in treatment plant effluent during dry weather. For example, if not properly designed, a clarifier modified for wet weather flows may have inadequate settling characteristics during dry weather (Metcalf and Eddy 2003). Further, modifications that require operator attention before and after a wet weather event may interrupt regular dry weather operations and potentially compromise the quality of treated wastewater during dry weather.

MSD has made a significant investment in various unit processes to maximize the treatment capacity of the Morris Forman WQTC to make the best use of the asset that exists and to make the process as effective as possible.

3.2.4.9 Interaction with Other Collection and Treatment System Objectives

The Final CSO LTCP developed is based on a "system-wide, annual average basis" in accordance with EPA's CSO Control Policy (1994) using system characterization model (i.e. CSS model) with watershed approach. The CSS model was utilized to explore the following elements, which affects baseline flows and loads:

- Interaction with upstream separate sewer systems
- Integration of current CSO control efforts
- Incorporation of Green Demonstration Projects and Green Infrastructure Program
- Morris Forman WQTC wet weather treatment capacity
- Integration with NMC Program

The CSS provides approximately 45 percent of the total sanitary flow conveyed to Morris Forman WQTC. The remaining flow is contributed by upstream separate sanitary sewer systems (SSS). There are six boundary points in the CSS model where SSS flows contribute to the CSS. The details on model development and location of these boundary points are in Chapter 2, Section 2.4.6.3.

The existing SSSs upstream of the CSS are susceptible to significant wet weather inflow and infiltration. Therefore the quantities of flow entering the CSS from the SSSs are substantially greater during wet weather periods than during dry weather periods. IOAP Volume 3, the Final Sanitary Sewer Discharge Plan (SSDP), addresses the excessive rainfall-derived infiltration and inflow (RDI/I) in the SSS upstream of CSS.

Because of the interaction between SSSs and CSS within Morris Forman WQTC service area, both LTCP and SSDP controls were developed with the understanding that selected controls for one program will likely affect the other program. Sewer models for both LTCP and SSDP were developed with defined boundary points where information such as flows and level were exchanged to establish the appropriate boundary conditions for various alternatives.

One example of the coordination between the CSS and the SSSs upstream is the incorporation of Interim Sanitary Sewer Discharge Plan (Interim SSDP) projects into the separate sewer system model to redefine the inflow contributed to the CSS system. Projects defined in the Interim SSDP reduce the significant amount of wet weather inflow contribution to CSS system by reducing RDI/I within the new sewer system and diverting more wet weather flow to Derek R. Guthrie WQTC. Another example was during alternative evaluation phase for SSO controls in the Beargrass Creek Middle Fork watershed. The hydraulic gradeline in the upper reach of the CSS was analyzed to determine the maximum water surface elevation and peak flow rate required from the upstream SSS to reduce surcharging and eliminate SSOs near a boundary point.

To establish the "baseline" condition prior to implementation of the Final CSO LTCP, current CSS operating parameters were determined by the hydraulic model to provide a reference for evaluating proposed controls. Current CSO control efforts such as RTC Phase II projects, CSO206 (Cherokee Park) sewer separation project, and other CSO elimination projects that are scheduled are incorporated in the baseline model. More details are documented in the 2008 CSO LTCP System Hydraulic Modeling Condition Technical Memo in Appendix 3.2.1.

For the Final CSO LTCP, the watershed approach is multi-scale, ranging from a site-specific solution, to a regional program and it incorporates both "gray" and "green infrastructure" solutions. System-wide green infrastructure opportunity evaluations were performed and a set of specific green projects as well as the Green Infrastructure Program components were identified. The CSS model incorporated the elements of a Green Infrastructure Program such as downspout disconnection, rain gardens, bio-swale, green roof, porous pavement, and dry wells to simulate the reduced stormwater runoff to the CSS. The wet weather treatment capacity at Morris Forman WQTC was confirmed to be 350 MG per day (mgd) peak, and 325 mgd sustainable through stress tests of total plant flows. Expansion of the Nightingale Pump Station and redirecting wet weather flow to Derek R. Guthrie WQTC was evaluated to increase CSO wet weather flow to the Morris Forman WQTC and reduce CSO to the Beargrass Creek.

3.2.5 Approach to Green Infrastructure

The purpose of MSD's green infrastructure initiative is to develop a program that reduces CSO frequency, duration and volume utilizing environmentally sensitive techniques that more closely mimic natural hydrologic processes when compared to more traditional engineering solutions or "gray" infrastructure solutions that are typically employed in CSO control programs. Gray infrastructure solutions for CSO control typically consist of large pipes, storage tanks, tunnels, and high rate treatment facilities.

Green Infrastructure Projects

- Achieve multiple objectives and provide multiple benefits including: reduction of sewer overflows
- Improvement in air and water quality
- Increased green space and wildlife habitat
- Community beautification

Although conventional engineering alternatives such as high rate treatment, sewer separation, tunnels, and remote storage facilities represent the core elements of MSD's wet weather control program, the opportunities to supplement these conventional engineering solutions with green infrastructure are abundant.

A fundamental principle of the MSD approach is that, while green infrastructure best management practices (BMP) on individual sites are a step in the right direction, a green infrastructure plan that establishes connectivity between neighborhoods, watersheds and ultimately the entire MSD service area results in far greater benefits to the community than the sum of the individual components. Additionally, when compared to gray solutions, the green infrastructure techniques have a much greater potential for leveraging funding from sources other than sanitary sewer and stormwater user fees.

3.2.5.1 Green Infrastructure Initiative

MSD's proposed green infrastructure initiative involved three main components. These components are a compilation and review of pertinent information, identification, and exploration of green infrastructure opportunities, and development of a recommended green infrastructure plan.

The recommended plan is the result of comprehensive evaluations of local conditions including soils, geology, hydrology, natural systems, impervious area, topography, parcel ownership, and canopy cover within the CSS area. The proposed green infrastructure plan contemplates a considerable investment by MSD in the design, construction and implementation of green techniques across the service area to achieve significant reductions in CSO activity. This investment is supported by a "business case" evaluation of the green infrastructure investments to ensure that money spent supporting the Green Infrastructure Program is cost-effective when compared to equivalent levels of CSO reduction achieved through traditional gray solutions.

Major Elements of MSD's Proposed Green Infrastructure Plan

- Downspout disconnection program
- Rain barrel program
- Rain garden program
- Vegetated roof program
- Dry well program
- Green streets
- Green parking lots
- Green alleys
- Urban reforestation

Conservative estimates indicate that implementation of a long-term green infrastructure plan may remove nearly one billion gallons (BG) of stormwater runoff from the CSS annually at a cumulative cost to MSD of approximately $0.09/gallon to MSD. Preliminary reductions in stormwater volume based on the use of green infrastructure were developed using a green infrastructure costing tool developed as part of the business case evaluation. Based on assumed performance levels of green controls the cost tool takes into account the implementation of various green controls and the drainage area to the BMPs to determine a reduction in stormwater runoff for a typical year of rainfall. This is different from the CSS hydraulic model which provides a more conservative estimate of the benefit of the green infrastructure plan because the model represents a continuous simulation and accounts for antecedent moisture conditions, infiltration limitations, and pervious connectivity to storm drains. Additionally, the CSS model is utilized to predict the effects of green infrastructure implementation on the Average Annual Overflow Volumes (AAOV) for each CSO. This AAOV reduction does not match the stormwater reductions into the CSS due to specifics stated above as well as the attenuation and peak flow timing.

Partnering and working with local entities allows MSD to cost share the greater overall investment in green infrastructure lowering MSD's effective cost per gallon. This cost per gallon estimate is comparable to and in many cases much less than, more conventional gray alternatives, such as pipes and storage facilities. In addition, this analysis is based solely on a cost/gallon basis and does not consider the many other benefits that green infrastructure provides.

3.2.5.2 Green Infrastructure Background

The terms of this Consent Decree included the requirements to eliminate SSOs and minimize CSOs. While there are no specific requirements in the Consent Decree regarding the use of green infrastructure BMPs, EPA is certainly encouraging communities to explore innovative techniques and practices such as Low Impact Development and green infrastructure to reduce CSO discharges.

At the national level, the Natural Resources Defense Council released a report titled "Rooftops to Rivers" (June 2006) which identified green infrastructure as a viable strategy for reducing the impacts of CSO discharges on the water quality of our nation's waterways. This report provides case studies from numerous communities that have successfully incorporated green infrastructure strategies into their CSO reduction programs.

On March 5, 2007, Benjamin Grumbles, the Assistant Administrator of Water for the EPA released a memorandum to the EPA Regional Administrators regarding "Using Green Infrastructure to Protect Water Quality in Stormwater, CSO, Nonpoint Source and other water programs."

In this memorandum, Mr. Grumbles stated:

> *"Green infrastructure can be both a cost effective and environmentally preferable approach to reduce stormwater and other excess flows entering combined or separate sewer systems in combination with, or in lieu of, centralized hard infrastructure solutions."*

Mr. Grumbles went on to say:

> *"I strongly support the use of green infrastructure approaches described in the Natural Resource Defense Council report…"*

As MSD initiated the development of the Interim CSO LTCP, a decision was made to aggressively explore green infrastructure opportunities within the CSS area with the goal of developing a comprehensive Green Infrastructure Program that would be integrated into the Final CSO LTCP. While it is recognized that traditional gray solutions will play a major role in the Final CSO LTCP, MSD is committed to maximizing the use of green infrastructure elements in the overall solution matrix. The following is a description of this green infrastructure planning effort and the recommended green infrastructure components.

3.2.5.3 Green Infrastructure Philosophy

Estimates indicate that the CSS discharges approximately 2.833 BG per year of untreated flow to local waterways. As plans were developed to minimize these discharges and comply with the terms of the Consent Decree, MSD realized that a considerable amount of local ratepayers' dollars was going to be invested in pipes, storage, and treatment facilities throughout the community. While these traditional engineering solutions are effective at reducing the volume of untreated flow discharging to local streams, these techniques may not provide benefits in other important areas such as air quality, wildlife habitat, or urban beautification. Considering the significant community resources that will be directed toward CSO mitigation, it seemed logical to explore innovative approaches that would maximize the benefits to the community for the dollars invested.

The WWT Stakeholder Group assisted MSD in the development of the Final CSO LTCP, supporting and encouraging the development of a Green Infrastructure Program as part of the Final CSO LTCP. Based on a review of local conditions, feedback from the WWT and a review of green infrastructure case study information, MSD identified four principles to guide the development of the Final CSO LTCP Green Infrastructure Program:

- Enhance and preserve natural systems
- Implement green roadways, rooftops and parking lots
- Foster strategic partnerships
- Connect green infrastructure systems to other community assets

3.2.5.4 Strategy

With the guiding principles established, MSD created a strategic approach for the development of the Green Infrastructure Program. MSD recognized that while many communities had successfully implemented green infrastructure elements targeting CSO control, few, if any, had developed comprehensive Green Infrastructure Programs during the initial phases of their LTCPs. MSD viewed this as an opportunity to maximize the role of green infrastructure and the associated benefits to the community.

MSD emphasized the importance in evaluating and integrating green infrastructure opportunities at a variety of physical scales including sites, neighborhoods, sewersheds and regions in order to establish a connected network of green components that merge into a single regional vision. See Figure 3.2.1 located at the end of this chapter for a graphical depiction of the vision that emerged from this effort.

MSD used this regional vision to develop a Green Infrastructure Program in order to reduce the amount of stormwater entering the CSS. For the purpose of evaluating the potential stormwater reductions achievable through the use of green infrastructure, the regional evaluation used a 15-year planning horizon. However, as discussed later in the chapter, MSD will assess the performance of green infrastructure demonstration projects and programs during the first six years of implementation with the goal of evaluating and adjusting financial allocations for particular programs based on a benefit-cost analysis. While green infrastructure is an important component of the Final CSO LTCP, MSD's long range commitment to this program will be based on how green technologies perform in comparison to more traditional gray solutions.

Developing a comprehensive, regional Green Infrastructure Program at the front end of a LTCP effort is an innovative and progressive approach to CSO mitigation and one that is consistent with the recommendations of the Natural Resource Defense Council and EPA.

3.2.5.5 Regional Evaluation

The regional evaluation process is relatively complex and involves a thorough understanding of site-specific issues within the community including physical, political, financial, and technical parameters. The following section provides a discussion of the eight key steps in completing this process.

Regional Evaluation Step 1 – Identification of Existing Green Infrastructure Programs

The regional evaluations began with a compilation of existing information on current green infrastructure projects and programs throughout Louisville Metro. Numerous green infrastructure activities already underway provide an important stepping-stone for the implementation of MSD's green infrastructure initiative.

Following is an explanation of some of the existing initiatives in Louisville Metro.

Existing Green Infrastructure Initiatives

- Kentucky Green and Healthy Schools
- City of Parks
- Partnership for a Green City
- 21st Century Parks

1. Kentucky Green and Healthy Schools

   According to the Kentucky Green and Healthy School's website, "The Kentucky Green and Healthy Schools Program is a new, voluntary effort to empower students and staff with the tools needed to take action and make their school operate at peak efficiency." Kentucky Green and Healthy Schools incorporates a two-pronged approach as follows:

   - New or renovated schools may include a "green and healthy" design from the start.
   - Existing schools allow students to inventory current school operations and environments in an effort to implement action plans that will improve school health and sustainability."

2. City of Parks

   According to www.LouisvilleKy.gov the City of Parks is a visionary and aggressive expansion of Louisville's Metro's park system, adding thousands of acres of green space, a 100-mile paved trail encircling the city, and improvement projects at hundreds of existing parks all over the Metro area.

3. Partnership for a Green City

   According to the Jefferson County Public School (JCPS) Center for Environmental Education, "the Partnership for a Green City began in August 2004, as a major step toward overcoming challenges to Louisville's environmental practices. The Partnership represents a collaborative effort to improve environmental education, environmental health, and environmental management by three of Louisville's largest public entities: Louisville Metro

Government, the University of Louisville, and the JCPS. Most recently, the Partnership, and the three agencies have adopted a *Statement of Environmental Principles*. The *Principles* will be used to guide policy, budget, and program decisions being made by the Partners to incorporate sustainable ideas."

4. 21st Century Parks

According to its website, 21st Century Parks was "founded in 2005, and is a Kentucky-based, private, non-profit corporation, created to bring a fresh vision to the preservation and development of new public parklands. Their current project is *The Fork*; planned for eastern and southern Louisville Metro, it will be one section of a new 100-mile loop creating one of the largest new urban park systems in the nation. Building on the visionary effort of former Lt. Governor Steve Henry and The Future Fund, Inc. and joining in partnership with Louisville Metro Government and Louisville Metro Parks; *The Fork* encompasses over 3,000 acres of preserved lands in southeast Louisville."

Each of these existing initiatives has the potential to impact MSD's CSO control efforts and the green infrastructure initiative in particular. MSD will continue to explore opportunities with these key stakeholders to identify mutually beneficial partnerships. See Table 3.2.1 for a partial list of existing programs.

TABLE 3.2.1

CURRENT GREEN INFRASTRUCTURE PROGRAMS WITH MSD INVOLVEMENT

Activity	Participants
Rain Gardens	Youth Build, ACTIVE Louisville
Rain Barrels	Youth Build, Louisville Nature Center
Outdoor Classrooms	Jefferson County Public Schools (JCPS), Partnership for a Green City
Riparian Buffers	Metro Parks/Olmsted Parks Conservancy
Invasive Species Removal	Metro Parks, Olmsted Parks Conservancy, Living Lands and Waters
Stream Clean-Up	Living Lands and Waters
Litter Clean Up/Beautification	Operation Brightside
Community of Trees	Louisville Metro Council, Metro Parks, Housing Authority, Muscular Dystrophy Association, Operation Brightside

The importance of these partnerships and strategic collaboration on projects with other entities is further discussed below.

Regional Evaluation Step 2 – Establish Project Awareness and Potential Project Partners

Impervious surfaces such as streets, parking lots, and rooftops are the major source of runoff in the CSS Area. While a considerable amount of land within the CSS is publicly owned, (nine percent), MSD owns a very small percentage (0.2 percent) of this land. Therefore, in order for MSD to implement effectively a source control strategy, partnerships with local property owners are essential.

In recent years downtown Louisville Metro has been the beneficiary of considerable redevelopment activities. As the trend continues, development and re-development projects in the CSS represent opportunities for MSD to partner with both public and private entities to encourage, incentivize and/or fund the construction of green infrastructure to reduce stormwater runoff entering the CSS. Incorporating green techniques into a site plan is most effectively accomplished if the green components are developed early in the process.

A key element of MSD's overall green strategy is to identify partnership opportunities throughout the community. There are numerous public agencies in Louisville Metro with plans to invest significant amounts of money over the next decade in the construction and upgrade of public infrastructure including streets, schools, parks, highways, and public housing. Each public project represents an opportunity to incorporate green infrastructure. By coordinating the design and construction of green controls into planned public projects, MSD will realize stormwater reduction benefits at a fraction of the cost compared to retrofitting green controls after the planned projects are built.

MSD staff has put considerable effort into the development of partnerships with other local public agencies to evaluate the potential to incorporate green components into planned capital improvement projects. For example, JCPS has a five-year capital improvement plan budget of $50 million for upgrades to local schools. There are 45 public schools located in the CSS and JCPS has budgeted $5.5 million for roof and site improvements for these schools.

MSD and JCPS have agreed to work together to create "win-win" projects that meet the needs of the school district while reducing the runoff from the sites. Numerous green infrastructure concept plans have been developed, including those for Roosevelt Perry Elementary and Engelhard Elementary schools.

MSD has also initiated discussions with other agencies including Louisville Metro Housing and Metro Public Works. Both agencies have expressed considerable interest in green techniques and a willingness to incorporate green elements into planned capital projects where feasible. Other agencies MSD has met with include:

- Mayor's Office
- Economic Development
- Private Developers/Architects/Engineers/Landscape Architects
- Metro Parks/21st Century Parks/Future Fund
- City of St. Mathews

- ACTIVE Louisville
- Partnership for a Green City
- Kentucky Association of Festivals
- Neighborhood Associations

These entities are potential project partners that could become “green ambassadors” promoting the inclusion of green infrastructure throughout the community.

Regional Evaluation Step 3 – Existing Green Infrastructure Initiatives Mapping

Awareness of other activities, developments, and programs within the MSD service area will allow MSD to make informed decisions about where their green efforts should be focused and how they may incorporate green infrastructure components into others’ activities. This is an ongoing effort intended to identify opportunities for MSD to promote the incorporation of green infrastructure techniques into projects being funded by other local agencies at their earliest stages. In certain instances, MSD may decide to partner with these agencies to design and/or construct green infrastructure elements into these projects.

MSD has compiled information on existing Green Infrastructure Programs and planned projects and created Geographic Information System (GIS)-based maps to facilitate the integration of these projects into the community-wide green vision. Figure 3.2.2 located at the end of this chapter displays some of these key programs and opportunities in the community that support and augment MSD’s green vision. These include the Community of Trees planting plan, proposed urban redevelopment projects, bikeways, existing and proposed green infrastructure projects, rain barrels, and other green infrastructure initiatives.

Regional Evaluation Step 4 – Impervious Area Evaluations

MSD’s Consent Decree mandates the minimization of overflows from the CSS. Wet weather CSOs occur when too much stormwater runoff enters the CSS and the system capacity is exceeded resulting in discharges directly to local receiving streams. A root cause of the excessive stormwater runoff is impervious surfaces. As landscapes are developed and natural vegetation is replaced with pavements and rooftops, the rate and volume of stormwater runoff that occurs during precipitation events dramatically increases.

Ideally, post construction green infrastructure techniques would be designed to match the pre-development hydrology of the system in terms of infiltration, evaporation, and runoff. Obviously, this is not realistic, particularly from the perspective of retrofitting a highly urbanized environment. However, a Green Infrastructure Program designed to reduce CSOs must decrease the amount of impervious surface and/or reduce the volume of runoff entering the CSS.

A detailed impervious area evaluation was performed for the entire combined sewer area – which totals approximately 37 square miles utilizing available information in the Louisville Jefferson County Information Consortium (LOJIC) GIS database. The objective of this evaluation was to determine the distribution of impervious surfaces and their relative significance throughout the CSS. This information is critical in identifying major categories of impervious surfaces and in selecting appropriate green techniques to reduce stormwater from these sources. This evaluation was a significant factor in the development of the regional plan.

The result of this exercise revealed that the CSS contains approximately 500 million square feet (sq. ft.) of impervious area, which represents approximately 19 square miles, or 51 percent, of the combined system. This total impervious area was further divided into specific categories including rooftops, roadways, and parking lots. The area of each surface type was determined, along with the relative percentages of each, in relation to the total impervious area contained within the CSS. Roads represent 135 million square feet, buildings 187 million sq. ft. and parking, sidewalks and driveways represent another 183 million sq. ft. of hard surface.

Impervious Surfaces in the CSS

The following is a breakdown of the primary landuse types and distribution of the total impervious area throughout the CSS.

- Roads 26 percent impervious
- Single Family 27 percent impervious
- Industrial Property 17 percent impervious
- Commercial Property 13 percent impervious
- Other 17 percent impervious

Additionally, an impervious area evaluation by landuse type was performed. This evaluation showed that 36 percent of the impervious surfaces in the CSS are located on publicly owned property, including roadways. Schools account for over eight million sq. ft. of impervious surface while MSD owned property comprises only 1.2 million sq. ft. of hard surface, underscoring the importance of partnerships.

See Appendix 3.2.2 Impervious Area Evaluation for a detailed description of the impervious area distribution within the CSS. Figure 3.2.3 located at the end of this chapter is a map showing the extent of impervious surfaces within the combined system.

In summary, in order for the Green Infrastructure Program to have a major impact on CSO reduction in Louisville Metro, the program will need to target roads, residential properties, and some percentage of industrial/commercial landuses.

Regional Evaluation Step 5 – Natural Systems Evaluations

Natural systems such as stream networks (existing and historical), soils, geology and wetlands were evaluated and considered in the identification of opportunities to implement green infrastructure. With the stated goal of promoting techniques that are consistent with the natural hydrologic cycle, an important first step in the green evaluation process was to develop an understanding of natural systems. This understanding involves reviewing locations, capacities, and suitabilities to accommodate additional runoff, including historic resources that are now less visible.

Historic maps were reviewed in an effort to better understand the evolution of natural drainage systems for the CSS Area. Information was compiled showing the location of stream networks, historic wetlands and major pond features from over one hundred years ago. Many of these streams and drainage features are no longer evident. Figure 3.2.4 located at the end of this chapter is map from the Civil War era that shows where streams once existed west of downtown and how the Beargrass Creek and other features have been modified over time. Appendix 3.2.3 Historic and Natural Systems Mapping contains other historic and natural systems mapping that were compiled as part of this effort.

A general philosophy of MSD's green approach is to capitalize on these natural systems to allow them to function more as nature intended to provide beneficial functions. The urbanization of cities has involved the systematic replacement of streams and wetlands with hard surfaces and piping networks. The result has been a lower groundwater table, lower base flows in our streams, higher peak flows in the streams during wet weather and an overall change in the natural hydrologic and hydraulic cycle.

As shown in Figure 3.2.5, located at the end of this chapter, under natural conditions a large percentage of annual precipitation either infiltrates or evaporates with only approximately ten percent of rainfall resulting in runoff. Landuse changes associated with urbanization can have a dramatic effect on this overall water balance resulting in large increases in runoff volumes and corresponding decreases in infiltration and evaporation.

A key objective of MSD's green infrastructure approach is to protect this natural water balance in less developed and undeveloped areas of the community especially with anticipated landuse changes. The second half of the objective is to restore, where supported by the business case, the natural hydrologic balance that existed in the downtown area prior to major urbanization. By understanding the natural systems, specific practices can be implemented to restore or enhance the pre-developed function of the land.

The Green Infrastructure Program contemplates the use of existing natural systems and the replacement of impervious surfaces with vegetated surfaces to both minimize runoff and to convey redirected runoff from the CSS to existing natural systems. Both of these approaches should assist in reducing CSOs.

Regional Evaluation Step 6 – Tree Canopy Coverage

As discussed above, downtown Louisville Metro is comprised of significant amounts of impervious surfaces. With the increase of hard surfaces such as roads, parking lots and buildings there is usually a corresponding decrease in tree canopy cover. The loss of canopy cover can have a significant impact on stormwater runoff.

As noted on EPA's website: [See EPA fact sheets in Appendix 3.2.4].

> *"A study done by the U.S. Department of Agriculture's Center for Urban Forest Research found that a medium-sized tree can intercept 2,380 gallons of rain per year" (Center for Urban Forest Research 2002).*

> *"Trees also absorb carbon dioxide, decrease temperatures, and provide habitat for urban wildlife. Urban forestry also reduces noise levels and provides recreational benefits."*

With the proper tools, types of plants, planting, and maintenance, reforestation can effectively reduce both the pollutants in, and the volume of, stormwater. The nonprofit organization American Forests conducted a study in the Houston area to document urban forest covering a 3.2-million-acre area. They also analyzed 25 specific sites with aerial photography using CITYgreen software to map and measure tree cover. Study results show that trees provide significant benefits relative to the quality and quantity of stormwater runoff and energy savings. The study found that Houston's tree cover reduces the need for stormwater management by 2.4 billion cubic feet per peak storm event, saving $1.33 billion in one-time construction costs (ENN, 2001).

A CITYgreen evaluation was performed for the CSS area. CITYgreen is GIS software that analyzes the ecological and economic benefits of tree canopy and other green space. CITYgreen was developed by American Forests, a pioneer in the science and practice of urban forestry. The software works only in conjunction with analysis software from the Environmental Systems Research Institute. In addition to computing air pollution removal and carbon storage, this software application computes stormwater runoff using the Natural Resource Conservation Service model. CITYgreen software has been successfully used by major cities across the nation to implement Green Infrastructure Programs.

The results of the CITYgreen exercise, summarized in Table 3.2.2, indicate that the current canopy cover, which is only 11 percent of the CSS area (2,600 acres), represents over $30 million in onetime stormwater storage benefits to the community, in lieu of constructing stormwater detention facilities. The evaluation further indicates that by increasing canopy cover to the point where it represents 26 percent of the CSSA or 6,200 acres would provide an additional $43 million in stormwater storage benefits. For more information about the CITYgreen exercise please see Appendix 3.2.5 CITYgreen Analysis.

TABLE 3.2.2

STORMWATER STORAGE BENEFITS BASED ON AN INCREASE IN TREE CANOPY

	Tree Canopy		Onetime Stormwater Storage Benefits
	Acres	% of CSSA	CITYgreen Exercise
Existing Conditions	2,600	11%	$30,000,000
Increase Tree Canopy	6,200	26%	$73,000,000

In addition to the increase in stormwater storage benefits, other benefits associated with a 26 percent tree canopy cover include:

- Carbon stored: 266,600 tons total
- Carbon sequestered: 2,100 tons per year
- Air pollution removal: 629,700 lbs per year

The Clifton neighborhood, located on the east side of the CSS, was selected as a pilot area to conduct a more detailed and accurate CITYgreen evaluation. Canopy cover values were developed by manually digitizing aerial photographs. It was determined that approximately 45 percent of the study area has impervious surfaces and 20 percent is tree canopy. The CITYgreen analysis indicated that the current canopy represents $1.1 million in stormwater storage benefits. This benefit could be increased by $500,000 if only 15 percent or 29 acres of the existing impervious surface area were replaced with tree canopy.

As part of the evaluation, a review of Louisville Metro's Land Development Code for canopy cover requirements for various landuses were compared to target values established by American Forests, Inc. Louisville Metro's current regulations exceed recommended values for urban residential landuses but have significantly lower requirements than suggested for suburban landuses. See Figure 3.2.6 located at the end of this chapter.

Regional Evaluation Step 7 - Stormwater Redirection

Sewer separation is a common technique used to reduce CSOs. While this is an effective technique from a CSO discharge reduction perspective, it may simply move the additional stormwater runoff from one pipe system to another and can aggravate a number of other concerns associated with urbanization such as water balance, loss of habitat and low base flows in local streams.

In order for redirection of runoff from the CSS to be a viable part of the CSO control program, an alternative conveyance system to transport stormwater flows needs to be identified. The natural systems mapping exercise revealed: with the exception of the Beargrass Creek, few natural drainage features remain within the CSS. However, a number of local streams, particularly in the southwest section of Louisville Metro, are located in close proximity to the outer edge of the CSS boundary.

Figure 3.2.7, located at the end of this chapter, shows the delineation of the CSS system and the local stream networks. A review of this map indicates that there may be potential to separate stormwater from areas near the outer boundary of the CSS and redirect this flow to existing streams located outside the CSS area. This approach is referred to as "offloading." Further evaluation of these streams will need to be performed to ensure that the additional flows do not create new, or aggravate existing problems such as hydromodification or flooding prior to actual implementation of these types of projects.

A study area, delineated by a dashed line in Figure 3.2.8 that parallels the CSS boundary but is located 1/4 mile inside the existing perimeter, was established for the purpose of further exploring this option. Figure 3.2.8 is located at the end of this chapter. This zone contains approximately 8,000 acres and generates approximately four BG of stormwater runoff annually. Successful redirection of even a small percentage of the runoff generated in this area would result in significant reductions in flow to the CSS. Several focus areas along this boundary were identified through this process and will be discussed further in Section 3.2.6.7.

Regional Evaluation Step 8 – Subsurface Evaluations

Many green infrastructure techniques rely on infiltration as the primary mechanism to achieve runoff volume reductions. Soils and geology are important components in determining if and where stormwater runoff can be infiltrated into the subsurface. Soil permeability plays a major role in the design configuration and the functionality of certain green control techniques. High permeability rates can reduce the footprint and/or profile of a proposed green component resulting in very cost effective designs. Understanding local soil characteristics is very important in the development of a recommended program. Unfortunately, adequate soils information was not readily available for the CSS area. The soil information contained in the LOJIC database for the CSS area simply showed a single polygon with the classification of "urban soils." The Natural Resource Conservation Service database showed slightly more detail but the core downtown region of Louisville Metro was still labeled "Urban Area."

Therefore, MSD worked with a local geotechnical engineer with years of experience in the Louisville Metro area to evaluate further the soils and geology in this region. A generalized map of soil and rock conditions was generated using a combination of published subsurface data, engineering experience, and local records of excavations and soil test borings within the CSS boundaries. This map, while somewhat coarse, provides a general guide for directing the types of green techniques that are applicable in the different regions throughout the Louisville Metro area. While this evaluation is an important tool to guide the selection of BMPs, it is only a preliminary delineation and site-specific evaluations will be necessary for final design.

Figure 3.2.9, located at the end of this chapter, is a geologic map of Kentucky, which shows that the Louisville Metro is located on the western edge of the geological formation known as the Cincinnati Arch. The eastern portion of the Louisville Metro is located in the uplifted fringe of this formation. In addition to having greater topographic relief than the western part of the City, the geologic characteristics of east Louisville Metro differ significantly from the rest of the City. The eastern portion of the CSS, particularly in the Beargrass Creek area, is dominated by bedrock forming karst uplands with sinkholes. The karst geology in this area contains limestone bedrock with sinkholes that may be considered for infiltration if supplemented with biofiltration strategies. The following is a brief description of the results of the subsurface evaluation:

- The Louisville Metro area is composed of two basic geologic settings: deposits related to past activities and alignments of the Ohio River (alluvium) and residual soils (soils weathered in place) derived from limestone and shale layers.
- The downtown area is immediately adjacent to the Ohio River and lies on deep sand and gravel layers extending down about 100 feet to limestone.
- The west part of the city also was formerly located in the riverbed but has more recently been part of backwater, or slower, depositional characteristics. These conditions produced silt and clay layers over the deeper alluvial strata.
- To the south, the depth to rock becomes much shallower, and the upper rock surface is composed of relatively impermeable shale. The combination of the fine-grained backwater soils and the impermeable rock creates very soft, poorly drained conditions.

Easily weathered shales on the slopes along the southern edge of the CSS area add slope instability to the soft conditions.

- The eastern and southeastern portion of the Louisville Metro is composed mainly of fine-grained soils, but these are residual soils weathered from shale and limestone. The soils typically are moderately to highly plastic clays, low in permeability. The residual deposits are relatively thin and overlay variably solutioned limestone. Sinkhole development is common, particularly in those areas underlain by the Jeffersonville limestone formation.

Published data from the United States Geological Survey (USGS) and the Natural Resource Conservation Service were used to draw approximate boundaries between the aforementioned conditions. Experience with soil test borings and excavation was referenced to refine those boundaries and define a number of "classifications" for soil conditions within the CSS project area. Those classifications indicated that:

- Several areas in the center and the west of the CSS area would be suitable for green methodologies involving discharge of surface water runoff into the subsurface.
- Some sections in the north-central and southwest portions of the subject area were found to be suitable for shallow infiltration methods, such as bioswales, green streets, and green parking lots.
- Areas in the west and north central were identified as appropriate for applications, which discharge runoff deeper in the subgrade (dry wells) where shallow fine-grained (lower permeability) deposits overlay more permeable sands and gravels.
- The eastern and southeastern sections of the CSS area were considered to be very sensitive due to the possibility of sinkhole development with the introduction of runoff into subsurface conditions where subsidence over karst terrain is possible.
- The subsurface conditions map (see Appendix 3.2.6, Regional Soils Evaluation) divides the CSS area into six different zones based on shallow soils and geology types.

The six zone delineations are as follows:

- Zone 1 – Alluvium: shallow infiltration due to recent deposits of sand, gravel, and silt
- Zone 2 – Clay: typically 5 - 20 ft. of low permeability, risk of sinkhole activity
- Zone 3 – Clay with shallow shale: no shallow infiltration, unstable on slopes
- Zone 4 – Loess: unconsolidated silt over shallow shale
- Zone 5 – Outwash: silts and clays in the upper 15 - 20 ft., sands below grading to gravel
- Zone 6 – Terrace: silts and clays in upper 15 - 20 ft., over shale

Special conditions, such as second- or third-generation redevelopment and old underground utilities, were noted as being pertinent with regard to the suitability of subsurface discharge methods and the possible corresponding problems. These conditions were identified as being characteristic of particular areas so that they became considerations when green methods were suggested for specific sites. Most of the northern part of downtown Louisville Metro is second- or third-generation construction, and past demolition methods involved razing old buildings and pushing the debris into the subsurface on the site. Typically, fine-grained fill soils, such as silty clays, have been compacted over the debris-filled layers to create building pads. The resulting subsurface conditions include large voids. Runoff flowing down through such deposits can transport the fine-grained fill into the voids in the deeper strata, causing subsidence to occur under existing structures. In addition, numerous old utilities are present throughout downtown, most of which act as conduits for water flowing down through the soil. Increasing runoff to zones containing such utilities can cause dropouts and large volumes of subsidence. Known sites containing old debris and abandoned utilities were avoided when considering potential sites for green demonstration projects.

A number of older buildings in downtown also were constructed at a time when excessive groundwater was not considered in design. Infiltration of significant volumes of runoff into the foundation bearing soils and basement wall backfill around such buildings could cause structural problems, so the general locations of these buildings were considered when evaluating specific green application locations.

A final condition evaluated for the soils map was the presence of large contamination zones in the sand and gravels layers in the center and western portions of the combined sewer service area. Published environmental records were reviewed to identify areas of significant contamination so that green measures, such as dry wells, would not expand contamination plumes or otherwise exacerbate existing problems. Refer to Appendix 3.2.7 Contamination Regions for a map showing the contaminated regions in the CSS. See Figure 3.2.10, at the end of this chapter, showing the hydric soils result in a soil with distinctly different properties than non-hydric soils.

Regional Evaluation Summary

The eight steps in this regional evaluation process are a unique effort that was designed specifically for the MSD's green infrastructure process. By completing a comprehensive regional green infrastructure planning initiative at the front end of the Final CSO LTCP, MSD is poised to be a national model for the use of green infrastructure in the control and mitigation of combined sewer overflows. A graphical depiction summarizing the results of this complex regional evaluation has been developed and is presented in Figure 3.2.11 located at the end of this chapter. This regional plan will serve as the roadmap to guide Louisville Metro to a greener, more livable and sustainable future.

3.2.5.6 CSO Sewershed Evaluations

Much of the data generated during the regional sewershed evaluation provided valuable information that opened opportunity for detailed assessments of green opportunities at a smaller scale. The CSS area is divided into over 100 smaller sewersheds that generally represent the local drainage area to a particular permitted overflow point. These individual sewersheds provided logical study units for performing this detailed evaluation.

Each sewershed with an active overflow was reviewed for potential green opportunities. For the purpose of consistency, a standard set of criteria was developed to evaluate each sewershed basin. The following is a brief description of the criteria that were used for this exercise:

- Public alleys were considered for porous pavements.
- Publicly owned buildings were candidates for green roofs.
- Mapped sinkholes were considered for stormwater offloading.
- Publicly owned green spaces were considered for biofiltration techniques.
- Publicly owned parking lots were considered for biofiltration techniques.
- Catch basins in Zone 5 were considered for dry wells.
- Residential housing in Zone 5 was considered for downspout disconnection.

In addition to this standardized set of criteria, the following information was included on each opportunities map, to assist in with the green evaluation:

- Overflow characterization (volume, duration and frequency)
- Percent tree canopy
- Number of catch basins
- Population

The purpose of this assessment was to objectively examine each sewershed and identify the potential opportunities to implement green infrastructure within that particular study area. The result of this exercise was the generation of approximately 100 maps of individual sewersheds, each with specific green infrastructure opportunities identified. See Appendix 3.2.8 Green Opportunities Maps for Individual CSO Basins for the green infrastructure opportunities maps for each sewershed.

This assessment task was not intended to provide a detailed evaluation of each of the identified opportunities but rather to understand the various types of opportunities and their relative significance across the CSS. With this understanding, MSD identified a short list of green infrastructure techniques along with candidate locations to evaluate further for the implementation of various demonstration projects.

Information obtained from LOJIC data served as the basis for this evaluation and included the following data:

- Imperviousness
- Landuse
- Public ownership
- Single family homes
- Commercial/Industrial property

Each of these categories is described in more detail below.

Imperviousness

As discussed earlier, an impervious area is a root cause of CSOs. The result of increased impervious surface is an increase in both peak discharge rates of stormwater runoff and an increase in the overall volume of stormwater runoff. In the CSS, all this additional stormwater runoff must be conveyed by a pipe network that in some cases is over 100 years old. When the capacity of the CSS is exceeded, overflows occur. Therefore, developing a Green Infrastructure Program that emphasizes source control requires that the distribution of impervious surfaces within each sewershed be determined.

The data contained in the LOJIC database allowed for a more detailed evaluation of imperviousness for individual basins. In general, impervious areas were divided into three major categories: rooftops, roadways, and miscellaneous transportation areas such as parking lots, sidewalks and driveways.

By evaluating the impervious area distribution within each individual sewershed and evaluating this in the context of a particular CSO, MSD can begin to target particular types of impervious surface and identify effective green infrastructure techniques to reduce the associated runoff.

Landuse

Landuse is important in this process because the types of impervious surfaces are directly linked to landuse types. Landuse distribution was calculated for each sewershed based on identified categories. These categories included residential, commercial, industrial, parks and open space and public space.

This data helps determine which green infrastructure techniques may be most appropriate for a particular area. For example, in an area comprised predominantly of residential landuse, most of the impervious surface is residential rooftops and roadways. Therefore, a recommended Green Infrastructure Program targeting this area would need to identify techniques that are suitable for these types of impervious surfaces and would likely not anticipate a large benefit from a control such as a green roof program.

Public Ownership

Using data provided by LOJIC, public properties within each basin were identified and included police stations, fire stations, post offices, schools, and other government buildings. The total roof area and parking lot area associated with publicly owned lands were calculated for each sewershed basin. This determined how much public property was contributing to the imperviousness of the sewershed. Public buildings were marked as a potential for a green roof and public parking lots were marked as a potential for permeable pavement or biofiltration techniques. In order for the MSD green initiative to be successful, major property owners within the CSS will need to become partners in the implementation of green infrastructure techniques. Large land owning public agencies represent good candidates to fulfill this need.

Single Family Homes

Utilizing LOJIC data, the number of single-family homes and associated rooftop area, in each sewershed, was calculated based on the "Single Family" landuse delineation. This determined the total single-family rooftop area that contributed to the imperviousness of the basin. Based on the size of the residential parcels, the density of the homes, the percentage of the impervious area, and the subsurface conditions of the area, a ranking of good, fair, or poor was given to each basin regarding the potential effectiveness of a downspout disconnection program.

Commercial/Industrial Property

The LOJIC database contains landuse information that delineates commercial and industrial properties from other landuse types. While MSD is actively working with this sector in new and redevelopment projects to educate and incentivize green practices, MSD has opted to be very conservative in its estimates of green benefits in the context of the Final CSO LTCP and therefore has not projected CSO reductions from projects in this landuse class.

3.2.5.7 Neighborhood and Focus Area Evaluations

An important outcome of the regional evaluation was the identification of seven focus areas recommended for further evaluation. While each site has unique characteristics, they all represent opportunities to:

- Offload or remove significant amounts of stormwater runoff from the CSS
- Partner with a public agency
- Establish connectivity of green spaces

The focus areas and the associated CSO reduction projects discussed below represent conceptual solutions only. Each area will require additional study to determine the feasibility of the proposed techniques. Most of the proposed concepts involve a combination of green and gray infrastructure technologies.

Focus Area 1 – Northwest Area

Focus Area 1, located in the northwest portion of the combined sewer service area is comprised of residential and industrial landuses with a significant amount of Right of Way (ROW). A total of 272 acres have been identified within this Focus Area 1.

Based on an analysis of existing surface drainage patterns, soil characteristics and available land area the following green infrastructure opportunities exist:

- Redirect stormwater runoff from the interstate system to biofiltration facilities and dry wells located in the I-264 ROW.
- Capture, treat, and redirect runoff from rail yard to facilities in I-264 ROW.
- Construct porous alleys in local neighborhoods.
- Separate storm sewers in local neighborhoods and redirect to the biofiltration facilities and dry wells located in the I-264 ROW.

Refer to Figure 3.2.12, located at the end of this chapter, for the features and conditions of the Northwest Focus Area.

Focus Area 2 - Northeast Area

Focus Area 2, located in the northeast portion of the combined sewer area is comprised of residential, industrial, natural stream network and a significant amount of ROW. Based on an analysis of existing surface drainage patterns, soil characteristics and available land area the following green opportunities exist:

- Separate storm sewers in local neighborhoods and redirect to stream system or biofiltration, wetlands and/or sinkholes facilities along stream corridor.
- Enhance local greenway system and establish greater connectivity between neighborhoods.
- Incorporate green infrastructure controls into major planned State highway corridor reconfigurations adjacent to the Ohio River.
- Capitalize on existing neighborhood organizations and areas with public support for green infrastructure through targeted downspout disconnection programs, rain barrel distribution, and residential rain garden installations.

Refer to Figure 3.2.13, located at the end of this chapter, for the features and conditions of the Northeast Focus Area.

Focus Area 3 – South Central West Area

Focus Area 3, located in the south central west portion of the combined sewer area is primarily residential landuse along with a number of schools and some ROW. Based on an analysis of existing surface drainage patterns, soil characteristics, and available land area the following green infrastructure opportunities exist:

- Separate storm sewers in local neighborhoods and redirect to adjacent stream networks.
- Create strategic partnerships with local schools to incorporate green infrastructure components on school properties that also provide educational opportunities.
- Implement green infrastructure techniques on Louisville Metro Municipal Housing Authority property.
- Retrofit existing detention facilities to incorporate water quality-based design elements and/or infiltration components.

Refer to Figure 3.2.14, located at the end of this chapter, for the features and conditions of the South Central West Focus Area.

Focus Area 4 - South Central East Area

Focus Area 4, located in the south central east portion of the combined sewer area is comprised of residential, industrial and a significant amount of interstate ROW. This focus area has tremendous opportunity to forge valuable strategic partnerships. Key landowners in this area include Kentucky Exposition Center, Kentucky Transportation Cabinet, University of Louisville, Churchill Downs, and Louisville International Airport.

There are a relatively high percentage of pavements in this study area in the form of parking lots, roadways, and runways contributing large amounts of stormwater runoff to the CSS. Based on an analysis of existing surface drainage patterns, soil characteristics, and available land area the following green infrastructure opportunities exist:

- Redirect stormwater runoff from the interstate system to biofiltration facilities and dry wells located in the I-65 ROW.
- Install pervious pavements in large parking lot areas.
- Incorporate vegetated stormwater controls into existing large parking lot areas.
- Implement green street practices.
- Increase canopy cover.

Refer to Figure 3.2.15, located at the end of this chapter, for the features and conditions of the South Central East Focus Area.

Focus Area 5 – Southwestern Parkway Area

Focus Area 5, located in the southwestern parkway portion of the combined sewer area is comprised primarily of residential landuse along with interstate ROW. Based on an analysis of existing surface drainage patterns, soil characteristics, and available land area the following green infrastructure opportunities exist:

- Strong potential for green street techniques at multiple scales of roadway systems ranging from local, to collector to state highways.
- Potential to utilize various techniques to control roadway runoff ranging from dry wells to biofiltration to rain gardens.
- Utilize interchange area in State ROW for infiltration of runoff.
- Separate storm sewers in two local neighborhoods and discharge directly to the Ohio River.
- Utilize green streets to provide connectivity to local parks.

Refer to Figure 3.2.16 located at the end of this chapter for the features and conditions of the Southwestern Parkway Focus Area.

Focus Area 6 – Southwest Greenway and Parkway Area

Focus Area 6, located in the southwest greenway and parkway portion of the combined sewer area is comprised of residential, industrial, interstate ROW, and a utility corridor. This Focus Area includes an existing MSD detention basin and a natural stream. Based on an analysis of existing surface drainage patterns, soil characteristics, and available land area the following green infrastructure opportunities exist:

- Potential to develop a greenway connection
- Ability to enhance existing detention basins
- Opportunity to work with strategic partners
- Potential to infiltrate into glacial outwash

Refer to Figure 3.2.17, located at the end of this chapter, for the features and conditions of the Southwest Greenway and Parkway Focus Area.

Focus Area 7 – Central Business District Area

Focus Area 7, located in the Central Business District portion of the combined sewer area is comprised of mostly impervious surfaces including buildings, roadways, and large parking lots.

This central downtown area provides a great opportunity to utilize green controls to capture runoff while connecting the community. The following green opportunities exist:

- Strong potential for green street techniques at multiple scales of roadway systems ranging from local to collector streets.
- Potential to retrofit existing buildings with vegetated roofs
- Opportunity to retrofit existing parking lots with biofiltration techniques or rain gardens. Refer to Figure 3.2.18, located at the end of this chapter, for the green street concept plan for the Central Business District Focus Area.

As discussed, each Focus Areas will require additional evaluation to determine which, if any, of the proposed concepts are in fact feasible. Stormwater offloading, strategic partnerships and the use of natural systems are key elements to each area. Each proposed project has the potential to have a significant impact on both the green infrastructure initiative as well as MSD's overall CSO mitigation program, which may translate into the elimination and/or reduction of proposed gray controls.

Additional maps for each focus area can be found in Appendix 3.2.9 Seven Focus Areas.

3.2.5.8 Site Evaluations

As previously mentioned, MSD has worked intensely to develop effective partnerships, where multiple entities benefit from implementation of green infrastructure practices. A good example of this effort is the relationship MSD has developed with JCPS. MSD has worked with JCPS to develop green concept plans for two schools - Roosevelt Perry Elementary and Engelhard Elementary - both located within the CSS. These concept plans provide the schools with new site plans that incorporate green elements, enhance the functionality of the sites, improve aesthetics, and provide a reduction in stormwater runoff entering the CSS.

An initial test site was installed in 2007 at a parking lot for the Girl Scouts of Kentuckiana's new headquarters on Lexington Road.

Roosevelt Perry Elementary is located on the west side of Downtown Louisville Metro. This site has approximately 2.5 acres of impervious surface. The existing site is somewhat disjointed with parking adjacent to and close to the building, while playground areas are located around the corner of an adjacent building next to a very busy road. Currently, the runoff from this site discharges directly to the CSS – approximately 2.3 MG per year. A revised site plan was developed that addresses the needs of JCPS and targets the reduction of runoff from the site. The proposed plan incorporates pervious pavements, bio-swales, a small vegetated roof, outdoor educational space, and a cistern and curbs extensions that result in an estimated 79 percent reduction (1.8 MG) of annual runoff to the CSS. Additionally, the parking was moved to the perimeter of the site, hard and soft playground areas were moved to the middle of the property, and outdoor classroom facilities were located just outside of the existing school.

The Roosevelt Perry concept plan also represents a great example of the benefits that a multi-scaled approach can achieve. Interviews with school officials determined that most of the students enrolled in this school live in the adjacent neighborhoods. The concept plan incorporates revised street designs that improve pedestrian safety through the use of vegetated curb bump outs at cross walks that serve as a traffic calming elements and also infiltrate stormwater runoff from the roadways. Simple modifications to an adjacent, underutilized park create a more valuable community asset and a badly needed functional playground for an urban school. The multi-scale site plan should serve as the catalyst for a meaningful partnership between JCPS, Metro Parks, Public Works, and MSD that collectively achieves far more community benefit by targeting limited resources at an integrated, coordinated plan.

Engelhard Elementary, the second concept plan site, is located just south of Downtown Louisville Metro. The site is comprised of one building, a parking lot, and a grass play area. Approximately 1.8 acres of impervious surface discharge approximately 1.8 MG per year directly to the combined sewer. The green concept plan incorporates pervious concrete, a bio-retention swale, reinforced turf, and curb cuts resulting in an estimated reduction of 1.4 MG per year to the CSS. In addition to the green elements, the proposed concept plan relocated the play area closer to the school, dramatically improved traffic flow through the site and provided much needed parking facilities.

According to the 2007 JCPS Facility Needs Survey, there is $75,000 worth of site and pavement work planned for Engelhard in the next five years. Discussions are currently ongoing, between MSD and JCPS to determine the benefits and logistics of implementing the proposed plan or some version of it.

Each of these schools provided an opportunity to demonstrate the importance of evaluating individual sites from a variety of perspectives. While the specific conditions of each site were improved in terms of stormwater runoff, safety, traffic flow and parking, each proposed plan stepped beyond the parcel boundaries of the individual school site to identify opportunities to effectively integrate these school sites into a larger context of the neighborhood and the sewershed. See Appendix 3.2.10 Concept Plans.

3.2.5.9 Green infrastructure Demonstration Projects

Upon completion of the green CSO sewershed evaluations, workshops were conducted to review the results of each of the basin evaluations. The result of these workshops was the identification of a subset of basins that were deemed to be candidates for more detailed evaluations with the objective of selecting 19 green infrastructure demonstration projects. Site visits were performed at each of the candidate locations and an evaluation was performed that considered numerous factors including property ownership, public visibility, soils, geology, basin size, proximity to adjacent structures and age of those structures.

The result of this effort was the selection of 19 potential locations in the CSS for the construction of green infrastructure projects that generally can be categorized into five major component types. These types are biofiltration, green alleys, green streets, dry wells, sinkholes and wetlands creation or restoration. Greater detail of each of these component types is presented in the following pages.

Biofiltration Techniques

Similar to most highly urbanized areas, downtown Louisville Metro contains a high percentage of impervious area. One of the primary objectives of the green infrastructure effort is to replace hard infrastructure with vegetation where practical. Biofiltration techniques provide a means to reduce stormwater runoff, promote groundwater recharge, maximize evapotranspiration and reduce the total impervious surface in the CSS. While biofiltration is an important component of this program, the performance of infiltration techniques in downtown areas may be negatively impacted as a result of the compaction of native soils that typically occurs in urban settings. MSD will explore techniques such as soil aeration to enhance the ability of public green spaces to infiltrate stormwater runoff.

From a geologic standpoint, several types of alluvial deposits underlie downtown Louisville Metro. Some areas contain fine-grained layers near the ground surface, but silty sands and sands at depths of less than five to seven feet underlie many portions of central and south central downtown. Such relatively permeable conditions are conducive to effective installation and function of bioswales.

Parking lots provide ample opportunity to cost effectively utilize biofiltration techniques. Based on the impervious area evaluation, parking lots represent a significant portion of the impervious area within the CSS. Retrofitting existing parking lots and redirecting runoff to vegetated perimeters and medians will effectively and efficiently reduce the volume of water entering the combined system. Five parking lots were identified as candidates for demonstration projects. These sites were selected based on the presence of relatively permeable stratigraphic conditions in the subsurface and the absence of any indication of leaking or malfunctioning infrastructure or sensitive building foundations in the immediate vicinities of the chosen sites. If properly designed these systems will reduce the runoff from the site and provide needed green space to these large impervious areas. Appendix 3.2.11 Biofiltration Technique Cross Sections provides some cross-sectional details for this type of green infrastructure technique. Parking lots were identified as candidates for demonstration projects at the following locations:

- CSO053 – MSD Main Office Parking Lot Biofiltration Swale
- CSO053 – Seventh and Cedar Green Parking Lot
- CSO181 – Second and Broadway Green Parking Lot
- CSO198 – Third and West Ormsby Biofiltration Swales
- CSO022 – Sixth Street and Muhammad Ali Green Parking Lot

Rain Gardens

Rain gardens are vegetative systems used to intercept runoff from relatively small drainage areas. Runoff directed to rain gardens is reduced through infiltration and evapotranspiration practices. MSD has been implementing a residential rain garden program for many years. See Section 3.2.5.10.

In an effort to expand the application of this technique to the urban setting, MSD has identified one site downtown to construct a rain garden. The site is within the sewershed of CSO028 and located at Sixth Street and Broadway. Additionally, MSD is committed to identifying four additional sites within the first year of the program to more fully evaluate the applicability of rain gardens to reduce CSOs in the downtown area.

Green Alleys

The transportation network in downtown Louisville Metro includes a large number of alleys - over 500 in the CSS area. A partnership between MSD and Louisville Metro Public Works would facilitate the utilization of porous pavement technology during the alley renovation process and could prove to be a cost effective technique for CSO control.

As stated previously, many portions of downtown Louisville Metro are underlain by silty sand and sand deposits that allow infiltration rates suitable for the installation of porous pavements. Many portions of west Louisville also include similar subsurface conditions, and alleys were included in almost all of the original road construction in that area. A limiting factor, however, is the widespread presence of old, leaking infrastructure under and in close proximity to many alleys. Increased infiltration into the subgrade around these compromised pipes and associated structures could lead to subsidence under the alleys and surrounding structures. Therefore, green alleys were chosen with special consideration of available information on the existing active and inactive infrastructure.

While there are numerous porous pavement technologies available including porous asphalt, porous pavers, bricks with spacers, etc., the technology selected for these demonstration projects is pervious concrete. Two types of alley configurations were selected for these demonstration projects. The first configuration assumes that the entire alley surface would be replaced with a pervious concrete surface. The other configuration assumes that only a 4-foot wide center strip of porous concrete will be constructed. Appendix 3.2.12 Porous Concrete Cross Sections provides typical details for pervious concrete.

Pervious concrete contains less lime and finer particles than ordinary concrete.

The following three alleys were identified as candidate demonstration projects:

- CSO015 – Seventeenth and W Hill Permeable Alley
- CSO053 – Seventh and Market Permeable Alley
- CSO121 – Campbell and Main Permeable Alley

Green Streets

A large percentage (27 percent) of the impervious surfaces in the CSS is associated with roadways. Green street techniques have the potential to play a significant role in MSD's Green Infrastructure Program. While numerous configurations ranging from street edge alternatives, to sidewalk planters, to porous pavements are all components of green streets, this evaluation did not identify the specific techniques to be used in the demonstration project, but rather recognized that each street will require a site-specific design.

Stratigraphy suitable for the green street application is similar to that of green alleys, so the same areas of downtown were evaluated for potential candidates. Some green street techniques allow a slightly deeper discharge depth, such as street edge solutions, but for the purposes of this part of the project, areas with relatively shallow (five feet to seven feet deep) silty sands and sands were considered. Many of the possible green street locations included open space on adjacent parcels to minimize the risk of destabilization of shallow, soil-bearing foundations by saturation of the bearing soils.

One location - Housing Authority Property: Beecher Terrace in CSO208 was identified for a green street demonstration project. This location includes shallow foundations at a distance of at least 40 feet from the nearest infiltration point. This distance was considered to be sufficient to minimize the chances of saturating the foundation bearing soils. General assumptions for cost and performance were utilized for the evaluation with the understanding that these values would need to be refined once a final concept plan was developed for the site.

Dry wells

Dry well construction was considered to have a high potential for offloading surface water runoff from the CSS in the central and western portions of the CSS area. Dry wells can have a relatively high capacity compared to other green infrastructure techniques, and they typically are used in areas where surficial fine-grained clays and silts reduce shallow infiltration rates and prohibit the effective use of methods like bioswales and green streets.

A dry well typically consists of a concrete pipe section that is inserted into the ground and transports runoff from an existing stormwater sewer line to permeable layers in the subsurface. The dry well system can include any number of filtration devices to prevent contaminants from being discharged into the aquifer. The number and type of such devices depends on the origin of the runoff and the presence of other filters prior to the runoff entering the sewer system.

To develop a dry well properly, a soil test boring should be advanced at the location of the proposed dry well. The stratigraphy revealed by the boring should be evaluated to determine at what depth soil permeability will permit infiltration rates that will allow rapid discharge of surface water runoff into the subsurface. The boring information also should be used to characterize groundwater levels in order to define boundaries between saturated and unsaturated zones. After permeability and groundwater conditions have been established, the structure can be sized assuming an infiltration rate at a given discharge depth.

Dry wells proposed to be used in the MSD project likely will be constructed to discharge at depths of 15 to 25 feet below the ground surface into fine- to medium-grained sands. Groundwater levels in the target zones in the western and north central portions of the CSO area have been recorded to be between 30 feet and 65 feet below the ground surface causing the proposed dry wells to discharge in the unsaturated zone. As a result, infiltration rates will be required to be estimated, and conservative estimates will be used.

A number of potential dry well locations were identified on publicly owned parcels where soil test borings on nearby sites indicated sands and gravels at depths of 15 to 20 feet below the existing ground surface. Several public agencies, including the Louisville Metro Housing Authority and the JCPS expressed their willingness to allow dry well construction on their properties in order to further the green initiative. See Appendix 3.2.13 for a standard drywell cross-section.

The construction of dry wells will most likely require obtaining an Underground Injection Control permit. In Kentucky, the Underground Injection Control permitting process is administered through EPA - Region 4 in Atlanta. The agency requires that a form be completed detailing the location of the proposed dry well, the type of construction and documentation on any known sources of contamination in the area, or any vicinity-wide plumes of contamination. The data is reviewed to determine if the feature will be introducing any new contaminants into the aquifer or will be attenuating any existing plumes of contamination. If the EPA does not believe the dry well poses a significant risk to the quality of the aquifer, a rule authorization is granted. See Appendix 3.2.14 Drywell Rule Authorization Form for a copy of the required form.

Five candidate locations were selected for the construction of dry wells.

- CSO189 – I-264 Off-Ramp Dry Well
- CSO019 – I-264 On-Ramp Dry Well
- CSO191 – I-264 and Gibson Dry Well
- CSO191 – Russell Lee Drive Dry Well
- CSO191 – JFK Montessori Area Dry Well

Sinkholes and Wetlands

There is a possibility that sinkholes with well-defined throats could be used as dry wells. Dry well installation is common in the karst terrain in southern Indiana and central Kentucky. Solution features in the calcareous rock layers (usually limestone) were formed by groundwater flow, so a discharge capacity of some volume typically is present in the rock layers beneath a sinkhole of substantial size. The difficult part of developing a dry well in a sinkhole is evaluating the capacity and determining whether the solution features in the immediate zone beneath the upper rock surface are clogged with soil fines and may be flushed out with hydrostatic pressure. Specific geotechnical evaluations will be necessary before discharging any additional runoff to the subsurface in the eastern portion of the CSO area, due to the potential of causing karst-related subsidence.

A dry well in a sinkhole is constructed in much the same manner as a dry well in an alluvial stratigraphy. The most significant difference is that considerable work must be completed to identify the throat, which is the opening in the upper rock surface into the network of solution features.

Placement of dry wells in sinkholes is difficult because there is no order or regularity to the location of such features. The probability of a sinkhole with adequate capacity to receive runoff being located on accessible property near sewer structures with significant flow is low. However, several closed contour depressions were identified in areas where stormwater runoff could be offloaded from the CSO system. One such location is in close proximity to a delineated wetland adjacent to the Beargrass Creek. Preliminary plans have been discussed to separate nearby sewers and discharge the flow to the existing wetland area. The wetland would need to be expanded and enhanced and reconfigured to allow large flows to discharge directly to a very large existing sinkhole feature.

Exploration of the sinkhole for capacity should be performed by exposing the throat and doing a series of pump tests in which water is discharged into the feature in several manners. One test should include a large volume of water in a short flow duration, to simulate a brief, intense precipitation event. At least one other test should be conducted by discharging a steady flow into the feature for an extended time to explore constant flow capacity, intermediate storage, and possible silting in.

This project represents an opportunity to utilize a natural system for stormwater control, improve an existing resource, and potentially reduce and/or eliminate a gray control. Due to the unique nature of this project, a more detailed preliminary evaluation can be found in Appendix 3.2.15 Wetland/Sinkhole Preliminary Evaluation.

The 19 proposed demonstration projects will cost approximately $1.5 million to implement and will remove an estimated 10 MG of stormwater from the CSS annually. But more importantly, these projects represent an opportunity to demonstrate various green techniques, develop more accurate and locally based cost information and monitor their performance.

3.2.5.10 Green Program Development

In addition to the 19 demonstration projects, MSD's recommended green infrastructure plan includes six programs elements. These program elements are downspout disconnection, rain barrel program, residential rain gardens, green roof incentives, urban reforestation, and dry wells.

These programs will be implemented on a regional level by MSD in an effort to reduce CSOs, as well as to raise public awareness of the responsibility that individuals have in protecting and enhancing our local water resources. Each of the green programs, and costs associated with their implementation, is described in more detail below.

It is important to note that for the purpose of evaluating the potential stormwater reductions achievable through the use of green infrastructure, the regional evaluation used a 15-year planning horizon. However, as will be discussed later in the document, MSD plans on assessing the performance of green infrastructure demonstration projects and programs during the first six years of implementation with the goal of evaluating and adjusting financial allocations for particular programs based on a benefit-cost analysis. By July 2010 MSD will finalize the details for a regional downspout disconnect and rain barrel programs. In addition, MSD will define a more formal strategy for developing programs, such as a vegetative roof incentive or urban reforestation program, that deal with public and private partners by July 2010.

Concurrent with the development of the green programs, MSD plans to begin design and construction of several of the green demonstration projects in July 2009 and estimates that all 19 demonstration projects will be constructed by December 2011. The completion of these demonstration projects will allow for the development of more formal partnership arrangements with other local agencies such as Metro Housing Authority, Public Works, and JCPS. Successful implementation of the demonstration projects should provide a level of confidence in the community to more readily commit to widespread application of specific techniques on public property outside the control of MSD that can then be translated into formal green programs, including budgets and implementation levels, for elements such as green streets, permeable alleys, and green parking lots.

Once the demonstration projects have been completed and proven successful to allow for widespread implementation, MSD will work with the necessary entities to develop other formal programs for green controls such as porous alleys, rain gardens and green streets. MSD will define the strategy for the development of additional green projects by the end of 2013. Therefore, while green infrastructure is envisioned to be an important component to the overall Final CSO LTCP, MSD's long range commitment to this program will be based on how green performs in comparison to more traditional gray solutions.

Downspout Disconnection

Single-family rooftops account for 18 percent of the impervious area within the CSS area. By disconnecting roof downspouts, a significant portion of this impervious area can be removed from the combined system. MSD will develop an incentive-based Downspout Disconnection Program to target the stormwater entering the CSS from residential landuse.

The proposed program will offer homeowners financial incentives per disconnected downspout. The financial incentive will motivate homeowners to participate in the program and should result in higher participation rates.

Utilizing LOJIC data the total square footage of single-family rooftops was calculated for each basin. Field surveys of approximately 30 basins were conducted in an effort to determine the percentage of single-family homes with downspouts that are directly connected to the CSS. The results of this effort indicated that, on average, approximately 65 percent of parcels have downspouts that were directly connected to the combined sewer. In estimating the potential benefits of the downspout disconnection program in basins that were not field surveyed, it was assumed that 65 percent of the total residential rooftop area was available for disconnection For those sewersheds where field surveys were conducted the actual percent of downspouts connected was utilized in the evaluation.

In estimating the potential stormwater reduction from this program, each basin was given a rating of high, medium, or low for both effectiveness and participation. The “effectiveness” rating was based on criteria such as soil conditions, lot size and density of the homes. This variable is intended to provide an estimate of the percentage of the stormwater removed during the disconnection that somehow flows back into the CSS through either direct or indirect means. Even if a downspout is disconnected from the CSS, some of the redirected runoff still have the potential to re-enter the CSS.

The “participation” rating was based on local knowledge of the neighborhoods and types of residents within the area. A 10 percent participation rate implies that 10 percent of the homes will participate in the program. However, note that based on assumptions stated above, even if a homeowner agrees to participate, for the purposes of this evaluation, stormwater reduction estimates only assume that 50 percent of the roof is disconnected.

Furthermore, because of the potential for sinkhole creation, green components that require shallow infiltration will not be recommended on the eastside of the CSS area without further geotechnical investigation. Therefore, basins that were tagged as not suitable for infiltration, based on the regional soils evaluation, discussed in Section 3.2.6.4, were automatically given an implementation rate of zero. After further investigation, certain areas in this region will be eligible for a downspout disconnection program, thus increasing the benefit of the program.

Utilizing the matrix in Table 3.2.3 an estimate of the stormwater removal effectiveness was determined for each sewershed. For example, if for a particular sewershed the participation rate is estimated to be low, but the effectiveness of disconnected water remaining out of the CSS is medium, then the matrix indicates that the program will in effect, removing 10 percent of the roof area from the CSS.

TABLE 3.2.3

DOWNSPOUT DISCONNECTION STORMWATER REDUCTION MATRIX

PARTICIPATION		EFFECTIVENESS: LOW	EFFECTIVENESS: MEDIUM	EFFECTIVENESS: HIGH
PARTICIPATION	HIGH	15%	35%	40%
PARTICIPATION	MEDIUM	10%	25%	35%
PARTICIPATION	LOW	5%	10%	15%

The results of each sewershed evaluation were combined and totaled. Using conservative estimates for each program variable, it has been estimated that once fully implemented the downspout disconnection program will remove approximately seven percent of connected single-family roof area from the CSS that translates into the removal of 134 MG of stormwater annually. To see specific reductions for each basin and a program flowchart please see Appendix 3.2.16 Downspout Disconnection Reductions and Program Flowchart.

Based on an evaluation of anticipated administrative and reimbursement costs, $250 per downspout was used to establish a program budget. The cost for program management and marketing costs was derived from data provided by the City of Portland, Oregon Stormwater Retrofit Program Manager.

The program participation estimates assume that 1,545 downspouts will be disconnected annually, which equates to approximately $0.05 per gallon removed. MSD will strategically perform geotechnical evaluations for basins originally marked as unsuitable for downspout disconnection in order to increase the overall effectiveness of this program.

TABLE 3.2.4

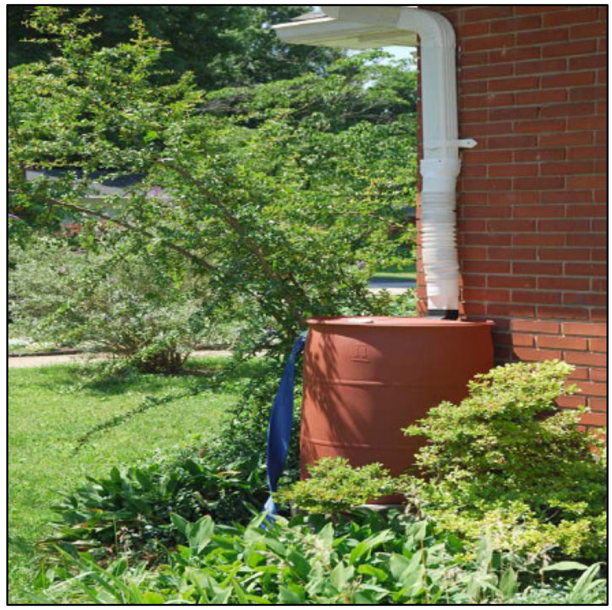
DOWNSPOUT DISCONNECTION PROGRAM COSTS

Downspout Disconnect Program Costs	
Estimated Program Cost per Downspout	$250
Estimated Downspouts Disconnected	1,545
TOTAL	**$386,000**

As stated earlier, the 15-year timeframe is used for planning purposes only to estimate potential long-term reductions in stormwater runoff to the CSS. Many assumptions have been made regarding the performance of this program that will need to be evaluated during the first six years of implementation. Therefore, while downspout disconnection is envisioned to be an important component to the Final CSO LTCP, MSD's long range commitment to this program will be based on the cost effectiveness of this technique in comparison to more traditional gray solutions.

Rain Barrel Program

Rain barrels are an effective way to educate the public about CSOs and provide an opportunity for homeowners to actively participate in the reduction of overflows. MSD currently has a rain barrel program in place, and has distributed rain barrels to over 350 residents within the MSD service area. The current program is being performed in partnership with Youth Build and the Louisville Nature Center. However, MSD will continue to explore other opportunities to increase overall distribution and use of rain barrels throughout the CSS area.



Rain barrels collect and store rainwater from the roof to use later for watering. Each barrel provides storage for 58 gallons of water.

Because MSD cannot control rain barrel use and maintenance, the potential reductions of stormwater runoff provided by rain barrels will not be included in the Final CSO LTCP, in terms of downsizing proposed gray controls. As the number of rain barrel installations increase, MSD may begin to realize volume reduction benefits of this program. If monitoring suggests a measurable decrease in the stormwater entering the CSS as a result of this program, MSD will re-evaluate how this program can be incorporated into the Final CSO LTCP. See Appendix 3.2.17 Rain Barrel Program Flow Chart for a program flowchart.

MSD's program will develop and distribute annual brochures to homeowners with rain barrel tips and information on proper operation and maintenance. In addition, MSD will continue to distribute marketing information and pamphlets, make presentations at public meetings, and use other techniques to encourage and educate homeowners throughout the community to participate in the rain barrel program.

For budgeting purposes, MSD assumes 1,000 rain barrels will be distributed annually. This will result in an annual program cost of approximately $165,000. See Table 3.2.5 for a more detailed breakdown of annual costs.

TABLE 3.2.5 RAIN BARREL PROGRAM COSTS

Annual Rain Barrel Program Costs	
Estimated Program Cost per Rain Barrel	$165
Estimated Rain Barrel Target	1,000
TOTAL	$165,000

Private Property Rain Garden Program

A residential rain garden program provides MSD with an opportunity to enhance the downspout disconnection program. By assisting homeowners with the proper redirection of downspouts to an appropriately sized rain garden, both MSD and homeowners benefit.

MSD has developed an educational manual, *A How-To Guide for Building Your Own Rain Garden*, to assist homeowners with the design and implementation of a residential rain garden. Interested homeowners are encouraged to contact MSD for information about installing a rain garden on their property. The residential rain garden program requires that homeowner's actively participate in the planning and construction phases. If desired by the homeowner, MSD staff will assist with plant selection, design calculations, and construction. Appendix 3.2.18 Residential Rain Garden Program Flowchart shows the MSD flowchart for program implementation.

Rain Garden on Harvard Street

Based on MSD's experience, the costs to construct residential rain gardens, including plants, range from $1,000 to $2,500. The actual costs are affected by the size of the garden and level of participation by the homeowner with construction and plant selection activities. For budgeting purposes, MSD assumes design and construction of 24 rain gardens per year.

TABLE 3.2.6

PRIVATE PROPERTY RAIN GARDEN PROGRAM COST

Annual Rain Garden Program Costs	
Estimated Program Cost per Rain Garden	$1,300
Estimated Rain Garden Installation Target	24
TOTAL	$31,000

Green Roof Incentive Program

Vegetated roofs, or green roofs, are vegetated areas that are designed as part of a roof system. While this technology has been used in Europe for many years, it is only in recent years that vegetated roof systems have become an accepted practice in the U. S. These systems can be utilized on commercial, industrial or residential roofs. Data from monitored vegetated roof systems indicate a significant reduction in annual runoff from these systems when compared to more traditional metal or asphalt roofs.

The following information, taken from the EPA fact sheet on green roofs (See Appendix 3.2.4) presents the results of a green roof performance study:

> *Penn State Green Roof Research Center has also noted a decrease in both total stormwater runoff and peak flow discharge. […] In this 1+ inch storm event, the green roofs captured approximately 25% of total runoff compared to the conventional roofs. Over the period from May 23, 2003 to June 1, 2003, 2.21 inches of rain fell, of which the green roof detained 1.05 inches (~47 %). The center noted that the spring of 2003 was wet and cool.*

A number of both public and private entities involved in new development and re-development activities in the MSD service area have been considering the installation of vegetated roofs. MSD has performed evaluations at a number of MSD owned buildings regarding the structural suitability of existing facilities to be retrofitted with vegetated roofs. MSD is committed to demonstrating this technology and an appropriate site will be identified to install a vegetated roof.

However, MSD recognizes the potential benefits that green roofs represent in terms of stormwater reductions to the CSS and has evaluated approaches to encourage or incentivize more widespread application of this technique throughout Louisville Metro. An evaluation of the potential benefits that MSD would realize from the installation of a green roof indicated that a square foot of a typical vegetated green roof ranges from $3.00 - $5.00 in equivalent “gray” CSO control.

A number of details associated with this program still need to be finalized. Issues such as design and performance standards, reimbursement levels for different types of vegetated systems, stormwater credits, plan review and approvals, inspections and maintenance issues still need to be finalized. However, MSD is committed to this program and has developed a budget for implementation.

MSD estimates that the average stormwater benefit for installation of a vegetated roof is $4 per square foot. For budgeting purposes, the following assumptions have been made:

- Ten percent of public buildings will install vegetated roofs (1.8 million sq ft)
- Two percent of commercial buildings will install vegetated roofs (504,000 sq ft)
- Two percent of industrial buildings will install vegetated roofs (753,000 sq ft)

TABLE 3.2.7

GREEN ROOF PROGRAM COSTS

Annual Green Roof Program Costs	
Estimated Program Cost per Square Foot of Green Roof	$4.00
Estimated Square Foot of Green Roof Installed	222,900
TOTAL	**$892,000**

Based on these assumptions, over three million sq. ft. of vegetated roofs will be constructed in Louisville Metro over the next 15 years. At an average of $4 per square foot, this equates to $13.4 Million.

As stated earlier, the 15-year timeframe is used for planning purposes only to estimate potential long-term reductions in stormwater runoff to the CSS. Many assumptions have been made regarding the performance of this program that will need to be evaluated during the first six years of implementation. Therefore, while a green roof incentive program is envisioned to be an important component to the Final CSO LTCP, MSD's long range commitment to this program will be based on the cost effectiveness of this technique in comparison to more traditional gray solutions.

Urban Reforestation Program

Urban reforestation is the practice of enhancing and restoring vegetative cover in urban areas. Trees provide natural control of stormwater runoff as well as other benefits such as improved air quality, increased wildlife habitat, and cooler temperatures.

A number of studies have been completed to evaluate the annual stormwater runoff reductions that a single urban tree can achieve. According to an article from *Stormwater: The Journal for Surface Water Quality Professionals:*

> *"Horticulturists note that trees' weekly water needs equal 5 gal. plus 5 gal. per caliper inch. For example, a 2-caliper-inch tree needs 15 gal. (5 + [5 x 2] = 15) weekly. This calculation, of course, is for minimum needs; many trees can take in more water."*

Based on this information, a 2-inch caliper tree would require at a minimum 780 gallons per year. According to the New York City (NYC) Department of Parks and Recreation, the average NYC tree captures 1,432 gallons of stormwater each year. Research published in June 2005 and conducted in the city of Minneapolis by the Center for Urban Forest Research indicated that a tree could soak up to 2,000 gallons annually.

An evaluation of the system-wide unit cost ($/gallon) of gray solutions determined the marginal unit cost of gray controls (based on the unit cost per gallon to go from eight to four overflows per year) is approximately $0.30 per gallon. Using $0.30 per gallon as a basis, MSD could justify spending up to $240/tree (medium sized) based on the reduction in stormwater entering the CSS. However, MSD is committed to this program and has developed a preliminary budget for implementation.

The cost of trees varies substantially depending on the size and type of tree and the location for the proposed planting. Section 3.2.5.5 suggested that existing canopy cover in the CSS be increased by approximately 2,000 acres. Assuming that a medium sized tree has a 20-foot canopy, approximately 139 trees would be required to provide an acre of canopy cover and 278,000 trees to achieve the recommended goal. MSD can play a subordinate yet important role in this effort.

Based on the estimated benefits that trees provide to MSD and the community, the Green Infrastructure Program recommends that MSD allocate funds annually to promote and enhance tree planting programs throughout the City. The program will include financial assistance to a variety of programs including sapling give-aways and cost sharing in urban streetscape programs.

Based on the results of this evaluation, MSD will explore opportunities to work with other public and private entities within the Louisville Metro area to increase the current tree canopy by at eight percent over the duration of the Consent Decree. See Table 3.2.8 for program costs.

TABLE 3.2.8

URBAN REFORESTATION PROGRAM COST

Annual Urban Reforestation Program Costs	
Estimated Program Cost per Tree	$240
Estimated Trees Planted	933
TOTAL	$224,000

Dry Wells

The geology of the west side of Louisville Metro – Zone 5 on the soil map (Appendix 3.2.6) – is suitable for deep infiltration techniques. The recommended green program suggest evaluating the feasibility of utilizing dry wells throughout this area as a mechanism to off load flow from street inlets into the subsurface. This approach has been successfully employed in other CSO communities, most notably in Portland, Oregon.

MSD owns approximately 18,000 inlets in Zone 5. For the purpose of estimating potential benefits from this program, assume that 50 percent of these street inlets will be directed to a dry well system. The estimation also assumes that each inlet has a drainage area of approximately 7,500 sq. ft. and that each dry well will receive flow from two existing inlet structures. If fully implemented, this program could remove 1.4 BG of stormwater from the CSS annually.

The most significant concern regarding dry wells is the potential challenge the permitting of these facilities presents. EPA Region 4 administers the Underground Injection Control Program in Kentucky. A dialogue needs to occur between EPA Region 4 and MSD to gain a better understanding of the extent of these requirements.

Because of the highly permeable soils present in the CSS area, MSD has elected to pursue the use of dry well technologies as part of the Final CSO LTCP. The purpose of the demonstration project is to evaluate the feasibility of permitting dry wells as a stormwater control technique and to obtain a better understanding of the cost implications of complying with the permitting requirements. Based on the results of the demonstration projects, MSD will determine if it is appropriate to include dry wells as a component of its regional green infrastructure Programs.

Dry well costs vary significantly based on type of construction, size, and depth. Dry wells installed in other communities with average diameters of four feet to six feet and average depths ranging from 15 feet – 25 feet have had costs of $15,000 to $40,000, including exploratory costs and engineering evaluation.

Because of the significant impact on stormwater flows that this program represents, MSD is committed to exploring the feasibility of this technique for LTCP compliance. However, until the permitting issues are resolved, MSD will not assume any benefits from this program in the context of the LTCP, and has not established program budget for dry wells.

3.2.5.11 Green Cost Tool

To ensure that the proposed Green Infrastructure Program is in fact cost effective, a green infrastructure cost/performance tool was developed. The two primary components of the MSD green plan include both programs and projects. Programmatic elements include such items as downspout disconnection and rain barrel distribution while the project components include items such as green streets and green alleys.

The differentiating factor between the two components is that programs will be implemented across large portions of the CSS area, while projects will be more localized and site specific. The green infrastructure cost/performance tool is a spreadsheet that computes costs and benefits (in terms of stormwater reduction) for both elements - programs and projects. This planning level tool integrates assumptions ranging from implementation levels, to costs, and stormwater reductions.

The purpose of the demonstration projects is to evaluate many of the assumptions that were used in the development of the cost tool. However, it is important to note that while MSD is committed to implementing an aggressive Green Infrastructure Program, MSD will direct appropriate resources toward those green components that are demonstrating the most benefit for the money invested. Therefore, the cost tool will likely be frequently updated to reflect actual cost and performance data and provide MSD with a mechanism to readily adjust program and project allocations in an effort to maximize the benefits achieved through implementation of the Green Infrastructure Program.

The components evaluated in the green cost tool include:

Programs

- downspout disconnection
- rain barrels
- vegetated roof
- urban reforestation

Projects

- green parking lots
- dry wells
- green streets
- green alleys
- biofiltration

For each component, the costing model considers a projected implementation rate and an estimated effectiveness. In some instances, for example downspout disconnection, these values are derived on a sewershed-specific basis and then summarized to produce an overall result.

For other components such as green alleys, benefits are derived by taking a standard performance value (gallons removed per year) and typical unit costs and applying these values to an estimated number of green alley projects expected to be constructed. This results in projected benefits of the program in terms of cost per gallon of stormwater removed on an annual basis.

This green cost tool allows MSD to compare proposed green infrastructure components to alternative gray controls by sewershed, or on a regional level. In situations where gray controls are relatively expensive, it may make sense to pursue more aggressively green controls. In other instances, green techniques may not be part of the recommended solution.

The results of the regional evaluation indicate that when implemented, the recommended green plan may remove nearly one BG of stormwater from the CSS at a cost of approximately $0.09/gallon to MSD. Preliminary assumed reductions in stormwater volume based on the use of green infrastructure were developed using the green costing tool developed as part of the business case evaluation, as previously discussed. This is different from the CSS hydraulic model which provides a more conservative estimate of the benefit of green because the model represents a continuous simulation and accounts for antecedent moisture conditions, infiltration limitations, and pervious connectivity to storm drains. Additionally, the CSS model is utilized to predict the effects of green infrastructure implementation on the AAOV for each CSO. This AAOV reduction does not match the stormwater reductions into the CSS due to attenuation and peak flow timing. This evaluation, which is intentionally conservative in terms of estimating green performance, reveals that green infrastructure can be a very cost competitive solution, with successful partnerships and cost sharing, when compared to more traditional gray controls. Based on this evaluation, MSD is committing to a green program with an annual budget in excess of $6 million/year, for the first six years. For a more detailed breakdown of the green plan, see Chapter 4, Section 4.1.2.1.

3.2.5.12 Integrating Green with Gray

The integration of the green infrastructure efforts and the gray infrastructure controls is a critical component of the successful implementation of Final CSO LTCP. Planned green controls were translated into an estimated reduction in impervious surface for each basin. Inputs to the collection system model will be revised to reflect these changes and the model will be run to determine the potential decrease in CSO activity and the corresponding reduction of proposed gray controls that may result from the implementation of green components. See Appendix 3.2.19: Green Infrastructure AAOV Impact Assessment and Modeling for details of the modeling approach used to estimate the overflow volume and frequency reduction. As the first sets of green infrastructure demonstration projects are built, the controls will be monitored and data on the effectiveness in reducing stormwater runoff will be generated and analyzed. Based on the results of the post construction monitoring of the green controls, MSD will re-evaluate and adjust the size of planned gray projects to provide the target level of CSO control.

Once MSD has selected a location for a green best management practice (BMP) and has identified and worked with potential partners, MSD will begin the design phase of the project. During the design phase, MSD and the project partner will establish an O&M agreement for the specific green control. After the project has been constructed, the location will be entered in MSD's Hansen tracking system. This will allow for data on the location, size, construction cost, and inspection results to be readily available in a GIS format.

Each green control will be inspected on a regular basis to gather information on performance and maintenance routines. System monitoring will be evaluated and the performance information will be used within the collection system model to perform typical year model simulations. The impacts of green infrastructure on AAOV and peak flow rates will be used to adjust the size of the planned gray projects. Figure 3.2.19, located at the end of this chapter, is an implementation diagram of the Green Infrastructure Program, inclusive of the process for constructing, inspecting, and monitoring a green project in order to assess impact on the size a gray control.

Additionally, MSD will use the schedule developed for the design and construction of gray projects to assist in targeting green demonstration projects. At this time MSD estimates that green demonstration projects will be constructed by December 2011. MSD will conduct performance monitoring and/or CSS modeling before any modification to the gray projects are recommended. Therefore, gray projects scheduled for implementation after this timeframe will be targeted as priority areas to implement green components in order to evaluate the possibility of resizing gray controls due to the impact of the green infrastructure.

3.2.5.13 Conclusion of Green Infrastructure Evaluation

MSD is one of the first CSO communities in the country to integrate a comprehensive green infrastructure initiative into the LTCP planning process. Over the past few years, MSD has demonstrated its commitment to green practices by implementing numerous pilot efforts such as the initial rain garden and rain barrel programs in an effort to reduce CSOs and to engage the community in understanding the importance of our water resources. With the completion of the comprehensive green plan, MSD has now established itself as a national leader in green infrastructure planning. MSD's approach to CSO compliance should serve as a valuable model to other agencies committed to achieving regulatory compliance while maximizing community benefits. The development of the green plan involved a systematic approach of reviewing available information, exploring potential opportunities and ultimately developing a comprehensive green vision for the community.

MSD has successfully enrolled key stakeholders throughout the community as partners committed to exploring aggressive implementation of green infrastructure initiatives. These stakeholders include Louisville Metro Government, University of Louisville, JCPS, and Louisville Housing Authority. Each entity owns considerable amounts of property within the combined system, has significant resources committed to capital improvement projects over the duration of the Consent Decree, and presents a valuable partner in implementation of green programs.

The review of local conditions, particularly soils and geology, had a significant impact on the development of the overall program. The CSS was divided into six zones based on subsurface conditions, each of which had specific recommendations for the types of green techniques that could be implemented. This approach reinforces the fact that Green Infrastructure Programs are site specific and need to be designed to accommodate local constraints in order to be successful.

Green infrastructure opportunities evaluations were performed at multiple levels including the site, the sewershed and the region. This approach led to the development of a well integrated regional vision for the community that will serve as a roadmap for a sustainable Louisville Metro. Successful implementation of this regional vision cannot be accomplished by MSD alone; everyone in the community has a role to play. Homeowners must disconnect downspouts and install rain barrels; public agencies must build green roofs, green streets and biofiltration systems in their parking lots; private developers must include green practices in their site designs; the school systems need to embrace green stormwater controls and incorporate them into the curricula; and MSD must lead by example.

The objective of the 19 demonstration projects is for MSD to build and monitor the variety of green techniques during the initial years of the Final CSO LTCP in order to develop and refine effective design standards and operation and maintenance information. MSD has participated in discussions with Sanitation District No. 1 of Northern Kentucky (SD1) and Clermont County Stormwater Management Department of Ohio, to partner on the development of a regional BMP manual. MSD, SD1, and Clermont County will work together over the next two years to develop and finalize a BMP manual for green infrastructure techniques, such as rain gardens, green roofs, porous pavements, reforestation, and rain barrels. The deadline for completion of the BMP manual is July 2011. In addition, MSD will use information gathered from the first several demonstration projects to refine specific design and construction standards, and operation and maintenance information for inclusion in future updates of the manual, to be revised by December 2012.

Operation and maintenance of green BMPs will be very site specific. As MSD partners with other Louisville Metro public agencies or entities , specific operation and maintenance agreements will be developed for each BMP. These agreements will establish the roles and responsibilities for both MSD and the partner for the specific BMP. As operation and maintenance techniques are refined, updates will be made to the BMP manual.

Within the first year following construction, MSD will develop an inspection and tracking program for green BMPs for evaluation. After the first year, the inspection results will be reviewed and the inspection cycle will be appropriately adjusted. MSD will also track the locations of these projects in Hansen. Information entered into Hansen may include BMP type, construction date, construction cost, ownership, BMP footprint if applicable, maintenance responsibilities, performance information, stormwater credit information, and inspection results. As new demonstration projects, partner opportunities, and private property programs are constructed and implemented the locations and information for the green controls will be added to Hansen on an annual basis. Using updated Hansen information, a GIS layer will be generated showing locations of green controls in the Louisville Metro area including; dry wells, downspout disconnects, rain barrels, green roofs, porous pavements, and rain gardens. MSD will utilize the information gathered from the initial demonstration projects to develop administrative tracking and inspection practices, triggers for maintenance, as well as specific maintenance procedures for the different types of green controls being implemented in Louisville.

In addition, over the next year, MSD will evaluate and review current regulations, for example the Land Development Code for Jefferson County, with the goal of promoting green infrastructure throughout the community. Recommendations for revisions to local regulations will be submitted to the appropriate agencies in order for green infrastructure to be made widely incorporated in the Louisville Metro area. However, it is important to understand that MSD can only make recommendations regarding revisions to ordinances, manuals and codes outside of its own jurisdiction and cannot commit to a date for adoption of said recommendations.

In summary, MSD has projected that a green plan can be a cost effective part of the Final CSO LTCP. Conservative estimates of the expected impact of this plan indicate that after full implementation of the recommended components, MSD will have potentially reduced stormwater runoff in CSS area in volumes by nearly one BG per year at a cost of $0.09/gallon, which is consistent with and in many instances significantly less than the costs to control overflows using more traditional gray techniques.

3.2.6 Definition of Water Quality and CSO Controls

The ultimate goal of the CSO Policy is to bring CSO communities into compliance with requirements of the Clean Water Act (CWA) (59 CFR 18688). This includes meeting the technology-based requirements (through NMC) and the water quality-based requirements through development of the Final CSO LTCP. MSD established initial CSO control goals based on a review of the recreational and aquatic life use impairments in Beargrass Creek and the Ohio River. The initial water quality and CSO control goals were established by evaluating the relative impact of CSOs on fecal coliform bacteria and dissolved oxygen with water quality models.

Beargrass Creek and the Ohio River are highly urbanized systems, which have been affected by hydromodifications such as construction of channels for flood control and locks and dams for navigation. Water quality modeling showed that attainment of the bacteria criteria in both water bodies, and dissolved oxygen criteria in Beargrass Creek, was not possible under all conditions even with complete elimination of CSOs. MSD programmatically decided to evaluate the Green Infrastructure Program and therefore evaluated a range of gray CSO control alternatives as defined in the CSO Policy (specifically zero, two, four, and eight overflows per typical year). These alternatives were then simulated with the water quality models to generate a knee of the curve for locations along the Ohio River and Beargrass Creek. The knee of the curve was used to determine where the increment of water quality benefit gained (in terms of compliance with the water quality criteria) diminishes compared to the increased costs, in accordance with the CSO Policy (59 CFR 18688). A description of knee of the curve is provided in Chapter 4.

The EPA recognizes that this analysis may result in a community establishing goals for CSO control where water quality standards are met with the exception of a few remaining overflow events (EPA, 1995, pgs. 3-21). In these instances, the CSO community needs to work with the regulatory agencies to identify mechanisms to reduce other pollutant sources, obtain a variance, partial use designation, or a revision to water quality standards as outlined in the CSO Policy. MSD intends to monitor the reduction in other sources as part of its post-construction compliance monitoring program. If necessary, MSD will work with ORSANCO and the Kentucky Department of Environmental Protection (KDEP) to provide that the Final CSO LTCP will conform to the CWA, either through identifying additional CSO control after implementation of the Final CSO LTCP or revision of the water quality standards or both.

3.2.7 Approaches to Structuring Cost Control Alternatives

The initial step in deriving gray infrastructure CSO control alternatives was to list location of CSOs (See Figure 3.2.20, located at the end of this chapter); identify viable technologies; determine single versus multiple CSO solutions; and assess siting issues.

MSD's CSS contains 106 CSOs discharging to four receiving waters:

- Ohio River
- Beargrass Creek Muddy Fork
- Beargrass Creek Middle Fork
- Beargrass Creek South Fork

Five CSO control technologies were initially considered, consisting of the following:

- Sewer Separation
- In-line Storage
- Off-line Storage (Figures 3.2.21 and 3.2.22, located at the end of the Chapter)
- Treatment (two processes, Figures 3.2.23 and 3.2.24, located at the end of the Chapter)
- Hybrid Technologies (RTC with storage; RTC with treatment, Figures 3.2.25, 3.2.26, and 3.2.27 located at the end of the Chapter)

During the development of project alternatives, a sixth technology, Pump Station Expansion, was added. As discussed in Section 3.1.2, initial CSO control alternatives were identified jointly by MSD and IOAP program consultants, taking under consideration factors such as regulatory compliance, implementability, operations and maintenance, public acceptance, etc. Typically using geographic criteria, CSO control projects were established either as individual or as groups, with numerous permutations of groupings, with multiple technologies to provide a broad array of projects for evaluation of the best CSO control solution for a given CSO/location.

The original project list provided 198 initial project alternatives. Due to an initial screening, the original list was reduced to 136 projects, distributed as shown in Table 3.2.9 across the various technologies.

TABLE 3.2.9

CSO CONTROL TECHNOLOGY ALTERNATIVES

Project Type	Project Identification Code (Used in the project tracking database)	Number of Projects Evaluated
Pump Station Expansion	03	1
Sewer Separation	08	49
Off-line Storage	09B	49
Treatment	10	17
Hybrid Technologies	13	20

Tables 3.2.10 through 3.2.14, located at the end of this chapter, list the initial 136 projects by receiving stream. Those projects which are highlighted indicate the preferred solution for the given watershed. These projects were later subject to further optimization.

The criteria for the initial screening included technology viability and performance, neighborhood impact, professional assessment of groupings, etc. An example of the initial project screening is in-line storage technology; this was deleted as a stand-alone solution as previous CSS capacity studies indicated this technology, alone, would not achieve goals set for CSS performance.

Appendices 3.2.22 through 3.2.26 list details of the following data associated with initial solutions:

- Appendix 3.2.22 Initial Project Fact Sheets
- Appendix 3.2.23 Initial Project Location Maps
- Appendix 3.2.24 Initial Project Cost Summary
- Appendix 3.2.25 Initial Project Benefit Summary
- Appendix 3.2.26 Initial Project Ground Truthing Documents

3.2.7.1 Projects Common to All Alternatives

Projects that are termed, "Common to All Alternatives" are those that have a system-wide impact. These include projects implemented under NMC, the Green Infrastructure Program, which provides source control/reduction (reducing CSO frequency and volume), the RTC Program, which is designed to maximize system storage, and Pump Station Expansion, which re-directs flow within the CSS to different watersheds. NMC and the Green Infrastructure Program are described extensively in other sections of the IOAP; RTC and the Pump Station projects will be discussed in following sections.

3.2.7.2 Outfall-Specific Solutions

Outfall-specific solutions are considered where multiple CSOs share a common outfall; where a CSO is remote and cost-prohibitive to convey to a CSO control group; or where the disruption caused by constructing conveyance (such as dense urbanization, heavy traffic corridor, etc.) is deemed too significant.

The MSD CSS includes several CSOs that fall under these categories. Several common outfalls convey discharge to the receiving stream from two-to-three individual CSOs. However, two major collectors/outfalls convey a significant number of CSOs: Sneads Branch Relief Drain, which collects discharge from 11 CSOs with a single discharge point to Beargrass Creek South Fork, and Central Relief Drain, which collects discharge from 22 CSOs into a common outfall to the Ohio River. Of the 136 projects evaluated, 83 were outfall-specific solutions.

3.2.7.3 Localized Consolidation of Outfalls

The geographic distribution of MSD CSOs provides excellent opportunity for consolidation of CSO controls, primarily in the Central Business District and the three Beargrass Creek Forks. Unfortunately, these regions are highly urbanized, limiting the number of available facility locations. Fifty-seven consolidated projects were evaluated during development of the Final CSO LTCP. The localized consolidations grouped from as few as three to as many as 32 CSOs into a single control location.

3.2.7.4 Regional Consolidation

The localized consolidation concept was expanded to an evaluation of two regional consolidation configurations. Both of these involved the use of a single CSO control technology, specifically large diameter off-line tunnels with an appropriately-sized dewatering pump station, to capture CSO for storage and subsequent conveyance to and treatment at the Morris Forman WQTC. The facilities included 35 CSOs in one configuration and the 106 CSOs in the second configuration.

3.2.7.5 Utilization of Morris Forman WQTC Capacity

The Final CSO LTCP evaluates off-line system storage with pump-back into the CSS as interceptor and treatment capacity becomes available following a wet weather event. As such, evaluation of the sustained wet weather treatment capacity of the CSS receiving treatment facility, Morris Forman WQTC, was warranted. Note that the Morris Forman WQTC is the only treatment facility in the MSD system that receives combined sewage.

MSD prepared a hydraulic model of the Morris Forman process train, and conducted process stress tests in October 2002. These tests are documented in a report from CH2M HILL dated March 23, 2003. The results of the hydraulic modeling and stress testing were used to prepare the "MFWTP - Wet Weather Standard Operating Procedure" dated May 25, 2004 and included in Appendix 3.2.20. This document includes the first version of a "capacity calculator" that is still used today, with minor modifications.

The calculator considers the number of process units available for use, from bar screens through chlorine contact basins. It also considers the depth of the sludge blankets in the primary sedimentation basins and the secondary clarifiers, since sludge blanket depth impacts the amount of flow that can be treated through the units without washing out solids.

With all process units on-line, and primary sedimentation basin and secondary clarifier sludge blankets at optimum levels, the peak flow capacity of the Morris Forman WQTC is 350 mgd. Attempting to take more than 350 mgd through the primary sedimentation basins will flood the effluent weirs and wash out solids regardless of blanket depth. If some treatment units are out of service, the peak capacity will be less, proportional to the capacity of the treatment units not in service.

Operating experience shows that the peak capacity of 350 mgd cannot be sustained for long periods of time without loss of process efficiency or washing out of solids. The maximum sustained capacity of the Morris Forman WQTC has been determined to be 325 mgd if all process units are in service and sludge blankets are at optimal levels.

While the peak hydraulic capacity of the plant is 350 mgd not all of that flow can pass through the secondary treatment process. With all units in service, and secondary clarifier sludge blankets at optimal level, the maximum capacity of the secondary treatment system is 140 mgd. The portions of the flow that do not receive secondary treatment do receive screening, grit removal, primary sedimentation, and disinfection.

In addition to evaluating the current capacity of the Morris Forman WQTC, MSD also conducted a study to evaluate the potential for plant expansion on the current site. This evaluation is documented in the “Morris Forman WWTP Expansion” Technical Memo, Appendix 3.2.21. The conclusion of this evaluation was that the existing site was fully developed, and constrained from expanding due to topography. The study evaluated satellite treatment at two nearby sites, and using two different treatment technologies. These evaluations are also included in the technical memorandum.

The result of these evaluations was the establishment of standard operating procedures (SOP) to maximize treatment at the Morris Forman WQTC, and confirmation that expansion of the treatment plant on the existing site is not practical. If additional treatment capacity is needed to achieve the objectives of the Final CSO LTCP, off-site satellite treatment will be necessary. A further discussion of treatment alternatives and evaluation is provided in Section 3.3.

3.2.7.6 Consideration of Sensitive and Priority Areas

EPA’s “Combined Sewer Overflows Guidance for Long-Term Control Plan” expects that a LTCP will give the highest priority to controlling overflows to sensitive areas, defined in other Chapters of Volume 2. According to the CSO Control Policy sensitive area criteria, all waters of the Ohio River through Jefferson County and all waters of Beargrass Creek within the CSS are categorized as sensitive areas.

As described in Chapter 1, Section 1.6.7.1 and Chapter 2, Section 2.8, a study was completed within the three Forks of Beargrass Creek to segment and rank stream reaches based on their ecological sensitivity. These results determined which reaches would realize greater benefit from water quality improvements and should be given higher priority consideration during the CSO control and implementation decision process. The results of this prioritization process and ecological reach ranking are not the sole determining factor; however, it is one of several variables integrated into the Final CSO LTCP CSO control projects selection process and implementation schedule discussed in detail in Chapter 4.

Individual stream segments have an ecological rating derived from the sum of its weighted parameter points, discussed in detail in Chapter 2.8. Stream segment scores and their priority rankings are shown in Table 3.2.15.

Of the 37 Beargrass Creek stream reaches within the CSS, priority designations include:

- 4 rated - Highest Priority
- 6 rated - High / Medium Priority
- 8 rated - Medium Priority
- 6 rated - Medium / Low Priority
- 13 rated - Lowest Priority

For a preferred control alternative, ratings for the individual CSO reaches involved in the project were summed and averaged. This numerical average score was assigned a priority level using the priority delineations discussed in Chapter 2.8 to give the project an appropriate ecological rating. Averaging reach scores versus summing reach scores reduces the bias that would be created by assuming ecological improvement potential is higher for projects that group a large number of CSOs into a single control. In the case of the MSD CSS, the highest priority projects, per summing ecological reach ratings, would be those overflowing into the concrete-lined improved channel of Beargrass Creek South Fork, shown in Figure 3.2.8. Of the 42 CSOs discharging into Beargrass Creek South Fork, 32 discharge to the concrete-lined improved channel. The ratings calculated by summing reach scores, would imply that there is potential for significant improvement in the concrete-lined channel, which is not the case.

FIGURE 3.2.8 LOW PRIORITY REACH (SOUTH FORK BEARGRASS CREEK CSO081 AND CSO118)

This resulting rating was used in conjunction with other selection criteria in order to determine the order of implementation of recommended projects. Other factors that affect the schedule include, but are not limited to, benefit-cost ratio, coordination with proposed development projects, site availability, costs, and cash flow.

TABLE 3.2.15
STREAM SEGMENT PRIORITY SCORES AND RATINGS

Reach Name	Accessibility	Threatened /Endangered Species or their Habit	Stream Rapid Bioassessment Protocol	Bank Erosion Hazard Index	Index of Biotic Integrity	CSO Average Annual Overflow Volume (AAOV)	Landuse	Land Cover	Restoration Potential	Reach Length	Score	Priority Rating Category
MI206	10	9	9	5	10	2	10	7	10	10	110	Highest
S109	4	4	9	7	10	7	10	10	8	10	102	Highest
S108	7	5	9	8	10	2	10	10	7	9	101	Highest
S018	5	4	9	6	10	8	10	10	7	8	100	Highest
S137	4	4	8	9	10	8	10	10	8	1	94	High/Medium
S097	7	5	8	10	10	2	7	7	8	6	93	High/Medium
S106	4	4	5	9	10	9	10	10	8	1	89	High/Medium
S081/088	6	4	10	7	1	10	8	8	8	10	87	High/Medium
MI126	9	5	3	4	5	9	10	10	10	4	82	High/Medium
MI144	6	5	7	4	5	8	5	5	9	9	80	High/Medium
MI127	9	5	7	3	5	3	5	8	10	7	79	Medium
MI166	9	5	3	7	5	3	10	7	10	7	79	Medium
MI125	9	5	4	4	5	3	10	9	10	3	76	Medium
S093	3	3	9	7	1	10	3	7	8	6	70	Medium
S130	3	3	10	7	1	5	1	7	8	5	64	Medium
S087/131	1	2	9	7	1	9	2	5	8	5	61	Medium
MI140	2	3	4	5	5	5	1	6	5	9	57	Medium
MI086	1	2	2	6	5	10	1	4	5	2	47	Medium
MU132/154/167	2	1	1	7	1	1	8	8	8	4	44	Medium/Low
S091	1	1	1	1	5	10	4	5	1	7	43	Medium/Low
S092	1	1	1	1	5	10	4	5	1	5	41	Medium/Low
S111/148	1	1	1	1	5	3	5	6	1	8	39	Medium/Low
S113	1	1	1	1	5	4	5	6	1	5	37	Medium/Low
S151	1	1	1	1	5	1	5	8	1	6	37	Medium/Low
S152	4	1	1	1	5	3	3	6	1	4	36	Lowest
S110	4	1	1	1	5	6	5	4	1	1	36	Lowest
S142	1	1	1	1	5	10	2	2	1	2	33	Lowest
S119	1	1	1	1	5	7	1	1	1	7	33	Lowest
S082	2	1	1	1	1	9	1	4	1	8	32	Lowest
S153	1	1	1	1	5	4	1	5	1	5	32	Lowest
S141	1	1	1	1	5	10	1	3	1	1	32	Lowest
S121	1	1	1	1	5	6	1	5	1	2	31	Lowest
S117/149/179	1	1	1	1	5	2	1	1	1	9	30	Lowest
S084	1	1	1	1	5	7	1	1	1	1	27	Lowest
S120	1	1	1	1	5	5	1	1	1	2	26	Lowest
S146/147	1	1	1	1	5	1	1	2	1	2	23	Lowest
S083/118	1	1	1	1	5	1	1	1	1	1	21	Lowest

Range:	95-130	Highest Priority
	80-94	High / Medium Priority
	46-79	Medium Priority
	37-45	Medium / Low Priority
	13-36	Lowest Priority

3.3 EVALUATION OF CSO CONTROL ALTERNATIVES

In this section, the process of designing and estimating costs for the initial CSO control alternatives presented in Section 3.2.7 is discussed. Furthermore, the methodology for selecting and optimizing control alternatives, including the preferred solutions, is presented. Figure 3.3.1, summarizes the CSO controls alternative process.

FIGURE 3.3.1 CSO CONTROL ALTERNATIVE PROCESS

3.3.1 CSO Controls Sizing and Conceptual Design

The initial step in developing CSO control projects was determination of CSO frequency, flow rate, and volume. As discussed in Chapter 2.4, Jefferson County, Kentucky 2001 rainfall data was established as the yearly rainfall data to be used for sizing. A series of InfoWorks CS model runs were performed under varying CSS configurations, applying the 2001 rainfall data modes. The eventual CSS model conditions for sizing gray infrastructure alternatives were defined to include the following:

- Green Infrastructure Program build-out
- RTC program implementation
- Flow re-direction from Beargrass Creek South Fork watershed to the Ohio River watershed
- Reduced inflow contribution from the separate sewer system based on flow re-direction projects planned for the sanitary sewer system

The CSS hydraulic model output produced a list that included the number of overflows predicted for each CSO in the CSS for the 2001 annual rainfall. Each overflow or event was defined by volume, flow rate, and duration. This data was then used to size conveyance and volume required to achieve a performance goal. The performance goal or target for the initial suite of 136 projects was set at a level of four overflows per year, per the presumptive approach. Per this goal, the conveyance rate design basis was set at the fifth highest flow rate, providing that only the four higher flows would exceed the hydraulic capacity of the collection system and associated overflow control. Likewise, the volumetric design basis was set at the fifth highest overflow volume, providing capture of overflows that are lesser in volume than the largest four events. Note that the conveyance rate and volumetric design parameters are independent since model results indicated different storms produced overflow volumes and rates that are precipitation simulation-driven, not event-driven. Thus, the fifth highest overflow may not necessarily occur at the fifth highest conveyance rate.

For conceptual design of sewer separation projects, pipe diameters were set equal to the diameter of the existing combined conveyance pipe. For nearly all separation projects, a new stormwater system, or modifications to the existing system for conversion to stormwater only, was considered. Of 49 sewer separation projects evaluated, 44 were storm sewers only, two were sanitary only, and three were a mix of systems.

In executing conceptual design of the storage and treatment projects, the Project Cost Estimating Document, MSD's Design Manual, MSD Record Drawings, LOJIC and GIS data were the primary guides and data sources. Conveyance piping was sized using the minimum pipe slope set by MSD guidelines. Basin storage depths were set at 15 feet, with an additional two feet freeboard, in an effort to minimize excavation costs. However, to offset the cost of large pump stations required by the high flow rates predicted by the model, basins were typically set at a depth that allowed gravity in – pump out operation (24-hour return for conceptual sizing), resulting in some basins to be up to 40~50 feet below grade. It is expected that pump station sizing and basin depth will be optimized as part of the final design process.

In regard to the regional storage facilities (tunnels) considered, two configurations, the Ohio River drainage basin, as depicted in Figure 3.3.2 and the entire CSS as depicted in Figure 3.3.3, that are located at the end of the chapter are inclusive of the Ohio River and Beargrass Creek drainage basins, were conceptually laid out. The Ohio River facility encompassed 35 CSOs and the CSS facility encompassed all 106 CSOs. Both configurations envisioned storage per the CSO controls sizing parameters discussed above, and included 48-hour pump-back stations. The average depth of each facility was assumed to be 100 feet. As such, a "mixed face" was assumed, versus a rock face, based on anecdotal information as to subsurface soil conditions along the proposed alignment.

As discussed in Section 3.2.7, satellite treatment considered two treatment processes: ballasted flocculation and retention treatment basin. The criterion for selection of treatment was the modeled treatment rate; five mgd for ballasted flocculation and 0.5 mgd for retention treatment basin. Of the 17 treatment plants evaluated, seven were ballasted flocculation and 10 were retention treatment basin.

The RTC program has been under consideration by MSD since 1999. Several inflatable dams are in operation to maximize storage in the Southwest Outfall and Sneads Branch Relief Drain. However, no RTC project alone is predicted by the model to provide sufficient storage to achieve the CSO target of four overflows per year. Hybrid projects are RTC projects paired with either storage or treatment, to take advantage of maximum in-line storage, thus reducing the size of the CSO control. Of the 20 hybrid technology projects evaluated, 19 were RTC-storage and one was RTC-treatment.

Also inclusive of the design process was identification of potential sites for construction of control alternatives. Most alternatives considered more than one location. In order to evaluate the feasibility of a site, a ground-truthing exercise was performed. This exercise reviewed the following parameters:

- Property Use Classification
- Utility Conflicts
- Site Constructability
- Adjacent Transportation Corridors
- Adjacent Property Use Classification

3.3.2 Project Costs

The Project Cost Estimating Document was utilized to determine estimated costs for CSO control alternatives. The tool served to generate consistent conceptual/planning level costs for technology solutions being analyzed for each respective scenario. The costing platform (data workbook) utilized by the tool to generate these planning level costs was built from a database of costing and construction data compiled from a variety of sources associated with similar construction projects. The tool also institutes planning level contingencies for the uncertainties encountered with each respective project. The planning level costs generated by the tool may vary +50 percent to -30 percent from a detailed cost for a specific project. As such, the main focus of the tool is to compare (not develop) planning level estimates for the projects being evaluated while taking into account each site's individual constraints.

The tool is used to evaluate a multitude of project approaches/technologies that could be utilized for addressing CSO controls. Specific to this Final CSO LTCP, these approaches/technologies are as follows:

- Flow Redirection
- RTC Flow Control
- Sewer Separation
- Storage
- Satellite Treatment

The tool is populated with individual construction costing modules/worksheets that correspond to the construction aspects that are relative to each of the above overflow reduction approaches/technologies. The costing modules/worksheets incorporated with the tool cover:

- Conveyance/In-line Storage – planning level cost development for open-cut, auger bored, micro-tunneled, or open-faced tunnel-boring machine sewers.
- Pump Stations – planning level cost development for pump stations with below ground wet wells, bar screens, a super structure, submersible pumps, piping, controls, and a backup generator.
- Force Mains – planning level cost development for the trench installation of ductile iron force mains utilizing the same costing methodology as open-cut sewers.
- Flow Control – planning level cost development for the installation of either inflatable dams (in pipeline or channels) or an RTC adjustable sluice gate.
- Off-line Storage – planning level cost development either covered or uncovered storage, concrete or earthen structure, with facilities consisting of a diversion structure, grit pit, coarse screening, flushing, instrumentation, standby generator, sump pumps and tankage.
- Satellite Treatment – planning level cost development for either ballasted flocculation or retention treatment basin facilities, including screening and disinfection.

These modules also have parameters associated with them that consider the constraints and conditions of the respective project site / tract being evaluated.

In addition, the tool also possesses ancillary costing modules that generate additional non-construction costs that include: program management costs, administration costs, real estate costs, contingency costs, engineering and inspection costs, planning and preliminary design costs, design services costs, interest costs, and costs for performance bonds.

3.3.3 Performance

The performance of CSO controls is difficult to predict precisely. As noted in earlier sections of this chapter, the target goal for the initial control alternatives was four overflows per year, which established the sizing of control projects. Different technologies provide different water quality outcomes even as they eliminate or reduce CSO overflow volume and frequency. Future conditions or regulations may require a higher level of CSO control than is provided for in this Final CSO LTCP. Higher levels of control may be obtained through expansion of existing controls (where space allows), addition of facilities such as supplemental storage in other locations, or retrofitting modifications to existing facilities (such as making process additions, for example, coagulant addition and disinfection to convert storage basins to discharging equivalent primary treatment under some flow conditions). Other opportunities to modify the level of CSO controls may include enhancement or expansion of the Green Infrastructure Program should monitoring indicate cost-effective source runoff reduction.

The five technologies evaluated, listed in Section 3.2.7, include the following:

- Pump Station Expansion
- Sewer Separation
- Off-line Storage
- Treatment
- Hybrid Technologies

Sewer separation, which separates sanitary sewage and stormwater into distinct, respective piping systems, can potentially result in continued discharge of poor water quality to a receiving stream (depending on pollutant load). In applying the benefit tool described in Section 3.1.2.2, this potential is factored into project scoring by assigning no improvement to the public health value, although technically the CSO overflow/volume is eliminated by sewer separation.

Reduction of CSO to a receiving stream by utilizing off-line storage can have a wide range of volumetric performance based on the hydraulic characteristics of the CSS. The percent capture is dependent on the distribution of the overflow event volumes; the remaining overflows of the preferred performance level (zero-12 overflows per year) could comprise a significant portion of the annual overflow volume generated by a respective CSO or group of CSOs. The project technologies and associated level of CSO control recommended, discussed in Chapter 4, are eventually input into the CSS model to determine system-wide CSO capture.

The two high rate physical-chemical treatment equivalent primary technologies evaluated, retention treatment basin (and ballasted flocculation produce different levels of effluent water quality. Retention treatment facilities are essentially settling basins with enhanced settling created by chemical (coagulant) addition. Settling is followed by addition of disinfectant, typically chlorine, followed by a de-chlorination agent. Overflow rates are typically several thousand gallons per day per square foot (gpd/sq ft), allowing the facility footprint to be minimal compared to conventional treatment. Treatment is only initiated once the volume of the basin is exceeded; otherwise the stored sewer overflow is pumped back to the CSS once capacity is available following the wet weather event.

Ballasted flocculation is a higher level of treatment than retention treatment basin, primarily resulting from higher clarification performance. Higher mixing energies, coupled with a ballasted settling material (for example, microsand) and significantly higher surface overflow rates (several orders of magnitude higher) result in higher quality effluent. Similar to retention treatment basin, chlorination-dechlorination is applied to reduce pathogen counts to within regulatory limits. UV or oxidants may also be used for pathogen inactivation. Due to operating requirements, and unlike retention treatment basin, a storage basin is added at the head of the plant to allow operator travel time and plant start-up. Also similar to retention treatment basin, treatment is only initiated once the volume of the tank is exceeded; otherwise the stored overflow is pumped back to the CSS.

Capital costs for construction of the treatment facilities (excluding pump stations and tanks) vary significantly: approximately $0.13 - $0.15 per gallon of treatment rate for retention treatment basin vs. approximately $0.45 - $0.50 per gallon for of ballasted flocculation treatment rate. Ballasted flocculation costs would actually be higher because a storage tank is required at the head of the facility. Operating costs, such as chemicals, power, maintenance, etc., are similarly higher for retention treatment basin vs. ballasted flocculation: $0.007 per gallon vs. $0.019 per gallon.

The treatment facility surface overflow design rates of 6,000 gpd/sq ft and 60 gpm/sq ft for retention treatment basin and ballasted flocculation respectively (per the Project Cost Estimating Document) will reduce pollutants and pathogen counts to the levels found in Table 3.3.1.

TABLE 3.3.1

SATELLITE TREATMENT PERFORMANCE

Parameter/Treatment Process	Ballasted Flocculation	Retention Treatment Basin
Total Suspended Solids (TSS)	80%-95% removal	50% removal
Biochemical Oxygen Demand (BOD)	60%-80% removal	30% removal
Pathogen Count	126 E. Coli/100 ml	126 E. Coli/100 ml

It is important to note that the CSO Control Policy permits treatment of CSO discharge to the following minimum levels of treatment:

- Primary clarification
- Solids and floatable removal and disposal
- Disinfection and removal of disinfectant residuals

The conceptual design elements and criteria of both processes listed above comply with these requirements. Whereas ballasted flocculation treatment exceeds the requirements dictated by the CSO Control Policy (hence the higher costs), retention treatment complies with the stated minimum requirements.

Performances of hybrid technologies are dependent on the types of systems merged into the control facility(s). The majority of hybrid projects evaluated were RTC with off-line storage, therefore performance of these controls would mirror that of off-line storage: determined by hydraulics of the respective CSOs. Where RTC is paired with treatment, the effluent quality of the treatment selected would determine the impact to the receiving stream.

The Pump Station Expansion project is utilized to re-direct flow within the CSS; the controls installed in the receiving sewershed will determine the performance of CSO control applied to that diverted volume of combined sewage.

3.3.4 Cost/Performance Evaluations

The benefit-cost ratio data generated by the benefit scoring and conceptual/planning-level cost estimates of the initial project list of 136 control alternatives was ultimately screened to a group of 19 preferred CSO control projects that were modeled to achieve the initial target overflow goal of four per year. While benefit-cost evaluations were the primary method to determine alternative selection, it was not the only factor considered in the decision process. Operational considerations, primarily the conveyance and treatment capacity available to empty the in-line and off-line storage basins, plus ecological reach ratings, described in Section 3.2.7.6, were also taken into consideration. As a result, two projects that were not the best-ranked benefit-cost ratio were recommended for the next step in the process (level of control optimization): one satellite treatment project, and one pump station expansion project.

Following the preliminary recommendation preferred of CSO control projects to MSD and the WWT, the preferred CSO control projects were subject to an optimization process level of control performance of zero, two, and eight overflows per year, to complement the initial performance sizing of four overflows per year. The benefit-cost calculations were also developed for the zero, two, and eight overflows per year, with the optimal benefit-cost ratio level of control recommended in the Final CSO LTCP.

This set of data for the various level of control projects was then plotted against performance targets to develop knee of the curve graphs. The graphs presented to the WWT included the following:

- Cost versus wet weather capture percentage
- Wet weather capture versus fecal coliform model predictions for both Ohio River and Beargrass Creek watersheds

The outcome of these CSO control project recommendations are presented in Chapter 4.

3.3.5 Rating and Ranking of Alternatives

At the completion of this evaluation process, the CSO projects were ranked by benefit-cost ratio. Outfall-specific solutions with one technology were compared technology versus technology. Localized consolidation projects grouped different combinations of CSOs in different geographic locations with competing control technologies. Typically, projects were selected by the highest benefit-cost ratio. Exceptions were made on ease of implementation per geographic requirements (available land area). In addition, CSS operation improvement opportunities, (basically reduction in pumping, or the need to add wet weather treatment capacity to the system) were included in the decision process.

Specific to Beargrass Creek South Fork, as a result of the significant number of CSOs (42), 34 permutations of CSO projects were evaluated. In addition, projects that were obvious geographic groupings were considered (see Figure 3.3.4, located at the end of this Chapter). Table 3.3.2 (also located at the end of this chapter), is a matrix comparing CSOs versus alternative-specific benefit-cost ratios which assisted in selection of the best localized consolidation project. This matrix served as a tool that could be used with other variables, primarily limited geographic sites to select a preferred alternative. The objective was to compare the benefit-cost ratios for the various clustered projects against obvious geographic clustering for any fatal flaw.

Following selection of preferred alternatives (the highlighted projects on Table 3.3.2); modifications to the operation of the CSS in the upper reach of Beargrass Creek South Fork were evaluated by MSD. This resulted in modifying the selected project, L_SO_MF_097_M_09B_B_D, shown on Figure 3.3.5 located at the end of this Chapter. These modifications include upgrading a pump station to divert flow from the Beargrass Creek South Fork watershed to the Ohio River watershed. This resulted in two CSOs (CSO018 and CSO108) from the original consolidated solution to become outfall specific solutions, shown on Figure 3.3.6 at the end of this Chapter. In addition, the overflow frequency of one CSO (CSO109) was reduced to two overflows per year, within the presumptive approach of no more than four overflows per year.

TABLE 3.1.1
CONTROL TECHNOLOGIES BY CSO

CSO No.	CSO Name	Receiving Stream	Drainage Area (ac.)	Sewer Separation	Off-Line Storage	In-Line Storage	Flow Control	Flow Diversion	Ballasted Flocculation Treatment	Retention Treatment Basin	Hybrid
CSO015	SOUTHWESTERN PS	OR	7,441.3		X	X	X		X	X	
CSO016	MILES PARK BYPASS	OR	0.0		X				X	X	
CSO018	NIGHTINGALE PS	BGCSF	0.0						X	X	
CSO019	34th STREET PS	OR	1,192.4		X	X			X	X	
CSO020	BUCHANAN PS	OR	86.6				X				
CSO022	FOURTH ST PS	OR	95.2		X					X	
CSO023	ORI @ 4th ST PS	OR	--		X					X	
CSO026	CRD 6th & BROADWAY	OR	8.4	X	X	X				X	
CSO027	CRD 7th & BROADWAY	OR	10.1	X	X	X				X	
CSO028	CRD 6th & YORK	OR	6.1	X	X	X				X	
CSO029	CRD 8th & YORK	OR	0.0	X	X	X				X	
CSO030	CRD 9th & YORK "A"	OR	Eliminated								
CSO031	CRD 6th & BRECKINRIDGE	OR	3.8	X	X	X				X	
CSO032	CRD 4th & BRECKINRIDGE	OR	Eliminated								
CSO033	CRD ON YORK E OF 4th	OR	Eliminated								
CSO034	CRD 4th & YORK	OR	5.1	X	X	X				X	
CSO035	CRD 2nd & BROADWAY NO 1	OR	0.0	X	X	X				X	
CSO036	CRD 3rd & BROADWAY	OR	20.0	X	X	X				X	
CSO038	CRD 5th & BROADWAY	OR	9.5	X	X	X				X	
CSO049-SM	PRESTON ST	OR	Eliminated								
CSO050	12th STREET	OR	36.3	X	X						
CSO051	11th STREET	OR	6.3	X	X						

TABLE 3.1.1
CONTROL TECHNOLOGIES BY CSO

CSO No.	CSO Name	Receiving Stream	Drainage Area (ac.)	Sewer Separation	Off-Line Storage	In-Line Storage	Flow Control	Flow Diversion	Ballasted Flocculation Treatment	Retention Treatment Basin	Hybrid
CSO052	10th STREET	OR	8.7	X	X						
CSO053	8th STREET	OR	34.1	X							
CSO054	7th STREET	OR	7.1	X	X						
CSO055	6th STREET	OR	18.0	X	X						
CSO056	5th STREET	OR	22.0	X	X						
CSO057	FIRST STREET OVERFLOW WEIR	OR	--		X						
CSO058	PRESTON ST OVERFLOW WEIR	OR	105.4	X	X						
CSO062	LOGAN COMPANY	OR	--				X				
CSO065	LAMPTON ST	BGCSF	Eliminated								
CSO080	PAYNE ST	BGCMF	Eliminated								
CSO081	LETTERLE	BGCSF	Eliminated								
CSO082	BGI AT BGC	BGCSF	16.0		X			X	X	X	
CSO083	BRENT ST & BROADWAY CONNECT	BGCSF	45.7		X			X	X	X	
CSO084	BRENT ST @ BGC	BGCSF	125.1		X				X	X	
CSO086	PAYNE AT SPRING	BGCMF	6.1	X	X					X	
CSO087	BLUEHORSE	BGCSF	Eliminated								
CSO088	MELLWOOD AVE INT	BGCSF									
CSO091	SCHILLER AVE OVERFLOW	BGCSF	15.0	X				X	X	X	
CSO092	ST CATHERINE @ BGC	BGCSF	7.7	X	X			X	X	X	
CSO093	SPRING STREET	BGCSF	20.8	X							
CSO097	CANTONMENT SIPHON NO 2	BGCSF	--		X				X	X	
CSO104	SW PKWY SEWER @ BROADWAY	OR	62.0		X	X	X		X	X	

TABLE 3.1.1
CONTROL TECHNOLOGIES BY CSO

CSO No.	CSO Name	Receiving Stream	Drainage Area (ac.)	Sewer Separation	Off-Line Storage	In-Line Storage	Flow Control	Flow Diversion	Ballasted Flocculation Treatment	Retention Treatment Basin	Hybrid
CSO105	WESTERN OUTFALL @ BROADWAY	OR	1,893.0		X	X	X		X	X	
CSO106	ROYAL - NEFF	BGCSF	11.8	X	X				X	X	
CSO108	REG N0 1 - NEWBURG	BGCSF	485.2		X	X				X	
CSO109	REG NO 2 - DEER PARK	BGCSF	95.4		X				X	X	
CSO110	REG NO 3 - GOSS AVE	BGCSF	73.0		X			X	X	X	
CSO111	EMERSON STREET SEWER	BGCSF	99.4		X			X	X	X	
CSO113	ELLISON AVENUE SEWER	BGCSF	67.6		X			X	X	X	
CSO117	REG NO 11 - DRY RUN	BGCSF	74.2		X	X		X	X	X	
CSO118	REG NO 15 - E BROADWAY	BGCSF	354.1		X	X		X	X	X	
CSO119	BRENT STREET SEWER	BGCSF	--		X			X	X	X	
CSO120	PHOENIX HILL SEWER	BGCSF	7.7	X	X			X	X	X	
CSO121	REG NO 18 - GREEN ST	BGCSF	107.2		X			X	X	X	
CSO123	REG NO 20 – RUTH-SLUGRV	BGCMF	Eliminated								
CSO125	REG NO 24 - GRINSTEAD DR	BGCMF	391.0		X					X	X
CSO126	REG NO 26 - RAYMOND AVE	BGCMF	35.3		X					X	X
CSO127	ETLEY AVENUE	BGCMF	192.3		X					X	X
CSO130	WEBSTER STREET	BGCSF	28.4	X	X						
CSO131	REG NO 33 - MELLWOOD & FRANKFORT	BGCSF	50.3	X							
CSO132	REG NO 35 - BROWNSBORO	BGCMF	674.0		X	X			X	X	
CSO137	CALVARY CEMETERY	BGCSF	26.7		X				X	X	
CSO140	LOCUST STREET	BGCMF	75.5	X	X					X	
CSO141	BAXTER AVE @ BGC	BGCSF	16.5	X	X			X	X	X	

TABLE 3.1.1
CONTROL TECHNOLOGIES BY CSO

CSO No.	CSO Name	Receiving Stream	Drainage Area (ac.)	Sewer Separation	Off-Line Storage	In-Line Storage	Flow Control	Flow Diversion	Ballasted Flocculation Treatment	Retention Treatment Basin	Hybrid
CSO142	SBR LOGAN ST @ ST CATHERINE	BGCSF	0.0		X				X	X	
CSO144	VANCE ST REGULATOR	BGCMF	16.4	X	X					X	X
CSO145	POINT PUMP STATION	BGCSF	Eliminated								
CSO146	SNEADS BRANCH DIVERSION	BGCSF	724.6		X			X	X	X	
CSO147	SWAN STREET DIVERSION	BGCSF	Eliminated								
CSO148	EASTERN PKWY DIVERSION	BGCSF	24.9		X			X	X	X	
CSO149	DRY RUN DIVERSION	BGCSF	225.8		X			X	X	X	
CSO150	8th ST @ COMMON PLACE	OR	1.8	X	X						
CSO151	REG NO 5 - CASTLEWOOD	BGCSF	232.5		X			X	X	X	
CSO152	REG NO 7 - SOUTHEASTERN	BGCSF	260.6		X			X	X	X	
CSO153	COOPER STREET	BGCSF	41.7		X			X	X	X	
CSO154	MELLWOOD @ SCHOEFFEL	BGCMU	31.0		X				X	X	
CSO155	ROWAN ST @ 12th ST	OR	11.9	X	X						
CSO156	6th & WASHINGTON SAN DIV	OR	--	X	X						
CSO160	SEWER IN ALLEY SAN DIV	OR	2.0	X	X						
CSO161	MARKET ST SAN DIV	OR	2.5	X	X						
CSO162	BEALS BRANCH HW REG	BGCMF	Eliminated								
CSO166	BEALS BRANCH SAN DIV	BGCMF	681.1		X	X				X	X
CSO167	BROWNSBORO LAT NO 2	BGCMF	11.0		X				X	X	
CSO172	ADAMS STREET	OR	13.7	X	X				X	X	
CSO174	SBR GOSS & BOYLE	BGCSF	169.6		X	X			X	X	
CSO178	CRD 9th & YORK "B"	OR	29.7	X	X	X				X	

TABLE 3.1.1
CONTROL TECHNOLOGIES BY CSO

CSO No.	CSO Name	Receiving Stream	Drainage Area (ac.)	Sewer Separation	Off-Line Storage	In-Line Storage	Flow Control	Flow Diversion	Ballasted Flocculation Treatment	Retention Treatment Basin	Hybrid
CSO179	KENTUCKY ST SEWER OVERFLOW	BGCSF	461.8		X	X		X	X	X	
CSO180	SBR ORMSBY AVE RELIEF	BGCSF	2.8		X					X	
CSO181	CRD 2nd & BROADWAY NO 2	OR	22.6	X	X	X				X	
CSO182	SBR SHELBY & BURNETT	BGCSF	147.3		X				X	X	
CSO183	SBR ALEXANDER & KESWICK	BGCSF	3.2		X				X	X	
CSO184	SBR FETTER & ALEXANDER	BGCSF	109.3		X				X	X	
CSO185	SBR SHELBY & KESWICK	BGCSF	145.8		X				X	X	
CSO186	SBR LOGAN & OAK	BGCSF	0.0		X				X	X	
CSO187	SBR SHELBY & CAMP	BGCSF	5.2		X				X	X	
CSO188	SBR SHELBY & CLAY	BGCSF	14.7		X				X	X	
CSO189	NORTHWESTERN SAN DIV	OR	1,148.7		X	X	X		X	X	
CSO190	SEVENTEENTH ST SAN DIV	OR	145.4		X					X	
CSO191	ALGONQUIN PKWY SAN DIV	OR	339.8		X	X			X	X	
CSO192	CRD S 6th & GARLAND	OR	9.0	X	X	X				X	
CSO193	CRD S 6th & KENTUCKY	OR	22.7	X	X	X				X	
CSO194	CRD S OAK W of 4th	OR	Eliminated								
CSO195	CRD S 4th & OAK	OR	7.3	X	X	X				X	
CSO196	CRD S 3rd & OAK	OR	--	X	X	X				X	
CSO197	CRD S 3rd S OF OAK	OR	--	X	X	X				X	
CSO198	CRD S 3rd & ORMSBY	OR	13.0	X	X	X				X	
CSO199	CRD S 3rd N OF MAGNOLIA	OR	--	X	X	X				X	
CSO200	CRD S 3rd & MAGNOLIA	OR	10.3	X	X	X				X	

TABLE 3.1.1
CONTROL TECHNOLOGIES BY CSO

CSO No.	CSO Name	Receiving Stream	Drainage Area (ac.)	Sewer Separation	Off-Line Storage	In-Line Storage	Flow Control	Flow Diversion	Ballasted Flocculation Treatment	Retention Treatment Basin	Hybrid
CSO201	CRD S 5th & KENTUCKY	OR	--	X	X	X				X	
CSO202	CRD S ORMSBY W of 3rd	OR	5.32	X	X					X	
CSO203	CRD S 4th & ORMSBY	OR	14.2	X	X	X				X	
CSO204	CRD S 5th & BRECKINRIDGE	OR	Eliminated								
CSO205	SBR MORGAN STREET RELIEF	BGCSF	9.5		X				X	X	
CSO206	CHEROKEE PARK @ SPRING DR	BGCMF	Being Separated								
CSO207	2nd & JEFFERSON	OR	2.5								
CSO208	12th & JEFFERSON	OR	11.2	X	X						
CSO209	CHEROKEE PARK @ PARK BD RD	BGCMF	Eliminated								
CSO210	45th STREET-GREENWOOD	OR	166.7		X				X	X	
CSO211	MAIN DIVERSION STRUCTURE	OR	3,620.3		X		X		X	X	

Legend: BGCMU – Beargrass Creek Muddy Fork; BGCMI - Beargrass Creek Middle Fork; BGCSF - Beargrass Creek South Fork; OR – Ohio River; CRD-Central Relief Drain; SBR-Sneads Branch Relief; BGI - Beargrass Interceptor;

TABLE 3.2.10

BEARGRASS CREEK MUDDY FORK (BGCMU) INITIAL SOLUTIONS

Project ID	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_MU_MF_154_M_09B_B_A	**Off-Line Storage**	CSO132, CSO154, CSO167	This project includes a 7.95 MG underground covered storage basin for CSOs 132, 154 and 167. The facility will require a 7.95 mgd PS to return the stored flow back to the interceptor.	24.36
L_MU_MF_154_S_09B_B_A	**Off-Line Storage**	CSO154	This project includes a 0.17 MG underground covered storage basin for CSO 154. The facility will require a 0.17 mgd PS to return the stored flow to the interceptor.	45.73
L_MU_MF_154_M_13_B_A	**RTC with Storage**	CSO132, CSO154, CSO167	This project includes a 7.45 MG underground covered storage basin for CSOs 132, 154 and 167. The facility requires a 7.45 mgd PS to return stored flow back to interceptor and a 0.5 MG RTC in-line storage using an inflatable gate in the Brownsboro Road Trunk Sewer.	21.56
L_MU_MF_132_M_09B_B_A	**Off-Line Storage**	CSO132, CSO167	This project includes a 7.78 MG underground covered storage basin for CSOs 132 and 167. The facility will require a 7.78 mgd PS to return the stored flow back to the interceptor.	20.38
L_MU_MF_132_M_13_B_A	**RTC with Storage**	CSO132, CSO167	This project includes a 7.19 MG underground covered storage basin for CSOs 132 and 167. The facility will require a 7.19 mgd PS to return stored flow back to interceptor and a 0.5 MG RTC in-line storage using an inflatable gate in the Brownsboro Road Trunk Sewer.	18.17
L_MU_MF_154_M_10_B_A	**Treatment Facility**	CSO132, CSO154, CSO167	This project is to provide a 81 mgd RTB High Rate Treatment Facility for CSOs 132, 154 and 167. Annual volume stored is approximately 153 MG, operated 58 times per year.	17.19
L_MU_MF_132_M_10_B_A	**Treatment Facility**	CSO132, CSO167	This project is to provide a 78 mgd RTB High Rate Treatment Facility for CSO 132 and 167. Annual volume stored is approximately 58 MG, operated 58 times per year.	14.85

Legend: ILS- In-Line Storage; LF- Linear Feet, RTB –Retention Treatment Basin,
Selected Projects are in Yellow

TABLE 3.2.11

BEARGRASS CREEK MIDDLE FORK (BGCMI) INITIAL SOLUTIONS

Project ID	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_MI_MF_127_M_09B_B_A	**Off-Line Storage**	CSO125, CSO126, CSO127, CSO166	This project is to provide a 4.13 off-line storage facility consisting of a covered concrete basin for CSOs 125, 126, 127 & 166. Annual volume stored is approximately 59.79 MG, operated 54 times per year.	40.63
L_MI_MF_144_M_09B_B_A	**Off-Line Storage**	CSO125, CSO126, CSO127, CSO144, CSO166	This project is to provide a 4.13 off-line storage facility consisting of a small uncovered concrete basin followed by a large earthen storage basin for CSOs 125, 126, 127, 144 (zero AAOV) & 166. Annual volume stored is approximately 59.79 MG.	60.03
L_MI_MF_144_M_09B_B_B	**Off-Line Storage**	CSO086, CSO125, CSO126, CSO127, CSO140, CSO144, CSO166	This project is to provide a 5.11 MG off-line storage facility consisting of a small uncovered concrete basin & a large earthen storage basin for CSOs 086, 125, 126, 127, 140, 144 (zero AAOV) & 166. Annual volume stored is approximately 76.32 MG.	60.01
L_MI_MF_144_M_13_B_A	**RTC with Storage**	CSO086, CSO125, CSO126, CSO127, CSO140, CSO144, CSO166	This project is to provide a 4.6 MG off-line storage facility consisting of a small uncovered concrete basin & a large earthen storage basin for CSOs 086, 125, 126, 127, 140, 144 (zero AAOV) & 166 and 0.5 MG of RTC-ILS at CSO 166 using an inflatable gate.	46.35
L_MI_MF_144_M_13_B_B	**RTC with Storage**	CSO125, CSO126, CSO127, CSO144, CSO166	This project is to provide a 3.63 off-line storage facility consisting of a small uncovered concrete basin followed by a large earthen storage basin for CSOs 125, 126, 127, 144 (zero AAOV) & 166 and 0.5 MG of RTC-ILS at CSO 166 using an inflatable gate.	44.10
L_MI_MF_166_M_09B_B_A	**Off-Line Storage**	CSO086, CSO125, CSO126, CSO127, CSO140, CSO144, CSO166	This project will provide a 5.11 MG off-line storage facility with a covered concrete off-line storage facility for CSOs 086(zero AAOV), 125, 126, 127, 140, 144 (zero AAOV) & 166. Annual volume stored is approximately 76.32 MG. Facility will require a 5.1 mgd PS	39.71
L_MI_MF_126_M_09B_B_A	**Off-Line Storage**	CSO125, CSO126, CSO127, CSO166	This project is to provide a 4.13 off-line storage facility consisting of a covered concrete basin for CSOs 125, 126, 127 & 166. Annual volume stored is approximately 59.79 MG, operated 54 times per year.	35.82
L_MI_MF_166_M_13_B_A	**RTC with Storage**	CSO086, CSO125, CSO126, CSO127, CSO140, CSO144, CSO166	This project is to provide a 4.6 MG off-line storage facility with a covered concrete basin for CSOs 086 (zero AAOV), 125, 126, 127, 140, 144 (zero AAOV) & 166 & 0.5 MG of RTC-ILS at CSO166. Annual volume stored is appr. 69.42 MG. Facility requires a 4.6 mgd PS.	34.02

TABLE 3.2.11

BEARGRASS CREEK MIDDLE FORK (BGCMI) INITIAL SOLUTIONS

Project ID	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_MI_MF_127_M_13_B_A	**RTC with Storage**	CSO125, CSO126, CSO127, CSO166	This project is to provide a 3.63 off-line storage facility consisting of a covered concrete basin for CSOs 125, 126, 127 & 166 and 0.5 MG of RTC-ILS at CSO 166. Annual volume stored is approximately 53 MG, operated 54 times per year.	33.85
L_MI_MF_126_M_13_B_A	**RTC with Storage**	CSO125, CSO126, CSO127, CSO166	This project is to provide a 3.63 MG off-line storage facility consisting of a covered concrete basin for CSOs 125, 126, 127 & 166 and 0.5 MG of RTC-ILS at CSO 166 using an inflatable gate. The basin is located just north of I-64 adjacent to CSO 126.	28.93
L_MI_MF_144_S_08_A_A	**Sewer Separation**	CSO144	This project includes the construction of a new water storm system consisting of 2,560 LF of 12" pipe in street, 2,060 LF of 15" pipe in street, 355 LF of 15" pipe out of street and 780 LF of 36" pipe in street.	-38.19
L_MI_MF_140_S_08_A_A	**Sewer Separation**	CSO140	This project includes the construction of a new storm sewer system consisting of 4,185 LF of pipe in street & 6,610 LF of pipe out of street.	26.24
L_MI_MF_140_M_09B_B_A	**Off-Line Storage**	CSO086, CSO140	This project is to provide a 0.97 MG underground covered concrete storage basin for CSOs 86 (zero AAOV) and 140 to reduce overflows to no more than 4 per year. Annual stored volume is approximately 16.53 MG; 54 operations per year.	30.85
L_MI_MF_086_S_08_A_A	**Sewer Separation**	CSO086	This project includes the construction of a new storm sewer system consisting of 390 LF of 12" pipe in street, 145 LF of 15" pipe in street, 1,205 LF of 18" pipe in street and 460 LF of 21" pipe in street.	-72.51

Legend: ILS- In-Line Storage; LF- Linear Feet, RTB –Retention Treatment Basin,
Selected Projects are in Yellow

TABLE 3.2.12

BEARGRASS CREEK SOUTH FORK (BGCSF) INITIAL SOLUTIONS

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit Cost Ratio (Present Worth)
L_SO_MF_097_M_09B_B_D	**Off-Line Storage**	CSO018, CSO097, CSO106, CSO108, CSO109, CSO110, CSO111, CSO137, CSO148, CSO151	This project includes an 8.63 MG underground covered storage basin for CSOs 018, 97, 106, 108, 109, 110, 111, 137, 148, and 151. The facility will require an 8.63 mgd PS to return flow to the interceptor. (CSO 111 (zero AAOV) and CSO 109 has 3 OF per year)	35.79
L_SO_MF_106_S_08_A_A	**Sewer Separation**	CSO106	This project includes the construction of a new storm sewer system consisting of 60 LF of 12" pipe in street and 20 LF of 27" pipe in street; plus 20 LF of 12" pipe out of street, 555 LF of 24" pipe out of street, and 390 LF of 27" pipe out of street.	194.69
L_SO_MF_097_M_09B_B_A	**Off-Line Storage**	CSO097, CSO106, CSO137	This project includes the construction of a 0.98 MG off-line underground covered storage basin for CSOs 097, CSOs 097, 106 & 137. The facility will require 0.98 mgd effluent PS to return the stored flow to the interceptor over a 24 hour time period.	53.19
L_SO_MF_111_M_09B_B_A	**Off-Line Storage**	CSO097, CSO106, CSO110, CSO111, CSO137, CSO148,	This project includes a 2.64 MG underground covered storage basin for CSOs 097, CSOs 097, 106, 110, 111 (zero AAOV), 137 & 148. The basin will have an effluent PS sized to empty the basin within a 24 hour period.	51.83
L_SO_MF_113_M_09B_B_A	**Off-Line Storage**	CSO097, CSO106, CSO110, CSO111, CSO113, CSO137, CSO148, CSO151	This project includes a 6.64 MG underground covered storage basin for CSOs 097, CSOs 097, 106, 110, 111 (zero AAOV), 113, 137, 148 and 151. The facility will require a 6.64 mgd PS to return flow over a 24 hour period.	41.18
L_SO_MF_151_M_09B_B_A	**Off-Line Storage**	CSO097, CSO106, CSO110, CSO111, CSO137, CSO148, CSO151	This project includes a 6.21 MG underground covered storage basin for CSOs 097, CSOs 097, 106, 110, 111 (zero AAOV), 137, 148, and 151. The facility will require a 6.21 mgd PS to return stored flow to the interceptor over a 24 hour period.	36.64
L_SO_MF_110_M_09B_B_A	**Off-Line Storage**	CSO110, CSO111, CSO148	This project includes a 1.66 MG underground covered storage basin for CSOs 110, 111 (zero AAOV) & 148. The basin is adjacent to CSO 110, BGC and a cemetery south of Eastern Parkway. The basin will have a PS to empty it within a 24 hour period.	35.52
L_SO_MF_097_M_09B_B_B	**Off-Line Storage**	CSO097, CSO108, CSO109, CSO110, CSO111, CSO148, CSO151	This project includes the construction of an 6.73 MG off-line underground storage basin for CSOs 097, 108, 109, 110, 111 (zero AAOV), 148 & 151. The facility will require a 6.73 mgd effluent PS to return the stored flow over a 24-hour period.	34.06

TABLE 3.2.12

BEARGRASS CREEK SOUTH FORK (BGCSF) INITIAL SOLUTIONS

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit Cost Ratio (Present Worth)
L_SO_MF_097_M_09B_B_C	**Off-Line Storage**	CSO097, CSO110, CSO151	This project includes the construction of a 5.85 MG off-line underground storage basin for CSOs 097, 110, & 151. The facility will require a 5.85 mgd effluent PS to return the stored flow to the interceptor over a 24-hour period.	31.34
L_SO_MF_097_M_10_B_A	**Treatment Facility**	CSO097, CSO106, CSO137	This project is to provide a 9.6 mgd RTB High Rate Treatment Facility for CSOs 097, CSOs 097, 106 & 137. The basin is located on undeveloped property between CSOs 97 & 106 near the SFBGC. Annual volume stored is approximately 16.61 MG, operated 48 times per year.	28.30
L_SO_MF_151_M_09B_B_B	**Off-Line Storage**	CSO110, CSO111, CSO148, CSO151	This project includes the construction of a 5.23 MG off-line underground storage basin for CSOs 110, 111 (zero AAOV), 148 & 151. The facility will require a 5.23 mgd effluent PS to return the stored flow to the interceptor over a 24-hour period.	27.97
L_SO_MF_151_M_09B_B_C	**Off-Line Storage**	CSO110, CSO111, CSO151	This project includes the construction of a 5.14 MG off-line underground storage basin for CSOs 110, 111 (zero AAOV), & 151. The facility will require a 5.14 mgd effluent PS to return the stored flow to the interceptor over a 24-hour period.	25.15
L_SO_MF_018_M_09B_B_A	**Off-Line Storage**	CSO018, CSO108	This proposed project includes a 2.42 MG underground closed off-line storage basin for CSO's 018 and 108. The basin will be fed by gravity and have a small PS and FM to empty the basin over a 24-HR period.	23.88
L_SO_MF_097_M_10_B_B	**Treatment Facility**	CSO018, CSO097, CSO106, CSO108, CSO109, CSO110, CSO111, CSO137, CSO148, CSO151	This project is to provide a 79.3 mgd RTB High Rate Treatment Facility for CSOs 018, 097, 106, 108, 109, 110, 111, 137, 148 & 151. Annual volume stored is approximately 155 MG, operated 59 times per year.	21.18
L_SO_MF_108_S_09B_B_A	**Off-Line Storage**	CSO108	This project includes an underground covered off-line storage basin to reduce overflows at CSO 108. Assumes 300' of gravity line to a 0.79 MG basin and includes a new PS and FM to empty the basin and return flows to the interceptor.	14.69
L_SO_MF_018_S_09B_B_A	**Off-Line Storage**	CSO018	This proposed project includes a 1.63 MG underground closed off-line storage basin. The basin will be feed by gravity and have a small PS and FM to empty the basin over a 24-HR period.	13.42

TABLE 3.2.12

BEARGRASS CREEK SOUTH FORK (BGCSF) INITIAL SOLUTIONS

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit Cost Ratio (Present Worth)
L_SO_MF_018_M_10_B_A	**Treatment Facility**	CSO018, CSO108	This project is to provide an above-grade 21 mgd BF High Rate Treatment Facility and a below-grade 2.5 MG off-line concrete storage basin for CSOs 018 and 108. Average annual volume of captured CSO is ~30 MG.	6.58
L_SO_MF_092_M_09B_B_D	**Off-Line Storage**	CSO091, CSO092, CSO113, CSO117, CSO146, CSO149, CSO152, CSO179, & SBR	This project includes a 17.65 MG underground covered storage basin for CSOs 113, 152, 091, 092, 146, 179, 149, 117, & the 11 SBR CSOs. The facility will require a 17.65 mgd PS to return stored flow to the BGI after the event. (CSOs 92 & 179 have zero AAOV).	32.99
L_SO_MF_092_M_09B_B_B	**Off-Line Storage**	CSO092, CSO113, CSO152	This project includes a 4.42 MG underground covered storage basin for CSOs 113 and 152. The facility will require a 4.42 mgd PS to return stored flow to the BGI over a 24 hour period. (CSO 92 has zero AAOV)	32.74
L_SO_MF_092_M_09B_B_C	**Off-Line Storage**	CS0113, CSO117, CSO149, CSO152	This project includes a 13.09 MG underground covered storage basin for CSOs 113, 152 149, & 117. The facility will require a 13.09 mgd PS to return stored flow to the BGI over a 24 hour period. (CSOs 92 & 179 have zero AAOV)	32.61
L_SO_MF_152_M_09B_B_A	**Off-Line Storage**	CSO091, CSO092, CSO113, CSO152	This project includes a 4.5 MG underground covered storage basin for CSOs 091, 092, 113, & 152. The facility will require a 4.5 mgd PS to return stored flow to the BGI over a 24 hour period.	31.58
L_SO_MF_152_M_09B_B_B	**Off-Line Storage**	CSO091, CSO092, CSO113, CSO146, CSO152	This project includes a 7.65 MG underground covered storage basin for CSOs 113, 146, 091, 092 & 152. The facility will require a 7.65 mgd PS to return stored flow to the interceptor.	30.42
L_SO_MF_117_M_13_B_A	**RTC with Storage**	CSO117, CSO149, CSO179	This project includes a 5.47 MG underground covered storage basin for CSOs 117, 149, & 179 and 3.2 MG of RTC-ILS for the CSO group using inflatable and adjustable gates. The facility will require a 5.47 mgd PS to return stored flow back to the interceptor.	26.56
L_SO_MF_117_M_09B_B_B	**Off-Line Storage**	CSO117, CSO146, CSO149, CSO179	This project includes a 11.82 MG underground covered storage basin for CSOs 117, 146, 149 and 179. The facility will require a 11.82 mgd PS to pump stored flow back to the interceptor. (CSO 179 had zero AAOV)	26.50
L_SO_MF_117_M_10_B_B	**Treatment Facility**	CSO117, CSO146, CSO149	This project is to provide an above-grade 37.5 mgd BF High Rate Treatment Facility and a below-grade 2 MG off-line storage basin for CSOs 117, 146 and 149. AAOV of captured CSO is ~225 MG.	17.63

TABLE 3.2.12

BEARGRASS CREEK SOUTH FORK (BGCSF) INITIAL SOLUTIONS

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit Cost Ratio (Present Worth)
L_SO_MF_117_M_10_B_A	**Treatment Facility**	CSO117, CSO149, CSO179	This project is to provide a 94.5 mgd RTB High Rate Treatment Facility for CSOs 117, 149, & 179. Annual volume stored is approximately 578 MG, operated 41 times per year.	16.53
L_SO_MF_091_S_08_A_A	**Sewer Separation**	CSO091	This project includes the construction of a new storm sewer system consisting of 580 LF of 12" pipe in street, 1,100 LF of 12" pipe out of street and 20 LF of 24" pipe in street.	-62.64
L_SO_MF_092_S_08_A_A	**Sewer Separation**	CSO092	This project includes the construction of a new storm sewer system consisting of 970 LF of 12" pipe in street plus 665 LF of 12" pipe out of street.	-106.15
L_SO_MF_083_M_09B_B_A	**Off-Line Storage**	CSO082, CSO083, CSO084, CSO118, CSO119, CSO120, CSO121, CSO141, CSO153	This project includes a 9.46 MG off-line covered storage basin for CSOs 082, 083 (zero AAOV), 084, 118, 119, 120, 121, 141 and 153 to reduce overflows to no more than 4 per year. The basin will require an 9.46 mgd PS.	40.31
L_SO_MF_141_S_08_A_A	**Sewer Separation**	CSO141	This project includes the construction of a new storm sewer system consisting of 515 LF of 12" pipe in street plus 1,920 LF of 15" pipe in street.	74.97
L_SO_MF_153_M_09B_B_B	**Off-Line Storage**	CSO082, CSO120, CSO121, CSO141, CSO153	This project includes a 2.35 MG underground covered storage basin for CSOs 082,120, 121, 141 and 153. The facility will require a 2.35 mgd pump station to return the stored flow to the interceptor over a 24 hour period.	53.26
L_SO_MF_153_M_09B_B_A	**Off-Line Storage**	CSO120, CSO121, CSO141, CSO153	This project includes a 2.25 MG underground covered storage basin for CSOs 120, 121, 141 and 153. The facility will require a 2.25 mgd pump station to return the stored flow to the interceptor over a 24 hour period.	50.09
L_SO_MF_082_M_09B_B_B	**Off-Line Storage**	CSO082, CSO120, CSO121, CSO153	This project includes a 2.04 MG underground covered storage basin for CSOs 082, 120, 121 and 153. The facility will require a 2.04 mgd pump station to return the stored flow to the interceptor over a 24 hour period.	45.82
L_SO_MF_120_S_08_A_A	**Sewer Separation**	CSO120	This project includes the construction of a new storm sewer system consisting of 4,035 LF of 15" pipe in street, 180 LF of 18" pipe in street, 285 LF of 30" pipe in street and 245 LF of 30" pipe out of street.	43.80

TABLE 3.2.12

BEARGRASS CREEK SOUTH FORK (BGCSF) INITIAL SOLUTIONS

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit Cost Ratio (Present Worth)
L_SO_MF_083_M_13_B_A	**RTC with Storage**	CSO082, CSO083, CSO084, CSO118, CSO119, CSO120, CSO121, CSO141, CSO153	This project includes an 8.66 MG off-line covered storage basin for CSOs 082, 083 (zero AAOV), 084, 118, 119, 120, 121, 141 and 153 and 0.8 MG of RTC-ILS at CSO 118. The basin will require an 8.66 mgd PS to return the stored flow after the event.	38.12
L_SO_MF_082_M_09B_B_A	**Off-Line Storage**	CSO082, CSO083, CSO084, CSO091, CSO092, CSO110, CSO111, CSO113, CSO117, CSO118, CSO119, CSO120, CSO121, CSO141, CSO146, CSO148, CSO149, CSO151, CSO152, CSO153, CSO179	This project includes a 32.65 MG off-line covered storage basin for CSOs 082, 083 (zero AAOV), 84, 091, 092, 110, 111 (zero AAOV), 113, 117, 118, 119, 120, 121, 141, 146, 148, 149, 151, 152, 153, 179. The basin will require a 32.65 mgd PS.	27.81
L_SO_MF_118_M_09B_B_A	**Off-Line Storage**	CSO083, CSO084, CSO118, CSO119	This project includes a 7.42 MG off-line covered storage basin for CSOs 083 (zero AAOV), 084, 118 & 119 to reduce overflows to no more than 4 per year. The basin will require a 7.42 mgd PS to return the stored flow to the interceptor after the event.	23.40
L_SO_MF_118_M_13_B_A	**RTC with Storage**	CSO083, CSO084, CSO118, CSO119	This project includes a 6.62 MG off-line covered storage basin for CSOs 083 (zero AAOV), 84, 118 & 119 and 0.8 MG of RTC-ILS at CSO 118. The basin will require a 6.62 mgd PS to return the stored flow to the interceptor after the event.	21.73
L_SO_MF_083_M_10_B_A	**Treatment Facility**	CSO084, CSO118, CSO119, CSO120, CSO121, CSO141, CSO153	This project is to provide an above-grade 8.5 mgd BF High Rate Treatment Facility and a below-grade 11.5 MG off-line storage basin CSOs 084, 118, 119, 120, 121, 141, 153. The BF AAOV of captured CSO is ~171 MG.	19.45
L_SO_MF_118_S_09B_B_A	**Off-Line Storage**	CSO118	This project includes a 5.79 MG off-line covered storage basin for CSO 118 to reduce overflows to no more than 4 per year. The basin will require an effluent pump station to return stored flow to the interceptor.	14.65
L_SO_MF_118_M_10_B_A	**Treatment Facility**	CSO083, CSO084, CSO118, CSO119	This project is to provide a 89.2 mgd RTB High Rate Treatment Facility for CSOs 083 (zero AAOV), 084, 118 & 119. Annual volume stored is approximately 130 MG, operated 40 times per year.	14.27

TABLE 3.2.12

BEARGRASS CREEK SOUTH FORK (BGCSF) INITIAL SOLUTIONS

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit Cost Ratio (Present Worth)
L_SO_MF_118_S_13_B_A	**RTC with Storage**	CSO118	This project includes a 4.99 MG off-line covered storage basin for CSO 118 and 0.8 MG of RTC-ILS at CSO 118 to reduce overflows to no more than 4 per year. The basin will require an effluent pump station to return stored flow to the interceptor.	13.45
L_SO_MF_093_S_08_A_A	**Sewer Separation**	CSO093	This project includes the construction of a new storm sewer system consisting of 2,975 LF of 12" pipe in street plus 350 LF of 12" out of street.	46.32
L_SO_MF_130_S_09B_B_A	**Off-Line Storage**	CSO130	This project includes the construction of a 0.1 MG off-line underground covered storage basin for CSO 130. The facility will require a small pump station to return the stored flow to the interceptor following the wet weather event.	40.48
L_SO_MF_130_M_09B_B_A	**Off-Line Storage**	CSO093, CSO130	This project includes the construction of a 0.2 MG off-line underground covered storage basin for CSOs 093 and 130. The facility will require a small pump station to return the stored flow to the interceptor following the wet weather event.	40.39
L_SO_MF_130_S_10_B_A	**Treatment Facility**	CSO130	This project is to provide a 2 mgd RTB High Rate Treatment Facility for CSO 130. Annual volume stored is approximately 1 MG, operated 9 times per year.	20.96
L_SO_MF_130_S_08_A_A	**Sewer Separation**	CSO130	Project includes construction of new storm sewer system consisting of 2,610 LF of 12" pipe in street,10 LF of 12" pipe out of street, 985 LF of 18" pipe in street, 360 LF of 30" pipe in street, 35 LF of 48" pipe in street, 440 LF of 48" pipe out of street	-18.17

Legend: ILS- In-Line Storage; LF- Linear Feet, RTB –Retention Treatment Basin,
Selected Projects are in Yellow

TABLE 3.2.13

INITIAL PROJECT LIST FOR OHIO RIVER WEST REGION

Project ID	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_OR_MF_015_M_13_B_B	**ILS with Treatment**	CSO015, CSO191	This project is to provide a 110 mgd RTB High Rate Treatment Facility for CSOs 015 and 191. Annual volume treated is approximately 527.41 MG, operated 64 times per year.	7.59
L_OR_MF_015_M_13_B_A	**ILS with Storage**	CSO015, CSO191	This project includes a 25.6 MG open concrete basin for CSOs 015 and 191, incorporating 20 MG RTC-ILS between PRFPS and SGC in SWO. The basin is located east of I-264 adjacent to MSD property. The facility is gravity in-gravity out operation.	8.46
L_OR_MF_015_M_09B_B_A	**Off-Line Storage**	CSO015, CSO191	This project includes a 45.61 MG open concrete basin for CSOs 015 and 191. The basin is located on adjacent MSD property. The facility will require a 45 mgd PS to return the stored flow back to the interceptor.	6.74
L_OR_MF_015_M_13_B_C	**ILS with Storage**	CSO015, CSO191	This project includes a 25.6 MG covered concrete basin for CSOs 015 and 191, incorporating 20 MG RTC-ILS between Paddy's Run FPS and Sluice gates in Southwestern Outfall. The basin is located east of I-264 adjacent to MSD property. The facility is gravity in-gravity out.	4.75
L_OR_MF_015_M_09B_B_B	**Off-Line Storage**	CSO015, CSO191	This project includes a 45.61 MG covered concrete basin for CSOs 015 and 191. The basin is located on adjacent MSD property. The facility will require a 45 mgd PS to return the stored flow back to the interceptor.	3.06
L_OR_MF_015_M_10_B_A	**Treatment Facility**	CSO015, CSO191	This project is to provide a 671.1 mgd RTB High Rate Treatment Facility for CSOs 015 and 191. Annual volume stored is approximately 527.41 MG, operated 64 times per year. The basin is located on adjacent MSD property.	1.78
L_OR_MF_211_M_13_B_A	**ILS with Storage**	CSO016, CSO210, CSO211	This project includes a 23.97 MG underground open concrete basin for CSOs 016, 210, and 211. The facility will be a gravity in-gravity out operation. Project also includes RTC-ILS at two locations within the SO for a total of 16.1 MG of storage.	15.17
L_OR_MF_211_M_09B_B_A	**Off-Line Storage**	CSO016, CSO210, CSO211	This project includes a 40.07 MG underground open concrete basin for CSOs 016, 210, and 211. The basin is located on MSD property near I-264. The facility will be a gravity in-gravity out operation.	15.03

TABLE 3.2.13

INITIAL PROJECT LIST FOR OHIO RIVER WEST REGION

Project ID	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_OR_MF_211_M_10_B_A	**Treatment Facility**	CSO016, CSO210, CSO211	This project is to provide an above-grade 60 mgd Ballasted Flocculation High Rate Treatment Facility. A below-grade 31 MG off-line concrete storage basin will provide the requisite 4 hours of storage for CSOs 016, 210, and 211 prior to activation of the BF process.	7.29
L_OR_MF_211_M_13_B_B	**ILS with Storage**	CSO016, CSO210, CSO211	This project includes a 23.97 MG underground covered concrete basin for CSOs 016, 210, and 211. The facility will be a gravity in-gravity out operation. Project also includes RTC-ILS at two locations within the SO for a total of 16.1 MG of storage.	8.38
L_OR_MF_211_M_09B_B_B	**Off-Line Storage**	CSO016, CSO210, CSO211	This project includes a 40.07 MG underground covered concrete basin for CSOs 016, 210, and 211. The basin is located on MSD property near I-264. The facility will be a gravity in-gravity out operation.	6.13
L_OR_MF_105_M_13_B_A	**ILS with Storage**	CSO104, CSO105,CSO189	This project includes a 4.26 MG underground covered concrete basin for CSOs 104, 105, and 189 and RTC-ILS in the Western Outfall and the Northwestern Interceptor for a total of 8.8 MG using adjustable gates. The facility will be filled and emptied by gravity. Project includes park improvements.	20.51
L_OR_MF_105_M_09B_B_A	**Off-Line Storage**	CSO104, CSO105	This project is to provide a 1.84 MG, underground, off-line, covered storage basin to reduce overflows at CSOs 104 and 105 to no more than 4 per year. Annual volume stored is approximately 19 MG. Project includes park improvements.	17.31
L_OR_MF_104_M_13_B_A	**ILS with Storage**	CSO104, CSO105, CSO189	This project includes a 4.26 MG underground covered concrete basin for CSO s 104, 105, and 189 and 8.8 MG of RTC-ILS using adjustable gates in the Northwestern Interceptor, the Western Interceptor, and Western Outfall. The project includes a 4.26 mgd pump out facility. Project includes park improvements.	15.04
L_OR_MF_189_S_13_B_A	**ILS with Storage**	CSO189	This project includes a 6.22 MG underground covered concrete basin for CSO 189 and 5.0 MG of RTC-ILS using an inflatable gate in the Northwestern Interceptor. The project includes a 6.25 mgd pump out facility. Project includes park improvements.	9.97

TABLE 3.2.13

INITIAL PROJECT LIST FOR OHIO RIVER WEST REGION

Project ID	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_OR_MF_104_M_09B_B_A	**Off-Line Storage**	CSO104, CSO105, CSO189	This project includes a 13.06 MG underground covered concrete basin for CSOs 104, 105, and 189. The facility will require a 13 mgd PS to return the stored flow back to the interceptor. Project includes park improvements.	8.74
L_OR_MF_189_S_09B_B_A	**Off-Line Storage**	CSO189	This project includes a 11.22 MG underground covered concrete basin for CSO 189. The basin is located in Shawnee Park. The project includes an 11.25 mgd pump out facility. Project includes park improvements.	5.97
L_OR_MF_105_M_10_B_A	**Treatment Facility**	CSO104, CSO105	This project is to provide a 23.1 mgd RTB High Rate Treatment Facility for CSOs 104 & 105 in Shawnee Park. Annual volume stored is approximately 21.63 MG, operated 19 times per year. Project includes park improvements.	5.45
L_OR_MF_104_M_10_B_A	**Treatment Facility**	CSO104, CSO105, CSO189	This project includes a 126.9 RTB treatment plant for CSOs 104, 105, and 189. The basin is located in Shawnee Park. Project includes park improvements. The plant is operated 39 times per year treating 197.42 MG.	4.99
L_OR_MF_189_S_10_B_A	**Treatment Facility**	CSO189	This project includes a 110 mgd Retention Treatment Basin plant for CSO 189 based on the 5th highest flow rate. The facility will require a 110 mgd PS to pump into the RTB plant. Project includes park improvements.	3.60

Legend: ILS- In-Line Storage; LF- Linear Feet, RTB –Retention Treatment Basin

Selected Projects are in Yellow

TABLE 3.2.14

INITIAL PROJECT LIST FOR OHIO RIVER NORTH REGION

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_OR_MF_019_S_13_B_A	**ILS with Storage**	CSO019	This project includes a 12.7 MG underground covered concrete basin for CSO 019. The facility will require a 12.7 mgd PS to return the stored flow back to the interceptor. Project also includes 1.8 MG of RTC-ILS using an inflatable gate. Project includes park improvements.	7.41
L_OR_MF_019_S_09B_B_A	**Off-Line Storage**	CSO019	This project includes a 14.54 MG underground covered concrete basin for CSO 019. The facility will require a 14.5 mgd PS to return the stored flow back to the interceptor. Project includes park improvements.	6.83
L_OR_MF_019_S_10_B_A	**Treatment Facility**	CSO019	This project is to provide an above-grade 108 mgd Treatment Facility and a below-grade 10 MG off-line concrete storage. The average annual volume of captured CSO is ~298 MG. Project includes park improvements.	2.24
L_OR_MF_190_S_09B_B_A	**Off-Line Storage**	CSO190	This project includes a 1.95 MG underground covered concrete basin for CSO 190. The basin is located in a vacant lot near I-64. The project includes a 2 mgd pump out facility.	26.85
L_OR_MF_190_S_10_B_A	**Treatment Facility**	CSO190	This project is to provide a 27 mgd RTB High Rate Treatment Facility for CSO 190. The basin is located in a vacant lot near I-64. Annual volume stored is approximately 36 MG, operated 50 times per year.	17.60
L_OR_MF_199_S_08_A_A	**Sewer Separation**	CSO199	This project includes the construction of a new storm sewer system consisting of 410 LF of 15" pipe in street.	151.32
L_OR_MF_053_S_08_A_A	**Sewer Separation**	CSO053	This project includes the construction of both a new sanitary sewer system and a new storm sewer system. The sanitary system consists of 15 LF of 36" pipe in street. The storm system consists of 10 LF of 36" pipe in street.	144.44

TABLE 3.2.14

INITIAL PROJECT LIST FOR OHIO RIVER NORTH REGION

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_OR_MF_027_M_09B_B_A	**Off-Line Storage**	CSO026, CSO027, CSO028, CSO029, ~~CSO030,~~ CSO031, ~~CSO033,~~ CSO034, CSO035, CSO036, CSO038, CSO178, CSO181, CSO192, CSO193, CSO195, CSO196, CSO197, CSO198, CSO199, CSO200, CSO201, CSO202, CSO203	This project includes a 1.21 MG underground covered concrete basin for Central Relief Drain CSOs. The basin is located beneath MSD HQ parking lot. The facility will require a 1.2 mgd PS to return the stored flow back to the interceptor.	83.52
L_OR_MF_035_S_08_A_A	**Sewer Separation**	CSO035	This project includes the construction of a new storm sewer system consisting of 1,875 LF of 15" pipe in street plus 985 LF of 15" pipe out of street.	80.62
L_OR_MF_201_S_08_A_A	**Sewer Separation**	CSO201	This project includes the construction of a new storm sewer system consisting of 630 LF of 15" pipe in street and 830 LF of 15" pipe out of street.	52.72
L_OR_MF_050_S_08_A_A	**Sewer Separation**	CSO050	This project includes the construction of a new storm sewer system consisting of 4,715 LF of 15" pipe in street plus 475 LF of 15" pipe out of street.	44.31
L_OR_MF_193_S_08_A_A	**Sewer Separation**	CSO193	This project includes the construction of a new storm sewer system consisting of 2,920 LF of 15" pipe in street.	39.04
L_OR_MF_203_S_08_A_A	**Sewer Separation**	CSO203	This project includes the construction of a new storm sewer system consisting of 545 LF of 15" pipe in street and 1,450 LF of 15" pipe out of street.	37.31
L_OR_MF_178_S_08_A_A	**Sewer Separation**	CSO178	This project includes the construction of a new storm sewer system consisting of 2,050 LF of 12" pipe in street, 95 LF of 12" pipe out of street, 2,660 LF of 15" pipe in street and 475 LF of 18" pipe in street.	11.54
L_OR_MF_029_S_08_A_A	**Sewer Separation**	CSO029	This project includes the construction of a new storm sewer system consisting of 1,675 LF of 15" pipe in street plus 2,110 LF of 15" pipe out of street. It also consists of 925 LF of 21" pipe in street.	-6.18

TABLE 3.2.14

INITIAL PROJECT LIST FOR OHIO RIVER NORTH REGION

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_OR_MF_181_S_08_A_A	**Sewer Separation**	CSO181	This project includes the construction of a new storm sewer system consisting of 2,425 LF of 12" pipe in street, 15 LF of 12" pipe out of street, 845 LF of 15" pipe in street, 1,035 LF of 27" pipe in street and 75 LF of 72" pipe in street.	-33.73
L_OR_MF_054_S_08_A_A	**Sewer Separation**	CSO054	This project includes the construction of a new storm sewer system consisting of 340 LF of 15" pipe in street plus 1,135 LF of 15" pipe out of street.	-37.99
L_OR_MF_156_S_08_A_A	**Sewer Separation**	CSO156	This project includes the construction of a new storm sewer system consisting of 2,925 of 12" pipe in street and 75 LF of 15" pipe in street.	-55.84
L_OR_MF_052_S_08_A_A	**Sewer Separation**	CSO052	Project includes construction of a new sanitary and storm sewer system. The sanitary system consists of 170 LF of 6" pipe in street plus 490 LF of 15" pipe in street. The storm system consists of 360 LF of 15" pipe in street plus 290 LF of 15" pipe out of street	-56.99
L_OR_MF_036_S_08_A_A	**Sewer Separation**	CSO036	This project includes the construction of a new storm sewer system consisting of 1,870 LF of 15" pipe in street, 450 LF of 15" pipe out of street, 1,030 LF of 18" pipe in street and 735 LF of 21" pipe in street.	-69.06
L_OR_MF_150_S_08_A_A	**Sewer Separation**	CSO150	This project includes the construction of a new storm sewer system consisting of 80 LF of 12" pipe in street, 175 LF of 12" pipe out of street and 405 LF of 30" pipe in street.	-94.22
L_OR_MF_056_S_08_A_A	**Sewer Separation**	CSO056	This project includes the construction of a new sanitary sewer system consisting of 130 LF of 10" pipe in street, 780 LF of 10" pipe out of street, 385 LF of 12" pipe in street and 325 LF of 12" pipe out of street.	-98.05
L_OR_MF_038_S_08_A_A	**Sewer Separation**	CSO038	This project includes the construction of a new storm sewer system consisting of 1,235 LF of 15" pipe in street plus 905 LF of 18" pipe in street.	-100.42
L_OR_MF_195_S_08_A_A	**Sewer Separation**	CSO195	This project includes the construction of a new storm sewer system consisting of 800 LF of 15" pipe in street.	-124.10

TABLE 3.2.14

INITIAL PROJECT LIST FOR OHIO RIVER NORTH REGION

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_OR_MF_200_S_08_A_A	**Sewer Separation**	CSO200	This project includes the construction of a new storm sewer system consisting of 595 LF of 15" pipe in street.	-162.30
L_OR_MF_192_S_08_A_A	**Sewer Separation**	CSO192	This project includes the construction of a new storm sewer system consisting of 75 LF of 12" pipe in street, 35 LF of 12" pipe out of street, and 550 LF of 15" pipe in street.	-214.39
L_OR_MF_034_S_08_A_A	**Sewer Separation**	CSO034	This project includes the construction of a new storm sewer system consisting of 735 LF of 15" pipe in street plus 15 LF of 15" pipe out of street.	-247.05
L_OR_MF_198_S_08_A_A	**Sewer Separation**	CSO198	This project includes the construction of a new storm sewer system consisting of 145 LF 15" pipe in street.	-254.50
L_OR_MF_197_S_08_A_A	**Sewer Separation**	CSO197	This project includes the construction of a new storm sewer system consisting of 30 LF of 15" pipe in street.	-292.68
L_OR_MF_051_S_08_A_A	**Sewer Separation**	CSO051	Project includes construction of a new sanitary & storm sewer system. The sanitary system consists of 30 LF of 8" pipe in street plus 195 LF of 8" pipe out of street. The storm system consists of 120 LF of 12" pipe in St. plus 235 LF of 12" pipe out of St	-331.37
L_OR_MF_026_S_08_A_A	**Sewer Separation**	CSO026	This project include construction of a new storm sewer system consisting of 300 LF of 15" pipe in street plus 20 LF of 30" pipe in street.	-483.97
L_OR_MF_055_S_08_A_A	**Sewer Separation**	CSO055	This project includes the construction of a new sanitary sewer system consisting of 55 LF of 15" pipe in street.	-514.92
L_OR_MF_028_S_08_A_A	**Sewer Separation**	CSO028	This project includes the construction of a new storm sewer system consisting of 180 LF of 15" pipe in street plus 490 LF of 15" pipe out of street.	-534.34
L_OR_MF_027_S_08_A_A	**Sewer Separation**	CSO027	This project includes construction of a new storm sewer system consisting of 135 LF of 15" pipe in street plus 70 LF of 30" pipe in street.	-618.43
L_OR_MF_031_S_08_A_A	**Sewer Separation**	CSO031	This project includes the construction of a new storm sewer system consisting of 140 LF of 15" pipe in street.	-641.79

TABLE 3.2.14

INITIAL PROJECT LIST FOR OHIO RIVER NORTH REGION

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_OR_MF_196_S_08_A_A	**Sewer Separation**	CSO196	This project includes the construction of a new storm sewer system consisting of 45 LF of 15" pipe in street.	-844.76
L_OR_MF_155_M_09B_B_B	**Off-Line Storage**	CSO022, CSO023, CSO050, CSO051, CSO052, CSO053, CSO054, CSO055, CSO056, CSO150, CSO155, CSO156, CSO208, CRD CSOs (27 individual CSOs)	This project includes a 66" collector and 11.83 MG underground covered concrete basin for CSOs 022, 023, 050, 051, 052, 053, 054, 055, 056, 150, 155, 156, 208 and CRD. The facility requires a 11.83 mgd PS.	30.13
L_OR_MF_208_S_08_A_A	**Sewer Separation**	CSO208	This project includes the construction of a new storm sewer system consisting of 270 LF of 12" pipe in street.	163.03
L_OR_MF_155_M_09B_B_A	**Off-Line Storage**	CSO022, CSO023, CSO050, CSO051, CSO052, CSO053, CSO054, CSO055, CSO056, CSO150, CSO155, CSO156, CSO208	This project includes a 66" collector and 10.57 MG underground covered concrete basin for CSOs 022, 023, 050, 051, 052, 053, 054, 055, 056, 150, 155, 156, and 208. The facility requires a 10.5 mgd PS.	26.87
L_OR_MF_058_S_08_A_A	**Sewer Separation**	CSO058	This project is a complete sewer separation project for the CSO 58 service area. The project will consist of the construction of 2,000 LF of new storm sewers and the conversion of the ex. combined sewer to a sanitary sewer with elimination of the CSO.	87.57
L_OR_MF_058_S_09B_B_A	**Off-Line Storage**	CSO058	This project includes a 5.22 MG covered concrete basin for CSO 058. The basin is located near Slugger Field. The facility will be gravity in-gravity out operation.	7.88
L_OR_MF_160_S_08_A_A	**Sewer Separation**	CSO160	This project includes the construction of a new storm sewer system consisting of 425 LF of 15" pipe in street.	-233.49
L_OR_MF_057_M_09B_B_A	**Off-Line Storage**	CSO057, CSO160, CSO161	This project includes a 0.02 MG underground covered concrete basin for CSOs 057 (zero AAOV), 160, and 161. The basin is located beneath a parking lot on 1st St between Market and Main Streets.	140.62

TABLE 3.2.14

INITIAL PROJECT LIST FOR OHIO RIVER NORTH REGION

Project or Cost Sheet Name	Solution Technology Details	CSOs Addressed	Project Description	Benefit /Cost Ratio (Present Worth)
L_OR_MF_161_S_08_A_A	**Sewer Separation**	CSO161	This project includes the construction of a new storm sewer system consisting of 700 LF of a 12" pipe in street.	83.21
L_OR_MF_020_S_09B_B_A	**Off-Line Storage**	CSO020	This project includes the construction of a 0.62 MG off-line underground covered storage basin for CSO 20. The facility will require a small pump station to pump the stored flow to the Robert Starkey pump station following the wet weather event.	25.34
L_OR_MF_172_S_09B_B_A	**Off-Line Storage**	CSO172	This project includes a 0.08 MG underground covered concrete basin for CSO 172. The basin is located near River Road/CSX RR. The facility will be gravity in-gravity out operation.	111.09
L_OR_MF_172_M_09B_B_A	**Off-Line Storage**	CSO132, CSO154, CSO167, CSO172	This project includes a 8.36 MG underground covered concrete basin for CSOs 132, 154, 167, and 172. The basin is located near Mellwood Avenue. The facility will be gravity in-gravity out operation.	21.84
L_OR_MF_172_S_08_A_A	**Sewer Separation**	CSO172	This project includes the construction of a new storm sewer system consisting of 695 LF of 12" pipe in street, 155 LF of 12" pipe out of street, 1,110 LF of 18" pipe in street and 795 LF of 54" pipe in street.	-94.95

Legend: ILS- In-Line Storage; LF- Linear Feet, RTB –Retention Treatment Basin, CRD- Central Relief Drain, PS – pump station
Selected Projects are in Yellow

TABLE 3.3.2
BEARGRASS CREEK SOUTH FORK (BGCSF) INITIAL SOLUTIONS CSO BENEFIT-COST RATIO MATRIX

Project ID	108	018	109	137	106	97	148	110	151	113	152	91	146	117	149	SBR	118	84	119	120	141	121	153	82	130	93
L_SO_MF_097_M_09B_B_D	**35.79**	**35.79**	**35.79**	**35.79**	**35.79**	**35.79**	**35.79**	**35.79**	**35.79**																	
L_SO_MF_097_M_09B_B_B	34.06		34.06			34.06	34.06	34.06	34.06																	
L_SO_MF_018_M_09B_B_A	23.88	23.88																								
L_SO_MF_097_M_10_B_B	21.18	21.18	21.18	21.18		21.18	21.18	21.18	21.18																	
L_SO_MF_108_S_09B_B_A	14.69																									
L_SO_MF_018_M_10_B_A	6.58	6.58	6.58																							
L_SO_MF_018_S_09B_B_A		13.42																								
L_SO_MF_097_M_09B_B_A[a]				53.19	53.19	53.19																				
L_SO_MF_111_M_09B_B_A[a]				51.83	51.83	51.83	51.83	51.83																		
L_SO_MF_113_M_09B_B_A				41.18	41.18	41.18	41.18	41.18	41.18	41.18																
L_SO_MF_151_M_09B_B_A[a]				36.64	36.64	36.64	36.64	36.64	36.64																	
L_SO_MF_097_M_10_B_A				28.3	28.3	28.3																				
L_SO_MF_097_M_09B_B_C						31.34		31.34	31.34																	
L_SO_MF_110_M_09B_B_A							35.52	35.52																		
L_SO_MF_151_M_09B_B_B							27.97	27.97	27.97																	
L_SO_MF_151_M_09B_B_C								25.15	25.15																	
L_SO_MF_092_M_09B_B_D										**32.99**	**32.99**	**32.99**	**32.99**	**32.99**	**32.99**	**32.99**										
L_SO_MF_092_M_09B_B_B										32.74	32.74															
L_SO_MF_092_M_09B_B_C										32.61	32.61			32.61	32.61	32.61										
L_SO_MF_152_M_09B_B_A										31.58	31.58	31.58														
L_SO_MF_152_M_09B_B_B										30.42	30.42	30.42	30.42													
L_SO_MF_082_M_09B_B_A							27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81	27.81		
L_SO_MF_117_M_09B_B_B													26.5	26.5	26.5											
L_SO_MF_117_M_10_B_B													17.63	17.63	17.63											
L_SO_MF_117_M_13_B_A														26.56	26.56											
L_SO_MF_117_M_10_B_A														16.53	16.53											
L_SO_MF_083_M_09B_B_A																	**40.31**	**40.31**	**40.31**	**40.31**	**40.31**	**40.31**	**40.31**	**40.31**		
L_SO_MF_083_M_13_B_A																	38.12	38.12	38.12	38.12	38.12	38.12	38.12	38.12		
L_SO_MF_118_M_09B_B_A																	23.4	23.4	23.4							
L_SO_MF_118_M_13_B_A																	21.73	21.73	21.73							
L_SO_MF_083_M_10_B_A																	19.45	19.45	19.45	19.45		19.45	19.45	19.45		
L_SO_MF_118_S_09B_B_A																	14.65									
L_SO_MF_118_M_10_B_A																	14.27	14.27	14.27							
L_SO_MF_118_S_13_B_A																	13.45									
L_SO_MF_153_M_09B_B_B[a]																				53.26	53.26	53.26	53.26	53.26		
L_SO_MF_153_M_09B_B_A																				50.09	50.09	50.09	50.09			
L_SO_MF_082_M_09B_B_B[a]																				45.82		45.82	45.82	45.82		
L_SO_MF_093_S_08_A_A																										**46.32**
L_SO_MF_130_S_09B_B_A																									**40.48**	
L_SO_MF_130_M_09B_B_A																									40.39	40.39
L_SO_MF_130_S_10_B_A																									20.96	

Footnotes:
a- In several cases, highest benefit-cost ratio score not selected in order to maximize CSOs per group due to dense urbanization (site availability limitations), plus fewer facilities reduces operations and maintenance tasks following wet weather events.
b- Highlighted cells indicate preferred projects.