Lower Mill Creek Partial Remedy

MSD's Recommendation to the Co-Defendants of LMCPR Alternative

September 26, 2012

METROPOLITAN SEWER DISTRICT of greater CINCINNATI

TABLE OF CONTENTS

Tables

Figures

1. EXECUTIVE SUMMARY

The Lower Mill Creek Study (LMC) is a submission required under the Final Wet Weather Improvement Plan approved under the federal Consent Decree entered into by Co-Defendants Hamilton County and the City of Cincinnati and Plaintiff Regulators USEPA, Ohio EPA and ORSANCO. One purpose of the LMC Study is to examine and propose alternative projects to fulfill the requirements of the WWIP for a Lower Mill Creek Partial Remedy project. The LMC Study will outline any such alternatives so that the Regulators can determine, under the standards applicable for Clean Water Act CSO Consent Decrees, whether an alternative is satisfactory and approvable. If an alternative does not meet EPA standards, it will not be approved.

The alternatives analysis performed for the Lower Mill Creek Study (LMCPR Revised Plan) is essentially the same, but greatly enhanced, as that performed in the preparation of the Final WWIP as contemplated under the federal Consent Decree. The extensive WWIP project selection and cost analysis set the groundwork for the cost analyses that have been performed to-date. Costs are reported in 2006 dollars to enable direct comparison with the WWIP costs. EPA cost-effectiveness analysis guidelines were used for the WWIP and still govern for this type of planning document which is essentially an equivalent to a small Long-Term CSO Control Plan. This is the legal framework under which the LMC Study must be undertaken.

Great care was taken in the preparation of design concepts and cost estimates to address lessons learned and to develop costs that are least likely to increase as projects proceed through the detailed planning, design, and construction phases. Preliminary geotechnical and environmental investigations and utility searches were conducted in Lick Run to identify factors that could increase implementation costs. Projects that are further along in the planning or design phases have progressively lower contingencies to account for the fact that there are fewer unknowns as the project progresses, but the 10 percent project contingency is applied to all projects.

The Final WWIP specifies that any alternative LMCPR proposed by the Co-Defendants must meet three criteria: 1) control a significant annual volume of Lower Mill Creek CSO (as much as 2 BG); 2) be able to be completed by applicable Phase 1 end date; and 3) work within a concept for a Lower Mill Creek Final Remedy. The alternatives identified to-date are the lowest cost, best grey and sustainable alternatives under the relevant industry standards to meet the applicable requirements of the Final WWIP.

MSD has completed the analysis associated with both the grey and sustainable alternatives. Given the results of these analyses, MSD recommends the Co-Defendants pursue the Sustainable Alternative for the Lower Mill Creek Partial Remedy (LMCPR). MSD also recommends that the Co-Defendants engage the Regulators in legal discussions to resolve ambiguities in the WWIP and explore additional cost savings. The relevant criteria utilized to develop this recommendation include: policy, costs, benefits, and risks.

MSD's recommendation complies with all applicable policies. MSD's integrated approach identified the most cost-effective, sustainable, and beneficial combination of infrastructure types for the Lower Mill Creek watershed. A sustainable solution offers a cost-effective balance between the grey and source control perspectives. It represents a hybrid solution with an emphasis on overall watershed CSO reduction and maximizing opportunities to accelerate "low hanging fruit" projects.

The Sustainable Alternative complies and/or conforms with:

- 2 BG CSO reduction target of the WWIP
- State and federal laws regarding stormwater management and flood control

- USEPA's guidance for development of a LMCPR alternative
- Hamilton County's July 18th resolution regarding cost control
- USEPA Sustainable Policies
- USEPA's Integrated Planning Framework Policy.

The Sustainable Alternative offers the lowest capital cost and lowest life-cycle cost for achieving 2 billion gallons of CSO reduction in the Lower Mill Creek watershed. MSD's recommendation is grounded by the policy direction received from the Hamilton County Board of Commission's July 18th Resolution regarding cost control within WWIP estimates. The $316 million Sustainable Alternative achieves the 2 BG CSO reduction at a cost much closer to the original $244 million WWIP estimate than the $537 million Grey Alternative.

As with every large infrastructure improvement program, MSD recognizes the need to identify and mitigate risks associated with projects. Each project within the Sustainable Alternative has gone through a risk analysis. Risk registers were developed allowing the project teams to thoroughly understand and plan for risks in their projects and designs. This level of risk assessment is not a normal part of a large, conceptual planning project, but is important to consider when alternatives will require significant capital investment. MSD's LMC Study team developed detailed risk mitigation strategies for many potential risks, including but not limited to:

- Coordination of planned traffic patterns within Lick Run Corridor
- Property acquisitions challenges including easements, relocations, and demolition
- Conveyance of new volumes of stormwater and the potential for flooding
- Encountering unknown historical, archeological, environmental, geotechnical, and buried utility conditions during construction
- Ability to garner consensus between all agencies and organizations
- Generating community support for the project
- Early coordination to ensure necessary federal, state, and local permits are obtained timely
- Ensuring public safety regarding an open waterway
- Detention basin volumes and heights with respect to ODNR Class 1 dam standards
- Determining if sufficient Contractor capacity is available during construction

In addition to a significant cost savings, the recommended Sustainable Alternative provides benefits to ratepayers, the environment, and the community. Benefits to ratepayers are achieved through lower capital and lifecycle costs in addition to construction coordination. When utilities coordinate capital planning projects, ratepayers realize savings from economies of scale, lower costs for risk mitigation, and consolidation of infrastructure into one project. The Harrison Avenue Phase A sewer separation project was coordinated with the City of Cincinnati's Department of Transportation and Engineering planned roadway improvements project. By completing the two projects concurrently, MSD's construction costs were 34-percent below the estimate.

The Sustainable Alternative will benefit the environment by returning natural drainage to tributaries and streams and through reduction combined sewer overflows by two billion gallons during the typical year. The pollutant loading discharges to Mill Creek from the sustainable projects will decrease significantly when compared to existing conditions given the differences between combined sewer overflow and stormwater characteristics. Directing natural drainage and stormwater to water bodies will result in additional base flow to support aquatic life.

The Sustainable Alternative is recommended by MSD because it represents solution that brings historical water wealth normally below ground to the surface to create a benefit the community can see. The Sustainable Alternative satisfies the relevant evaluation criteria related to policy, cost, benefits, and risks. The alternative ultimately selected by the Co-Defendants must conform first and foremost with EPA requirements, because the Regulators must approve any alternative. MSD recognizes that there are related issues associated with the Sustainable Alternative, under the WWIP and otherwise, and will continue to assist the City and County to address them with the Regulators and others.

2. MSD RECOMMENDATION

After three years of detailed analysis and evaluation, MSD recommends the use of a sustainable approach for the LMCPR alternative, as this represents the lowest cost solution and complies with policy guidance from the Regulators and the Co-Defendants. Because the Regulators must approve the Alternative, the recommendation conforms first and foremost with EPA requirements, and is designed to provide equal control of annual CSO volume defined as 2 BG in Attachment 1C to the WWIP. MSD recognizes that there are related issues associated with each alternative, under the WWIP and otherwise, many of which require additional engagement with the Regulators. MSD is ready to assist the Co-Defendants with those efforts.

The recommended projects result in a total CSO reduction of 2 BG. The projects evaluated, but not included in this recommendation, can be incorporated into a sustainable approach for the LMCFR.

The recommended suite of projects is reflected in the table below.

Recommended Suite of Projects

Lick Run partial separation & channel conveyance projects	Kings Run partial separation & Wooden Shoe Storage
• 72,600 feet of storm sewer • 7,700 feet of relocated combined • 8 SW detention basins/floodplain enhancments; approximately 22 acre feet of storage • 5 Vortech Units • 8,700 feet of valley conveyance system with approximately 5,600 linear feet daylighting as partial open conveyance system • 9,900 feet of natural conveyance, inlet sealing and stream restoration	• 5,700 feet of storm sewer • 7,200 feet of combined sewer converted as SW only pipe and new combined sewer • 1.5 million gallons combined storage at CSO 217 • 5 SW detention basins; approximately 21 acre feet of storage • Streambank Stabilization and restoration measures
West Fork partial separation & channel conveyance projects	**Real Time Control/Combined Flow Storage**
• 20,000 feet of storm sewer • 12,500 feet of new combined interceptor sewer • 3 million gallons of CSO storage in 2 tanks • 2 SW detention basins; approximately 23 acre feet of storage • 5,500 feet of re-naturalized stream (West Fork Branch) • 10,400 feet of natural conveyance, inlet sealing and stream restoration	• RTCs at CSOs 5, 482, 485, 125 and raising of the West Fork channel grates (already constructed) • Bloody Run (CSO 181) watershed RTC • 2 million gallons of combined storage at CSO 488 in the South Branch Mill Creek watershed

2.1. INTEGRATED WATERSHED APPROACH

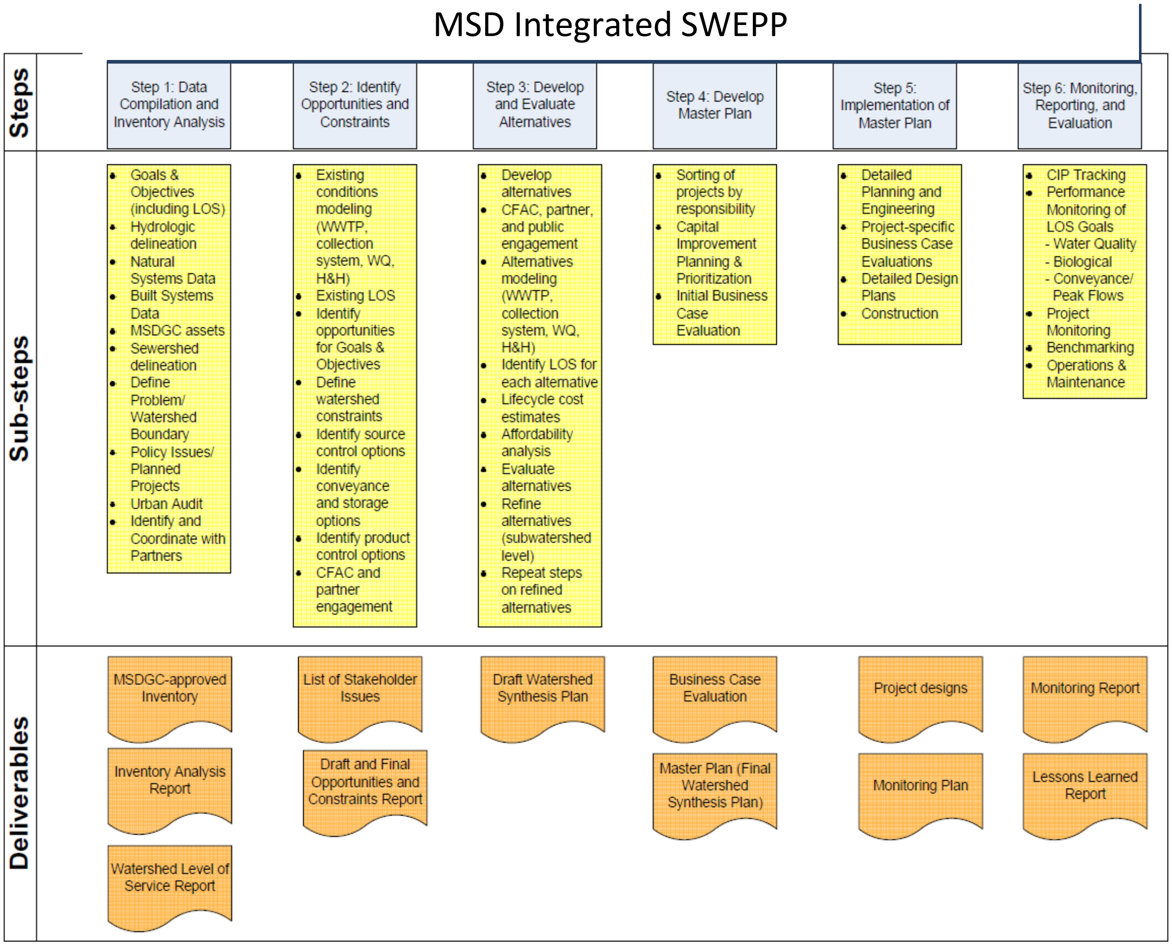
In June 2012, USEPA finalized the "Integrated Wastewater and Stormwater Policy Framework" to assist communities in developing solutions in a more cost effective and environmentally sound way based on community priorities. In that policy, USEPA affirmed that is has "increasingly embraced integrated planning approaches to municipal wastewater and stormwater management." The policy also explains that integrated planning can "facilitate the use of sustainable and comprehensive solutions, including green infrastructure, that protect human health, improve water quality, manage stormwater as a resource, and support other economic benefits and quality of life attributes that enhance the vitality of communities."

The development of the integrated approach came out of a growing body of research and case studies on the use of green infrastructure to address wet weather discharges. In 2007, USEPA issued a memorandum (USEPA, 2007) supporting the "development and use of green infrastructure in water program implementation."

In 2007, the County led an effort to develop a green infrastructure program and conceptual outline to address CSOs, but that approach was rejected by the Regulators because it would not assure long term reductions. In 2008, Hamilton County pursued changes to the ORC 6117 to allow sewer districts to fund stormwater mitigation projects to reduce CSOs, and the County provided MSD with policy direction supporting the use of green/sustainable infrastructure. The Co-Defendants then submitted a new plan that was conditionally approved by the Regulators in 2009, and formally approved the Revised WWIP in 2010, which included a 3 year LMC Study to develop alternatives to the default solution. In April, 2012 MSD submitted the Preliminary Findings of that study to the Co-Defendants.

As such, MSD is following USEPA's lead and using this planning framework in its efforts to comply with federal mandates and this recommendation and work product is in line with that policy. In 2009, MSD began developing an integrated approach, using what is now the sustainable watershed evaluation and planning process (SWEPP) to identify the most cost-effective, sustainable, and beneficial combination of infrastructure types for a given watershed. Many of the Lower Mill Creek watersheds were part of a SWEP evaluation and that helped to formulate the recommendation.

The SWEP is a formal planning process to facilitate an integrated decision support system for prioritizing and determining wastewater collection or treatment needs, particularly for the LMCPR, CSO volume reduction alternatives, that use a hybrid of both grey and green infrastructure which MSD had defined as sustainable infrastructure, facilitate other local community and economic benefits, and meet the objectives. Originally developed as a four step process, MSD has enhanced the SWEPP process with six broad steps to develop and implement integrated watershed-based master plans; Data and Inventory Analysis, Opportunities & Constraints, Alternatives Evaluation, Development of a Master Plan, Implementation and Monitoring, Reporting and Evaluation. The updated 6-step process is described in the diagram below.



Similar to comprehensive planning, the SWEPP identifies and analyzes the important relationships among the environment, infrastructure, the economy, transportation, communities/neighborhoods, and other components. It does so on a watershed-wide basis and in the context of a wider region and objective. MSD has draft a SWEPP manual on how it performs SWEPPs to guide further efforts and replicate the process in other watersheds and communities.

2.1.1. Convey, Store and Treat Perspective

Traditionally for CSO communities, wet weather overflows have been solved and mitigated with construction of new gray infrastructure, such as relief sewers, overflow storage tunnels, overflow storage tanks, and satellite high rate treatment facilities. Systems include conveyance systems to move the water to the plant for treatment, combined overflow storage tanks to hold the water and discharge it back into the combined system for treatment at the plant and/or combined overflow storage/treatment facilities that would treat the overflow and discharge it to the environment. Combinations of these types of control create combined storage tunnels that convey and store in one structure, and are designed to provide a specific level of control at the CSOs based on modeling the typical year.

2.1.2. Source Control Perspective

MSD has determined source control to be an integral step in achieving the long-term goals and solutions outlined in the WWIP. The geographical area served by MSD has grown from small developer built systems to an interconnected regionalized system. Today, it is imperative for utilities to work with a "regional" perspective and to consider projects, infrastructure needs, and system operations from a holistic approach that incorporates integrated watershed planning.

The first step in reducing MSD's combined sewer overflows is to remove the natural drainage and cleaner stormwater from the combined sewer system. Over the last 100 years, natural drainage features have been replaced with hard-piped combined sewers. From a Source Control perspective, stormwater is considered a resource to be utilized for much broader sustainability purposes, rather than remain combined with sanitary sewage. This approach is consistent with the policy direction of USEPA and the County. Using a watershed approach to identify areas to control or limit natural drainage and stormwater from entering into the combined system, the Co-Defendants can submit to the Regulators alternative source control solutions that reduce CSOs, utilize bioengineered systems that mimic natural systems and can provide opportunities for more sustainable community redevelopment. Additionally, source control solutions can help prepare communities for climate change effects and potential offset requirements, promote energy efficiency, and improve air quality, making communities more livable and desirable.

Source controls may also be significantly more cost effective than end-of-pipe controls, and have been proven effective and are supported by the EPA.

There are 3 distinct source control project types know as Direct, Enabled and Inform and Influence. For the last 3 years, MSD has been using this framework to develop integrated watershed solutions to CSO reduction, identifying source control opportunities.

The projects identified in the recommendation are direct projects that MSD would own and operate to reduce CSO volumes. Direct source control projects are planned and designed to achieve CSO reduction goals, but they may also address other community priorities, water quality and/or public health needs. These issues are taken into account to develop projects within the context of existing community or watershed conditions.

Sewer Separation, Natural Conveyance in Ault Park, Upper Duck Watershed, 2012 MSDGC. Flow previously was directed into the combined sewer; this separation project has removed an additional 100 acres of park land from draining into the combined sewer.

Strategic separation and large-scale source control measures are the hallmark of the LMCPR Sustainable Alternative plan. This plan is adaptable and other features and measures can be added in the future to improve CSO mitigation and other overall benefits. While considering watershed approaches and watershed-specific solutions and strategies, areas within the Lower Mill Creek have been categorized as Tier 1 areas where specific source control or partial separation projects are proposed as well as Tier 2 areas where large scale solutions are not proposed but rather onsite solutions will be implemented over time to detain flows prior to discharge through existing or new policies and land use changes that could help implement innovative stormwater related reductions over time through enable impact projects. Source control solutions serve to increase local capacity and provide a higher level of service because they achieve the following results:

- Provides parallel, separate stormwater conveyance system
- Reduces sewer surcharging
- Reduces sewage in basement issues
- Reduces localized flooding
- Reduces energy costs and carbon footprint

Additional analysis and planning has been done to evaluate water quality implications of Lick Run in particular using the Mill Creek Total Maximum Daily Load (TMDL) to identify water quality best management practices and features that reduce nutrient and sediment loading from the Lick Run watershed. This analysis identified locations for optimized water quality measures to reduce nutrients and sediment based on current land uses; additional water quality features could be added over time.

When considering the long-term sustainability of infrastructure solutions it is important to include triple bottom line benefits, community and stakeholder input, opportunities for repurposing land, and opportunities for Brownfield remediation. MSD has incoporatated these components into the recommendation.

MSD considered best management practices (BMPs) in developing specific source control strategies, and recommended several be included in the Lower Mill Creek sustainable projects. They include the following:

STRATEGIC SEPARATION: Strategic sewer separation is a targeted or prioritized approach to partial sewer separation within a watershed. Where strategic separation is used, typically there may be two different watershed zones – Tier 1 (priority) and Tier 2 (non-priority). Tier-1 areas of a watershed, uses validated system-wide hydraulic model to optimize facility sizing for CSO control, stormwater pollution control, stream morphology, and sewer system capacity to remove stormwater from the combined system by means that are cost effective to meet the pre-established WWIP target and give priority to approaches that best reflect sustainability and selected community value. Strategic separation provides an opportunity to also integrate the use of small, regional or large-scale stormwater BMPs in Teir-2 areas where separation is not pursued (i.e. non-separated /non-priority areas) to achieve wet weather reduction and community goals. The approach represents an opportunity to target investment in new traditional infrastructure and lay the foundation for more sustainable infrastructure use in an integrated, watershed-based solution.

Strategic Separation involves characterizing watershed conditions, identifying volumes to redirect through an alternative stormwater offloading conveyance system. Source control volumes are determined, modeled and potential alignment identified, relative cost and risks determined and considered. As part of strategic separation, several items are considered including on-site storage, regional detention basins or wetlands are evaluated based on existing utilities, vertical alignment of storm sewers, potential for natural conveyance, maximum excavation depths/extents, bedrock and groundwater depths revealed through geotechnical borings, environmental site conditions, access for construction and maintenance, alternative inlet/outlet structures, and maximum side slopes based on safety and geotechnical considerations.

GREEN STREET FEATURES: Also known as curb extensions, these features extend into existing parking lanes. Stormwater collected in the gutter flows into and through the bump-out. The bump-out serves as a temporary wet weather storage, filter, and infiltration. Additionally, it introduces green space and calms the traffic. These features offer the benefit of reducing peak impacts of small storms.

PERVIOUS PAVEMENT: This BMP replaces the existing impervious surface with high rate infiltration pervious materials (pervious asphalt or pervious concrete). The pervious pavement system is comprised of two layers: bottom layer is comprised of gravel to allow water to drain quickly and the top layer of is comprised of pervious material. Stormwater infiltrates through the surface as it flows over parking lanes. Regular maintenance is required to maintain the porosity and prevent clogging. This can be accomplished with bi-annual street sweeping.

PERMEABLE PAVERS: This BMP replaces This BMP replaces the impervious parking and walking surfaces with pervious material such as paving blocks. The paving blocks are laid across a surface with spaces left in between (interlocking) to allow the water to infiltrate. The pervious pavement system is comprised of three layers: bottom layer of gravel storage; middle layer of compacted leveling sand; and top layer of pavers. These pavers are typically used in low traffic areas. Regular maintenance is required to maintain the porosity and prevent clogging. This can be accomplished with street sweeping.

EXTENDED DETENTION WETLANDS: These features are recognized as stormwater storage BMP. They provide treatment, habitat and eliminate permanent pooling. Wetland systems can be designed to recharge local groundwater sources. They provide the benefit of storing water over time and preventing downstream flooding. Additionally, the wetlands enhance the pollutant removal capacity.

DETENTION BASINS: A detention basin is a stormwater BMP structure that stores the water over a short period of time (if it is always full, then it is called retention) and then the water gets released slowly back into the system. Detention basins offer benefits of reducing peak flows, potentially reducing proposed storm sewer sizes, and providing stormwater quality benefits. Factors to consider include existing terrain and features, existing basins and depressions, and estimated pollutant loadings.

OPEN CHANNEL CONVEYANCE: Locations have an existing ravine traversing the project limits may be favorable for open channel conveyance. Factors to consider include geotechnical conditions, existing vegetation, disturbance limits, required easements, inlet sealing and stability and construction cost and impacts.

REFORESTATION: Reforestation in stormwater management is important because it increases the capture of stormwater which reduces the intensity of rain over the surface. This results with reduced stormwater runoff and prevents sediment erosion. Additionally, reforestation is essential to the restoration of many natural habitats. Forested buffers that lie between land and water are an essential part of the ecosystem. Reforestation programs attempt to preserve and restore forested buffers and natural forests. Further through reforestation, municipalities can accomplish several tasks, including park improvement, neighborhood and highway beautification, and the planting of shade trees in parking and pedestrian areas.

SEDIMENT FOREBAY: A sediment forebay is a small pool located near the inlet of a storm basin or other stormwater management facility. These devices are designed as initial storage areas to trap and settle out sediment and heavy pollutants before they reach the main basin. Installing an earth berm, gabion wall, or other barrier near the inlet to cause stormwater to pool temporarily can form the pool area. Sediment forebays act as a pretreatment feature on a stormwater pond and can greatly reduce the overall pond maintenance requirements. Forebays also make basin maintenance easier and less costly by trapping sediment in one small area where it is easily removed, and preventing sediment buildup in the rest of the facility.

ENABLED IMPACT PROJECTS: Direct source control solutions have been developed in Lick Run, West Fork, Bloody Run, Kings Run, Denham and Ludlow Run; these watersheds have been the focus of this evaluation. However, it should be noted and understood that source control offers additional flexibility to engage the private sector and other public partners in implementing Enabled Impact Projects. While most enabled impact projects will not reduce large volumes of CSO, these projects over time could be beneficial. Using an integrated approach could drive market forces to enable projects and the private sector to implement source control solutions to reduce runoff from entering the combined system, helping MSD to reduce overall costs of CSO reduction, while providing more community benefits. As redevelopment of new or old sites occurs, MSD, local policies or codes could enable a developer to implement additional source controls on their sites at costs born partially by them. Enabled impact projects could be additionally incentivized and influenced by polices set by the City or County as part of land development codes or form based codes.

To date, the MSD developed a successful Enabled Impact Program, capturing approximately 44 million gallons of stormwater from the combined system through partnerships with other public or private entities approximately 30 to date. Through current enable impact projects, MSD provides cost participation and in return, the enable impact partners agree to maintain the sites and stormwater reduction benefits. These market-driven efforts are part of what make source control attractive. With an intentional strategy to capture reductions from enabled impact projects each year, over 20-30 years, there could be considerable benefits for MSD, its ratepayers and the community at large to close the gap more cost effectively than through traditional solutions. The figure below illustrates the numerous enabled impact projects identified and considered throughout the Lick Run watershed; some of these projects are either constructed or in planning and design.

LICK RUN WATERSHED ENABLED IMPACT PROJECTS

2.2. DISCUSSION OF LOWER MILL CREEK STUDY AND ANALYSIS

The Recommendation has undergone significant analysis review and where necessary modifications were made to the modeling, costing and to a lesser degree, the technical components of the projects, to establish and maintain consistency for the LMCPR study.

As part of the LMC Study, the LMC Study team reviewed and updated past WWIP modeling and costing standards with updated MSD standards and protocols, to include recent local data (i.e., flow monitoring, model updates, actual project costs), and to ensure a consistency for comparison of alternatives and for the implementation of the LMCPR Revised Plan when it's selected. Model and Cost methodology and assumptions for the LMC Study are discussed in this Section.

2.2.1. LICK RUN

The Lick Run project is anchored with a valley conveyance system to convey natural drainage and stormwater from strategic separation projects to the Mill Creek, thus removing significant water volume from the combined sewer system.

The urban valley conveyance system is a hybrid system of a box conduit and above ground naturalized channel system. Because this integrated system will receive the stormwater runoff captured and conveyed from the strategic sewer separation areas, as well as overland flow that is expected to occur during large storm events, the valley conveyance system would be designed to provide both quality and quantity features as necessary parts of this CSO reduction project. The features that are included in the cost breakdown within sustainable infrastructure projects are components that provide or protect CSO reduction benefits. They may also help incorporate the project into the neighborhood while addressing water quality, maintenance, and safety needs of the project.

The Lick Run watershed approach integrates features within that topography and landscape to function as a bioengineered system for CSO reduction, water quality improvement and community integration. The costs associated with constructing and managing this system were evaluated and accounted for in the base Lick Run capital costs.

For areas where green infrastructure is used for a naturalized conveyance system or a valley conveyance system (as shown in the figure below), the project includes maintenance access pathways, lighting, and safety features that are essential to long term assurance of the CSO reduction feature of the Lick Run project. These features and components were highlighted and recommended by the Value Engineering Study, the community design workshop, and the Master Plan. Specifically, maintenance access pathways could serve as community walking trails. Lighting around the water features protect them from vandalism, while railings along the waterway protect the public from high channel flows likely to occur during wet weather conditions. Additionally, retaining walls are required to protect MSD's existing sewer system assets, as well as roadways and other utilities.

Best Management Practices (BMPs) are incorporated into both the valley conveyance system and upland areas of the watershed to improve the water quality prior to discharge into the receiving stream. Sustainable watershed infrastructure solutions are recognizably different from conventional/traditional solutions; as such, MSD has developed and incorporated project costs to maintain the green infrastructure features to provide long term assurance the asset will function as designed for CSO reduction. MSD considers these features to be essential to meet Regulator and Community expectations.

The preliminary planning document, which was the basis of the LMCPR study costs, has been vetted, revised, and updated based on a strong level of participation and support by the community, and formulated into a Lick Run Master Plan. All elements included in the base project of the Master Plan are considered essential to achieving the CSO reduction objectives in a manner consistent with the values of the local neighborhood and community at large. Elements afforded by the sustainable projects will be integrated into the community to assure the long term stability and maintenance of the asset.

The total construction cost and capital cost of the individual separation projects which include storm sewers, enhanced stormwater detention basins, and the valley conveyance system project are summarized in the table below.

Lick Run Sub-Basin Costs (2006$)

Project	Total Construction Cost	Capital Cost
Sunset Avenue SSA	$7,132,000	$10,290,000
Rapid Run ESP	$1,254,000	$1,894,000
Wyoming Avenue	$1,595,000	$2,560,000
Harrison Avenue Phase A	$1,767,000	$2,652,000
Harrison Avenue Phase B	$1,032,000	$1,887,000
State Avenue	$1,935,000	$2,978,000

Project	Total Construction Cost	Capital Cost
White Street	$3,412,000	$5,689,000
Quebec Road	$4,352,000	$7,274,000
Queen City Avenue Phase 2 (Western)	$5,781,000	$8,863,000
Queen City and Cora Avenue (Fenton)	$2,052,000	$4,350,000
Quebec Heights Phase 1 (Glenway Woods)	$2,006,000	$3,391,000
Quebec Heights Phase 2 (Wells Street)	$428,000	$816,000
Grand and Selim Avenue	$5,763,000	$9,679,000
Queen City Phase 3 (Eastern)	$3,245,000	$4,891,000
Westwood Avenue	$3,807,000	$5,412,000
Queen City Avenue Phase 1 (Central)	$3,611,000	$5,242,000
Valley Conveyance (Lick Run Channel)	$72,741,000	$122,624,000
Total	**$121,913,000**	**$200,492,000**

2.2.1.1. Sustainable Infrastructure Elements

Project components of the Lick Run solution, which are included in the cost analysis of the "base project," were developed through an iterative process of agency coordination and community design and review process. The resulting "base project" is the outcome of this coordination, as detailed in the Lick Run Master Plan. While some components may appear to be strictly optional amenities, these components are reflective of USEPA's stated expectations for CSO reduction related expenses for an alternative solution under the integrated planning framework.

The following features are included in the base cost for the Lick Run sustainable infrastructure projects, and described in more detail below:

1. ***Valley Conveyance System (VCS):*** The valley conveyance system achieves anticipated hydraulic performance requirements while accounting for existing physical constraints within the conveyance corridor, and was developed to support MSD's Communities of the Future initiative objectives. This alternative sustainable CSO reduction project has features that are designed using a natural systems approach for optimal integration of water quality and quantity needs.

2. ***Maintenance Access Paths:*** The VCS is a functioning water conveyance system that will need maintenance and therefore maintenance access. The concrete pathway along the channel will act as this maintenance access, so service vehicles can access the VCS at any given point, as well as provide protection and access to the large diameter combined sewer that is located beneath the concrete pathway. When the concrete access path is not being used for maintenance, it will provide public access, allowing for a dual purpose out of this public investment. The public access provisions of the path will enhance available pedestrian routes through the corridor, as well as offset disruptions and barriers to existing pedestrian routes resulting from the construction of the VCS.

3. ***Railings around the Wetland Forebay:*** The railings are incorporated into the bridge across the wetland forebay as a safety element for pedestrians.

4. ***Pedestrian Bridges and Railings:*** The VCS is designed to meet volumetric stormwater conveyance needs; however, it will cut off several existing pedestrian connections. The community has also expressed concerns about the VCS being a barrier dividing the north and south areas of South Fairmount. As a community request, pedestrian bridges have been incorporated in the base project to allow these connections to continue safely but in a limited area. The bridges also provide ADA accessible public access to the channel and educational vantage points for water quality feature observation. Railings are provided wherever local or state safety requirements for fall distances adjacent to public access.

5. ***Safety & Interpretive Signage:*** Signage serves two purposes. First, safety signing communicates the inherent risks associated with high water/flood elevations, flowing channels, and/or bodies of water. Secondly, signage educates the public through interpretive signage and messages intended to meet the EPA Phase 2 Stormwater Regulations. The interpretive signage included for the Lick Run base project will communicate MSD's improvements to the area and provide information on the function of the VCS, including an overview of watershed-wide information down to the project-specific channel. Providing visual support to aid MSD in communicating its commitment to water quality and sustainable infrastructure is not a new approach. In fact, similar features have been developed and incorporated within various MSD facilities, such as the mini-wastewater treatment process example at the entrance to MSD Engineering Building, green roofs, and rain gardens on MSD's campus.

6. ***Trailhead Parking:*** This includes porous pavement, brick pavers, trees, lighting and landscape plantings. The block in which this parking lot is situated will be significantly impacted by the construction of the VCS portion of the SI project. Existing parking and traffic conditions are inadequate to provide reasonable site access during and following construction. The parking area will provide construction access and staging areas for the VCS and adjacent SI projects during construction, and maintenance access for these facilities following construction.

7. ***Safety Lighting:*** Lighting in accordance with recommendations of CPTED (Crime Prevention through Environmental Design) principles (a widely-accepted planning and design tool) will be provided to enhance safety. All lighting shown in the base plan is for pedestrian and maintenance safety along the channel, as recommended by CPTED principles.

8. ***Benches, Trash Receptacles, Bike Racks:*** Seating will be provided at minimal distances along the maintenance corridor to accommodate seniors and other pedestrians with mobility challenges, where lack of refuge areas might otherwise exclude their participation in the use of the public elements associated with the project. Trash receptacles are being provided as a public service to users of the area. Trash receptacles will also promote maintenance reductions, specifically the volume of daily trash pick-up in concentrated use areas. Bike racks will be placed in key areas at a minimum. The more accommodations are made for pedestrian access and use, the more users will feel safe and be encouraged to use the space.

9. ***Terraced Stone Walls:*** The walls are in-stream elements or within flood limits used to provide transition for grades in the area of the Cincinnati Recreation Commission ("CRC") property and at the daylighting feature. They are used only when necessary to transition grades making them an essential function of the channel. The terraced stone walls are intended to stabilize the edges of the channel at different flood levels below the 100 year flood event.

10. ***Ledge Rock, Natural Stone, and Boulders:*** These elements are all essential elements of the channel for stability, depth control, energy dissipation, water quality and aerating the water within the channel. Over time the stone will grow algae and other organisms that will continue to improve water quality.

11. ***Brick Pavers:*** Specialized pavements have been used minimally due to budgetary concerns in the base project and limited to areas providing VCS maintenance access. These areas include entrances to the maintenance access pathway, to provide visual cues to pedestrians and vehicles for potential intersections. Other special pavements include the functional access from on-street parking on Westwood Avenue to the multipurpose trail along Westwood for pedestrians to cross over the stormwater planters running parallel to the street. These costs are included in the Lick Run base project.

12. ***Plantings and Trees:*** Plantings and trees are added minimally to provide a varied ecoscape capable of providing low level habitat while stabilizing ground areas from erosion and attenuating storm water runoff. Porous pavement and/or brick pavers attenuate stormwater runoff, reducing overall peak flows in areas that are otherwise impervious

13. ***Landscape Plantings:*** All plantings are within disturbed or impacted areas of the channel construction. Plantings and trees are added minimally to provide a varied ecoscape capable of providing low level habitat while stabilizing ground areas from erosion and attenuating storm water runoff. The plantings are focused on native species that require less maintenance once established.

14. ***Trees for making wooded areas:*** Trees are included within the waterway in planted areas as essential landscape elements. Trees have proven to provide value in stormwater reduction, carbon sequestration and particulate removal. In addition, their long term benefit includes maintenance reduction

15. ***Trees in Stormwater Planters:*** Trees are included within the stormwater planters as essential landscape elements. As noted above, trees have proven to provide value in stormwater reduction, carbon sequestration and particulate removal. In addition, their long term benefit includes maintenance reduction. These costs are included in the Lick Run base project.

16. ***Stormwater Planters:*** Bioswales have been updated to be individual stormwater planters along Westwood and Queen City Ave in strategic locations for the greatest stormwater benefit. The stormwater planters are envisioned to be water quality features that will slow and clean stormwater runoff from Queen City and Westwood Avenues prior to its discharge into the VCS. These costs are included in the Lick Run base project.

17. ***Steps and Open Space Turf:*** Steps have been reduced to the minimum required to provide access from the CRC property to the VCS. Access to the channel in this area is similar to the pedestrian bridge at the channel headwater in that it is for public access and educational vantage point for water quality feature. Turf is replacing the multi-purpose lawn that existed prior to the channel construction.

18. ***Meadow:*** Meadow is part of the outer edge of the channel within the flood level. This riparian edge is critical to the health of the channel and this edge needs to be flexible in its habitat because it could be flooded with water or dry. A native meadow is one of the best applications for this type of function. These costs are included in the Lick Run base project.

19. ***Reforestation and Meadow Plantings:*** The water quality feature at the east end of the channel provides essential water quality elements at the end of the channel. As stated in previous comments on plantings and trees, these living elements are essential to water quality

20. ***Irrigation:*** Irrigation has been included as a project element to protect MSD's investment in plantings and landscaping. In turn, the health and well-being of these features protects against erosion and reduces overall stormwater runoff. Reliance on in-ground permanent irrigation systems is becoming widely recognized as a cost saving tool that helps minimize staff labor and therefore costs associated with landscape management activities for open space areas such as those proposed for the VCS portion of the SI project.

Replacements of existing infrastructure impacted by the Lick Run sustainable projects, which are included in the base costs, are summarized below:

1. ***Shelter:*** The picnic shelter within the CRC property is being impacted by the construction of the VCS and will be restored as part of the project to replace what was removed for construction. Shelter type and style will be selected during the initial design phase through a review process that attempts to match performance and durability requirements with community standards and values, including strict conformance with ADA accessibility requirements.

2. ***Relocated existing basketball courts:*** The basketball courts within the CRC property are being impacted by the construction of the channel and will be restored as part of the project to replace what was removed for construction.

3. ***Picnic Grove:*** The picnic grove and associated elements, such as trees, picnic tables, and trash receptacles shown in the preliminary planning documents, have been removed from the base project.

4. ***Recreational Field – Baseball and half football field:*** The recreational fields shown in preliminary planning documents have been removed from the base project.

5. ***Drinking fountains:*** Drinking fountains have been removed from the base project. The only drinking fountains that may be included are those within the CRC property that are being impacted and will require replacement.

6. ***Playground:*** The playground within the CRC property is being impacted by the construction of the VCS and will be restored as part of the project to replace what was removed for construction. However, modern performance and safety requirements with conformance with ADA accessibility requirements will need to be provided.

7. ***Multi-purpose trail and trail lighting:*** All lighting shown in the base project is for safety of pedestrian and maintenance, as recommended by CPTED principles. The existing walkway along Westwood will be impacted as a result of the VCS construction, and is being replaced to current standards that support and encourage multi-modal traffic in the area.

8. ***Crosswalks – Brick Pavers:*** Safety is of particular concern to the community and providing safer, more visual crosswalks is essential. The intersection pavement and crosswalks will be disturbed during construction, and will need to be restored. The proposed colored concrete crosswalks provide a contrasting pavement to the adjacent asphalt road surface and improve visibility for motorists who may not be accustomed to the changes in pedestrian movements that will likely occur with the VCS.

9. ***Street Lighting along Queen City Avenue:*** Any street lighting included in the base project will replace existing street lights being impacted by the channel construction. The new street lighting will be chosen using a consistent style throughout the impacted corridor. All other lighting is not included as a part of the base project.

10. ***Green Streets – Bioswales, Street Trees, Street Lighting:*** Any street lighting included in the base project is replacing existing street lights being impacted by the project construction, or for safety of pedestrian and maintenance personnel as recommended by CPTED principles.

11. ***Lawn areas:*** Lawn areas included in the base project costs will replace the multi-purpose lawn, which will be impacted by VCS construction.

12. ***South Fairmount Civic Space:*** The current VCS Base Plan refers to a Recreation Hub and contains the existing CRC property, which will be impacted by the alignment of the VCS and the associated floodplain. Based on public feedback and coordination with the City of Cincinnati, the CRC property is and has been a vital public open space for the community. The community overwhelmingly expressed concerns for the potential loss of public open space. Through the extensive community design input process, the community requested that any loss of existing open space should be offset through property reallocation.

2.2.2. West Fork

The West Fork project is also an integration of both green and grey infrastructure that strategically separates natural streams and storm water from the combined system. The existing interceptor located in and under the West Fork Branch channel will be abandoned and a new combined interceptor will be constructed outside of the waterway. Portions of the channel between Mt Airy Forest and Northside (at Colerain bridge) are proposed to be re-naturalized with enhanced floodplain characteristics in areas that have historically flooded or experienced basement sewage backups. Two combined storage tanks are proposed to mitigate overflows into the West Fork branch downstream of the re-naturalization portion of the branch. The total construction cost and capital cost are summarized in the table below.

West Fork Sub-Basin Costs (2006$)

Project	Total Construction Cost	Capital Cost
CS0 117 - Fay Apartments Street Separation	$1,347,000	$2,121,000
CSO 125 – Stream Separation	$6,036,000	$10,020,000
CSO 126 – Stream Separation	$1,494,000	$2,757,000
CSO 127 – Stream Separation	$97,000	$189,000
CSO 128 – Stream Separation/Relocate Regulator	$843,000	$1,308,000
CSO 130 – Stream Separation	$4,750,000	$8,001,000
West Fork 84” Interceptor	$5,679,000	$7,989,000
1.5 MG Tank	$7,843,000	$10,403,000
CSO 125 1.5 MG Tank	$9,294,000	$12,447,000
CSO 528 – Street Separation	$371,000	$619,000
CSO 529 – Street Separation	$359,000	$603,000
CSO 530 – Street Separation	$1,542,000	$2,298,000
Channel Renaturalization and Enhanced Floodplain Characteristics	$9,927,000	$15,216,000
Total	**$49,582,000**	**$73,971,000**

2.2.3. Kings Run

The Kings Run project is a combination of strategic sewer separation, natural stormwater detention basins and one combined overflow storage tank at CSO 217. With the construction of this project, the CSO 217 will not be nested above CSO 483 which will remove the double handling of flow. Originally an EHRT was planned for CSO 217; however, the storage tank at CSO 217 provides more protection of the downstream run since overflows are held and then dewatered back into the combined system. The total construction cost and capital cost are summarized in the table below.

Kings Sub-Basin Costs (2006$)

Project	Total Construction Cost	Capital Cost
Stream Removal/Sewer Separation	$10,403,000	$17,282,000
1.5 MG Tank at CSO 217	$7,036,000	$10,252,000
Total	**$17,439,000**	**$27,534,000**

2.2.4. CSO 488 Storage

The CSO 488 storage project provides 1.5 million gallons of overflow storage within the Upper South Branch Mill Creek watershed. Strategic separation was not deemed cost effective due to the large diameter stormwater sewer required and the difficulty of finding an alignment through the congested urban streets. In addition, the maximum possible separation was not extensive enough to meet the desired level of control without the addition of a combined storage tank. The total construction cost and capital cost are summarized in the table below.

CSO 488 Storage Costs (2006$)

Project	Total Construction Cost	Capital Cost
CSO 488 Storage	$7,864,000	$10,651,000

2.2.5. Bloody Run RTC

Of the sustainable project for Bloody Run, the RTC was identified for consideration for Phase 1. The RTC facility coupled with regulator improvements at CSO 181 will use in-system storage within the existing 10 ft x 15 ft combined trunk sewer. The conceptual analysis of the RTC was incorporated near the end of the Bloody Run sustainable study. Additional flow monitoring is occurring in the Bloody Run basin currently. The specific alternative analysis for the RTC will be performed in 2013 where additional site specific analysis will occur. In addition, coordination with ODOT is on-going at CSO 181 based on the I-75 project that is currently in planning. The table below shows the total construction and capital cost for the RTC. Appendix C includes more detailed information.

Bloody Run Sub-Basin Costs (2006$)

Project	Total Construction Cost	Capital Cost
Real-Time Control	$2,375,000	$3,421,000

The table below summarizes the total construction cost, capital cost, and lifecycle cost as defined by the LMCPR costing protocol including project-specific real estate costs.

Summary of Identified Sustainable Projects Costs[1] (2006$)

Sub-Basin	Total Construction Cost	Capital Cost	Lifecycle Cost
Lick Run	$121,913,000	$200,492,000	$154,856,000
West Fork	$49,582,000	$73,971,000	$60,067,000
Kings Run (Wooden Shoe)	$16,729,000	$ 27,534,000	$23,055,000
CSO 488 Storage	$7,864,000	$10,651,000	$10,143,000
Bloody Run	$2,375,000	$3,421,000	$2,503,000
Total	**$198,463,000**	**$316,069,000**	**$250,624,000**

1 Sustainable project costs have been reviewed and modified through the LMCPR study for consistency and in accordance with MSD standards.

The Sustainable Alternative project offers integrated grey and green solutions throughout the watershed with natural conveyance and pipe conveyance features to reduce mixing of stormwater and natural drainage with sewage. While the SI solution does include a fair amount of separate stormwater pipes, it also includes a substantial amount of green infrastructure components that play critical functions of the CSO reduction project. The integration allows for improved water quality and/or water quantity reduction solutions to be site specific and create co-benefits where the alternative CSO reduction project is located.

The table below summarizes the overflow reduction in a typical year, capital cost in 2006 dollars and the resulting cost-benefit metric. The overflow reduction volumes were developed from subtracting the system-wide detailed Phase 1 Max Sustainability model results from the updated system-wide detailed model of record version 3.2 results for all of the sub-basins except Lick Run and West Fork Branch. The full system-wide model 4.0.10 is used as the baseline for the Lick Run sub-basin which represents the system as of December 2010 after the RTCs were operational and the raising of the West Fork grates (CSO 5 RTC removed 455 MG in typical year; West Fork grates + CSO 125 RTC removed 97 MG in typical year). By using version 4.0.10 as the baseline, the benefits of the RTCs built before 2010 at Lick Run and West Fork are excluded from the cost benefit metric.

Sustainable Alternative Phase 1 Excluding Existing RTC Benefit and Cost

Watershed/Project	Capital Cost[1] (2006$)	Overflow Gallons Reduction in Typical Year[2] (gallons)	Cost per gallon (2006$/gal)
Lick Run	$200,492,000	726,000,000	$0.28
West Fork	$73,971,000	299,000,000	$0.25
Kings Run	$26,572,000	156,000,000[3]	$0.17
CSO 488 Storage	$10,651,000	47,000,000	$0.23
Bloody Run RTC	$3,421,000	93,000,000	$0.04
TOTAL	**$315,107,000**	**1,321,000,000**	**$0.24**

1 Sustainable project costs have been reviewed and modified through the LMCPR study for consistency and in accordance with MSD standards.

2 Source data for model results includes the following reports and tables: LMC-SA System Wide Model Restructuring Version 3.2 Report, Version 4.0.10, and Version 4.2 (dated June 1, 2012); Lower Mill Creek Partial Remedy Study Revised Plan Phase 1 Report (dated June 1, 2012), and Maximum Sustainable Infrastructure + Real Time Control results table (dated 6/8/2012).

3 Kings Run overflow reduction is equal to the existing system CSO 483 overflow volume minus the proposed system CSO 483 and CSO 217 overflow volumes. Since the CSO 217 will not be nested in the proposed solution, the remaining overflow must be taken into account.

When the four existing RTCs and raising of the West Fork Branch grates are included in the calculation of cost and benefit, the total expended and future costs are: $323.4 million (2006$) with an overall benefit of 2,058 million gallons removed, or $0.16/gallon.

The tables below show the cost and cost/benefit based on revised cost and model data that has been developed subsequent to the Preliminary Findings Report based upon model runs completed in August 2012. Generally the cost-per-gallon metrics were similar between the two sets of numbers.

Sustainable Alternative Phase 1 Including Existing RTC Benefit and Cost

Watershed/Project	Capital Cost (2006$)	Gallons Removed	Cost per gallon
Lick Run	$200,492,000	726,000,000	$0.28
West Fork	$73,971,000	299,000,000	$0.25
Kings Run	$26,572,000	156,000,000	$0.17
CSO 488 Storage	$10,651,000	47,000,000	$0.23
Bloody Run	$3,421,000	93,000,000	$0.04
Four Existing RTCs (1)	$8,301,000	737,000,000	$0.01
TOTAL SI Alternative	**$323,408,000**	**2,058,000,000**	**$0.16**

Note (1) Existing RTCs Project Costs based on actual October 2011 costs

- *CSO 487 Ross Run Twin Outfall RTC $4,122,210*
- *CSO 482 Mitchell Avenue RTC $2,157,630*
- *CSO 125 Badgeley Run Outfall RTC $2,041,070*
- *CSO 5 Lick Run Interceptor Chamber $914,122*
- *Total Actual Capital Cost for RTCs = $9,235,033*
- *De-escalation 4Q2009 to 3Q2006 dollars = 1.112482*
- *Total Actual Capital Cost for RTCs in 2006 dollars $8,301,000*

Additional CSO reduction resulting from "green" projects will provide a greater margin of volume capture certainty. The stormwater capture and therefore potential CSO reduction from the enabled impact projects is not included in the modeling results, and would provide a greater margin of volume capture.

Specific cost information for the identified Phase 1 projects are described in the subsections below.

3. HYDRAULIC & HYDROLOGIC MODELING

3.1. MODEL HISTORY

The early consent decree negotiations required the Defendants to develop a system-wide model under an approved plan by the Regulators. The Regulators approved the model development plan, the completed model and ultimately technical decisions based on the model results. The review of the model and any related risks, and any mitigation actions required were also within the scope of Camp Dresser and McKee Inc. (CDM), as a program manager appointed by the Co-Defendants.

The Lower Mill Creek Partial Remedy Partial Remedy (LMCPR) project has involved a comprehensive review and updating process of the Lower Mill Creek System Wide Model (LMC SWM). The LMC SWM updating process began in 2009 with the intent of an in-depth review on the combined sewer areas overflowing to the Mill Creek. Numerous activities improved system knowledge through flow monitoring, field investigations, review of record drawings, review of Geographic Information System (GIS) information, and operational information. The goal of the model updating processes has always been to improve the ability of the model to predict overflow and support the development of alternative solutions to reduce overflow volumes, and ultimately to serve as a guide to the design process for those solutions.

In 2004, MSD was using the SWMM version 4 model, which was state-of-the-art at the time and used to develop MSD's Capacity Assurance Program Plan (CAPP). Version 4 was converted to SWMM version 5 beta G and used to develop MSD's 2006 Long Term Control Plan (LTCP). The "typical year" was 1970 based upon rainfall analysis of a historical data set (41 inches of rain, and 106 rainfall events having 12-hour dry period between events). The hydrology between separated and combined areas remained the same as in version 5. The Regulators approved MSD's use of version 5 beta G.

The kinematic wave model (version 5 beta G) uses cut-off values to simulate operating conditions. The modeling team performed an assessment at 200 CSO locations to determine the cut-off values used to model the volume of overflows. The modeling team then entered time-steps into the model to predict annual overflows. Simple arithmetic was used to add the values for the resulting 13.893 billion gallons of system-wide overflow. The kinematic wave type of model has significant limitations because the assumptions do not reflect actual system operations. Use of the kinematic wave model limited MSD's ability to reflect system storage.

MSD moved to a dynamic solution so design could be supported for each of the project bundles. Monitoring data collected after 2004 supported model updates. Conversion to the dynamic model involved both physical and operational system changes used to reflect interceptor interactions. This was a reduction in the uncertainty because the dynamic model more realistically models the system components and overflow occurrences.

Modeling technology has evolved with respect to computational power (core and PC machines having 8 processors, 24 gig of RAM, and solid state hard drives).

The dynamic model simulates surcharge and backflow conditions within the interceptors. The dynamic model solves a more robust set of equations, St. Venant Equations. The dynamic model also takes into account the inherent storage present in the interceptors and collection system. While this consideration is not helpful for the larger storms; for the smaller storms system storage prevents overflows from occurring.

The 2011 model update incorporated infrastructure improvements including real time control facilities, new sewers, pump station eliminations, treatment plant upgrades, and the high water/dry weather projects completed by MSD's Wastewater Collections Division. Many of these projects helped minimize the volume of stream flow entering the system, and improve MSD's ability to measure flow at diversion dam locations.

In 2011, MSD converted its SWMM version 5 beta G kinematic wave model to SWMM version 5.0.13 dynamic model. The updated version utilizes more advanced methodology instead of assignment of fixed cut-off values. The updated version offers benefits including:

- more realistically models components of the system;
- incorporation of pan evaporation into the model;
- reviewed hydraulic parameters using construction drawings, CAGIS, and field visits;
- pipe shapes were adjusted to account for the fact many older pipes are not round and were hand constructed;
- some areas of sediment accumulation were noted particularly in locations where system capacity is restricted.

3.2. Model-Related Terminology

During the course of updating the LMC SWM, multiple model versions were developed. The model versions referenced during the LMCPR Study are defined herein for clarity.

WWIP Baseline Model: The WWIP was based upon MSD's system-wide model in affect during 2004-2006. In 2004 MSD's SWM model was originally constructed using SWMM 4.0 software as a detailed hydraulic model using the EXTRAN solution to simulate complex hydraulic conditions. The primary application of the SWM was for capacity assessment (CAPP) and single event analysis. The complexity of the SWM based in EXTRAN made it impractical for CSO planning and long-term simulations. Therefore, the SWMM 4.0 was converted into the newly available (at the time) SWMM 5.0 Beta Version G and converted into a TRANSPORT or kinematic wave model. This version of the model was utilized for development of MSD's Long-Term Control Plan (LTCP) Update.

Updated Baseline Model Version 3.2: The kinematic wave solution does not recognize surcharge or backwater conditions. As such, MSD converted the SWMM 5.0 version from a kinematic wave model to a fully dynamic model using SWMM 5.0.13. Version 3.2 represents MSD's system and installed infrastructure as of December 2007. It is intended to be the updated model of record for use in studying the system response and developing alternatives. The update was a result of reviewing runoff catchment parameters, weir and orifice settings, regulator functions, etc. Dry and wet weather flows were calibrated with flow and level data collected from 2004 – 2011.

Current System Model Version 4.2: The model version 4.2 is based on changes made in the version 3.2 review process. This model contains all sewer infrastructure projects that were constructed after December 2007 through December 2010. These changes include the construction of four Real Time Control (RTC) facilities, grating changes to CSO 191 and CSO 111, West Fork Channel grate modifications, and removal of sediment/sewer cleaning of the Mill Creek Interceptor. This model version also accounted for projects in design or construction during 2011 that will be constructed by 2014. However, evaluation of performance is always done in comparison to version 3.2.

The following completed projects were included in model version 4.2.

- 10142440 = CSO 191 - 7601 Production Drive Grating (V4.0.10, V4.0.11, V4.2)
- 10145220 = RTC at Ross Run at CSO 487 (V4.0.10, V4.0.11, V4.2)
- 10145280 = RTC at Mitchell at CSO 482 (V4.0.10, V4.0.11, V4.2)
- 10145300 = RTC at Badgeley Run at CSO 125 (V4.0.10, V4.0.11, V4.2)
- 10145320 = RTC at Lick Run at CSO 5 (V4.0.10, V4.0.11, V4.2)
- 10240065 = CSO 37 Maple St. Diversion Dam Improvements (V4.0.11, V4.2)
- 10240075 = CSO 39 64th St. Diversion Dam Improvements (V4.0.11, V4.2)
- 10240136 = Spring Grove Ave and Clifton Ave Sewer Separation (CSO 25) (V4.2)
- West Fork Channel Grate Modifications (V4.0.10, V4.0.11, V4.2)
- CSO 111 Grating Modification (V4.0.10, V4.0.11, V4.2)

The following planned projects were included in model version 4.2.

- 10141080 = Ludlow Run (CSO 179)
- 10142020 = Daly Road to Compton Road Sewer Improvements
- 10143220 = CSO 179 Scarlett Oaks Sewer Separation
- 10143960 = VSO 525 Mt. Airy Grating Sewer Separation, Contract 1 only
- 10180900 = Cincinnati State Detention System
- 10180900 = Cincinnati Zoo Sewer Separation
- Stream Separation for CSOs 127 & 128

The details regarding the evolution of the model from version 3 to version 4 are detailed in the *"Lower Mill Creek Systems Analysis Mill Creek Updated Model"* Report prepared by XCG Consultants, Inc. in September, 2010. Additional terminology related to the model and its results are further defined herein.

ALTERNATIVE MODELS: Future condition models were developed for each alternative proposed in this report. These proposed solutions were added into model version 4.2. The CSO statistics were calculated by comparing the results from the alternative model to model version 4.2. These models are denoted as alternative model 4.2.

COMBINED SYSTEM INFLOW: The system inflow is defined as the volume (MG) of flow entering the system consisting of sanitary base flow and storm water inflow. This value is calculated by the model software based upon the system input parameters and hydrology.

STORM WATER SEPARATED: The amount of storm water (MG) redirected away from the system through partial separation projects represents a quantity of storm water that is not being directed to the Mill Creek Wastewater Treatment Plant for processing. It is calculated from the model as the existing system as of December 31, 2007 (version 3.2) combined system inflow minus the alternative's combined system inflow (version 4.2+alternative).

OVERFLOW MITIGATED: The amount of overflow removed from the combined system (MG) is calculated as the existing system as of December 31, 2007 (version 3.2) remaining overflow volume minus the alternative's remaining overflow volume (version 4.2+alternative).

REMAINING OVERFLOW VOLUME: The amount of combined sewer overflow remaining (MG) in the modeled alternative is determined from the model simulation output.

PERCENT CONTROL: The percent control is calculated as the (existing system as of December 31, 2007 (version 3.2) volume minus the alternative remaining overflow volume (4.2)) divided by the existing system as of December 2007 inflow volume. It represents the percent of wet weather flow that has been either removed or not allowed to overflow (captured in the system) from the baseline model condition.

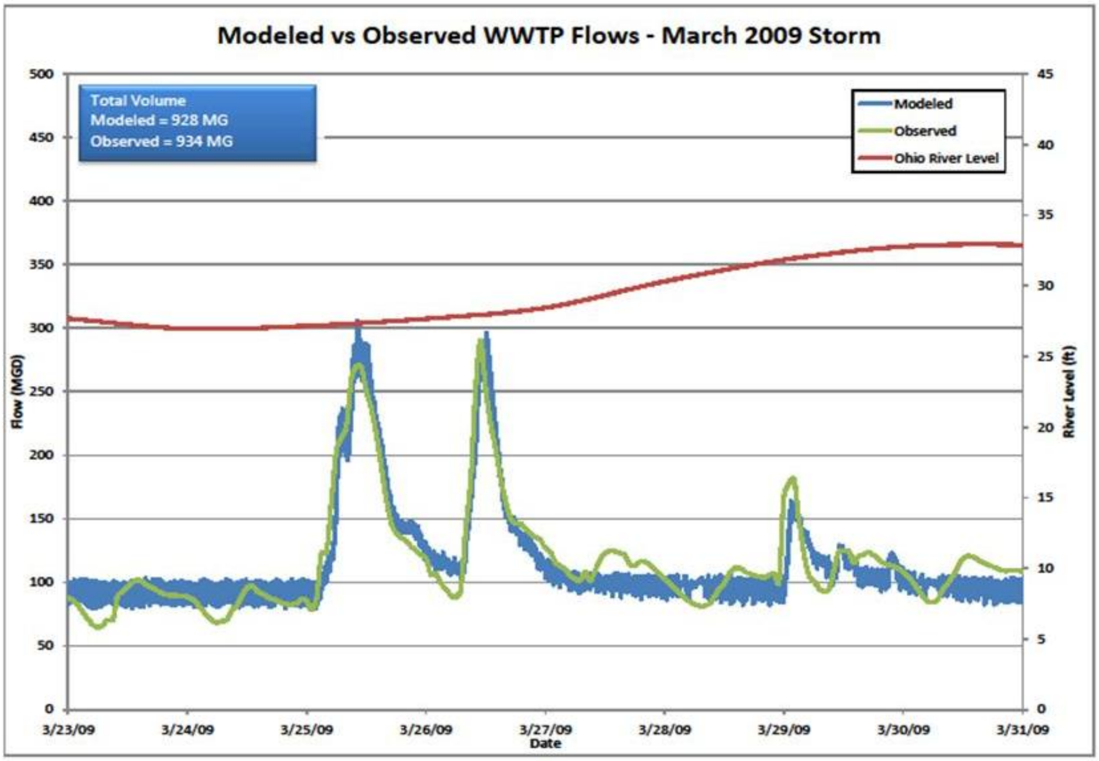
FLOW TREATED AT EHRT: The volume of flow treated at an Enhanced High Rate Treatment facility represents a volume of flow that is captured and directed to a remote treatment facility in lieu of the Mill Creek Wastewater Treatment Plant. It is calculated from the model timeseries results. Note the SSO 700 is not included in these calculations.

FLOW TREATED AT WWTP: The volume of flow treated at the Mill Creek Wastewater Treatment Plant is represented by the underflow volume (MG) reflected in the model. The amount of flow receiving primary treatment is calculated from the model time-series results. The amount of flow receiving secondary treatment is calculated by subtracting the alternative's primary treatment flow from the alternative's flows treated at the WWTP.

3.3. UPDATED BASELINE SYSTEM-WIDE MODEL

The updating process necessitated changes to components of the original SWM hydrologic and hydraulic model based on the availability of new information collected by MSD since the development of the Wet Weather Improvement Program in 2006. Given the changes made to the LMC SWM, a detailed calibration process was undertaken to ensure the model is representative of system performance based on the best available information. Additionally, the model was subjected to a rigorous validation exercise utilizing independent data sets not used in the calibration. The purpose of the validation exercise was to verify that the calibration process had successfully and effectively adjusted the LMC SWM to simulate conditions within the collection system as compared to available data. An example model validation hydrograph is shown in the figure below. Details are provided in report titled *"Lower Mill Creek Partial Remedy System Wide Model Validation Report" prepared by XCG Consultants, Inc. dated January 2012*.

EXAMPLE MODEL VALIDATION HYDROGRAPH



The MSD Modeling Guidelines and Standards were consulted to evaluate whether the peak flow and total volume amounts were within acceptable ranges. The draft modeling guidelines suggest an acceptable difference between observed and model values of -15% to +25% for the peak flow, -10% to +20% for the total flow volume, and -15% to +15% for the peak depth of each storm. The goal for validation was for 60% of the simulated versus measured values (peak flows, volumes, and depths) to be within the acceptable difference.

To calculate percent control and CSO volume removed statistics for proposed and actual projects, all statistics are compared to the December 2007 baseline system performance. For the WWIP, the WWIP Baseline Model was used. For the LMCPR study, MSD proposes to use the Updated Baseline Model Version 3.2, an updated, calibrated, dynamic model that reflects system conditions as of December 2007. It is important to note that model version 3.2 was not available as many of the sustainable projects were studied and evaluated. Therefore, the statistics included in many of the reports are different than those presented in this LMCPR document. As part of the LMCPR study, the modeling of discrete CSO solutions was incorporated as complete alternatives, into the system-wide model, to measure complete solution effectiveness.

As was expected, converting a kinematic-wave model to a fully dynamic model revised the inflow and overflow volumes for the modeled system. A summary of these results is shown in the table below.

MODEL VERSIONS COMPARISON

Model Version	Inflow (MG/year)	Intercepted (MG/year)	Overflow (MG/year)
2006 LTCP Update (Kinematic)	13,282	4,995	8,286
2007 LMC Baseline (Dynamic – Version 3.2)	10,159	5,017	5,231
2010 LMC Current System (Dynamic – Version 4.2)	8,702	4,384	4,421

The WWIP requires that the revised remedy provides equal or greater control of CSO annual volumes as the Original default LMCPR. For the purpose of MSD's LMC Study, 2 billion gallons was used as the metric of CSO control for the Phase 1 alternatives which exceeds the original WWIP control requirement as a percentage of the updated inflow volume.

An important point to remember is that models are a tool to help size facilities which improve on some of the simplified techniques used in the past to size sewer facilities. Models are not 100% accurate, but are based on a reasonable match of observed versus actual conditions for several wet weather periods, they can increase the confidence that a facility is being appropriately and cost-effectively sized.

3.3.1. Rainfall Derived Inflow & Infiltration (RDII)

In the existing conditions system wide model, the surface runoff (stormwater) and any RDII added based on observed data was calibrated to the observed data. In the separation alternatives, the surface runoff volume is maintained in both volume and hydrograph shape by splitting the subcatchment into two new subcatchments and adjusting the widths. The fraction of the original subcatchment that is routed to the storm sewer is the percent effectiveness of the separation. If the percent effectiveness is 75%, then three quarters of the original subcatchment is routed to the proposed storm sewer and the remaining 25% is routed to the combined sewer.

RDII Modeled in System

RDII was added to the existing conditions system wide model along with the surface runoff to the combined system, if the flow monitoring data and the calibration adjustments indicated the need for additional flows. The surface runoff subcatchments were adjusted to match the rising limb, the peak, and the early recession limb of the observed hydrographs. If the later portions of the recession limb of the hydrograph or subsequent peak flows needed additional flows to achieve calibration, RDII was added to the combined sewer flows.

Using the RTK method of three RDII hydrographs (short term, intermediate term, long term), the short term RDII was assumed to be included in the surface runoff modeling and not added to the combined sewer modeling. Short term RDII is the direct connections to the sewer such as downspouts, yard and driveway drains, etc. The RDII added to the combined sewer based on the flow monitoring was assumed to be slower infiltration sources such as leaking laterals and mains. The assumption used in the alternative model reflecting sewer separation was that the intermediate and long term RDII remained in the existing combined sewer while the new storm sewer was installed as a tight pipe with only surface runoff.

RDII Entry into System

The occurrence of infiltration and inflow (I/I) in gravity sewers is influenced by a number of factors, including depth of groundwater, condition of structures, manhole casting type and condition, condition of pipe, pipe joint type and condition, porosity of surrounding soils, topography, flooding susceptibility, sewer hydraulic capacity and cross connections, among other things. For combined sewers and storm sewers, I/I is generally not a significant concern other than it could be an indicator of advanced deterioration of a piping segment. I/I is made up of 2 components, infiltration, and inflow. Infiltration is generally considered to be related to groundwater that leaks continuously into the pipe, at pipe and manhole joints, or through cracks in the pipe or manhole walls. Inflow on the other hand is generally considered to be related to direct sources of flow such as water from a running stream that might run into the top of a manhole or directly connected flows such as downspouts or driveway drains. Often inflow is event driven with peak conditions occurring during periods of extremely wet weather.

When combined sewers and storm sewers are operating at surcharged conditions, the infiltration component of I/I is minimal whenever the groundwater elevations are below the top of the pipe. Under severe surcharged sewer conditions, where water is actually exiting sewer structures (exfiltration or overflowing), the inflow component of I/I is likewise affected. A combined sewer is sized to accommodate inflow up to a certain design runoff event, after which it no longer can accept additional inflow.

The addition of a storm sewer system that operates in parallel with a combined sewer will significantly reduce the occurrence of inflow into the combined sewer, by capturing the storm water runoff that previously had entered the combined sewer. This reduction presumably will reduce the overall hydraulic loading on the combined sewer, to the point where it will see fewer episodes of surcharged operation.

In certain situations, the elimination of surcharged conditions could lead to increased I/I. As previously noted, if groundwater conditions are below the top of the pipe, under surcharged conditions, infiltration of this groundwater into the pipe cannot occur. However, if the surcharged conditions are relieved the opposite is true, and infiltration can occur- when groundwater is present.

For the Lick Run Basin, infiltration is not expected to occur as groundwater conditions throughout the project areas are typically well below the existing combined sewers. Groundwater elevations from over 300 borings that were completed by MSD's soil consultant for the various SI projects provide documentation of these conditions.[96]

In addition to the existing groundwater conditions, the terrain and soils of the basin provide conditions that would also minimize infiltration. Soil conditions throughout the basin are generally Hydrologic Soil Group (HSG) Type C *(Table 2.02-1 of the Lick Run CDR64),* and restrict the free movement of groundwater. This in turn minimizes the groundwater available for pipe infiltration. Furthermore, the vast majority of the Tier 1 areas include hillside slopes in excess of 15 percent *(Figure 2.02-3 of the Lick Run CDR)*. This type of terrain provides for well drained conditions that minimize the potential for groundwater infiltration, in turn also minimizing the groundwater available for pipe infiltration. With these conditions in place, a reduction in surcharged pipe conditions in the combined sewer is unlikely to produce any meaningful changes in the occurrence of pipe infiltration.

The occurrence of inflow into the combined sewer is largely a surface related phenomenon. As with infiltration, the steep, well drained slopes, and relatively tight soils found within the Lick Run Basin provide conditions that would discourage inflow into the combined sewer so long as surface entry points were properly sealed. Replacement of grated lid castings on the combined sewer with watertight castings and elimination of cross connections with storm water inlets and other clear water sources such as drain tiles and roof drains are the types of controls that would further restrict any significant changes in inflow to the combined sewer regardless of its propensity to operate in a surcharged condition.

For Lick Run in particular and for other CSOs generally, the RDII required to cause or extend an overflow is much larger than the dry weather flow (DWF) for the CSO. For Lick Run, the underflow capacity is approximately 30 cfs while the DWF is around 5.5 cfs. Other CSOs have similar ratios of underflow capacity and DWF rates. For the RDII to cause flows at the CSO regulator to be than greater the underflow capacity for meaningful durations, the RDII flows would be apparent during the calibration of the surface runoff against the observed data. The modeled hydrograph would consistently underestimate the recession limb of the hydrograph for most storms. However, that is not what the data and hydrographs show.

3.4. Sub-Basin Models

Modeling for source control projects, especially related to sizing of proposed improvements, is an iterative process involving use of different software from both hydrologic and hydraulic models. Potential CSO reductions from source control projects were assessed using the previously-mentioned Alternative models in the SWMM 5 software.

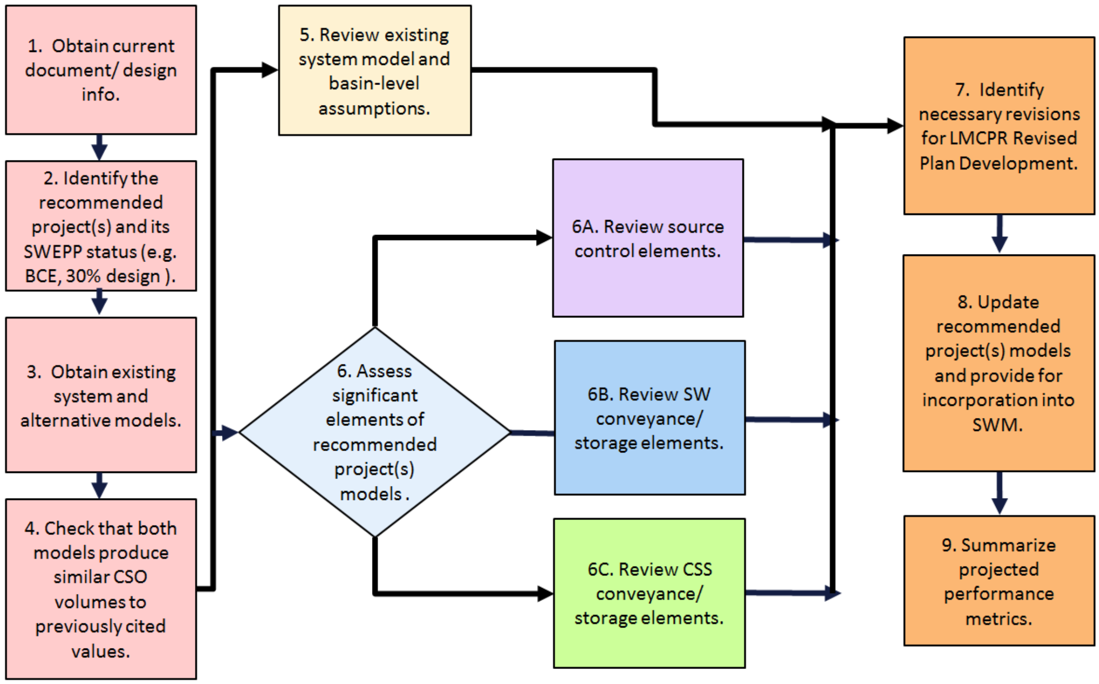
Hydrologic Modeling: Hydrologic models were used to generate flows given topographic and hydrologic parameters. SWMM, Hydro CAD and HEC-HMS were used to varying degrees. These hydrologic flows were used as inputs for hydraulic models in many cases.

Hydraulic Modeling: The proposed storm sewer projects are modeled using XPSWMM, SWMM, CDSS or StormCAD to determine appropriate pipe sizes, slopes, and invert elevations necessary to meet local design requirements and avoid existing utility conflicts. Input parameters include in part or in total, the following: existing ground surface, preliminary storm sewer alignments and profiles, pipe material, and structure size information. The peak flows, as determined from the hydrologic model results, are entered at each anticipated change in flow (inlet, catch basin, headwall, and detention basin outfall). Modeling is completed based on Stormwater Management Utility (SMU) Rules and Regulations and specific guidance provided by SMU. Stream systems were modeled using HEC-RAS.

Originating from MSDGC’s Sustainable Watershed Evaluation Planning Process, sustainable projects from six sub-basins were assessed to identify solutions for use in the development of system-wide alternatives for the LMCPR Revised Plan. These alternative evaluations used MSDGC’s System-Wide Model (SWM) to establish benefits from the sustainable projects with the overall alternative targeting equal or greater control of annual CSO volumes as the Default Plan by the end of Phase I.

The model review approach includes detailed evaluations of the existing system and alternative models for the sustainable projects within the sub-basins of interest. The figure below shows the overall model review process, which focuses on reality and consistency checks of the magnitude of potential CSO and stormwater (SW) runoff volume reductions across the various projects and consistency with the LMCPR Default Plan projections.

Sustainable Project - Model Review Process



With the focus on consistency checks of the magnitude of potential CSO reductions from implementation of these projects, the model review included the following elements:

- Evaluating input data (level of detail, hydraulic and hydrologic inputs, etc.) within the existing system model, relative to assessing the benefits of the proposed sustainable projects;
- Evaluating if implementation and performance assumptions for source control sustainable projects are realistic;
- Confirming that model inputs for the source control sustainable projects comply with MSDGC/industry standards modeling guidance;
- Documenting sizing criteria, and confirming that storm sustainable projects, where explicitly modeled, divert stormwater flows correctly and appropriately.

Meetings were held with the sustainable project teams to document the performance assumptions and methodology. Modifications were made to the model as necessary to improve consistency across the sustainable projects and to ensure that the basin models could be uploaded into the system-wide model.

3.5. Performance Assumptions

With separation a significant part of the recommended suite of projects, confirming realistic implementation and performance assumptions is an essential step in reality-checking the magnitude of potential CSO volume reductions. However, identifying realistic and achievable performance goals is challenging because of the large number of often site-specific factors, which influence CSS separation success. These factors include:

- Distribution of stormwater source type (streets, roofs, etc.)
- Public vs. private sources

- Tributary sewer type (storm only, CSS, etc.)
- Tributary sewer age and condition
- Location and age of nearby existing sewers
- Land use
- Impervious area
- Topography
- Soils
- Proposed separation technology
- Implementation practices during construction

Guiding questions for review of the implementation and performance assumptions include:

- What were the separation assumptions?
- As stated, where they implemented correctly within the model?
- Are these assumptions realistic for the selected separation area?
- Are these assumptions consistent with assumptions across all SI project models?
- Is additional conservatism in the performance assumptions desired for the LMCPR Study?
- How significant an impact will the proposed changes have on projected annual CSO volume ?

For the sustainable separation projects, initial implementation and performance assumptions (i.e. percent effective statistics) were assigned based on sub-basin specific evaluations, where the level of detail in those evaluations varied with the project's status (i.e., conceptual planning through preliminary/detailed design) in the SWEPP. These percent effective statistics were subsequently revised in order to ensure a consistent methodology across all sub-basins. The revision process included application of threshold values for percent effectiveness to confirm realistic assumptions for separation success in each sub-basin. Assessing the implementation and performance assumptions is an essential step in reality-checking the magnitude of potential CSO reductions, since approximately 66% of the CSS drainage area in the six sub-basins is targeted for separation.

The Mill Creek SWM uses RTK unit hydrographs for representing RDII flows in the CSS for several sub-basins; therefore, the evaluations of the implementation and performance assumptions used percent reductions in wet-weather volume as the metric for percent effectiveness. This metric is appropriate for RTK models, as it integrates the effectiveness of a potentially large set of model RTK parameters into a single measure. The explicit definition for "Percent Wet-Weather Volume Reduction" is provided below:

Percent Wet-Weather Volume Reduction =

$$\frac{\text{(Total runoff volume and RDII volume re-directed to the SW system)}}{\text{(Total runoff volume and RDII volume from the project basin)}} \times 100$$

The table below provides the initial wet-weather volume reduction statistics for the sustainable projects by sub-basin along with the CSS runoff drainage area and the total area targeted for separation (Tier 1 or "priority" areas). These calculations were developed by the SWEPP consultants and constitute the original implementation and performance assumptions used for each sub-basin's sustainable separation projects. Open space Tier 1 areas with percent wet-weather volume reduction values at or near 100% constitute significant portions of Kings Run sub-basin. These areas are dominated by large-scale opportunities to remove stream flow and/or existing local separate storm systems from the CSS. Percent wet-weather volume reduction values for the other four sub-basins also track with the land use/development density, with lower values correlating with the more dense urban sub-basins.

Initial Percent Wet-Weather Volume Reduction Averages for Sustainable Projects

Sub-Basin	Separation Type Technology	Modeled Drainage Area Tributary to CSS (acres)[1]	Tier 1 Area/ Drainage Area Targeted for Separation (acres)[1]	Initial Percent Wet-Weather Volume Reduction Averages[1]			
				Tier 1 – Open Space/ Transportation (O/T) Areas	Tier 1 – Developed (D) Areas	Weighted Average over Tier 1 Areas	Weighted Average over Entire Sub-Basin
Bloody Run	Partial separation with new storm infrastructure	2,224	1,237	57%	63%	62%	31%
Kings Run	Partial sewer and stream separation with conversion of CSS sewers to storm	1,145	425	100%	100%	100%	34%
Lick Run	Partial separation with new storm infrastructure	2,878	1,922	92%	83%	87%	58%
West Fork	Partial sewer and stream separation with conversion of CSS sewers to storm, new storm sewers	2,973	2,069	86%	71%	83%	52%

1. Source data for model results is the original sub-basin models for the sustainable projects received from MSDGC/ SWEPP consultant in Fall 2011 plus model review updates for hydrologic inputs.

The implementation and performance assumptions review began by comparing the initial percent wet-weather volume reduction statistics for the two land use/development categories within the Tier 1 areas with threshold metrics, summarized below:

- **Open space/ Transportation Areas (O/T):** Maximum 95% reduction in wet-weather volumes with routing to storm systems, and
- **Developed Areas (D):** Maximum 50% reduction in wet-weather volumes with routing to storm systems, averaged across the Tier 1 areas and subject to local impervious cover estimates/ separation implementation choices.

The land use/development categories of "Open Space/Transportation" and "Developed" were assigned to each Tier 1 subcatchment based on reviews of recent digital aerial photos and CAGIS. The term "Developed" was applied quite broadly and includes both low density suburban areas and high density urban development. The threshold value for open space/transportation areas was selected to provide a level of conservatism even for area, that are easily separated. Five percent of the pre-separation drainage area remains on the CSS to account for situations where stormwater runoff from damaged pipes and manholes may continue flowing into the CSS.

For developed areas, values less than 50% are typical conceptual planning assumptions for projects involving separation of streets and sidewalks draining into the public right of way in dense urban areas; therefore, the threshold metric of 50% is reasonable. These assumptions are high-level and do not include site visits or extensive topographic analysis. Higher percent reductions in dense urban areas typically require private property inflow removal programs (i.e., separation of sump pumps, downspouts, area or driveway drains from the CSS) supported by field reconnaissance investigations.

Values in the original models above the threshold values then triggered more detailed reviews and meetings with MSDGC and the SWEPP consultant teams to document the specific situations and evaluations which support those implementation/performance assumptions. In many cases, higher values were appropriate based on the targeted stormwater sources (i.e., streets, roofs, already separated mini-systems, stream day lighting), level of field investigations, the location of nearby existing sewers, and the proposed separation technology, etc. In other cases, the review led to a reduction in the initial values, to ensure consistency across project areas.

The table below also provides justification for the revised wet-weather volume reduction percentages for developed areas in the other sub-basins of interest with its summaries of implementation choices, level of field investigations, and comparisons between model inputs and the targeted impervious cover/stormwater source type (i.e., targeted for separation).

Initial Implementation/Performance Assumptions Summary for Sustainable Projects

Sub Basins	Separation Assessment Level of Detail	Implementation Details – Initial Models	Tier 1 – Average Modeled Impervious Percentage Remaining on CSS[1]	Priority Area – CAGIS Impervious Area Percentages			Comments
				Public ROW	Roofs	Misc. Private Sources	
Kings Run	**Low** Aerial photos/CAGIS	Removal of all SW runoff sources	24%	25%	28%	47%	Model revised with roofs staying on CSS;; Pervious area in same proportion. OK to exceed thresholds, since model consistent with project implementation choices/costs to capture cost-effective private sources RTK not added to CSS for new 8,500 LF relocated CSS sewer (RDII *flows << CSS flows still in system).*
Lick Run	**High** Windshield surveys, aerial photos/CAGIS during conceptual planning; Field investigations of 87 subcatchments during design confirmed original values	Removal of all SW in the public ROW, and private pervious & impervious surfaces which drain to/near to public ROW (i.e., areas, which can be cost-effectively separated); Values not explicitly connected to removal of specific SW sources, but rather based on estimated percent area reductions assigned by subcatchment;	19%	23%	29%	48%	No changes in separation assumptions, although effects of downspout disconnect in non-priority areas were removed. Separation assumptions are slightly more aggressive than other sub-basins; however, separation assessment level of detail is higher. Model assumptions consistent with removal of all public ROW, private pervious & impervious surfaces, and 1/3 of roof drains). OK to exceed thresholds, since these values were confirmed through field reconnaissance during design. No RTK in existing system model

Sub Basins	Separation Assessment Level of Detail	Implementation Details – Initial Models	Tier 1 – Average Modeled Impervious Percentage Remaining on CSS[1]	Priority Area – CAGIS Impervious Area Percentages			Comments
				Public ROW	Roofs	Misc. Private Sources	
West Fork	**WNB CSOs - High** Parcel level-assessment **Remaining CSOs - Low** Windshield surveys; short field walks, aerial photos/CAGIS	**WNB CSOS –** Removal of all SW runoff from public ROW & private pervious / impervious surfaces which drain to/near to public ROW. Roofs/depressed driveways remain connected to CSS. **Remaining CSOs -** Removal of all SW runoff from public ROW and impervious surfaces which drain to/near to public ROW. Roofs remain connected to CSS, except where buildings are in floodplain (to be removed) or drain to defined connection point.	26%	31%	31%	38%	No changes in separation assumptions. Model assumptions consistent with removal of all public ROW, private pervious & impervious surfaces and ~16% of roof drains). OK to exceed thresholds, since these values were confirmed through field reconnaissance during design (WNB CSOs); without WNB CSOs, model assumptions consistent with removal of all public ROW, private pervious & impervious surfaces, and percent of roof drains). RTK to CSS/SW – separation technology dependent ; RTK not added to CSS for new 12,500 LF relocated CSS sewers (RDII flows << CSS flows still in system).

Following the detailed reviews and discussions with the sustainable project teams, modifications were made for use on the LMCPR Study. The tables below summarize the updated implementation/performance assumptions and the revised percent wet-weather volme reduction statistics for each sub-basin. The two main reasons for the reduced percentages include:

- Maintaining private property connections on the CSS, if they are currently assumed to drain to the CSS (e.g. roof downspouts), since the sustainable projects do not assume costs of private property separation.
- Implementing a 95% reduction cap (by area) for open space and transportation areas on average.

While the average wet weather volume reduction percentages for developed areas do exceed the threshold values, these values are typically applied for conceptual planning in dense urban areas. As shown in the tables below, most of the sustainable projects draw on site-specific assessments to some degree in the predictions of sewer separation success, which allows a lower level of conservatism.

Revised Percent Wet-Weather Volume Reduction Averages for Sustainable Projects

Sub-Basin	Revised Percent Wet-Weather Volume Reduction Averages[1]			
	Tier 1 – Open Space/ Transportation (O/T) Areas	Tier 1 – Developed (D) Areas	Weighted Average over Tier 1 Areas	Weighted Average over Entire Sub-Basin
Bloody Run	56%	61%	60%	30%
Kings Run	95%	76%	86%	29%
Lick Run	92%	83%	87%	58%
West Fork	81%	72%	79%	47%

Revised Implementation/Performance Assumptions Summary for Sustainable Projects

Sub-Basin	Separation Type Technology	Implementation Details within Sub-Basin
Bloody Run	Partial separation with new storm infrastructure	• O/T–Max 98% removal of SW (by area) for some areas directly abutting new storm sewer routes • Developed – Roofs/some grounds > 20 yrs old remain connected • RTK stays on CSS
Kings Run	Partial sewer and stream separation with conversion of CSS sewers to storm sewers	• O/T– Max 95% removal of SW runoff (by area) • Developed - Imp area remains on CSS = CAGIS roof fraction; Perv area in same proportion. • No RTK for CSS in separated areas (current version of model)
Lick Run	Partial separation with new storm infrastructure	• Removal of SW runoff in proportions at right • No RTK
West Fork	Partial sewer and stream separation with conversion of CSS sewers to storm sewers, new storm sewers	• O/T– Max 95% removal of SW runoff (by area) • Developed – Various (no change) • RTK to CSS/SW – separation technology dependent

3.6. Field Verification of Local Data

Recognizing the limitations encountered with collection of raw data at CSO 5, MSD conducted an evaluation to develop detailed percent effective values for the Tier 1 areas within the Lick Run Watershed. The detailed values were then compared to the original percent effective values and any changes were incorporated into the combined sewer model to determine impacts to estimated CSO reduction. The objective of this evaluation was to quantify the volume of stormwater runoff within the Lick Run Watershed that is anticipated to be collected by the proposed storm sewers. Specific tasks completed during the evaluation are described below.

<u>Digitization of Impervious Areas</u>

The first step in calculating new percent effective values was to digitize the impervious areas for the 125 catchments, as delineated in the combined sewer model, that comprise the Lick Run Watershed. CAGIS has an impervious area shapefile, but a distinction between types of impervious areas is not made. In addition, discrepancies between the shapefile and aerial photography were noted in some locations. Consequently, the existing CAGIS impervious area shapefile was not deemed accurate enough for this evaluation. MSD's Consultant, Strand & Associates, developed a new shapefile for the Lick Run Watershed which subdivided impervious area into buildings, roadways, driveways and sidewalks, parking lots, and miscellaneous impervious areas. Any area that was severely compacted, such as a gravel lot, was considered a miscellaneous impervious area. CAGIS does have individual shapefiles for buildings and roadways, and those were utilized to save time and effort. Driveways and sidewalks, parking lots, and other miscellaneous impervious areas were digitized by hand using 2011 aerial photography.

Field Investigations

After the detailed impervious area shapefile was created, field investigations were conducted for the 87 Tier 1 catchments, those that would have stormwater runoff entering the proposed storm sewers. The field investigations were conducted to gather information on specific impervious areas and identify discrepancies with the digitized impervious areas. Field reconnaissance was not performed in Tier 2 catchments because the percent effectiveness for these areas was assumed to be zero, i.e. all stormwater runoff will enter the combined sewer system, it was not necessary to make detailed observations on impervious areas.

- DOWNSPOUTS. Downspouts were checked on buildings to identify those that appeared to be disconnected from the combined sewer system. Where possible, the entire building was evaluated for disconnected downspouts; however, this was not always possible. If buildings were not accessible or downspouts were not visible they were assumed to be connected to the combined sewer. No residential private properties were entered during this effort. Downspouts were assumed to be disconnected if they met one of the following criteria:
    - The downspout entered the ground but a pipe from the property discharged to the curb.
    - The downspout was connected to a building within a larger development, e.g. a school or apartment complex, that is served by a separate storm sewer system according to CAGIS.
    - The downspout had fittings, bends, and/or appurtenances allowing runoff to flow overland.
    - In several instances downspouts did not enter the ground, but the disconnection did not appear to be intentional. For example, a section of downspout was missing and appeared to have fallen off or a section of gutter was missing. In these cases it was assumed that at some point, the downspout could easily be re-connected to the combined sewer and therefore the disconnection was termed accidental. For this evaluation, no credit was taken for accidental disconnections.
    - This downspout survey increased percent effective calculations because stormwater runoff from disconnected downspouts was assumed to flow overland and eventually enter the proposed storm sewer system. The original percent effective values were developed assuming rooftop areas drain to the combined sewer system with the exception of buildings that meet the second criteria listed above.
- PARKING LOTS. Large parking lots were also investigated to attempt to identify drainage patterns. Inlets, structures, and topography were noted, and used in conjunction with CAGIS information and record drawings, to determine the routing of stormwater runoff. This information was used to determine the volume of runoff anticipated to be captured by the proposed storm sewer system, and therefore the percent effective values were affected. The original percent effective values were developed assuming stormwater runoff from parking lots within the Tier 1 areas would enter the proposed storm sewer system.
- DRIVEWAYS. Driveway slopes were observed to determine if stormwater runoff was directed toward the street or the building. Stormwater runoff from driveways that sloped toward the street was assumed to enter street inlets while runoff from driveways that sloped toward the building was assumed to enter the combined sewer system directly. This impacted the percent effective calculations because runoff entering street inlets is

anticipated to be rerouted to the proposed storm sewers. The original percent effective values were developed assuming stormwater runoff from driveways within the Tier 1 areas would enter the proposed storm sewer system.

In addition, portions of the existing landscape changed since the 2011 aerial photograph was developed, including the demolition of houses and parking lots. Based on the results of the field reconnaissance, several modifications to the detailed impervious area shapefile were made.

Data Input

Following the field investigations, the data was compiled and entered into the detailed impervious area shapefile. Each impervious area shape was assigned a percent removed factor, used to represent the estimated amount of the area that would enter the proposed storm sewer system. For example, if a parking lot had a separate storm sewer system that was being rerouted to the proposed storm sewer system, it was assigned a percent removed factor of one. Single-family, detached residential buildings were assumed to have four downspouts unless more were observed during the field investigations. So if a building in this category had one disconnected downspout then a percent removed factor of 0.25 was assigned (i.e., stormwater runoff from one out of four downspouts will enter the proposed storm sewer system and therefore be removed from the combined sewer system). A percent removed factor of zero was used for all areas that would stay connected to the CSS.

Other impervious area shapes, including roadways, driveways and sidewalks, parking lots, and miscellaneous impervious areas, were assigned a percent removed factor of either zero or one. In cases where stormwater runoff from one of the impervious areas listed above is anticipated to enter both the proposed storm sewer system and the combined sewer system, the shape was split to accurately reflect drainage areas to each of the primary conveyance systems.

In some cases the stormwater collection and conveyance system in parking lots was not obvious through field investigations and review of available record drawings. Consequently, an accurate determination regarding the downstream connectivity of the stormwater infrastructure from these sites required additional information from MSD.

3.7. Model Results

For Revised Plan, the corresponding model run reference is SWM version 4.2 Detailed, Phase I Max Green, dated June 8, 2012. For the Attachment 1C Existing Four RTCs, the corresponding model run reference is Appendix E, *LMC-SA System Wide Model Restructuring Version 3.2 Report,* June 1, 2012. Volume and percent control values are based on a comparison with SWM Version 3.2 Detailed inflow and overflow values. The resulting CSO reduction and other system benefits are summarized in the table below in comparison to the updated baseline model version 3.2. This suite of projects reduces the overflow volume by 2,058 million gallons.

PHASE 1 SUSTAINABLE/HYBRID ALTERNATIVE PERFORMANCE METRICS

Performance Metrics	Updated Baseline Model 3.2	Phase 1 Sustainable/Hybrid Alternative
Combined System Inflow (MG)	10,148	7,710
Stormwater Separated (MG)	0	2,978
Overflow Mitigated (MG)	0	2,024
Flows Treated at EHRT (MG)	0	17
Flows Treated at WWTP (MG)	5,071	4,080
Remaining Overflow (MG)	5,077	3,145
Watershed % Control	50%	71%
Number of CSOs Eliminated	5	10
Number of CSOs > 85% Control	29	29
Number of CSOs < 85% Control	69	49
No. of CSOs >100 MG overflow	11	9

Detailed CSO benefits are summarized in the table below.

REVISED PLAN ALTERNATIVE PERFORMANCE METRICS PER CSO

<table>
<tr><th rowspan="2">CSO</th><th colspan="3">SWM Version 3.2 Detailed</th><th colspan="3">SWM Ver. 4.2 Detailed - Phase 1 Sustainable with Existing RTCs[1]</th></tr>
<tr><th>Inflow, MG</th><th>Overflow, MG</th><th>Percent Control</th><th>Overflow Volume Removed, MG</th><th>Overflow Remaining, MG</th><th>Percent Control</th></tr>
<tr><td colspan="7">Attachment 1C Existing Four RTCs[2]</td></tr>
<tr><td>5</td><td>1,844</td><td>1,454</td><td>21%</td><td>455</td><td>999</td><td>46%</td></tr>
<tr><td>482</td><td>485</td><td>219</td><td>55%</td><td>34</td><td>185</td><td>62%</td></tr>
<tr><td>485/487</td><td>828</td><td>346</td><td>58%</td><td>151</td><td>195</td><td>76%</td></tr>
<tr><td>125 + Raising West Fork Grates</td><td>1,671</td><td>376</td><td>77%</td><td>97</td><td>279</td><td>83%</td></tr>
<tr><td colspan="7">Revised LMCPR Plan[3]</td></tr>
<tr><td>5[4]</td><td colspan="3"></td><td>726</td><td>273</td><td>85%</td></tr>
<tr><td>217[5]</td><td>148</td><td>103</td><td>30%</td><td rowspan="2">156</td><td>13</td><td>91%</td></tr>
<tr><td>483</td><td>280</td><td>193</td><td>31%</td><td>24</td><td>91%</td></tr>
<tr><td>181</td><td>1,294</td><td>595</td><td>54%</td><td>93</td><td>502</td><td>61%</td></tr>
<tr><td>488</td><td>146</td><td>71</td><td>51%</td><td>47</td><td>24</td><td>84%</td></tr>
<tr><td>117</td><td>8</td><td>2</td><td>75%</td><td>1</td><td>1</td><td>91%</td></tr>
<tr><td>123</td><td>0</td><td>0</td><td>100%</td><td>0</td><td>0</td><td>100%</td></tr>
<tr><td>125[4]</td><td colspan="3" rowspan="2"></td><td>138</td><td>50</td><td>82%</td></tr>
<tr><td>West Fork Grates[4]</td><td>91</td><td colspan="2">Eliminated</td></tr>
<tr><td>126</td><td>53</td><td>28</td><td>46%</td><td>28</td><td colspan="2">Eliminated</td></tr>
<tr><td>127</td><td>26</td><td>16</td><td>37%</td><td>16</td><td colspan="2">Eliminated</td></tr>
<tr><td>128</td><td>14</td><td>6</td><td>58%</td><td>6</td><td colspan="2">Eliminated</td></tr>
<tr><td>130</td><td>198</td><td>47</td><td>76%</td><td rowspan="2">18</td><td rowspan="2">38</td><td rowspan="2">84%</td></tr>
<tr><td>203</td><td>35</td><td>9</td><td>73%</td></tr>
<tr><td>527</td><td>3</td><td>0</td><td>87%</td><td>0</td><td>0</td><td>90%</td></tr>
<tr><td>528</td><td>5</td><td>0</td><td>96%</td><td>0</td><td>0</td><td>100%</td></tr>
<tr><td>530</td><td>12</td><td>1</td><td>96%</td><td>1</td><td>0</td><td>99%</td></tr>
<tr><td>529</td><td>5</td><td>0</td><td>95%</td><td>0</td><td>0</td><td>100%</td></tr>
<tr><td>Overall Totals</td><td>6,907</td><td>3,363</td><td>51%</td><td>2,058</td><td>1,305</td><td>81%</td></tr>
</table>

1. Identified Phase I Sustainable Alternative includes projects for the Lick Run, West Fork, and Wooden Shoe watersheds, RTC at Bloody Run, and storage at CSO 488.
2. CSO volume reductions were calculated from the Appendix E, *LMC-SA System Wide Model Restructuring Version 3.2 Report,* June 1, 2012.
3. CSO volume reductions were calculated from the Maximum Sustainable Infrastructure + Real Time Control results tables (dated 6/8/2012) ("Phase I Max Green" or "Phase I Option A" scenarios as applicable). Values for the CSO 488 storage were calculated from the "Phase I Option A " scenario. Values for Bloody Run RTC benefit are cited as 93 MG in the Lower Mill Creek Partial Remedy Study Revised Plan Phase 1 Report, June 2012 (Section 3.1.3.3).
4. Percent control and volume removed statistics calculated relative to Detailed Model Version 3.2 SWM results listed earlier in table.
5. Totals for CSO 217 are treated differently in overall calculations since CSO 217 overflows to an open channel which enters the system at CSO 483. The sustainable solution removes the nested relationship of the two CSOs. Remaining volume of CSO 217 is accounted for in the Phase 1 sustainable results since it reaches the Mill Creek.

3.8. Sensitivity Analysis of Performance Metrics

The success achieved through separation projects can vary significantly depending on several factors, including the actual stormwater runoff sources removed and implementation practices during construction. As a result, the assumed effectiveness used in the LMCPR Study, no matter how justified during analysis, may not be achieved during implementation. To consider this uncertainty, sensitivity analyses have been performed to evaluate changes in CSO performance metrics with decreasing success in separation.

The sensitivity analysis regarding sewer separation effectiveness was first completed in 2010 prior to having the more detailed flow monitoring data, so extreme departures from the estimated percent effectiveness values were examined (i.e. as much as 50 or 75 percent). After a thorough review of how the percent effectiveness values were estimated, including two or three iterations in some sub-basins, the percent effectiveness values were lowered in the current analysis for the LMCPR study. They were adjusted further based on the flow monitoring results in separate sanitary and storm sewer areas. In the current analysis summarized in this section, the range of departure from the performance effectiveness assumptions was 15 and 25 percent.

Focusing on the identified Phase I sustainable alternative, the tables below summarize the resulting changes in annual CSO volume reductions with decreasing success in separation. In these model runs the decreased success in separation was simulated by assuming uniform reductions in the runoff drainage area diverted to storm systems through separation (i.e., additional area remained tributary to the combined sewer system). For example, the "15% Reduction in Separation Area to Storm" scenario involves a 15% reduction in the total area being routed to the storm system for areas being separated, with corresponding increases in tributary area and runoff volume routed to the combined sewer system.

Based on an understanding of how the performance effectiveness assumptions were developed, vetted, and modified, it is now considered likely that decreases in separation success would be limited to a 15% departure from the assumed percent effectiveness values. A 25% departure would constitute a very pessimistic upper boundary.

Sensitivity Analysis for Phase 1 Sustainable Alternative Including Existing RTCs and Raising West Fork Branch Grates

Sensitivity Analysis for Phase I Sustainable Alternative[1]	Total Annual CSO Volume Reductions (Phase 1 SI projects + Existing RTCs)[2]	Total Reduction Over (Under) 2.013 BG Target
Baseline (e.g., Identified Phase I Sustainable Alternative)	2,058 MG[3]	45
Baseline with 15% Reduction in Separation Area to Storm [4,5]	1,925 MG	(88)
Baseline with 25% Reduction in Separation Area to Storm [4,5]	1,832 MG	(181)

1. Phase I Sustainable Alternative includes partial separation for the Lick Run, West Fork, and Wooden Shoe watersheds only paired with RTC at Bloody Run and storage at CSO 488.
2. Annual CSO volume reductions include reductions associated with all proposed Phase I projects and the existing RTCs and raising of the West Fork Branch grates.
3. CSO volume reductions were calculated from the Maximum Sustainable Infrastructure + Real Time Control results tables (dated 6/8/2012) ("Phase I Max Green" or "Phase I Option A" scenarios as applicable). Values for Bloody Run RTC benefit are cited as 93 MG in the Lower Mill Creek Partial Remedy Study Revised Plan Phase 1 Report, June 2012 (Section 3.1.3.3).
4. Decreased success in separation was simulated by assuming uniform reductions in the runoff drainage area diverted to storm systems through separation for Lick Run, West Fork, and Wooden Shoe watersheds.
5. Incremental decreases in annual CSO volume reductions were calculated using sensitivity model runs (Consolidated model) described in Section 4.6.3, Working Draft Sustainable Projects Lower Mill Creek Partial Remedy Study Report, July, 16, 2012.

The sensitivity analysis above also shows that the relationship between lowering the percent effectiveness and the corresponding lowering of the modeled CSO volume reduction is not linear. Instead, the lowering of the CSO volume is less on a percentage basis. For the identified Phase 1 sustainable projects, including the existing RTCs and raising of the West Fork Branch grates, the following relationships are noted:

- 15% reduction in separation area = 6.5% decrease in the annual CSO volume reduction of the combined existing RTCs, raising of the grates, and the identified Phase 1 sustainable projects.
- 25% reduction in separation area = 11% decrease in the annual CSO volume reduction of the combined existing RTCs, raising of the grates, and the identified Phase 1 sustainable projects.

For the identified Phase 1 projects, excluding the RTCs and raising of the West Fork Branch grates, the following relationships are noted:

- 15% reduction in separation area = 10% decrease in the annual CSO volume reduction of the identified Phase 1 projects.
- 25% reduction in separation area = 17% decrease in the annual CSO volume reduction of the identified Phase 1 projects.

Focusing on Lick Run only without the existing RTC, the relationships become more linear because of the site-specific hydraulic nature of the system and the types of proposed sustainable projects:

- 15% reduction in separation area = 13% decrease in the annual CSO volume reduction for Lick Run only.
- 25% reduction in separation area = 23% decrease in the annual CSO volume reduction for Lick Run only.

The sensitivity analysis provides an analytical methodology for understanding the risk associated with not meeting the WWIP objective of significant overflow reductions in Phase 1. The results of this analysis were used in this recommendation of the projects suite that MSD is proposing as the alternative to the default remedy to the City Manager and County Commissioners.

Sensitivity Analysis for Phase 1 Sustainable Alternative Excluding Existing RTCs

Sensitivity Analysis for Phase I Sustainable Alternative[1]	Total Annual CSO Volume Reductions	Total Alternative Cost[2]	Alternative Cost Per Gallon[2]
Baseline (e.g., Identified Phase I Sustainable Alternative)	1,321 MG[3]	$316,069,000	$0.24
Baseline with 15% Reduction in Separation Area to Storm [4,5]	1,188 MG	$316,069,000	$0.27
Baseline with 25% Reduction in Separation Area to Storm [4,5]	1,095 MG	$316,069,000	$0.29

1. Phase I Sustainable Alternative includes partial separation for the Lick Run, West Fork, and Wooden Shoe watersheds only paired with RTC at Bloody Run and storage at CSO 488.
2. Annual CSO volume reductions include reductions associated with all proposed Phase I projects and the existing RTCs and raising of the West Fork Branch grates.
3. CSO volume reductions were calculated from the Maximum Sustainable Infrastructure + Real Time Control results tables (dated 6/8/2012) ("Phase I Max Green" or "Phase I Option A" scenarios as applicable). Values for Bloody Run RTC benefit are cited as 93 MG in the Lower Mill Creek Partial Remedy Study Revised Plan Phase 1 Report, June 2012 (Section 3.1.3.3).
4. Decreased success in separation was simulated by assuming uniform reductions in the runoff drainage area diverted to storm systems through separation for Lick Run, West Fork, and Wooden Shoe watersheds.
5. Incremental decreases in annual CSO volume reductions were calculated using sensitivity model runs (Consolidated model) described in Section 4.6.3, Working Draft Sustainable Projects Lower Mill Creek Partial Remedy Study Report, July, 16, 2012.

3.9. Flow Monitoring Program

MSD has on an on-going program of monitoring the combined sewer areas throughout its service area. The program has three major focuses:

- Overall Monitoring of the Combined Sewer System - The overall monitoring uses long term flow monitoring sites on major pipes and interceptors that can be used to calibrate and validate the System Wide Model.

- Specific Project Monitoring - Specific project monitoring uses a number of monitoring sites in and around near term projects to develop calibration of detailed models of the project area. The project area calibration supports the sizing of the specific project, modeling the impacts of the proposed project, and adds areas of detailed calibration to the System Wide Model.

- Overflow Monitoring - Overflow monitoring consists of level monitors at the overflow locations. The overflow monitoring is focused on detecting dry weather overflows and to aid in developing overflow reports to regulators. While not intended for model calibration, the overflow monitoring data can be used as a check on the overflow modeling.

Direct measurement of overflow volume reduction at CSO structures is difficult to accomplish, if not impossible, due to many factors including, but not limited to:

- large influent pipe size,
- highly variable flow and hydraulic conditions,
- hydraulic interference (i.e. receiving water levels),
- characteristics of combined wastewater (i.e. debris), and
- remote CSO structure locations.

Even if direct measurements of CSO volumes were practical to obtain, comparison of CSO volume measurements obtained before removal of stormwater from the combined sewer system with CSO volume measurements obtained following removal of stormwater from the combined sewer system as a result of constructing the SI projects, would be of limited use given the highly variable nature of wet weather events and their impact on receiving collection systems.

For instance, if pre-construction data were collected in a relatively dry period, and post- construction data were collected in a relatively wet period, it would be difficult to reach any meaningful conclusions concerning the impact that the SI projects had on CSO volume reductions. The pre- and post- measurement periods would need to occur over a substantial amount of time, so that normalcy can be applied to both conditions. Therefore, given the limitations associated with the use of direct measurements for the purpose of comparative analysis, hydraulic modeling is an industry standard developed and used to provide a more reliable comparison.

Hydraulic models of the system can be systematically created and calibrated to provide a useful understanding of overall system performance and ultimately CSO volume reduction. In order to construct these models for this situation, direct measurements of sewer flows would be obtained at the sewer separation project areas, ideally both pre- and post- construction. For pre-construction conditions, meters are installed in the combined sewer system before sewer separation elements are constructed, to determine baseline conditions. For post-construction conditions, meters are installed in both the stormwater conveyance and combined sewer systems to determine the changes in the hydraulic operation of the combined sewer system, as well as the hydraulic operation of the stormwater conveyance system. These results are used to calibrate the project area model to account for variations in hydrologic and hydraulic conditions due to the project construction and operation.

Pre- and post- sewer separation monitoring would be entered into the calibration of the System Wide Model. The updated model would then be run for the 1970 typical year as noted in *Consent Decree Attachments 1B & 2 under footnote 6*. Model updates would generate the CSO volume reduction for reporting purposes.

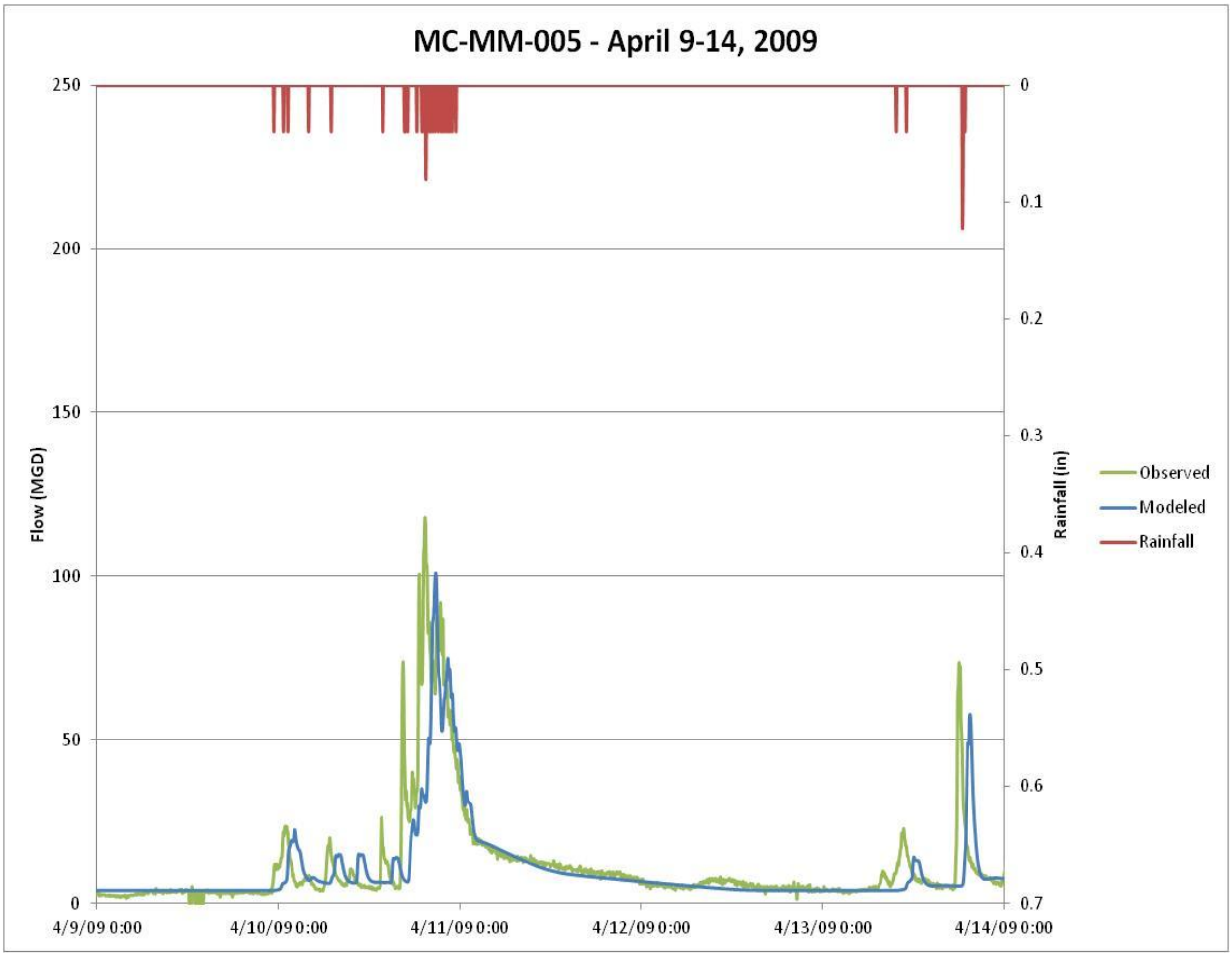
MSD has not yet completed construction on any separation projects that can be monitored. The Ault Park project is nearing completion, and Harrison Phase A is under construction. These, as well as the Westwood Northern projects will be the first to provide this type of data within MSD's service area. The most representative type of monitoring that could be done for the proposed type of separation projects is to monitor separate sanitary and storm sewers in an area proposed for separation. Existing storm sewers will be routed to new storm trunk and interceptor sewers, while sanitary sewers will continue to discharge to combined trunk and interceptor sewers.

It is reasonable to expect MSD's system-wide model correlates well with predictions regarding the flow conditions at CSO 5, because the model results for other key infrastructure locations match available flow monitoring data.

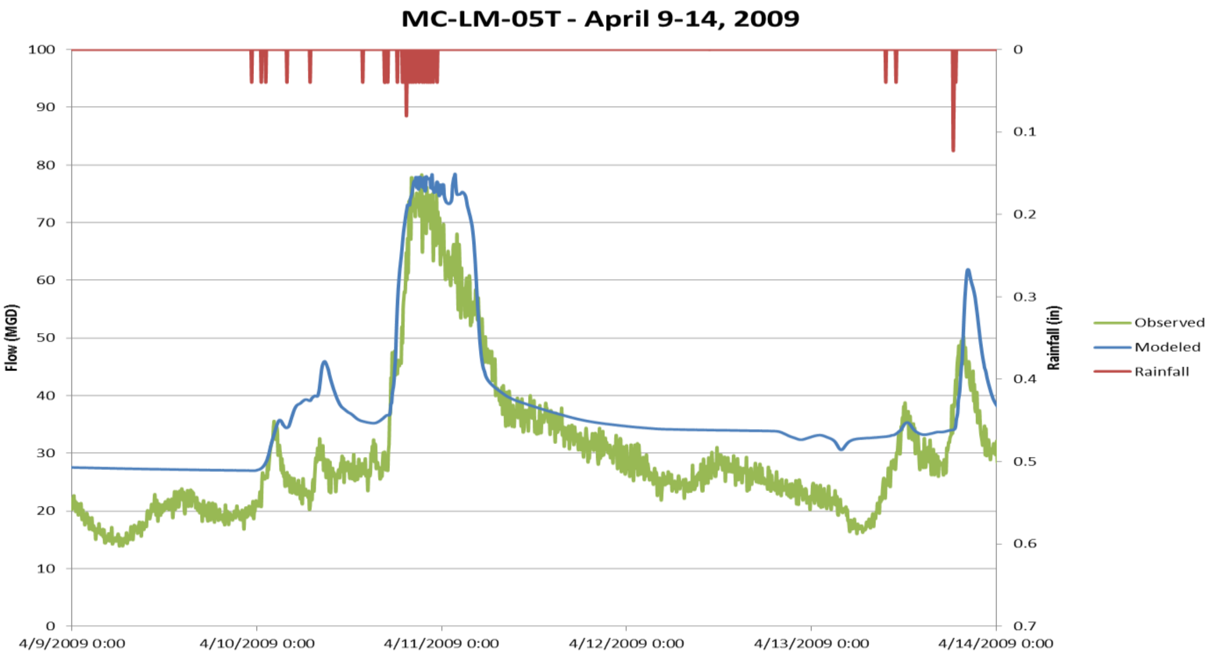
For example, the model simulates the volume of wastewater entering the wastewater treatment plant within 1% of actual flows. Similarly, the updated baseline model had good agreement between observed data from in-line flow meters and model results for Mill Creek Interceptor, Mill Creek Auxiliary Interceptor, and local sewershed locations such as Ross Run at CSO 485/487. Hydrographs demonstrating this agreement of data and results are presented below.

Comparison of Model Results with Ross Run Flows at CSO 485/487

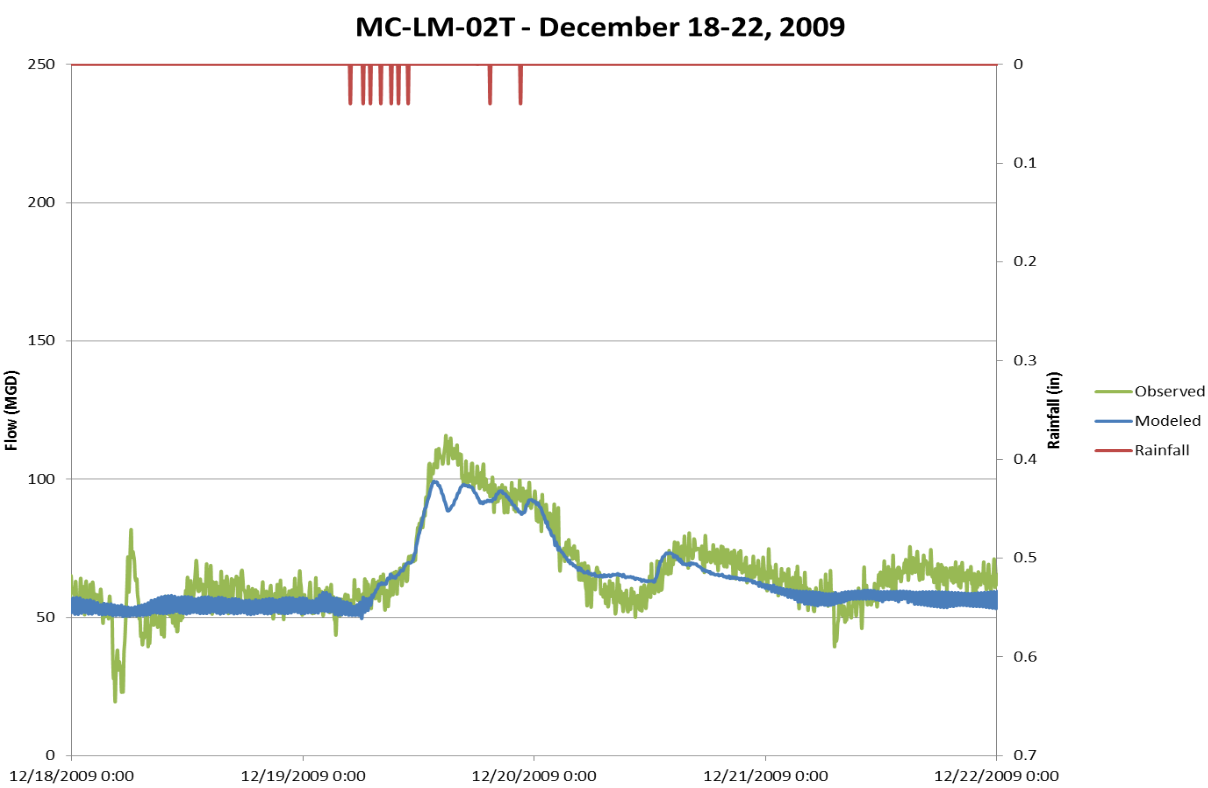
Ross Run is one of MSD's five largest CSOs.



Comparison of Model Results with Mill Creek Interceptor above West Fork



Comparison of Model Results with Mill Creek Auxiliary Interceptor



3.9.1. Lick Run Flow Monitoring

As noted in the Lick Run Calibration/Validation report and in previous discussions, MSD efforts to-date have focused on identifying viable alternatives for the purposes of alternative evaluation and not for detailed design of specific projects. In the Lick Run calibration, the data sets did not agree and there were various aspects (depth of flow, flow rate, volume of flow, percentage of rainfall captured) that were not in agreement from one year to the next. In reconciling the data, MSD considered and evaluated level data for the RTC and CSO 5 and compared four years of data with the 2011 level data. The data set that best matched up and were most appropriate to use were identified. MSD remains confident in the model results for Lick Run.

MSD has begun additional monitoring at 11 locations (10 temporary, 1 permanent) shown below to confirm and refine model calibration in the continuing, iterative modeling refinement efforts. Additional flow monitoring data collected during the design phase, which is typical in all WWIP projects, will be used for Lick Run projects for the purpose of validating pre-construction conditions. MSD is confident that its approach represents sound engineering practice and a solid, common-sense approach to the demands of this project.

Extensive flow monitoring throughout a sewer system as large as the Mill Creek basin is not practical or cost-effective for planning level alternatives evaluation. MSD has focused its efforts on getting to the point of alternative selection and its technical experts have indicated that model version 3.2 is suitable for alternative selection, while recognizing refinements will be needed as design advances. MSD is now at a point where viable alternatives have been identified and further focused flow monitoring and model refinements are needed to determine precise facility sizing and projected costs.

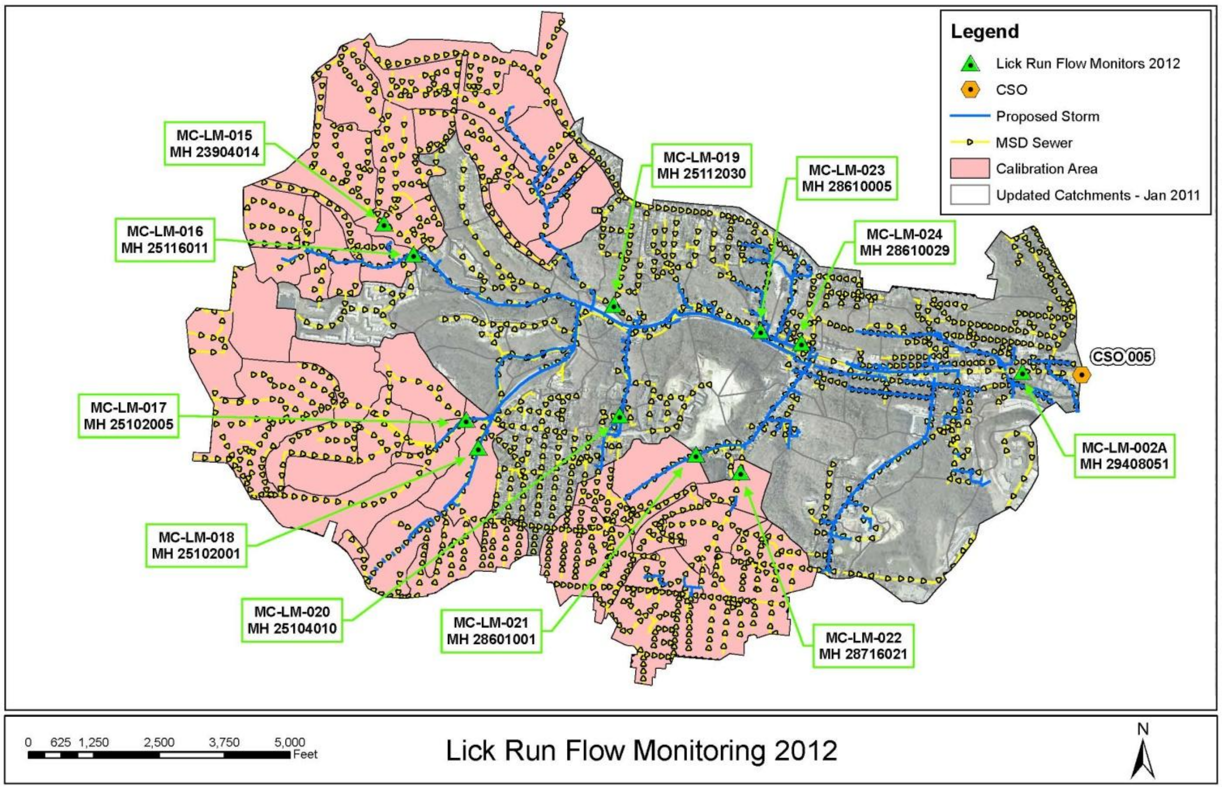
As previously noted, MSD continues to conduct additional monitoring beginning in September 2012 as part of more detailed design of specific projects. Due to the large size of pipes and the large swings in depth and velocities during wet weather, the Lick Run system is challenging to measure. As noted in the Lick Run Calibration Report, the 2009 flow monitoring data set was not usable for validation because of the high flows and velocities in the 19.5-foot diameter sewer coupled with the lack of reliable flow and velocity measurements from the monitoring devices deployed in 2009. The 2009 data set did not compare well with volumes and rainfall as well as other metrics; it was concluded that the solution is to conduct additional flow monitoring at more suitable locations to collect more data for model validation.

In Spring 2011, MSD conducted some flow monitoring in the watershed to collect additional data. Three upstream locations were selected for flow metering in Lick Run combined sewers. These locations were still in relatively large diameter pipes (78-inch and 84-inch in diameter) and the flow monitoring yielded incomplete and unreliable data due to excessively high velocity and debris - similar issues to those encountered when monitoring the 20-foot diameter combined sewer.

MSD's current flow monitoring plan takes many of the Lick Run challenges into account – such as slope, debris, pipe size, velocity. The plan recently underwent refinement and verification through field inspection and includes the installation of 11 meters upstream of the current meter locations. The site selection criteria were based on smaller pipe sizes and slower velocities. Initial field inspections were conducted for the locations. These inspections confirmed the suitability of the manholes with regard to crew safety and ability to install monitoring equipment. The flow meters will measure flows and levels at locations more likely to produce useful data individually, and as a set of locations that can be used to provide greater confidence in the flows at CSO 5 outfall and in the rainfall distribution and conditions of runoff attributed to land use, slope, infiltration, etc. These locations will also provide good pre-construction data flow data for many of the Lick Run separation projects. This additional monitoring data will help refine the design of the remainder of the projects and verify that the proposed projects will meet the overall reduction objectives.

In summary, the draft Flow Monitoring Plan will monitor flows in the upstream areas of the watershed in pipes no greater than 66-inch diameter and maximum velocities no greater than 12 feet per second. The sensors measure velocity and depth and MSD's selected sites are within the reliable range of the equipment. Historical data shows that there is greater success when focusing on sewers smaller than approximately 60-inch diameter and velocities less than 12 feet per second.

New Flow Monitoring Locations



As flow monitoring continues, MSD will use the data to refine the calibration for Lick Run for the pre-construction conditions; after improvements are made, a modified model will be developed for post-construction conditions. Following construction, a recalibration of the model based on the installed improvements and the post construction monitoring will proceed. The 1970 year storm will be run through the models and the difference will be the actual CSO reduction achieved.

Modeling is a continuous, iterative process that advances to support viable solutions and MSD will continue to update and refine modeling consistent with its process for detailed design of projects.

3.10. Pre & Post Construction Monitoring Program

MSD's approach to developing a flow monitoring plan is consistent with requirements posed by the USEPA. MSD's approach satisfies industry standards for CSO Wet Weather Programs. Every community addressing wet weather sewer overflows faces challenging but unique conditions. As such, USEPA issued a draft guidance document for Lower Mill Creek Study outlining the "industry standards" that need to be addressed for development of a suitable flow monitoring program.

> *"Unique issues that could arise in the context of developing the Post-Construction Monitoring Study required by Section X of the CSO Decree, in light of the source control/green infrastructure measures in the proposed Revised Original LMCPR (EPA Guidance-Draft for Discussion, October 2011)."*

The purpose of the guidance is to ensure that MSD has a sound approach and plan to implement to pre- and post-construction monitoring of source control projects. The discussion of MSD's prior and current flow monitoring efforts throughout the Lick Run basin demonstrates a commitment to identify the unique issues and diligence to resolve them. A one-size-fits-all approach is not appropriate for Consent Decree Programs. MSD has and continues to pursue every available action to collect useful and suitable flow monitoring data. The topography and existing infrastructure have posed unique challenges that continue to be overcome through an iterative process.

The primary objective of pre- and post-construction monitoring is to obtain the flow data necessary to refine the System-Wide Model (SWM) to generate pre- and post-construction typical year overflow volumes at a given CSO(s). The principal model elements to be refined are hydrologic parameters and RTK values. Seasonal changes in average dry weather flows should also be examined, as they influence the calculations of RTK values and overall wet weather volumes.

Comparison of overflow remaining volume or percent control to the individual CSO requirements will be performed to determine if the reduction goal has been met. In the case for the LMCPR, there is an aggregate goal that will also need tracked to ensure the overall goal is met.

An overall concern might come from the fact that MSD is calibrating different portions of the model using flow monitoring data collected at different points of time. Ideally, using a consistent flow monitoring period across the entire CSO service area would be preferred. This approach was not feasible for MSD's system-wide model and is seldom viable from a practical standpoint. It will be important to note differences in the flow monitoring periods; to try to select a broad range of storms that are reflective of typical year storms; to ensure good seasonal coverage with selected storms; and to possibly try to compensate for particularly wet or dry periods in the final selection of model parameters.

4. EVALUATION CRITERIA

The following sections are organized using on the draft guidance received for the Regulators in October 2012: Guidance pertaining to consideration of any proposed revised original Lower Mill Creed Partial Remedy Defendants may choose to submit in accordance with Paragraph A.2 of the WWIP.

- Policy
- Costing Protocols
- Potential Benefits
- Risk Analysis

4.1. Policy

MSD's recommendation complies with all applicable policies. MSD's integrated approach identified the most cost-effective, sustainable, and beneficial combination of infrastructure types for the Lower Mill Creek watershed. A sustainable solution offers a cost-effective balance between the grey and source control perspectives. It represents a solution with an emphasis on overall watershed CSO reduction and maximizing opportunities to accelerate "low hanging fruit" projects, and projects that offer opportunities to partner with private sector to remove stormwater and natural drainage from the CSS that reduces life cycle costs.

The Sustainable Alternative complies and/or conforms with:

- 2 BG CSO reduction target of the WWIP
- State and federal laws regarding stormwater management and flood control
- USEPA's guidance for development of a LMCPR alternative
- Hamilton County's July 18th resolution regarding cost control
- County policy direction/support of green/sustainable approaches to WWIP
- USEPA Sustainable Policies
- USEPA's Integrated Planning Framework Policy.

4.2. Cost Certainty

The cost-effectiveness analysis guidelines, created by EPA shortly after the passage of the Clean Water Act in 1972, were used for estimating costs for the projects included in the WWIP. Key elements of the cost-effectiveness analysis guidelines are the use of a short-range planning period (generally 20 years), a constant interest rate, no inflation, and the use of remaining value to account for the remaining useful life and value of long-term assets like sewers when comparing life-cycle costs.

The following industry standard practices are applicable to the LMC Study.

- Hamilton County Metropolitan Sewer District of Greater Cincinnati, City of Cincinnati Department of Public Works Stormwater Management, November 1991, Cost Estimating and Cost Referencing Methodology, Stormwater Wastewater Integrated Management (SWIM), Prepared by Camp Dresser & McKee and Woolpert Consultants.

- R.S. Means. 2005. Building Construction Cost Data, 63rd Annual Edition.
- Estimates, Project No. CS-1314. Detroit Water and Sewerage Department. United States Environmental Protection Agency. December 1976. Cost Estimating Manual – Combined Sewer Overflow Storage and Treatment, EPA-600/2-76/286. Cincinnati, OH: National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency.
- United States Environmental Protection Agency. January 1981. Construction costs for Municipal Wastewater Conveyance Systems: 1973-1979, EPA-430/9-81/003. Washington, D.C.: United States Environmental Protection Agency.
- United States Environmental Protection Agency. January 2002. Costs of Urban Stormwater Control, EPA-600/R-02/021. Cincinnati, OH: National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency.
- “Preliminary Data Summary of Urban Storm Water Best Management Practices”, Publication EPA-821-R-99-012, August 1999.
- “Storm Water Technology Fact Sheet Bioretention” Publication EPA-832-F-99-012, September 1999.
- “Storm Water Technology Fact Sheet Wet Detention Ponds” Publication EPA-832-F-99-048, September 1999.
- “Combined Sewer Overflow Management Fact Sheet Sewer Separation” Publication EPA-832-F-99-041, September 1999.
- MSDGC Estimating Guidelines and MSDGC Financial Analysis Manual.
- Guidance document from the Association for the Advancement of Cost Engineering International.

In 2004, MSD developed a set of cost estimating tools used to create the Capacity Assurance Program Plan (CAPP). Development of this tool was based on standard cost estimating practice, which has at its core development of a standard set of procedures proven to create consistent estimates from conceptual design to design development and through construction documents. A comprehensive set of potential project types that could be considered for solutions for the CAPP and Long Term Control Plan (LTCP) were assembled and costing tools were developed using Microsoft Excel spreadsheets. These costing tools were used to develop planning level project costs for potential solutions for individual capacity issues throughout the system. Another set of tools was developed to allow multiple projects to be assembled into a regional solution that is expressed in a present worth life-cycle cost. This enables a fair comparison of the alternatives including operation and maintenance costs as well as other periodic costs over the planning period such as equipment replacement.

MSD’s intent for investing time and money into development of a comprehensive costing tool was to provide defensible data to document the long term costs of the program. Documentation was provided outlining the use of the tools as well as the basis for cost development. These CAPP costing tools became the basis for a more detailed cost estimating tool used to develop MSD's Combined Sewer Overflow LTCP and Wet Weather Improvement Program (WWIP).

The costing tool was developed and refined through the collaborative efforts of many professionals having detailed knowledge of MSD's infrastructure including, but not limited to the following firms:

- A&A Safety
- Black & Veatch
- CH2MHill
- Camp Dresser & McKee
- Greeley and Hanson LLC
- Malcolm Pirnie, Inc.
- Metcalf & Eddy
- Parsons Brinkerhoff
- XCG Consulting Engineers

For the Sustainable Alternative, cost opinions were developed separately for each of the individual projects using historical cost information from actual Contractor bids submitted to ODOT, CDOTE, SMU, and others. These data sources included relatively large sample sizes for the major project components associated with storm sewer construction. The use of locally available cost data for conventional construction elements such as these is generally considered to provide the most relevant opinion of construction costs in the area for upcoming construction seasons. Even so, these costs were compared to cost opinions derived from an analysis of individual cost components, where estimates were made for labor, equipment, and material costs for individual construction items such as storm sewer construction.

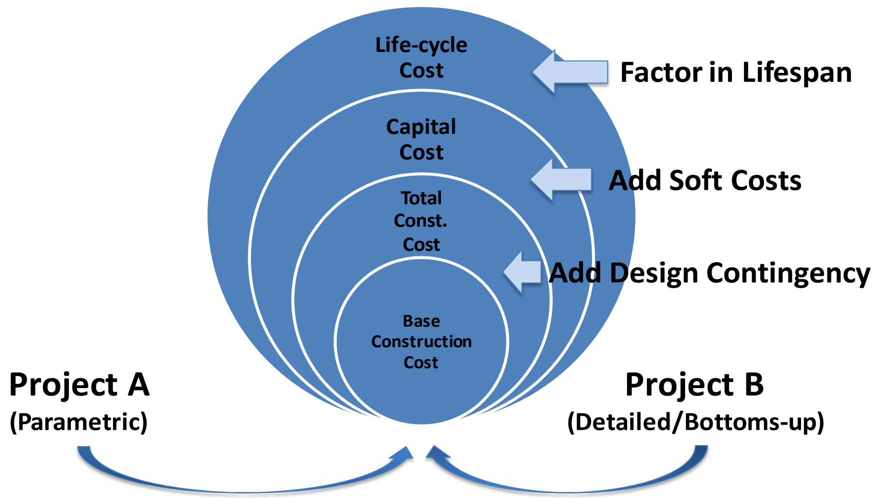
In practice, MSD bottom-up cost methodology has proven to be accurate, and to provide a high level of confidence. To-date one SI project within the Lick Run watershed, the Harrison Avenue Phase A Sewer Separation Project, has been bid out for construction. The design engineer's opinion of probable cost for this project was $1.99M, based on the methodology discussed above. The actual bid price came in at $1.48M. Based on this comparison, the design engineer's opinion of probable cost was 34% above the actual bid price. As such this project is a local example of using MSD protocols to generate a construction cost estimate. The cost results for this project provide a high level of confidence the methodologies being used to estimate project costs by MSD are conservative. It also demonstrates the highly competitive nature of the local construction industry.

4.2.1. Costing-Related Terminology

The cost estimating protocols for the LMCPR Study was designed to standardize and normalize alternatives for comparison purposes. The basis for the cost estimation was historical data from local MSD experiences; data collected from other municipalities with similar projects; and published USEPA costing data. The costs are estimated primarily on the basis of the size or capacity of the facility required, but they also include allowances for the features unique to the particular installation. For example, new sewer costs may be adjusted for expected construction difficulties through bedrock and storage costs may be adjusted to reflect extraordinary odor control needs.

The foundation of this consistency lies with the definition of terms being used to refer to specific values for a project. The four types of project costs used in the LMCPR Revised Plan are illustrated in the figure below followed by definitions.

LMC STUDY COST DEVELOPMENT



BASE CONSTRUCTION COST: Represents the foundation of all project costs. Base construction costs were calculated differently, utilizing methods appropriate to the maturity of the project; inclusive the following line items:

CONTRACTOR'S BASE COSTS: Are made up of unit costs for each element of construction necessary to build a project. The components of the Contractor's Base Cost include the following:

> **MATERIAL COSTS:** Are based on a unit prices derived from vendor quotes or historical cost data.
>
> **LABOR COSTS:** Are based on probable labor production rates and crew sizes. This rate varies between trades, projects, climatic conditions, job supervision, complexity of the installation process, and other factors.
>
> **EQUIPMENT:** Consists of the contractor's major construction equipment costs including rental, transportation, handling on the job, operation, and maintenance costs.
>
> **SUBCONTRACTOR COSTS:** Include costs of material, labor, and equipment incurred by subcontractors.
>
> **OTHER CONSTRUCTION COSTS (ALLOWANCES):** Includes miscellaneous cost items that are not included in the unit costs. They may include costs associated with the following factors: weather, crew transportation, soil conditions, hazardous material removal, utility relocations, wetland replacements, road/highway/special crossings, traffic control, ground water, labor strikes, material and/or subcontractor availability, general material economic conditions, complexity of the project, and construction phasing.

CONTRACTOR'S ON-SITE GENERAL CONDITIONS: Account for the cost of items that cannot be associated with a specific element of work but must be furnished to complete a project including supervision, temporary facilities, office trailers, toilets, utilities, permits, photographs, small tools, local Business and Occupation (B&O) taxes, and mobilization/de-mobilization. Some unforeseen conditions may include traffic control and barricades, construction crew parking, right of way costs, testing, staff time to attend and conduct meetings, restoration of property, OSHA requirements, new design or building code standards, work hour restrictions, and pollution controls. General conditions costs are based on the monthly cost of the project and can be calculated as a percentage of the construction cost.

CONTRACTOR'S OVERHEAD: Is calculated by gauging the amount of annual construction work of the contractor performing the work, the particular project size and complexity, and the knowledge of what historically has been used on similar projects of this type. For the LMCPR Analysis the Contractor's overhead will be applied as a 10% multiplier to the sum of the contractor's base costs and contractor's on-site general conditions to account for the cost of doing business.

CONTRACTOR'S PROFIT: Includes compensation for risk and efforts made to complete the project and are based on economic conditions for the local construction industry, the individual contractor's overhead costs, and their perception of the risk of losing money on the project. Contractor's profit will be applied as a 5% multiplier to the sum of the contractor's base costs and contractor's on-site general conditions.

TOTAL CONSTRUCTION COST: Includes the cost of design contingency, bonding, and insurance in addition to the base construction cost.

DESIGN CONTINGENCY: Is calculated as a percentage of the base construction cost, dependent upon the stage of the project, to account for the accuracy of a construction estimate at the given stage of development. Projects estimated at the conceptual planning stage have limited details, leading to a high level of uncertainty regarding the final cost to build the project. Therefore, these projects have the largest design contingency multiplier. The design contingency multiplier becomes progressively smaller as a project proceeds through preliminary and final design stages since more details are known, leading to less uncertainty regarding the overall cost of the project. The stage of the project was assigned by the Project Engineer developing the construction cost estimate, as they are best positioned to understand the level of detail in the design documents, project scope, and assumptions upon which the estimate is based. Design contingencies used for the LMCPR Study are summarized in the table below.

DESIGN CONTINGENCIES

Project Stage	Multiplier
Conceptual Planning	35
Facilities Planning	25
Preliminary Design	20
30% Design	15
60% Design	10
90% Design	5

BONDING COSTS: Account for the cost of the contractor bond and are determined as a 1% multiplier on the sum of the base construction cost and the cost of design contingency. This percentage was developed by CH2M HILL based on a review of historical projects and was agreed to by the LMCPR Revised Plan project team.

INSURANCE COSTS: Account for the cost of protection against on-site accidents and are determined as a 1% multiplier on the sum of the base construction cost and the cost of design contingency. This percentage was developed by CH2M HILL based on a review of historical projects and was agreed to by the LMCPR Revised Plan project team.

CAPITAL COST: Represents the known or estimated real estate costs and several soft cost multipliers applied to the total construction cost. Soft costs represent expenditures necessary for the successful completion of the project that are outside of the building contractors' costs but are borne by the utility and therefore must be accounted for in budgeting for such a project.

REAL ESTATE COSTS: Include the cost of the easement and property acquisition that occur to enable construction. Real estate costs can be incorporated into the capital cost of a project using actual property acquisition costs, if known, or by estimating acquisition costs based on the Project Engineer's knowledge of the property(ies) involved along the proposed alignment or around the proposed site. It is suggested that the Project Engineer refer to the Hamilton County Auditors web site for values of properties that will need to be purchased. If specific location information is not available and assumptions must be made regarding the cost of land acquisition, real estate cost curves were used in order to provide consistency in alternative cost comparisons. For conveyance projects, which typically involve easements along a route, the real estate costs were developed based on historical MSD project information. For storage and treatment-related projects, which require the purchase of a certain amount of land, costs are estimated using the equations that translated the volume or flow rate, respectively, of the proposed facility to a footprint and then applied a real estate unit cost of $130,680 per acre or approximately $3 per square foot. This is the same process as was used for the development of real estate costs for the WWIP, at which time specific property acquisition information was unavailable for a majority of the projects.

For the sustainable projects, the costs were developed using a bottom-up estimate provided by MSD using a uniform methodology. Real estate costs of permanent easements, temporary easements and full takes have been calculated based the best available information of the current project alignment. The costs include the property value as well as soft costs such as appraisals, titles, closing costs, relocations, property management, potential environmental site assessments, potential appropriation, and staff administration. Supplemental assistance benefits for business owners and the demotion of buildings on purchased properties are also included in this line item.

SOFT COST MARKUPS:

> **ADMINISTRATION:** Adds a multiplier that varies by project (based on its type, total construction cost, and construction duration) to account for various administrative costs such as MSD labor, legal fees or use of consultant staff support services for project management.
>
> **PROJECT CONTINGENCY:** Is a fixed 10% multiplier applied to the total construction cost of every project to account for the uncertainty of actual construction methods, unanticipated project requirements, cost overruns during planning, design or construction phases of the project, and any additional requirements of the owner not yet defined. This percentage is based on guidance from MSD's Financial Analysis Manual.
>
> **CONSTRUCTION INTEREST:** Accounts for the cost of bonds being issued to finance the projects during the construction phase.
>
> **MISCELLANEOUS:** Includes other undesignated costs. Pre-construction phase miscellaneous costs include but are not limited to permits, plan review fees, geotechnical investigations, environmental investigations, and right-of-way costs associated with property owners, paperwork, and legal work. Construction phase miscellaneous costs include but are not limited to contract permits, inspection fees, materials testing, geotechnical testing, environmental testing, training, instrumentation and control, and public relations.

FIELD ENGINEERING AND INSPECTION: Accounts for project engineering and inspection cost of personnel and professional services used during construction.

DESIGN AND ENGINEERING SERVICES: Accounts for costs of services provided by outside (non-MSD or supplemental staff) engineering consultants and is determined as a percentage of the total construction cost.

PLANNING AND PRELIMINARY DESIGN: Accounts for work by MSD's internal planning division that occurs before construction on projects. This would include preliminary modeling, alternative analysis, life cycle comparisons, project scope definition, project schedules, and project presentations to stakeholders.

LIFE CYCLE COST: All life cycle costs are reported in terms of present worth (in 2006 dollars) using an analysis period of 25 years and a discount rate, i, of 4.2% The life span of each asset type (conveyance element or facility), and part of a facility (superstructure, foundation, tankage, mechanical, electrical, etc.), is taken into consideration when calculating equipment replacement costs and determining any remaining value in those assets at the end of the analysis period. These considerations are paramount to assuring the comparability of project and alternative costs. Each life cycle estimate consists of the sum of the following net present values:

- Capital Cost minus the present worth of the residual value of the asset
- Present worth of the periodic equipment replacement costs and any residual values
- Present Worth of the annual operations and maintenance (O&M) costs

LIFE CYCLE COST COMPARISON ASSUMPTIONS:

- Annual O&M costs for conveyance assets are $1.22 per foot of sewer.
- Fixed facility maintenance costs are calculated assuming that storage facilities require 8 hours of labor per week, or 416 hours per year (except stormwater detention basins); pump stations require 4 hours a week, or 208 hours per year; and treatment facilities require 40 hours a week, or 2080 hours per year, to maintain.
- Fixed facility maintenance costs for stormwater detention basins are calculated assuming that facilities require 52 hours per year and 0.5 hours per wet weather event.
- For storage facilities, an additional 8 hours of labor are included per wet weather event (which is a number provided by estimator/Project Engineer). For treatment facilities, an additional 16 hours are added per event.
- The cost of labor, including fringe benefits, for all assets is assumed to be $39.57 per hour based on the union prevailing wage rates in Hamilton County for services in this field, from the State of Ohio Department of Commerce—Bureau of Wage and Hour Administration (http://www.com.ohio.gov/laws).
- Energy costs are based on the annual volume and the total dynamic head pumped, assuming a pump efficiency of 75%, a motor efficiency of 95%, and variable frequency drive efficiency of 98%. Electric costs estimated to be $0.104 per kilowatt-hour.
- The cost of Mill Creek Wastewater Treatment Plant operations is $250.00 per million gallons, which includes the cost for energy, utilities, lab services, overtime labor, chemicals, and supplies.
- The cost of treatment chemicals is $365.00 per million gallons for a ballasted flocculation facility and $99.00 per million gallons for an EHRT facility.

- The cost of disinfection chemicals for the ballasted flocculation or EHRT is $174.81 per million gallons treated, which includes chlorination and dechlorination.

Some of the green infrastructure is not included in the LMCPR parametric method. Therefore, life cycle costs such as operations and maintenance and replacement costs associated with green infrastructure were developed using various sources as described in the specific project sections, such as Lick Run for the valley conveyance system. These additional costs were added to the previously determined costs from the parametric method.

BOTTOM-UP ESTIMATING: Is Bottom-up estimating is the practice of developing detailed quantity take-offs for each material or component need to construct an asset or facility and applying widely accepted unit costs and factors to those quantities to arrive at costs. Such estimates are unique to each project and require a higher level of project definition.

PARAMETRIC ESTIMATING: Is Parametric estimating is the practice of using algorithms or cost of parametric costs relationships that are highly probabilistic in nature (i.e., the parameters or quantified inputs tend to be abstractions of the scope). An example would be the use of a storage facility's overall capacity to derive a construction cost from a cost curve. The algorithms or cost relationships are different for each type of asset and are developed from a wide range of resources.

LMC STUDY COST ESTIMATING SOURCES/FACTORS

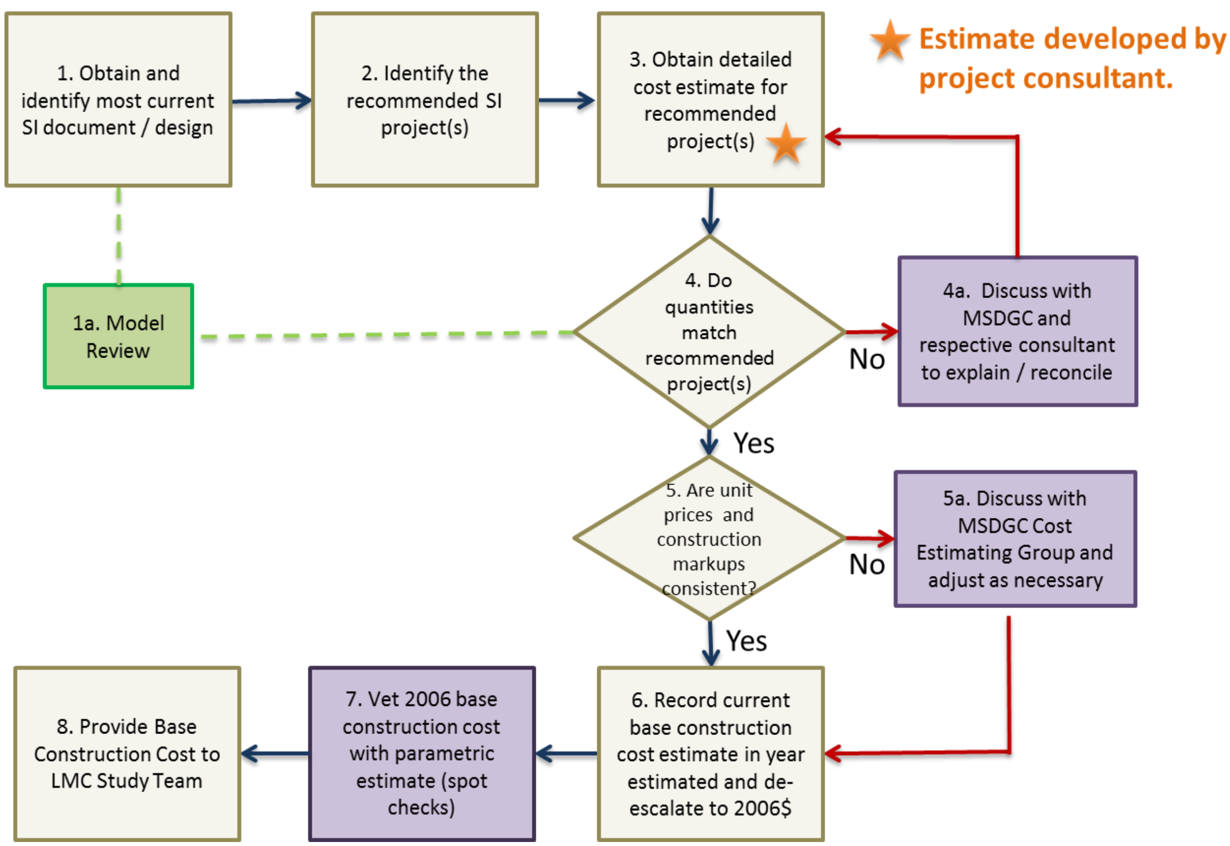
Estimate Component	Source or Factor
Life Cycle Cost	
Present Worth of Residual Value	Straight-line Depreciation of Capital Cost over 25-year Period
Present Worth of Equipment Replacement	% of Capital Cost Replaced at 10, 20, and 30-year Intervals
Present Worth of Annual Operations and Maintenance	Unit Costs for Fixed Maintenance, Event Maintenance, Labor, Energy, & Chemicals
Capital Cost	
Real Estate Costs	Curve, County Auditor, or MSD
Administration Costs	Conveyance: 8.5%, Storage/Treatment: curve
Project Contingency	10%
Construction Interest	0.5(i)(Y)(TCC) where i=4.2%
Miscellaneous	Curve (0.5% minimum)
Field Engineering & Inspection	Conveyance: 3.5%, Storage/Treatment: curve
Design & Engineering Services	Curve (6% minimum)
Planning & Preliminary Design	Curve (3% minimum)
Construction Cost	
Insurance	1%
Bonding	1%
Design Contingency	5% to 35%
Contractor Cost	
Contractor's Profit	5%
Contractor's Overhead	10%
Contractor's On-Site General Conditions	Parametric Curve or Detailed Estimate
Contractor's Base Cost	Parametric Curve or Detailed Estimate

4.2.2. Cost Review Methodology of Sustainable Projects

The focus of consistency checks on the cost estimating from the sub-basin projects was driven by the need to perform an alternatives analysis and to be able to add and compare "bottom-up" cost estimates from more developed projects (e.g. preliminary design, 30% design) to parametric estimates from a conceptual design process. Standardization of what is included in the base construction, such as general condition items and overhead and profit was made more consistent between the projects. Confirmation of the level of the project (e.g. preliminary design) allowed for standardization of the design contingency. In addition, quantities and unit prices were generally checked with the assistance of MSDGC Cost Estimating. The capital cost soft costs applied to the total construction cost estimate were also updated to correspond throughout all Lower Mill Creek alternatives. The capital and life cycle costs are also defined by the LMCPR costing protocol and project-specific real estate costs and operations and maintenance costs.

The sustainable project costs developed by the sustainable infrastructure (SI) design team were reviewed with a standard and normalized approach for comparison purposes. This multi-step process, as shown below, included numerous checks and reconciliation steps to ensure comparable costs. This cost review task was important due to such factors as the different stages in planning or design that each project was in, the various models that existed for the projects, the costing approach taken by the different MSD sub-basin SI design consultants to determine the total construction cost, and the differing methods used for determining operation and maintenance costs to derive the life cycle cost.

Sustainable Project Cost Review Process



As noted below, the first three steps in this process were to identify and obtain the most current planning and/or design documents, including the representative models for each sub-basin. For sub-basins with projects in the planning phase, the report documents consisted of alternative analysis reports or business case evaluations. The recommended sustainable project for each sub-basin was then identified and the detailed cost estimate from the consultant was obtained. The most recent cost estimates provided by the consultants as of December 2011 were used as the basis for the cost review for all projects except for the West Fork sub-basin. In early 2012, constructability issues were resolved and updated cost estimates were obtained in March 2012.

In Step 4 of the cost review process, the detailed cost estimates were reviewed to check recommended quantities for all project components against the most current planning and/or design documents. Where quantities did not match, MSD and the respective project consultant were contacted to explain and/or reconcile the differences. Construction mark-ups and unit prices for all project components were reviewed in Step 5.

Finally, in Step 6, the base construction costs were de-escalated to 2006 dollars (if necessary) and recorded as the base construction costs. Most SI design teams' base construction costs required an update although it may have been minor.

As a check (Step 7), the projects for Bloody Run and West Fork were estimated using the LMCPR parametric method and compared against the base construction costs. In Step 8, the base construction cost was provided to the team for total construction cost and capital cost estimation.

The table below identifies the project stage of each of the individual SI projects. As projects move through planning into detailed design, more information is available to inform the estimator of required project costs. Therefore, there is a higher probability for inaccuracy at the lower level of planning. As the survey, geotechnical data, and other utility locations are made available the sewer alignment and elevation become set and the costs become more accurate. This is mitigated by the design contingency and by engineering judgment of unit price assumptions.

4.2.3. CONTINGENCY

The Association for the Advancement of Cost Engineering International (AACEI) guidelines recommends the use of contingency for cost risks. It is a standard practice within the wastewater industry to account for program level risks by assigning a contingency value or percentage of Total Construction Cost to be included in the Capital Cost. This risk factor can be applied as a consistent percentage to the program costs or a detailed risk assessment can be performed on each individual project to develop project specific risk factors. The project team, in collaboration with MSD, determined that a fixed program contingency of 10% would be used and applied to each project during this evaluation. A more detailed analysis of the risk factors would have been costly and time consuming without providing a clear benefit for the alternatives evaluation.

In accordance with MSD's Estimating Guide, and AACEI Estimate Classification system, contingency factors are included in the cost estimates for both design and construction of all SI elements, to account for potential unknown project risks. These contingency factors vary based on the level of project design and estimate class.

Projects at a lower level of design, such as long-range planning or planning level, are categorized with a Class 5 or 4 estimate, respectively, and therefore have higher design and construction contingencies applied. Projects at 30% design are categorized with a Class 3 estimate, and have the respective design and construction contingencies applied. As the project design is advanced, and potential unknown project risks are reduced, the contingencies applied to the base construction cost will be reduced accordingly.

The tables below identify areas where a line-item contingency factor was applied to a particular aspect of the project. This approach provides for a more representative estimate in that conditions unique to the projects are explicitly addressed. This also minimizes the level of "unknown" information typically lumped into a construction contingency amount.

Line Item Contingency Cost Estimating Items for all Projects

Line Item Contingency Item	Description
On-Site General Conditions	Accounts for the cost of items that cannot be associated with a specific element of work but must be furnished to complete a project: supervision, temp facilities, office trailers, utilities, permits, small tools, traffic control, barricades, construction crew parking, testing, staff time for meetings, restoration, OSHA requirements, building code standards, work hour restrictions, pollution controls.
Contractor's Overhead	Accounts for the cost of doing business: historical values, project size and complexity, annual work volume.
Contractor's Profit	Compensation for risk and efforts made to complete the project based on: economic conditions for local construction industry, individual contractor's overhead costs, and perception of risk.
Bonding	Accounts for the cost to the contractor to secure bonding for completion of the work.
Insurance	Accounts for the cost to the contractor to secure insurance against accidents while performing the work.
Administration	Accounts for various administrative costs such as legal fees or use of consultant staff support service for project management. Multiplier varies by project.
Miscellaneous	Accounts for the cost to the project for activities not having a unique line-item cost estimate: permits, plan review fees, inspection fees, geotechnical investigations, environmental investigation and testing, materials testing, paperwork, legal work, training, instrumentation and control, public relations.
Field Engineering & Inspection	Accounts for the cost of personnel used for project engineering and inspection services during construction. Cost dependent on project type.

Line Item Contingency Cost Estimating Items for Sustainable Projects

Line Item Contingency Item	Description
Construction in Rock	Accounts for the cost of constructing the project in rock by applying a 50% multiplier to construction cost.
Dewatering	Accounts for the cost of trench dewatering to enable construction to proceed by applying a 10% multiplier to construction cost.
Maintenance of Flow	Accounts for the cost of maintaining operations of conveyance, pumping, or treatment facilities during construction: bypass piping and/or pumping, field personnel, energy costs by applying a multiplier to construction cost.
Brownfields	Accounts for the cost of excavation and handling of soil that may be contaminated by applying a 5% multiplier to the construction cost.
Clearing and Grubbing	Accounts for the cost of preparing a site(s) to remove vegetation, trees, structures, misc. to facilitate construction activities based upon pipe size and length of piping impacted.
Maintenance of Traffic	Accounts for the cost of maintaining vehicular and/or pedestrian traffic along roadways, streets, or sidewalks during construction in compliance with local and state regulations. Multiplier varies by project.

Line Item Contingency Item	Description
Urban Alignment	Accounts for the cost associated with construction of conveyance systems within urban environments subject to an increased level of utility conflicts, differing site conditions, and unexpected field conditions.
Creek Crossing	Accounts for the cost associated with the size of creek to be traversed, the level and frequency of flow, and receiving stream criteria.
Number of Manholes	Accounts for the grade changes, pipe size changes, bends, and intersections of conveyance sewers.
Number of Utility Crossings	Accounts for the cost associated with crossing either over or under existing utilities along the proposed alignment.
Street Width	Accounts for the cost required to resurface roadways after construction is completed.
Small Job Cost Increase	Accounts for the cost of projects involving less than 3,100 feet of sewer.
Storage Tank Configuration	Accounts for the cost differences with construction of an above ground facility vs. a below ground facility requiring excavation, sheeting, bracing, and backfill.

Line Item Contingency Cost Estimating Items for Grey Projects

Line Item Contingency Item	Description
Number of Pits or Shafts	Accounts for the cost of any additional pits or shafts beyond those included in the initial base project cost.
Average Depth	Accounts for the cost of construction required for vertical lineal feet of construction. Initial cost up to 15 feet of depth is included within the parametric curve and additional $2,200 for each additional foot over 15 feet is added to the base project cost.
Number of Flow Control Structures	Accounts for the cost of incorporating additional flow diversion structures into the project as determined necessary during project planning and design activities.
Jack-and-Bore Construction	Accounts for the cost of constructing infrastructure to depths 6-inches to 36-inches below ground surface.
Micro Tunneling Construction	Accounts for the cost of constructing infrastructure to depths ranging from 21-inches to 72-inches below ground surface.
Macro Tunneling Construction	Accounts for the cost of constructing infrastructure to depths more than 72-inches below ground surface.
Grade < 1%	Accounts for the cost of constructing infrastructure via jack-and-bore method on low grades by adding a 50% increase to the base construction cost.
Grade 1% to 2%	Accounts for the cost of constructing infrastructure via jack-and-bore method on low grades by adding a 30% increase to the base construction cost
Non-Homogenous Subsurface	Accounts for the cost of conditions creating difficulty in selecting the tunneling machine and greater risk of emergency recovery shafts by adding a 50% increase to the base construction cost.
Dewatering Required	Accounts for the cost to dewater trenches to facilitate construction by using a 10% multiplier to the base construction cost.
Railroad Crossing	Accounts for the cost to obtain railroad crossing permits and for additional requirements imposed by the railroad during construction by adding a 2% increase to the base construction cost.

The table below identifies the project stage of each of the individual SI projects. As projects move through planning into detailed design, more information is available to inform the estimator of required project costs. Therefore, there is a higher probability for inaccuracy at the lower level of planning. As the survey, geotechnical data, and other utility locations are made available the sewer alignment and elevation become set and the costs become more accurate. This is mitigated by the design contingency and by engineering judgment of unit price assumptions.

Projects for Design Contingency Consideration

CSO	Project Name	Project Stage
Bloody Run Basin		
CSO 181	RTC	Preliminary
Kings Run Basin		
CSO 217/483	Stream Removal/Sewer Separation	Preliminary
CSO 217	1.5 MG Tank @ CSO 217 (Replaced 20 MGD HRT)	Conceptual
Lick Run Basin		
CSO 5	Sunset Avenue	30% Design
	Rapid Run Early Success Project	30% Design
	Wyoming Avenue	30% Design
	Harrison Avenue Phase A	90% Design
	Harrison Avenue Phase B	30% Design
	State Avenue	Preliminary
	White Street	30% Design
	Quebec Road	30% Design
	Queen City Ave Phase 2 (Western)	30% Design
	Queen City and Cora Ave (Fenton)	30% Design
	Quebec Heights Phase 1 (Glenway Woods)	30% Design
	Quebec Heights Phase 2 (Wells Street)	Preliminary
	Grand and Selim Ave	Preliminary
	Queen City Phase 3 (Eastern)	Preliminary
	Westwood Ave	Preliminary
	Queen City Ave Phase 1 (Central)	30% Design
	Valley Conveyance (Lick Run Channel)	Preliminary
West Fork Basin		
CSO 117	Fay Apartments Street Separation	Preliminary
CSO 125	Stream Separation	60%
CSO 126	Stream Separation	Preliminary
CSO 127	Stream Separation	Preliminary
CSO 128	Stream Separation / Relocate Regulator	Preliminary
CSO 130	Stream Separation	Preliminary
All	West Fork 84" Interceptor	Preliminary
CSO 130, 204	1.5 MG Tank	Facilities
CSO 125	CSO 125 1.5 MG Storage Tank	Facilities
CSO 528	Street Separation	Facilities
CSO 529	Street Separation	Facilities
CSO 530	Street Separation	Facilities
All	Channel Re-naturalization and Park Amenities	Conceptual

Note: Project stage as of April 2012. Most projects are further advanced and Harrison Road Phase 1 is under construction.

The project cost estimates include three layers of contingency as described below.

- Line-Item Contingencies. The costing tool developed for the CAPP, LTCP, and WWIP provides engineers and estimators with the ability to account for field-specific conditions and apply a contingency to particular activities. A good example of the line-item contingency is the method to estimate Maintenance of Traffic (MOT) costs. There is a multiplier on the "Open Cut Sewer" tab of the costing tool that applies a 1% markup for maintenance of traffic that was utilized for a few projects. There is also the option to include Urban Setting that increases the cost by 50% if a sewer project runs through a city setting to account for extra traffic control as well as the additional delay and resource location issues that affect the contractor. For the sustainable projects MOT costs were included in the estimates in various forms at the consulting engineer's discretion and dependent on the project stage. Consideration was given to the roadways impacted and construction duration. For example, MOT costs were included within the general conditions (as a percentage of the construction cost), or as a separate line item as a percentage of the construction cost or as a cost per linear feet of pipe within the street. These MOT costs were also reviewed through the MSD cost estimate review process.

- Design Contingency. The 5 to 35 percent design contingency was applied to the base construction cost to account for unknown cost elements that diminish as planning and design progress. As a project advances in design, the design contingency is lowered as the unknown elements are minimized with detailed engineering and field gathered information.

- Construction Contingency. The 10 percent construction contingency is intended to cover cost increases that may occur during the construction phase of the project due to unforeseen physical conditions, schedule delays, and other factors.

These three layers of contingency (design contingency, line-item contingencies, and construction contingency) comply with all industry standard practices for estimating project costs. The LMCPR project will be financed primarily through bond proceeds. MSD intends to maximize the use of grants and low-interest loans to the fullest extent possible.

4.2.4. Cost Refinements

Upon continued review of the costs since the Preliminary Findings Report was developed in April 2012 and placed on Project Groundwork in June 2012, some costs have been identified to be incorporated into this recommendation. Changes in design (i.e., replacement of CSO 217 20 MGD EHRT with a 1.5 MG CSO storage tank) and some minor QA/QC adjustments reflect a new cost of $308,763,000 down from the previous $317,447,000 in the Preliminary Findings Report (in 2006 $). Subsequently, additional adjustments have been identified in August and September to be include in the LMCPR Revised Plan as listed below:

Items added to updated capital cost:

- DEMOLITION - Demolition of properties for Lick Run, Kings Run, and West Fork had not been previously included and 2006$ estimates were incorporated into the LMCPR Revised Plan: Lick Run - $3,771,000, Kings Run (Wooden Shoe) - $121,000 and West Fork - $692,000 (MSDGC participation only; FEMA grant received for the balance of the cost).

- SUPPLEMENTAL BENEFITS PROGRAM: The Program was developed by the City to incentivize owners to sell their properties and tenants to vacate properties required for time-sensitive projects: $4.9 million in current dollars (converted to 2006$ for the analysis = $4.1 million) for the South Fairmount Corridor.

- ODNR CLASS 1 DAM for KINGS RUN MEASURE 3 BASIN - $471,000 capital cost in 2006$ was added to the cost estimate of the Kings Run Sustainable project to account for a potential ODNR Class 1 dam. The alternatives analysis for this basin will be conducted in 2013.

- STREAM RESTORATION FOR KINGS RUN - Kings Run has been reduced by urbanization from its historical extent to approximately 3,400 lineal feet of surface stream underlain by a combined sewer. Design of waterway improvements, consistent with regional sustainable watershed planning approaches, will utilize concepts that efficiently transport flood water away from urbanized areas yet retain low flow and high flow habitat features and enhance the surrounding riparian and upland communities in an aesthetically pleasing fashion. $962,000 capital cost in 2006$ was added to the cost estimate of the Kings Run Sustainable project.

Cost refinements in the updated capital cost:

PROPERTY ACQUISITION - Over the past year, property acquisition and easement costs were compared against budgets and updated with the 60-percent design submittals. In the development of the costs, MSD was conservative due to the difficulty of estimating property acquisition costs and being consistent between projects. The approach and methodology developed has greatly increased the confidence that the budgets are adequate and conservative. The updated capital cost values also reflect the reduction of property acquisition costs for Sunset, Queen City Ave Phase 1, and Valley Conveyance. Projects advancing to detailed design during the past six months, adjustment of required parcels were made and the decrease in capital cost in 2006$ is: Lick Run total -$2,827,085. More specifically: VCS -$1,956,994, Sunset -$295, 470, and Queen City Ave Phase 1 -$574,621.

4.2.5. Value Engineering

In December 2010 and January 2011, MSD conducted a Value Engineering (VE) Study on the recommended plan for the Lick Run Wet Weather Strategy. An independent team of seven industry experts completed a detailed review of all the supporting documents, analyses, and modeling available at the time. The evaluation was completed based on the preliminary 30% designs for the fourteen sewer separation projects and the preliminary engineering plans for the valley conveyance system. The Lick Run VE Study offered a number of recommendations which are summarized in the *"Lick Run Wet Weather Strategy Value Engineering Study Report"*.

The conclusions of the VE team include:

- The approach being taken to control wet weather-related CSOs in the Lick Run sub-basin – stormwater separation from the combined sewer system - appears to be sufficient towards achieving the goal of reducing combined sewer overflows by 2 billion gallons in the Typical Year and meeting the USEPA consent decree.
- The model calibration with respect to existing conditions is reasonable, leading one to believe the model results for predicted stormwater capture of the proposed solution is reasonable.
- The 2.18 billion gallons of annual CSO volume reduction is achievable by the sewer separation projects both within and outside of the Lick Run watershed and provides a 1.09 safety factor. Note, this 2.18 BG volume is based on estimates at the time of the VE Study in 2010 and was not reflected in the updated system wide model nor the suite of projects that have been identified as part of the LMCPR study.

Additional analysis has been conducted by the team to evaluate design-related suggestions to reduce cost, such as considering the use of the existing combined sewer system for stormwater conveyance in lieu of installing new stormwater systems. The analysis demonstrated that the cost for constructing all new storm sewers would be over three times more costly than the sustainable alternative. The extent of the new sanitary system needed and the condition of the existing combined system both structurally and hydraulically are the primary drivers for these costs. Community impacts were also further examined including maintenance of traffic and associated costs.

The VE study also included recommendations for the urban valley conveyance system (VCS). These recommendations addressed issues including water quality, constructability, cost, maintenance, environmental factors and habitat, and community enhancements. MSD completed a preliminary evaluation of the recommendations and used this approach to further evaluate and develop ideas that have been incorporated into the Community Design Workshops process and the Lick Run Master Plan. These topics will be further refined during detailed design.

While the strategic separation projects will provide an immediate localized benefit upon implementation, the anticipated CSO reduction benefit is a result of the strategic separation projects in conjunction with the urban valley conveyance system. The conclusions of the VE Study mirror the conclusions contained in previous planning and preliminary engineering studies and analyses - that the sustainable project provides a reasonable and cost-effective solution for reducing current CSOs from the Lick Run sub-basin.

4.2.6. Cost Certainty

The confidence level of the program is directly dependent upon and correlates to the confidence level associated with the individual projects. As noted above, MSD has been constructing utility infrastructure for decades, and as such understand the need to identify potential risks in order to gain confidence with estimated costs. Project level certainty is increased with more robust and detailed processes available for conducting risk assessments. MSD employs such techniques on its preliminary design and final design projects. At this stage of a planning-level alternatives analysis where capital costs of the Grey and Sustainable Alternatives differ by 70 percent, a detailed risk assessment analysis is not going to change the answer. This is particularly true in this instance, where the Grey Alternative is a tunnel project where cost overruns often result due to unforeseen physical conditions far beneath the ground surface.

MSD considered risks while developing the scope, cost, and schedule of each sustainable infrastructure project. Risks were mitigated through substantial field investigations, engineering evaluations, and project-specific information and considerations.

The largest component of the Sustainable Alternative costs is traditional sewer construction. MSD is very well versed in the factors that can affect the costs of sewer construction and has planned for and managed these costs increasingly well over the past few years

Considerable due diligence has been performed during the planning and preliminary design of most of the Sustainable Alternative projects by conducting sewer alignment surveys, assessing potential easement acquisition needs, preliminary geotechnical investigations, Phase I environmental studies, and utilities surveys. These efforts allow MSD to provide adequate cost allowances to the base construction cost estimate, and, in conjunction with additional design contingency factors, reduce the potential risk for bid prices exceeding budget allowances.

Sizing of proposed new storm sewers is based on stormwater system models and the City's Stormwater Management Unit (SMU) requirements to convey a 10-year, 24 hour duration storm with the pipe flowing full, and to convey a 25-year 24 hour duration storm without stormwater exiting the system through manholes or storm inlets. This will improve the level of service in some areas where existing combined sewers do not provide as high a level of service.

The use of a declining scale of design contingencies to cover unknown costs as a project progresses from conceptual planning through final design is a type of cost sensitivity analysis. Conceptual planning estimates have a design contingency factor of 35 percent, in recognition of the fact that there are many unknown factors that could affect costs. This conceptual planning level contingency allowance exceeds that used in the preparation of the WWIP by 10 percent. Even so, there were extra measures taken during the preparation of the LMC Study to consider actual sites for remote facilities during conceptual planning to determine lengths of pipe required, the need for pumping, availability of adequate land for siting of facilities, special good-neighbor features that might be required in affected neighborhoods (like architectural treatments, noise control, and odor control), and easement and site acquisition costs.

4.2.7. MSD'S TRACK RECORD

MSD has proven the costing tool developed for the CAPP, LTCP, and final WWIP is a reasonable, accurate, and fiscally sound method to forecast project capital costs. Attachment 1B of the Final WWIP identifies 116 specific projects; including the 52 projects listed in Attachment 1A and an additional 64 projects targeted at CSO reduction, which must be constructed no later than December 18, 2018. The capital cost for each of these projects was estimated using the approach described herein.

As of June 30, 2012, MSD has fully completed 88 of the 116 projects; 10 projects are under construction, 5 are in right-of-way, 7 are in design, and 6 are in planning with Business Case Evaluations under development. Of the 88 projects completed, all 88 were constructed within the WWIP established budget. The financial details for each of cost estimate and budgets approved by the 88 completed WWIP projects are presented in the table below.

MSD takes cost control very seriously. MSD understands large capital programs can only be successful if cost and schedule are well maintained. The remaining 26 projects to be completed by December 2018 are forecasted to be collectively within the original WWIP established cost estimate. The scope of work for some of these projects has been revised from the conceptual status that used to develop those budgets, and as a result some projects have higher capital costs, while others have lower capital costs. The net result is maintaining WWIP expenditures within the Phase 1 cost estimate established in 2006. By contrast, the Lower Mill Creek Partial Remedy (LMCPR) is a highly complex project which has experienced a significant cost variance due to a significant revised scope of work as contemplated under the WWIP LMC Study provisions for which Co-Defendants negotiated. The balance of Phase 1 projects are not as complex.

Budget History of Completed WWIP Projects (2006$)

ID	PROJECT DESCRIPTION	CURRENT STATUS	TOTAL WWIP BUDGET	TOTAL PROJECT BUDGET	BUDGET VARIANCE
10110300	Durango Green-Shady Lane	Closed	$540,150	$540,150	$0
10120340	Streamwood Pump Station Elimination	Closed	$367,607	$286,198	-$81,409
10120360	Pebble Creek Treatment Plant Elimination	Closed	$1,476,446	$923,539	-$552,907
10120380	Hengehold 4th & Yates 3rd PSE	Closed	$1,101,154	$763,116	-$338,038
10120400	Arrow St. WWTP Elimination & North Bend Crossing P.S. Elimination	Closed	$1,397,845	$1,372,731	-$25,114
10120420	Diamond Oaks, Regency Ridge, Windmere 3rd P.S. Eliminations	Closed	$1,643,019	$805,587	-$837,432
10130420	Wulff Run Parallel Sewer	Closed	$152,187	$86,696	-$65,491
10130560	Muddy Creek WWTP Secondary Flow Enhancement	Closed	$11,023,486	$9,774,676	-$1,248,810
10130565	Muddy Creek WWTP Influent Effluent Pumping Upgrade	Closed	$3,409,124	$1,769,281	-$1,639,843
10130680	Harwinton Lane Sewer Replacement	Closed	$1,166,716	$770,636	-$396,080
10131003	Muddy Creek East Branch Interceptor East Half P.S. "A" Mods	Closed	$861,975	$861,975	$0
10131004	East Branch Muddy Creek CSO Elimination River Road Demo	Closed	$246,641	$246,641	$0
10131200	Mt. St. Joseph Sewer Replacement	Closed	$1,030,826	$501,204	-$529,622
10141200	Northbrook Relief Sewer Contract II	Closed	$1,423,853	$1,423,853	$0
10141220	North College Hill Replacement Sewer Phases 2D, & 3	Closed	$5,391,761	$5,391,761	$0
10141240	Sewer 155 Cooper Creek Contracts 2A & 2B	Closed	$5,104,573	$5,104,573	$0
10141260	Springdale-Sharonville Sewer Phase 3	Closed	$2,401,605	$2,401,605	$0
10141300	Camberly Acres PS	Closed	$321,573	$321,573	$0
10141340	Greenridge 5th PS Upgrade	Closed	$668,196	$570,783	-$97,413
10141360	Garden Hill PS Elimination	Closed	$1,065,355	$1,065,355	$0
10141380	N. Bend Rd./Connecticut Sewer	Closed	$1,188,652	$908,865	-$279,787
10141400	Deer Park Relief Sewer	Closed	$2,076,612	$2,076,612	$0
10141420	Centurion Estates PS Elimination	Closed	$692,622	$367,235	-$325,387
10141440	Millbrook 1 PS Upgrade	Closed	$704,872	$544,382	-$160,490
10141480	Mill Rd. Sewer Replacement Ph. 1 & Ph. 2	Closed	$1,855,869	$1,855,869	$0
10141500	Pleasant Run PS Facilities Plan	Closed	$6,817,628	$6,337,323	-$480,305
10141520	Arrowood P.S. Elimination	Closed	$1,038,808	$757,269	-$281,539
10141540	Winton and Sherwood Ph1 PS	Closed	$2,399,094	$2,112,204	-$286,890
10141560	Winton 1 & 2 and Sherwood P.S. Consolidation	Closeout	$1,660,263	$1,013,658	-$646,605
10141580	Mill Creek WWTP Liquid Treatment Process Coarse Screen	Closed	$2,813,073	$2,813,073	$0
10141600	Mill Creek WWTP Coarse Screens Replacement Phase 2	Closed	$3,620,680	$2,885,600	-$735,080

ID	PROJECT DESCRIPTION	CURRENT STATUS	TOTAL WWIP BUDGET	TOTAL PROJECT BUDGET	BUDGET VARIANCE
10141620	Mill Creek WWTP Solids Management Plan Phase 3A	Closed	$2,616,020	$2,616,020	$0
10141640	Mill Creek WWTP Solids Phase 3B - Sludge Thickening	Closed	$10,208,487	$10,208,487	$0
10141660	Norman Ave. Relief Sewer	Closed	$137,501	$137,501	$0
10141680	406 Elliot Ave. Sewer Replacement	Closed	$130,892	$130,892	$0
10141700	Mill Creek WWTP Incinerator Scrubber Aux. Air Supply	Closed	$215,096	$215,096	$0
10141720	Goodman Ave. Sewer Replacement	Closed	$1,607,061	$1,607,061	$0
10141740	St. Clair Ave. & Elizabeth St. Sewer Replacement	Closed	$1,454,250	$1,454,250	$0
10141760	Mill Creek WWTP Raw Sewage Pumps	Closed	$4,018,226	$3,165,237	-$852,989
10141780	Arrowhead Ct. PS Upgrade & Marview Terrace PS Elimination	Closed	$788,641	$626,679	-$161,962
10141820	SSO 700 CEHRS Treatment Facility	Closed	$14,230,459	$13,765,775	-$464,684
10141840	McGrew Ave Pump Station Upgrade	Closed	$309,253	$288,737	-$20,516
10141880	Laboiteaux Ave. Sewer Replacement, SSO 597 Elimination	Closed	$181,725	$181,725	$0
10142000	SSO 574 Elimination	Closed	$794,722	$422,091	-$372,631
10142040	Compton Road Sewer Improvements	Closed	$210,603	$210,603	$0
10142440	7601 Production Dr. Grating	Closed	$226,997	$126,096	-$100,901
10144900	Ludlow Run Relief Sewer	Closed	$3,106,250	$2,608,575	-$497,675
10144920	CSO 4 Modifications Harrison & State Aves. East	Closed	$171,990	$171,990	$0
10144940	CSO 451 Elimination Sawyer Point	Closed	$33,298	$33,298	$0
10144960	CSO 3 High Water/Dry Weather Protection	Closed	$325,357	$325,357	$0
10144980	Ross Run Grit Pit	Closed	$523,746	$523,746	$0
10145000	CSO 29 Elimination Mitchell Ave.	Closed	$615,916	$615,916	$0
10145020	Montana Ave. Sewer Separation	Closed	$138,382	$138,382	$0
10145040	West 3rd St. Ph3 CSO 437	Closed	$356,683	$309,233	-$47,450
10145080	Eastern Ave. Sewer Separation Collins to Bayou Phase 2	Closed	$451,318	$451,318	$0
10145100	Ross Run Sewer Separation	Closed	$1,957,626	$1,509,989	-$447,637
10145120	Eggleston Avenue Tide Gate Replacement	Closed	$64,109	$64,109	$0
10145140	Givaudan Sewer Separation	Closed	$67,933	$67,933	$0
10145180	Mill Creek Interceptor Diversion Chambers	Closed	$1,588,861	$1,207,226	-$381,635
10145200	CSO 450 Elimination Butler St.	Closed	$94,432	$94,432	$0
10145220	Ross Run CSO 487 Twin Outfall	Closed	$4,491,478	$3,914,234	-$577,244
10145240	Este Avenue Flood Remediation Project	Closed	$167,551	$90,009	-$77,542
10145280	CSO 482 Mitchell Avenue Real Time Control Facility	Closed	$2,643,352	$1,962,166	-$681,186
10145300	CSO 125 Badgeley Run Outfall	Closed	$2,922,912	$1,843,251	-$1,079,661
10145320	Lick Run Interceptor Chamber Real Time Control	Closed	$1,453,334	$759,494	-$693,840

ID	PROJECT DESCRIPTION	CURRENT STATUS	TOTAL WWIP BUDGET	TOTAL PROJECT BUDGET	BUDGET VARIANCE
10145400	Samoht Ridge Relief Sewer	Closed	$2,144	$2,144	$0
10145580	Millcreek WWTP Additional Primary Sludge Pumping	Closeout	$1,315,000	$831,968	-$483,032
10150000	Polk Run WWTP Expansion Ph. 2	Closed	$11,186,361	$9,723,694	-$1,462,667
10150011	Polk Run WWTP PS Elimination Phase 3A	Closed	$667,943	$1,978,392	$1,310,449
10150012	Polk Run WWTP Improvements Phase 3B	Closed	$2,127,133	$1,304,139	-$822,994
10150240	Supplemental Agreement for Maple Ave. Sewer Upgrade	Closed	$233,361	$233,361	$0
10160000	Sycamore WWTP Phase 1 & 2	Closed	$29,601,788	$29,134,974	-$466,814
10160005	Sycamore WWTP Phase 3	Closeout	$8,885,201	$7,982,335	-$902,866
10170020	Camargo Rd. Sewer Replacement Ph. 2	Closed	$3,410,084	$3,410,084	$0
10170040	Euclid & Laurel Avenues SSO 570 & 1017 Relief Sewer	Closed	$3,357,676	$3,357,676	$0
10170060	Mariemont Outfall Sewer SSO 679A, 679B & 680 Elimination	Closed	$9,081,115	$8,664,632	-$416,483
10170081	Montgomery and Lester Sewer Replacement (48% WWIP)	Closed	$1,042,580	$565,077	-$477,503
10170560	Britney Acres P.S. Upgrade	Closed	$1,001,671	$668,175	-$333,496
10170780	Little Miami WWTP Activated Sludge Thickening	Closed	$5,776,675	$5,652,142	-$124,533
10170800	Berkley Woods PS Elimination	Closed	$321,991	$197,351	-$124,640
10170820	Gungadin and Paddison Road Relief Sewer	Closed	$3,126,594	$3,126,594	$0
10170840	Johnson Road Pump Station Elimination Phases 1 & 2	Closed	$859,015	$585,747	-$273,268
10170940	CSO 557 Elimination	Closed	$412,420	$412,420	$0
10171420	CSO 86 High Water/Dry Weather Protection	Closed	$244,636	$244,636	$0
10171820	Beechmont Avenue Area Sluice/Shear Gate Replacements	Closed	$1,979,757	$1,847,474	-$132,283
10171980	Eastern Delta Sewer Separation Phase 1A	Closeout	$43,679,717	$39,695,333	-$3,984,384
10172090	Kenwood Rd. P.S. Elimination	Closed	$2,132,375	$1,420,548	-$711,827
10172200	Broadview Drive & Country Club Place Sewer Separation	Closed	$1,521,582	$991,599	-$529,983
	88 Projects in Total		**$255,933,545**	**$230,531,427**	**-$25,402,118**

4.2.8. Operations & Maintenance Costs

MSD will operate and maintain the new infrastructure constructed for the LMCPR. These costs are included in the alternatives analysis. New storm sewers have stormwater best management practices (BMPs) to address water quality concerns and mitigation of those concerns, and costs are also included for constructing, operating, and maintaining the BMP facilities. EPA direction is moving towards integrated watershed planning that addresses quantity and quality of all wet weather discharges, and this is the hallmark of MSD's Sustainable Watershed Evaluation Planning Process (SWEPP).

Some references to O&M cost development for Sustainable Alternative are provided in the Working Draft Document including the Sustainable Costing Information that was provided to the County in July 2012. All references to costs were eliminated for the public/regulatory agency version of this document at the County's request. For example, if the O&M costs needed to be higher, say even twice as high as projected, then Sustainable Alternative life-cycle costs would increase another 2 percent. Given the large differential in life-cycle costs between the grey and sustainable alternatives, this is almost negligible.

Because the objective of the SI projects is to reduce CSOs in a more sustainable and cost effective manner, the immediate and long-term impacts of the SI projects need to be considered., These include the costs and ease with which the SI projects can be constructed and maintained, coordination with and impact to other utilities and agencies, the disruption and maintenance of traffic, and the impact to the surrounding community during and following construction.

Consideration of community impact is standard procedure in the wastewater industry. In the instance of construction a pump station or well, water or wastewater treatment plant, solid waste disposal, highway, etc. The standard of care is to provide a facility that does not negatively impact the surrounding properties and public, or would compromise the smell, sight, sound, safety or health. Odor control facilities may be installed; sight screening, landscaping or architectural construction embracing the surrounding community; sound barriers or noise reduction; safety fencing or other such precautions; and lastly monitoring of water and air quality for public health. All of these items listed are vital parts to a project, however very few if any are *necessary* for the day-to-day function of the facility.

O&M Data Sources

A number of local and national sources were used for general guidance in the operation and maintenance of green infrastructure, specifically policies and procedures, maintenance implementation, maintenance needs, and maintenance costs. Sources include, but are not limited to:

- USEPA Green Infrastructure Program
- Water Environment Research Foundation's (WERF's) 2005 Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems
- A.J. Erickson, J.S. Gulliver, P.T. Weiss and C.B. Wilson 2005 "The Cost and Effectiveness of Stormwater Management Practices"
- 2009 "Survey of Stormwater BMP Maintenance Practices", along with numerous municipal BMP manuals through the United States

Most recently, the Cincinnati Park Board provided their annual maintenance plan and budget for a local urban park similar in size and complexity to the upslope areas of the proposed Lick Run Valley Conveyance System. The park maintenance plan included a spreadsheet with a breakdown of hours associated with each task, a staff breakdown of each task, and staff pay rate. For all typical landscape elements (lawns, planting beds, tree maintenance, site furnishings) this information was used to estimate rates and hours based on area, frequency, schedule and average annual cost. This data was adapted to the elements and areas shown on the Lick Run Master Plan.

For all riparian edges and biofeatures of the Lick Run Valley Conveyance System, a recent competitive bid for maintenance for a local company's campus was used in comparison from a Spring 2012 bidding effort. The maintenance scope and scale was similar to the proposed Lick Run Valley Conveyance System for the native planted areas in the riparian edges and biofeatures. A weekly maintenance cost was included, based on the known acreage of that project, extrapolated an average per-acre cost, and then applied to Lick Run for similar areas with similar maintenance scope (tasks and frequency).

4.3. Benefits

4.3.1. Factor of Safety

With the assumptions utilized for the LMC Study, the recommended projects are determined to meet the volumetric reductions of the WWIP targets under Phase 1. The LMC Study included a sensitivity analysis that provides an analytical methodology for understanding the risk associated with not meeting the WWIP objective of significant overflow reductions in Phase 1. The results of this analysis were used in this recommendation of the projects suite that MSD is proposing as the alternative to the default remedy.

There are projects incorporated into the model version 4.2 that are included in both the grey and sustainable alternative – CSO 25 for example. This asset management project that provides flood control benefits provides 23 million gallons of CSO reduction. Currently, this is not a Phase 1 project in the WWIP but a Phase 2 LMCFR project. CSOs 37 and 39 regulator improvements are examples of Phase 2 projects that were completed in Phase 1 resulting with a combined total CSO reduction of 4 million gallons.

4.3.2. Water Quality Improvement

The recommended projects will benefit the environment by returning natural drainage to tributaries and streams and through reduction combined sewer overflows by two billion gallons during the typical year. The pollutant loading discharges to Mill Creek from the sustainable projects will decrease significantly when compared to existing conditions given the differences between combined sewer overflow and stormwater characteristics. Directing natural drainage and stormwater to water bodies will result in additional base flow to support aquatic life.

The WWIP is focused on volumetric control and no water quality criteria are required to be included in the submittal to USEPA. In addition, USEPA has provided guidance as to the type of information desired in such a submittal, and has made no mention of water quality. Specifically, see the *Guidance Pertaining to Consideration of Any Proposed Revised Original Lower Mill Creek Partial Remedy Defendants May Choose to Submit in Accordance with Paragraph A.2 of the Wet Weather Improvement Plan*, included in *Appendix C to the LMCPR Alternatives Evaluations Preliminary Findings Report*. Nonetheless, the results of the water quality modeling conducted by MSD suggests that the remaining CSOs for either alternative will neither cause or contribute to the impairment of water quality in the Mill Creek.

As mentioned, it is anticipated that volumetric discharges to Mill Creek associated with peak flows from the proposed Sustainable Alternative would be relatively minor impacts in comparison to existing conditions. However, the <u>pollutant loading discharges to Mill Creek from the SI projects would decrease significantly when compared to existing conditions</u> given the differences between combined sewer overflow and stormwater characteristics. From a regulatory perspective, these differences are substantial.

The attainment of designated uses as described in the Ohio WQS for aquatic life and recreation in urban streams can be problematic. As recognized by Chris Yoder and the Midwest Biodiversity Institute, MSD has developed a remediation plan that would be effective, but still affordable for local ratepayers. Yoder affirms that MSD's sustainable infrastructure approach includes the consideration of alternatives to classic "grey" engineering alternatives and coupled with the knowledge being generated by the watershed assessment program it provides the opportunity to seek solutions that are more environmentally and cost-effective. Yoder provides that:

> *Unfortunately, "grey" approaches to pollution abatement frequently ignore the importance of base flow and at times have encouraged practices that degrade the base flow regime in the interest of achieving the "zero discharge" of pollutants. This has already happened to some extent in Hamilton County via the issuance of NPDES permits that in effect "regionalize" sewage flows by diverting them away from headwater streams towards the largest rivers in the area. When such strategies "sweep up" and divert storm runoff from smaller streams, impairment of aquatic life results simply from the lack of sufficient water and habitat. Simply put the streams in the watershed become "flow starved". Shifting our thinking more towards the augmentation of low flows (even with treated effluent) would be a positive step for improving overall chemical, physical, and biological quality and in moving towards the ultimate goal of full use attainment."*

An issue with CSO and SSO flow reduction strategies that divert all flows can result in a worsening of the base flow problem particularly in smaller tributaries of impacted watersheds. Diverting combined sewage and stormwater flows to places of sequestration (e.g., to tunnels or oversized interceptor sewers) may appear to address the overall pollution problem by eliminating those discharges, but it can ignore the need to keep the non-sanitary flows distributed as naturally as is possible within a watershed. Criticisms of such holistic and innovative approaches to urban stormwater management as being esoteric or unconnected to the treatment of such flows reflects a lack of awareness about the complex mechanisms of aquatic life use impairments. An over-reliance on traditional "grey" infrastructure solutions can too easily become disconnected from the overall goals of water quality restoration efforts particularly when the underlying assumptions are focused on administrative measures or surrogate performance targets rather than on direct and more complete measures of designated use attainment (e.g., aquatic life). Innovative approaches that are "green" or a mix of "green" and "grey" can not only be more cost-effective compared to "grey" approaches alone, but are more likely to broadly address the actual designated use goals of water quality restoration (U.S. EPA 2007). Recent studies are documenting that "green" infrastructure and the restoration of natural functions and features can also be important drivers of economic re-development in urban areas (Adelaja et al. 2012).

Ohio offers an advanced setting in having tiered aquatic life designated uses in their WQS which provides an impetus to consider all of the factors that drive quality in rivers and streams. Neither does it hold all waters to a single uniform standard, but rather recognizes that restoration potentials can vary from biologically and physically limited waters to biological unique and diverse waters thus allowing restoration projects to take these differences in potential into account. The potential costs and benefits of properly restoring ecosystem services in urban areas can be complex and a sound scientific basis for guiding water quality management is imperative. Such an ecologically-focused approach allows a broader consideration of ecosystem services that are produced by watersheds including nutrient and waste assimilation, water conservation, recreational attributes, maintenance and protection of biodiversity, as well as more global and diffuse benefits such as carbon and nutrient control and climate change benefits.

4.3.3. Community Livability

The Lick Run CSO mitigation project and the associated increase in green space will provide direct market benefits as estimated by the University of Cincinnati in its estimates of impacted businesses and private investment dollars. The project will also produce non-market benefits in the watersheds where urban waterway features are enhanced for CSO reduction with the installation of Valley Conveyance Systems or naturalized conveyance systems such as in Lick Run or West Fork. The benefits estimated associated with the MSD's Recommendations is estimated to also include a range of potential benefits for the following community attributes:

- Reduced energy usage
- Community livability
    - Improved aesthetics
    - Improved recreation opportunities
    - Reduced carbon emissions

4.3.4. Additional Direct Reduction Opportunity

The LMC Study included watershed evaluations in many watersheds not included in the LMCPR recommendation. Those opportunities still remain viable for consideration for additional future reductions.

Although not incorporated toward the reduction goal, enabled impact projects provide a level of CSO reduction to the system. Burnet Woods is within the Clifton Watershed and is a joint MSDGC and City of Cincinnati Parks potential enabled impact project. Burnet Woods provides some daylighting through the park as well as additional detention that when integrated with University of Cincinnati's enabled impact proposal would reduce and detain flow from entering the combined system. Burnet Woods could provide additional benefits for CSO reductions above of those projected in the LMC study as well as help to illustrate larger scale enabled impact projects that could highlight a broader sustainable approach to inform and influence private partners for CSO reduction solutions.

MSD has been working closely with ODOT to address CSO reduction needs associated with highway reconstruction and specifically coordinating stormwater management infrastructure and strategic separation projects to reduce flows to CSOs. There are several locations along I-75 where separation pipes are being designed and constructed under I-75 with ODOT's active construction projects that will provide CSO reduction benefits in near term but the primary purpose and benefit of coordinating with ODOT are the additional reductions that can occur in the future once the separation barriers are eliminated through the coordination efforts along the highway. These benefits have not been included in the LMCPR estimates. The planning and coordination done now will help to facilitate a more sustainable final remedy in Clifton, Mitchell and Bloody that currently lack a separate conveyance to the Mill Creek. The design and construction coordination efforts in phase 1 are conservatively estimated to be approximately 10 million gallons. However, post 2018 when future projects could strategically separate flows within Clifton, Bloody or Mitchell, additional reductions could reasonably be expected to exceed 200 MG.

4.3.5. Additional Enabled Impact CSO Reduction Opportunity

The Recommendation provides for private sector investments to reduce CSO volume generated on private property. Through an enhanced enabled impact program, MSD can develop partnerships with agreements that generate long-term CSO reduction benefits. MSD and its partners can identify integrated, on-site source control solutions. This approach will facilitate and capture the benefits of future land use changes and private property investments.

LOCAL DEMONSTRATION PROJECTS DATA

Beginning in 2010, as part of the Enabled Impact (EI) Program, MSD engaged in a multi-faceted effort to document and evaluate the overall performance and localized effectiveness of sustainable stormwater infrastructure. This is being accomplished through identification and implementation of various types of monitoring practices with different objectives conducted at different scales. The objectives include:

1. Quantifying stormwater runoff and CSO volume reductions;
2. Identification of design lessons-learned;
3. Identification of constructability constraints;
4. Determining vegetative successes;
5. Summarizing operational/functional issues;
6. Clarifying maintenance needs and long-term viability.

These objectives lend themselves to both quantitative and qualitative monitoring approaches, depending on the nature of a specific project. MSD outlined its approach to meet these objectives in the *Enabled Impact Program Interim Summary Report, December 2011* and the *Enabled Impact Project Monitoring Program Interim Summary Report, January, 2012*. The EIP Interim Summary Report for September 2012 has been provided to the Co-Defendants and is available upon request. In December of 2012, MSD plans to update these reports in a combined document summarizing accomplishments through the end of 2012.

Included in these reports is information summarizing progress of the EI program, including flow monitoring data collected at select EI projects throughout the program, as well as examples of the post-construction site inspections performed on completed projects and comprehensive summaries of all active and completed EI projects.

In order to maintain objectivity in the monitoring efforts, and to capitalize on expertise available in the industry, MSD initiated strategic partnerships to assist and collaborate in the collection and evaluation of sustainable stormwater infrastructure. These strategic partners, along with MSD, have been collecting data on select projects throughout the implementation of the EI Program. The table below summarizes these efforts, which are described in detail in the previously mentioned interim summary reports.

Existing & Planned Enabled Impact Program Monitoring Efforts

Entity	Project	Monitoring Effort
MSD	Clark Montessori	CSS flow monitoring
	Cincinnati State	
	University of Cincinnati	
	Cincinnati Zoo	
Cincinnati Park Board	(all completed projects)	Post-construction site inspections on a quarterly basis
University of Alabama	Cincinnati State	Development of monitoring strategies
	Cincinnati Zoo	
University of Cincinnati	University of Cincinnati	
	Cincinnati State	Implementation of monitoring strategies
	Cincinnati Zoo	
	University of Cincinnati	
USEPA	St. Francis Court Apartments	Groundwater level and soil moisture monitoring.
	Clark Montessori School	
	Cincinnati State	
USGS	St. Francis Court Apartments	
	Cincinnati Zoo	
Civic Garden Center	Green Learning Station	Groundwater level, soil moisture, water balance, rainwater harvesting, infiltration monitoring

MSD has utilized the assistance of Dr. Robert Pitt of University of Alabama to develop monitoring efforts coordinating with the Cincinnati State, University of Cincinnati, and Cincinnati Zoo. Dr. Robert Pitt has more than 40 years for experience in research and development of stormwater controls and has partnered with the Center for Watershed Protection to develop the National Stormwater Quality Database (NSQD), of which local projects will feed into. Additionally, USEPA and USGS engaged during construction of the St. Francis Court Apartments, Clark Montessori, and Cincinnati State projects to install groundwater sensors and moisture probes within the bioinfiltration and pervious pavement systems on these projects. These partnerships have yielded a substantial amount of data; primarily useful in establishing baselines for pre-existing conditions at each of the localized project sites. This information will be invaluable in determining each project's percent stormwater capture and overall CSO volume reductions from the CSS.

This baseline of pre-existing conditions is complemented by post-construction site inspections performed by Cincinnati Park Board on all completed projects, and post-construction monitoring data collected at the St. Francis Court Apartments, Clark Montessori, Cincinnati State, and Cincinnati Zoo project sites. Following at least two years of data collection, this monitoring will provide a dataset suitable to characterize the performance of the installed sustainable stormwater infrastructure. As MSD and its partners continue to move forward in implementing the monitoring program, the evaluation of this comprehensive dataset will provide MSD with objective data supporting the effectiveness of sustainable stormwater infrastructure for inclusion into future reductions and integrated opportunities. MSD will utilize facility performance characterizations to properly size future sustainable stormwater infrastructure projects, and ultimately optimize the CSS.

4.3.6. Opportunities for Construction Coordination

A preliminary project phasing plan[64] has been developed for the Lick Run projects to be staged in a single watershed as part of the Sustainable Alternative. Approximately three or four projects would be started in any particular year and most have construction durations of one year or less. Construction phasing was selected based on minimizing interferences and coordination between adjacent projects. A preliminary project phasing plan for Lick Run projects was presented in planning documents prepared over two years ago, and which have been made available to the County. Project definition and scheduling has varied little since that time. If the Sustainable Alternative is likely to be implemented in Phase 1, then additional scheduling details can be developed and presented. At this stage in the planning process, there is a parallel path of projects and costs that limits the appetite for spending additional funds.

A great deal of effort and coordination with local agencies and utilities has gone into Sustainable Alternative project sequencing, to minimize project costs and community disruption. Duke Energy, GCWW, MSD, CDOTE and ODOT all have capital improvement plans that have been taken into consideration for developing the schedule, sharing of construction costs, and maintenance of traffic.

- <u>WEST FORK</u> - Within the West Fork watershed, there are no key sequencing needs or traffic impacts at this time. ODOT has on-going arterial and interchange construction work in this area associated with I-75 and I-74; however, this construction work is anticipated to be complete before the implementation phase begins for the SI projects in the watershed.

- <u>BLOODY RUN</u> - Within the Bloody Run watershed, the key sequencing need is with ODOT regarding potential I-75 construction work which would impact the CSO 181 location. Meetings have been held with ODOT to discuss coordination and schedule. It is anticipated, at this time, that the ODOT work would begin in 2018.

- <u>KINGS RUN/WOODEN SHOE</u> - Within the Wooden Shoe watershed, the key sequencing need is with CDOTE regarding a street improvement project along Winton Road scheduled to begin construction in January 2013. In order to coordinate with CDOTE and the project schedule, the design of a phase of the sustainable project within Wooden Shoe – installation of new storm system along Winton Road – is being advanced at this time, to be constructed within the same timeframe. It has been agreed that CDOTE will prepare the maintenance of traffic notes. It should be noted that savings in construction costs will be realized through this coordination effort.

- <u>LICK RUN</u> - Within the Lick Run watershed, there are a number of sequencing needs or traffic impacts with respect to capital improvement projects and schedules for Duke Energy, GCWW, CDOTE and ODOT. The sequencing needs and impacts were accounted in the cost estimates presented for the SI projects. A more detailed discussion of utility coordination is provided in this report.

    - <u>HARRISON AVENUE</u> - The first SI project to be constructed is the Harrison Phase A Sewer Separation project, which was strategically designed and bid with the CDOTE Harrison Avenue Realignment Project. If MSD had not opted to collaborate with CDOTE to coordination construction needs in this corridor, then project costs would have increased at least $350,000. This accounts for more than a 20% cost savings on the bid price for the MSD portion of the Harrison Phase A Sewer Separation Project. With Harrison Avenue Realignment project under construction, Harrison Avenue will be closed to traffic for the summer months of 2013. CDOTE had requested that no other sewer separation projects be constructed that would affect the detour route on White Street or the alternate through route of Queen City Avenue during this time. Therefore, the remaining sewer separation projects have a start date that occurs after Harrison Avenue is reopened to traffic.

- SUNSET AVENUE, GRAND AVENUE, QUEBEC ROAD - CDOTE requested that the large parallel collector to be located along streets of Sunset Avenue, Grand Avenue and Quebec Road be sequenced such that they are not under construction at the same time. These projects have then been scheduled to minimize impact to traffic and overall disruption of the community.

- WESTERN HILLS VIADUCT – MSD has performed additional coordination with CDOTE and ODOT related to the Western Hills Viaduct and Brent Spence Bridge projects; as well as with Duke Energy and GCWW on opportunities to synchronize construction schedules for gas and water main rehabilitation/replacement through the corridor to minimize community and traffic disruption.

4.3.7. Partnership Opportunities

As outlined in the Lick Run Master Plan, a number of potential partners and funding sources have been identified for components of the long-term community vision not associated directly with MSD's wet weather improvements are summarized in the table and figure below.

Potential Funding Sources for Non-CSO Amenities

	MSD	Potential Partners & Funding Sources					
		National (public)	National (private)	State (public)	State (private)	Local (public)	Local (private)
Urban Waterway	●					●	
Transportation Network	●					●	
Waterway & Infrastructure Maintenance Access, Public Access	●					●	
Cultural Resources: Mitigation Strategies	●					●	●
Recreation Facilities: Maintaining Existing Uses	●					●	
Natural Conveyance Systems	●			●		●	
Separate Storm Sewer Network, Detention	●					●	
Enabled Impact Projects	●			●	●	●	
Future Recreation/Open Space						●	●
Environmental Education	●	●	●	●	●	●	●
Queen City/Westwood: Further Technical Analysis		●		●		●	
Neighborhood/Business Zone Investment			●		●		●
Streetscape Improvements		●		●		●	
Improved Access to Public Transportation				●		●	
Urban Design Guidelines						●	●
South Fairmount Cultural Trail	●	●	●	●	●	●	●
Public Art, Interactive/interpretive Elements		●	●	●	●	●	●
Sustainable Systems	●	●		●		●	
Watershed Planning Tools	●	●				●	●

Potential Partners and Funding Sources

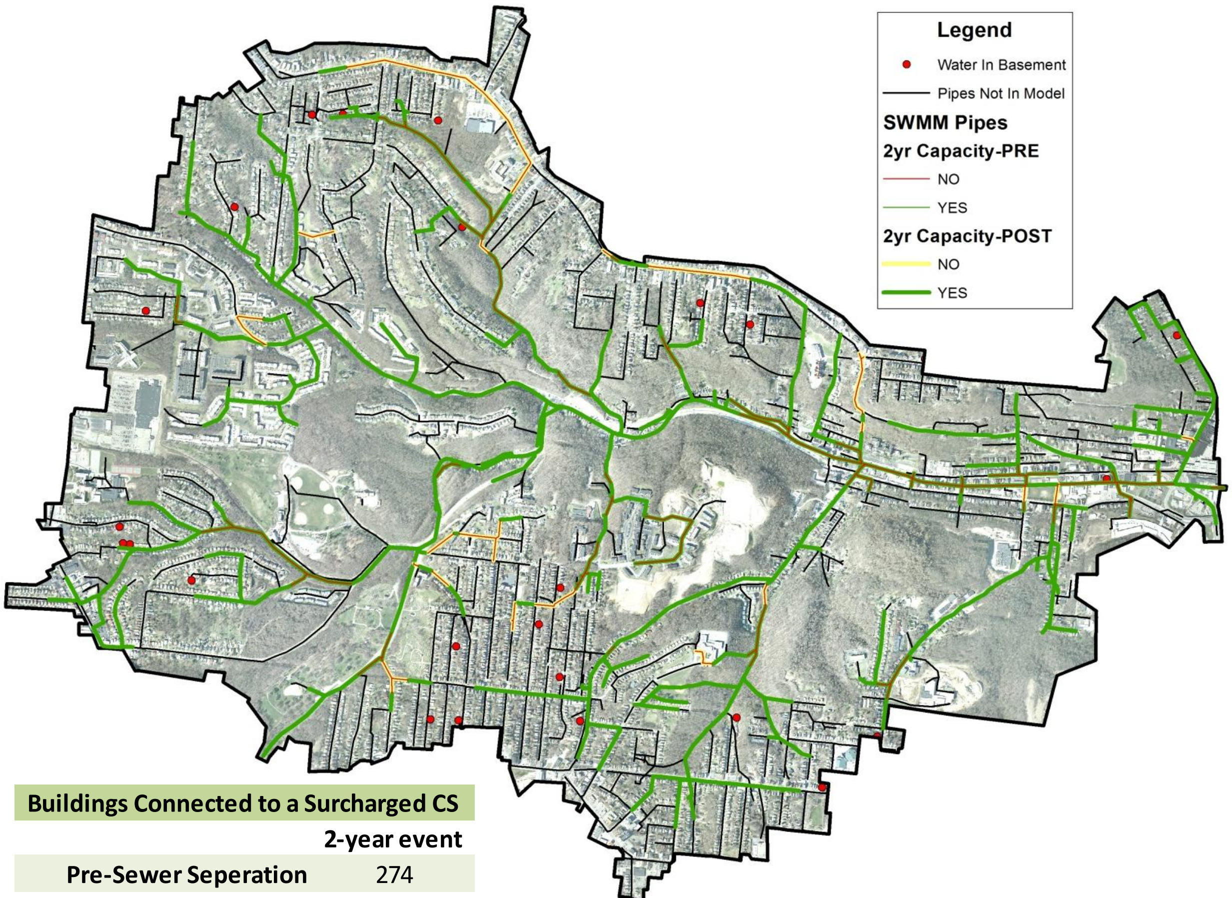
Potential Partners and Funding Sources	
National Level – public entities	US Environmental Protection Agency (USEPA) USEPA/HUD/DOR Sustainable Communities Partnership Federal Highway Administration (FHWA) National Parks Services Recreational Trails (NPS) National Forestry Service (NFS) Department of Energy (DOE) US Geological Survey (USGS)
State Level – public entities	Water Resource Restoration Partner Program (WWRSP) Ohio Environmental Protection Agency (OEPA) Ohio Department of Natural Resources (ODNR) Ohio Department of Transportation (ODOT) Ohio Department of Development (ODOD)
Local Level – public entities	Cincinnati Dept. of Transportation & Engineering (CDOTE) Cincinnati Recreation Commission (CRC) Cincinnati Park Board (CPB) Greater Cincinnati Water Works (GCWW) Cincinnati Public Schools (CPS)
National & State – private entities	Corporate Foundations Non-Profit Organizations
Local Level – private entities	Community Development Corporations Greater Cincinnati Foundation Corporate Foundations Non-Profit Organizations Duke Energy Businesses (existing and future) Developers Banks

The base plan referenced in these responses has been through an extensive community process, and revised since preliminary planning documents as guided by the USEPA draft guidance document. The base plan has been vetted, revised, and updated based on a strong level of support by the community. Some of these funding sources have already provided funding assistance to SI projects. MSD has been partnering with Hamilton County Regional Planning, City Planning, Cincinnati Park Board, Mill Creek Watershed Council, and Mill Creek Restoration Project and others to complete a watershed action plan, which can be used to secure alternative funding.

4.3.8. Water in Basement Reduction

There is a potential for Water in Basement (WIB) to be reduced by 103 buildings (38%), with a 67% overall reduction in surcharged combined sewers during a 2-year return interval storm event. WIB potential reduction is due to buildings being connected via service lateral to a combined sewer that is no longer surcharged, as a result of the sewer separation project. Pipes 18-inches and larger are modeled in SWM. The vast majority of the WIB's occur in areas with collector sewers, as opposed to interceptors, that are not modeled. Therefore a greater amount of combined sewer surcharging and WIB's would be anticipated to be relieved than currently modeled. The increased level of service is shown below. Similar results were determined for the 5-year and 10-year storm events.

Increased Level of Service for 2-Year Storm Event



Buildings Connected to a Surcharged CS	
	2-year event
Pre-Sewer Seperation	274
Post-Sewer Seperation	171
Difference	103
% Reduction	**38%**

Length of Surcharged CS	
	2-year event
Pre-Sewer Seperation	41,334
Post-Sewer Seperation	13,622
Difference	27,712
% Reduction	**67%**

4.4. Risk Analysis

Each project within the Sustainable Alternative has gone through a risk analysis, and risk registers have been developed in accordance with MSD Master Program Management Plan Procedure MPMP-05-06, allowing the project team to thoroughly understand and plan for risks in their projects and designs. A risk register is created that shows risk probability ranges and associated cost ranges to mitigate the risk for a large number of items. The process involves the design team, MSD staff from planning, project delivery, construction inspection, and wastewater collections, and treatment groups, as applicable to a particular project and project phase. This process has proven to be an effective tool for communicating and managing risks and their associated costs. This level of risk assessment was not a normal part of a large, conceptual planning project, but is important to consider when alternatives will require significant capital investment. Additional analysis and information regarding the cost evaluation of the LMCPR Revised Plan from identified risks is described below.

4.4.1. Modification of Traffic Patterns

The modification of traffic patterns along Westwood Avenue and Queen City Avenue relate to the conversion of both streets from a one-way pair to convention two-way, including a boulevard concept for Westwood Avenue. This traffic proposal was developed based on community input and incorporated into the Lick Run Master Plan as part of the long-term vision of the community. It has repeatedly been made clear that any modifications to Westwood Avenue or Queen City Avenue would not be initiated or funded by MSD. The advancement of this long-term component of the master plan would need to be supported by the community and other stakeholders such as ODOT and CDOTE.

The opinion of probable costs for the Lick Run Sustainable Alternative does not include provisions for the conversion of the current traffic patterns on Queen City and Westwood, because these traffic pattern conversions are not necessary as a part of the Valley Conveyance System element. Therefore, the projected $23M - $29M opinion of probable costs for the reconstruction of Westwood and Queen City Avenue to support this conversion are not included in the Sustainable Alternative costs. Should the reconstruction of Westwood and Queen City Avenue be made to support a traffic pattern conversion as described above, they would likely be funded through sources other than MSD, such as FHWA, ODOT, and CDOTE.

In April 2012, CDOTE initiated coordination with the Hamilton County Transportation Improvement District (HCTID) to seek grant funding for the boulevard projects. The HCTID agreed to package and submit the request and in August 2012 it received notice that they are the recipient of a $6 million grant through the FHWA Surface Transportation Program (STP) for the Lick Run/Westwood Boulevard project. Six million dollars is a the maximum amount awarded per grant cycle, and future STP grant applications are anticipated to be submitted by CDOTE/HCTID for future grant cycles to fund the remainder of the project. As $6 million will only cover a portion of the Westwood Boulevard project, this project is anticipated to be divided into 'phases' to utilize grant monies as they are available.

Beekman Street is proposed to be eliminated as a part of the VCS element of the Lick Run SI project. The costs associated with this aspect of the roadway modifications, including accommodating this traffic on Harrison Avenue, and intersection reconfigurations on Queen City and Westwood Avenue have been accounted for and included in the opinions of cost prepared for the Valley Conveyance System.

It should further be noted that implementation of the Lick Run Sustainable Alternative will impact traffic in the corridor during construction, and the VCS opinion of probable cost accounts for this within the maintenance of traffic component.

4.4.2. Property Acquisition

Property acquisition is a complex challenge that can affect schedule and budget. Cost estimating for right-of-way during the early stages of projects is difficult because of the lack of information regarding the extent and nature of property needs. As project designs progress, right-of-way estimates are updated to reflect changes in property needs. The identified risk is that property acquisition challenges (relocation, loss of business, funding constraints) may incur additional costs and delays.

MSD has created a property acquisition team which is managing the day to day aspects of real estate transactions. The risk of budget and schedule impacts associated with property acquisition has been minimized by the development of the detailed itemization of costs. This detailed itemization assists in ensuring the completeness of the estimate as described in Real Estate Cost Estimation Assumptions dated February 29, 2012. In an effort to mitigate cost overruns, conservative assumptions in estimating right-of-way costs included the following:

- ACQUISITION COSTS: A 1.5 multiplier was applied to the Auditor's Market Value for each parcel as the basis for anticipated acquisition costs. The 1.5 multiplier was derived from a review of properties already acquired within the Lick Run corridor which revealed that appraised values and actual acquisition prices were approximately 50% above Auditor's Market Values. Easement acquisition costs were based on standard estimating principles derived from design consultants currently working on the projects. These estimates are based on square footage and the type of easement being acquired, e.g., permanent residential easement, temporary non-residential easement.

  - The Auditor's Market Values are established pursuant to ORC 5713.33 which requires that every six years, the tax commissioner verify that properties are being assessed in accordance with law. The assessments are intended to equalize imbalances in property values. Examples of why such imbalances occur are: economic trends that vary from neighborhood to neighborhood and among different types of properties; improvements to the property; demolition of structures; and, additional or new tax levies.

  - The most recent reappraisal resulted in new value assessments effective for the January 2011 tax period. The valuations were prepared by Lexur, a company that specializes in property revaluation programs.

- RELOCATION COSTS: Relocation estimates were derived from a review of various guidance materials prepared by ODOT, FHWA, HUD and other publications prepared for public agencies and specifically to conform with the Uniform Relocation Act (URA). Relocation estimates are very conservative due to the number and size of commercial properties being displaced. Further, industry guidance cautions that relocation costs account for the majority of cost overruns for public acquisition projects.

- PROPERTY MANAGEMENT: Property management cost estimates were derived from actual costs related to properties already acquired by MSD, including Lick Run, North Fairmount and West Fork. Cost overruns associated with property management could result if structures are required to be maintained beyond the time frames included in the base project cost. For the Lick Run corridor the base project cost estimates include real estate property management for 2½ years. Projects outside of the Lick Run corridor included a 12-month service period.

- ENVIRONMENTAL SITE ASSESSMENT (ESA): ESA cost estimates were derived from information provided by Strand, ATC & Associates, Kermada, and the City of Cincinnati Office of Environmental Quality (OEQ).

In an effort to mitigate schedule overruns, conservative assumptions in estimating right-of-way costs included the following:

- SUPPLEMENTAL ASSISTANCE BENEFITS PROGRAM: The USEPA Consent Decree places strict acquisition, planning and construction timelines on MSD. MSD believes that early completion of projects will reduce personnel hours, project delivery time and construction costs resulting in significant savings for ratepayers.

The City Manager approved the City's use of the Supplemental Assistance Benefits Program for the Lick Run Valley Conveyance System. The Program was developed by the City to incentivize owners to sell their properties and tenants to vacate properties required for time-sensitive projects. Amounts anticipated to be paid under this program were not included in original cost estimates but have been incorporated into the most current updated base project cost. Total costs are approximately $4.9 million.

- QUICK TAKE: Quick take provides MSDGC with the ability to control construction deadlines by authorizing expedited access to and possession of property being appropriated to public use. Such access and possession is contingent upon a complaint for appropriation being filed and the appraised value of the appropriated property being deposited in escrow with the court. Appropriation petitions are filed when an agreement for the purchase of property cannot be reached in good faith.

    - ORC 163.07 allows possession of vacant land being appropriated immediately after the complaint is filed and the appraised value is deposited in escrow with the court. For property that includes structures, the owner or occupant is required to vacate the land and structures within sixty days after service of the summons. After the expiration of 60 days, MSDGC has the authority to remove any structures prior to a jury establishing a value to the property. At any time after MSDGC deposits the appraised value with the court, the owner may apply to the court to withdraw the deposit. Withdrawal of the money does not have any impact on the court proceeding except that the sum withdrawn is deducted from the sum of the final verdict or award and no interest accrues or is payable on the amount deposited with the court.

    - In an appropriation proceeding where quick take authority exists, the defendant does not have the right to question or argue the necessity of the project requiring the acquisition of the property or whether the need for the property involves a public use. The defendant is limited to questions of whether the property has been blighted and/or whether the offer represents just compensation for the property. Note that quick take authority will limit prevalent suppositions that MSDGC is acquiring property in excess to be turned over to private parties for future development.

- STAFFING: The acquisition of property interests for the Kings Run, Lick Run and West Fork watersheds have been estimated to require 134 full takes and 1,906 easements by the end of 2014. Timely acquisition is essential to clearing the right-of-way to accommodate construction schedules. Staffing concerns that align with and support MSD goals take into consideration typical acquisition activities result in approximately 75-120 easements per year for a full-time acquisition specialist. Likewise, MSD expects to acquire anywhere between 20 to 30 full-takes on an annual basis. Based on these assumptions, and the goal of 2014 for completion of acquisition, MSD is monitoring staffing needs on a regular basis to mitigate potential delays.

- PUBLIC FORUMS TO ACQUIRE BULK EASEMENTS: In an effort to expedite acquisition, MSD is working with ODOT and FHWA to develop a process for purchasing easements at public forums. This technique has been used by public agencies and has substantially reduced project delivery costs and time delays.

- ADVANCED ACQUISTIONS: MSD has proceeded with advanced acquisitions prior to final plan development or approval by the County or USEPA to prevent potential development and increased costs on the preferred location (Protective Buying), and to alleviate hardship to a property owner or owners on the preferred location (Hardship Acquisition). This strategy is allowed under regulatory authority.

4.4.3. Stormwater Volume and Flooding

Concerns regarding flooding and water in basement with the separation projects was identified as a risk to the sustainable projects, for example, if the South Fairmount Corridor does not accommodate storm water volume due to design storm being exceeded, or if the flow model projections are incorrect or other hydraulic issues such as backwater caused by elevated stage levels at Mill Creek or Ohio River. If the South Fairmount Corridor cannot accommodate the volume of water that is projected to flow through the open channel, localized flooding will occur which could threaten real property and human life.

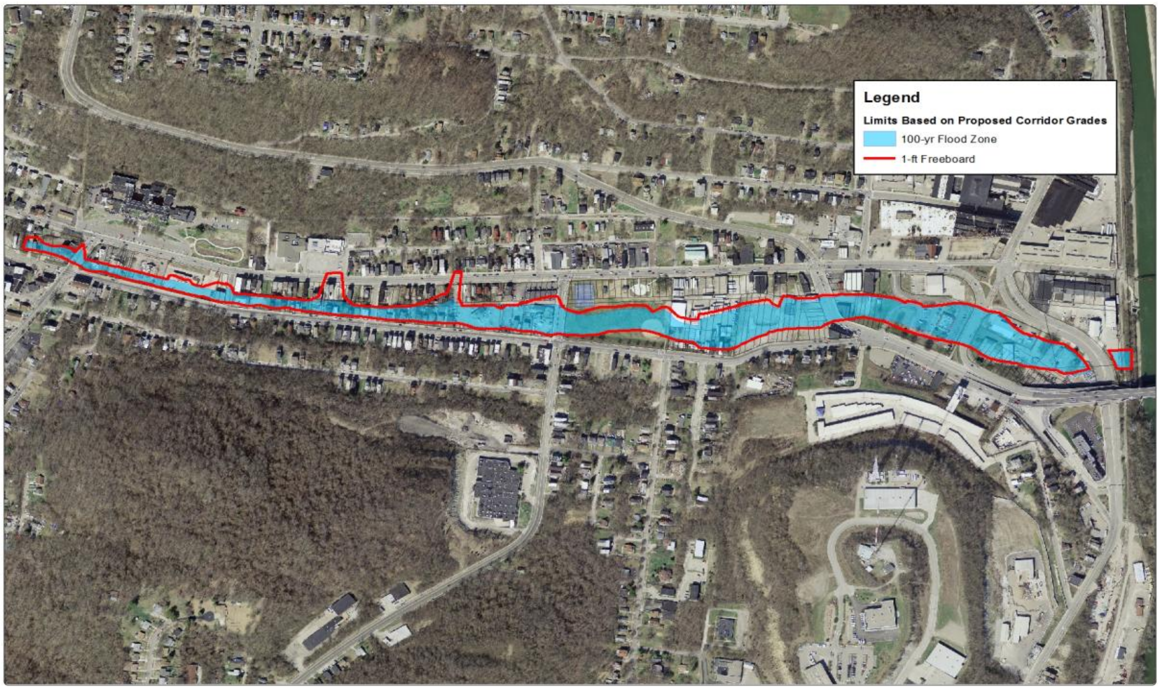
- FEMA Studies/Floodplain elevations will be conducted as design proceeds. The acquisition plan initially set out to procure of all parcels within the target area for construction of potential solution, including contouring and development of a proper floodplain to accommodate the 100 year storm. Availability of assembled property will be used in design.

- Preliminary Engineering Analysis included HEC HMS/HEC RAS modeling for storm sewer area and channel evaluations. Modeled projections and scenarios are used as design criteria to protect the anticipated future condition for the 100-year floodplain.

- The Valley Conveyance System is a strategy to ensure adequate volume capacity in a hybrid grey and green system of a box conduit underneath a naturalized conveyance system. Detailed designs will be completed. The channel and conveyance system within the corridor are sized to account for the entire watershed draining through the target area; this is conservative design criteria and provides additional protection to reduce likelihood of localized flooding.

In relation to the Sustainable Alternative, <u>MSD is not establishing new flow routes but rather augmenting stormwater conveyance capacity along existing flow routes</u>. The proposed strategic sewer separation projects are expected to provide a significant increase in the current level of service provided by the existing combined sewer system. By installing a new parallel stormwater conveyance system sized to convey up to 25 year stormwater flows from the Tier 1 areas, accounting for approximately two-thirds of the Lick Run watershed area, MSD is providing significant improvement to the overall stormwater and combined sewer drainage systems serving this community. The VCS is sized to convey up to a 100-year storm event peak flows tributary from the entire Lick Run watershed, with a minimum of 1-ft freeboard to adjacent roadway and bridge infrastructure, as well as developed areas remaining after the SI project construction.

Lick Run VCS 100-Year Flood Zone and Freeboard Area



<u>Impact of Peak Flows</u>

MSD does not model the Mill Creek or the Ohio River as part of the system-wide model. The drainage area of the Ohio River is so large that the water level in the river is generally independent of storms impacting MSD's service area. The lower Mill Creek water level is impacted by the water level in the Ohio River either through backwater or the operation of the Barrier Dam. The mouth of the West Fork Channel on the Mill Creek is monitored as having significant impacts (up to 9 feet of standing water) from the high Ohio River levels.

The tributaries located in the combined sewer area and that are independent of Mill Creek and the Ohio River are modeled within the system-wide model. Specific examples include the West Fork Channel, Kings Run, and the ponds and channels in Spring Grove Cemetery.

It is anticipated that <u>impacts to Mill Creek associated with peak flows from the proposed SI projects would be relatively minor impacts in comparison to existing conditions</u>. System-wide modeling efforts have indicated, a significant portion of the combined sewer system is inundated during storm events in excess of a 6-month return interval, and existing CSOs provide discharges to Mill Creek for storm events on a similarly frequent basis. In Lick Run specifically, the CSO volume discharged to Mill Creek in the Typical Year is estimated to be approximately 1,000 million gallons (system-wide model version 4.2). After implementation of the Lick Run SI projects, the CSO volume discharged to Mill Creek in the Typical Year is estimated to be approximately 263 million gallons, and the SI project volume discharged to Mill Creek in a typical year is estimated to be approximately 1,070 million gallons. There is a net difference of 333 million gallons. Accordingly, the volume differences between the wet weather flows tributary to Mill Creek pre- and post- SI project construction are anticipated to be relatively insignificant.

Modeling efforts to-date has shown that large portions of the existing combined sewer system are surcharged during storm events as frequent as a two-year event. The Lick Run system-wide model(s) simulate all combined sewers that are 18-inches in diameter or larger, accounting for approximately 150,000 feet of the Lick Run

Watershed's total 358,000 feet of CSS (41 percent). Because the Tier 2 areas are highly developed upland areas, with a significant portion of the smaller un-modeled combined sewers, nearly all the combined sewers in the Tier 1 areas are included in the system-wide models and can provide a direct correlation to the effectiveness of the parallel storm water conveyance system on the combined sewer system level of service.

A comparison was performed evaluating the combined sewer system surcharging pre-sewer separation in the Lick Run existing conditions SWM and against the combined sewer system surcharging post-sewer separation in the Lick Run ultimate conditions SWM. A summary of these results is presented in the table below.

Critical Duration Storm Events

Critical Duration Storm Events (Percent Modeled CSS Surcharged)					
	6 month	2 year	5 Year	10 Year	25 Year
Pre-Sewer Separation CSS Surcharging	8%	28%	36%	42%	46%
Post-Sewer Separation CSS Surcharging	5%	9%	14%	19%	21%
Percent Reduction in CSS Surcharging	**35%**	**67%**	**60%**	**55%**	**54%**

The indication from the results shown in the table above is that greater than a 50 percent increase in combined sewer system level of service can be expected in all modeled storm events greater than a six-month return interval. This further translates to an anticipated decrease of localized flooding, of greater than 50 percent during all storm events exceeding a six-month return interval.

The location of the VCS element in the Lick Run SI project is at the lowest point in the watershed, where all wet weather flows that are not able to get into the inundated combined sewer system currently travel overland. Theses flows have established routes to Mill Creek, or otherwise result in localized flooding. As mentioned previously, the VCS is sized to convey up to a 100-year storm event peak flows tributary from the entire Lick Run watershed, with a minimum of 1-ft freeboard to adjacent roadway and bridge infrastructure, as well as developed areas remaining after the SI project construction. As such, localized flooding and/or flow routes currently existing in this area will be controlled to a much higher level. Further, the 100-year capacity of the VCS will provide increased reliability in the performance of the tributary storm sewer connections up to their design limitations.

4.4.4. Unknowns During Construction

Risk Identification:

Project corridor has historical, archeological, environmental, geotechnical and buried utility unknowns that will be uncovered during construction leading to delays and cost overruns.

Risk Assessment:

The area was first settled in the late 1800s and was a mixed use community with several commercial and some industrial uses. Because of the valley configuration, the geology of the area does have significant amounts of rock and hillside issues to address during design and construction. Because of the proximity to the Mill Creek and other important social, cultural and historical factors, as well as the likelihood of potential on-site disposal from the commercial and industrial operations, there is a possibility for this project to have several unknown characteristics. The exact location and condition of the existing utilities is somewhat uncertain. To address these potential issues, the relocation, protection and/or replacement of underground utilities may be required to fully implement the project plan.

Risk Strategy:

- The area-wide Phase 1 Environmental Site Assessment included the completion of four sampling and analysis plans for the 4 focus areas. An area-wide Phase 1 ESA under the USEPA Targeted Brownfield Assessment Program has been completed for the corridor and four primary areas of concern were identified within the project corridor. Phase 2 ESAs of the focus areas have been initiated and completed for the majority of the high risk areas within the corridor. MSD anticipates submitting grant applications for continued assessment and cleanup of brownfield areas that could be integrated with sustainable infrastructure.

- A historical and archaeological consultant has assessed and surveyed the project corridor. The State Historic Preservation Office (SHPO) has been contacted as a courtesy. No project parcels within the target area are listed on the National Historic Registry and corridor was evaluated in 1978, 2002, and 2011 to determine if a historic district exists. All surveys concluded sufficient resources are not present for consideration as a historic district.

- Utility Review, Topographic Review, Geotechnical Review, Intersection Traffic Movement Assessment & subsequent traffic Alternatives Development and Refinement Report, Geotechnical Exploration Report have been completed to identify unknowns. All information will be incorporated into project detailed designs.

- Regarding conditions assessment, existing Pipeline Assessment & Certification Program (PACP) information has been reviewed, where available; in most areas pipes greater than 30" had recent inspections conducted. Appropriate measures will be incorporated into the detailed design and construction documents.

- Inventory of underground locate openings (ULOs) that will be necessary to locate to complete design; there are over 100 of these that will require location between the 30-90% design completion phases.

- An ecological investigation will determine whether a field survey will need to be completed to identify threatened and endangered species. The Glenway and Fenton areas have undergone a QHE 1 and HHE 1 analysis of stream conditions as well as jurisdictional determinant request by the USACE.

Utility Coordination

Through the development of the sustainable alternative, MSD design teams have coordinated directly with utilities to gain confidence in the impact as well as cost of utility relocation. The type of costs being referred to, i.e. utilities relocation costs, are the types of costs included in design contingency allowances in the early planning phases of a project. Costs are not normally included in the base construction costs, before the addition of contingencies, until design of a project is begun. A range 6.5 to 9 percent is cited on page 10 of the County monitor's report for utilities relocation costs, before contingencies are added. When both design contingencies and project contingencies are added, this range will increase to 10 to 15 percent.

A great deal of effort and coordination with local agencies and utilities has gone into sustainable project sequencing, to coordinate construction and utility impacts, minimize project costs and community disruption. Duke Energy, GCWW, MSD and CDOTE all have capital improvement plans (CIP's) that have been taken into consideration for developing the schedule, sharing of construction costs, and maintenance of traffic. Coordination and communication for West Fork, Bloody Run, Kings Run/Wooden Show and Lick Run has occurred via Ohio Utilities Protection Service (OUPS) requests, County Wide Construction Coordination System, and planning or design meetings.

For example, in the case of Lick Run, specifically the 31 utility coordination meetings have taken place, with the respective agencies as noted in the table below, in which meeting minutes are available upon request:

Utility Coordination Meetings on the Lick Run Project

Utility	Meeting Dates
CDOTE	February 14, 2011; March 6, 2011; June 3, 2011: July 8, 2011; August 31, 2011; September 23, 2011; October 14, 2011; December 20, 2011; March 7 & 9, 2012
Cincinnati Bell	August 31, 2011; October 6, 2011; January 25, 2012; March 7, 2012
Cincinnati Parks Department	July 31, 2011; January 25, 2012
Duke Energy	June 1, 2011; July 13, 2011; August 17 & 31, 2011; January 25, 2012
Greater Cincinnati Water Works	June 1, 2011; July 13, 2011; October 6, 2011; March 7, 2012
SMU	June 1, 2011; July 13, 2011; August 31, 2011; January 25, 2012; March 7, 2012
Time Warner Cable	September 12, 2011

The key points of coordination at this time include:

- **Cincinnati Bell** does not have any CIP's that are scheduled in conjunction with the SI projects.
- **Duke Energy** has a significant gas main replacement CIP on Harrison and Queen City Avenues, from the intersection of Harrison Avenue/State Street at Mill Creek, west to Queen City Avenue/Quebec Road. This project was initially scheduled to be constructed in 2013; however in an effort to coordinate projects and share/reduce overall construction costs, Duke will be constructing the gas main replacements in conjunction with the SI projects.
- **GCWW** is replacing small and aged water mains in areas that SI projects are being constructed. GCWW had these CIP's quite a bit further out in their schedule, however the ability to coordinate projects and share/reduce overall construction costs was favorable enough for GCWW and MSD these CIP's were moved up in schedule to coincide with the SI projects.

As is typical, utility coordination is on-going through the respective advanced planning and detailed design phases. Additional meetings have occurred and will continue for some of the sewer separation projects to further refine utility impact needs and to properly account for costs.

As a standard rule of practice MSD Estimating uses its information database to estimate water and gas line, electrical and cable relocations. MSD receives budgetary quotes from Duke Energy for power pole support or relocation, and other items. For other specific scopes of work MSD obtains quotes from the specific utility. MSD estimating allows for additional labor & equipment time to excavate and backfill around existing utilities. In the Lick Run basin there are allowances contained in the base cost estimate for water and gas lines, and electrical structure and wire relocates.

4.4.5. Agency Alignment

Risk Identification:

Inability to get alignment/consensus between all agencies and organizations around a community of the future solution leads to suspension/cancelation of the project.

Risk Assessment:

As the driver of the comprehensive, watershed-based wet weather solution, MSD will be dependent upon other agencies and organizations to support this approach and strategy. MSD has limited or no control over these agencies. The inability to get alignment and buy-in around this alternative project is a risk. This project will require MSD to develop new partnerships.

Risk Strategy:

- As part of Project Groundwork, MSD developed a concept called "Communities of the Future," which integrates sustainable sewer infrastructure improvements with urban renewal in areas that experience high volume or frequent CSOs. To assist and guide MSD with this vision, a Communities of the Future Advisory Committee (CFAC) was created in March 2010. The CFAC is comprised of about 100 representatives of a cross-section of public agencies, community members, and members of County Administration and legal team. CFAC meetings are planned, coordinated and scheduled with representatives from Hamilton County Regional Planning. The CFAC has met quarterly throughout the more than two years of the project to provide input to Project Groundwork. Members of the South Fairmount community who have expressed interest have been invited to participate with this group. The President and the Vice President of the South Fairmount Community Council (SFCC), as well as the President and Vice President of the South Fairmount Business Association (SFBA) attended CFAC meetings as well as meetings of the three sub-groups formed by CFAC to address specific issues.

- Development and refinement of a Communication Strategy & Plan. Materials were created to inform and influence key leaders and potential partners for framing the project need and vision.

- The Lick Run Master Plan completed with the assistance of CFAC, an open house (January 2011) and three community design workshops, provides for an overall plan for an integrated watershed based CSO reduction approach married with consideration for community redevelopment. The Lick Run alternative is an approach to align with the HUD DOT EPA Sustainable Communities Partnership Program. In 2010, the City was awarded a HUD grant for development of a Land Development Code Update specifically identifying Lick Run as a watershed demonstration project.

- Completion of a SWEPP manual to streamline and standardize the systematic watershed approach to identify and develop solutions.

4.4.6. Community Support

Risk Identification:

Public resistant to the project for a variety of reasons, including lack of public trust and support to community development benefits by sewer projects due to the lack of prior examples.

Risk Assessment:

The South Fairmount community has experienced continued economic decline for decades. Local residents refer to a "feeling of abandonment" and suffer from systematic disinvestment. They perceive the community is being ignored by the City and County governments.

Risk Strategy:

- Community engagement in South Fairmount, Westwood, East and Lower Price Hill and other Lower Mill Creek communities is focused around the Early Success Projects and the LMC Study.
- A Community Open House was held January 2010 followed by three concept design workshops in 2011 and 2012.
- MSD has had a community relations specialist attend monthly South Fairmount Community Council meetings since July 2010.
- MSD has been engaging the Community to provide complete, up-to-date information in a transparent forum to receive feedback in a positive manner. Two Town Hall meetings were held in August 2012. All comments received are documented in the Lower Mill Creek Partial Remedy Community Outreach Report to Hamilton County and City of Cincinnati, September 13, 2012 draft.

4.4.7. Public Safety

Risk Identification:

The resulting proposed project design will require certain mitigation strategies regarding an open waterway to address potential public safety issues.

Risk Assessment:

With daylighting of the Lick Run Channel, there will be concerns about children and others being exposed to a potential health and safety risk. Traditionally, we have used pipe and concrete channels and open water ways are less common; we need to educate the public about open waterway safety practices.

Risk Strategy:

- The channel design will address and mitigate associated impacts. The basis of design report considered the depth of water and potential impact water inflow and is designed to reduce the risk with the proposal of a dual conveyance system - one underground, one above ground so that high flows will be reduced by underground conveyance.
- Mitigate through design to reduce risks by incorporating features such as railing, safe access pathways for viewing and maintaining the channel amenity and incorporation of signage for safety and education.

4.4.8. Regulator Support

Risk Identification:

Delays in acquiring the necessary federal, state and local permits or regulator support could delay or suspend project implementation.

Risk Assessment:

Failure to gain regulator support/approval, funding or flexibility could suspend or reduce the project. An environmental review document may be required by the provisions of NEPA. NEPA has historically been active in projects requiring federal funding to ensure projects comply with the Act. The nature and extent of the environmental documentation could affect the implementation schedule for the project.

Risk Strategy:

- Seek federal lead agency for Section 106 Historical Review and develop BMP for historical and cultural review should no federal agency be identified.

- USEPA (April 2011) Office of Water and Compliance Enforcement Memo recognized MSDGC for the Lick Run Approach.

- Regulator support for SI projects was documented in the *Green Infrastructure Statement of Intent (April 19, 2007)* - A joint statement signed by USEPA, National Association of Clean Water Agencies (NACWA), Natural Resources Defense Council (NRDC), Low Impact Development Center (LID), & Association of State and Interstate Water Pollution Control Administrators (ASIWPCA).

    - *"The purpose of this Statement is to formalize a collaborative effort among the signatory organizations in order to promote the benefits of using green infrastructure in protecting drinking water supplies and public health, mitigating overflows from combined and separate sewers and reducing stormwater pollution, and to encourage the use of green infrastructure by cities and wastewater treatment plants as a prominent component of their Combined and Separate Sewer Overflow (CSO & SSO) and municipal stormwater (MS4) programs."*

    - *"The objectives of this Statement are to: Affirm the belief by the signatory organizations in the value of green infrastructure as both a cost effective and an 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…"*

- Regulators recognized utilities need flexibility in addressing wet weather problems. As documented in the *USEPA Report to Congress on the Impacts and Control of CSOs and SSOs (August 26, 2004)***.** This report was delivered to Congress on Thursday, August 26, 2004. The Report presents a comprehensive characterization of CSOs and SSOs, including the extent of environmental and human health impacts caused by CSOs and SSOs, the technologies used by municipalities to address these impacts, and the resources spent by municipalities to control CSO and SSO discharges.

    - *"It is unlikely that LID techniques alone are sufficient to fully control CSOs, yet they have shown promise as part of larger programs in reducing the size of structural controls (e.g. storage)."*

- *"Inflow reduction and LID techniques reduce the quantity of storm water runoff that enters a sewer system. Since these controls can reduce both the peak flow rate and volume of storm water delivered to a sewer system, the size of more capital-intensive downstream control measures, such as storage facilities or treatment technologies, can be reduced, or, in some cases, eliminated completely."*

- MSD and Hamilton County have been vetting the updated baseline model, sustainable projects models, framework for a potential Sustainable Alternative, default grey alternative costs, and Sustainable Alternative costs with USEPA Region 5, Ohio EPA, and ORSANCO. Technical teleconferences or workshops were held with the Regulators on November 17, 2011; December 6, 2011; July 26, 2012, August 6, 8, 16, 23, & 30, 2012; and September 6, 13, 2012. The Regulators have gained confidence in the methodologies and approaches utilized by MSD for development and evaluation of the LMC Study alternatives.

MSD has invested time and resources to identify, assess, and mitigate risks associated with the sustainable alternative. As presented herein, the cost risks identified for these projects were addressed by revising the scope of the project and updating the estimated cost of the project based on the revised scope. The revised project costs were included in the Preliminary Findings Report. MSD does not believe carrying a program reserve will result in improved cost estimates. Rather, <u>a detailed and comprehensive understanding of project components will enable engineering professionals to better scope and estimate each project</u>.

4.4.9. Class 1 Dam Standards

As MSD reported to the County monitor team on May 4, 2012, detention basin volume and dam height were considered for determination of dam designation as defined in the Ohio Administrative Code (OAC), Section 1501:21-13-01. The intent of the sustainable projects is to design detention basins that are not classified as dams or that minimize dam impacts.

For the sustainable projects evaluated during the LMC Study, 15 of the 18 proposed detention basins will be automatically exempt from dam classification due to their capacities of not more than 15 acre-feet of total storage. Of the remaining three detention basins, one has been reviewed by ODNR and would be classified as a Class 1 Dam (Wooden Shoe Measure 3). The other two remaining detention basins (Techsolve in Bloody Run and North Basin in CSO 125 stream separation) exceed the volume limit and have been designed such that the height is lower than the regulated limit and therefore would not be classified as dams.

For Phase 1 (Lick Run, West Fork and Kings Run watershed projects), there are 15 detention basins in the Sustainable Alternative as shown in the table below. [Note: The three remaining detention basins are scheduled to be included in the Phase 2 LMC evaluation (Techsolve basin at CSO 181, two Denham basins).] The Kings Run Measure 4 basin dropped out due to geotechnical issues. For the West Fork North Basin, the dam height must be 10 feet or less since the capacity of these basins is between 15 and 50 acre-feet. A dam's height is defined as the vertical dimension as measured from the elevation at the downstream or outside toe of a dam to the elevation of the top of the dam. The North Basin located in the CSO 125 Stream Separation project is being designed to be exempt by maintaining the height requirement. Wooden Shoe Measure 3 is being evaluated in accordance with meetings with ODNR.

The Measure 3 basin is located above CSO 217. Its purpose is to detain surface run-off and discharge it back into the combined sewer system. The size of the detention basin affects the sizing of the CSO storage tank located at

CSO 217. Since the capital costs of building a larger Measure 3 basin of 20 ac-ft was not defined and had been complicated by ODNR proposing the existing detention basin should be classified as a Class 1 dam, the LMC Study team maintained the planning level size of 5.2 ac-ft to correspond to the consultants cost estimate. In addition, by keeping the detention basin small, the downstream CSO tank was sized larger to accommodate the smaller basin size. The CSO tank size downstream of the smaller detention basin is 1.5 MG. If the detention basin is sized to be 20 ac-ft, then the CSO tank size would be 1.3 MG. The large cost of the CSO was preferred to account for the worst case scenario of not being able to construct the larger detention basin.

The Engineer will be performing an alternative analysis on Measure 3 detention: Retrofitting the existing basin or building a new basin upstream of the existing. Both would be classified as a dam but the type of classification (1, 2, 3, or 4) will be a part of the analysis. Although a conservative approach was applied for the sizing of the 217 CSO storage tank, costs for larger dam construction and dam permit requirements were not included. MSD will include the estimated $471,000 cost for the dam in the updated capital cost in 2006$.

Phase 1 Sustainable Alternative Proposed Detention Basins and Capacities

Sub Basin	CSO of Interest	Basin Name	Proposed Capacity as of 03/2012 (acre-ft)	Automatic Exemption as Dam?	Notes
Wooden Shoe	217/483	Measure 1	2.3	Yes	
		Measure 2	1.0	Yes	
		Measure 3	20.0 or 5.2	No	Under review due to dam permit issues. 5.2 ac-ft used in LMCPR study to match planning cost estimate. Larger size being considered in design phase.
		Measure 4	0.7	Yes	Basin eliminated due to geotechnical issues.
		Measure 15	12.0	Yes	
Lick Run	5	DB 01 (Queen City Ave Phase 2)	1.2	Yes	
		DB 02 (Queen City Ave Phase 2)	1.4	Yes	
		DB 07 (Queen City and Cora Aves)	2.5	Yes	
		DB 09 (Queen City and Cora Aves)	4.0	Yes	
		DB 10 (Queen City and Cora Aves)	8.6	Yes	
		DB 14 (Queen City Ave Phase 1)	1.6	Yes	
		DB 17 (Quebec Heights Phase 1)	2.4	Yes	
		DB 21 (Sunset Ave)	0.5	Yes	
West Fork	125	Martha Basin	2.2	Yes	
		North Basin	21.2	No	Exceeded ODNR volume threshold; therefore exemption from dam permit will be based on height requirement

4.4.10. Contractor Capacity Evaluation

In August 2011, MSD retained industry expert, FMI Corporation, to perform an assessment of the Contractor Capacity as compared to the anticipated requirements for the LMCPR. For more than 50 years, FMI has worked with leading contractors, manufacturers, trade engineers, labor associations, and public/private owners. The forecasted trends from the 2009 report conducted for MSD were accurate. The 2011 update report identified the following issues:

- The current and expected labor supply is expected to maintain a narrow labor surplus through 2020. Cincinnati and the surrounding region will not face a shortage of skilled labor outside seasonal peaks for construction labor.

- Shortages are not forecasted in engineering resources through 2020.
- Shortages in three trade occupations are forecasted during peak seasons beginning in 2014 through 2020 (masonry, concrete finishing, and operating engineers).
- All skilled craft categories are forecasted to be near capacity beginning in 2012.

FMI recommends MSD expedite construction of WWIP projects to benefit from current economies.

5. CONCLUSIONS

Over the past three years, MSD has conducted the LMC Study to evaluate the viability and cost associated with the best grey and best sustainable alternatives for the LMCPR. Today, given the results of the comprehensive level of effort and technical scrutiny both alternatives received, MSD recommends the Co-Defendants submit the Sustainable Alternative for consideration by the Regulators. This recommendation is based on a myriad of reasons that are best summarized herein.

- The Sustainable Alternative is the lowest cost and lowest risk LMCPR solution. Applicable industry standards for cost estimating and risk assessment have been utilized to fully evaluate the LMCPR alternatives. The Sustainable Alternative is 40% lower in capital cost and is much closer to the original WWIP estimate than the Grey Alternative.

- The Sustainable Alternative is supported and has been vetted with the Regulators. USEPA recognizes at a national level that *"integrated planning with assist municipalities on their critical paths to achieving human health and water quality objectives of the Clean Water Act by identifying efficiencies in implementing requirements that arise from distinct wastewater and stormwater programs"*. Starting last July, MSD and the County have held weekly technical calls to discuss modeling, costing, and the technical approaches used to evaluate the LMC Study alternatives. The Regulators have clearly articulated they find NO red flags with MSD's approach for developing the Sustainable Alternative.

- The Sustainable Alternative offers more opportunities for external funding partners to participate with Enabled Impact Projects; grant targeting Brownfields, flood control, and stormwater management; as well as integration of green infrastructure into MSD's plan for addressing wet weather.

- The components and features proposed by MSD in the Sustainable Alternative are not new or untested technology. In fact, a literature review of work on-going by similar utilities has determined that nearly every city faced with meeting Consent Decree milestone compliance deadlines, is turning to sustainable infrastructure. Examples of other cities include New York City, Philadelphia, Portland, Detroit, Seattle, Milwaukee, Chicago, Kansas City, Cleveland, St. Louis, Washington D.C., Toronto, Louisville, Vancouver, and Pittsburgh.

- The Sustainable Alternative will benefit the environment by returning natural drainage to tributaries and streams and through reduction combined sewer overflows by two billion gallons during the typical year. The pollutant loading discharges to Mill Creek from the sustainable projects will decrease significantly when compared to existing conditions given the differences between combined sewer overflow and stormwater characteristics. Directing natural drainage and stormwater to water bodies will result in additional base flow to support aquatic life.

- The Sustainable Alternative provides the Co-Defendants with flexibility to adapt to future conditions such as regulatory changes, climate change, new development, and redevelopment opportunities.

- The Sustainable Alternative is simply the best solution to achieve relevant criteria discussed within this Recommendations Report to achieve 2 billion gallons of CSO reduction during the Typical Year.

BIBLIOGRAPHY

1. ''Wet Weather Improvement Plan (WWIP) - FINAL''. Prepared by MSDGC. June 2009.

2. “Estimating National Costs Associated with Public Law 92-500 (The Federal Water Pollution Control Act Amendments of 1972)”, Metcalf & Eddy, Inc. (Michael Giggey & Stanley Elkerton)

2. Hamilton County Metropolitan Sewer District of Greater Cincinnati, City of Cincinnati Department of Public Works Stormwater Management, November 1991, Cost Estimating and Cost Referencing Methodology, Stormwater Wastewater Integrated Management (SWIM), Prepared by Camp Dresser & McKee and Woolpert Consultants.

3. R.S. Means. 2005. Building Construction Cost Data, 63rd Annual Edition. [Copyright 2003 by Reed Construction Data, Inc. All rights reserved]

4. Estimates, Project No. CS-1314. Detroit Water and Sewerage Department. United States Environmental Protection Agency. December 1976. Cost Estimating Manual – Combined Sewer Overflow Storage and Treatment, EPA-600/2-76/286. Cincinnati, OH: National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency.

5. United States Environmental Protection Agency. January 1981. Construction costs for Municipal Wastewater Conveyance systems: 1973-1979, EPA-430/9-81/003. Washington, D.C.: United States Environmental Protection Agency.

6. United States Environmental Protection Agency. January 2002. Costs of Urban Stormwater Control, EPA-600/R-02/021. Cincinnati, OH: National Risk Management Research Laboratory Office of Research and Development United States Environmental Protection Agency.

7. “Preliminary "Preliminary Data Summary of Urban Storm Water Best Management Practices", Publication EPA-821-R-99-012, August 1999.

8. "Storm Water Technology Fact Sheet Bioretention" Publication EPA-832-F-99-012, September 1999.

9. "Storm Water Technology Fact Sheet Wet Detention Ponds" Publication EPA-832-F-99-048, September 1999.

10. "Combined Sewer Overflow Management Fact Sheet Sewer Separation" Publication EPA-832-F-99-041, September 1999.

11. ''MSDGC's Financial Analysis Manual''. Prepared by MSDGC. January 2011.

12. Refer to Reference 76.

13. “Capacity Assurance Program Project Cost Estimating Reference Document for Metropolitan Sewer District of Greater Cincinnati” Prepared by BBS. April 2006.

14. ''Capacity Assurance Program and Combined Sewer Overflow Long Term Control Program''. Prepared by MSDGC. June 2006.

15. ''Combined Sewer Overflow Long Term Control Update''. Prepared by MSDGC. April 2006.

16. Executive Summary, Wet Weather Program Cost Documentation, CSO Program, SSO Program, May 2001, April 2003 BBS Corporation

17. ''Costing Protocol TM_DRAFT_110902''. Prepared by CH2M Hill, Inc. September 2011.

18. ''Lower Mill Creek Partial Remedy Revised Plan, Task 107: Project Cost Estimating Protocols''. Prepared by CH2MHill, Inc. February 2012.

19. ''Lower Mill Creek Partial Remedy Study, Costing Protocols Presentation to the County Monitor Team''. Prepared by CH2M Hill, Inc. February 2010.

20. "100% Design – Engineers Opinion of Construction Cost: CSO 12". Prepared by Stantec Consulting Services, Inc. July 2011.

21. "CSO 10 Reconciled Estimate". Prepared by BHE Environmental. August 2011.

22. "CSO 24 Cost Opinion Reconciled". Prepared by Mactec. September 2011.

23. "Harrison Avenue Improvement Final Bid Set". Prepared by City of Cincinnati Department of Transportation and Engineering. February 7, 2012.

24. "Master Program Management Plan" Prepared by MSDGC.

25. Refer to Appendix A.

26. "Lick Run Preliminary Engineering Analysis – Hydrology and Hydraulic Report and Appendices" Prepared by Strand. November 2009.

27. "Real Estate Cost Estimation Assumptions". Prepared by Beth Sutherland for MSD. February 29, 2012.

28. "Auditor's Market Values". Prepared by Lexur and published by the Hamilton County Auditor. June 30, 2011 through December 31, 2011.

29. Guidance document for relocation costs from ODOT are listed below - as to all: Prepared by the Ohio Department of Transportation, Office of Real Estate - October, 2011 (unless otherwise noted).
    - General Relocation Requirements
    - Relocation Planning and Advisory Services
    - Required Relocation Notices
    - Moving Payments - Residential
    - Moving Payments - Non-Residential
    - Replacement Housing Payments
    - Relocation Assistance Non-Residential Brochure - 10/20/2010
    - When ODOT Needs Your Property Brochure - 10/14/2010

- Residential Relocation Assistance Program Brochure - 10/21/2010
- Tenant Owned-Owner Retention Brochure 2012 - 4/23/2012

30. Guidance document for relocation costs from FWHA. Prepared by the Federal Highway Administration, Office of Planning, Environment & Realty (unless otherwise noted - dates prepared noted with each listed item - documents highlighted are reproductions of regulations published in the Code of Federal Regulations and the Federal Register)
    - 49 CFR 24 Uniform Relocation Assistance and Real Property Acquisition for Federal and Federally-Assisted Programs - 01/04/2005
    - Uniform Relocation and Real Property Acquisition for Federal and Federally-Assisted Programs; Fixed Payment for Moving Expenses; Residential Moves - 05/16/2005
    - General Relocation Requirements (Federal-Aid Policy Guide, NS 49 CFR 24C) - 02/16/2006
    - Payments for Moving and Related Expenses (Federal-Aid Policy Guide, NS 49 CFR 24D) -02/16/2006
    - Real Property Acquisition: Applicability of Acquisition Requirements (Federal-Aid Policy Guide, NS 49 CFR 24B 101) - 02/16/2006
    - Real Property Acquisition: Basic Acquisition Policies (Federal-Aid Policy Guide, NS 49 CFR 24B 102) - 02/16/2006
    - Replacement Housing Payments (Federal-Aid Policy Guide, NS 49 CFR 24E) - 11/01/2007
    - Side-by-side Comparisons of Changes to the Uniform Act FAQ - 02/03/2009
    - Uniform Relocation Assistance and Real Property Acquisition for Federal and Federally Assisted Programs (Federal-Aid Policy Guide, NS 49 CFR 24A) - 02/23/2007
    - 49 CFR 24 Final Rule Changes - 02/01/2005
    - 49 CFR 24 final Rule Informational Guide - 02/01/2005
    - Applicability of the Uniform Relocation Act to Nonprofit Organizations. Prepared by Barbara K. Orski, Director, Office of Right-of-Way, Federal Highway Administration - 05/20/1994
    - Eligibility for Reestablishment and Moving Expense Payment. Prepared by Barbara K. Orski, Director, Office of Right-of-Way, Federal Highway Administration - 08/21/1996
    - Major Projects Guidance and Division Right-of-Way Function. Prepared by Gloria M. Shepherd, Associate Administrator for Planning, Environment & Realty, Federal Highway Administration - 05/23/2007
    - Uniform Relocation Assistance and Real Property Acquisition Policies Act, as amended, Fixed Residential Moving Cost Schedule 08/22/2008
    - Uniform Act Final Rule Extracts and Updated Information 2005
    - Uniform Act Final Rule Implementation - Video, Informational Guide, and Slide Show -02/12/2008
    - Uniform Act Low Income Calculation - 03/01/2009
    - Uniform Act Tutorial - 11/28/2006
    - Relocation Retrospective Study - 01/01/1996
    - Acquiring Real Property for Federal and Federal-aid Programs and Projects - 02/07/2006
    - National Business Relocation Study - 11/22/2008
    - Temporary Programmatic Waiver: Waiver of 49 CFR 24.401(b)(1)--Calculation of Replacement Housing Payment for Negative Equity. Prepared by Janis Gramatins, Acting Director, Office of Real Estate Services, Federal Highway Administration - 11/10/2010
    - Uniform Relocation Assistance and Real Property Acquisition for Federal and Federally-Assisted Programs; Proposed Rule - 12/17/2003
    - Uniform Act Frequently Asked Questions (FAQs) - 02/03/2009
    - Your Rights and Benefits as a Displaced Person under the Federal Relocation Assistance Program - 06/01/2005

31. Guidance document for relocation cost from HUD are listed below - all documents were prepared by the U.S. Department of Housing and Urban Development Office of Community Planning and Development
    - Real Estate Acquisition and Relocation Policy and Guidance - HUD Handbook 1378
    - Illegal Aliens and the Uniform Act Questions and Answers on Public Law 105-117 - August 9, 1999

- Uniform Act Frequently Asked Questions (FAQs) - 2010
- Summary of Major Differences Between URA & 104(D) Relocation Assistance For Displaced Residential Tenants - September, 2011
- Relocation Assistance to Tenants Displaced And Urban Development From Their Homes - March, 2005
- Relocation Assistance to Displaced Businesses, Nonprofit Organizations and Farms - February, 2005
- Relocation Assistance to Persons Displaced From Their Homes (Section 104(D)) - January, 2006
- Relocation Assistance to Displaced Homeowner Occupants - March, 2005
-

32. Guidance document for relocation costs from public agencies
    - City of Cincinnati Municipal Code: Chapter 740 - Displacement and Relocation and Relocation Benefits for city-Assisted Projects

33. "Phase 1 Environmental Site Assessment Report for Lick Run – South Fairmount Neighborhood". Prepared by Weston Solutions. April 1, 2010.

34. "Phase 2 Environmental Site Assessment – Former Foundry and Surrounding Parcels, Lick Run". Prepared by ATC Associates. February 2, 2011.

35. "Voluntary Action Plan Phase 1 Property Assessment – The Lick Run – South Fairmount Neighborhood". Prepared by Kermida. May 1, 2011.

36. "Voluntary Action Plan Phase 2 Property Assessment – The Lick Run – South Fairmount Neighborhood". Prepared by Kermida. July 1, 2011.

37. ''Global Consent Decree''. Prepared by U.S. Department of Justice, on behalf of the U.S. EPA and Ohio EPA, and with the approval of the Hamilton County Board of Commissioners and the City of Cincinnati. June 2004.

38. ''Interim Partial Consent Decree on Sanitary Sewer Overflows''. Prepared by U.S. Department of Justice, on behalf of the U.S. EPA and Ohio EPA, and with the approval of the Hamilton County Board of Commissioners and the City of Cincinnati. February 2002.

39. Ohio Revised Code Section 6117.39

40. "Preliminary Property Acquisition Plan for Lick Run Wet Weather Strategy Basis of Design". Prepared by Strand. October 2009.

41. "Easement Acquisition Cost Estimating: CSO 217/483 Stream Separation". Prepared by BHE Environmental. January 2012.

42. "MSDGC Property Acquisition Report". Prepared by MSDGC. March 2012.

43. Regulatory Authority for Advanced Acquisitions
    - Code of Federal Regulation Chapter 23, Section 701.501 Subpart E - Property Acquisition Alternatives - Early acquisition.
    - Code of Federal Regulation Chapter 23, Section 701.503 Subpart E - Property Acquisition Alternative - Protective buying and hardship acquisition.

44. "Lick Run Preliminary Engineering Analysis – Hydrology and Hydraulics – Report". Prepared by Strand Associates Inc. November 2009.

45. "South Fairmount – CSO 5 Urban Audit". Prepared by Hamilton County Regional Planning Commission. September 2009.

46. "Phase 1 Environmental Site Assessment Report for Lick Run – South Fairmount Neighborhood". Prepared by Weston Solutions. February 17, 2010, April 1, 2010.

47. EPA Targeted Brownfields Assessment Program – www.epa.gov/brownfields/grant_info/tba.htm.

48. National Register of Historic Places – http://www/nps.gov/nr/.

49. "Lower Mill Creek Coarse Evaluation". Prepared by Strand. November 2009.

50. Refer to Reference 64.

51. "Glenway Woods Project Concept Plan Technical Memo". Prepared by Strand. May 2011.

52. "Communities of the Future Advisory Committee – White Paper". Prepared by Hamilton County Regional Planning Commission. February 2010.

53. "Lick Run Wet Weather Strategy Community Opportunities Plan". Prepared by Human Nature/Strand. April 2010.

54. "Lick Run Watershed Master Plan". Prepared by Human Nature. March 2012.

55. "Lick Run Wet Weather Strategic Integration Plan – FINAL". Prepared by USEPA. August 2011.

56. Partnership for Sustainable Communities – http://www.sustainablecommunities.gov/.

57. "US Department of Housing and Urban Development – news release: http://archives.hug.gov/local/oh/news/pr2010-10-20.cfm. October 20, 2010.

58. "MSDGC's Sustainable Watershed Evaluation Planning Process Manual". Prepared by MSDGC. September 2012.

59. "Community Design Workshop #1 Results". Prepared by MSDGC. August 2011.

60. "Community Design Workshop #2 Results". Prepared by MSDGC. October 2011.

61. "Community Design Workshop #3 Results". Prepared by MSDGC. February 2012.

62. "Public Communication Documentation" Prepared by MSDGC. September 2012.

63. "Lick Run Comprehensive Design Report (CDR)". Prepared by Strand. September 2011.

64. USEPA National Environmental Policy Act Policies & Guidance - http://www.epa.gov/compliance/resources/policies/nepa/.

65. "Protecting Water Quality with Green Infrastructure in EPA Water Permitting and Enforcement Programs" Prepared by USEPA. April 20, 2011.

66. Green Infrastructure Statement of Intent. U.S. EPA, April 2007. http://water.epa.gov/infrastructure/greeninfrastructure/upload/gi_intentstatement.pdf.

67. EPA Report to Congress on the Impacts and Control of CSOs and SSOs (Ch. 8). U.S. EPA, August, 2004. http://www.epa.gov/npdes/pubs/csossoRTC2004_chapter08.pdf

68. "Lower Mill Creek Partial Remedy Alternatives Evaluation Preliminary Findings Report". Prepared by MSDGC. June 25, 2012.

69. "Default Tunnel Task 108 Risk Management". Prepared by Black and Veatch Corporation. May 2010

70. "MSDGC's LMC-SA System-Wide Model Restructuring Version 3.2, Version 4.1.0 and Version 4.2". Prepared by XCG Consultants, Inc. June 1, 2012.

71. "Update to the 2009 Comprehensive Contractor Capacity Study". Prepared by FMC Corporation. August 30, 2012.

72. "Analysis of Value Engineering Recommendations: CSO 5". Prepared by Strand. August 2011.

73. "Value Engineering Study: CSO 5". Prepared by Arcadis et. Al. January 2011.

74. "City of Cincinnati Stormwater Management Rules and Regulations". June 1989.

75. "AACE International Recommended Practice No. 18R-97 COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT, AND CONSTRUCTION FOR THE PROCESS INDUSTRIES TCM Framework: 7.3 – Cost Estimating and Budgeting." Prepared by The American Association of Cost Estimating. 2005.

76. "Ohio Kentucky Indiana (OKI) Regional Council of Governments – press release. http://www.oki.org/departments/communications/pressreleases/2012/OKItoaward85million.pdf. August 8, 2012.

77. Code of Federal Regulations, Title 40 – Protection of the Environment, Part 35, Subpart E, Appendix A – Cost-Effectiveness Analysis Guidelines.

78. "West Fork Sustainable Watershed Evaluation (SWEP) Report". Prepared by Strand. May 2011.

79. "Bloody Run Watershed SWEP Evaluation – FINAL". Prepared by Strand. March 2011.

80. "City of Cincinnati Transportation & Engineering – Projects List – http://www.cincinnati-oh.gov/dote/dote-projects/.

81. "CSO 483 Winton Road Sewer Separation PID No. 10240021 – 60% Design Package". Prepared by BHE Environmental, Inc. August 31, 2012.

82. "Integrated Municipal Stormwater and Wastewater Planning Framework". Prepared by USEPA. June 5, 2012.

83. Refer to Reference 59.

84. "Guidance Pertaining to Consideration of Any Proposed Revised Original Lower Mill Creek Partial Remedy Defendants May Choose to Submit in Accordance with Paragraph A.2 of the Wet Weather Improvement Program". Issued by USEPA, October 11, 2011.

85. Federal Register – 64 FR 68722, December 8, 1999. And U.S. EPA NPDES Stormwater Phase II Final Rule – Public Education and Outreach, and Public Participation/Involvement Minimum Control Measures Fact Sheets http://cfpub.epa.gov/npdes/stormwater/swfinal.cfm.

86. "Creating Defensible Space". Prepared by Oscar Newman/Institute for Community Design Analysis/Rutgers University Center". Prepared by Urban Policy Research for USDHUD. April 1996.

87. Refer to Reference 97.

88. Cincinnati Park Board Annual Maintenance Plan.

89. "Enabled Impact Report – Interim Project Summary". Prepared by MSDGC. December 2011.

90. "Enabled Impact Report – Interim Project Summary". Prepared by MSDGC. September 2012.

91. Not Used.

92. "Narrative Overview of BMP Database Study Characteristics". Prepared by National Stormwater BMP Database. July 2012.

93. MSDGC Contract #15x11155 - Ault Park Sewer Enhancements, Project ID 10270023. September 7, 2011.

94. "Lick Run Calibration Validation Report". Prepared by XCG Consultants, Inc. February 7, 2012.

95. Refer to Reference 64.

96. "MSDGC's Working Draft Sustainable Projects Technical Memo, Lower Mill Creek Partial Remedy". Prepared by Arcadis, September 2012.

97. "Burnet Woods Green Infrastructure Modeling". Prepared by Stantec Consulting Services, Inc. December 2011.

98. ODOT, Revive I-75 Initiative.

99. "Default Tunnel Task 308 Revised Concept Design Report". Prepared by Black and Veatch Corporation. March 2011.

100. "Default Tunnel Task 203 Geotechnical Investigation Report - FINAL''. Prepared by Black and Veatch Corporation. June 2010.

101. Rooftops to Rivers. National Resources Defense Council (NRDC), June 2006. http://www.nrdc.org/water/pollution/rooftops/rooftops.pdf.

102. http://www.epa.gov/aboutepa/owaa.html.

103. Banking on Green. American Society of Landscape Architects, April, 2012. http://www.asla.org/uploadedFiles/CMS/Government_Affairs/Federal_Government_Affairs/Banking%20on%20Green%20HighRes.pdf.

104. Cost Comparison of Conventional Gray Combined Sewer Overflow Control Infrastructure versus a Green/Gray Combination. Cohen, Jeffrey et al. Journal of Irrigation and Drainage Engineering. June, 2012.

105. Reflections on Green Infrastructure Economics. Jaffe, Martin. Environmental Practice. December, 2010.

106. A Comparison of Runoff Quantity and Quality from Two Small Basins Undergoing Implementation of Conventional and Low-Impact-Development (LID) Strategies: Cross Plains, Wisconsin, Water Years 1999–2005.

107. U.S. Geological Survey Scientific Investigations Report 2008–5008. 2008.

108. New York City Green Infrastructure Plan. NYC Department of Environmental Protection (DEP), September 2011. http://www.nyc.gov/html/dep/pdf/green_infrastructure/NYCGreenInfrastructurePlan_LowRes.pdf

109. Green Infrastructure Storms Ahead. Berkooz, Corry B. Planning magazine, March 2011.

110. The Benefits of Green Infrastructure and Low Impact Development on the Nation's Water Quality, Economy and Communities- U.S. House of Representatives Transportation and Infrastructure Subcommittee on Water Resources and Environment. Neukrug, Howard from Philadelphia Water Department testifying. September 30, 2010.

111. The Benefits of Green Infrastructure and Low Impact Development on the Nation's Water Quality, Economy and Communities. September 20, 2010.

112. Banking on Green. American Society of Landscape Architects, April, 2012.

113. Rooftops to Rivers. NRDC, June 2006.

114. Rooftops to Rivers. NRDC, June 2006.

115. Green Infrastructure Storms Ahead. March 2011..

116. Rooftops to Rivers. NRDC, June 2006.

117. Rooftops to Rivers. NRDC, June 2006.

118. Rooftops to Rivers. NRDC, June 2006.

119. Banking on Green. American Society of Landscape Architects, April, 2012.

120. Rooftops to Rivers. NRDC, June 2006.

121. Community Partner Profiles: Kansas City, Missouri. U.S. EPA, 2011. http://water.epa.gov/infrastructure/greeninfrastructure/upload/Region-7.pdf

122. Overflow Control Plan. Kansas City, Missouri, January 2009.

123. http://www.neorsd.org/projectcleanlake.php

124. Sewer district putting green ($42M) on green projects. Davis, Dave. The Cleveland Plain Dealer, October 3, 2011.

125. MSD to attack runoff using green project; Stormwater diversion plan called for by EPA will start on north side. Tomich, Jeffrey. St. Louis Post – Dispatch, December 30, 2011: A.1.

126. Green Infrastructure Community Profile: Washington, D.C. Center for Neighborhood Technology, 2007.

127. Rooftops to Rivers. NRDC, June 2006.

128. Banking on Green. American Society of Landscape Architects, April, 2012.

129. Rooftops to Rivers. NRDC, June 2006.

130. Alcosan plan has no 'green' components $3.6 billion project relies on expanded facilities, tunnels to stop sewer overflows. Hopey, Don . Pittsburgh Post – Gazette, July 2012: A.3.

131. 119.Rooftops to Rivers. NRDC, June 2006.

132. “Daylighting New Life for Buried Streams”. Prepared by Richard Pinkham, Rocky Mountain Institute. 2000.

133. "The Importance of Base Flow to the Restoration and Attainment of WQS Designated Uses in Cincinnati Area Streams". Prepared by Edward Rankin and Chris Yoder, Midwest Biodiversity Institute. September 6, 2012.

134. "Reducing Stormwater Costs Through Low Impact Development (LID) Strategies and Practices". Prepared by USEPA Publication No. 841-F-07-006. December 2007.

135. "Drivers of economic performance in Michigan: Natural features, green infrastructure and social/cultural amenities." Prepared by Land Policy Institute, Michigan State University. 2012.

136. http://cfpub.epa.gov/npdes/stormwater/rulemaking.cfm

LIST OF ACRONYMS

AACE	Association for the Advancement of Cost Estimating
ADA	American with Disabilities Act
ASIWPCA	Association of State and Interstate Water Pollution Control Administrators
ASLA	American Society of Landscape Architects
BG	billion gallons
BMP	Best Management Practice
BoCC	Board of County Commissioners
CAGIS	Cincinnati Area Geographical Interface System
CAPP	Capacity Assurance Program Plan
CDOTE	Cincinnati Department of Transportation & Engineering
CDR	Comprehensive Design Report
CFAC	Communities of the Future Advisory Committee
CIP	Capital Improvement Program
CPB	Cincinnati Parks Board
CPS	Cincinnati Public Schools
CPTED	Crime Prevention through Environmental Design
CRC	Cincinnati Recreation Commission
CSO	Combined Sewer Overflow
CSS	Combined Sewer System
DB	Detention Basin
DOE	Department of Energy
DOT	Department of Transportation
DWF	Dry Weather Flow
EHRT	Enhanced High Rate Treatment Facility
EI, EIP	Enabled Impact Project
EPA, USEPA	United States Environmental Protection Agency
ESA	Environmental Site Assessment
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
GAO	Government Accounting Office
GCWW	Greater Cincinnati Water Works
HCTID	Hamilton County Transportation Improvement District
HMS/HEC	Hydraulic model of water flow through natural rivers and other channels
HRT	High Rate Treatment Facility
HSG	Hydrologic Soil Group
I/I	Infiltration & Inflow
LID	Low Impact Development
LMC	Lower Mill Creek
LMCFR	Lower Mill Creek Final Remedy
LMCPR	Lower Mill Creek Partial Remedy
LTCP	Long Term Control Plan
MG	million gallons
MGD	million gallons per day

MOT	Maintenance of Traffic
MSD, MSDGC	Metropolitan Sewer District of Greater Cincinnati
NACWA	National Association of Clean Water Agencies
NASA	National Aeronautics & Space Administration
NEPA	National Environmental Policy Act
NFS	National Forestry Service
NORDS	Northeast Ohio Regional Sewer District's
NPDES	National Pollutant Discharge Elimination System
NPS	National Parks Services
NRDC	Natural Resources Defense Council
NSQD	National Stormwater Quality Database
O&M	Operations & Maintenance
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
ODOT	Ohio Department of Transportation
OEPA	Ohio Environmental Protection Agency
OEQ	Cincinnati Office of Environmental Quality
ORC	Ohio Revised Code
OUPS	Ohio Utilities Protection Service
PACP	Pipeline Assessment & Certification Program
RDII	Rainfall Derived Inflow and Infiltration
ROW	Right-of-Way
RTC	Real Time Control Facility
RTK	Abbreviation for hydraulic parameters
SFBA	South Fairmount Business Association
SFCC	South Fairmount Community Council
SHPO	State Historic Preservation Office
SI	Sustainable Infrastructure
SMU	Stormwater Management Utility
SSO	Sanitary Sewer Overflow
STP	Surface Transportation Program
SWEP	Sustainable Watershed Evaluation Plan
SWEPP	Sustainable Watershed Evaluation Planning Process
SWIM	Stormwater Wastewater Integrated Management
SWM	System-Wide Model
TPC	Total Project Cost
ULO	Underground Locate Openings
URA	Uniform Relocation Act
USACE	United States Army Corps of Engineers
USFRA	United States Federal Railroad Administration
USGS	United States Geological Survey
VCS	Valley Conveyance System
VE	Value Engineering
WERF	Water Environment Research Foundation
WQS	Water Quality Standard

WRRSP	Water Resources Restoration Partner Program
WWIP	Wet Weather Improvement Program