# Task 2 - Leavenworth Basin Green Solutions TM

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## Purpose

The purpose of this Technical Memorandum (TM) is to perform a preliminary evaluation and recommend applicable Green Solutions for the Leavenworth Basin. These Green Solutions would complement the structural Combined Sewer Overflow (CSO) controls previously identified for the two CSO outfalls (CSOs 109 and 121) in the Leavenworth basin by reducing the volume of wet weather runoff entering the Combined Sewer System (CSS) through the use of source control Best Management Practices (BMPs). It is the proposed BMPs that constitute the Green Solutions that will reduce the volume and peak storm inflow to the CSS. It should be noted that the LTCP structural controls will result in diverting all the flow from CSO 121 to CSO 109 for events less than or equal to the Level 4 Control storm for the representative rainfall year. For this reason, our review will focus on a discussion of the impact on a combined CSO121/109 outfall system.

The recommended Green Solutions from the Leavenworth basin will be combined with Green Solutions from the other nine (9) CSO basins and evaluated by the City of Omaha (City) and Program Management Team (PMT). The results of this analysis will be to identify which Green Solutions will be incorporated into the Final Long Term Control Plan (LTCP) to be submitted in October 2009.

## Program Background

The City of Omaha (City) sewer system includes over 1,950 miles of combined and sanitary sewers. In the eastern portion of the City, most of the storm and sanitary sewers are combined. This combined sewer system (CSS) area encompasses approximately 51 square miles in two watersheds: the Missouri River and the Papillion Creek watershed. The entire CSS area has been divided into ten basins for evaluation as part of the Omaha Combined Sewer Overflow (CSO) Control Program. The overall purpose of the Program is to develop a Long Term Control Plan (LTCP) for the control of CSOs. The LTCP must meet regulatory requirements, be affordable to rate payers, and be acceptable to the citizens of Omaha. Currently, the Omaha CSO Program is in the 2-year refinement phase between the Substantively Complete LTCP, submitted to the Nebraska Department of Environmental Quality (NDEQ) in October of 2007, and the final LTCP to be submitted in October 2009.

## Green Solutions Identification and Selection Process

The Task 2 Team developed the "Green Solutions Guidance for the City of Omaha CSO Long Term Control Plan" Technical Memorandum (TM) dated August 18, 2008. This TM summarized the potential locations for Green Solutions in the City of Omaha based on GIS data, the identification and prioritization of Green Solution opportunities, and the Green Solution technology types recommended for consideration and their function. In the second portion of the TM, design criteria and unit cost data for each technology types are given. Finally, the methodology for selecting the Green Solutions technologies was presented.

Figure 1 below summarizes the methodology used to identify, characterize, select green solution technologies, and size the facilities.

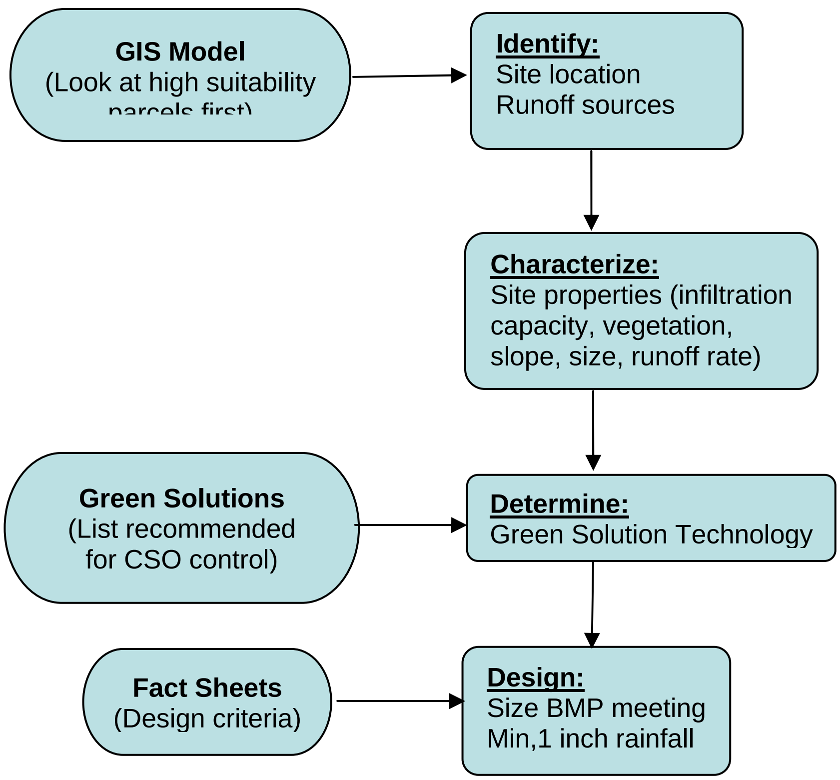


**Figure 1 – Green Solutions Technology Selection Methodology**

The first step in BMP implementation consists in identifying the appropriate site location from the opportunity map developed by the GIS modeling team. The parcels with high suitability (or high numbers on a scale from 0 to 100) should be considered first. Sources and quantity of runoff to a site should be considered as well. Once the site is found, its properties need to be characterized: infiltration capacity of the soil, vegetation cover, slope, and size of parcel. In addition, the runoff rate needs to be calculated by considering the drainage area and the imperviousness of the lots draining towards the BMP site. The appropriate BMP technology can be determined by reviewing the list of recommended Green Solutions included in the guidance document. Finally, the chosen BMP should be sized, at a minimum, to capture the resulting runoff volume from a 1-inch storm event, and using the design criteria found in the fact sheets included in the guidance document. However, if space is available, the facility can be upsized to handle up to 2.5 inches of runoff volume.

## Design Criteria

Sizing criteria was developed for the Missouri River Watershed by evaluating the "existing conditions" CSO InfoWorks model for the Representative Year. The depth of rainfall was compared to the CSO events for each outfall to determine a beneficial rainfall depth to use for sizing criteria. The determination of a rainfall (storm) depth for sizing criteria was accomplished by plotting the cumulative number of CSO events versus the storm depth causing these events. Sizing curves were developed for the watershed by incorporating the total number of CSO events per year. The sizing criteria resulting from this analysis has been developed by grouping CSO events for the watershed. This evaluation could be refined to be specific to each outfall; however, it is outside the scope of this project.

Table 1 shows the data used for developing the sizing curves for the Missouri River Watershed. The plot in Figure 2 shows an inflection in the curve at about 1 inch of rainfall for the watershed. This means that most of the CSO events occur for rainfall depths below 1 inch (steeper curve). During larger events, the number of CSO events does not increase significantly. The inflection in the curve is the point at which the magnitude of the event increases more rapidly than the number of occurring events (California Stormwater BMP Handbook). If BMP's are sized for larger rainfall depths, the size and costs of the BMP's are no longer practical for CSO reduction (known as diminishing returns).

If the BMP's are sized to capture the runoff resulting from a 1 inch of rainfall across the entire watershed, about 85% of all CSO events are eliminated for the watershed.

**Table 1 – Missouri River Watershed BMP Sizing Criteria Development**

| Events Grouping | Max Storm Depth (in) | Number of events for each grouping | Cumulative number of events |
|---|---|---|---|
| 0-0.25 in | 0.25 | 26 | 26 |
| 0.26- 0.5 in | 0.5 | 9 | 35 |
| 0.5- 0.75 in | 0.75 | 4 | 39 |
| 0.76 - 1 in | 1 | 7 | 46 |
| 1.01-1.25 in | 1.25 | 3 | 49 |
| 1.26-1.5 in | 1.5 | 2 | 51 |
| 1.51-1.75 in | 1.75 | 0 | 51 |
| 1.76-2 in | 2 | 1 | 52 |
| 2.01-2.25 in | 2.25 | 0 | 52 |
| 2.26-2.5 in | 2.5 | 1 | 53 |
| 2.56-2.75 in | 2.75 | 0 | 53 |
| 2.76-3in | 3 | 1 | 54 |

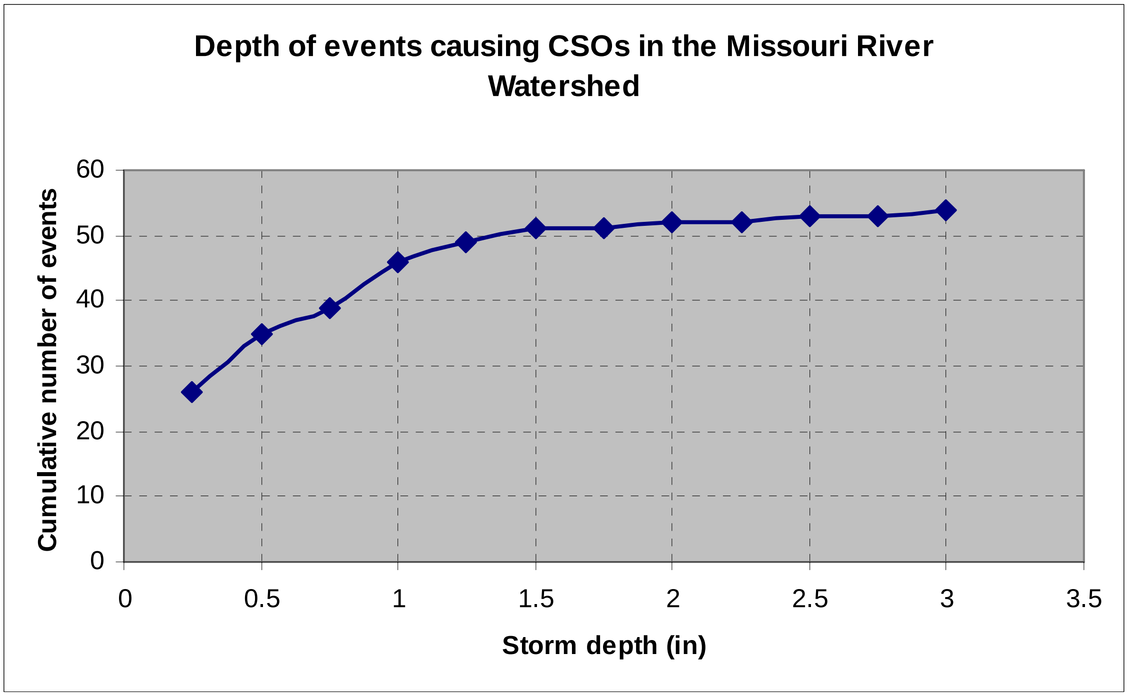


**Figure 2 – Depths of Events Causing CSOs in the Missouri River Watershed**

The design of BMPs is based on the tributary area to the location of the BMP and on the runoff from the watershed due to a storm event. The amount of storm water runoff is determined from the rainfall depth of the particular event and the runoff coefficient, which in turn depends on watershed characteristics (such as basin imperviousness, local depressions, flow routing) of the tributary area. To calculate the runoff to each BMP, the median event duration for the watershed is assumed to be 6 hours.

# Cost Development

The Cost Estimation Tool developed for the City of Omaha CSO Program does not currently include Green Solutions cost estimates, with the exception of bioretention. Therefore, Table 4 of the Green Solutions Guidance Document provided planning level costs to aid in the development of budgets and pricing for the various technologies. In general, the lifespan of a BMP is 20 years but varies based on level of maintenance and type of BMP.

In addition to construction cost, 20% should be added for contingency, 10% for mobilization, and 20% for engineering (design/consulting). This document provides information at a planning level. There are not enough data available on the individual BMP's to be implemented in each basin to provide detailed cost estimates.

# Screening of Green Solution Locations

The Leavenworth Basin team reviewed the information provided on Plates 5, 6, and 7 of the Green Solutions Guidance Document which identify the suitability index for green solutions on City Owned Parcels, City Owned and Semi-Public Parcels, and Public and Private

Parcels, respectively. The Leavenworth Basin is highly developed with few open, publicly owned parcels of significant size required for incorporating effective green solutions. As a result, two (2) large sites commonly referred to as the Hanscom Park and James F. Lynch Park were identified for further evaluation of green solutions technology applicability. Table 2 summarizes the Hanscom and James F. Lynch Parks suitability index rankings for each of the plate maps.

**Table 2 – Green Solution Locations Identified in the Guidance Document**

| Location | Coordinate Location | Description | City Owned Parcel Suitability Ranking (Plate 5) | City Owned and Semi-Public Parcel Ranking (Plate 6) | Public and Private Parcel Ranking (Plate 7) | Comment |
|---|---|---|---|---|---|---|
| Ed Creighton Ave & Park Ave | N: 538945.21 ft, E: 2751310.28 ft | Hanscom Park | 44 – 49 through 54 – 57 | 44 – 49 through 54 – 56 | 13 – 51 through 56 – 58 | Site was carried through for further analysis. |
| Martha St.& South 21st St | N: 538521.23 ft, E: 2755100.46 ft | James F. Lynch Park | 44 – 49 through 54 – 57 | 44 – 49 through 54 – 56 | 13 – 51 through 56 – 58 | Site was carried through for further analysis. |

It is noted that other possible locations (public or private) may exist within the Leavenworth Basin area that could be suitable for application of green solutions. However, these small sites would control a very small amount of runoff volume and have a negligible impact on CSO overflow volumes. For this reason, no further effort was expended by the LV Basin team to identify these locations.

The City and PMT may want to consider using the BAP panel process to identify possible locations and/or sponsors that would be interested in implementing a green solution at small sites.

# Green Solution Analysis

Hanscom and James F. Lynch Parks are further analyzed and described in this section below. Most of the data needed to populate Table 3 was obtained from the GIS files accompanying the Guidance Document. Calculations for determining facility runoff rates were performed using the Rational Method and are included in Attachment 3.

## Hanscom Park (GS-109/121-1)

Hanscom Park was identified in the Green Solutions GIS Model as having a moderate suitability for BMP implementation. The site is a public park that includes various recreational features. An aerial view of the site with contours is shown in Figure 3. Photographs of the site are provided in Attachment 1. Table 3 summarizes the site characteristics at Hanscom Park.

**Table 3 – Hanscom Park Information**

| | |
|---|---|
| **Identifier** | CSO-109/121-1 |
| **Area** | Hanscom Park |
| **Parcel Owner** | City of Omaha |
| **Parcel Size** | 57.6 ac |
| **Available area for BMPs** | 40% |
| **Slope of Site** | 2% to 18% |
| **Vegetation** | Grasses and native plants |
| **Soil per NRCS Survey** | Silty-Clay Loam |
| **Infiltration Capacity** | Average |
| **Drainage Area (to BMP)** | 67 ac |
| **Q(2-year) in** | 58 cfs |
| **Q(10-year) in** | 89 cfs |
| **Pipes Out** | 39" RCP @ 1.21%<br>21" RCP @ 0.67% |
| **Pipe Capacity Out** | 58 cfs<br>8 cfs |
| **Available Volume (BMPs)** | 5.3 ac-ft |
| **Cover on Existing Sewers** | +/- 8 ft |
| **Runoff Volume of 2.5" Rainfall** | 5.3 ac-ft |
| **Ranking of City Owned Parcels** | 44 to 49 (Between Low and Moderate Suitability) through 54 to 57 (Moderate Suitability) |
| **Ranking of City & Semi Public** | 44 to 49 (Moderate Suitability) through 54 to 56 (Moderate Suitability) |
| **Ranking of Public & Private Parcels** | 13 to 51 (Low Suitability) through 56 to 58 (Between Low to Moderate Suitability) |

Table 4 below summarizes the suitability of Green Solutions in Hanscom Park.

**Table 4 – Hanscom Park Technology Screening**

| **BMP Technology** | **Suitability for Site** | **Comments** |
|---|---|---|
| Constructed Wetland | High | Park has extensive open space areas. Would like to consider terraced wetland concept through steep "ravine" areas. |
| Wet Pond | High | Additional wet pond areas could be added. Would need to consider access to existing manhole structures in low lying area. |
| Vegetated Swale | High | Runoff from local streets could be diverted into a vegetated swale along the streets. Swales would require routine maintenance. Swales would be sized for smaller storm events. Large events |

| BMP Technology | Suitability for Site | Comments |
|---|---|---|
| | | would continue to flow in the street. |
| Vegetated Filter Strips | Low | Not applicable. Runoff through the park currently flows through vegetated areas. |
| Rain Gardens | High | Small rain garden(s) could be constructed in available areas of the park to take overland flow from the local streets or diverted storm sewers. Events with greater than 1″ rainfall would continue to experience flow in the street. |
| Pervious Pavement | Moderate | Pervious pavement could be implemented for future park road or parking area replacement work. |
| Infiltration Basin / Trench | Moderate | Potential use in open areas of the park. Infiltration rates would need to be verified. |
| Green Roofs | Low | Green roofs could be used on a reconstructed building. |
| Dry Detention Pond | High | The park already acts as a detention area during large storm events. Areas of the park could be deepened and runoff from local streets or sewers diverted to a dry pond prior to re-entering the storm sewer system. Limited degree of sewer separation will be required. |
| Bioretention | High | Bioretention areas could be constructed to take low flows and would fit in well with park setting. |

## Facility Cost

The cost information from the Green Solutions Guidance Document was utilized to develop a representative cost estimate for the Hanscom Park green solutions. Table 5 identifies the costs for this facility.

**Table 5 – Hanscom Park Cost Estimate**

| Description | Units | Unit Cost | Construction Cost | Annual Maintenance Cost (% of Capital) |
|---|---|---|---|---|
| Wet Ponds | 1.43 ac. ft. | $57,500/ac. ft. | $ 82,225 | $ 16,445 |
| Pervious Pavement | 12,632 sq. ft. | $12/sq. ft. | $ 151,584 | $ 10,611 |
| Bioretention | 12,002 sq. ft. | $20/sq. ft. | $ 240,040 | $ 12,002 |
| Wetlands | 3.44 ac. ft. | $71,250/ac. ft. | $ 245,100 | $ 24,510 |
| Rain Gardens | 15,019 sq. ft. | $10/sq. ft. | $ 150,190 | $ 38,250 |
| Sewer Work | $ 765,000 | $ 765,000 | $ 765,000 | $ 109,327 |
| | | **Subtotal** | $ 1,634,139 | |
| | | **Contingency (20%)** | $ 326,828 | |
| | | **Mobilization (10%)** | $ 163,414 | |
| | | **Engineering (20%)** | $ 326,828 | |
| | | **Total** | $ 2,451,209 | $ 109,327 |
| | | **20 Year Present Worth Calculation[1]** | | $ 3,705,185 |
| | | **$/MG Stored** | | $ 2,179,521 |

1 – Assumed 6% inflation rate for present worth calculation

## Recommendation

The site currently functions as an urban park area with an existing open water lagoon feature. The development of green solutions at the park will need to be integrated with the rolling pastoral terrain and recreational uses programmed for the park. Balancing the areas for recreational uses with the areas proposed for implementing green solutions is a key decision for the City policy makers that should occur early in the feasibility process. However, we suggest that the green solutions can be designed in a manner to provide aesthetically pleasing features that contextually fit into most of the existing uses of this urban park. An integral benefit is that implementation within this venue could prove to be an excellent demonstration area for several green solution practices.

For example, at the north end of the park, a series of rain garden cells could be integrated into the landscape of the park with minimal loss of use and provide demonstration gardens for education to the public and special interest groups on the benefits of this green solution practice. Sources for the runoff to support the rain gardens would come from the nearby road drainage. In another example, the northeastern valley that traverses this part of the park could be graded to construct a series of tiered constructed wetlands to store and treat the contributing area storm water runoff. Constructed wetlands could provide stormwater services within a marginally useable recreational open space. Other benefits of implementing this project include introducing wetland aquatic habitat within an urban setting that has aesthetic qualities that is reasonably accessible to large population. A perimeter pedestrian pathway with an elevated boardwalk path overlooking the wetland could provide opportunities for educational/interpretive exhibits as well as passive recreation benefits.

Other concepts for integration of green solutions are presented at the southwestern area of the site. In this area, off-site storm water could be redirected to flow into a constructed wet pond to detain and treat the contributing stormwater. Overflow from the wet pond could be directed into a bioretention basin area located just west of the existing lagoon. Both of these solutions will cause loss of recreational uses and therefore will need further analysis and decision making on the part of the project stakeholders.

All of the green solution technologies suggested in this document will require additional technical data collection and assessment to determine the feasibility of the concepts to the site specific constraints such as subsurface soil conditions, infiltration rates, impacts to infrastructure, and constructability issues.

Figure 4 delineates the potential location and size of the green solution BMP's that could produce improvements in stormwater management for both on-site park infrastructure and the surrounding sewershed. Photographs of the site are provided in Attachment 2. Information with regard to sizing of these facilities is provided in Attachment 3.

In summary, numerous non-monetary benefits for implementing the green solutions at this urban park can be achieved and include public educational opportunities as well as an opportunity to implement demonstration projects for a variety of green practices. In addition, the implementation of the projects could provide valuable training for the contractors desiring to implement these projects and improve on the construction technologies for implementing future green solutions.

In the event that discussions with the Parks department lead to downsizing or elimination of green solutions at this site, it is recommended that the other public sites be identified and funding be reallocated to these projects within the LV Basin. Given the fact that the Leavenworth Basin does not currently have any visible CSO projects planned within the upper reaches of the basin, this may be an approach worth pursuing.

## James F. Lynch Park (GS-109/121-2)

James F. Lynch Park was identified in the Green Solutions GIS Model as having a moderate suitability for BMP implementation. The site is a public park that includes various recreational features including a baseball field. An aerial view of the site with contours is shown in Figure 5. Pictures of the site are provided in Attachment 2. Table 5 summarizes the site characteristics at James F. Lynch Park.

**Table 5 – James F. Lynch Park Information**

| | |
|---|---|
| **Identifier** | CSO-109/121-2 |
| **Area** | James F. Lynch Park |
| **Parcel Owner** | City of Omaha |
| **Parcel Size** | 14.7 ac |
| **Available area for BMPs** | 6.8% |
| **Slope of Site** | 0% to 16% |
| **Vegetation** | Grasses and native plants |
| **Soil per NRCS Survey** | Silt Loam |
| **Infiltration Capacity** | Average |
| **Drainage Area (to BMP)** | 11.7 ac |
| **Q(2-year) in** | 74 cfs |
| **Q(10-year) in** | 278 cfs |
| **Pipes Out** | 84″ RCP @ 1.26%<br>54″ RCP @ 1.35% |
| **Pipe Capacity Out** | 719 cfs<br>229 cfs |
| **Available Volume (BMPs)** | 6.9 ac-ft |
| **Cover on Existing Sewers** | +/- 34 ft |
| **Runoff Volume from 2.5″ Rainfall** | 6.9 ac-ft |
| **Ranking of City Owned Parcels** | 54 to 57 (Moderate Suitability) |
| **Ranking of City & Semi Public** | 44 to 49 (Moderate Suitability) |
| **Ranking of Public & Private Parcels** | 56 to 60 (Between Low to Moderate Suitability) |

Table 6 below summarizes the suitability of Green Solutions in James F. Lynch Park.

**Table 6 – James F. Lynch Park Technology Screening**

| **BMP Technology** | **Suitability for Site** | **Comments** |
|---|---|---|
| Constructed Wetland | High | Park has several open space areas |
| Wet Pond | High | A wet pond area could be added. |
| Vegetated Swale | High | Runoff from local streets could be diverted into a vegetated swale along the streets. Swales would require routine maintenance. Swales would be sized for smaller storm events. Large events would continue to flow in the street. |
| Vegetated Filter Strips | Low | Not applicable. Runoff through the park currently flows through vegetated areas. |
| Rain Gardens | High | Small rain garden(s) could be constructed in |

| BMP Technology | Suitability for Site | Comments |
|---|---|---|
| | | available areas of the park to take overland flow from the local streets, parking areas, or tennis courts. |
| Pervious Pavement | Moderate | Existing park roads and parking areas could be replaced with pervious pavement. |
| Infiltration Basin / Trench | Moderate | Potential use in open areas of the park. Infiltration rates would need to be verified. |
| Green Roofs | Low | Green roofs could be used on any reconstructed building structures such as the restroom building. |
| Dry Detention Pond | High | Areas of the park could be deepened and runoff from diverted to a dry pond prior to re-entering the combined sewer system. |
| Bioretention | High | Bioretention areas could be constructed to take flows and would fit in well with park setting. |

### Facility Cost

The cost information from the Green Solutions Guidance Document was used to develop a representative cost estimate for the James F. Lynch Park green solutions. Table 7 provides a breakdown of the costs for this facility.

**Table 7 – James F. Lynch Park Cost Estimate**

| Description | Units | Unit Cost | Construction Cost | Annual Maintenance Cost (% of Capital) |
|---|---|---|---|---|
| Bioretention | 7,714 sq. ft. | $20/sq. ft. | $ 154,280 | $ 7,714 |
| Wetlands | 1.04 ac. ft. | $71,250/ac. ft. | $ 74,100 | $ 7,410 |
| Sewer Work | 300 ft. | $530/ft. | $ 159,000 | $ 7,950 |
| | | **Subtotal** | $ 387,380 | $ 23,074 |
| | | **Contingency (20%)** | $ 77,476 | |
| | | **Mobilization (10%)** | $ 38,738 | |
| | | **Engineering (20%)** | $ 77,476 | |
| | | **Total** | $ 581,070 | $ 23,074 |
| | | **20 Year Present Worth Calculation[1]** | | $ 845,727 |
| | | **$/MG Stored** | | $ 2,114,317 |

1 – Assumed 6% inflation rate for present worth calculation

## Recommendation

The Lynch Park site is an active recreational park located in a dense urban area. Current recreational features include baseball fields, a playground and tennis courts. The land slopes generally south to northeast with a large hill located at the southern extent of the site. Due to this rolling topography in the southern half of the site, it appears that this area has limited opportunity for incorporating green solutions. However, two sites within the central and northeast areas are relatively flat areas of the park and are undeveloped for the most part. The two areas depicted in the plan have adequate topography and space sufficient to create BMP technologies to effectively manage stormwater flows at the park site.

At the center of the site, immediately west of the central parking area, is an open area that could be retrofitted with a bioretention basin that could be sized to attenuate and infiltrate high frequency storm events. Runoff from the parking area and surrounding ball fields is proposed to be re-routed to the bioretention basin providing attenuation and treatment of the stormwater generated from the site that would have been collected in the combined sewer traversing the site from south to east.

At the north end of the site is an open area north and east of the baseball field. This area is proposed to be retrofitted with a large wetland area. Due to its size, this wetland could contain both deep water (3 to 7 feet) and emergent vegetation zones (12-inches or less). The high frequency storm event volume from the nearby drainage area adjacent to this area could be diverted to the constructed wetland for treatment and extended detention thereby providing peak reduction and treatment benefits.

Both of these BMP's will need to be coordinated with the City Parks Department for review and approval of the concepts prior to moving forward with the design. In addition, site geotechnical data including soil type, infiltration rates, seasonal high ground water elevation as well as depth to bedrock will need to be obtained.

Figure 6 delineates the potential location and size of the green solution BMPs that could reduce the amount of storm volume entering the combined sewer system and resulting outfalls. Information with regard to sizing of these facilities is provided in Attachment 3.

In the event that discussions with the Parks department lead to downsizing or elimination of green solutions at this site, it is recommended that the other public sites be identified and funding be reallocated to these projects within the LV Basin. Given the fact that the Leavenworth Basin does not currently have any visible CSO projects planned within the upper reaches of the basin, this may be an approach worth pursuing.

| Acronym/Term | Definition |
|---|---|
| BC | Basin Consultant |
| BMP | Best Management Practices |
| CIP | Capital Improvement Program |
| City | City of Omaha |
| CSO | Combined Sewer Overflow |
| CSS | Combined Sewer System |
| GIS | Geographic Information System |
| HRT | High-Rate Treatment |
| LTCP | Long Term Control Plan |
| LV | Leavenworth |
| MRWWTP | Missouri River Wastewater Treatment Plant |
| MUD | Metropolitan Utilities District |
| NDOR | Nebraska Department of Roads |
| PMT | Program Management Team |
| RTB | Retention Treatment Basin |
| TM | Technical Memorandum |

# Attachments

Attachment 1 – Photographs of Hanscom Park

Attachment 2 – Photographs of James F. Lynch Park

Attachment 3 – Green Solution Sizing Calculations

# Attachment 1 – Hanscom Park Site Photographs

# Attachment 2 – James F. Lynch Park Site Photographs

# Attachment 3 – Green Solutions Sizing Calculations

## Leavenworth Basin - Design Calculations for Green Solutions

| Parameter | Hanscom Park | | | | | James F. Lynch Park | | | Criteria / Assumptions |
|---|---|---|---|---|---|---|---|---|---|
| | Bioretention | Rain Gardens | Wet Pond | Wetland | Total | Bioretention | Wetland | Total | |
| Drainage Area (ac) | 5.29 | 3.31 | 17.1 | 41.3 | 67 | 1.7 | 10 | 11.7 | |
| Rain Depth (in) | 2.5 | 2.5 | 2.5 | 2.5 | | 2.5 | 2.5 | | Per PMT comments on draft TM |
| Runoff Coefficient | 0.25 | 0.25 | 0.4 | 0.4 | | 0.5 | 0.5 | | Table 2-3 of the Omaha Stormwater Design Manual (April 2006) |
| Total Runoff Volume (ac-ft) | 0.28 | 0.17 | **1.43** | **3.44** | 5.3 | 0.18 | 1.04 | 1.2 | Volume = Drainage Area x Depth x C |
| Total Runoff Volume (cf) | 12,002 | 7,510 | 62,073 | 149,919 | | 7,714 | 45,375 | | |
| Average Depth (ft) | 1 | 0.5 | 3 | 1.5 | | 1 | 1.5 | | Depths within ranges provided in City Guidelines |
| Length-to-Width Ratio | 1.5 | 1.5 | 1.5 | 2 | | 1.5 | 2 | | Minimum per City Guidelines |
| Side Slope | na | na | 0.33 | 0.33 | | na | 0.33 | | Maximum per City Guidelines (1V:3H) |
| Average Width (ft) | 89 | 100 | 117 | 224 | | 72 | 123 | | Assumed rectagular geometry, Max Width = (Vol / (Depth x L:W Ratio))^0.5 |
| Average Length (ft) | 134 | 150 | 176 | 447 | | 108 | 246 | | |
| Required Surface Area for Storage (sqft) | **12,002** | **15,019** | 20,691 | 99,946 | | **7,714** | 30,250 | | SA = Max Width x Max Length |
| Required Surface Area for Storage (ac) | 0.28 | 0.34 | 0.48 | 2.29 | | 0.18 | 0.69 | | |
| Percent of Required Surface Area for Sediment Forebay (ac) | na | na | 10 | 0 | | na | 0 | | 10% of required area required for sediment forebay |
| Total Surface Area (ac) | 0.28 | 0.34 | 0.52 | 2.29 | 3.4 | 0.18 | 0.69 | 6.6 | |