HINKSON CREEK WATERSHED RESTORATION PROGRAM

BOONE COUNTY, MISSOURI

FEASIBILITY ANALYSIS FOR RETROFITTING STORMWATER TREATMENT STRUCTURES OR BEST MANAGEMENT PRACTICES

PREPARED FOR:

BOONE COUNTY PLANNING AND BUILDING DEPARTMENT

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PROJECT BACKGROUND (From RFP#: 67-30DEC08)

Since 1998, the Missouri Department of Natural Resources (MDNR) has listed Hinkson Creek on the 303(d) list of impaired waters. Neither the source of pollution nor the specific pollutants responsible for the impairment have been identified, despite a recent three year study by MDNR. In 2004, the Hinkson Creek Watershed Restoration Project (HCWRP) was funded by a four year grant from the Environmental Protection Agency (EPA) through the MDNR. In addition to education activities directed at the development community and residents, the grant project developed a watershed management plan. This plan and the (MDNR) authors of the ongoing Hinkson Creek Total Maximum Daily Load (TMDL) have indicated a focus on stormwater runoff as the key to restoring the health of Hinkson Creek. An "area of interest" has been identified in the plan as a place to concentrate efforts to provide cost-share funding to landowners who agree to install stormwater best management practices (BMPs).

The area of interest is comprised of the commercial lots located in the general area of the I-70 and Hwy-63 intersection. The lots in question lie east of Hwy-63 and both north and south of I-70. The area has been identified because the beginning of the impaired section of Hinkson Creek is adjacent to this area, nearby stormwater outfalls have had elevated levels of contaminants, and the area has a high concentration of impervious surface cover.

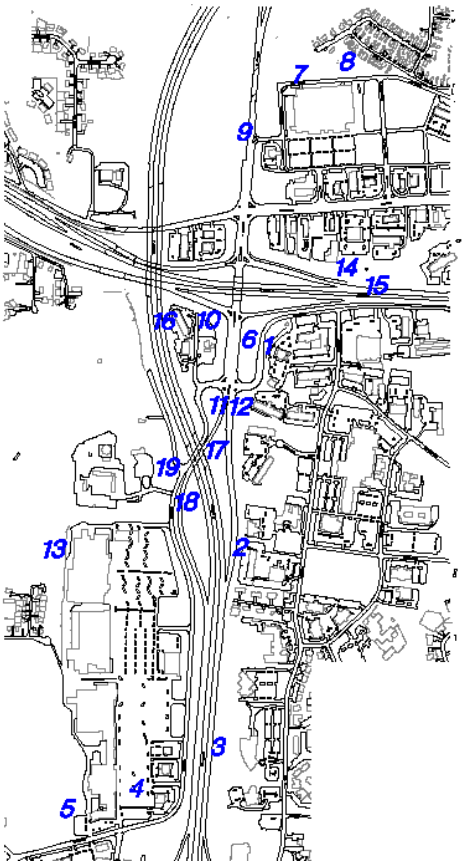
A stormwater ordinance and a stream buffer ordinance were both recently passed by the City of Columbia in 2007. Neither ordinance is retroactive: only new development and redevelopment are affected. The stream buffer ordinance requires a setback of varying width, dependent upon the size of the stream. The stormwater ordinance requires a level of service approach be taken on applicable developments: run-off from areas converted to impervious surface is ameliorated by various BMPs that must be installed to detain and treat the stormwater. These ordinances are intended to prevent further degradation of Columbia streams. The focus of this grant is to improve the health of Hinkson Creek by

retrofitting BMPs on parcels not affected by these ordinances, or to fund improved BMPs on parcels that are affected by these ordinances.

SCOPE OF FEASIBILITY STUDY AND COST BENEFIT ANALYSIS

This study was completed in an effort to determine the feasibility of retro-fitting properties within the area of interest with stormwater treatment and detention structures or practices. BMP and site selection criteria outlined within the proposal request include installation cost, 15-year maintenance cost, the amount of impervious area treated, and the level of treatment provided. This report outlines additional site and BMP selection criteria used to evaluate site and BMP combinations resulting in a list of recommended sites and their corresponding BMPs. In addition to the selection criteria detailed within this report, a Site and BMP Selection Questionnaire and a BMP Scoring Matrix have been developed to assist in selection of BMP sites and applicable BMPs.

The following Figure shows selected BMP sites within the area of interest.



SITE AND BMP SELECTION METHODOLOGY:

Upon receipt of GIS information from both the City of Columbia and Boone County, a base map of the entire area of interest was compiled. The base map was then overlaid with aerial photography, topographic maps, and utility maps. The topographic maps and the storm water utility maps were utilized to delineate watersheds and sub-watersheds within the area of interest. From this point, potential BMP sites were selected for further investigation subject to the following criteria and ideology.

Previous Developments Influence on Stormwater Infrastructure and Stormwater Quantity:

Waterways and receiving waters near urban and suburban areas are often adversely affected by urban stormwater runoff. The degree and type of impact varies from location to location, but it is often significant relative to other sources of pollution and environmental degradation. Urban stormwater runoff affects water quality, water quantity, habitat and biological resources, public health, and the aesthetic appearance of urban waterways. As reported in the National Water Quality Inventory 1996 Report to Congress (US EPA, 1998d), urban runoff was the leading source of pollutants causing water quality impairment related to human activities in ocean shoreline waters and the second leading cause in estuaries across the nation. Urban runoff was also a significant source of impairment in rivers and lakes. The percent of total impairment attributed to urban runoff is substantial. This impairment constitutes approximately 5,000 square miles of estuaries, 1.4 million acres of lakes, and 30,000 miles of rivers. Seven states also reported in the inventory that urban runoff contributes to wetland degradation. (US EPA Preliminary Data Summary of Urban Stormwater Best Management Practices, EPA-821-R-99-012, August 1999).

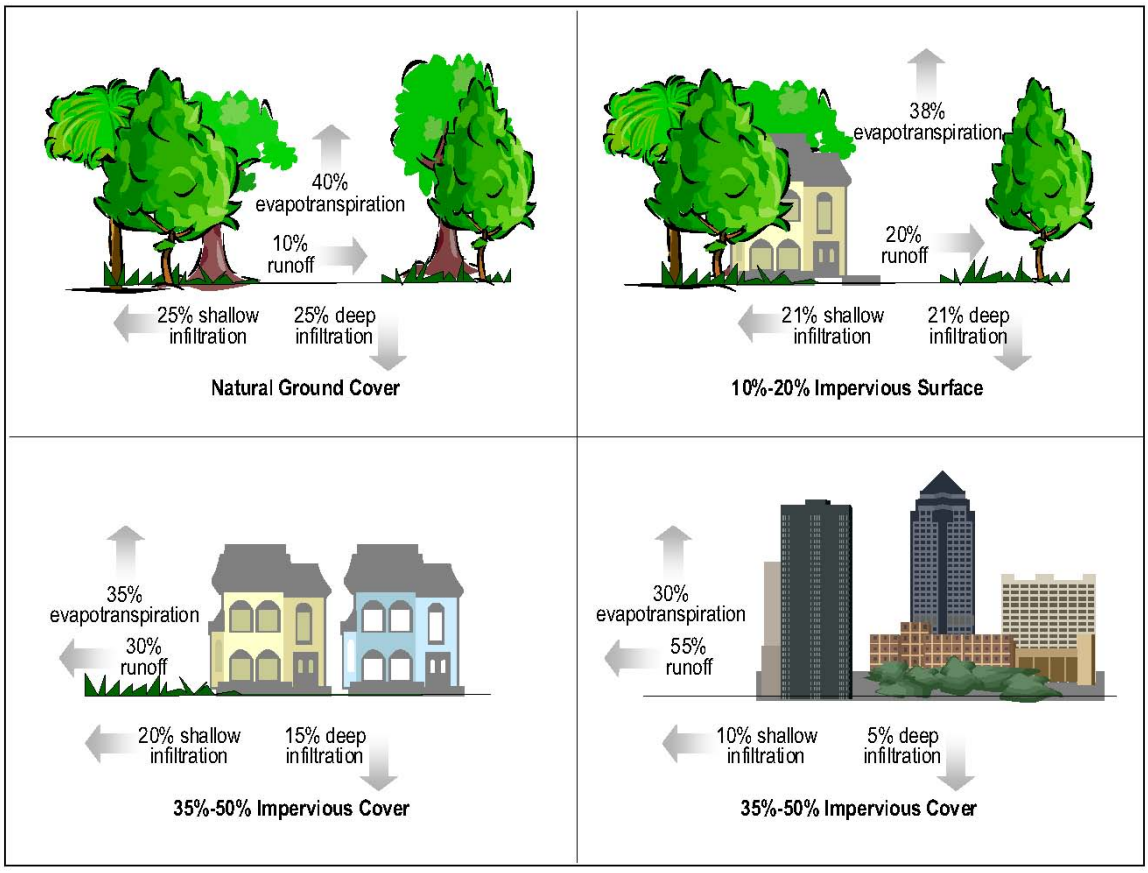
Leading sources[b] of water quality impairment related to human activities for rivers, lakes, and estuaries (USEPA, 2002b).

Rivers and Streams	Lakes, Ponds, and Reservoirs	Estuaries
Agriculture (48%) [a]	Agriculture (41%) [a]	Municipal point sources (37%)[a]
Hydrologic modifications (20%)	Hydrologic modifications (18%)	Urban runoff/storm sewers (32%)
Habitat modifications (14%)	Urban runoff/storm sewers (18%)	Industrial discharges (26%)
Urban runoff/storm sewers (13%)	Misc. nonpoint source pollution (14%)	Atmospheric deposition (24%)

[a]Values in parentheses represent the percentage of assessed river miles, lake acres, or estuary square miles that are classified as impaired. States assessed 19% of stream miles, 43% of lakes, ponds, and reservoirs, and 36% of square mileage of estuaries.
[b]Excluding unknown, natural, and "other" sources.

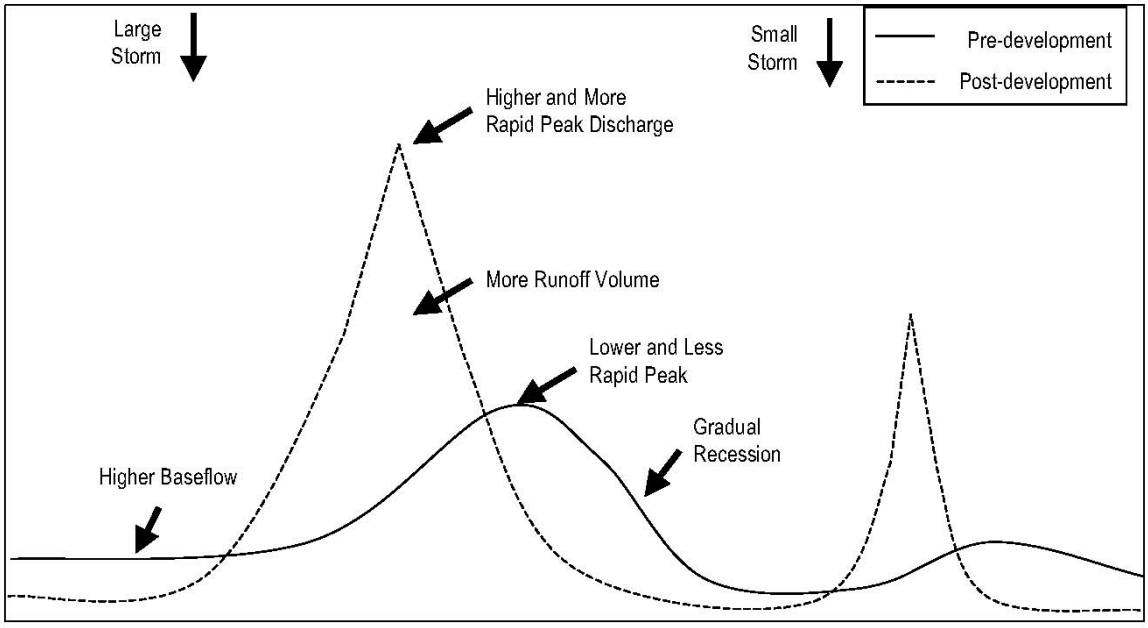
While water quality impacts are often unobserved by the general public, other stormwater impacts are more visible. Stream channel erosion and channel bank scour provide direct evidence of water quantity impacts caused by urban stormwater. Urban runoff increases directly with imperviousness and the degree of watershed development. As urban areas grow, urban streams are forced to accommodate larger volumes of stormwater runoff that recur on a more frequent basis. This leads to stream channel instability. The change in watershed hydrology associated with urban development also causes channel widening and scour, and the introduction of larger amounts of sediment to urban streams. Visible impacts include eroded and exposed stream banks, fallen trees, sedimentation, and recognizably turbid conditions. The increased frequency of flooding in urban areas also poses a threat to public safety and property. (US EPA Preliminary Data Summary of Urban Stormwater Best Management Practices, EPA-821-R-99-012, August 1999).

Historically, as urbanization occurred and storm drainage infrastructure systems were developed in this country, the primary concern was to limit nuisance and potentially damaging flooding due to the large volumes of storm water runoff that are generated. Little, if any, thought was given to the environmental impacts of such practices. As a result, streams that receive stormwater runoff frequently cannot convey the large volumes of water generated during runoff events without significant degradation of the receiving stream.



Impacts of urbanization on the water cycle (Adapted from FIRSWG, 1998).

In addition to the problems associated with excess water volume, the levels of toxic or otherwise harmful pollutants in stormwater runoff and combined sewer overflows can cause significant water quality problems in receiving streams (US EPA Preliminary Data Summary of Urban Stormwater Best Management Practices, EPA-821-R-99-012, August 1999).



Changes in stream flow hydrograph as a result of urbanization (Schueler, 1987).

Previous Developments Influence on Stormwater Quality:

During the development process, both the existing landscape and hydrology are altered. As development occurs, soil porosity decreases due to removal of vegetation and compaction of topsoil by construction equipment. Impervious surfaces increase with the addition of rooftops and paving. Artificial conveyances such as pipes and lined channels are constructed to rapidly convey stormwater. Existing slope angles become less acute, vegetative cover decreases and surface roughness decreases. (EPA-841-B-05-004)

Everyday activities that occur after development may cause the discharge of pollutants in runoff that can have harmful effects on waters and habitat. Pollutants related to vehicle petroleum and coolant leaks and overflows, tire and brake wear, pet waste, pesticides, and fertilizers can be carried into estuaries, streams, rivers, and lakes through runoff. Soils and sediment can constitute a significant fraction of the solids on urban surfaces. Weather related erosion and transport of eroded soil increases solids in urban areas. Other sources of solids on urban surfaces are wear of automotive parts, combustion products from diesel and gasoline fueled engines, fireplaces, construction sites, and industrial facilities. (EPA-841-B-05-004)

Typical pollutant concentrations found in urban storm water (adapted from MDE, 1999, and Terrene Institute, 1994).

Typical Pollutants Found in Storm Water Runoff	Units	Residential[a]	Mixed[a]	Commercial[a]	General Urban[b]
Total suspended solids	mg/L	101	67	69	80[c]
Total phosphorus	mg/L	383	263	201	0.30[c]
Total nitrogen	mg/L	–	–	–	2.0[c]
Total Kjeldahl nitrogen	mg/L	1.9	1.3	1.2	–
Nitrate + Nitrite	µg/L	736	558	572	–
Total organic carbon	mg/L	–	–	–	12.7[c]
Biological oxygen demand	mg/L	10	7.8	9.3	–
Chemical oxygen demand	mg/L	73	65	57	–
Fecal coliform bacteria	MPN/100 mL	–	–	–	3,600[c]
E. coli bacteria	MPN/100 mL	–	–	–	1,450[c]
Petroleum hydrocarbons	mg/L	–	–	–	3.5[c]
Oil and grease	mg/L	–	–	–	2 to 10[d]
Cadmium	µg/L	–	–	–	2[c]
Copper	µg/L	33	27	29	10[c]
Lead	µg/L	144	114	104	18[c]
Zinc	µg/L	135	154	226	140[c]
Chlorides (winter only)	mg/L	–	–	–	230[c]
Insecticides	µg/L	–	–	–	0.1 to 2.0[c]
Herbicides	µg/L	–	–	–	1 to 5.0[c]

[a] Source: USEPA, 1983.
[b] These concentrations represent mean or median storm concentrations measured at typical sites and may be greater during individual storms. Also note that mean or median runoff concentrations from storm water "hotspots" are 2 to 10 times higher than those shown here. Units: mg/L = milligrams/liter, µg/L = micrograms/l, MPN = most probable number.
[c] Source: MDE, 1999.
[d] Source: Terrene Institute, 1994.

Many pollutants bind to and are entrained in sediment or particulate loadings. Particulates include suspended, settleable, and bedload solids. Metals, phosphorus, nitrogen, hydrocarbons and pesticides are commonly found in urban sediments.

Total suspended solids (TSS) is a measure of the concentrations of sediment and other solid particles suspended in the water column of a stream, lake, or other water resource. TSS is an important parameter because it quantifies the amount of sediment entrained in runoff. This information can be used to link sources of sediments to the resulting sedimentation in a stream, lake, wetland, or other water resources. TSS is also an indirect measure of other pollutants carried by runoff, because nutrients (phosphorus, metals, and organic compounds) are typically attached to sediment particles. (EPA-841-B-05-004)

Physical Properties of Soils in the Area of Interest:

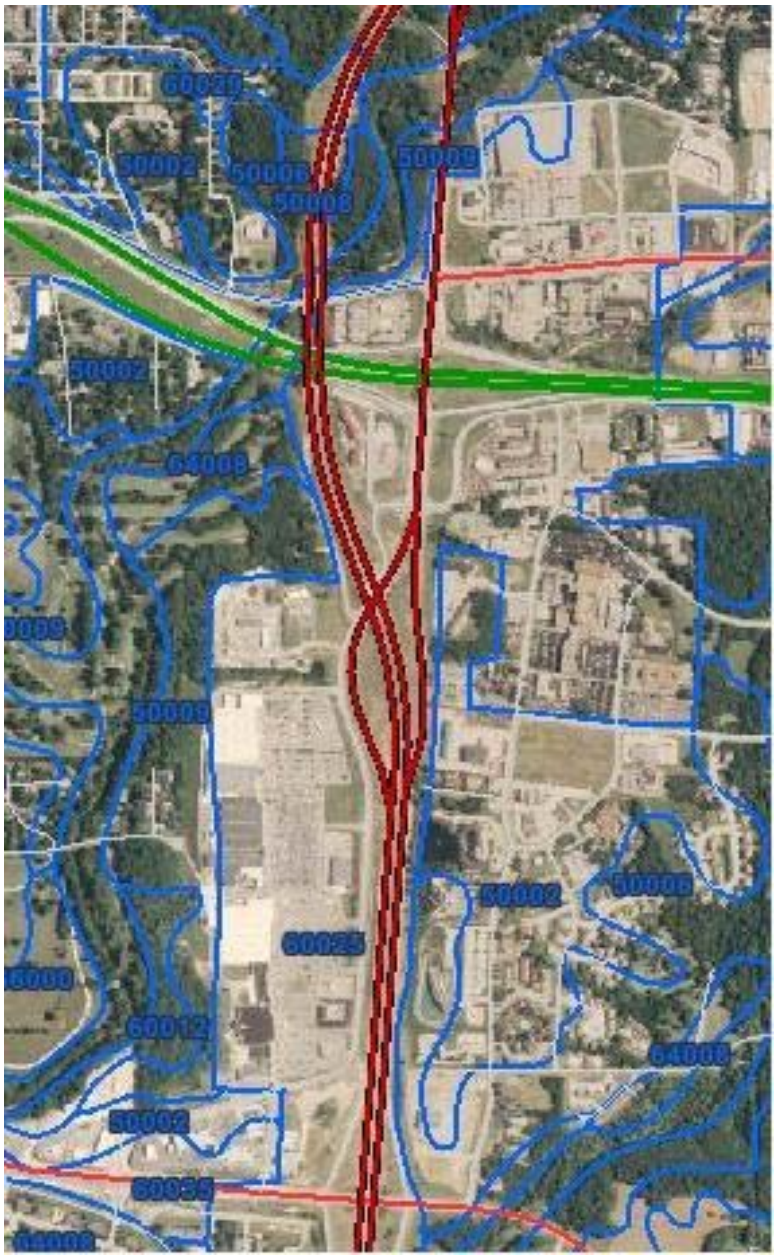
The efficacy of infiltration BMPs, such as infiltration basins and infiltration trenches, varies greatly with the rate at which the surrounding soil can accept the excess stormwater. Because infiltration BMPs are meant to treat stormwater through infiltration into the surrounding soil, guidelines have been established that set minimum values for the infiltration rate of the soil within which the BMP is constructed. These minimum infiltration rate values were set in an effort to ensure that ponding within an infiltration BMP does not reach a duration which might cause loss of vegetation or a habitat for mosquito breeding. Infiltration rate guidelines have also been set to promote the infiltration of excess stormwater within a reasonable time frame to ensure that the BMP is capable of receiving stormwater from subsequent rainfall events. The City of Columbia Stormwater Management and Water Quality Manual states that the minimum infiltration rate for soils surrounding an infiltration trench is 0.5 inches per hour. It also states that the minimum infiltration rate for soils surrounding an infiltration basin is 0.33 inches per hour, based on a maximum ponding depth of 24 inches and a maximum ponded duration of 72 hours. Because of these minimum infiltration rate guidelines, the opportunity to place infiltration BMPs has been significantly reduced within the City of Columbia (based on prior design projects completed by A Civil Group). Some of the soils within the area of interest do exhibit infiltration rates greater than the 0.5 inch per hour minimum, however, to construct the basin or trench, the upper soil horizons must often be removed, either exposing the lower horizon or substantially decreasing the distance to the lower horizon which often has a much lower hydraulic conductivity.

Utilizing data taken from the Boone County Soil Survey (http://soildatamart.nrcs.usda.gov/Manuscripts/MO019/0/boone_MO.pdf) in conjunction with soil mapping offered through the CARES website (http://www.cares.missouri.edu/) the predominant soils within the area of interest were determined and their corresponding saturated hydraulic conductivities were noted.

The area of interest is comprised of six soils from four different soil series. The soil series include the Keswick Series, Vanmeter Series, Bardley Series, and the Harvester

Series. The soil classification map (follows) shows outlines of the soil types and their corresponding classification number in and around the area of interest.

Soil Map within the Area of Interest: SSURGO Soil Outlines (2008 Update), USDA – NRCS, June 9, 2008, http://cares.missouri.edu/



The following data, taken from the Boone County Soil Survey, lists the soils present within the area of interest, their typical slopes, parent material and saturated hydraulic conductivity.

50002 – Keswick-Urban Land Complex

Typical Slope: 5% - 9%

Parent Material: Loess over clayey till

Saturated Hydraulic Conductivity:

0” – 7” Depth: 0.5”/hr – 2.0”/hr

7” – 20” Depth: 0.06”/hr – 0.2” / hr

50006 – Vanmeter Clay Loam

Typical Slope: 5% - 14%

Parent Material: Residuum derived from clayey shale

Saturated Hydraulic Conductivity:

0” – 5” Depth: 0.2”/hr – 0.6”/hr

5” – 12” Depth: 0.2”/hr – 0.6” / hr

12” – 23” Depth: 0.001”/hr – 0.06”/hr

50008 – Keswick Silt Loam

Typical Slope: 5% - 9%

Parent Material: Loess over clayey till

Saturated Hydraulic Conductivity:

0” – 7” Depth: 0.5”/hr – 2.0”/hr

7” – 20” Depth: 0.06”/hr – 0.2” / hr

50009 – Keswick Silt Loam

Typical Slope: 9% - 14%

Parent Material: Loess over clayey till

Saturated Hydraulic Conductivity:

0” – 4” Depth: 0.5”/hr – 2.0”/hr

4” – 53” Depth: 0.06”/hr – 0.2” / hr

60012 – Bardley-Clinkenbeard Complex

Typical Slope: 20% - 45%

Parent Material: Colluvium over clayey residuum derived from cherty limestone

Saturated Hydraulic Conductivity:

0” – 3” Depth: 0.5”/hr – 2.0”/hr

3” – 9” Depth: 0.5”/hr – 2.0” / hr

9” – 36” Depth: 0.5”/hr – 2.0”/hr

60025 – Urban Land-Harvester Complex

Typical Slope: 2% - 9%

Parent Material: Fine silty loess

Saturated Hydraulic Conductivity:

0” – 6” Depth: 0.2”/hr – 0.6”/hr

6” – 30” Depth: 0.2”/hr – 0.6” / hr

Regional Approach vs. Small Area BMPs & the Benefits of Regional Treatment:

With the exception of steep terrain, poorly drained or low lying areas, MODOT right-of-way, and small pockets of green space, the vast majority of the area of interest is fully developed. Throughout the development of this area, storm water was dealt with on a site-by-site basis along with the stormwater infrastructure established by MODOT. As such; the existing storm water infrastructure rapidly combines flows from contributing areas into concentrated flow paths at a considerable distance from Hinkson Creek, relative to the extent of the area of interest.

Because of the development density, the abundance of impervious area, and the existing stormwater infrastructure, the area of interest has few locations suitable for placement of small area BMPs capable of effectively detaining and treating their impervious contributing areas while surviving the heavier rainfall events. Because the existing infrastructure concentrates the flows high in the area of interest watershed, the only applicability for small area BMPs is at the very top of said watershed or offline from the

concentrated flows, leaving the remainder of the watershed more applicable to regional treatment options. Regional treatment options such as dry extended detention basins and wet extended detention basins have been shown to remove an average of 61% and 80%, respectively, of total suspended solids. (EPA-841-B-05-004)

Small area BMPs such as rain gardens, infiltration basins, filter strips, and bio-retention basins have been shown very effective at increasing water quality and ground water recharge, however, they require placement in close proximity to their contributing area and often require sheet flow and a pre-filtering BMP. (See City of Columbia, Missouri Stormwater Management and Water Quality Manual, EPA-821-R-99-012)

Effectiveness of management practices for runoff control (adapted from Caraco and Winer, 2000).

Runoff Treatment or Control Practice Category or Type	Median Pollutant Removal (Percent)							
	No. of studies	TSS	TP	OP	TN	NOx	Cu	Zn
Quality Control Pond	3	3	19	N/A	5	9	10	5
Dry Extended Detention Pond	6	61	20	N/A	31	-2	29	29
Dry Ponds	9	47	19	N/A	25	3.5	26	26
Wet Extended Detention Pond	14	80	55	69	35	63	44	69
Multiple-Pond System	1	91	76	N/A	N/A	87	N/A	N/A
Wet Pond	28	79	49	39	32	36	58	65
Wet Ponds	43	80	51	65	33	43	57	66
Shallow Marsh	20	83	43	66	26	73	33	42
Extended Detention Wetland	4	69	39	59	56	35	N/A	-74
Pond/Wetland System	10	71	56	37	19	40	58	56
Submerged Gravel Wetland	2	83	64	14	19	81	21	55
Wetlands	36	76	49	48	30	67	40	44
Organic Filter	7	88	61	30	41	-15	66	89
Perimeter Sand Filter	3	79	41	68	47	-53	25	69
Surface Sand Filter	7	87	59	N/A	31.5	-13	49	80
Vertical Sand Filter	2	58	45	21	15	-87	32	56
Bioretention	1	N/A	65	N/A	49	16	97	95
Filtering Practices[a]	18	86	59	*57*	38	-14	49	88
Infiltration Trench	3	100	42	100	42	82	N/A	N/A
Porous Pavement	3	95	65	10	83	N/A	N/A	99
Ditches[b]	9	31	-16	N/A	-9	24	14	0
Grass Channel	3	68	29	32	N/A	-25	42	45
Dry Swale	4	93	83	70	92	90	70	86
Wet Swale	2	74	28	-31	40	31	11	33
Open Channel Practices	9	81	34	*1.0*	*84*	31	51	71
Oil-Grit Separator	1	-8	-41	40	N/A	47	-11	17

Shaded rows show data for groups of practices (i.e., dry ponds include quality control ponds and dry extended detention ponds).
Numbers in italics are based on fewer than five data points.
[a] Excludes vertical sand filters
[b] Refers to open channel practices not designed for water quality.
TSS=total suspended solids, TP=total phosphorus, OP=ortho-phosphorus, TN=total nitrogen, NOx=nitrate and nitrite nitrogen, Cu=copper, Zn=zinc.

Due to their limited capacity, small area BMPs are suitable for small contributing areas only, and they offer little to no benefit during significant rainfall events. Were it possible to place BMPs such as these at every development within the area of interest, the use of regional facilities might not be necessary, however; because not all sites can be retrofitted with these BMPs, a regional treatment approach offers water quality treatment and more significant detention to a much greater percentage of the area of interest, than would the placement of small area BMPs at the top of the watershed.

Property Owner Cooperation and BMP Maintenance:

The use of small area BMPs to attain similar water quality and detention levels of service that can be provided by the larger regional facilities would require the placement of small area BMPs at the majority of the 155 (approximate) developed sites. For this to occur, the majority of the owners of those sites must cooperate with the County in these efforts. Were cooperation of the majority of the owners to occur, and the small area BMPs were to be constructed, there would then be a large number of small area BMPs subject to the voluntary inspection and maintenance by the owners. The placement of larger regional facilities on much fewer sites would still require inspection and maintenance, however; because there are substantially fewer sites, any oversight or even periodic inspection by the applicable governing authority or a third party would be more feasible. In addition, the proper functioning of the larger regional facilities (wet ponds, dry ponds, etc) is more visually apparent than that of the small area BMPs, and if properly established; the larger facilities require less frequent maintenance (excluding mowing). The larger regional facilities are also less susceptible to the negative impact of sediment and small debris (common roadside trash) than are the small area BMPs.

BMP Proximity to Hinkson Creek:

With the underlying goal of this study being to determine what locations and their corresponding BMPs will have the maximum positive impact on the health of Hinkson Creek, it should be considered that treated stormwater can once again become polluted en route to Hinkson Creek. Placement of detention and water quality BMPs at the point of

concentrated flow outfalls to Hinkson Creek is the only way to ensure that all of the stormwater from that concentrated flow's contributing area is treated and detained.

Stormwater Conveyance Stabilization and Revegetation:

Within the area of interest the stormwater is conveyed towards Hinkson Creek through a combination of culverts, flumes, reinforced channels, and earthen channels. Throughout a field investigation conducted by A Civil Group, it was noted that substantial lengths of earthen channel, which comprise the majority of the conveyance length, are highly eroded and completely devoid of any vegetation. While the flumes and culverts do not offer any detention, infiltration, or opportunity for settlement of particulates, they do not worsen the quality of the storm water. The highly eroded channels, however; do little to slow the storm water as well as contributing additional sediment through continued scouring of the already worn thalweg and channel side slopes. Because these channels are so highly eroded and because they convey the majority of the stormwater from within the area of interest, they currently serve as a potential detriment to the quality of the stormwater, however; they have the opportunity to serve as a BMP. Within the area of interest, the restabilization of 8,920 linear feet of highly eroded channel has been proposed.

Native grass swales are inexpensive to construct and maintain in comparison with other stormwater BMPs. The native grass swales improve water quality through infiltration, sedimentation and biological uptake, reduce the total volume of water at the outfall, offer detention by slowing the flow velocity, and offer an aesthetic benefit. (EPA-841-B-05-004) The use of turf reinforcement mats beneath the channels offers protection against the heavier rainfall events and the channels could be outfitted with intermittent check dams to further promote detention, infiltration, and sediment deposition.

Selected BMP Information

Extended Wet Detention: Extended wet detention basins (EWDBs) are designed to collect stormwater runoff in a permanent pool and a temporary water quality pool during storm events (Urban Drainage and Flood Control District, 2005). The primary removal mechanism is settling as stormwater runoff resides in this pool, but pollutant uptake, particularly of nutrients, also occurs to some degree through biological and chemical activity in the pond (California Stormwater Quality Association, 2003). In addition, a temporary detention volume is provided above this permanent pool to capture the water quality volume and enhance sedimentation (Urban Drainage and Flood Control District, 2005).

EWDBs are similar to extended dry detention basins (EDDBs) because they are designed to capture runoff from frequently occurring storms. However, EWDBs differ from EDDBs because the influent water mixes with the permanent pool water as it rises above the permanent pool level. The surcharge captured volume above the permanent pool is then released over 40 hours (Urban Drainage and Flood Control District, 2005). EWDBs are also similar in function to constructed wetlands, and differ primarily in having a greater average depth (California Stormwater Quality Association, 2003)

EWDBs can be very effective in removing pollutants, and, under the proper conditions, can satisfy multiple objectives, including water quality improvement, flooding and erosion protection, creation of wildlife and aquatic habitats, and recreational and aesthetic provision (Urban Drainage and Flood Control District, 2005) EWDBs can be used to improve stormwater runoff quality and reduce peak stormwater runoff rates and peak stages. An EWDB can be used to improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites, and is generally used to treat larger tributary areas than other best management practices or as follow-up treatment downstream of other BMPs. It can be used as an onsite BMP if the tributary area is sufficient to sustain a permanent pool. An EWDB works well in

conjunction with other BMPs, such as upstream onsite source controls and downstream filter basins or wetland channels (Urban Drainage and Flood Control District, 2005).

Extended Wet Detention Basin Advantages:

- Because of the presence of the permanent wet pool, properly designed and maintained EWDBs can provide significant water quality improvement across a relatively broad spectrum of target constituents, including dissolved nutrients and many urban pollutants (California Stormwater Quality Association, 2003) (Urban Drainage and Flood Control District, 2005).
- Widespread application of EWDBs with sufficient capture volume and a 40-hour water quality pool drawdown can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed (California Stormwater Quality Association, 2003).
- If properly designed, constructed, and maintained, EWDBs can provide substantial aesthetic / recreational value and wildlife and wetlands habitat (California Stormwater Quality Association, 2003).
- EWDBs can easily be designed to incorporate flood control volumes.
- EWDBs can be used for larger tributary areas.

Extended Wet Detention Basin Disadvantages:

- The public can sometimes view EWDBs as a safety concern (California Stormwater Quality Association, 2003).
- Maintenance and sediment removal can be more difficult for EWDBs than it is for EDDBs because of the presence of the permanent pool. Possible additional maintenance concerns with an EWDB include floating litter, scum and algal blooms, nuisance odors, and aquatic plants blocking outlet works (Urban Drainage and Flood Control District, 2005).
- EWDBs require a permanent pool to function properly (California Stormwater Quality Association, 2003). These facilities may not be feasible in some location because of insufficient tributary area to maintain the permanent pool.

- If not properly designed and maintained, the permanent pool may attract large numbers of geese, which can add to the nutrient and fecal coliform loads entering and leaving the facility (Urban Drainage and Flood Control District, 2005).
- In general, EWDBs can be more expensive and take more land than other BMPs (Besides EDDBs).

Extended Dry Detention: Extended dry detention basins (EDDBs) are designed to detain the stormwater water quality volume for 40 hours to allow particles and associated pollutants to settle (Urban Drainage and Flood Control District, Denver, Colorado, 2005). Unlike extended wet detention basins, these facilities do not maintain a permanent pool between storm events (California Stormwater Quality Association, 2003). However, EDDBs may develop wetland vegetation and sometimes shallow pools in the bottom portions of the facilities that can enhance the basin's soluble pollutant removal efficiency through maintenance removal and biological uptake (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

EDDBs can be used to improve stormwater runoff quality and reduce peak stormwater runoff rates and peak stages. If these basins are constructed early in the development cycle, they can also be used to trap sediment from construction activities within the tributary drainage area. The accumulated sediment, however, will need to be removed after upstream land disturbances cease and before the basin is placed into final long-term use.

EDDBs can be used to improve the quality of urban runoff coming from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites, and are generally used for site or regional treatment (Urban Drainage and Flood Control District, Denver, Colorado, 2005). They can be used as an onsite BMP that works well with other BMPs, such as upstream onsite source controls and downstream infiltration/filtration basins or wetland channels. If desired, additional volume can be provided in an EDDB for flood control benefits (Urban Drainage and Flood Control District, Denver, Colorado, 2005).

Extended Dry Detention Basin Advantages:

- Because of the design, extended detention basins are relatively easy and inexpensive to construct and operate (California Stormwater Quality Association, 2003).
- EDDBs can provide substantial capture of sediment and the pollutants adsorbed onto the surfaces of the particles (California Stormwater Quality Association, 2003).
- Widespread application of EDDBs with sufficient capture volume can provide significant control of channel erosion and enlargement caused by changes to flow frequency relationships resulting from the increase of impervious cover in a watershed (California Stormwater Quality Association, 2003).
- EDDBs can be designed to provide other benefits, such as recreation and open space opportunities, in addition to reducing peak runoff rates and improving water quality (Urban Drainage and Flood Control District, Denver, Colorado, 2005) (Metropolitan Nashville – Davidson County, 2000).

Extended Dry Detention Basin Disadvantages:

- EDDBs have only moderate pollutant removal when compared to some other structural stormwater practices, and they are relatively ineffective at removing soluble pollutants (California Stormwater Quality Association, 2003).
- Dry ponds can potentially detract from the value of a home because of the adverse aesthetics of dry, bare areas and inlet and outlet structures; however, wet ponds can increase property values (California Stormwater Quality Association, 2003)

Native Vegetation Swale: (Information taken from the City of Columbia Stormwater Management and Water Quality Manual) Native grass swales are broad, shallow, natural or constructed channels with a dense native grass stand covering the side slopes and channel bottom. They slowly convey stormwater runoff and, in the process promote infiltration, reduce flow velocities, and pretreat stormwater. Native grass swales can have either parabolic or trapezoidal cross sections and are intended to be used as a

substitute for traditional pipe systems to convey roadway, parking lot and other site drainage.

Native grass swales can serve as part of a stormwater drainage system and can replace curb and gutter storm sewer systems. Native grass swales promote infiltration and also help settle many particulate contaminants by slowing flow velocities. Native grass swales are intended to treat an area of approximately five acres or less to maintain their effectiveness. Larger drainage areas produce too much water for the swale to be effective. (City of Columbia Stormwater Management and Water Quality Manual)

Native Vegetation Swale Advantages:

- Constructed less expensively and maintained more easily than underground pipe stormwater conveyance systems.
- Improve water quality by infiltration, sedimentation and biological uptake.
- Reduce total volume of runoff to surrounding streams and rivers.
- Minimize erosion by slowing the conveyance of stormwater.

Native Vegetation Swale Disadvantages:

- May require irrigation to establish proper vegetative cover for controlling erosion and reducing pollution in the channel.
- May require the use of erosion control or turf reinforcement mats on slopes prior to full establishment of vegetation.
- May not be feasible to implement after development has occurred.
- Area requirements can be excessive for highly developed sites.
- Require relatively large areas, proper sloping, and connection with other conveyance components.
- The reduced velocity of stormwater conveyance through a native vegetation swale may increase the risk of flooding.

Bioswale: (Information taken from the City of Columbia Stormwater Management and Water Quality Manual) Bioswales are broad, shallow, natural, or constructed channels with a dense stand of vegetation covering the side slopes and channel bottom. They slowly convey stormwater runoff, and in the process promote infiltration, reduce flow velocities, and pretreat stormwater. Bioswales can have either parabolic or trapezoidal cross-sections. Bioswales include an engineered soil matrix and an under-drain system.

Bioswale Advantages:

- Constructed less expensively and maintained more easily than underground pipe stormwater conveyance systems.
- Underdrain system allows swale to remain dry most of the time.
- Bioswales improve water quality primarily by filtration through an engineered media. Pollutants are also removed through biological uptake.
- Bioswales can reduce the total volume of excess urban runoff to surrounding streams and rivers.
- Bioswales minimize stream erosion by slowing the conveyance of water.
- Bioswales enhance biological diversity and create beneficial habitat between upland and surface waters.

Bioswale Disadvantages:

- Bioswales may not be feasible to implement after development has occurred.
- Area requirements can be excessive for high-density development sites.
- The reduced velocity of stormwater conveyance through a bioswale may increase the risk of flooding.

Turf Swales: (Information taken from the City of Columbia Stormwater Management and Water Quality Manual) Turf grass swales are broad, shallow, natural, or constructed channels with a dense stand turf grass covering the side slopes and channel bottom. They slowly convey stormwater runoff, and in the process promote infiltration, reduce flow velocities, and pretreat stormwater. Turf grass swales are intended to be used as a substitute for traditional pipe systems to treat and convey roadway drainage.

Turf Swale Advantages:

- Constructed less expensively and maintained more easily than underground pipes.
- Improve water quality by infiltration, sedimentation and biological uptake.
- Reduce total volume of runoff to surrounding streams and rivers.
- Minimize erosion by slowing the conveyance of water

Turf Swale Disadvantages:

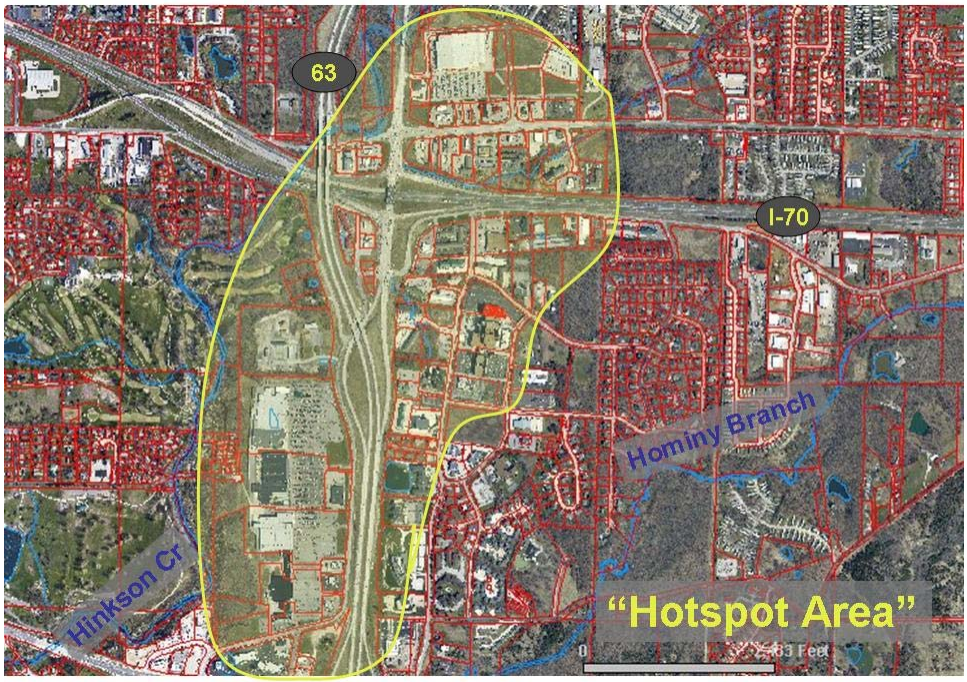
- May require irrigation to maintain proper vegetative cover for controlling erosion and reducing pollution in the channel.
- May not be feasible to implement after development as occurred.
- Require relatively large areas, proper sloping, and connection with other conveyance components.
- The reduced velocity of stormwater conveyance through a bioswale may increase the risk of flooding.

SITE SPECIFIC INFORMATION:

Area of Interest: The area of interest was chosen by the Missouri Department of Natural Resources as part of the Watershed Management Plan. The Watershed Management Plan was created through a grant for Hinkson Creek Watershed Restoration Project, funded by the Environmental Protection Agency.

Location: The area of interest (hotspot area) is comprised of the residential and commercial lots located in the general area of the I-70 and US Hwy-63 intersection. This area was chosen because it is adjacent to the beginning of the impaired section of Hinkson Creek.

Description: The area is fully developed and includes residential and commercial uses. The commercial uses include, but are not limited to: hotels, office, restaurants, convenience stores, medical buildings, big box retail, strip-mall retail, all associated paved parking area, and street, highway, and interstate pavement and infrastructure.



Composite Curve Number: The composite curve number for the 354.53-acre area was calculated to be 92.52 with 79.89 % impervious cover.

Water Quality Volume: The water quality volume for the entire area is 1,355,842 cubic feet.

1-year, 2-year, 10-year, 100-year Flow Rates: 1150 cfs, 1380 cfs, 2155 cfs, 3100 cfs.

Site #1

Location: BMP site #1 is located on MODOT right-of-way, southeast of I-70 Drive SE, northeast of and adjacent to the TGI Friday's restaurant.

Description: This BMP site consists of a fairly flat, open, turf-grass area. The proposed BMP would reside between the outfall of a stormwater culvert from the southeast and the invert of a stormwater culvert to the west. The BMP site is bordered by electrical utilities on the east side and a sanitary sewer line on the south. Site #1 discharges to sites #6 and #10.

Property Owner: Missouri Department of Transportation

Contributing Area Details: The site specific contributing area to site #1 is 11.0 acres and contains seven buildings with uses including hotel, office and restaurant. The site also receives stormwater runoff from the I-70 eastbound onramp, and I-70 Drive SE.

Total Area Treated by Site: 11.0 acres (3.1 % of total hotspot area)

Composite Curve Number: 94 (85 % impervious cover)

Water Quality Volume: 44,566 cubic feet (3.29 % of hotspot area total)

1-year, 2-year, 10-year, 100-year Flow Rates: 36 cfs, 44 cfs, 68 cfs, 98 cfs

Flow Distance / Conveyance Network to Hinkson Creek: 1,640 linear feet of earthen channel, reinforced channel, and culverts.

Area Available and Proposed BMP: Approximately 7,000 square feet with 3 feet of elevation drop across the site. The proposed BMP for this site is a vegetated extended wet detention basin. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a minor loss in water quality benefits.

Constructability: Access to site one is easily attained from either I-70 Drive SE or from the business lots immediately to the east. Site one has ample room for delivery and staging of construction equipment. This site should only require minimal traffic control during construction. I-70 Drive SE is a MODOT road, as such, work on site one will require a MODOT right-of-way permit. MODOT could potentially require the installation of a guardrail at this site as well.

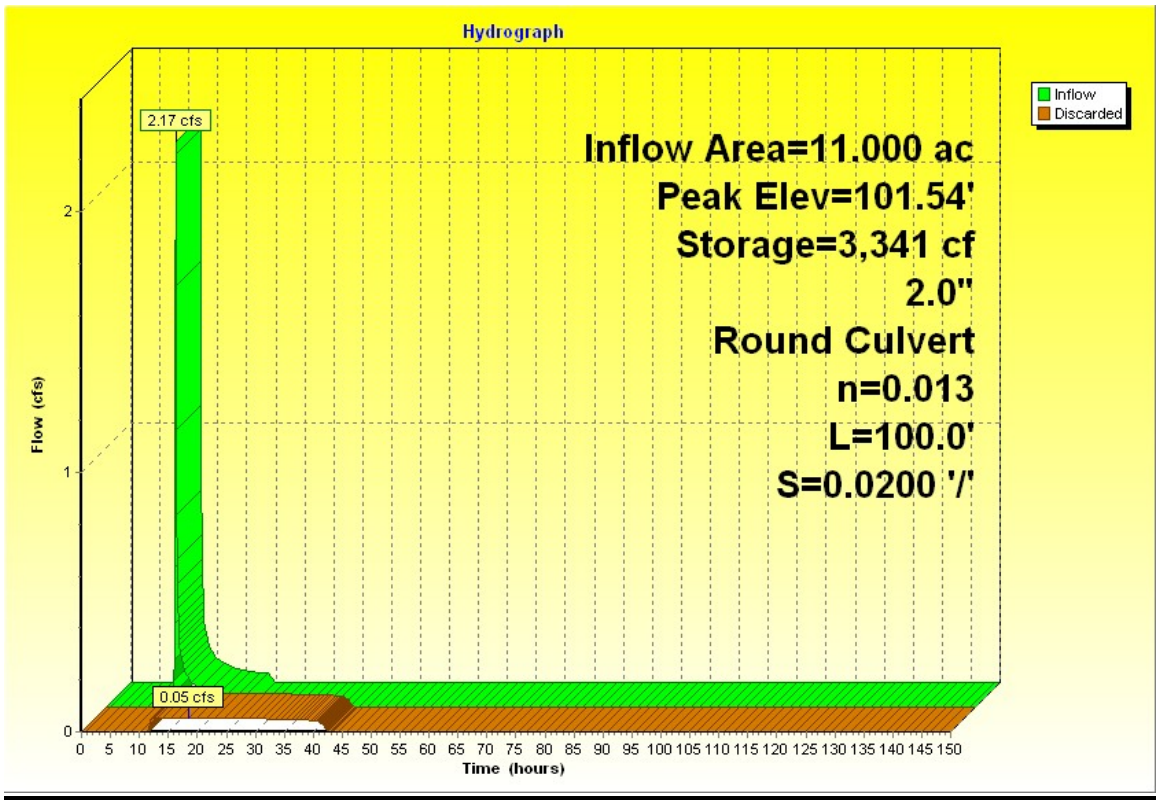
BMP Benefits: Detention, infiltration, pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 99.2 % reduction in the 1" 24-hour storm peak flow rate and a 97.7% reduction in the ½" 24-hour storm peak flow rate (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 1.41%

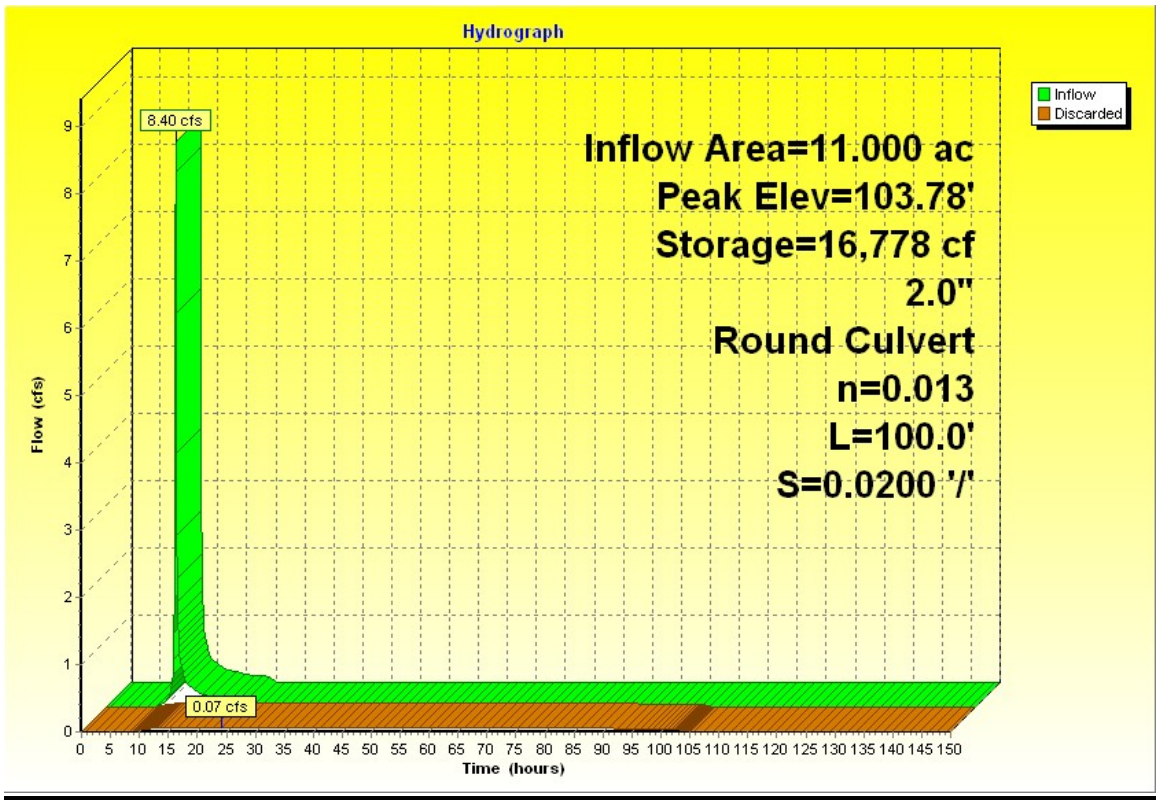
BMP Construction Cost: Estimated construction cost is $ 15,437

15-year Maintenance Cost: Estimated 15-year maintenance cost is $9,473

Site #1 Detention Hydrograph – ½” 24-Hour Storm Event



Site #1 Detention Hydrograph – 1” 24-Hour Storm Event



Site #2

Location: Site #2 is located within the MODOT right-of-way on the east side of the US Hwy-63 north bound offramp, in alignment with the western terminus of Lansing Avenue.

Description: Site #2 consists of an existing earthen channel, approximately 1,830 feet in length. The channel runs north / south parallel to the adjacent offramp and is sharply cut and highly eroded. The channel runs adjacent to an electric utility line. Site #2 discharges to site #10.

Property Owner: Missouri Department of Transportation

Contributing Area Details: The earthen channel in site #2 receives stormwater from approximately 1.0 acre consisting of drainage from US Hwy-63 and the rear yards of adjacent office sites.

Total Area Treated by Site: 1.05 acres (0.3 % of total hotspot area)

Composite Curve Number: 89 (70% impervious area)

Water Quality Volume: 3,544 cubic feet (0.26 % of hotspot area total)

1-year, 2-year, 10-year, 100-year Flow Rates: 3 cfs, 3.7 cfs, 6 cfs, 8.9 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 3,760 linear feet of earthen channel, reinforced channel, and culverts.

Area Available and Proposed BMP: The existing condition of the 1,830 linear feet of earthen channel is a detriment to the quality of the stormwater conveyed through it. The channel should be re-graded to a 6'-wide flat bottom trapezoidal channel, reinforced with turf reinforcement mat, and vegetated with native vegetation. Should native vegetation be undesirable the channel should be regraded, armored with turf reinforcement mat and vegetated with turf grass.

Constructability: Site two is most easily accessed via the shoulder of the US-63 northbound offramp. The shoulder should offer reasonable space for loading and unloading of equipment. Equipment could be stored on the commercial lots to the east. This site will require substantial traffic control due to it's proximity to US-63. Work on site two will require a MODOT right-of-way permit. MODOT could potentially require the installation of a guardrail at this site as well.

BMP Benefits: The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 55.2 %.

BMP Construction Cost: Estimated construction cost is $36,149

15-year Maintenance Cost: Estimated 15-year maintenance cost is $8,134

Site #3

Location: Site #3 is located adjacent to northbound US Hwy-63, immediately adjacent to the Missouri Employer's Mutual property.

Description: Site #3 consists of 1,380 linear feet of earthen channel. The channel runs north / south parallel to Hwy-63. The channel is moderately eroded with very sparse vegetation. Site #3 discharges to site #5.

Property Owner: Missouri Department of Transportation / Missouri Employers Mutual

Contributing Area Details: The earthen channel on site #3 receives stormwater from 17.01 acres. The 17.01 acres contains 7 buildings with office, residential care, and single family detached housing uses. The site also receives the discharge from a large pond located adjacent to the Missouri Employer's Mutual building.

Total Area Treated by Site: 17.01 acres (4.8 % of total hotspot area)

Composite Curve Number: 92 (82% impervious cover)

Water Quality Volume: 66,651 cubic feet (4.92 % of hotspot area total)

1-year, 2-year, 10-year, 100-year Flow Rates: 53.8 cfs, 65 cfs, 102.6 cfs, 148.5 cfs

Flow Distance / Conveyance Network to Hinkson Creek: 3,900 linear feet consisting of earthen channel and culverts.

Area Available and Proposed BMP: The 1,380 linear feet of channel is proposed for restabilization and revegetation. The channel should be graded to a 6'-wide flat bottom trapezoidal channel, reinforced with turf reinforcement mat and vegetated with native vegetation. Should native vegetation be undesirable at this location, turf grass may substitute with losses in water quality benefits.

Constructability: Site three can be accessed from either the shoulder of US-63 or the commercial lots to the east. Site three offers substantial room for equipment and material storage. Should site three be accessed from the shoulder of US-63, traffic control devices

will be necessary. Work on site three will require a MODOT right-of-way permit. MODOT could potentially require the installation of a guardrail at this site as well.

BMP Benefits: The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 42.7 %.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 3.90%

BMP Construction Cost: Estimated construction cost is $34,327.

15-year Maintenance Cost: Estimated maintenance cost is $13,724.

Site #4

Location: Site #4 consists of the vegetated parking lot islands within the Conley Road shopping complex.

Description: Site #4 consists of approximately 3.40 acres of paved parking area and drive aisle with intermittent vegetated parking lot islands.

Property Owner: Broadway Crossings II

Contributing Area Details: Site #4 receives flow generally from the adjacent parking and drive aisle areas as well as portions of the developed lots to the east. The site decreases in elevation from east to west.

Composite Curve Number: 98

Total Area Treated by Site: 3.40

1-year, 2-year, 10-year, 100-year Flow Rates: 12.51 cfs, 14.65 cfs, 21.90 cfs, 30.82 cfs

Flow Distance / Conveyance Network to Hinkson Creek: Approximately 1100 linear feet of surface flow over pavement followed by culverts to the outlet at Hinkson Creek.

Water Quality Volume: 14,842 cubic feet (1.09% of hotspot total)

Area Available and Proposed BMP: The 3.4 acres of site #4 contains several parking lot islands that are currently mulched and vegetated with shrubs and small trees. The vegetated parking lot islands currently serve as a BMP in the sense that they treat and detain or infiltrate the rainfall that lands directly on them, however; because they are curbed islands they do not receive drainage from any additional contributing area. The grading of the parking area as it currently exists conveys the greater concentration of stormwater down the center of the drive aisles, away from the curbed islands. Even with the use of structural soils, the curbs would have to be removed and the majority of the parking lot pavement removed, regraded, and repaved to promote the flow of stormwater to these islands. Because this area is already fully developed and the parking lot and islands constructed, this proposal is considered infeasible due to extreme cost and coordination with property owners.

Constructability: Site four resides completely on private property and is not in close proximity to a high-speed roadway. As such, the entire site is available for equipment loading and unloading as well as equipment and material storage. These operations as well as closure of the parking area would have to be coordinated with the property owner.

BMP Benefits: The rain gardens proposed for this site would offer stormwater retention and infiltration, as well as nutrient uptake by the vegetation within these islands.

BMP Construction Cost: Approx. $463,288

15-year Maintenance Cost: $7,500

Site #5

Location: Site #5 is located north of Trimble Road, west and adjacent to the Conley Road shopping complex. Site #5 resides in very close proximity to Hinkson Creek.

Description: Site #5 consists of several undeveloped lots that have been recently graded to a very minor slope from east to west. The site receives only minor surface flow from the paved areas to the south and east and the site discharges to a swale along its western edge. The swale currently conveys stormwater to a newly constructed detention facility at the north end of the site.

Property Owner: Broadway Crossings II

Contributing Area Details: The area draining to site #5 consists of overland flow from the commercial development to the east and south, as well as the discharge of two large culverts from the same development.

Composite Curve Number: 94

Total Area Treated by Site: 27.48 acres

1-year, 2-year, 10-year, 100-year Flow Rates: 92.55 cfs, 110.43 cfs, 170.58 cfs, 244.0 cfs

Flow Distance / Conveyance Network to Hinkson Creek: 1,520 lf of earthen channel to a detention basin, followed by discharge through an outlet structure to Hinkson Creek.

Water Quality Volume: 111,374 cubic feet (8.21% of hotspot total)

Area Available and Proposed BMP: Site #5 currently consists of a large, fairly flat turf grass field, all of which drains to a newly constructed detention basin via an earthen swale. Any structural stormwater BMP placed in this area is likely to be altered or removed entirely during continued development of this area, and new development of this area should be subject to the City of Columbia Storm Water Ordinance, requiring treatment and detention. Because the earthen swale is located near the rear (west side) of these lots, the proposal to regrade the earthen swale and convert it to a bioswale is likely the only option for construction of a BMP that will not require alteration or removal as the site continues to develop. Should the construction of a bioswale within the channel be undesirable, the channel should still be regraded, reinforced with turf reinforcement mat, vegetated, and intermittent rock checks should be place along its length to decrease flow velocity and promote sedimentation and infiltration.

Constructability: Site five is very easily accessible from either Trimble Road or from the paved area immediately east of site five and west of the adjacent commercial buildings. Site five is not in close proximity to any high-speed roadways and will not require any traffic control during equipment transport or construction. Site five also has ample space for equipment and material storage.

BMP Benefits: The bioswale offers improved water quality primarily through filtration through an engineered media. Pollutants are also removed through biological uptake. The bioswale will also offer a net reduction in stormwater discharged to Hinkson Creek (City of Columbia Stormwater Management and Water Quality Manual). Regrading of the swale and establishment of the bioswale vegetation should offer a 30% reduction in channel velocity.

BMP Construction Cost: Approx. $73,804

15-year Maintenance Cost: $16,606

Site #6

Location: Site #6 is located north and west of I-70 Drive SE, east of the US Hwy-63 connector, and south of the I-70 eastbound onramp.

Description: Site #6 consists of a large turf grassed area with sharply cut and highly eroded channels approaching from the south and from the east. The BMP site is proposed to reside between the outfall of a culvert from the east and the invert of a culvert to the west, as well as the channels to the east and south. The BMP area is bordered by a sanitary sewer line in the south-central area as well as a water line on the southern end. Site #6 receives flow from site #1 and discharges to site #10.

Property Owner: Missouri Department of Transportation

Contributing Area Details: The site and earthen channels receive stormwater from portions of I-70 Drive SE as well as the right-of-way upon which the site resides. This site also receives all of the discharge from site #1. The site specific contributing area for site #6 is 1.41 acres.

Total Area Treated by Site: 15.99 acres (4.51 % of total hotspot area)

Composite Curve Number: 94 (85% impervious)

Water Quality Volume: 64,819 cubic feet (4.78 of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 52.0 cfs, 64.3 cfs, 99.3 cfs, 142.0 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 1,500 linear feet of culvert, earthen channel, and reinforced channel.

Area Available and Proposed BMP: There is approximately 33,000 square feet available for a detention structure capable of receiving stormwater from the earthen channels from the east and south as well as receiving stormwater from the eastern culvert. The area is suitable for placement of an extended wet detention basin at the outfall of the eastern culvert. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits. Along with the detention basin, there is approximately 1,070 linear feet of highly eroded, sharply cut channel on the site that should be regraded to a 6'-wide flat bottom trapezoidal channel, reinforced with turf reinforcement mat, and vegetated with native plants and grasses. Should native vegetation be undesirable, turf grass may substitute with decreases in water quality benefit.

Constructability: Site six will be most easily accessed from the north and west shoulders of I-70 Drive SE. Traffic control will be required during equipment transport, but once on site, no traffic control should be necessary. The site offers substantial room for material and equipment storage within the project area. Work on site six will require a MODOT right-of-way permit. The possibility does exist that MODOT would require the installation of a guardrail at this site.

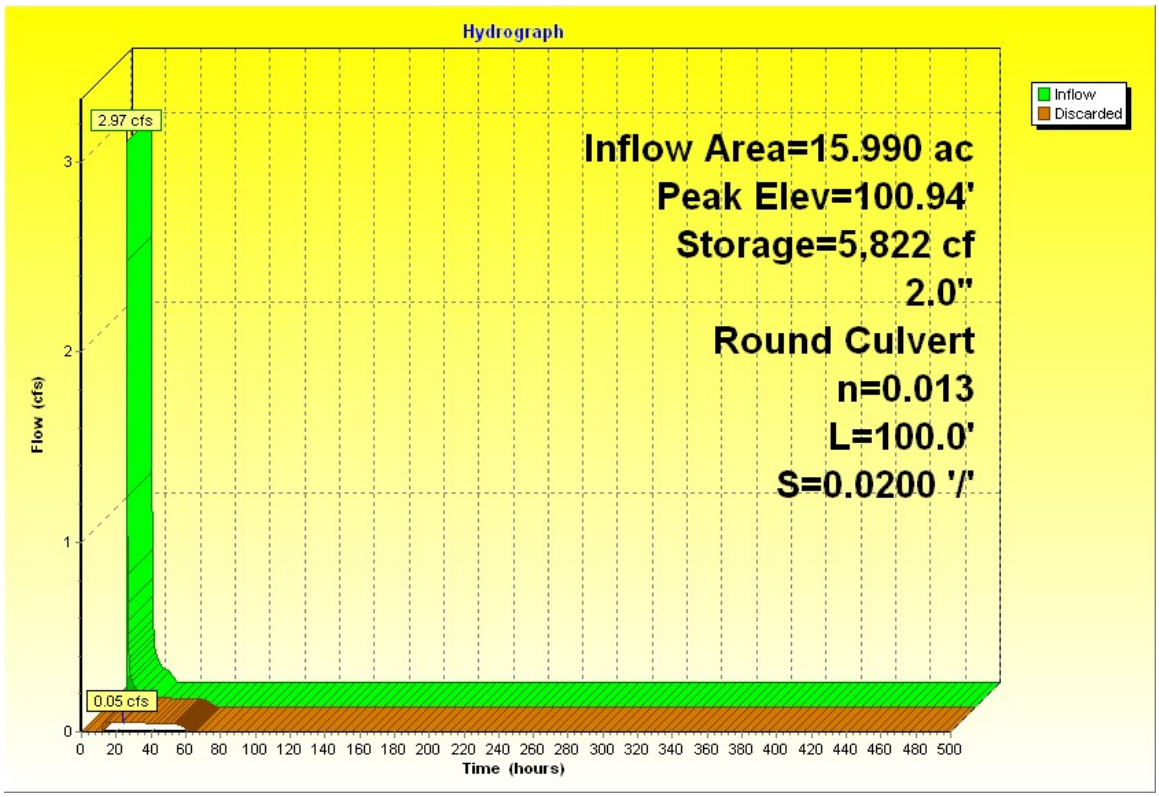
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 99.5 % reduction in the 1" 24-hour storm peak flow rate and a 98.3% reduction in the ½" 24-hour storm peak flow rate (see hydrographs). The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 42.9 %.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 4.09%

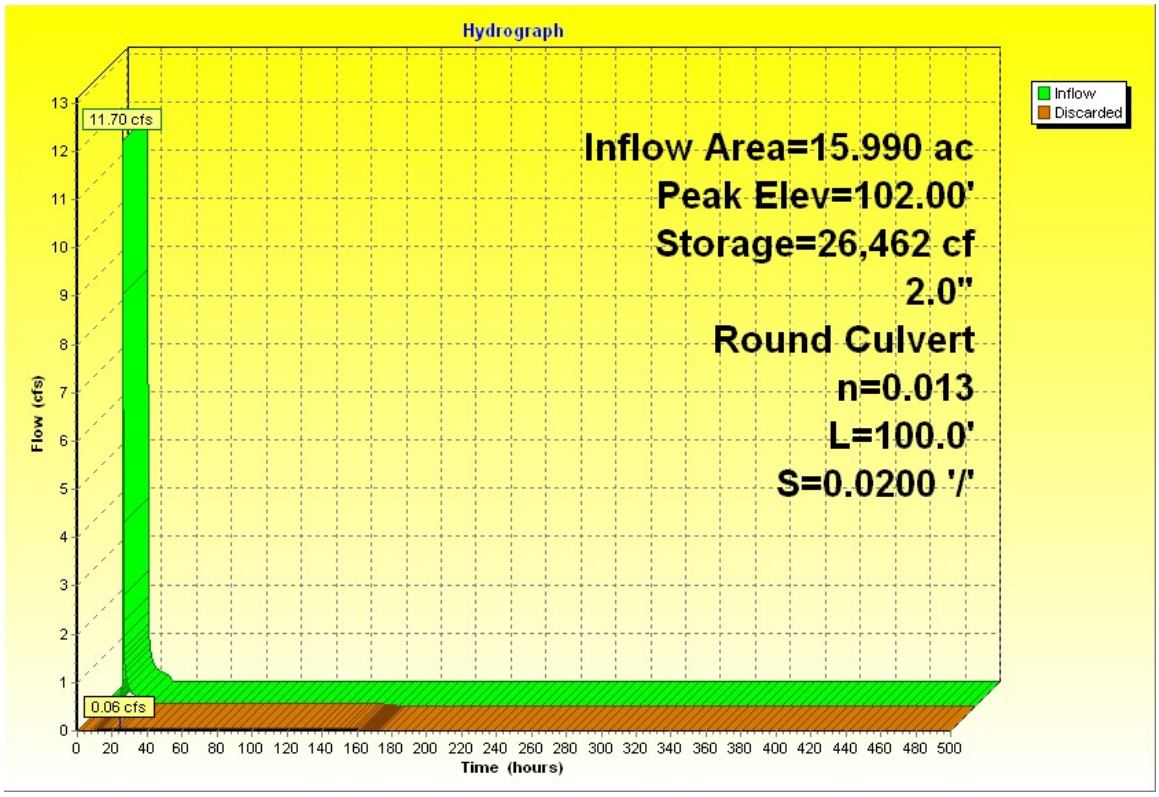
BMP Construction Cost: The estimated construction cost is $82,334

15-year Maintenance Cost: The estimated maintenance cost is $24,525

Site #6 Detention Hydrograph – ½” 24-Hour Storm Event



Site #6 Detention Hydrograph – 1” 24-Hour Storm Event



Site #7

Location: Site #7 is located east of the US Hwy-63 northbound onramp and north-northwest of and adjacent to Home Depot.

Description: The site consists of a large turf-grass open area fairly flat on the east half, then dropping rather quickly towards the northwest corner. The northwest corner contains the outfall of two large culverts and a very broken and semi-vegetated concrete flume. This BMP area is bordered by a sanitary sewer line to the west and a water line to the east. Site #7 does not receive water from or discharge to any other BMP sites.

Property Owner: Home Depot USA, Inc. / Robert J. Tull et al, Trustee

Contributing Area Details: The contributing area to site #7 includes 18 buildings with single family detached residential, big box retail, mixed retail, restaurant, and bank uses. The site specific contributing area for site #7 is 45.70 acres.

Total Area Treated by Site: 45.70 acres (12.89 % of total hotspot area)

Composite Curve Number: 94 (85 % impervious area)

Water Quality Volume: 185,227 cubic feet (13.66 % of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 147.7 cfs, 183.6 cfs, 283.7 cfs, 405.8 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 240 linear feet of earthen channel.

Area Available and Proposed BMP: An extended wet detention basin should be constructed on 25,000 square feet of the BMP site. The basin should intercept the flows from the two large culverts that discharge at the northwest corner of the site and the outfall of the proposed basin should reside just downstream from the location of the current outfall of the existing culverts. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits.

Constructability: Site seven will be most easily accessed from Penn Terrace, immediately south of the project site. Because Penn Terrace receives so little traffic, only minimal traffic control will be necessary, if at all. Site seven offers plenty of space for material and equipment storage and handling.

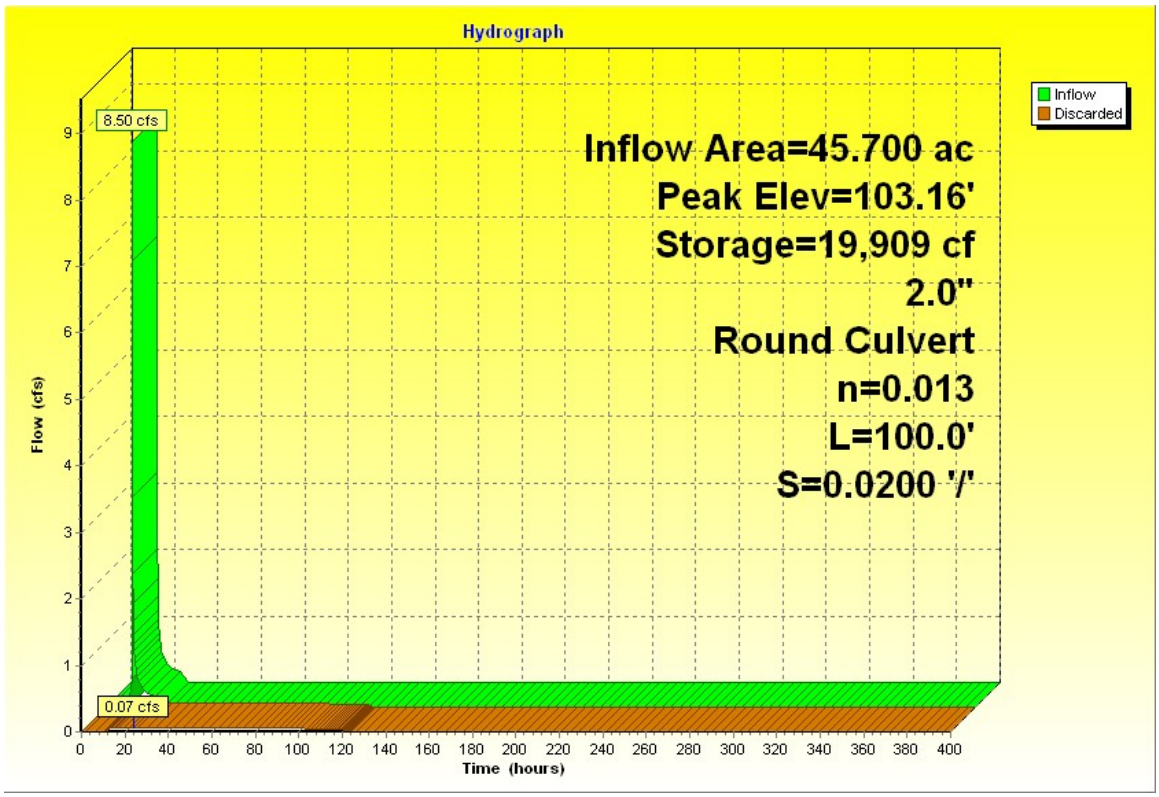
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 99.8 % reduction in the 1" 24-hour storm peak flow rate and a 99.2% reduction in the ½" 24-hour storm peak flow rate (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 10.01%

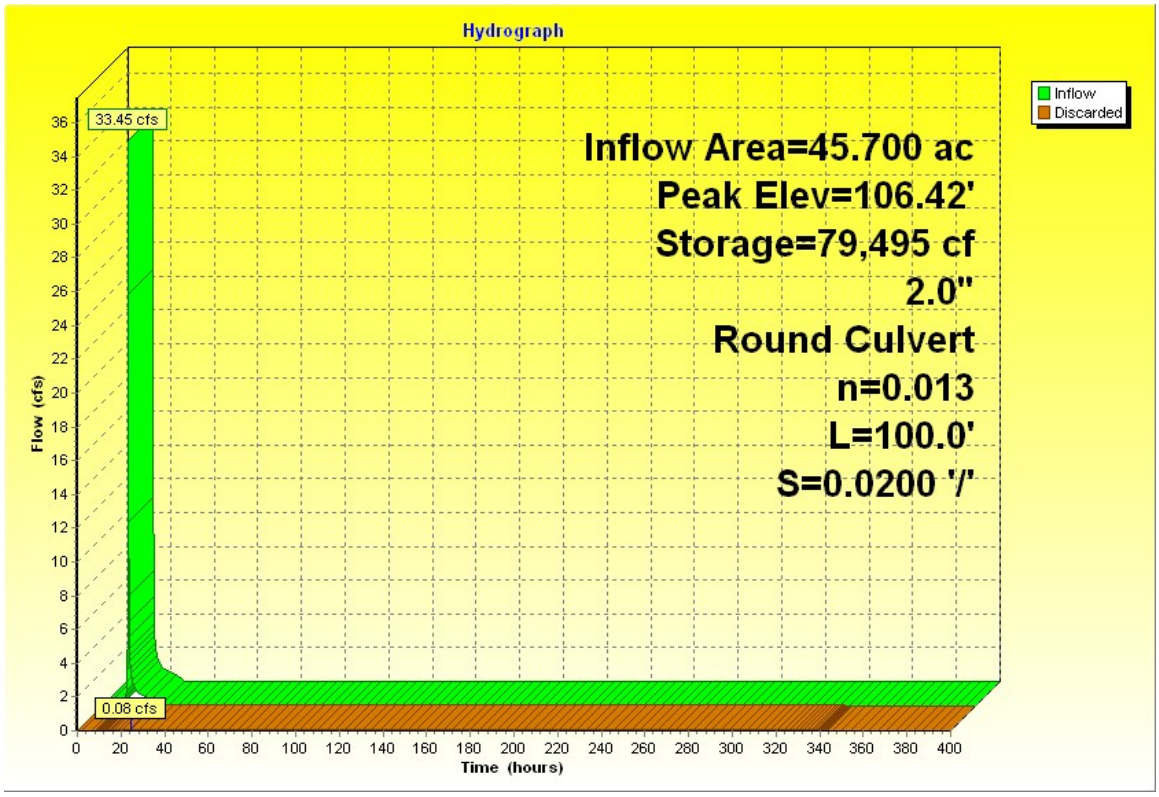
BMP Construction Cost: Estimated construction cost is $73,854.

15-year Maintenance Cost: Estimated maintenance cost is $22,617

Site #7 Detention Hydrograph – ½” 24-Hour Storm Event



Site #7 Detention Hydrograph – 1” 24-Hour Storm Event



Site #8

Location: Site #8 is located east of site #7, between Penn Terrace and the residential neighborhood to the northeast.

Description: Site #8 consists of a low lying turf-grass open area. The site breaks from the south and from the north creating a large swale formation that ultimately drains to the northwest. The site is bordered by sanitary lines, electrical lines, and water lines to the northeast and north west, and is bordered by electric lines to the southwest. Site #8 does not receive water from or discharge to any other BMP sites.

Property Owner: Home Depot USA, Inc. / Tull Group, LLC.

Contributing Area Details: Site #8 receives stormwater from 18 single family detached residences, as well as the open area to the southwest. The site specific contributing area for site #8 is 3.63 acres.

Total Area Treated by Site: 3.63 acres (1.02 % of total hotspot area)

Composite Curve Number: 83 (38 % impervious cover)

Water Quality Volume: 7,081 cubic feet (0.52 % of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 7.62 cfs, 10.21 cfs, 18.17 cfs, 28.17 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 430 linear feet of earthen channel.

Area Available and Proposed BMP: Site #8 is suitable for placement of a 5,000 square foot extended wet detention basin. The basin will drain to the northwest, following existing drainage patterns established within this area.

Constructability: Situated adjacent to site seven, site eight will be most easily accessed from Penn Terrace, immediately south of the project site. Because Penn Terrace receives so little traffic, only minimal traffic control will be necessary, if at all. Site eight offers plenty of space for material and equipment storage and handling.

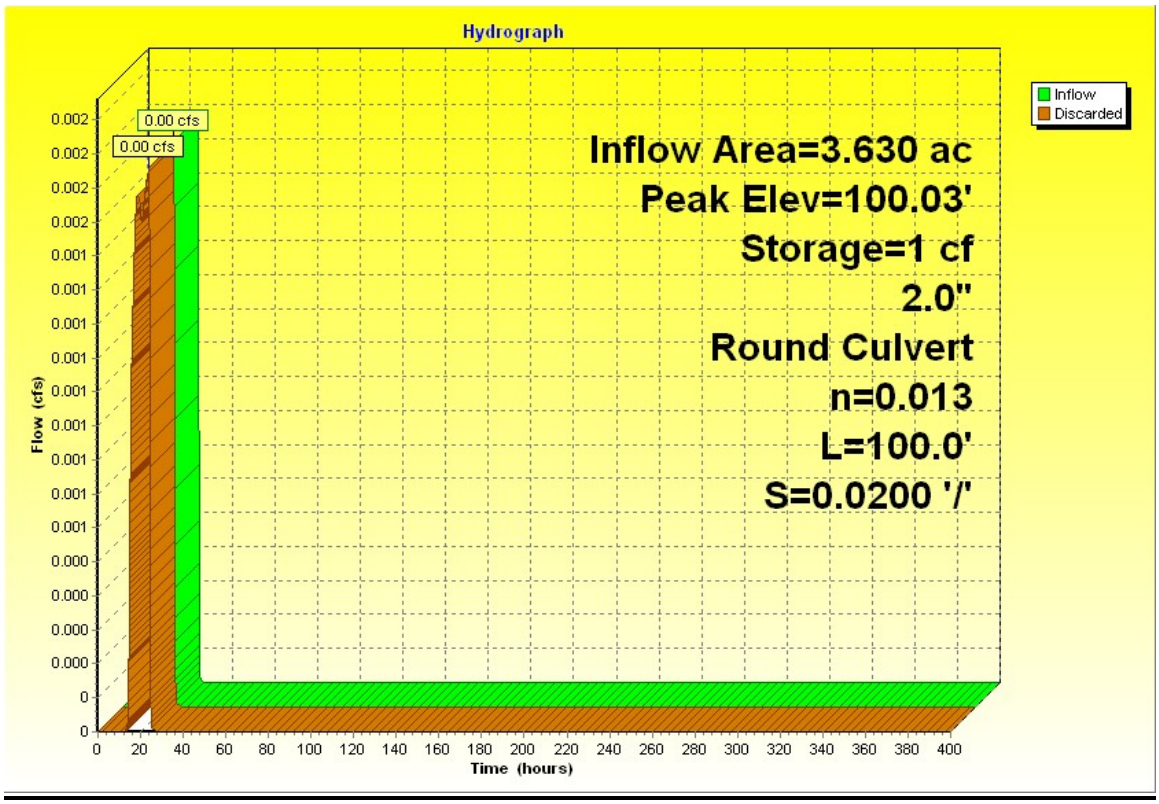
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 90.6 % reduction in the 1" 24-hour storm peak flow rate and due to the low curve number of the contributing area and the fact that the ½" storm modeled occurs over a 24-hour period, less than 0.01 cfs was seen entering the basin from the ½" event (see hydrographs). Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 0.57%

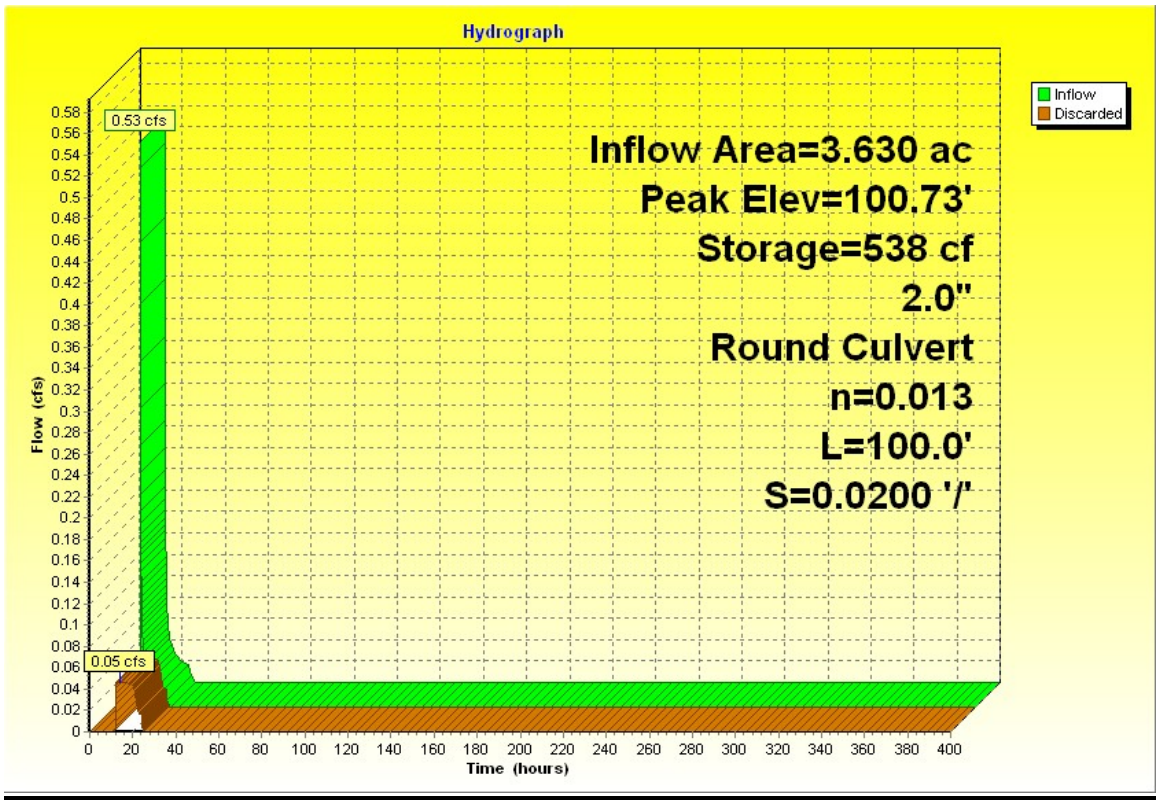
BMP Construction Cost: Estimated construction cost is $11,241

15-year Maintenance Cost: Estimated maintenance cost is $8,529

Site #8 Detention Hydrograph – ½” 24-Hour Storm Event



Site #8 Detention Hydrograph – 1” 24-Hour Storm Event



Site #9

Location: Site #9 is located adjacent to and west of the US Hwy-63 connector and extends from approximately 300 feet south of Clark Lane north to an existing concrete flume, along an existing earthen channel approximately 800 feet in length.

Description: Site #9 consists of the 800 foot length of earthen channel adjacent to the US Hwy-63 connector. The channel is moderately eroded, sparsely vegetated, and outfalls to a concrete flume on the north end, which conveys the stormwater north to Hinkson Creek. Site #9 does not receive water from or discharge to any other BMP sites.

Property Owner: City of Columbia / Missouri Department of Transportation

Contributing Area Details: Site #9 receives stormwater from the adjacent length of the US Hwy-63 connector. The site specific contributing area for site #9 is 1.87 acres.

Total Area Treated by Site: 1.87 acres (0.53 % of total hotspot area)

Composite Curve Number: 85 (50% impervious cover)

Water Quality Volume: 4,638 cubic feet (0.34 % of hotspot total**)**

1-year, 2-year, 10-year, 100-year Flow Rates: 5.5 cfs, 6.7 cfs, 10.9 cfs, 16.0 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 170 linear feet of concrete flume.

Area Available and Proposed BMP: The 800 linear feet of earthen channel is proposed for restabilization and revegetation. The channel is to be graded into a 6'-wide flat bottom trapezoidal channel, lined with turf reinforcement mat and vegetated with native plants. Should native vegetation be undesirable at this location, turf grass may substitute with a loss in water quality benefit.

Constructability: Site nine will be most easily accessed from the east shoulder of the US-63 connector. Material and equipment loading and unloading as well as the construction process will require traffic control due to the immediate proximity of the adjacent high-speed roadway. Work on site nine will require a MODOT right-of-way permit and could require installation of a guardrail along the adjacent section of roadway.

BMP Benefits: The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 51.9 %.

BMP Construction Cost: Estimated construction cost is $15,724.

15-year Maintenance Cost: Estimated maintenance cost is $9,538.

Site #10

Location: Site #10 is located west of and adjacent to the US Hwy-63 connector and south of the I-70 eastbound offramp.

Description: Site #10 consists of approximately 1,000 linear feet of riprap reinforced channel. The channel has substantial depth (12' – 30') and rises sharply to the adjacent roadways on the west and north, as well as to the commercial sites to the west and south. The channel receives substantial amounts of stormwater from the culverts to the south and east. Site #10 receives the second greatest volume of stormwater in comparison with the other 18 examined BMP sites, surpassed only by site #15. Site #10 receives water from sites #1, #2, #6, #11, #12, #17, #18, and #19.

Property Owner: Missouri Department of Transportation

Contributing Area Details: The site specific contributing area for site #10 is 6.97 acres, consisting of 2 buildings with retail and convenience store uses. Site #10 also receives the discharge from sites 1, 2, 6, 11, 12, 17, 18, and 19.

Total Area Treated by Site: 100.53 acres (28.4 % of total hotspot area)

Composite Curve Number: 92 (80% impervious cover)

Water Quality Volume: 384,948 cubic feet (28.39% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 306.7 cfs, 384.1 cfs, 606.6 cfs, 877.9 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 1600 linear feet of reinforced channel.

Area Available and Proposed BMP: Because of the substantial volume of stormwater received by site #10, the channel should remain armored with riprap as it currently exists. The placement of multiple rock checks with very shallow grades on the heel and toe of each check will offer multiple storage volumes for detention. The channel could also be vegetated with woody vegetation, capable of withstanding the heavy flows. Should any portion of the channel downstream of site ten, as it approaches Hinkson Creek, reside in an unarmored and eroded state, that portion of channel should be examined and armoring considered. However; if that portion of unarmored channel appears to be fairly stable then the detention and velocity dissipation offered from the proposed work at site ten will

decrease the likelihood of erosion in the downstream section and should offer the opportunity for increased vegetation establishment within the channel.

Constructability: Site ten will be most easily accessed from the commercial lots to the south and west, as well as the dead-end street that runs north-south and terminates on the south side of the west end of site ten. Although site ten resides many feet below the elevation of the adjacent eastbound I-70 offramp, traffic control will most likely be required because of the volume of traffic utilizing the offramp on a daily basis. Although difficult, tracked equipment should be capable of entering the site and working their way down the steep slopes to the channel thalweg. Should this not be an option, the use of a wheeled excavator, as opposed to tracked, could place material and perform the required grading from the top of the slope. Work within site ten will require a MODOT right-of-way permit. Most of the roadway adjacent to site ten already has a guardrail, however; MODOT could require all adjacent roadways to receive guardrail.

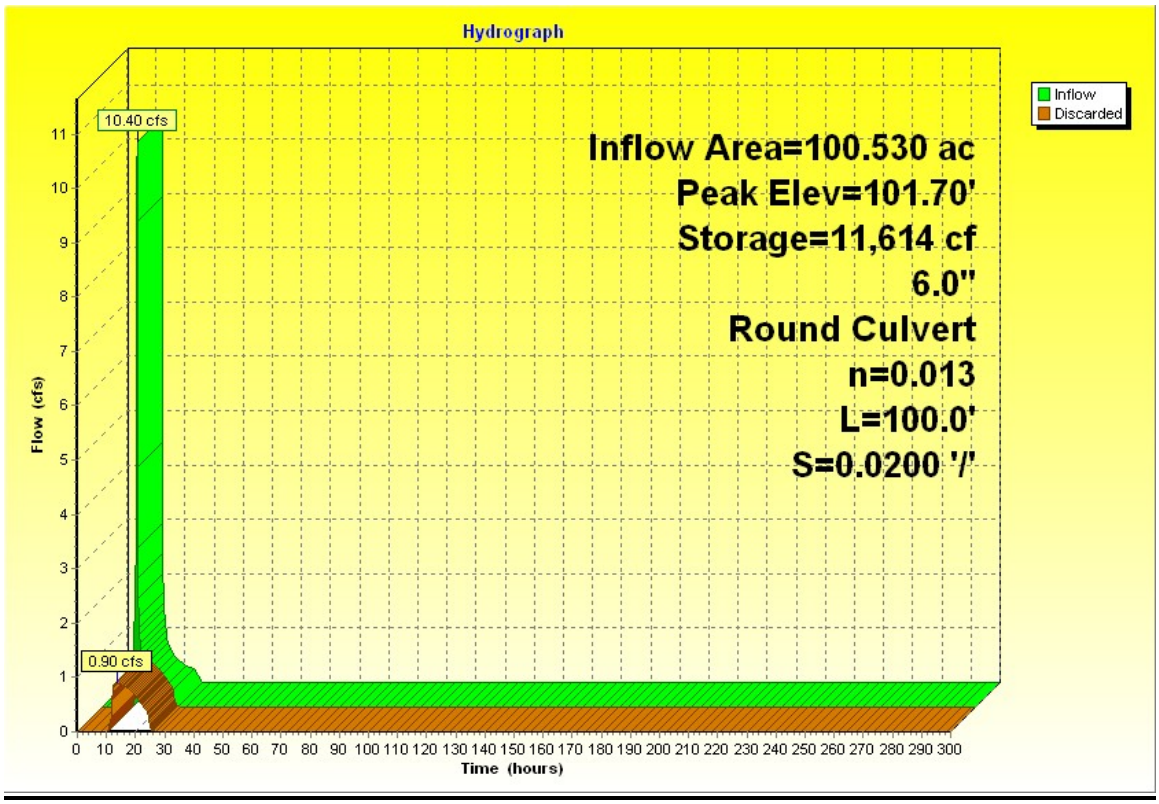
BMP Benefits: The intermittent rock checks will provide detention and promote infiltration as well as slowing the velocity within the channel. The woody vegetation will aid in slowing the velocity as well as pollutant uptake and shading to help minimize the temperature of the stormwater prior to discharge to Hinkson Creek. Detention provided by the intermittent rock checks along with the establishment of woody vegetation will offer a 97.7% reduction in the 1" 24-hour storm peak flow and a reduction of 91.3% of the ½" 24-hour storm peak flow (see hydrograph), as well as a 41% reduction in the peak velocity of the 1-year storm flow.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 9.99%

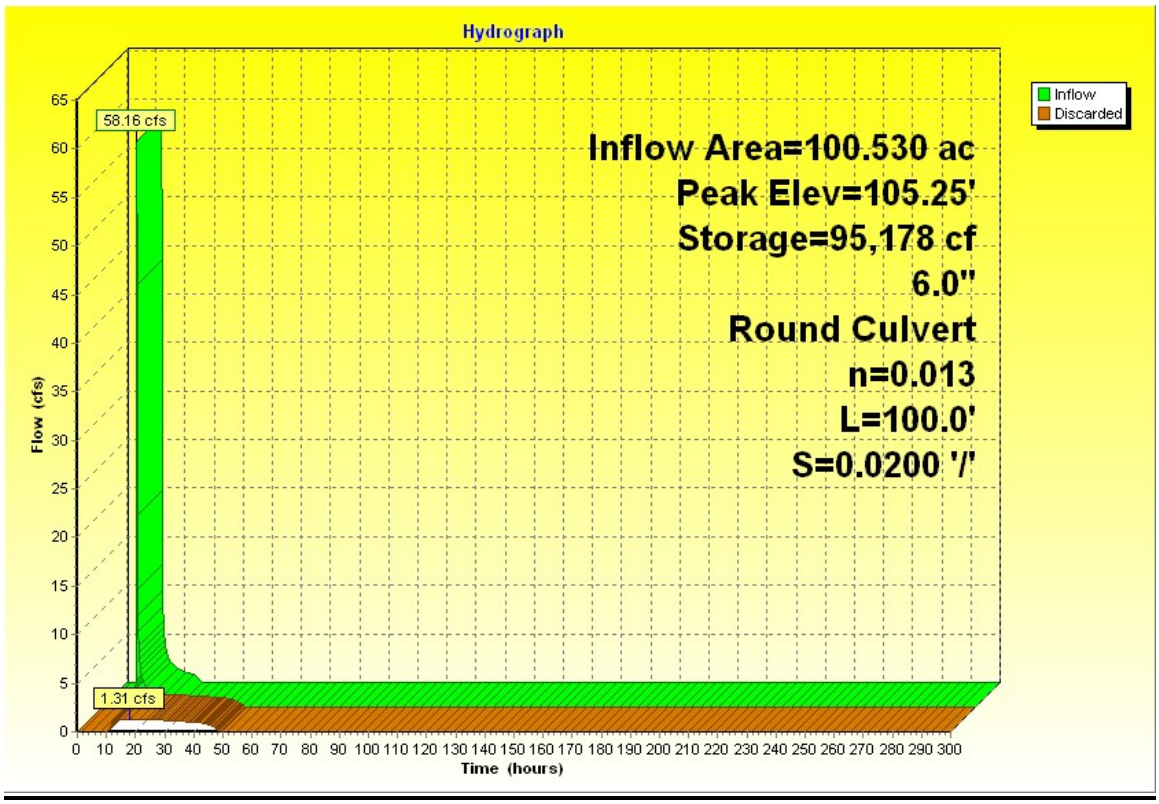
BMP Construction Cost: Estimated construction cost is $25,583.

15-year Maintenance Cost: Estimated maintenance cost is $11,756.

Site #10 Detention Hydrograph – ½” 24-Hour Storm Event



Site #10 Detention Hydrograph – 1” 24-Hour Storm Event

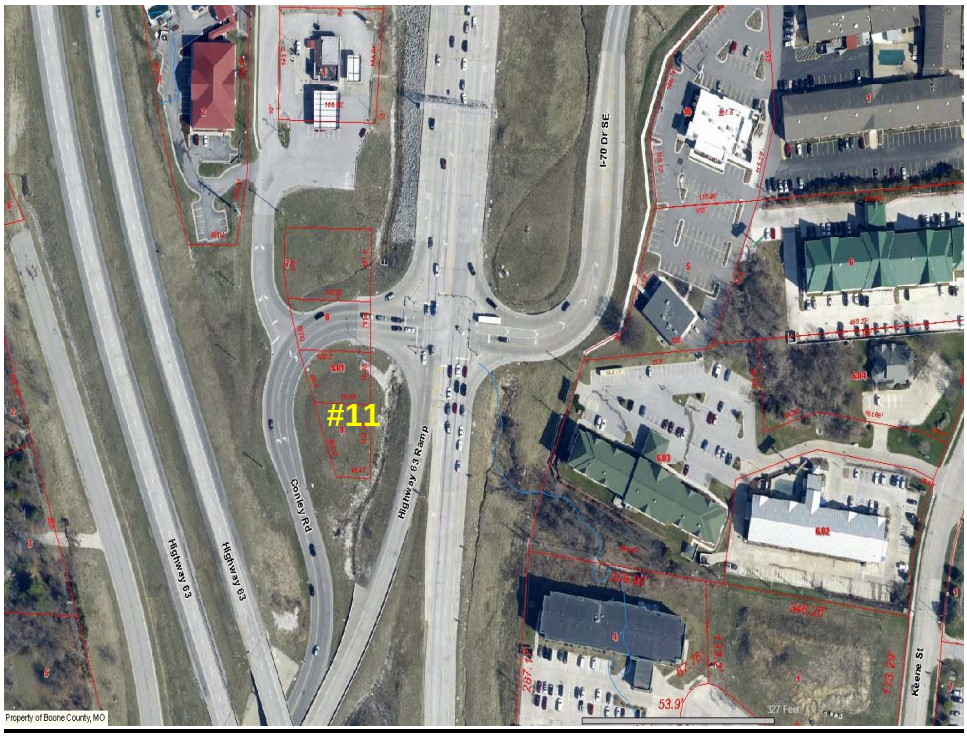


Site #11

Location: Site #11 is located west of and adjacent to the US Hwy-63 southbound onramp, and south and east of, and adjacent to Conley Road.

Description: Site #11 consists of a large open turf-grass area surrounded on all sides by roadways. The site receives flow from the south and west via four culverts and outfalls to the north via a culvert to site #10. Site #11 conveys stormwater from the discharging culverts to the outfall culvert through a series of highly eroded and sparsely vegetated earthen channels. The site is bordered on the south by electric and water utilities, and is bordered on the west by two sanitary sewer lines. Site #11 receives drainage from sites #17, #18 and #19 and discharges to site #10.

Property Owner: Missouri Department of Transportation / Missouri Highways & Transportation Commission



Contributing Area Details: Site #11 receives flow from Conley Road, the US Hwy-63 southbound onramp, the US Hwy-63 connector and US Hwy-63 northbound and southbound. The site specific contributing area to site #11 is 5.53 acres.

Total Area Treated by Site: 28.77 acres (8.12 % of total hotspot area)

Composite Curve Number: 91 (78 % impervious cover)

Water Quality Volume: 107,595 cubic feet (7.94% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 84.8 cfs, 106.9 cfs, 170.8 cfs, 248.8 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 1,880 linear feet of channel and culverts.

Area Available and Proposed BMP: Site #11 offers 4,375 square feet for placement of an extended wet detention basin along with 260 linear feet of channel for restabilization and revegetation. The extended wet detention basin should be located on the northeast corner of the site at the outfall of the culvert discharging from the west. The basin should be situated to discharge immediately to the existing outfall culvert on the north end of the site. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits. The 260 feet of channel should be regraded to a 6'-wide flat bottom trapezoidal channel, armored with turf reinforcement mat, and vegetated with native plants.

Constructability: Site eleven is bordered to the east and south by the US-63 southbound onramp and to the west and north by Conley Road. Because Conley Road is a low-speed roadway, in comparison to the highway onramp, a temporary construction entrance should be constructed off of Conley Road for access to the site. The site will likely require traffic control for both Conley Road and the US-63 onramp. Once on the site, sufficient room exists for material and equipment storage and operation. Work within site 11 will require a MODOT right-of-way permit and could require the installation of a guardrail along all adjacent roadway.

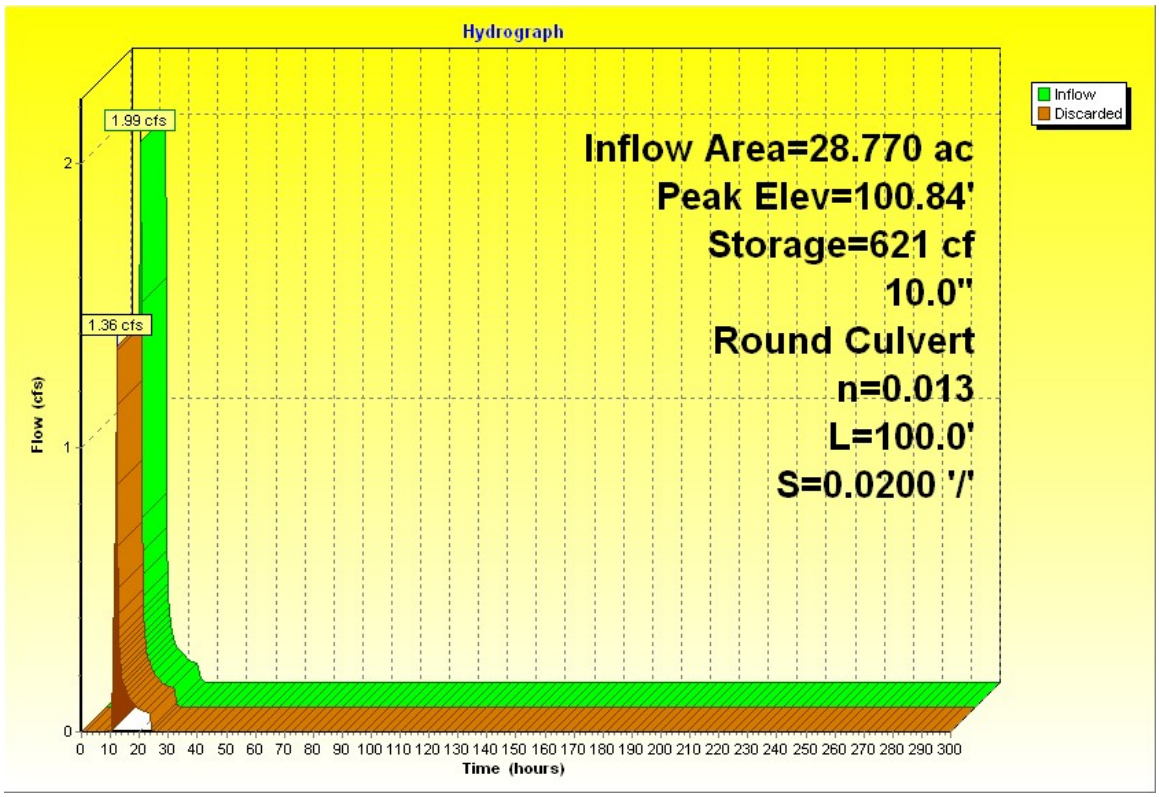
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 74.2 % reduction in the 1" 24-hour storm peak flow rate and a 31.7% reduction in the ½" 24-hour storm peak flow rate (see hydrographs). The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease the flow velocity of the 1-year storm by 41.9 %

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 0.77%

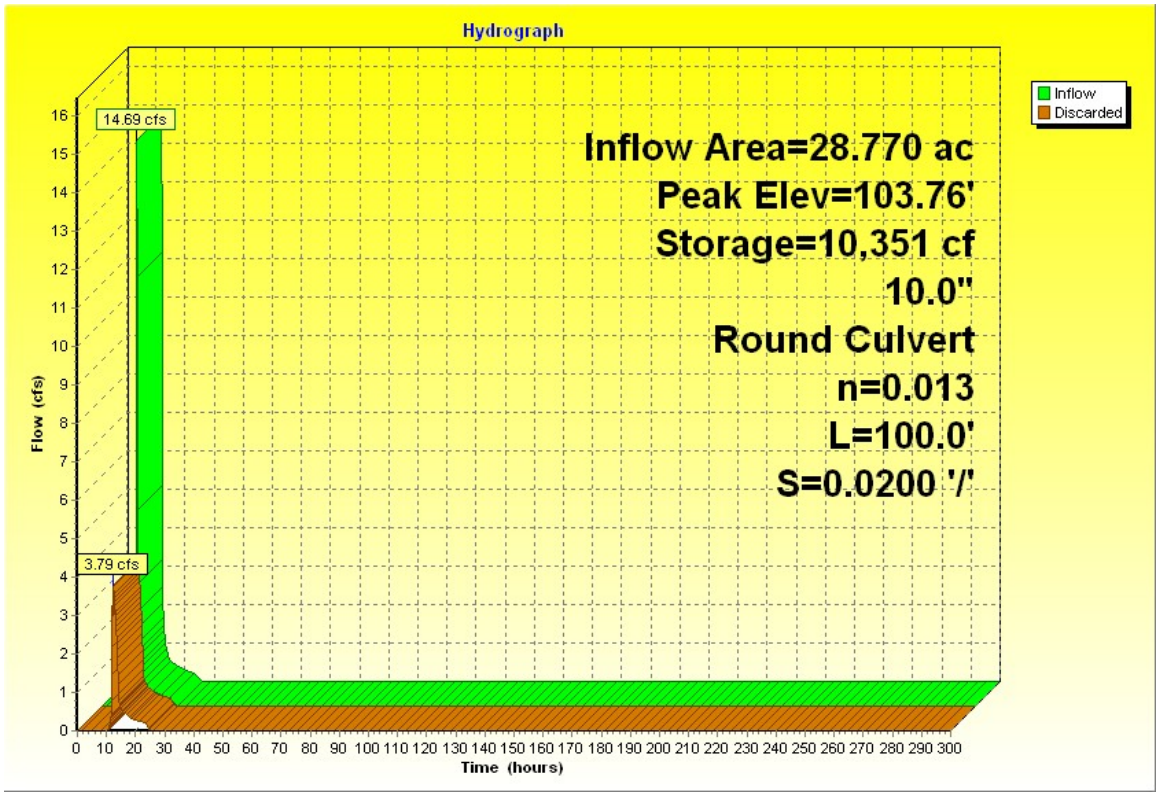
BMP Construction Cost: Estimated construction cost is $20,443.

15-year Maintenance Cost: Estimated maintenance cost is $10,600.

Site #11 Detention Hydrograph – ½” 24-Hour Storm Event



Site #11 Detention Hydrograph – 1” 24-Hour Storm Event

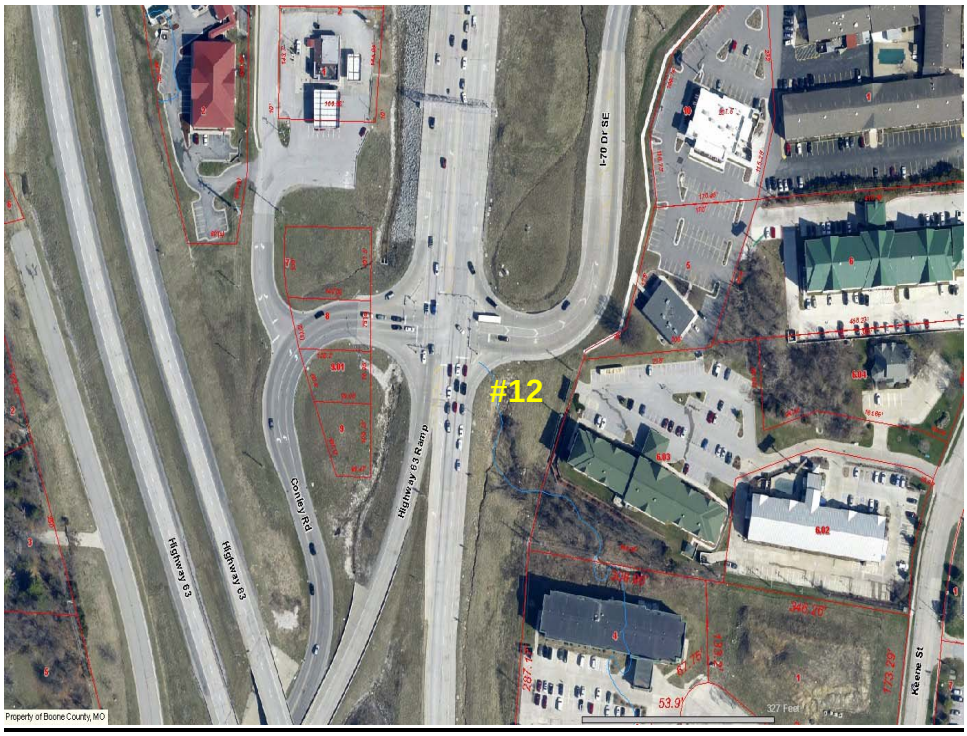


Site #12

Location: Site #12 is located south of and adjacent to I-70 Drive SE, and is east of and adjacent to the US Hwy-63 northbound offramp / US Hwy-63 connector.

Description: Site #12 consists of both a moderately sized open turf-grass area as well as 1,830 feet of channel running adjacent to the US Hwy-63 northbound offramp. The existing earthen channel is highly eroded sharply cut and devoid of vegetation. The channel and site drain to the north, to a culvert that ultimately discharges to site #10. The site is bordered by water and electric lines to the east and is crossed by water, electric and sewer lines approximately 200 feet from its northern end. Site #12 does not receive discharge from any other sites.

Property Owner: Missouri Department of Transportation



Contributing Area Details: Site #12 receives stormwater from the US Hwy-63 northbound offramp, as well as from 17 buildings with office, medical, and residential uses. The site specific contributing area to site #12 is 47.75 acres.

Total Area Treated by Site: 47.75 acres (13.5% of total hotspot area)

Composite Curve Number: 90 (76% impervious cover)

Water Quality Volume: 174,298 cubic feet (12.9% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 138.5 cfs, 172.2 cfs, 278.6 cfs, 408.6 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 1,900 feet of channel and culverts.

Area Available and Proposed BMP: Site #12 offers approximately 13,000 square feet for placement of an extended wet detention basin. The basin will be located at the northern end of the site and will discharge to the outfall culvert in the northwest corner. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits. The 1,830 feet of channel running adjacent to the US Hwy-63 northbound offramp should be regraded to a 6'-wide flat bottom trapezoidal channel, lined with turf reinforcement mat, and vegetated with native plants. Should native vegetation be undesirable at this location, turf grass may substitute.

Constructability: Site twelve could be most easily accessed from the south shoulder of I-70 Drive SE. Site twelve is adjacent to a hotel parking area to the east, however; the parking area resides at an elevation substantially higher than that of the site and access could require the inadvisable traversing of a retaining wall. Site twelve will likely require traffic control on both I-70 Drive SE and the northbound US-63 connector. This site should offer room for storage of materials and equipment at a reasonably safe distance from the US-63 connector. Work within site 12 will require a MODOT right-of-way permit and could require the installation of a guardrail along adjacent portions of roadway.

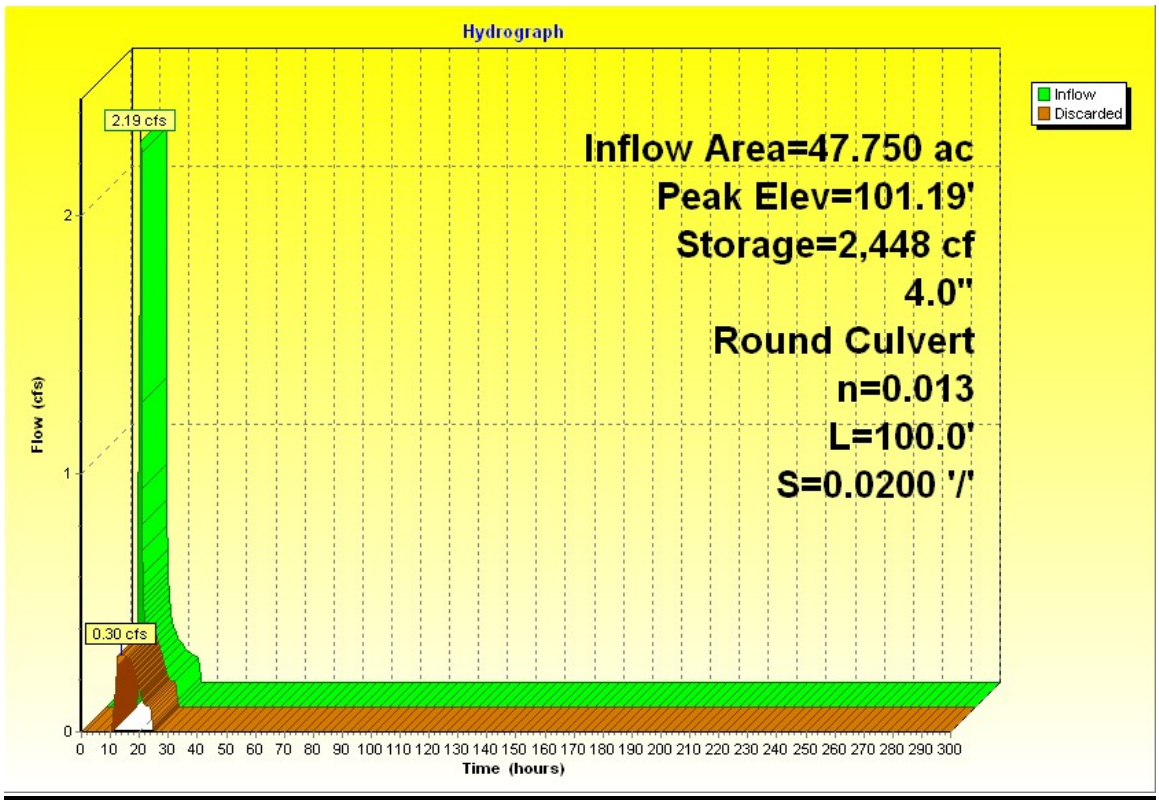
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 97.8 % reduction in the 1" 24-hour storm peak flow rate and a 86.3% reduction in the ½" 24-hour storm peak flow rate (see hydrographs). The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 41.5 %.

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 4.91%

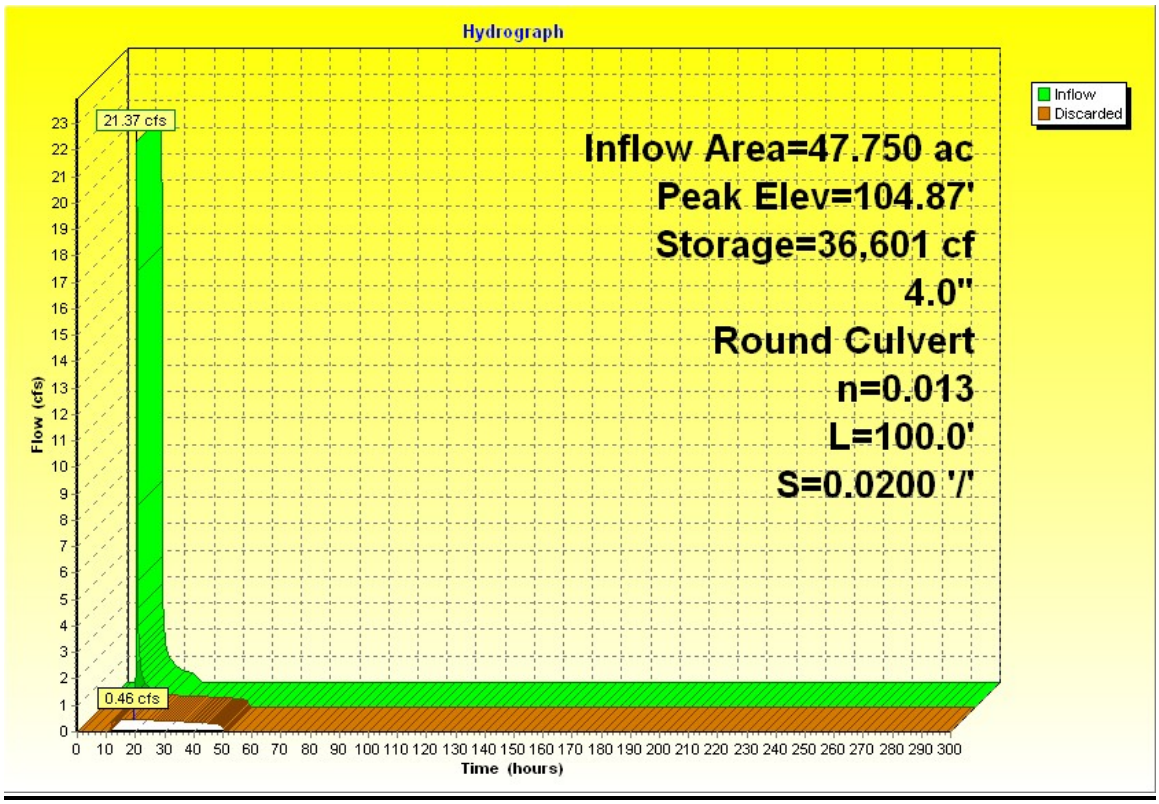
BMP Construction Cost: Estimated construction cost is $71,469.

15-year Maintenance Cost: Estimated maintenance cost is $22,081.

Site #12 Detention Hydrograph – ½” 24-Hour Storm Event



Site #12 Detention Hydrograph – 1” 24-Hour Storm Event



Site #13

Location: Site #13 resides west of and adjacent to the Wal-Mart Supercenter, near the buildings northwest corner.

Description: Site #13 consists of the turf grass area northwest of the existing Wal-Mart Supercenter. The area contains steep slopes that break to the west-southwest towards a newly constructed detention facility.

Property Owner: Conley Road Transportation Development District, RHL Columbia Development, LP

Contributing Area Details: Site #13 receives drainage from the fully developed retail area to the east. The vast majority of drainage to site #13 is via culverts, with only a very minor amount of surface flow.

Composite Curve Number: 95

Total Area Treated by Site: 24.16 acres

1-year, 2-year, 10-year, 100-year Flow Rates: 83.49 cfs, 99.07 cfs, 151.52 cfs, 215.63 cfs

Flow Distance / Conveyance Network to Hinkson Creek: The existing detention facility at site #13 discharges through a culvert, approximately 75 lf to Hinkson Creek

Water Quality Volume: 103,139 cubic feet (7.61% of hotspot total)

Area Available and Proposed BMP: Since the beginning of the Hinkson Creek Watershed Restoration Program, a private developer has constructed a large detention basin at site #13. Site #13 receives very little overland flow from the adjacent parking lot or roof tops and the area is in the process of becoming fully stabilized and vegetated. Any stormwater that does reach the northwest corner of the parking lot is picked up by a nearby curb inlet and discharged to the culvert that outfalls into the basin. All surface flow is conveyed along a vegetated swale, at a steep, yet unavoidable slope, towards the basin. Because of the volume of water received by the existing detention basin and the constructed volume of the basin, it is unlikely that the outlet structure could be altered to further detain any stormwater, except for only the smallest of flows. The BMP proposed for this site is the establishment of native vegetation within the basin and the placement of turf reinforcement mat and native vegetation within the swale leading down to the basin.

Constructability: Site 13 would be most easily accessed from the northern terminus of Willow Way, south of the site. The small residential street is very narrow, so coordination with adjacent property owners would be necessary for transport of equipment and materials. Once on site, there is substantial room for equipment and material storage. Because this site has been very recently graded and vegetated, light weight tracked vehicles are recommended for use on site. Site 13 resides at a very low elevation and in close proximity to Hinkson Creek, as such; it is possible that a no-rise certification be required for work within the floodway.

BMP Benefits: Establishment of native vegetation within the detention basin should provide additional opportunity for nutrient uptake from the deposited sediment as well as decreasing the total volume of water through evapotranspiration. Placement of native vegetation within the swale will offer similar benefits as well as decreasing the velocity of flow.

BMP Construction Cost: Estimated construction cost is $24,400.

15-year Maintenance Cost: Estimated maintenance cost is $5,490.

Site #14

Location: Site #14 is located south of and adjacent to the Cracker Barrel restaurant parking lot, on the south side of the building.

Description: The site consists of the existing failing detention structure that appears to have been cut-off from its incoming flows. The detention structure is an earthen basin with a concrete weir outlet structure that discharges to the south. Site #14 discharges to site #15 and does not receive stormwater from any other BMP sites.

Property Owner: Cracker Barrel Old Country Store, Inc.

Contributing Area Details: The 2.64 acres site specific contributing area includes 3 buildings of the restaurant, and hotel uses, along with their associated parking.

Total Area Treated by Site: 2.64 acres (0.74% of the total hotspot area)

Composite Curve Number: 94 (85% impervious cover)

Water Quality Volume: 7,858 cubic feet (0.58% of the hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 8.6 cfs, 10.3 cfs, 15.9 cfs, 22.7 cfs

Flow Distance / Conveyance Network to Hinkson Creek: 1,580 linear feet of channel and culverts.

Area Available and Proposed BMP: The existing detention basin and the surrounding area offer approximately 8,500 square feet for renovation of the existing basin. The basin

should be cleaned of all foreign debris, the floor of the basin should be regraded and leveled to an elevation below the lowest outlet invert, the earthen side slopes should be regraded to a mowable 3:1 slope and the outlet structure should be renovated or replaced to maximize the detention capability of the basin. The basin should then be revegetated with native plants. The culverts that were meant to discharge into the basin should be located and either repaired or cleaned to direct the stormwater from the adjacent contributing area back into the basin. Another option for this existing basin is reconstruction as outlined above, but with the inclusion of a bioretention basin within the detention basin. The bioretention basin consists of engineered filtration media and an underdrain system. Based on existing topographical maps, there appears to be sufficient fall from the floor of the basin to the adjacent lowland to allow for discharge of an underdrain system.

Constructability: Site 14 would be most easily accessed from the commercial parking lot to the north. The site does lie adjacent to westbound I-70, however; the highway is at a safe distance from site 14 and the highway resides at an elevation much greater than that of the site. No traffic control should be required for work on site 14. The open area adjacent to site 14, site 15, provides ample room for storage of material and equipment.

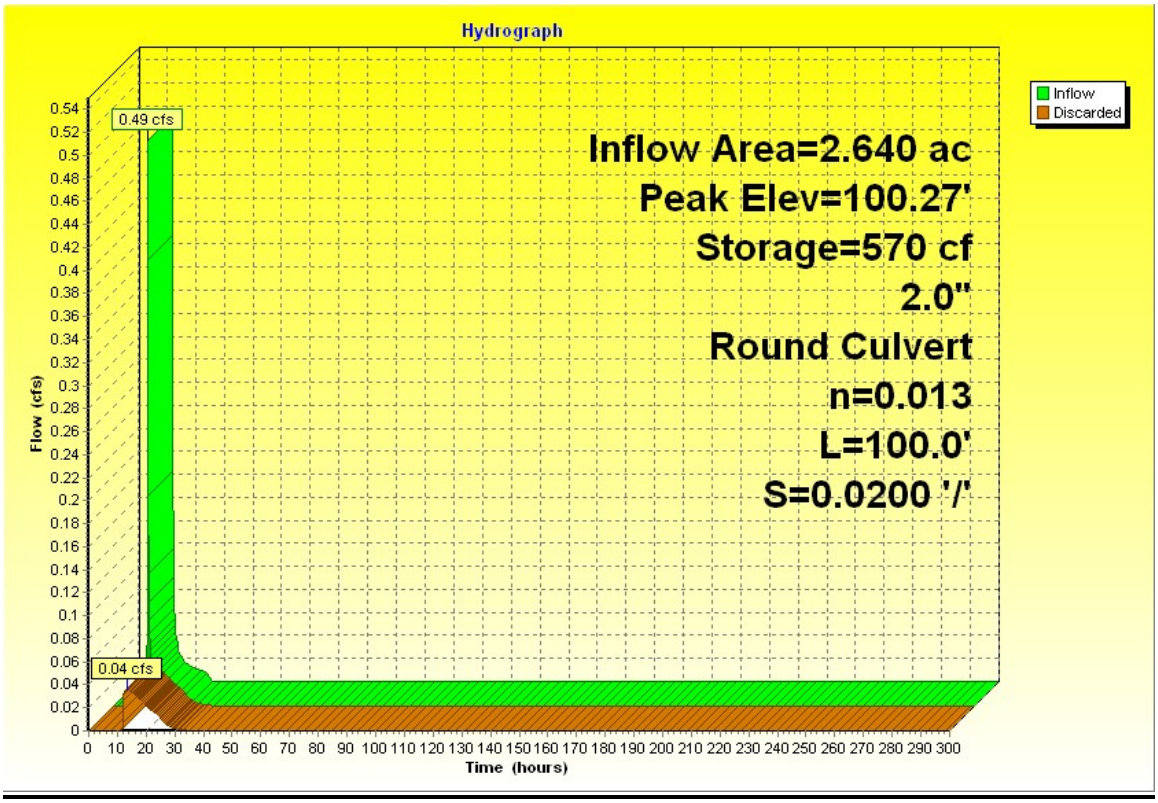
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 97.4 % reduction in the 1" 24-hour storm peak flow rate and a 91.8% reduction in the ½" 24-hour storm peak flow rate (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 0.73%

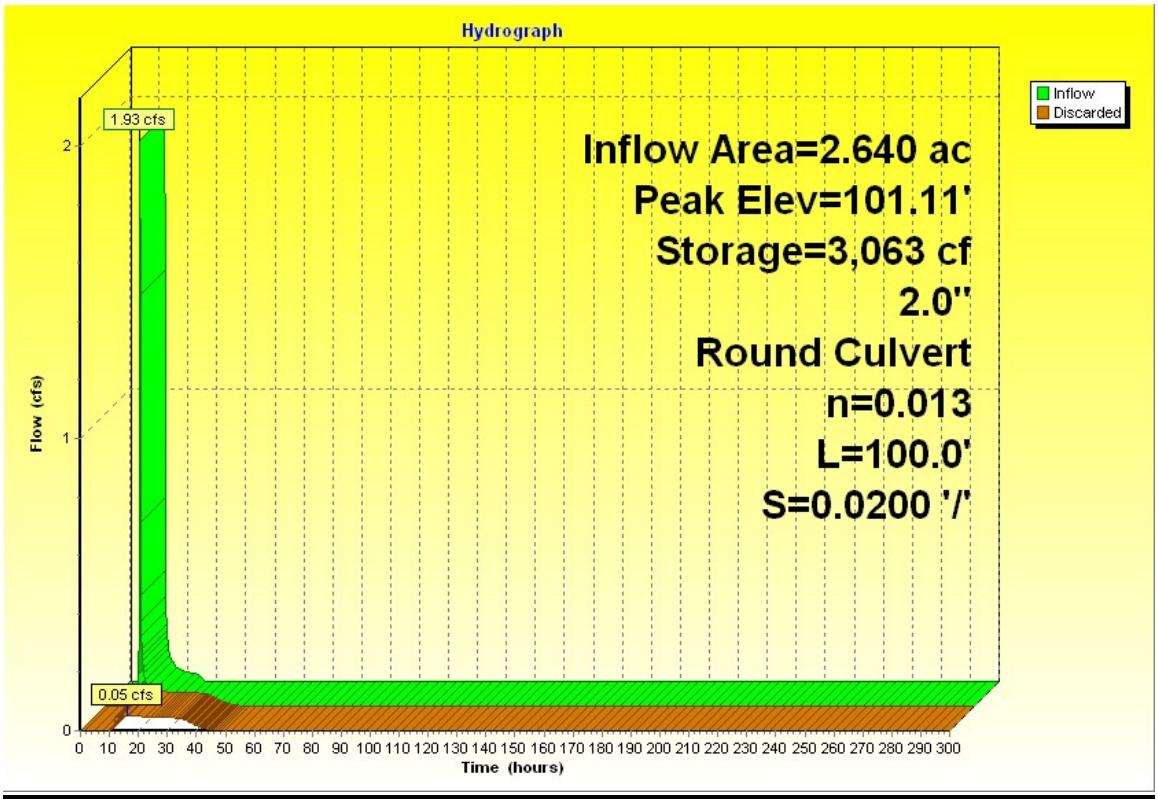
BMP Construction Cost: Estimated construction cost is $14,897.

15-year Maintenance Cost: Estimated maintenance cost is $9,352.

Site #14 Detention Hydrograph – ½” 24-Hour Storm Event



Site #14 Detention Hydrograph – 1” 24-Hour Storm Event



Site #15

Location: Site #15 resides south of and adjacent to the south Cracker Barrel parking lot and north of and adjacent to westbound I-70 and the westbound I-70 offramp. Site #15 encompasses the south and east sides of site #14

Description: Site #15 consists of a large low-lying open space between the highway to the south and the parking lot to the north. Site #15 contains the convergence of two channels, one entering from the east and one entering from the northeast. The site contains multiple billboards and their associated electrical connections as well as a sanitary sewer utility along the northern and eastern edges. Site #15 receives stormwater from site #14 and does not discharge to any other BMP sites.

Property Owner: Missouri Department of Transportation / Hazel E. Cannon 1991 Trust

Contributing Area Details: This site receives stormwater from a site specific contributing area of 143.4 acres including 50 buildings with office, retail, storage, and residential uses. This site receives stormwater from both the north and south sides of I-70.

Total Area Treated by Site: 143.4 acres (40.4 % of total hotspot area)

Composite Curve Number: 94 (85% impervious cover)

Water Quality Volume: 581,049 cubic feet (42.86 % of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 482.8 cfs, 576.1 cfs, 889.9 cfs, 1,272.9 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 1,580 feet of channel and culvert.

Area Available and Proposed BMP: Because site #15 has very little elevation across its length, the construction of a detention facility is infeasible. The channels within site #15 are fairly stabile given their enormous flow rates during heavy rainfall events. Site #15 does offer a substantial area (60,000 square feet) for establishment of a more suitable riparian buffer including the establishment of woody vegetation to help slow and control water during heavy flows.

Constructability: Like site 14, site 15 resides adjacent to I-70, but at a much lower elevation. Traffic control should not be required for work on site 14. The most convenient point of access to site 15 is via the commercial parking lots to the north and northeast. Site 15 has ample room for storage of material and equipment during the construction process. Site 15 could require a MODOT right-of-way permit.

BMP Benefits: The establishment of wetland woody vegetation will anchor the soil against erosion, shade the existing channel, offer pollutant and water uptake, and slow the flow velocity during heavier rainfall events.

BMP Construction Cost: Estimated construction cost is $66,000.

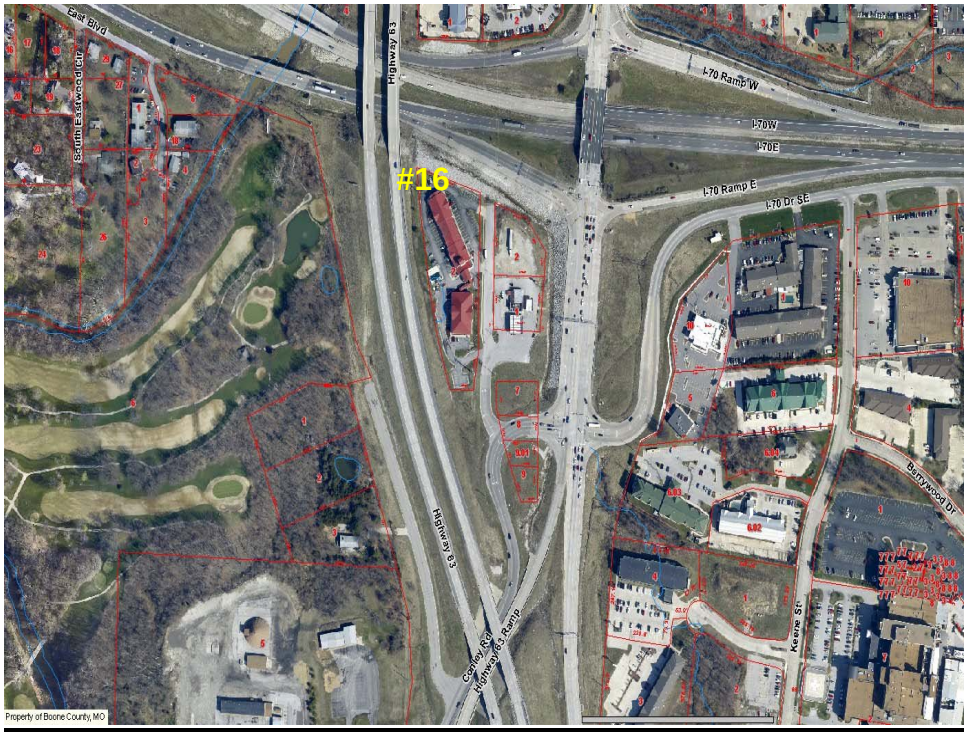
15-year Maintenance Cost: Estimated maintenance cost is $14,850.

Site #16

Location: Site #16 resides east of, adjacent to, and parallel with northbound US Hwy-63 and south of and adjacent to eastbound I-70.

Description: Site #16 consists of 750 feet of eroded and sparsely vegetated earthen channel running parallel from south to north along northbound US Hwy-63. The channel outfalls at its northern end to the western terminus of site #10 and is then conveyed to Hinkson Creek. Site #16 does not receive stormwater from any other BMP sites.

Property Owner: Missouri Department of Transportation



Contributing Area Details: Site #16 receives stormwater from northbound US Hwy-63 as well as from the rear yard of the adjacent hotel to the east. The site specific contributing area for site #16 is 1.81 acres.

Total Area Treated by Site: 1.81 acres (0.51% of the total hotspot area)

Composite Curve Number: 80 (40 % impervious cover)

Water Quality Volume: 3,687 cubic feet (0.27 % of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 3.4 cfs, 4.5 cfs, 8.4 cfs, 13.3 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 770 linear feet of channel.

Area Available and Proposed BMP: The 750 feet of highly eroded channel should be graded to a 6'-wide flat bottom trapezoidal channel, lined with turf reinforcement mat and vegetated with native plants. Turf grass may be substituted for the native vegetation, should native vegetation be undesirable at this location.

Constructability: Site 16 would be most easily accessed from the rear parking lot of the hotel immediately to the east. Site 16 is very narrow and lies adjacent to and in close proximity of northbound US-63. Traffic control along US-63 will most certainly be required and portions of the adjacent parking lot will likely be needed for material and equipment storage. Work on site 16 will require a MODOT right-of-way permit and will most likely require the installation of a guardrail along US-63.

BMP Benefits: The reinforced native vegetation swale will slow the flow velocity promoting infiltration and offering detention, as well as settling of particulates. The vegetation will decrease the total quantity of stormwater and offer pollutant uptake. Restabilization of this channel has been calculated to decrease flow velocities by 54.7 %.

BMP Construction Cost: Estimated construction cost is $14,742.

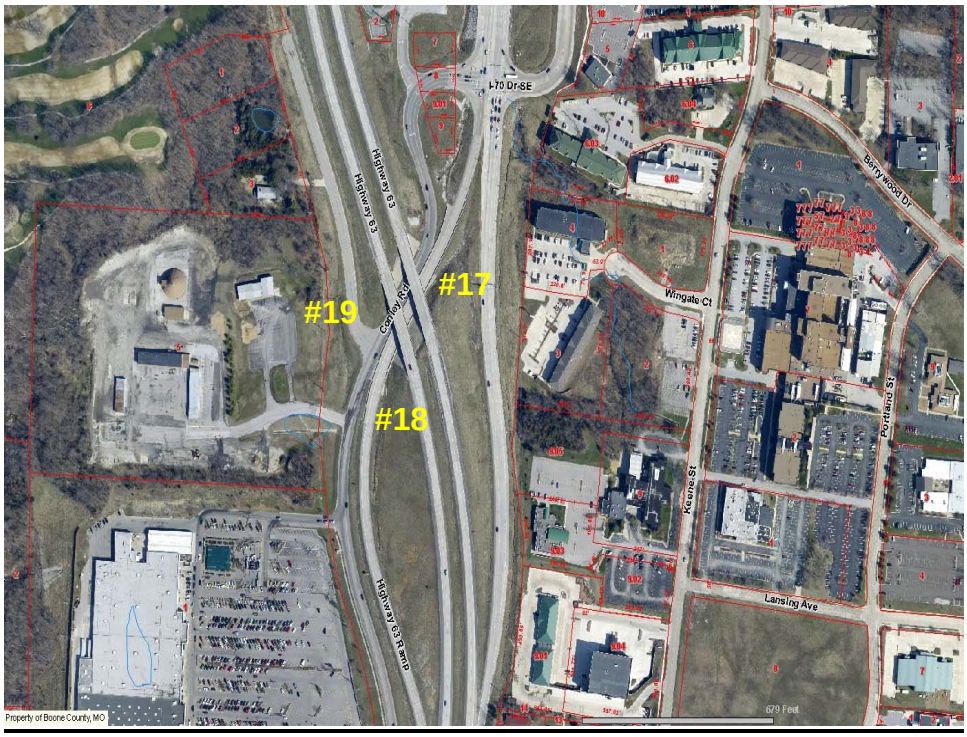
15-year Maintenance Cost: Estimated maintenance cost is $3,317.

Site #17

Location: Site #17 resides east of and adjacent to both northbound US Hwy-63 and the southbound US Hwy-63 onramp and west of and adjacent to the northbound US Hwy-63 offramp.

Description: Site #17 consists of a large turf-grass area along with the convergence of two roadside channels from the southeast and southwest. The site breaks to the north and outfalls to a culvert which conveys the stormwater to site #11. Site #17 is bordered by a water line and a sewer line at the extreme northern end of the site. Site #17 receives flow from site #18 and discharges to sites #11 and #10.

Property Owner: Missouri Department of Transportation



Contributing Area Details: Site #17 receives drainage from US Hwy-63 and from the US Hwy-63 northbound offramp. The site specific contributing area to site #17 is 8.40 acres.

Total Area Treated by Site: 12.89 acres (3.64% of total hotspot area)

Composite Curve Number: 84 (40% impervious cover)

Water Quality Volume: 26,277 cubic feet (1.94% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 27.9 cfs, 37.7 cfs, 66.2 cfs, 101.7 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 2,246 feet of culvert and channel.

Area Available and Proposed BMP: Site #17 offers approximately 15,150 square feet for placement of an extended wet detention basin at the convergence of the two incoming channels. The basin should be placed to outfall to the culvert leaving the site to the northwest. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits.

Constructability: Site 17 will be most easily accessed from the southbound US-63 onramp. Delivery of materials and equipment might be required to occur in the early morning hours to minimize the volume of traffic during delivery. Traffic control will likely be required for the US-63 southbound onramp, the northbound US-63 connector and for northbound US-63. A MODOT right-of-way permit will be required for work on site 17 and the possibility exists that MODOT will require guardrail installation along all adjacent roadway.

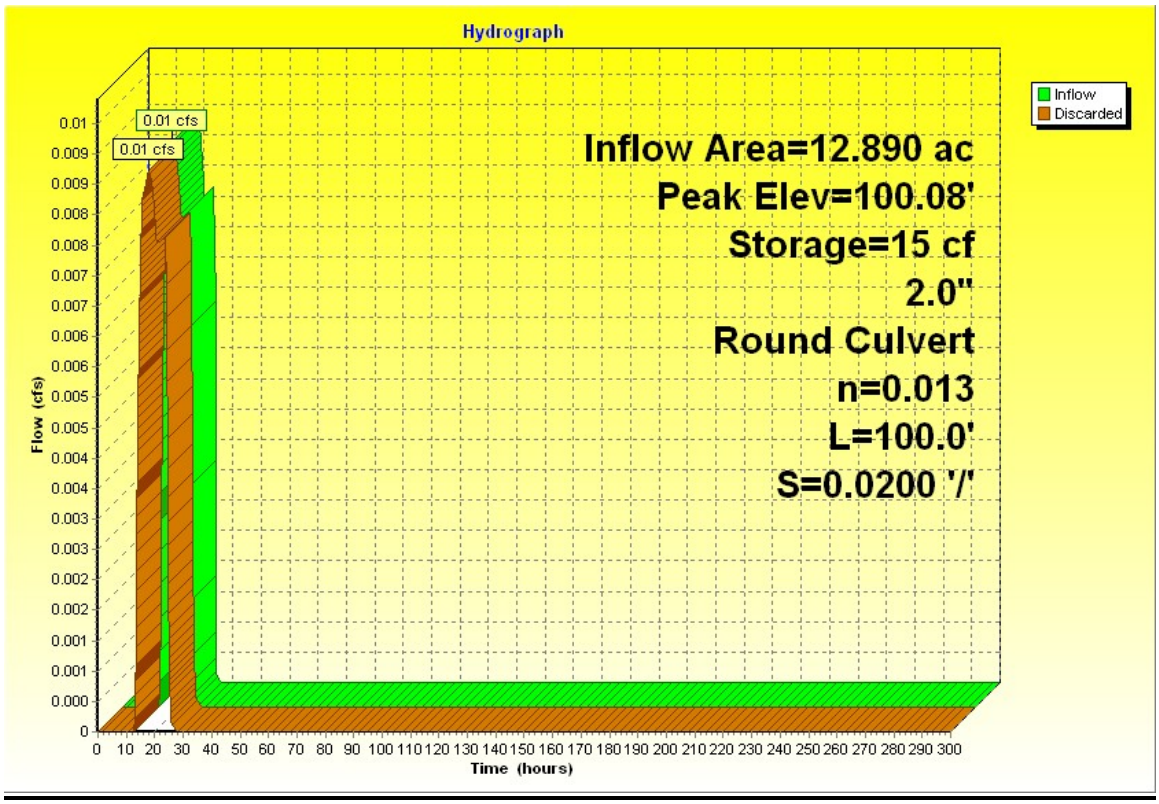
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 97.6 % reduction in the 1" 24-hour storm peak flow rate and due to the low curve number of the contributing area and the fact that the ½" storm modeled occurs over a 24-hour period, less than 0.01 cfs was seen entering the basin from the ½" event (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 1.15%

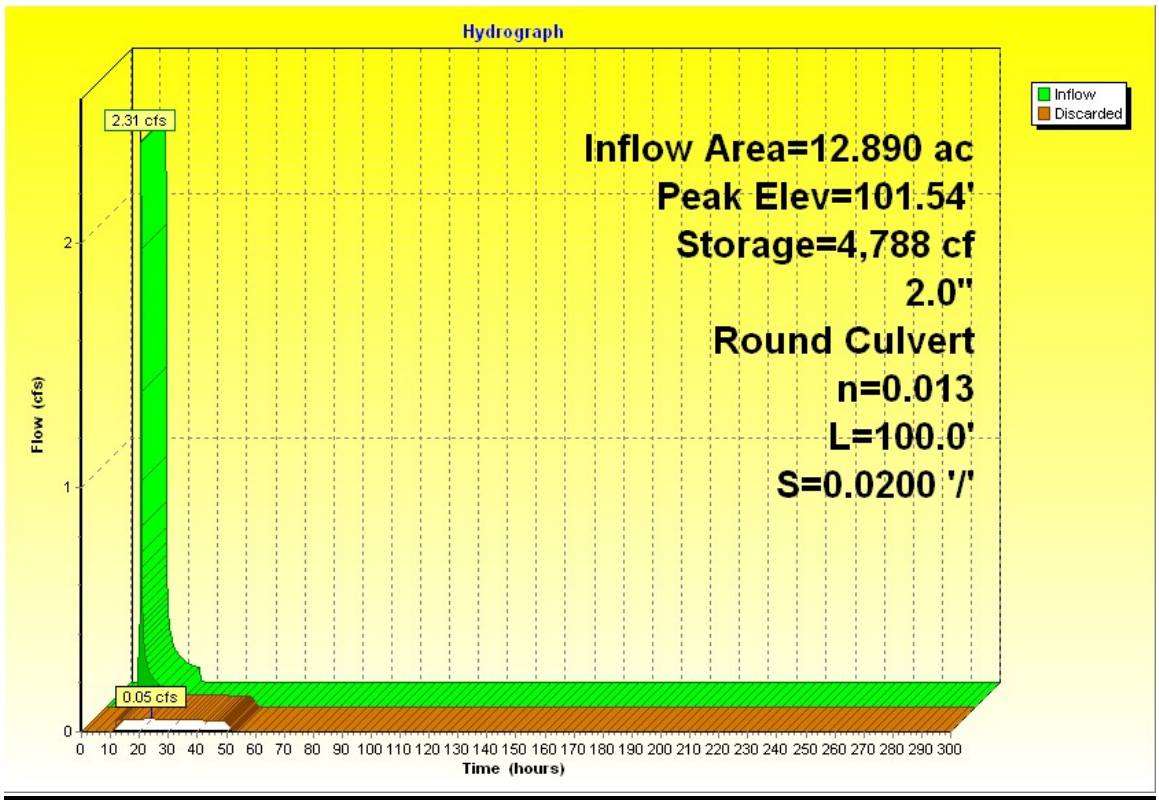
BMP Construction Cost: Estimated cost is $23,166.

15-year Maintenance Cost: Estimated maintenance cost is $11,212.

Site #17 Detention Hydrograph – ½” 24-Hour Storm Event



Site #17 Detention Hydrograph – 1” 24-Hour Storm Event

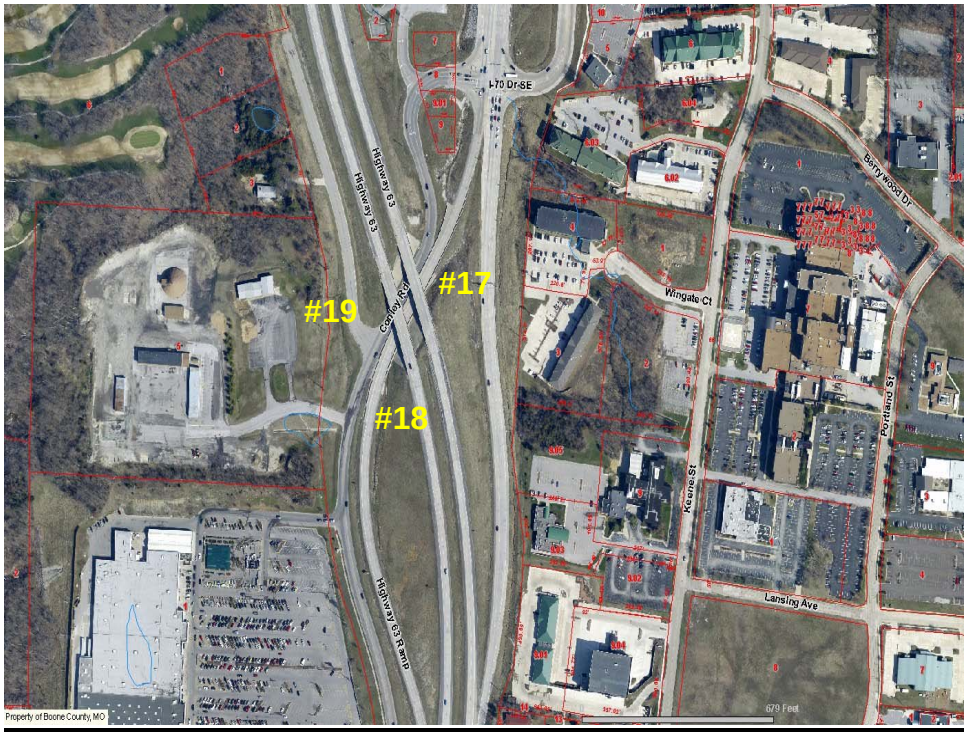


Site #18

Location: Site #18 is located east of and adjacent to the southbound US Hwy-63 onramp and west of and adjacent to southbound US Hwy-63.

Description: Site #18 consists of a large open area bordered on all sides by roadways. The site breaks consistently from southeast to northwest and contains the roadside drainage ditch adjacent to and parallel with the southbound US Hwy-63 onramp. The site does not appear to contain any utilities other than the concrete stormwater flume that the site discharges to on the north end. Site #18 discharges to sites #17, #11, and #10.

Property Owner: Missouri Department of Transportation



Contributing Area Details: Site #18 receives drainage from the southbound US Hwy-63 onramp as well as from southbound US Hwy-63. The total site specific contributing area for site #18 is 4.49 acres.

Total Area Treated by Site: 4.49 acres (1.27 % of total hotspot area)

Composite Curve Number: 78 (15% impervious cover)

Water Quality Volume: 4,133 cubic feet (0.30% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 7.2 cfs, 10.2 cfs, 19.6 cfs, 31.8 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 2,816 feet of channel, culverts, and concrete flume.

Area Available and Proposed BMP: Site #18 offers approximately 5,000 square feet for placement of an extended wet detention basin. The basin will reside along the west side of the site, adjacent to the southbound US Hwy-63 onramp. The space available for the basin is far greater than 5,000 square feet, however; because the ground slopes fairly rapidly and consistently up to the east, the additional surface area at suitable depth would require substantial grading, and without placement of a retaining structure, the remaining grade up to southbound US Hwy-63 could be unstable or un-mowable. The basin should reside such that it discharges immediately to the concrete flume on the northern end of the site. Should a permanent pool of water be undesirable at this location, a vegetated extended dry basin may be substituted with a loss in water quality benefits.

Constructability: Site 18 will be most easily accessed from the shoulder of the southbound US-63 onramp. Like site 17, equipment and material delivery might be required to occur during the early morning hours to minimize the volume of adjacent traffic. Once on site, site 18 offers substantial room for material and equipment storage and operation. A MODOT right-of-way permit will be required for work on site 18 and MODOT could require the installation of a guardrail along all adjacent roadways.

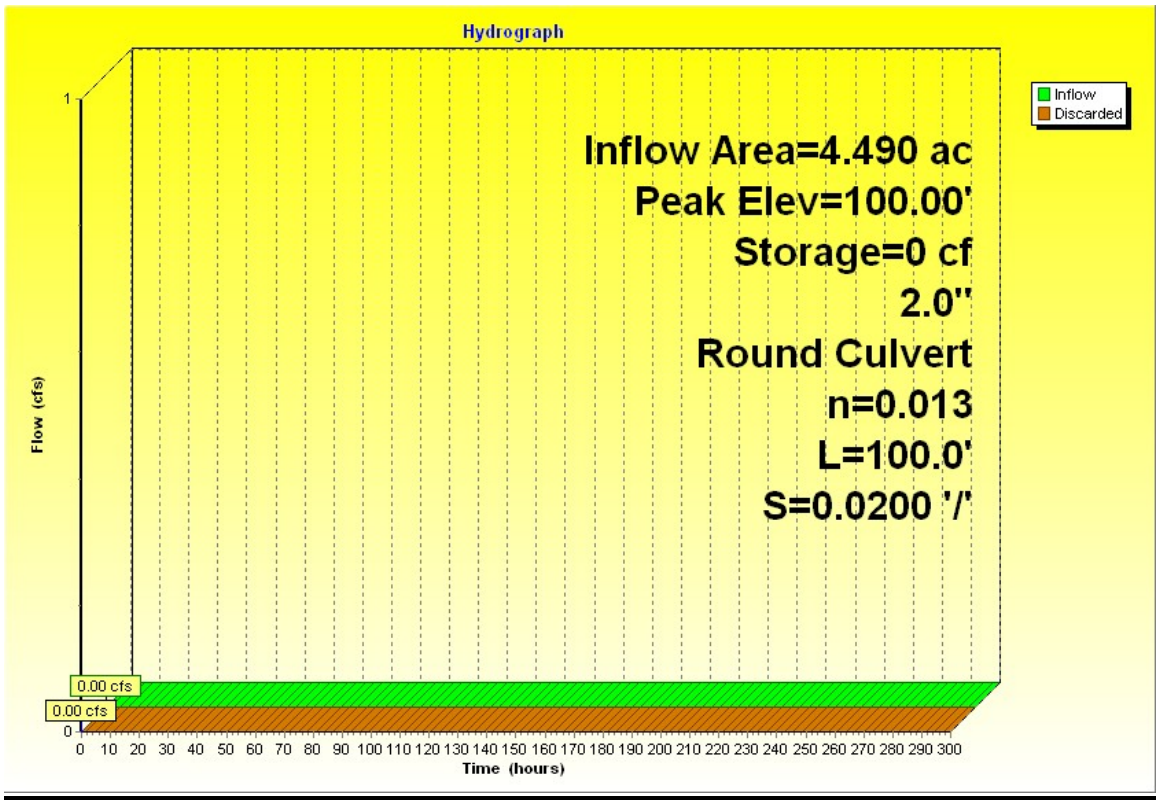
BMP Benefits: The extended wet detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 60% reduction in the 1" 24-hour storm peak flow rate and due to the low curve number of the contributing area and the fact that the ½" storm modeled occurs over a 24-hour period, no runoff was seen entering the basin from the ½" event (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 0.30%

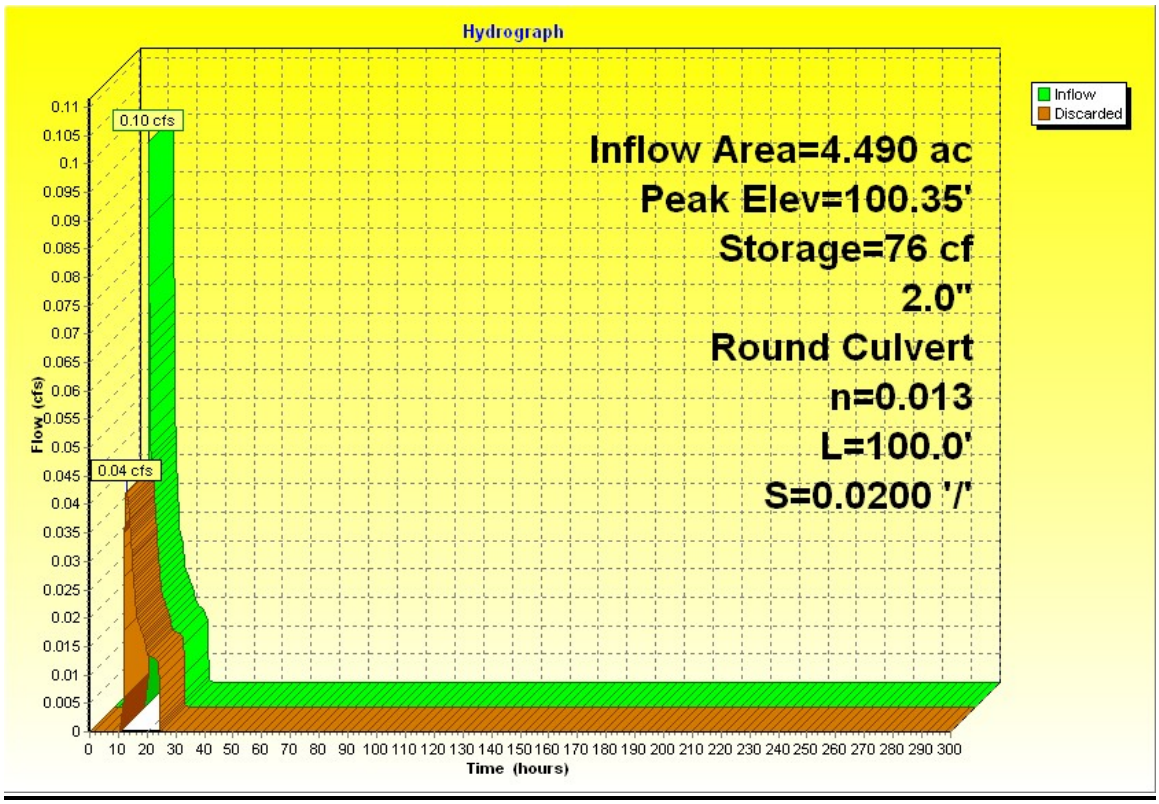
BMP Construction Cost: Estimated construction cost $8,509.

15-year Maintenance Cost: Estimated maintenance cost is $7,914.

Site #18 Detention Hydrograph – ½” 24-Hour Storm Event



Site #18 Detention Hydrograph – 1” 24-Hour Storm Event



Site #19

Location: Site #19 is located west of and adjacent to Conley Road and east of and adjacent to the old MODOT facility off of Conley Road.

Description: Site #19 consists of a large open turf grass area bordered on the east and south by roadways and bordered on the west by the MODOT facility. The site breaks primarily to the north to a culvert that discharges to site #11. The site resides in a large swale formed between the slope up to Conley Road on the east and the slope up to the MODOT facility on the west. The site is crossed by both water lines and electrical lines. Site #19 discharges to sites #11, and #10.

Property Owner: Missouri Department of Transportation / TKG Conley Rd. Investments, LLC.

Contributing Area Details: Site #19 receives stormwater from the MODOT facility as well as from two culverts that receive stormwater from the east and west sides of Conley Road. The site specific contributing area to site #19 is 10.36 acres.

Total Area Treated by Site: 10.36 acres (2.92% of total hotspot area)

Composite Curve Number: 90 (50% impervious cover)

Water Quality Volume: 25,755 cubic feet (1.90% of hotspot total)

1-year, 2-year, 10-year, 100-year Flow Rates: 29.5 cfs, 37.4 cfs, 60.4 cfs, 88.6 cfs.

Flow Distance / Conveyance Network to Hinkson Creek: 2,533 linear feet of culvert and channel.

Area Available and Proposed BMP: Because of the close proximity of the electric and water utilities, grading within this area should be kept to a minimum. With minimal grading, the site can offer 11,640 square feet of fairly shallow depth for establishment of an extended dry detention basin. The dry detention basin is recommended in this location because of the shallow water depths. The basin should be constructed to discharge to the outfall at the northern end of the site. The basin surface and volume detailed in this report are as the ground currently resides and will only require the construction of a dam and outlet structure.

Constructability: Site 19 will be most easily accessed from the unnamed road stemming off of Conley Road and proceeding to the north. The road sees very little traffic as it is a dead end, however, traffic control should still be provided on adjacent portions of Conley Road. The adjacent property to the west was previously occupied by MODOT, but now lies vacant and offers substantial room for material and equipment storage. A MODOT right-of-way permit will be required for work on site 19 and it is possible that MODOT will require guardrail installation along adjacent sections of roadway.

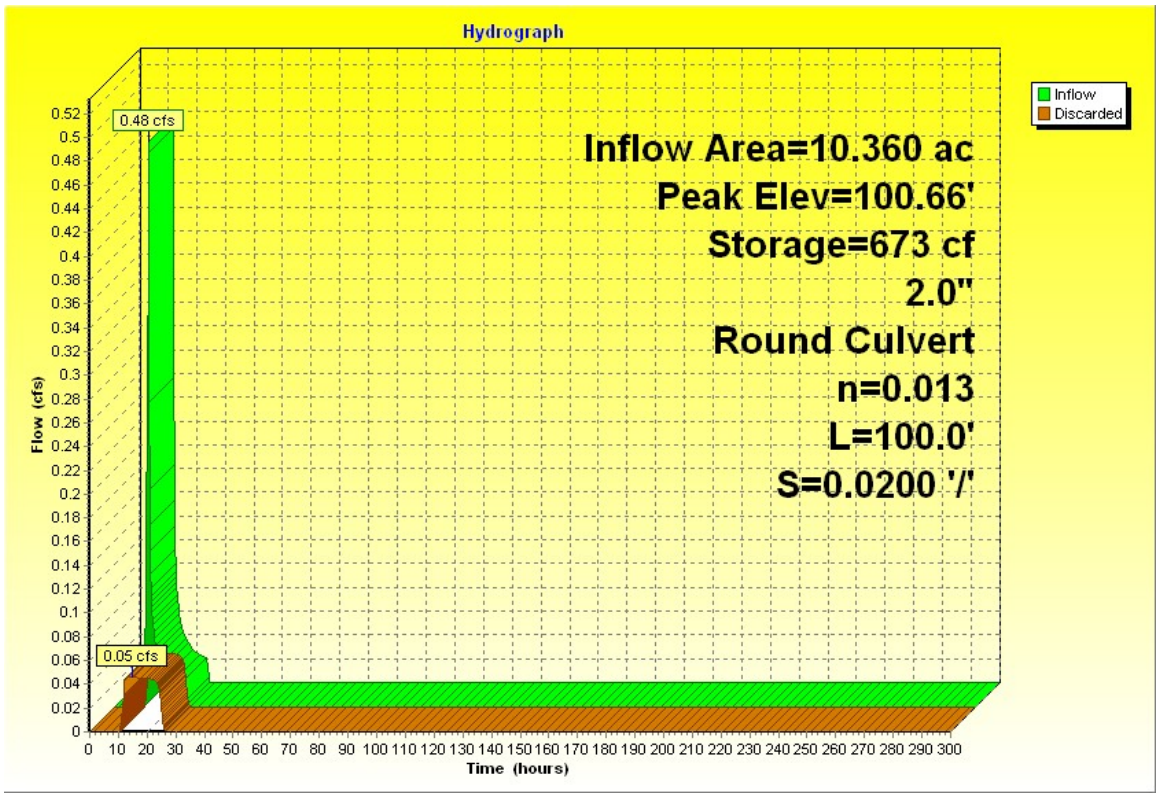
BMP Benefits: The extended dry detention basin will offer detention, infiltration, and pollutant uptake. Based on a preliminary design this extended wet detention basin can offer a 98.7 % reduction in the 1" 24-hour storm peak flow rate and a 89.6% reduction in the ½" 24-hour storm peak flow rate (see hydrographs).

Percent Reduction in 1-year Flow rate of Entire Hotspot Area: 2.06%

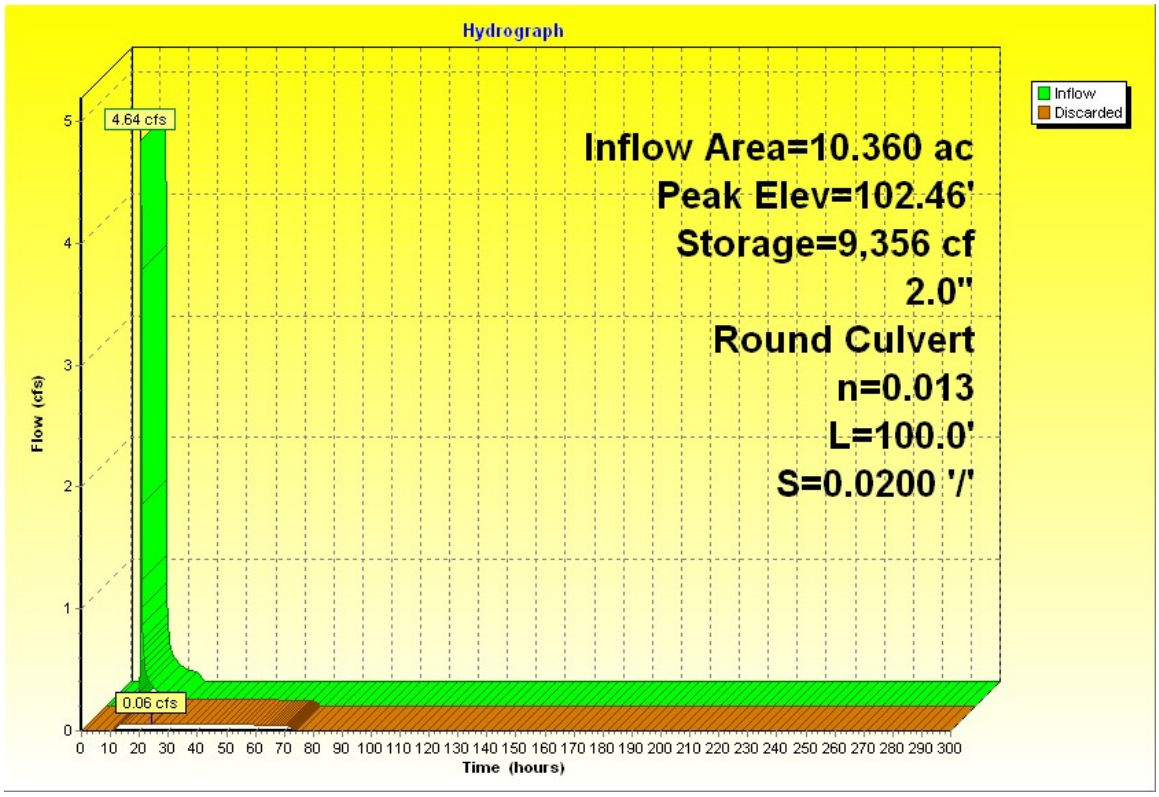
BMP Construction Cost: Estimated construction cost is $23,885.

15-year Maintenance Cost: Estimated maintenance cost is $11,374.

Site #19 Detention Hydrograph – ½” 24-Hour Storm Event



Site #19 Detention Hydrograph – 1” 24-Hour Storm Event



Summary of Overall Effects on Hotspot Area

(Summary Table listed in Appendices)

The following values are a total net effect on the hotspot area as a whole if all 19 subject sites were to be renovated with the BMPs proposed within this report.

Detention: There are a total of 11 detention structures proposed with a collective total of 442,969 cubic feet of storage, which is approximately 33% of the total hotspot water quality volume (WQ_v). Collectively, the detention structures will decrease the 1-year peak flow from the entire hotspot area by 42.54%. Because of their placement along existing concentrated flow paths, many of the detention basins have the opportunity to work in succession with other basins, further increasing detention and offering water quality treatment train benefits.

Channel Stabilization: There is a total of 8,920 linear feet of channel proposed for restabilization on eight of the BMP sites. The total water quality volume conveyed through these channels is 459,924 cubic feet, which is 34% of the total hotspot water quality volume. The average decrease in channel velocity among the restabilized channels is 46.48%, approximately doubling the residence time within the channels.

SUMMARY DATA

SUMMARY OF BMP PERFORMANCE AND COST

SITE	TOTAL AREA TREATED BY SITE (ACRES)	TOTAL AREA TREATED BY SITE AS A PERCENT OF TOTAL AREA (%)	PERCENT REDUCTION IN 1"-EVENT Q PER SITE (%)	PERCENT REDUCTION IN 0.5"-EVENT Q PER SITE (%)	PERCENT REDUCTION IN CHANNEL VELOCITY (%)	PROPOSED BMP	PROPERTY OWNER	ESTIMATED CONST. COST	ESTIMATED 15 YR MAINT. COST	TOTAL COST PER ACRE TREATED ($/ACRE)
1	11.0	3.10	99.20	97.70	NA	DETENTION	MODOT	$15,437	$9,473	$2,265
2	1.0	0.30	N/A	N/A	55.17	VEGETATED CHANNEL	MODOT	$36,149	$8,134	$42,259
3	17.0	4.80	N/A	N/A	42.73	VEGETATED CHANNEL	MODOT, MISSOURI EMPLOYERS MUTUAL	$34,327	$13,724	$2,825
4	3.4	0.96	N/A	N/A	N/A	PARKING ISLAND RAIN GARDENS	BROADWAY CROSSINGS II	$463,288	$7,500	$138,504
5	27.5	7.75	N/A	N/A	30.40	BIOSWALE	BROADWAY CROSSINGS II	$73,804	$16,606	$3,290
6	16.0	4.51	99.50	98.30	42.91	DETENTION, VEGETATED CHANNEL	MODOT	$82,334	$24,525	$6,682
7	45.7	12.89	99.80	99.20	NA	DETENTION	HOME DEPOT, TULL et al	$73,854	$22,617	$2,111
8	3.6	1.02	90.60	MIN.	NA	DETENTION	HOME DEPOT, TULL GROUP	$11,241	$8,529	$5,443
9	1.9	0.53	N/A	N/A	51.94	VEGETATED CHANNEL	CITY OF COLUMBIA, MODOT	$15,724	$9,538	$13,543
10	100.5	28.36	97.70	91.30	40.96	DETENTION, WOODY VEGETATION	MODOT	$25,583	$11,756	$371
11	28.8	8.12	74.20	31.70	41.88	DETENTION, VEGETATED CHANNEL	MODOT	$20,443	$10,600	$1,079
12	47.7	13.47	97.80	86.30	41.49	DETENTION, VEGETATED CHANNEL	MODOT	$71,469	$22,081	$1,959
13	24.1	6.80	N/A	N/A	N/A	NATIVE VEGETATION	CONLEY TDD, RHL COLUMBIA	$24,400	$5,490	$1,239
14	2.6	0.74	97.40	91.80	NA	DETENTION	CRACKER BARREL	$14,897	$9,352	$9,185
15	143.4	40.44	N/A	N/A	NA	WOODY VEGETATION	MODOT, CANNON TRUST	$66,000	$14,850	$564
16	1.8	0.51	N/A	N/A	54.68	VEGETATED CHANNEL	MODOT	$14,742	$3,317	$9,987
17	12.9	3.64	97.60	MIN.	NA	DETENTION	MODOT	$23,166	$11,212	$2,668
18	4.5	1.27	60.00	MIN.	NA	DETENTION	MODOT	$8,509	$7,914	$3,656
19	10.4	2.92	98.70	89.60	NA	DETENTION	MODOT	$23,885	$11,374	$3,404

DETENTION BMP PERFORMANCE

BMP SITE	OUTLET STRUCTURE DIAMETER (INCHES)	0.5 INCH INFLOW (CFS)	0.5 INCH ROUTED FLOW (CFS)	0.5 INCH TIME TO DRAIN (HRS)	0.5 INCH CM TO CM DETENTION (MINS)	1.0 INCH INFLOW (CFS)	1.0 INCH ROUTED FLOW (CFS)	1.0 INCH TIME TO DRAIN (HRS)	1.0 INCH CM TO CM DETENTION (MINS)
1	2.00	2.17	0.05	42.50	708.00	8.40	0.07	104.20	2,405.00
6	2.00	2.97	0.05	62.50	1,241.00	11.70	0.06	170.00	4,293.00
7	2.00	8.50	0.07	122.40	2,937.00	33.45	0.08	342.40	8,922.00
8	2.00	< 0.01	< 0.01	24.00	0.00	0.53	0.05	24.40	119.00
10	6.00	10.40	0.90	26.40	150.00	58.16	1.31	50.00	831.00
11	10.00	1.99	1.36	24.40	5.00	14.69	3.79	24.40	21.00
12	4.00	2.19	0.30	25.00	82.00	21.37	0.46	51.20	911.00
14	2.00	0.49	0.04	27.40	225.00	1.93	0.05	44.40	695.00
17	2.00	< 0.01	< 0.01	24.40	29.00	2.08	0.05	52.20	950.00
18	2.00	< 0.01	< 0.01	24.00	0.00	0.10	0.04	24.25	17.00
19	2.00	0.48	0.05	25.60	170.00	4.64	0.06	73.20	1,576.00

DETAILED COST ESTIMATE BREAKDOWN

sites	excavation (ft^3)	excavation cost ($)	riprap (tons)	riprap cost ($)	outlet structure / culverts costs ($)	vegetation area (ft^2)	vegetation cost ($)	turf reinforcement mat area (ft^2)	turf reinforcement mat cost ($)	New Pavement Cost	total construction cost ($)	15-year maintenance cost ($)
1	16185	2847	12	300	4590	7000	7700	0	0	0	$15,437	$9,473
2	12000	2111	0	0	0	10980	12078	10980	21960	0	$36,149	$8,134
3	49221	8659	0	0	0	8280	9108	8280	16560	0	$34,327	$13,724
4	11520	2027	0	0	0	0	0	0	0	461261	$463,288	**$7500
5	91200	16044	0	0	0	30400	33440	12160	24320	0	$73,804	$16,606
6	68378	12029	47	1163	12940	39420	43362	6420	12840	0	$82,334	$24,525
7	125059	22001	94	2344	22009	25000	27500	0	0	0	$73,854	$22,617
8	7118	1252	54	1350	3139	5000	5500	0	0	0	$11,241	$8,529
9	4800	844	0	0	0	4800	5280	4800	9600	0	$15,724	$9,538
10	117000	20583	200	5000	0	0	0	0	0	0	$25,583	$11,756
11	9004	1584	7	169	3441	7500	8250	3500	7000	0	$20,443	$10,600
12	50700	8919	38	938	10112	25000	27500	12000	24000	0	$71,469	$22,081
13	0	0	0	0	0	20000	22000	1200	2400	0	$24,400	$5,490
14	10000	1759	8	188	3600	8500	9350	0	0	0	$14,897	$9,352
15	0	0	0	0	0	60000	66000	0	0	0	$66,000	$14,850
16	4500	792	0	0	0	4500	4950	4500	9000	0	$14,742	$3,317
17	12728	2239	9	225	4036	15150	16665	0	0	0	$23,166	$11,212
18	2846	501	2	53	2455	5000	5500	0	0	0	$8,509	$7,914
19	25637	4510	19	469	6102	11640	12804	0	0	0	$23,885	$11,374

** 3% biennial charge is not applied to pavement

DEFINITIONS:

Water Quality Volume:

The water quality volume (WQ_v) is defined as the storage volume needed to capture and treat 90 percent of the average annual stormwater runoff volume. The water quality volume is based on the water quality storm, a site specific volumetric runoff coefficient, and the area of the site. (Per City of Columbia Stormwater Management and Water Quality Manual)

Water Quality Storm:

The water quality storm is defined as the storm event that produces less than or equal to 90 percent (by volume) of all 24-hour storms on an annual basis. The depth of the water quality storm for Columbia is 1.37 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

1-Year Storm Event:

The 1-year storm event has a statistical recurrence interval of one year and has a 100 percent statistical likelihood of occurrence on any given year. The 24-hour

rainfall depth for the 1-year storm event in Columbia is 3.0 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

2-Year Storm Event:

The 2-year storm event has a statistical recurrence interval of two years and has a 50 percent statistical likelihood of occurrence on any given year. The 24-hour rainfall depth for the 2-year storm event in Columbia is 3.5 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

10-Year Storm Event:

The 10-year storm event has a statistical recurrence interval of ten years and has a 10 percent statistical likelihood of occurrence on any given year. The 24-hour rainfall depth for the 10-year storm event in Columbia is 5.2 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

100-Year Storm Event:

The 100-year storm event has a statistical recurrence interval of one hundred years and has a 1 percent statistical likelihood of occurrence on any given year. The 24-hour rainfall depth for the 100-year storm event in Columbia is 7.3 inches. (Per City of Columbia Stormwater Management and Water Quality Manual)

Composite Curve Number:

The composite curve number is a curve number assigned to a specific sub-watershed and is based upon the sum of the products of the area (as a decimal percent of total area) for each individual surface cover type and its corresponding curve number. The composite curve number for a given watershed offers a more accurate representation of runoff rates than does the use of a general curve number often assigned to an area based solely on land use classification. Specific curve numbers were attained from the City of Columbia Stormwater Management and Water Quality Manual.

Composite Curve Number Calculation:

Composite CN = SUM $\{(A_1 / A_T)*CN_1 + (A_2 / A_T)*CN_2 + \ldots (A_N / A_T)*CN_N\}$

Where: A = Area

CN = Curve Number

Typical Composite Curve Numbers listed by cover type and land use are as follows (Per City of Columbia Stormwater Management and Water Quality Manual). Each item has four curve numbers listed which correspond to hydrologic soil groups A, B, C, and D, and are listed in that order:

		A B C D
Open Space / Lawn / Parks:	Poor	68, 79, 86, 89
Open Space / Lawn / Parks:	Fair	49, 69, 79, 84
Open Space / Lawn / Parks:	Good	30, 61, 74, 80
Pavement / Roofs		98, 98, 98, 98
Urban District - Commercial & Business		89, 92, 94, 95
Urban District - Industrial		81, 88, 91, 93
Residential – 1/8th acre lots		77, 85, 90, 92
Residential - 1/4th acre lots		61, 75, 83, 87
Residential – ½ acre lots		54, 79, 80, 85
Residential – 1 acre lots		51, 68, 79, 84
Completely Pervious – 100% Denuded		77, 86, 91, 94
Continuous Graze Pastureland:	Poor	68, 79, 86, 89
Continuous Graze Pastureland:	Fair	49, 69, 79, 84
Continuous Graze Pastureland:	Good	39, 61, 74, 80
Woods & Grass Combination	Poor	57, 73, 82, 86
Woods & Grass Combination	Fair	43, 65, 76, 82
Woods & Grass Combination	Good	32, 58, 72, 79
Woods Only	Poor	45, 66, 77, 83
Woods Only	Fair	36, 60, 73, 79
Woods Only	Good	30, 55, 70, 77

Treatment Train:

The treatment train refers to a series of BMPs used in succession to improve water quality (as opposed to the use of a single BMP).

Site Specific Contributing Area:

The term “site specific contributing area” is used to classify the contributing area that drains to one BMP site only. This contributing area value does not include the contribution of stormwater that has been previously intercepted by an upstream BMP site. It is necessary to determine for both calculation of total watershed area (as the sum of the individual site specific contributing areas) and the analysis of “treatment train” water quality levels of service. It should be noted that although the site specific contributing areas are listed for each site, the proposed BMP for each site is designed to treat the entire contributing area for each site which includes the site specific contributing area and the site specific contributing areas for any upstream sites, the sum of which is the total area treated by a site.

Total Area Treated By a Site:

The total area treated by a site is defined as the sum of the site specific contributing area and the site specific contributing areas of any upstream BMP sites which then contribute to the site in question. The total area treated by a site can also be defined by the common definitions of “contributing area” or “drainage area”.

Conveyance Network:

The conveyance network for outfall waters from a BMP site is defined by the underlying surface upon which water flows to reach a point of lower elevation. Conveyance networks include culverts, flumes, vegetated channels, reinforced channels, etc. or a combination thereof.

Flow Distance to Hinkson:

The flow distance to Hinkson Creek from each BMP site is defined as the distance of travel required for the outfall water from a BMP site to reach Hinkson Creek. The flow distance includes all applicable conveyance methods.

Area Available for BMP Placement:

The area available for BMP placement is defined as the amount of surface area at a proposed BMP site available for construction / maintenance of a BMP structure. Topographic and utility maps were reviewed for determination of this area and each area listed is based upon availability without the relocation of any utilities.

Elevation Available for BMP Placement:

Topographic maps and field research were utilized to determine the approximate elevation available for BMP placement at each site. The available elevation is primarily dictated by the difference between the flow line elevation into a BMP site and the flow line elevation out of a BMP site. The elevation available is necessary to determine the volume of storage that can be attained with various BMP structures within the area available for BMP placement, as well as to ensure that upon treatment or detention, an area will drain.

Estimated Construction Cost:

The estimated construction cost for the BMPs includes the cost of excavation, assuming no material is removed from or delivered to the site, as well as the material and placement cost for riprap, outlet structures, culverts, vegetation and turf reinforcement mat. Excavation cost is based on $4.75 per cubic yard excavated. Riprap cost is based on $25 per ton delivered and placed. Outlet structures, culverts, and vegetation are based on actual cost from previously completed projects. Turf reinforcement mat is based on $2 per square foot.

Estimated construction cost does not include temporary erosion control, permitting, easement acquisition and associated legal fees or traffic control.

Estimated 15-year Maintenance Cost:

The 15-year maintenance cost includes the cost of removing sediment and debris, re-vegetating, reinforcing, etc. on a biennial basis. This is a roughly estimated value and is subject to seasonal conditions, proper initial construction and unforeseen events. All BMPs receive an initial maintenance cost of 3% of initial construction cost on a biennial basis. Maintenance for BMPs likely to receive sediment also includes one full day of sediment removal on a biennial basis.

Maintenance cost does not include general grounds keeping such as mowing, etc.

Center-of-mass Detention:

Center of mass detention (noted as CM detention in accompanying tables) refers to the time-span between the center-of-mass of an inflow hydrograph and the center of mass of it's corresponding outflow hydrograph for a given stormwater detention structure.

SITE AND BMP SELECTION QUESTIONNAIRE

AND

BMP SCORING MATRIX

SITE SELECTION PROCESS:

The following questions regarding BMP site selection are meant to serve as reminders of some of the most fundamental factors that should be considered during the site selection process. Should the site in question fail to receive preference within this questionnaire, that site should not necessarily be dismissed, however; additional caution should be used during consideration of that site. Upon completion of the site selection process, proceed to the BMP selection portion of this questionnaire.

SITE SELECTION CONSIDERATIONS:

1. **Is the BMP site in question located such that any treated stormwater can be subject to re-contamination on its path to the outfall from the subject property?**

   Preference should be given to sites that will allow the treated stormwater to either discharge directly to the receiving stream, or to follow a path that will not subject the treated stormwater to any polluted or unstable surface prior to outfall from the property.

2. **What type of existing ground cover will be removed or disturbed for placement of a BMP at the site in question?**

   Preference should be given to sites that will not require the removal or disturbance of existing healthy vegetation including dense turf grass, trees or other native vegetation. Preference should also be given to BMP sites that will not require the disturbance or removal of an existing stable and healthy natural stormwater conveyance system, such as a stream.

3. **Does the BMP site display any topographical or geological characteristics that might cause excessive difficulty in BMP construction and maintenance, or that will substantially decrease the efficacy of a BMP, such as extreme slopes or exposed or shallow bedrock?**

   Preference should be given to sites that will not require the excavation and removal of large bedrock structures, due to excessive cost. Preference should also be given to sites that are not located on or immediately adjacent to extreme slopes due to the difficulty in stabilizing the adjacent slopes as well as the likelihood of slope failure due to the concentration of stormwater in the adjacent BMP.

4. **Is the BMP site located in close proximity to a direct conduit to groundwater, such as a sinkhole, losing stream, or cave system?**

   Preference should be given to sites that are not in close proximity to a direct conduit to ground water. BMP sites, during the course of treating stormwater, often concentrate pollutants until those pollutants can be assimilated. Excessive storm events can cause these pollutants to be removed from the BMP site and enter into these environmentally sensitive features.

5. **Does the BMP site in question offer reasonable access for routine maintenance?**

   Preference should be given to sites that are easily accessible during most weather conditions. Access to the site during varying weather conditions should be feasible to allow for inspection and maintenance. Any site that is likely to receive a BMP that promotes deposition of sediment should be accessible to equipment suitable for removal of sediment on an annual or biennial basis with minimum disturbance to the surrounding.

6. **Is the BMP site in question located such that construction, maintenance, or the existence of the BMP will place construction and maintenance personnel or the general public at excessive risk or subject the property owner to excessive liability?**

   Preference should be given to sites that are not located such that construction or maintenance personnel or the general public will be continuously subjected to excessive risk of injury during construction or maintenance on the BMP site.

   BMPs that will incorporate either permanent or long lasting pools of water should not be located in close proximity to areas of heavy pedestrian traffic, unless those sites can be fenced or offer some other deterrent.

7. **Is the BMP site in question within immediate proximity to a foundation, retaining wall, roadway or other structure that could be adversely affected by the frequent inundation of stormwater at the BMP site or repeated or constant elevated soil moisture levels?**

   Preference should be given to sites that will not pose a threat to the physical integrity of adjacent structures. Sites that lie adjacent to and upslope from these structures should be considered with a great deal of caution.

BMP SELECTION PROCESS:

The following portion of this questionnaire is meant to serve as guidance during the BMP selection process for a given site. The majority of BMPs can be altered or redesigned to work with sites outside of their normal or recommended scenarios, as such; dismissal of a BMP as a result of this questionnaire does not mean that the BMP can not be modified for use in the specific application. In addition, supplemental thought should be given to the BMP selected as a result of this questionnaire. The criteria for this BMP questionnaire and the associated BMP Scoring Matrix are based on common recommended practices.

The BMP scoring matrix should be present during completion of the following portion of this questionnaire.

1. Approximate the area available for placement of the BMP within the selected site.

   Area Available: _____

2. Approximate the size of the area draining to the proposed BMP site.

   Drainage Area: _____

3. Determine the size of the area available for BMP placement as a percent of the total drainage area.

   Percent of Drainage Area = (Area Available / Drainage Area) x 100

   Percent of Drainage Area: _____

4. Does the BMP site in question reside in close proximity to a structure as defined in item #7 of the BMP Site Selection Process? Consider close proximity as 10-feet or less from the downhill side or 100-feet or less from the uphill side.

   Distance to Structure (if applicable):_____

5. Will the proposed BMP site receive stormwater in the form of sheet flow or concentrated flow?

   Sheet Flow or Concentrated Flow: _____

6. Will a permanent or long term pool of water be acceptable at this BMP site?

   Pool Acceptable / Unacceptable: _____

7. Are the underlying soils of the proposed BMP site well drained soils or poorly drained soils? (high or low saturated hydraulic conductivity)

Well Drained / Poorly Drained Soils: _____

8. Is the ENTIRE area draining to the BMP site comprised of pervious surface, impervious surface, or both?

Pervious / Impervious / Both: _____

9. The BMP Scoring Matrix has rows labeled 1-8 that correspond to the answers from questions 1-8 of the BMP Selection Process, above. Proceeding with row #1, review each cell within that row and strike through any cell that does not concur with your answer from question #1.

Complete this same task for rows 2-8, corresponding to answers 2-8, above.

10. Strike through any column (1-19) that contains a cell that is struck through as a result of non-concurrence with answers 1-8, above.

11. The columns that remain are BMP options available for this particular site.

Each column lists the type of BMP as well as a ranking for various environmental, cost, and infrastructure criteria. The numeric rankings contain a number, one through five (1-5), five being the most desirable, and one being the least.

Example:

A BMP with a ranking of 5 in the row labeled “Detention” offers greater capability for stormwater detention than does a BMP with a ranking of 1 in the row labeled “Detention”

BMP SCORING MATRIX

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		NATIVE VEGETATION PRESERVED OR ESTABLISHED	RAIN GARDEN	INFILTRATION BASIN	INFILTRATION TRENCH	BIO-RETENTION BASIN	PERVIOUS PAVEMENT	EXTENDED DETENTION WETLAND	WETLAND SWALE	BIO-SWALE	SURFACE SAND FILTER	UNDERGROUND SAND FILTER	POCKET SAND FILTER	PERIMETER SAND FILTER	EXTENDED WET DETENTION BASIN	EXTENDED DRY DETENTION BASIN	NATIVE VEGETATION SWALE	TURF GRASS SWALE	HYDRODYNAMIC SEPARATOR	CATCH BASIN INSERT
1	AREA REQUIRED FOR BMP (MIN.)	NO MIN.	NO MIN.	NO MIN.	NO MIN.	25' X 40' MIN.	NO MIN.	NO MIN.	2' WIDTH MIN.	2' WIDTH MIN.	NO MIN.	NO MIN.	NO MIN.	NO MIN.	NO MIN.	NO MIN.	100' LENGTH MIN., 2' WIDTH MIN.	2' WIDTH MIN.	PER MANUFACTURER	PER MANUFACTURER
2	DRAINAGE AREA LIMITATIONS	NONE	4 ACRE MAX	2 ACRE MAX	2 ACRE MAX	4 ACRE MAX	3 X BMP AREA	NONE	5 ACRE MAX	NONE	5 ACRE MAX	1 ACRE MAX	5 ACRE MAX	1 ACRE MAX	2 ACRE MIN.	NONE	5 ACRE MAX	5 ACRE MAX	PER MANUFACTURER	PER MANUFACTURER
3	BMP AREA AS PERCENT OF DRAINAGE AREA (MIN.)	N/A	30% MIN.	12% MIN.	24% MIN	UP TO 15%	33% MIN	8% MIN	12% MIN.	12% MIN.	3% MIN.	3% MIN.	3% MIN.	3% MIN.	VARIES W/ DEPTH	VARIES W/ DEPTH	VARIES W/ SLOPE & WIDTH	VARIES W/ SLOPE & WIDTH	VARIES	VARIES
4	PROXIMITY TO STRUCTURES	ANY	10' MIN.	10' DOWNHILL,100' UPHILL	10' DOWNHILL,100' UPHILL	10' MIN.	10' DOWNHILL,100' UPHILL	10' DOWNHILL,100' UPHILL	10' DOWNHILL,100' UPHILL	10' DOWNHILL,100' UPHILL	10' MIN	ANY	10' MIN	ANY	10' DOWNHILL,100' UPHILL	10' DOWNHILL, 100' UPHILL	10' MIN	ANY	ANY	ANY
5	PREFERENCE FOR SHEET OR CONCENTRATED FLOW	SHEET	SHEET (UNLESS ENERGY DISSIPATOR)	EITHER	EITHER	EITHER	SHEET	EITHER	EITHER	SHEET (UNLESS ENERGY DISSIPATOR)	EITHER	CONCENTRATED	EITHER	SHEET	EITHER	EITHER	EITHER	SHEET (UNLESS ENERGY DISSIPATOR)	CONCENTRATED	CONCENTRATED
6	PERMANENT OR LONG TERM POOL	NONE	SHORT TERM, SHALLOW	NONE	NONE	SHORT TERM, SHALLOW	NONE	LONG TERM	LONG TERM	SHORT TERM, SHALLOW	NONE	NONE	NONE	NONE	PERMANENT	LONG TERM	SHORT TERM	NONE	NONE	NONE
7	WELL DRAINED OR POORLY DRAINED SOILS	ANY	WELL DRAINED	ANY (UNDERDRAIN)	WELL DRAINED	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (OUTLET)	ANY (OUTLET)	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (UNDERDRAIN)	ANY (MAY NEED LINER)	ANY	ANY	ANY	ANY	ANY
8	DRAINAGE AREA: PERVIOUS, IMPERVIOUS OR BOTH	EITHER	EITHER	EITHER	EITHER	EITHER	IMPERVIOUS	EITHER	EITHER	EITHER	EITHER	IMPERVIOUS	EITHER	IMPERVIOUS	EITHER	EITHER	EITHER	EITHER	IMPERVIOUS	IMPERVIOUS
	DETENTION	3	2	3	2	2	3	5	3	3	2	2	2	2	5	5	2	1	1	1
	VOLUME REDUCTION	3	4	3	5	3	2	3	3	2	2	2	2	2	3	2	2	1	1	1
	THERMAL REDUCTION	3	5	5	5	5	3	4	4	3	3	2	3	2	3	2	3	2	1	1
	TSS REMOVAL	3	5	4	4	4	5	5	4	4	5	5	5	5	5	3	4	4	3	4
	COMPATIBLE WITH EXISTING STORMWATER INFRASTRUCTURE	5	5	4	5	4	4	4	4	4	4	2	4	2	3	3	4	4	2	5
	AESTHETICS	5	5	4	3	4	1	4	4	4	4	1	4	1	4	2	4	3	1	1
	CONSTRUCTION COST	M	L	M	L	M	H	H	M	M	M	H	M	H	H	M	L	L	H	M
	MAINTENANCE COST	L	L	L	M	M	L	L	L	L	L	M	L	M	L	M	L	M	M	M
	COST PER AREA TREATED	H	M	M	H	L	M	L	L	L	L	H	L	H	L	L	L	L	H	H

RANKING 1-5 WHERE 5 IS MOST DESIRABLE, 1 IS LEAST DESIRABLE

H = HIGH, M = MODERATE, L = LOW

VALUES FOR THIS TABLE WERE ADAPTED FROM THE CITY OF COLUMBIA, MISSOURI, STORMWATER MANAGEMENT AND WATER QUALITY MANUAL AS WELL AS INFORMATION FROM THE UNITED STATES EPA NATIONAL MANAGEMENT MEASURES TO CONTROL NONPOINT SOURCE POLLUTION FROM URBAN AREAS, EPA-841-B-05-004

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