Nine Critical Element Plan for the Spencer Creek Watershed

CITY OF ST. PETERS, MISSOURI

BLACK AND VEATCH
8/1/2012

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Report Summary

This Nine Critical Element Plan for the Spencer Creek Watershed will be used for improving water quality and continuing compliance with Missouri Department of Natural Resources Municipal Separate Storm Sewer Systems (MDNR MS4) regulations. Preliminary investigations have evaluated the existing conditions of the City's open-channel stormwater infrastructure based on hydrologic and hydraulic modeling, field reconnaissance, water quality modeling, and review of relevant policies at the City, State, and Federal levels.

Spencer Creek drains about 5600 acres of some of the most highly developed areas in the watershed. It flows through a developed urban area of residential neighborhoods with traditional wide streets, curb and gutter drainage and passive flood control structures and through commercial areas with a high percentage of impervious area. Spencer Creek suffers, as do so many urban streams, from high runoff during relatively low intensity storm events.

The Spencer Creek Watershed is 94% contained within the City boundaries of St. Peters, Missouri. Spencer Creek is a tributary of Dardenne Creek, which flows directly to the Mississippi River approximately 5 miles downstream of the confluence with Spencer Creek.

Hydrologic and Hydraulic Modeling

The City's current stormwater master plan, completed in 2002, included computer models developed at a level of detail suitable for master planning. The 2002 study identified flooding and erosion problems within the City's watersheds, and provided conceptual improvements to alleviate the defined problems. In 2007, the USACE St. Louis District completed a study of the entire Dardenne Creek watershed. Both the 2002 and 2007 studies were referenced during the analysis of existing conditions.

The HEC-HMS model developed by the USACE St. Louis District was used as the basis for hydrologic modeling of the watersheds within and around St. Peters. The detention basins selected through a screening process were incorporated into the USACE hydrology model to allow the opportunity to gage effectiveness, model detention basin improvements, and evaluate downstream erosion effects. The methodology developed by the USACE St. Louis District was maintained for the hydrologic analysis of this watershed study and modifications to the model were limited to the addition of detention basins.

To evaluate open channel hydraulics, the HEC-RAS model developed by the USACE St. Louis District in 2007 was refined to represent the most current topographic information within the City limits. The USACE 2007 was based on a 3D terrain model created with digital orthophotos. The 2007 study model was based on additional data including limited bridge and culvert drawings, previous hydraulic models, rainfall and streamflow data, land use and soil maps, and other GIS data. Black & Veatch evaluated the existing model to establish continuity of peak flows, determine extents, and identify modeling constraints within the city limits. The review of the 2007 hydraulic model produced several concerns described in this report. For this study, Black & Veatch refined the 2007 HEC-RAS hydraulic model to represent the most current topographic information within the City limits, based on LiDAR data collected in 2008.

Flooding

Based on the updated hydraulic modeling, the area of inundation was established for the revised existing conditions model during the 100-year event. The results of the 2007 USACE hydraulic model were compared to the results of the updated model. On average, there was less than one foot of change in 100-year water surface elevation between the revised existing conditions model and the original 2007 USACE model. Typically, the water surface elevation decreased. There were, however, significant differences between the areas of inundation and the updated FEMA floodplain maps.

Stream Stability and Habitat

In April and May, Black & Veatch and PBA staff joined the City to evaluate stream stability and habitat within the City limits. As a team, Black & Veatch and PBA conducted a geomorphology and stream health field survey of the 47 miles of streams in the City of St. Peters, including 19 miles located in the Spencer Creek Watershed. The team applied standards developed by the Kansas City Metropolitan Chapter of American Public Works Association and the United States Department of Agriculture to evaluate stream stability throughout the City.

A majority of the stream network in St. Peters was documented to be incised, as described in the 2002 watershed study. Channel incision is a response to changes in the hydrology of the contributing drainage area as well as to changes in channel bed materials and downstream conditions. The stream network within the City limits has varying levels of stability and incision. The downstream ends of the main tributaries to Spencer Creek, West Spencer and East Spencer, have already experienced changes in structure and are now very incised. In these streams, further incision is likely to occur due to a small low flow channel cutting into the hard clay bed that was documented in the field. Grade control structures, such as rock checks, are recommended for many of these reaches experiencing incision. Reaches higher up in the watershed have very steep profiles and debris jams of roots or other material were often found to provide temporary vertical grade control.

Water Quality

The P8 model was used to predict pollutant removal efficiencies for each of the selected stormwater detention basins. The model simulated the generation and transport of stormwater runoff pollutants in the watersheds contributing to the detention basins. The simulations were driven by continuous hourly rainfall based on ten years of data recorded at the Lambert International Airport provided by the National Climatic Data Center.

Policies

This study provides a summary existing policies, ordinances, and design criteria. It also identifies regulations and other factors that may influence future policies and identifies preliminary recommendations for updating and adopting polices to meet regulations and achieve the goals for storm water management in St. Peters. The recommendations to the City's stormwater policies are suggested in the following areas: 1) Best Management Practices, 2) Low Impact Development, 3) Stream

Setbacks, 4) FEMA Community Rating System, 5) Street Sweeping, 6) Sediment and Erosion Control, 7) Homeowner Drainage Issues, and 8) Education and Awareness.

CIP

This study resulted in the development of over 100 projects with a total cost of $125,000,000. In the Spencer Creek Watershed, the CIP included 46 projects with a total cost of $50,000,000. These projects are located throughout the City and are classified as flooding, stream stability, detention, or preservation projects. Some projects are multi-functional and are associated with two or more of these categories. A comprehensive approach to solving stormwater-related concerns will include projects that are rated with a high priority score, projects that have a low cost benefit ratio and projects that preserve the City's existing resources.

Maps are provided in Appendix A.

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1. Introduction

In August 2010, St. Peters received approval from its voters to develop a master storm water management plan that addresses water quality issues in the watersheds throughout St. Peters, including those that flow to Dardenne Creek. The plan is a major assessment of water pollution sources and loadings from the City and provides a blueprint for projects and best management practices (BMPs) to address storm water management, reduce pollutant loading, and improve water quality. Once the planning process is complete, voters have authorized the City to spend up to $40 million over the next 20 years or more to implement the required projects.

This Nine Critical Elements Plan builds upon the efforts undertaken to complete the Master Stormwater Management Plan. This plan focuses on Spencer Creek, which is a major tributary to Dardenne Creek located in St. Peters as shown on Figure 1. Refer to Appendix A for larger maps.

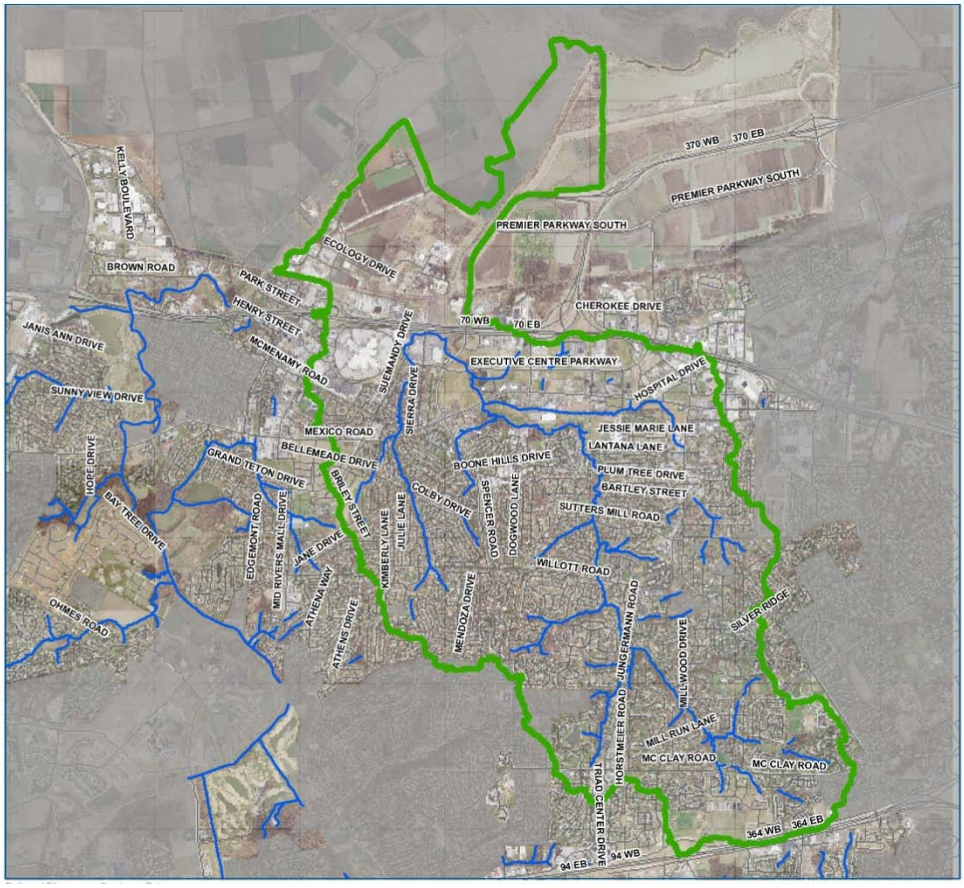

FIGURE 1. SPENCER CREEK WATERSHED AND STREAM NETWORK

1.1 Goals and Objectives

This Nine Critical Element plan for Spencer Creek identifies pollution sources and provides strategies and practices to improve water quality and stream stability developed through the nine-element planning process. The next step in the process will be to engage the City's previous partner, the Great Rivers Greenway District and the owners of the largest retail shopping development, Mid Rivers Mall, to assist in efforts and public outreach and education and to expand the planning process to the entire Dardenne Creek watershed.

Since Dardenne Creek spans many jurisdictions in St. Charles County, the City will work with other entities in the watershed to incorporate the findings and recommendations of this plan into comprehensive strategies for the entire Dardenne Creek Watershed. This plan will be a blueprint for improving water quality with Dardenne Creek and will include significant efforts to assess the amounts and sources of pollutant loading, practices necessary to reduction pollutant loads to targeted levels, costs and sources of funding, public education and outreach, public education and outreach, measures of load reductions, a monitoring plan and the other elements of a comprehensive watershed management plan.

1.2 Spencer Creek Watershed

Spencer Creek drains about 5600 acres of some of the most highly developed areas in the watershed. It flows through a developed urban area of residential neighborhoods with traditional wide streets, curb and gutter drainage and passive flood control structures and through commercial areas with a high percentage of impervious area. Spencer Creek suffers, as do so many urban streams, from high runoff during relatively low intensity storm events.

The Spencer Creek Watershed is 94% contained within the City boundaries of St. Peters, Missouri. Spencer Creek is a tributary of Dardenne Creek, which flows directly to the Mississippi River approximately 5 miles downstream of the confluence with Spencer Creek.

Interstate 70 intersects Spencer Creek in its downstream reach, and forms a major division in land use. In Spencer's upper reaches, the predominant land use is single-family residential with interspersed parks and some small pockets of commercial as shown on Figure 2. These areas, immediately South of Interstate 70 and within Spencer Watershed North of Interstate 70, are best characterized as commercial/industrial. The watershed is completely developed, with only small pockets of open development.

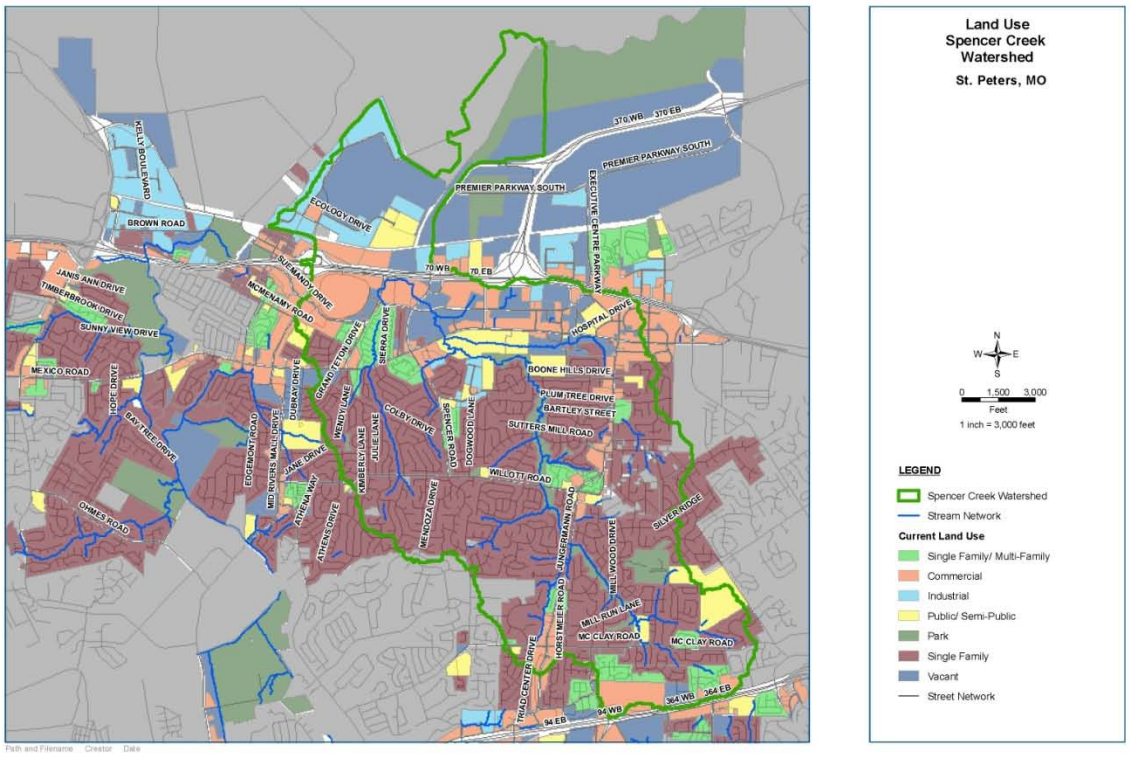

FIGURE 2. CURRENT LAND USE IN SPENCER CREEK WATERSHED

The watershed hydrologic soil classification is predominantly 'B' throughout the watershed south of Interstate 70, with hydrologic soil classifications 'C' and 'D' north of Interstate 70. Figure 3 shows the types of soils in the watershed. Refer to Appendix A for larger maps. The Spencer Creek study area is typical of St. Peters, Missouri, a developed low density urban area. It is characterized by a low percentage of permeable surface and large runoff volumes under relatively small rain events. The watershed is presumed to contain typical urban/residential pollutants such as sediment, chlorides, pesticides and nutrients and high oxygen demand. It is a major tributary to the Dardenne Creek which runs through much of St. Charles County. The Missouri Department of Natural Resources lists Dardenne Creek as impaired for low dissolved oxygen on the 303(d) list.

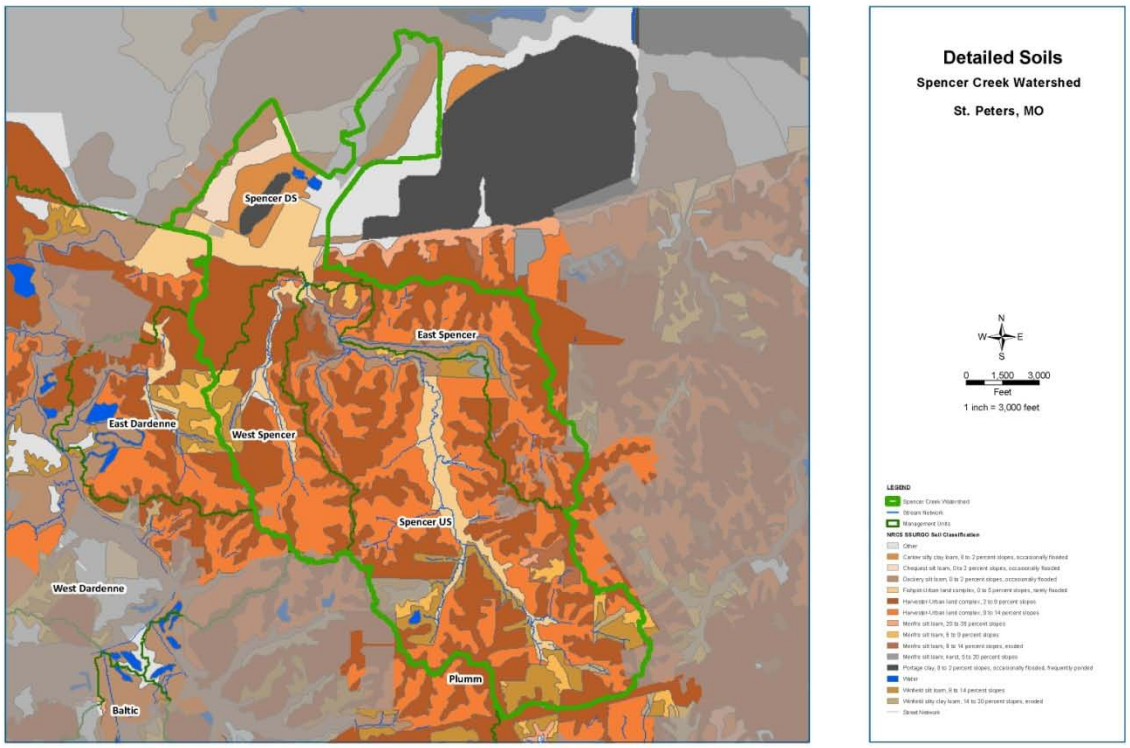

FIGURE 3. SOIL TYPES IN SPENCER CREEK WATERSHED

Figure 4 shows the streams in Spencer Creek and the limits of the 100-year FEMA floodplain.

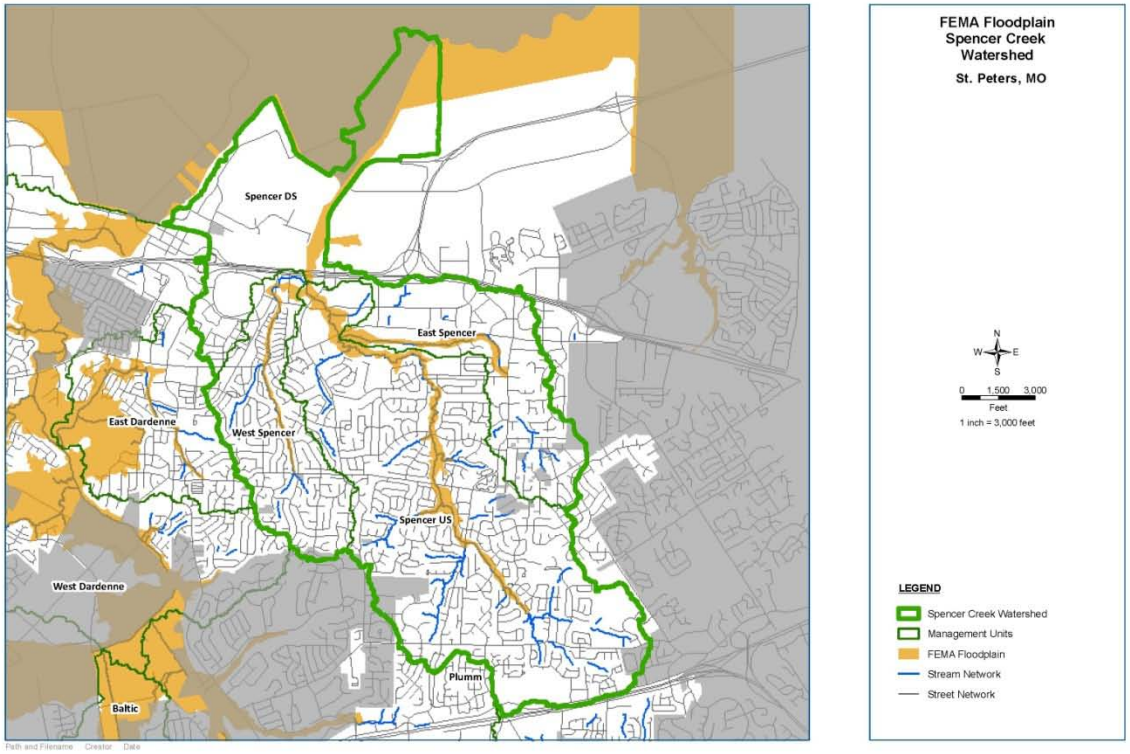

FIGURE 4. FEMA FLOODPLAIN, SPENCER CREEK WATERSHED

A majority of the stream network in St. Peters was documented to be incised, as described in the 2002 watershed study. Channel incision is a response to changes in the hydrology of the contributing drainage area as well as to changes in channel bed materials and downstream conditions. The stream network within the City limits has varying levels of stability and incision. The downstream ends of the main tributaries to Spencer Creek, West Spencer and East Spencer, have already experienced changes in structure and are now very incised. In these streams, further incision is likely to occur due to a small low flow channel cutting into the hard clay bed that was documented in the field. Grade control structures, such as rock checks, may be used to arrest further vertical incision. Reaches higher up in the watershed have very steep profiles and debris jams of roots or other material were often found to provide temporary vertical grade control.

Spencer Creek has experienced significant erosion and downcutting with banks 10 to 12 feet high in some areas.

FIGURE 5. EXAMPLE OF HIGH BANK EROSION IN SPENCER CREEK WATERSHED

2. Current Conditions

2.1 Physical Description

The City of St. Peters, Missouri has a population of approximately 57,000 and encompasses approximately 22 square miles. The City owns, operates and maintains over 166 miles of storm sewer pipe and associated structures, as well as three pump stations. The City contains more than 47 miles of waterway, 55 stream/roadway crossings, 43 wet retention basins and 207 dry detention basins. The majority of the City is situated in the Dardenne Creek Watershed, a 29 mile long basin that covers approximately the middle third of St. Charles County and drains to the Mississippi River. The primary subwatershed in St. Peters is Spencer Creek. Others identified by the Corps of Engineers include East Dardenne, Sandfort Creek, and un-named Tributaries No. 1 and No. 2. A small portion in the southeast of St. Peters drains to the Missouri River.

St. Peters lies on the boundary of the Glaciated Plains physiographic region which covers most of the State north of the Missouri River. The topography consists of rolling hills dissected by streams. Soils in this area are “glacial till” which consists of clay, silt, sand, gravel and boulders in widely varying amounts. “The glacial till of northern Missouri has a low permeability, therefore, infiltration is low and runoff is rapid” (1).

FIGURE 6. LAND TYPES, STATE OF MISSOURI

2.2 Existing Policy Framework

This section briefly summarizes existing policies, ordinances, and design criteria; identifies regulations and other factors that may influence future policies; and identifies preliminary recommendations for updating and adopting polices to meet regulations and achieve the goals for storm water management in St. Peters.

2.2.1 Existing Ordinances and Regulations

The City’s current existing ordinances and regulations provide for management of storm water. State and federal regulations also impact storm water management.

Current City Storm water Management Regulations

Existing ordinances and standards that address storm water and flood risk management in the City are briefly summarized below.

- Chapter 410 – Floodplain Management. Criteria in this section are consistent with FEMA requirements and limit development in the 100-year floodplain.
- Chapter 530 – Grading Regulations. These regulations require a permit when development will grade more than 300 cubic yards, or 20,000 square feet and are in general consistent with MDNR requirements.
- Chapter 550 – Storm Sewer and Drainage Facility Guidelines. A storm water management plan is required for every development under these guidelines sized for the 15-year, 20 minute design storm. These guidelines also require detention if runoff is increased by 15 % or more as a result of development. A 25 foot setback from streams is also required.
- Standards for Erosion and Sediment Management Practices, January 2001. This document provides design criteria for many erosion and sediment control best management practices. Many additional effective best management practices have been developed since 1991.

- Chapter 550 references "Standard Construction Specifications for Sewers and Drainage Facilities of the Metropolitan St. Louis Sewer District," 1992 and Chapter 4 "The Metropolitan St. Louis Sewer District – Rules and Regulations and Engineering Design Requirements for Sanitary Sewage and Storm Water Drainage Facilities", February 1997. Both of these documents have been updated.

State Stormwater Management Regulations

Construction Site Runoff Controls

The MDNR storm water regulations for Construction or Land Disturbance Activity MO-R101000 and MO-R100000 for existing sites and M0-R10A000 for new sites address construction site runoff controls. These permits are valid through February 7, 2012. The City's existing ordinance and design standards appear to address these requirements. However, newer design criteria are available that expand the number of BMPs that can be used to limit sediment from being discharged. These new design criteria are available in the following document: Protecting Water Quality: A field guide to erosion, sediment and storm water best management practices for development sites in Missouri and Kansas, January 2011.

Stormwater Discharge Permit

The MDNR storm water regulations for discharge from the Municipal Separate Storm Sewer System MO-R040044 (MS4 Permit) require that the storm water management program address the six minimum control measures. This permit is in effect until June 12, 2013.

Control measure 5 requires implementation of post construction storm water management in new development and redevelopment. From the permit, "prevent or minimize water quality impacts by reasonably mimicking pre-construction runoff conditions on all affected new development projects and by effectively utilizing water quality strategies and technologies on all affected redevelopment projects

to the maximum extent practicable". The City's existing design criteria require predevelopment peak flows to be managed for 2-year and 25-year design storms. The largest impact on water quality resulting from runoff is from more frequent events.

Federal Stormwater Management Regulations

EPA expects to publish new storm water regulations by the end of 2012 as result of the Natural Resources Commission study and report on the effectiveness of the current storm water regulations. Key findings and recommendations from that report are listed below.

Key findings of NRC report

- Current approach is unlikely to produce an accurate picture of the problem and unlikely to adequately control storm water's contribution to water body impairment
- Current requirements leave a great deal of discretion to dischargers to set their own standards and ensure compliance, which results in inconsistency across the nation
- Poor accountability and uncertain effectiveness in current approach to stormwater management

Key Recommendations

- A straightforward way to regulate storm water contributions to water body impairment would be to use flow or a surrogate like impervious cover as a measure of storm water loading
- Efforts to reduce storm water flow will automatically achieve reductions in pollutant loading. Moreover, flow is itself responsible for additional erosion and sedimentation that adversely impacts surface water quality
- Stormwater control measures that harvest, infiltrate and evapo-transpire storm water are critical to reducing the volume and pollutant loading of small storms

3. Watershed Assessment

3.1 Geomorphic Assessment of Existing Conditions

In April and May 2011, Black & Veatch and PBA staff joined the City to evaluate stream stability and habitat within the City limits. As a team, Black & Veatch and PBA conducted a geomorphology and stream health field survey of the 47 miles of streams in the City of St. Peters. The team applied standards developed by the Kansas City Metropolitan Chapter of American Public Works Association and various state and federal natural resource agencies. The field assessment data was used to characterize each reach of the stream network with a rating that reflects the level of stability.

3.1.1 Channel Condition Scoring Matrix

Black & Veatch applied a scoring matrix based on the APWA 5600 Channel Condition Scoring Matrix (CCSM) to determine the stability of stream reaches throughout the City. The CCSM indices used include the channel geometry, bank slope stability, streambed and bank material composition, and erosion issues. Existing channel bed and bank geometry was established using the LiDAR data. Stream bank and bed material were evaluated based on soil texture, sediment composition, consolidation, armoring

materials, and vegetative protection. Bank cutting, mass wasting, and excessive sediment deposition in localized areas were recorded. At select locations, existing riparian vegetation was documented. For each channel reach, the score of the indicator and the weighted rating for the stream were compiled in a GIS database.

The matrix provides a comparative score of reaches throughout the City and was used to identify areas of significant instability and to prioritize projects. The resulting score was divided into three groups that range between 10 and 25. A rating of 13 or less indicates a stream of moderate stability and may require only standard levels of protection during construction. A rating between 13 and 19 indicates limited instability and special measures may be needed to address specific issues that were rated poorly (i.e. debris jam). A rating that is greater than 19 indicates that the stream may be experiencing significant system-wide instability.

3.1.2 Stream Asset Inventory

The SAI methodology provided rapid and scientifically defensible indicators of water quality, stream stability, and habitat conditions at a given location that is selected to be representative of a larger stream reach. Assessment criteria of the SAI include erosion indicators; bed and bank composition; aquatic habitat features; tree canopy and understory coverage and composition; and indirect water quality indicators (visible or detectable degradation and presence/absence of aquatic life). The assessment criteria are assigned individual weighted scores to create a composite score of stream quality at each sampled location and a relative ranking of stream quality throughout the entire watershed.

Sample locations were selected in the field based on preliminary map assessments, the assessor's professional judgment, as well as accessibility and ability to observe as many assessment criteria as practical. Data was collected at least 100 feet from major human-made influences if possible (such as roads, bridges and culverts), as past experience indicates that these localized features negatively bias the assessment results. Some stream reaches smaller than 4th order streams were not sampled due to insufficient reach length necessary for sampling. Finally, the SAI procedure is not intended for ephemeral streams or man-made channels. In other locations not all components were observable (as described below), but data were collected if the locations otherwise met assessment criteria. PBA staff completed a survey checklist at 120 locations, or approximately every 3/8th stream mile, which exceeded the recommended data density of at least one survey point every stream mile.

The SAI procedure has four major categories with each category composed of five scoring components. Each component has a maximum potential score of 10 which creates a possible total SAI score of 200. By dividing the total SAI score by 20 (or by the number of measured components), the assessment provides a qualitative numerical score ranging from 0.0 to 10.0. A score of 10.0 would be considered optimal stream conditions while a score of 0.0 would indicate poor stream conditions. Some components were not applicable or observable in certain situations, and if so, the evaluation team did not assess that component. The final sampling point Total Score was calculated by dividing the sum of all four SAI categories by the number of components observed at that sampling location. For example,

where bed composition could not be observed due to high flows or turbid conditions, no points are assigned for the bed composition component and the total site score was divided by 19 rather than 20.

As detailed above in the methodology, stream reaches were assigned a composite score from 10.0 to 0.0 and were classified Type 1 (highest quality - 10.0) through Type 5 (lowest quality - 0.0) based on the statistical distribution of all study data. For example, a Type 3 stream score falls one standard deviation above or below the mean score, a Type 2 stream scores more than one standard deviation above the mean, etc. Stream segments were classified into five types:

> Type 1 - Highest Quality: Generally described as the highest quality naturally occurring stream with little negative impact. Erosion and sedimentation is low, water quality indicators are positive and the surrounding riparian zone is healthy, mature woodland or other high-quality environment.
>
> Type 2 - High Quality: This type of stream may have some down or side-cutting; however, bank and bed composition (bedrock) assist in keeping the impact low. Water quality is generally good and the riparian zone is largely intact, although vegetation may be negatively altered from that of a typical native plant association.
>
> Type 3 – Restorable: Deterioration of the channel and riparian corridor are more noticeable. While some remnant plant associations may be present, overall vegetative canopy cover is comprised of immature tree species. Water quality may be fair to marginal. The potential for restoration exists although erosion and sedimentation can be greater than desirable.
>
> Type 4 - Low Quality: Impacts are greater on this stream type with significant indicators of bank erosion and channel instability. The adjoining riparian corridor may be intact but vegetation is not representative of a native plant association. Water quality is typically poor.
>
> Type 5 - Lowest Quality: The channel in this type is the most changed. The riparian corridor is impaired to the point of providing little protection or benefit, and erosion and sedimentation indicators are significantly high. Water quality is poor with degradation and absence of macro-invertebrates, fish, mollusks, and amphibians.

The surveyed stream segments were classified relative to the sample population of surveyed streams, rather than applying an absolute score. The relative ranking is used for several reasons: (1) Scoring streams on an absolute scale may imply that the break points between classes are based on some quantitative linkage between the score and stream function, which is not the case; (2) Streams should be classified in comparison to general, regional conditions so that streams are assigned scores reasonable for their physiographic and development settings; and (3) relative distribution allows the assessor to identify the truly high-quality and low-quality streams within the study area.

3.2 Watershed Vulnerability Analysis

This section is taken from the MDNR Total Maximum Daily Load Information Sheet, Dardenne Creek, revised June 2004.

Spencer Creek is a tributary of Dardenne Creek. Beneficial uses of Dardenne Creek include livestock and wildlife watering, protection of warm water aquatic life, protection of human health associated with fish consumption, boating, and canoeing. The Missouri Department of Natural Resources (MDNR) has determined that Dardenne Creek is impaired for protection of water aquatic life. All water bodies in Missouri are protected by the *general* criteria (standards) contained in Missouri's Water Quality Standards (WQS), 10 CSR20-7.031(3). These criteria (also called *narrative* criteria) list substances that all waters "shall be free from". For example, points (3)(A), (C) and (G)state:

- Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses.
- Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses.
- Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community.

3.2.1 Background Information and Water Quality Data

The U. S. Environmental Protection Agency (EPA) placed Dardenne Creek on the 2002 303(d) list for unknown pollutants. EPA believes that the results and conclusions from the studies conducted by the Department of Natural Resources between 1998 and 2000 (see Tables 1 and 2 below) adequately demonstrate that Dardenne Creek is impaired. Aquatic Invertebrate sampling by the department in the spring of 2000 and the spring and fall of 2002 indicates poor water quality and/or poor aquatic habitat conditions in much of Dardenne Creek. This data is summarized in Table 1. The invertebrate scores used in this table compare the invertebrate community of the stream to the invertebrate community in a reference (high quality) stream in the same area of the state. Scores of 20-16 indicate a healthy invertebrate community.

TABLE 1. INVERTEBRATE SCORES AND PERCENT FINE SEDIMENT DEPOSITION IN DARDENNE CREEK

	Dardenne Creek upstream of Busch CA	**Dardenne Creek in Vicinity of Busch CA**	**Dardenne Creek Downstream of Highway 40**
Invertebrate Score Spring 2000	10-14	16-20	0-8
Invertebrate Score Spring 2002	8-12	14	
Invertebrate Score Fall 2002	10-16	16	
% Fine Sediment Deposition	23-71	70-100	

The poorer invertebrate scores below Highway 40 probably reflect the problems related to urbanization of that portion of the watershed. Results of cooperative water quality monitoring program of Dardenne Creek by the Departments of Natural Resources and Conservation are summarized below.

TABLE 2. MEAN WATER QUALITY DATA FOR DARDENNE CREEK 1998-2003

	Holt Rd.	**Hwy Z**	**Hopewell Rd.**	**Hwy DD**	**At Busch CA**	**Hwy N**	**Hwy C**
Water Temp, C	16	20	17	14	21	20	17.5
Dissolved Oxygen (mg/L)	11.9	7.1	10.3	8.6	7.0	8.2	9.4
Conductivity (umhos/cm)	440	414	290	339	334	389	445
Organic+NH3N (mg/L)		0.48	0.69	0.36	0.62	0.98	1.08
NH3N (mg/L)	<0.05	0.06	0.13	<0.05	<0.05	<0.05	<0.05
NO2-NO3N	0.35	0.17	0.47	0.23	0.22	0.25	0.42
Total Phosphorus (mg/L)	0.03	0.08	0.13	0.08	0.11	0.18	0.17
Volatile Susp. Solids (mg/L)		3.7	5.8		7.6		
Turbidity (NTU)		19.5	30		39.6		
Fecal Coliform Bacteria (col./100 mL)			59		104	145	394

Source: MDNR and Missouri Department of Conservation

Over the last several years, Missouri Volunteer Quality Monitoring monitors have been collecting data at nine sites along Dardenne Creek (see map below). In an effort to better understand the stream, the last three years of available volunteer data have been compiled and summarized (see table below). Volunteers sampled the creek for temperature (C°), dissolved oxygen (DO), biological oxygen demand (BOD), nitrates (NO3), ammonia (NH3), phosphate (PO4), specific conductance (SC), total solids (TS), total dissolved solids (TDS), turbidity (TURB), pH, and fecal coliform (FC). Missouri Water Quality Monitoring Volunteer Macroinvertebrate Water Quality Ratings (WQRate) were also included and are an indication of the diversity of macroinvertebrates present. The results of this sampling are discussed below.

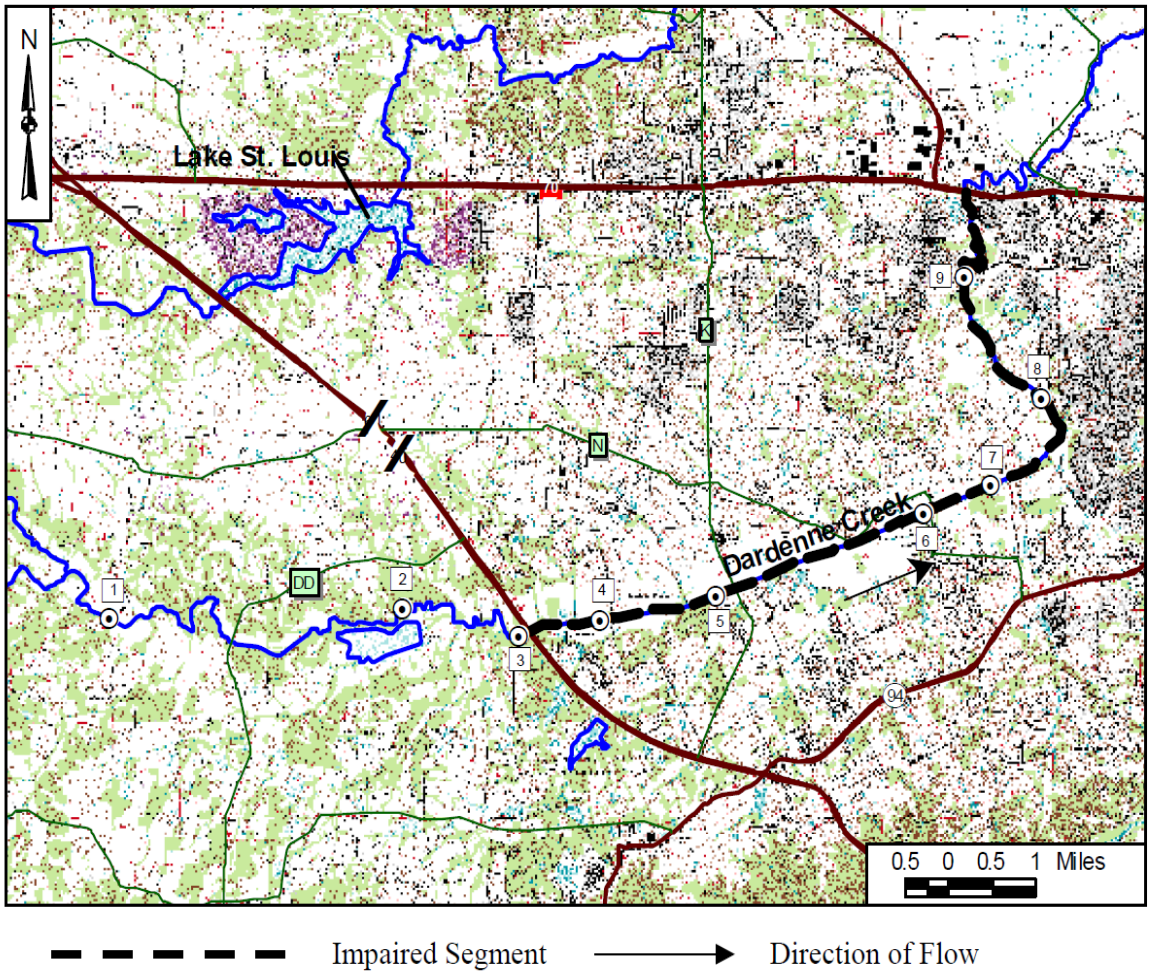

FIGURE 7. MISSOURI WATER QUALITY VOLUNTEER SAMPLING SITES

TABLE 3. RESULTS OF VOLUNTEER WATER QUALITY MONITORING: MEAN WATER QUALITY DATA

Location	WQ Rating	Temp C	DO mg/L	BOD mg/L	NO_2 mg/L	NH_3 mg/L	PO_4 mg/L	SC us	TS mg/L	TDS mg/L	TURB NTU	pH* us	FC** Cfu
1.Hopewell Road	26							469	802.9	176	8.8		
2. Busch Conservation Area		8.3	8.4	4.5	0.36	0.52	0.49	337			37.2	7.2	99
3. Highway 40	21	9.2	8.7	3.0	0.34	0.65	0.79	406	358.0		8.9	7.7	84
4. Henning Road		12.8	9.8	1.5	0.14	0.57	0.86	390			10.8	7.7	33
5. Highway K		9.3	7.0	3.0	1.79	0.75	0.29	630	270.6	242	22.5	7.7	203
6. Highway N		11.1	7.4	6.8	0.72	0.79	1.07	448	1108.0		22.7	7.5	20
7. Upstream of Mid-Rivers Mall	18.5	9.4	9.8	7.0	0.30	0.38	0.50	362	24.0		37.5	8.0	580
8. Downstream of Mid-Rivers Mall		9.3	9.2	4.2	0.24	0.22	0.5	498	232.0		22.6	7.8	227
9. Mexico Road		10.4	9.7	4.7	0.20	0.47	0.68	447			110.5	7.2	352
* Median Value, ** Geometric Mean													

Note: Data provided by Missouri Volunteer Water Quality Monitoring Program. Source: MDNR TMDL Information Sheet for Dardenne Creek, Revised 10/2011.

3.2.2 Water Quality Rating

Volunteer Water Quality Invertebrate Ratings were given at three sites, and a declining trend can be seen in a downstream direction. The Water Quality Rating at Hopewell Road in 2001 was 26, a score that indicates excellent water quality. The Water Quality Rating at Highway 40 in 2001 was 21, indicating relatively good water quality. Water Quality Ratings were given upstream of Mid-Rivers Mall in 1998 and 2001. In 1998, the score was 16, indicating fair water quality, but the Water Quality Rating at the same site in 2001 was 21, similar to the score at Highway 40. This Water Quality Rating is rather forgiving, and the limited amount of ratings makes it difficult to pinpoint a particular problem.

MISSOURI WATER QUALITY STANDARDS

According to the Dardenne Creek TMDL Information Sheet, produced by MDNR, inorganic sediment was delisted on October 6, 2011 as a pollutant of concern for Dardenne Creek. Low dissolved oxygen remains an issue and TMDL development is scheduled for 2016.

3.3 Resource Inventory

3.3.1 GIS Modeling

The application of geo-spatial databases is an efficient approach to asset management. The ESRI ArcView GIS was integrally related to the progress of this study and the development of the products. This section describes the GIS deliverables that result from this study and a GIS process used to determine optimal locations for stormwater BMPs.

A water quality best management practices (BMP) locator assessment was completed for the watersheds located within the City. The objective was to assess and classify the relative value of land for capturing, storing, and infiltrating stormwater runoff; and to identify vacant land that could be used to construct new water quality BMPs if desired to meet the City's stormwater management objectives. The following sections document the BMP locator process and summarize the inventory results.

The basic principal for the environmental sensitivity index (ESI) comes from the weighted factor overlay technique by Ian McHarg (1992). In GIS, the weighted overlay is done with numeric combinations of factor values that produce results which are good for spatial and statistical analysis, and map visualization. In the St Peters ESI model, 14 factors were combined into five categories for analysis: soils, hydrology, surface cover, topography, and social value.

After completing this initial analysis, the following additional analyses were completed to identify locations that are actually feasible for consideration as future BMP locations.

1. Surface flow patterns were analyzed using the DEM, and screened out parcels that are not on significant flow lines.
2. The analysis isolated parcels that are either public, semi-public, or institutionally owned, and privately owned vacant parcels that could potentially be acquired for BMP creation (either for this project, or future projects). This subset of parcels was then sorted by size to help categorize each opportunity's relative potential benefit into tiers. The tiers were: less than 2 acres; 2 to 10 acres; 10 to 40 acres; and greater than 40 acres.

In St. Peters, Missouri, high stormwater BMP suitability exists where soil, hydrologic, and vegetative systems overlay in a distinctive dissected, dendritic landscape matrix pattern with upland connections through suburban open space, roadways, and linear easements.

The data resulting from this analysis is shown on Figure 8 and provided in the GIS deliverable.

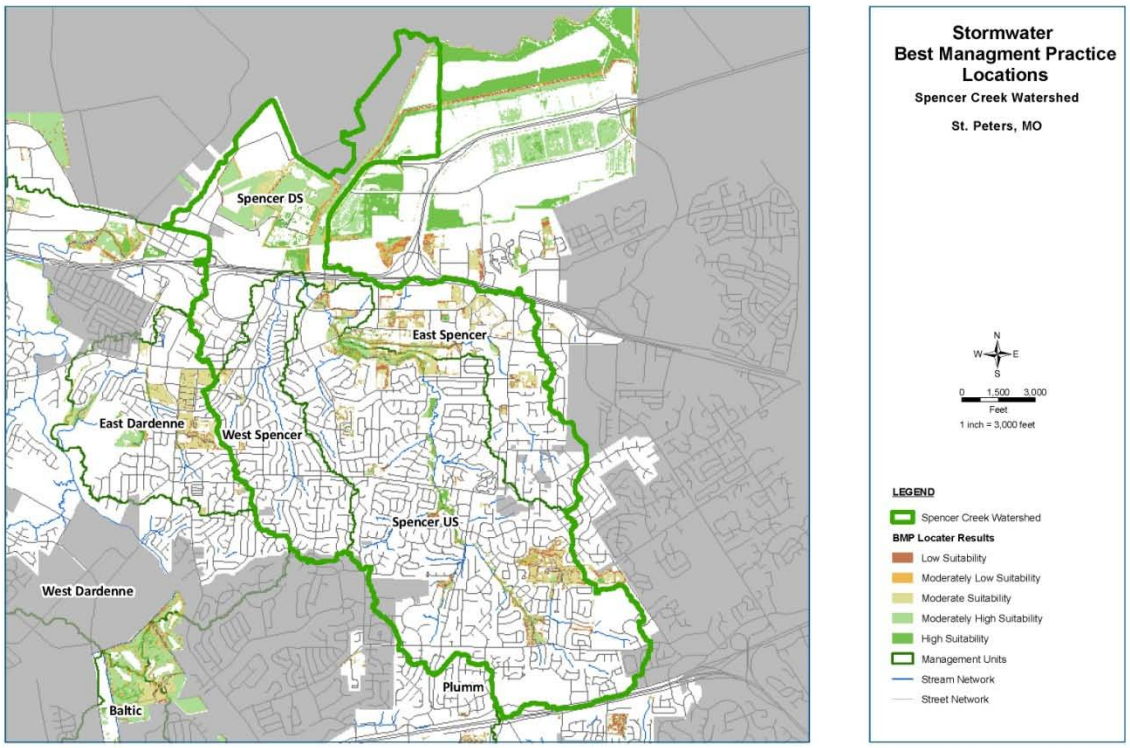

FIGURE 8. STORMWATER BEST MANAGEMENT PRACTICE LOCATIONS, SPENCER CREEK WATERSHED

3.4 Stream Assessment and Vulnerability Assessment

3.4.1 Geomorphic Stream Survey - Impairment of Streams

A majority of the stream network is incised, as documented in the 2002 watershed study (2). Channel incision is a response to changes in the hydrology of the contributing drainage area as well as channel bed materials and downstream conditions. The stream network within the City limits has varying levels of stability and incision. The downstream ends of the main tributaries to Spencer Creek have already experienced changes in structure and are now very incised. In these streams, further incision is likely to occur as a small low flow channel cutting into the hard clay bed was documented in the field. Grade control structures, such as rock checks, are recommended to prevent further incision. Reaches higher up in the watershed have very steep profiles and debris jams of roots or other material were often found to provide temporary vertical grade control.

FIGURE 9. INCISED REACH, EAST SPENCER TRIBUTARY NEAR CONFLUENCE WITH SPENCER CREEK

The field assessment highlighted soils in the lower part of both watersheds as a predominant concern. These soils significantly contribute to the sediment load in Spencer and Dardenne Creeks. The sandy clay soil composition found in several of these reaches has little resistance to shear stresses of flow. This type of soil is stable at a very mild slope and therefore will continue to degrade more rapidly in these areas. Many of the channels are incised and the banks with sandy or loamy clay material that will continue to degrade at a more rapid pace than hard clay or rocky banks. Figure 10 shows the relative classification of the streams within the Spencer Creek watershed.

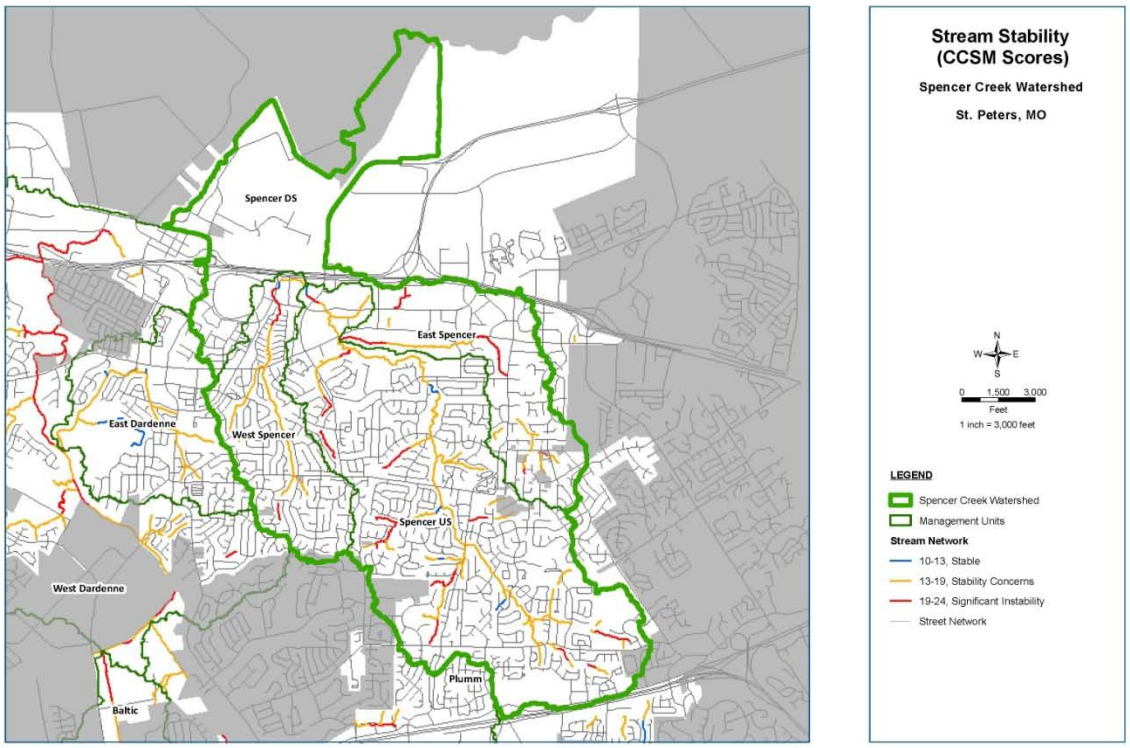

FIGURE 10. STREAM STABILITY IN SPENCER CREEK WATERSHED

PBA analyzed the SAI data to identify obvious trends. Figure 11 shows the SAI score for the streams. The quality riparian vegetation and water quality indicators appear to have the greatest correlation with overall stream quality (R= 0.60). When PBA narrowed the analysis to sample locations where all 20 components were scored (i.e. where all of the conditions were present and could be observed), the terrestrial habitat and water quality components correlated more strongly with the overall stream condition (R = 0.67). The presence or absence of quality riparian vegetation appears to have the greatest influence on overall stream quality, and water quality appears to be better in streams that are in better overall condition. Field observations and SAI scores support the theory that urbanization and degradation or loss of stream buffers negatively impact the overall stability and quality of streams throughout St. Peters. This is consistent with regional and national research indicating that an intact riparian buffer can reduce the impacts of impervious cover and intense runoff conditions in urban watersheds (Center for Watershed Protection 2003; PBA 2005a and 2005b; PBA 2007; Schulte, Scott A., Patricia A. Elbert Noll and Jeffrey Henson, 2008). These findings further support the importance of riparian buffers for protecting stream quality.

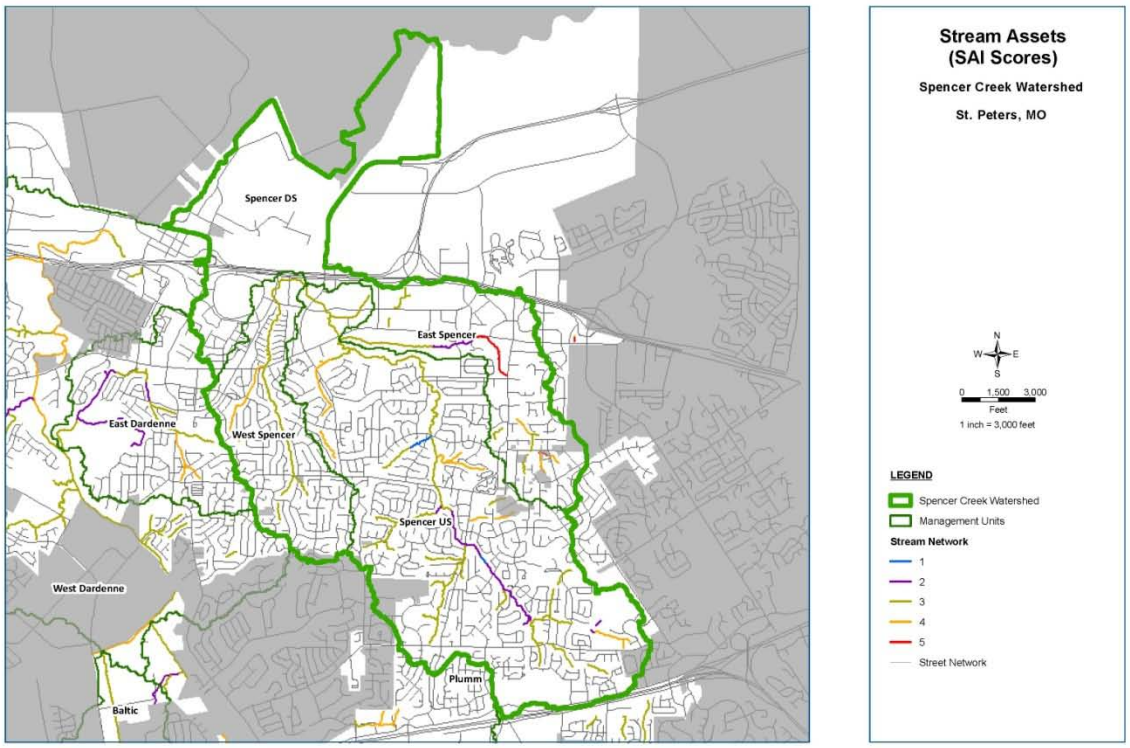

FIGURE 11. STREAM ASSETS IN SPENCER CREEK WATERSHED

A stream classification summary is provided in Appendix B.

3.4.2 Detention Basin Analysis

Detention basins in St. Peters impact the quantity and quality of runoff throughout the community. Therefore, it is important to account for the impacts in the analyses of the Spencer Creek watershed.

Detention Basin Documentation

The City compiled available documentation for each detention basin of interest. The level of detail in each document was variable and Black & Veatch was able to confirm existing conditions as documented on most detention basins. For each detention basin, Black & Veatch conducted a more thorough survey in the field to document existing conditions and to better determine outfall and storage characteristics. A standard documentation form was completed for each detention basin, and multiple pictures were taken to inform modeling and development of conceptual recommendations.

Detention Basin Screening Process

Black & Veatch developed a screening process with the City to prioritize existing detention facilities for inclusion in the hydrologic model. A total of 248 detention basins were included on the geodatabase provided by the City of St. Peters. The scope of the project included modeling of up to 75 detention basins. The screening process outlined below resulted in the selection of the most significant detention in the City.

Of the 248 detention basins, 82 had a surface area greater than ½ acre. The 166 detention basins with a smaller surface area were considered to have a less significant impact on the hydrology and were excluded. There were 29 basins with a surface area greater than 1 acre and these facilities were automatically included. The 53 basins that were between ½ acre and 1 acre in surface area were further analyzed to determine their significance. An additional four selection criteria were developed to screen the remaining basins. Basins that are located on public or vacant land are more easily retrofitted or altered because of ownership issues. Detention facilities that are properly sized for the associated contributing drainage area have increased functionality for affecting peak flows. Contributing drainage areas were established automatically using the ESRI ArcHydro tools. Similarly, detention basins in the floodplain are adjacent to streams and typically show improved function. Of the 50 intermediate sized basins, 5 basins were located on public land, 7 basins were situated on vacant land, 15 basins had a surface area that was greater than 5% of the contributing drainage area, and 3 basins were located within a floodplain. One of the basins located within a floodplain, DB-7270-05 in Carrington Estates, was selected by the screening process and then excluded due to lack of available data. An additional 12 basins were selected by the City to be evaluated.

Thirty of these basins are located within the Spencer Creek watershed. The detention basins selected for the study and located within the Spencer Creek watershed are presented in Figure 12 and Table 4. Each of these basins was visited in the field.

TABLE 4. SELECTED DETENTION BASINS, SPENCER CREEK WATERSHED

Detention Basin ID	**Subdivision**	**Basin Type**	**Contributing Drainage Area** *(acres)*	**Percent Impervious**
DB-7169-01	CARRINGTON PLACE	DRY	5	22%
DB-7169-09	BELLEMEADE	WET	7	14%
DB-7169-10	BELLEMEADE	DRY	11	3%
DB-7169-11	BELLEMEADE	DRY	9	7%
DB-7268-04	COUNTRY CREEK	WET	13	24%
DB-7268-06	ENWOOD	WET	21	29%
DB-7268-07	HIDDEN LAKE ESTATES	WET	23	12%
DB-7269-01	PENNY LANE	WET	70	27%
DB-7270-01	ST. PETERS EXECUTIVE CENTRE	WET	5	35%
DB-7270-05	CARRINGTON ESTATES	DRY	2	1%
DB-7270-09	I-70 EXECUTIVE CENTRE	DRY	55	26%
DB-7270-10	EXECUTIVE CENTRE PARKWAY	WET	13	52%
DB-7270-15	CITY OF ST PETERS	WET	8	43%
DB-7367-04	MC CLAY JUNGERMANN COMMERCIAL	DRY	5	41%
DB-7367-07	ASHLEIGH COMMERCIAL	DRY	4	42%
DB-7367-20	BELLA VISTA	WET	89	13%
DB-7368-08	COUNTRY LAKE ESTATES	WET	15	25%
DB-7368-09	LAUREL PARK	WET	8	10%
DB-7369-04	APPLEWOOD SUBDIVISION	WET	11	18%
DB-7369-06	HI-POINT ACRES	WET	142	16%
DB-7369-07	ST. PETERS CONDOS	DRY	2	28%
DB-7369-11	OAK TREE VILLAGE RETIREMENT	WET	28	35%
DB-7370-14	ST. PETERS CENTRE	DRY	59	24%
DB-7370-16	FORT ZUMWALT EAST	DRY	7	62%
DB-7467-04	SUN RIVER VILLAGE	DRY	32	35%
DB-7467-14	BELLA VISTA	DRY	7	4%
DB-7467-15	BELLA VISTA	DRY	13	4%
DB-7467-16	BELLA VISTA	DRY	28	26%
DB-7468-01	HUNTLEIGH ESTATES	WET	3	15%
DB-7468-06	LAUREL VILLAGE	WET	167	21%

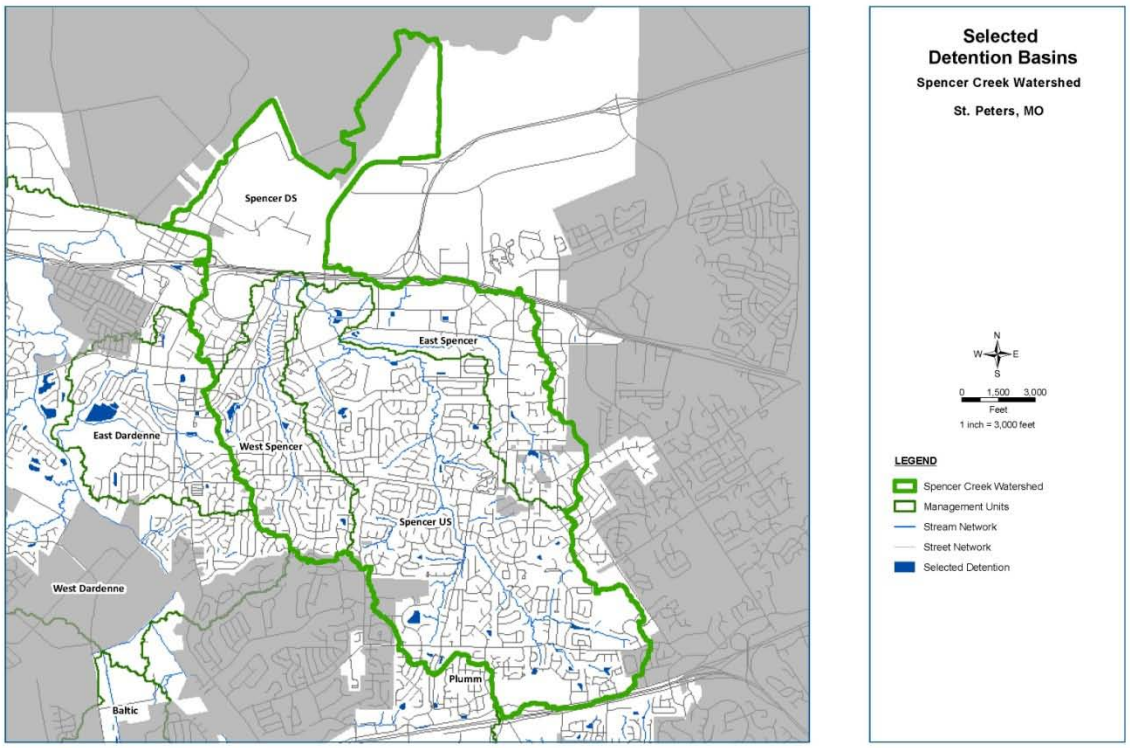

FIGURE 122. SELECTED DETENTION BASINS IN SPENCER CREEK WATERSHED

3.4.3 Stormwater Runoff Model

The P8 urban stormwater runoff model was used to predict pollutant removal efficiencies for each of the 29 existing stormwater detention ponds in the Spencer Creek watershed. The model simulated the generation and transport of stormwater runoff pollutants in the watersheds contributing to the detention ponds. The simulations were driven by continuous hourly rainfall based on ten years of data recorded at the Lambert International Airport provided by the National Climatic Data Center. During the period 2001 to 2009, the annual precipitation averaged 40.6 inches and ranged from 29.8 inches in 2006 to 58.0 inches in 2008.

The P8 model was pre-calibrated by its developer using the Nationwide Urban Runoff Program (NURP) database. Since data characterizing the quantity and quality of stormwater entering the ponds were not available, a site-specific calibration of the P8 model was not possible. Although P8 is capable of simulating total suspended solids (TSS), total phosphorus, total Kjeldahl nitrogen, copper, lead, zinc, and total hydrocarbons, TSS was assumed to be a surrogate pollutant because in stormwater runoff the other pollutants are almost all associated with the suspended solids.

P8 input parameters for each detention basin included the area and impervious fraction of the detention basin's contributing drainage area, the detention basin area and volume, and whether the basin was normally dry (extended detention) or contained a permanent pool (wet detention). The watershed areas and imperviousness were based on GIS data provided by the City and the HEC-HMS hydrology model. Detention basin volumes were determined by one of two methods. The method used

depended upon the information that was available from the City. If a complete hydrologic design report was available from the city for a given basin, the stage/storage/outflow information from the hydrologic report was incorporated into the model. If a hydrologic design report was not available from the City, the stage/storage curve was developed using the LiDAR contours. In this case, outflow information was developed based on field observations of the outlet works of the basin.

Of the 29 stormwater detention ponds evaluated in the Spencer Creek watershed, 19 of the ponds were located in the Spencer Upstream sub-basin. Nine of the ponds were normally dry and ten of the ponds were permanently wet. The P8 model predicted that the wet pond removal efficiencies were significantly higher than the dry ponds, averaging over 90 percent; the average removal of the dry ponds was approximately 25 percent. Wet ponds were more efficient in TSS removal because a full pond provides a longer hydraulic retention time, allowing more time for the TSS to settle out of the water column.

The average TSS removal of all the ponds in the Spencer Upstream sub-basin was 65 percent. Approximately 87,000 lb/yr was removed by the 20 ponds. The P8 model predicted that approximately 689,000 lbs per year (lb/yr) of TSS would be contained in stormwater runoff from the entire sub-basin; therefore, the overall TSS removal of the 20 ponds with respect to the loading from the entire sub-basin was 12.6 percent. The total TSS loading from the four sub-basins is approximately 1.4 million lb/yr. The average removal efficiency of the 29 ponds in the Spencer Creek watershed is 65 percent. The City's existing ponds are providing approximately a 9 percent reduction in TSS loading to Spencer Creek.

The following table summarizes the removal overall efficiencies for the 29 stormwater ponds in the 4 regional detention areas. Tables of removal efficiencies and other characteristics for each of the existing ponds are included in Appendix C.

TABLE 5. REMOVAL EFFICIENCIES FOR EXISTING STORMWATER DETENTION BASINS

		Total Regional Drainage	Detention Basins				Overall Removal
Regional Drainage Area	Number of Detention Basins	TSS-lb/yr	In TSS-lb/yr	Out TSS-lb/yr	Removed TSS-lb/yr	Removed %	%
East Spencer	5	271,909	61,911	21,479	40,432	65	14.9
Spencer Downstream	0	226,128	0	0	0	0	0.0
West Spencer	5	232,583	7,215	1,868	5,347	74	2.3
Spencer Upstream	19	688,865	134,126	47,549	86,577	65	12.6
Totals	29	1,419,485	203,252	70,896	132,356	65	9.3

The results of the geomorphic evaluations, stream asset inventory, and detention basin analyses were compiled and the results are shown in Figure 14 to demonstrate areas of impairment in the watershed.

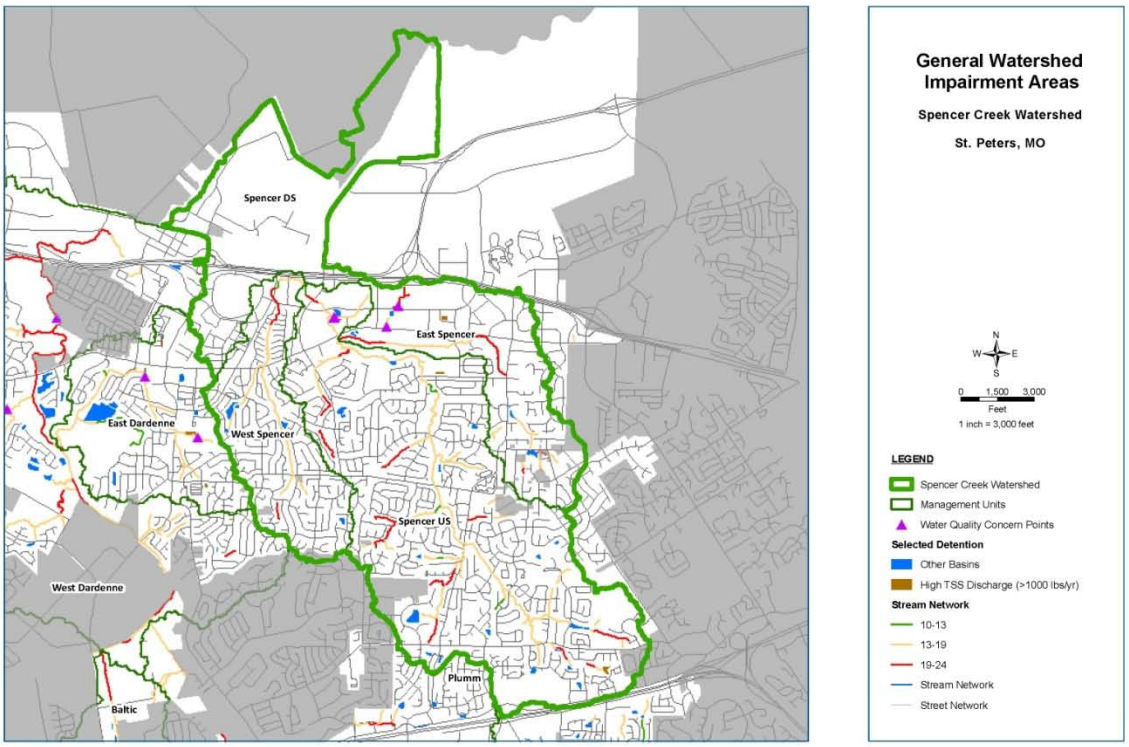

FIGURE 13. IMPAIRMENT AREAS IN THE SPENCER CREEK WATERSHED

4. Critical Issues Statement

The analysis of the basin resulted in the identification of the following critical issues in the Spencer Creek watershed.

- *Existing Resources are Threatened.* The field investigations identified several stream segments with high value. However, past development has threatened many of the stream segments through encroachment into the riparian zone and the increase of impervious surfaces in their tributary areas.
- *Many Stream Segments are Unstable.* Many segments of unstable streams were identified during the study. These are likely the result of the rapid development of the area prior to the recognition that storm water management controls can be effective at reducing the volume and peak rate of runoff.
- *Sediment Loads are High.* The field assessment and water quality modeling identified areas of the streams with excessive sediment loads. Stream instabilities contribute to the high sediment loads through mass wasting of channel banks and continued incision of the stream beds.

Several areas of relatively high sediment load carried in runoff were identified in the P8 modeling.

- *Detention Basins do not Perform Adequately.* Many of the basins in the City are owned privately either by commercial developments or residential subdivisions. These typically have not been maintained adequately and are not functioning as designed. This results in higher peak flow releases and high concentrations of suspended sediment in their discharges. Further, many of the basins are dry basins and therefore do not remove pollutants as effectively as they could if they were designed to be Extended Dry Detention or Extended Wet Basins.
- *Storm Water Management Polices Need to be updated.* The City's existing ordinances, design criteria, and policies achieve many of the goals of the City, but do not reflect recent advancements in storm water management. Policies and criteria designed specifically to address the issues identified in this plan are needed.

5. Goals, Objectives and Implementation

The following goal and objectives are identified to address the critical issues identified above. The first goal is to implement non-structural management measures focused on ordinance and policy improvements and adoption of updated design criteria.

5.1 Ordinance and Policy Improvements

The recommendations to the City's stormwater policies are suggested in the following areas:

- Best Management Practices
- Low Impact Development
- Stream Setbacks
- FEMA Community Rating System
- Street Sweeping
- Sediment and Erosion Control
- Homeowner Drainage Issues
- Education and Awareness

5.1.1 Best Management Practices

As discussed above, the current MS4 NPDES permit will expire in June 2013. Compliance with minimum control 5 – post construction runoff controls is the biggest issue. The City's current storm water regulations partially address this by requiring post construction runoff rates to match predevelopment runoff rates for the 2-year and 25-year design storms. While this minimizes changes in peak flows, it does not specifically address minimizing impacts to water quality. Therefore, it is recommended that the City adopt criteria to capture and treat runoff from common rainfall events to ensure compliance with the permit.

Communities in Missouri, including Kansas City and St. Louis MSD, have adopted criteria that capture and treat runoff from the Water Quality storm. The Water Quality storm is a storm in which the rainfall depth is equal to or less than the rainfall depth from 90 to 95% of the storms in a given year. St. Louis

has adopted criteria that use the 90% value or 1.14 inches of rainfall and it is recommended that St. Peters adopt these criteria as well. Similar to the existing criteria, it is recommended that this apply when the volume of runoff from a site will increase by 15 percent or more as a result of a 2-year 24 hour storm event.

The volume that is captured and treated is defined as the Water Quality Volume, WQ_v, where:

$$WQ_v = [(P)(R_v)(A)]/12$$

Where:

WQ_v = Water Quality Volume (acre-feet)

P = Rainfall depth in inches equal to the 90% runoff event (inches)

R_v = Volumetric runoff coefficient (dimensionless)

A = Area (acres)

$R_v = 0.05 + 0.009(I)$, I is the percent (whole number) impervious cover

Best management practices (BMP) are then designed to capture and treat this volume of runoff. BMP manuals tailored to a specific community and developed from scratch are typically expensive to develop. Much reference material has been developed within Missouri, the Midwest and across the country, so it is not recommended that the City develop its own BMP manual. Rather, it is recommended that appropriate sections of existing manuals and reference materials be adopted.

Existing BMP references used in Missouri include:

- Manual of Best Management Practices for Stormwater Quality, Mid America Regional Council, March 2008, used in the Kansas City area (MARC manual)(3).
- Erosion Prevention and Sediment Control Guidelines, City of Springfield Department of Public Works Storm Water Services Division, October 2008.
- Joplin, Missouri Stormwater Management Criteria, Allgeier, Martin and Associates, Inc., April 2009.
- Maryland Stormwater Design Manual, Volumes I & II, Center for Watershed Protection and the State of Maryland Department of the Environment, October 2000 effective date July 1, 2001, used by St. Louis MSD (Maryland manual).

It is recommended that the focus be placed on using extended dry or wet detention to capture and treat the water quality volume storm. This will minimize impacts to the local development community because detention is already required by existing criteria. The basins should be configured to provide 40 hours of detention for the water quality volume storm. Extended dry detention typically provides 60 to 80 percent removal of sediments while extended wet detention typically removes 90 percent of the

sediments. Both the MARC and Maryland manuals provide criteria for design of extended detention basins.

In addition to upgraded detention, the City should require hydrodynamic separators, filtration practices or proprietary BMP devices for "hot spots". Hot spots are land uses that contribute higher concentrations of metals, hydrocarbons and other pollutants and include the following from the MARC BMP Manual (3):

- Fuel dispensing facilities
- Aboveground storage of liquid materials
- Exterior storage of bulk materials
- Material transfer areas and loading docks
- Equipment and vehicle washing facilities
- Covered vehicle parking areas
- High-use vehicle and equipment traffic areas, parking and vehicle storage
- Dog kennels, doggie day care, and veterinary clinics

Both the MARC and Maryland manuals provide design guidance BMPs for these areas. In addition, St. Louis MSD has developed specific information on hydrodynamic separators and proprietary devices for hot spots that can be found at the following websites:

- http://www.stlmsd.com/engineering/planreview/PlanReviewInformation/ProprietaryBMPs
- http://www.stlmsd.com/portal/page/portal/engineering/planreview/PlanReviewInformation/ProprietaryBMPs/MSDProprietaryBMPProgramGuidance-080213rev090105.pdf

5.1.2 Low Impact Development

Creating an ordinance or other regulatory mechanism to require low impact development is not recommended because little developable property is left. Therefore, it is recommended that low impact development (LID) be encouraged but not required in new development or redevelopment projects. The purpose of encouraging LID is to minimize the runoff that occurs from development which reduces the detention and capture and treatment requirements discussed above. Principles of low impact development include the following (4):

- Plan first
- Prevent, then mitigate
- Minimize the disturbance
- Manage stormwater as a resource – not a waste
- Mimic the natural water cycle
- Disconnect, decentralize, distribute
- Integrate natural systems
- Maximize multiple benefits
- Make maintenance a priority

Planning for stormwater management from the earliest stages of the development process helps to ensure that natural resources are protected and the impacts of the site are minimized. Minimizing the amount of runoff generated from the site is the most effective way to manage stormwater. This is accomplished by **minimizing the disturbance** of existing vegetation and soils as well as minimizing the impervious area of the site. BMPs should be designed to capture and treat the runoff that does occur.

Designing sites to take advantage of stormwater runoff instead of getting rid of it can create community amenities, reduce irrigation needs and costs through rainwater harvesting for building and site uses, and protect natural resources. Designing ways to capture and store runoff supports all of these benefits. Planning a development around streams, ponds, wetlands, and rain gardens often attracts residents and adds value to lots near them.

Mimic the natural water cycle. Designing the site to control peak flows as well the volume of runoff and infiltration of precipitation minimizes the impacts on water quality and stream health. This results in management of the full range of precipitation from frequent rainfalls to the infrequent flood events.

Disconnect, decentralize, distribute. Capturing rainfall where it falls is a very effective stormwater management technique. This is accomplished by disconnecting impervious areas from the drainage system, installing BMPs at individual lots and neighborhoods, and spreading them throughout the development.

Integrate natural systems. Protecting and taking advantage of native soils, vegetation, and natural resources minimizes the impacts of a development and can increase its value. Natural resources are effective stormwater management systems that provide water quality benefits and reduce flood peaks.

Maximize multiple benefits. Designing the site to preserve natural resources and incorporate BMPs using native vegetation can add to the social and economic value of a development and community as well as provide water quality benefits including:

- creating open space for recreation and amenity value,
- increasing property values, and
- decreasing construction and maintenance costs.

Make maintenance a priority. BMPs often require different types of maintenance than typical crews are used to performing. Designing BMPs with maintenance requirements in mind reduces their impacts. They may often require more frequent maintenance than inlet and pipe systems. Placing priority on training crews to properly care for BMPs and planning for and committing to scheduled maintenance programs is important for their long-term function.

It is suggested that implementation of LID can be encouraged through reductions in any fees collected for storm water management in the future.

5.1.3 Policy Recommendations Impact on Development Code

Section 405 of the City's Code of Ordinances is known as the "The City of St. Peters, Missouri, Zoning and Subdivision Codes" (Section 405). Section 405 has been reviewed to identify potential conflicts between these policy recommendations and the existing code.

Low Impact Development

Many of the concepts promoted in LID involve minimizing impervious areas. Areas of conflict identified in Section 405 include the following:

- Minimum residential lot size of 10,000 square feet
- Overall density of a development should be 12,000 square feet per lot
- Impervious area can not cover more than 50% of the area of a lot
- Minimum home size of 1800 square feet for a one story house

Communities have adopted or allowed reduced requirements for these criteria in concepts such as cluster development where homes and businesses are concentrated in a portion of the overall development. The overall imperviousness of the development can be maintained or reduced and open space or natural resource areas increased.

FIGURE 14. CLUSTER DEVELOPMENT, METROPOLITAN DESIGN CENTER

A Planned Unit Development (PUD) can be developed to allow these concepts under Section 405. The PUD allows an increase in density of development of up to 30%. Also, PUD's commonly also allow other criteria to be modified as part of the agreement between the developer and the City. This existing mechanism can be promoted to encourage developers to employ LID principles.

Longer-term, adoption of Conservation Development code language is recommended. This code would specify the terms and conditions of the use of LID and reduce costs and staff-time in reviews compared to achieving LID through the PUD. The city of Kansas City, Missouri recently adopted conservation development and the code language can be accessed at the following website.

http://library.municode.com/index.aspx?clientID=10156&stateID=25&statename=Missouri

Once at this website, the Conservation Development code is Section 80-209 within Chapter 80.

Reduced Parking Space Requirements

Many communities have considered reducing parking space requirements to minimize impervious areas and impacts to stormwater runoff. Another method for reducing these impacts is to promote use of permeable pavement in low volume traffic areas. This is especially viable in large mall areas where the majority of the parking is used seasonally.

Reduced Pavement Widths

Communities have also used narrower pavement widths in the proper setting such as residential streets. Emergency vehicle access needs must be considered. If the City considers this as a means to reduce runoff, the emergency response groups should be involved in the development of the criteria.

5.1.4 Stream Setback Recommendations

The City's current stream setback requirement provides basic separation of development from the streams. Much of the City is already developed therefore; an extensive stream setback ordinance is not recommended. However, several enhancements listed below are recommended to reduce the potential for new development in flood-prone areas, development of areas susceptible to erosion along the streams, and to preserve and restore the natural setting of the City's streams.

1. Prevent construction of habitable buildings resulting from new development or redevelopment in the 100-year floodplain. Updated mapping has been developed that shows the limits of the 100-year floodplain. For stream reaches that do not have a defined floodplain, require that the floodplain be delineated as part of the development or redevelopment plan. Keep the 25 foot setback preventing all development from occurring in the 25 foot setback zone, and allow storage sheds and other small structures in the area outside of the 25 foot setback within the floodplain.
2. Prevent new development or redevelopment adjacent to areas of significant stream instability until the stream segment is stabilized.
3. Develop an education program for neighborhoods that provides information on stream stability and how the residents' actions impact the streams. An example brochure is provided in Appendix E. Meetings with neighborhoods should be scheduled to provide an overview of the City's stream protection/enhancement program and identify ways they can help protect/enhance the streams.
4. The following figure shows stream segments identified for protection and restoration. Target recommendations for no new development adjacent to these stream segments. This should be included in the City's Comprehensive Plan to bolster their legitimacy and effectiveness.

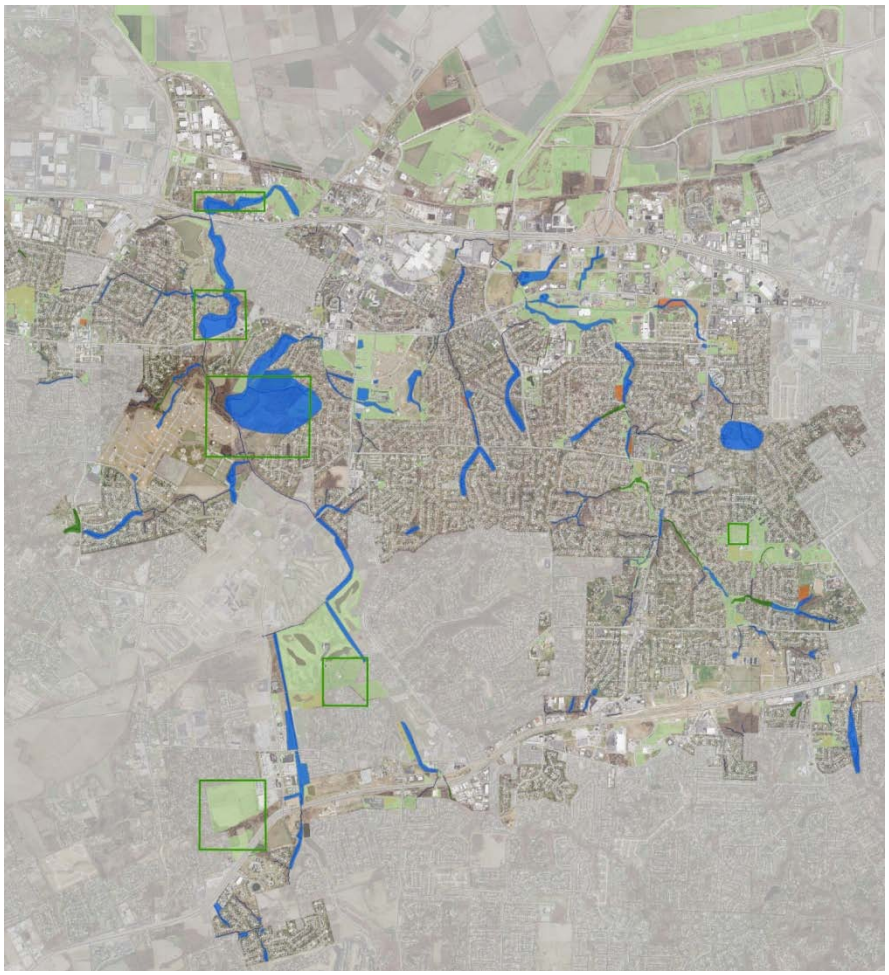

FIGURE 15. AREAS DESIGNATED FOR PRESERVATION (GREEN) AND RESTORATION (BLUE)

5. Encourage use of native and riparian species in the 25 foot setback zone and discourage turf grasses and mowing.
6. Establish setbacks as wide as practicable when completing improvement projects or easements along the streams. The goal of this program will be to achieve the performance as outlined in item 1, but will need to be determined on a project-by-project basis.

5.1.5 Street Sweeping

Recent research has shown that street sweeping is most effective when it occurs every two weeks (2,3). While that may not be practical for St. Peters, targeting the roadways that are nearest the streams for monthly cleaning is recommended. Streets with direct discharges to streams should be identified and targeted.

Research has also shown that street sweeping following thawing of significant snow events can be effective at removing the sand and salt and other debris buildup from these events. If budgets allow, this practice is recommended and at a minimum the streets should be cleaned early in the Spring.

5.1.6 Sediment and Erosion Control

The silt load in the City's streams has been identified as an on-going problem. One of the identified sources of the silt load is silt-laden runoff from construction sites. The existing ordinance provides the regulatory mechanism to address this issue for larger sites. Enforcement and education are recommended to minimize the impacts of construction. Enforcement requires adequate staff resources to inspect each site frequently enough to identify issues and require remedies before multiple storm events occur. Two existing City staff are currently dedicated to conducting Inspecting erosion and sediment control facilities weekly and after rain events. In addition, four engineers can fill in if needed. Another concern is the amount of sediment eroded from individual building lots. The current regulations exempt most residential home construction. Many examples exist where the exemption limits are much lower than St. Peters. One good example is in St. Louis County where the limits for exemption are a volume of 30 cubic yards or surface area of 2000 square feet. Lowering the limits to these values would significantly increase the number of home construction sites that are required to include sediment and erosion control. Building permits range from 30 to 100 annually. The City of Lincoln, Nebraska has recently implemented a program that addresses this issue. It can be found at the following website:

http://www.lincoln.ne.gov/city/pworks/watrshed/require/erosion/ilnoi.htm

It requires an individual lot notice of intent to comply with the City's requirements as well as a storm water pollution prevention plan to be submitted with the building permit.

The design standards used in St. Peters were adopted in the early 2000's. A new design guideline has been published by MDNR titled: **Protecting Water Quality: A field guide to erosion, sediment and storm water best management practices for development sites in Missouri and Kansas, January 2011.** It provides design standards for many newer BMPs for sediment and erosion control as well as updates to existing design standards that have been refined to incorporate lessons learned over the last decade. It is recommended that this document be adopted as a supplement to the existing design standard. MDNR completed a series of training sessions on this document. The City should send selected staff if additional training is scheduled. Further, developers and homeowners operating in St. Peters should be encouraged to attend.

The existing City code prohibits dumping of lawn waste into stream corridors in section 215.010.J.5. Dumping of other types of refuse is prohibited by 215.010.F. Abatement measures are also addressed in section 215.030. Therefore, additional ordinance language or policies are not required. However, current staff resources are not adequate to identify the sources of illegal dumping and enforce the existing ordinances. A public education program to inform residents of the existing rules, impacts of illegal dumping, and reporting mechanisms is recommended to reduce the amount and frequency of illegal dumping.

5.1.7 Homeowner Drainage Issues

During field investigations, it was noted that downspouts and pool drainage pipes extended beyond the stream banks. These cause erosion and are vulnerable to being swept away during large runoff events.

Development of a program to educate homeowners of alternatives to this is recommended. Alternatives for downspouts include discharge to a rain garden, swale with bed protection as needed, or burying the discharge pipe in the bank of the stream and directing its discharge to a pool or riffle in the stream. The MARC Manual includes rain garden design guidelines and many other on-line resources are available.

For pool drainage, use of temporary pipes to direct the flow into a pool riffle area of the stream is recommended.

Education and Awareness

A comprehensive education and awareness program is recommended to involve the community in the new approaches to storm water management. This should include not only the residents as noted above, but also developers, builders, and the designers that work in the City.

Homeowner Training

- Use of the City's compost program for grass clippings
- Importance of maintaining a buffer in your backyard
- Connection of downspouts to rain gardens or proper locations in the streams
- Native plant identification

Developer Training

- Participation program to inform them of the new policies and incorporate appropriate modifications
- Education on new extended detention basin and "hot spot" BMP design guidelines
- Education on erosion and sediment controls

Staff Training including other Departments that help manage Storm Water

- Checklist and training on proper installation and maintenance of erosion and sediment controls
- Vegetation identification for honeysuckle management
- BMP maintenance
- New policies

Water Quality Related Programming

- Clean Stream Teams to remove litter from streams
- Adopt-a-Wetland Teams

5.2 Objective: Preserve Streams.

It is important for the City to protect and preserve natural resources to protect warm water aquatic habitat, provide habitat for wildlife and for the enjoyment of the residents,. The existing trail system is enjoyed by many residents in St. Peters and preservation and protection of the high value streams will create opportunity for expansion of this system. Implementation of the updated policies, ordinances, and design criteria recommended in the previous section(s) is focused on preserving the high value streams in the watershed. Figure 17 shows stream segments, highlighted in green, identified for

preservation. This figure also identifies the specific location, highlighted with a purple box, where the LID principles discussed above are recommended.

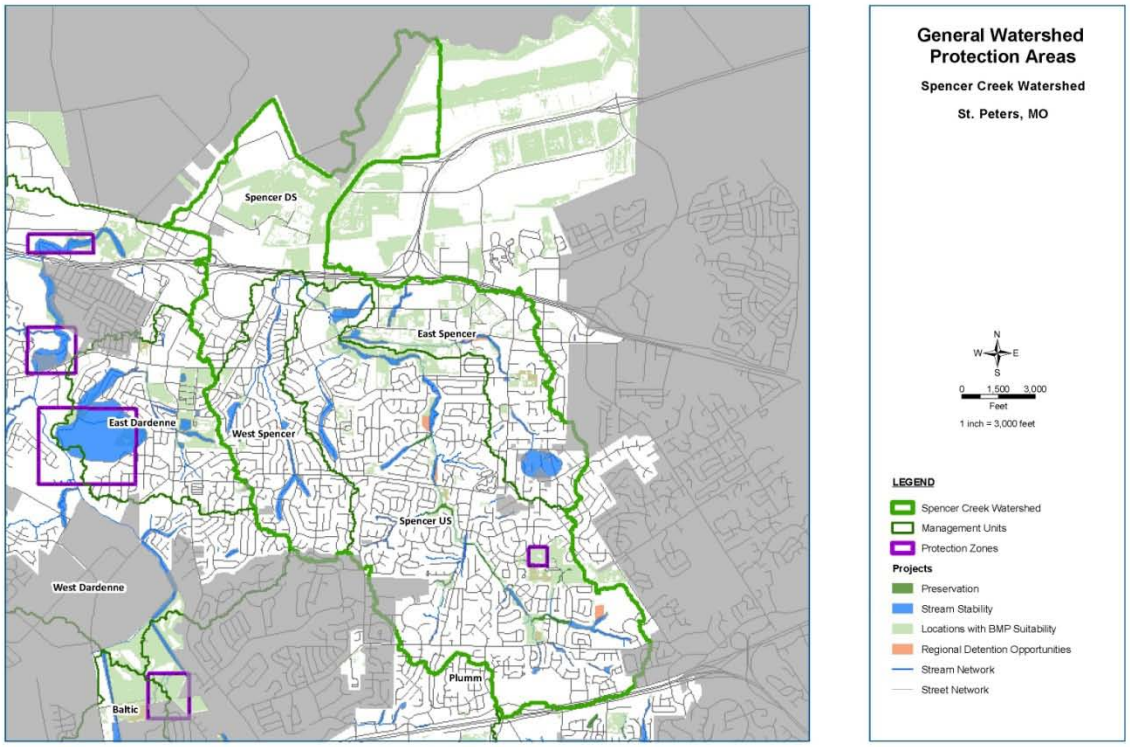

FIGURE 16. GENERAL WATERSHED PROTECTION AREAS

5.3 Objective: Restore Streams, Improve Water Quality and Reduce Flood Damages.

Restoration of the City's streams will accomplish many goals of the City and this plan. The mass wasting of stream banks and continued degradation of their bed caused by on-going incision contributes significant sediment loads. The stream degradation further threatens private and public property, City facilities and utilities. While restoring the streams, the City also will reduce flood damages throughout the watershed through stream improvements and detention basin upgrades. The recommended improvements also will improve water quality in the streams through reduced sediment loads and additional capture of pollutants in the watershed. Water quality improvement will also be achieved through implementation of the recommended policies.

This section introduces management measures that were considered to address these stormwater concerns. The following sections describe how these measures were evaluated. Detention basin retrofit and stream buffer examples are provided in Appendix D.

5.3.1 Stream Management Measures

Hydraulic modeling and field reconnaissance documented a variety of flooding and stability conditions, as presented previously.

Flooding Management Measures

Flooding locations were identified during the assessment of existing conditions with the use of hydraulic models and the geodatabase of anecdotal concerns provided by the City. Most flooding locations were addressed with a conceptual recommendation as part of the CIP. Some bridge crossings with flooding or insufficient freeboard were excluded, such as crossings on private roads.

Stream Stability Measures

The stream network in St. Peters includes approximately 12 miles of stream that are highly degraded and unstable, rated with a CCSM score of 19 or more. System stability is based not only on the stability of the banks, but also the vertical stability of the channel bed.

Bank Stability

The areas of mass wasting, bank slumping, and bank scour are representative of the channel's response to the rapid development that occurred over the last 30 years in the City. To prevent further migration of the bank in critical areas, several stability measures were considered.

Over the past decade, the City has applied a variety of bioengineered techniques incorporating synthetic and vegetative materials – with varying levels of success. Based on field observation, one of the most critical elements of successful stabilization projects is to ensure that sufficient flow and sediment conveyance are provided.

FIGURE 17. TRM SYNTHETIC STABILIZATION METHOD FAILURE

Three levels of bank stabilization were evaluated with consideration to materials that have demonstrated successful application in past City projects. The basic level includes riprap toe protection and establishment of vegetation to protect banks. The second level builds upon the basic cross section to include the integration of a floodbench so that higher flows can spread out over a wider conveyance area. The final level applies to reaches where there is not sufficient area to establish a stable bank slope or flood bench and a wall structure is integrated into the stream bank. This last case only applies to a few locations throughout the City.

Vertical Stability of the Channel Bed

The recommended management measure for vertical grade control is the establishment of rock check dams using riprap. A durable, properly sized riprap should be used; in the field, evidence of riprap deterioration was prevalent. Grade control structures should installed perpendicular to flow. They are best designed with respect to the channel bed and bedload materials and their optimal height and spacing depend upon achieving an equilibrium slope, preventing channel incision from migrating upstream. The riprap size is designed to resist velocities and shear stresses during a typical design event (i.e. 100-yr). Scour analyses is also necessary to understand localized channel hydraulics and critical shear stress values. The depth of excavation and placement of riprap below the channel bed is dependent on these calculations of scour. Hydraulic analysis is also recommended in order to evaluate the location of shear stress on the banks. To establish vegetation, riprap voids may be filled with a

granular soil mixture, sometimes using on-site excavated materials. Root cuttings such as willows have shown successful establishment in restoration projects in the City as well.

FIGURE 18. STABLE STREAM EXAMPLE WITH WILLOW CUTTING ESTABLISHMENT

5.3.2 Riparian Renovation

The primary goal of riparian preservation is to protect the function and aesthetics of streams through proper management of the riparian corridor vegetation. Preservation begins with floodplain management or stream setback policies (or both) that help limit encroachment of structures in the riparian corridor, and regulations and education to discourage inappropriate uses and activities that degrade natural function. However, preservation does not end there; there are three key components to consider with riparian preservation: management, vegetation type, and corridor width.

First, preservation does not mean taking a hands-off approach. Vegetative management must occur if the riparian corridor is to function properly. Second, management practices generally focus on reducing or eliminating non-native vegetation in an effort to support the growth of more desirable native varieties. Even some aggressive native plant species like bittersweet and trumpet vine can be undesirable within a riparian corridor. This may include replanting native species where non-native or aggressive vegetation is removed to prevent it from re-establishing, and planting natives where existing vegetation is thin (particularly along stream banks where the vegetation helps prevent erosion). Third, the width of the riparian zone is equally important in preserving function. A narrow riparian corridor is

far less effective in buffering streams from adjoining land uses than a wider corridor. Buffer widths vary with stream type (ephemeral, intermittent, or perennial) but, the general rule of thumb is to place wider buffers on smaller headwater streams that are often most neglected and impacted, and where benefits are often the greatest due to the preponderance of smaller streams in a watershed. Wider buffers are also desirable where high-quality riparian corridors exist to protect the integrity of these resources; and where stream restoration is a high priority.

A list of tree and shrub species, provided in Appendix F, includes varieties that are present in healthy, regional stream corridors. These species should be used for preservation and restoration efforts.

"Reference sites" are healthy stream corridors that provide helpful guides for riparian preservation and restoration. There are a few sites in the Spencer Creek and Dardenne Creek watersheds that would be considered reference sites for proper vegetation and buffer width. Most of these reference sites are located within parkland already owned and managed by the City. These sites include:

- Spencer Creek from Jungermann Road to Millwood Drive.
- Spencer Creek upstream of extended wet detention facility east of McClay Valley Boulevard.

Figures 20 and 21 illustrate a healthy riparian corridor, and a stream corridor with undesirable vegetation for comparison.

Desirable riparian corridor: this photo is of an area east of Jungermann Road and illustrates a good mix of canopy and understory species with very little undesirables; trees are a mix of ages, and the canopy is open enough to allow for good understory vegetation.

FIGURE 19. DESIRABLE RIPARIAN CORRIDOR CONDITIONS

Undesirable riparian corridor: this photo shows undesirable vegetation (honeysuckle) dominating one side of corridor; and a thin, almost non-existent corridor on the other side.

FIGURE 20. UNDESIRABLE RIPARIAN CORRIDOR CONDITIONS

5.4 Watershed Improvements

The management of stormwater as it flows across the landscape is the second critical section of management measures. This section presents the approach to developing detention basin retrofit options, an introduction to regional detention, and general stormwater best management practices.

5.4.1 Detention Basins

The detention basin improvements considered for this study considered the hydrologic as well as water quality needs of the watershed. The hydrologic needs were addressed largely by recommending improvements to the dam structure or outlet works, or by recommending increased storage behind the structure. Water quality improvements were addressed by recommending an alternative storage regime (dry detention to wet detention), improved plantings, or by the construction of a sediment forebay.

Three retrofit options were evaluated in this study.

Dry Detention Retrofit

A dry detention retrofit established a temporary pool that is sized to detain the water quality volume. Typically, this retrofit includes the establishment of native vegetation and amendment to the soil in the bottom of the basin to enhance infiltration.

Dry to Wet Detention Retrofit

Upon retrofit of a dry detention to a wet pond, a permanent pool that is equal to the volume of the water quality volume was established for each basin. Typically, a wetland bench of planting is recommended around the basin perimeter.

Wet Detention Retrofit

A wet basin retrofit includes establishment of a wetland buffer planting around the perimeter of the basin.

Additionally, sediment forebays were suggested for some detention basins based upon watershed characteristics or anecdotal information that sediment is an issue for that basin. In general, it is suggested that the City reference the Mid-America Regional Council (MARC) guidance on the construction and features of a sediment forebay. Key features of a sediment forebay include:

- Maintenance Schedule: Sediment forebays must be maintained on a frequent basis. Sediment must be removed periodically and hauled off-site. If a forebay is not periodically maintained, it will become choked with sediment, cease to function, and actually become a detriment to downstream facilities.
- Proper sizing: according to the maintenance schedule determined for the forebay, the facility must be properly sized to accept sediment between maintenance events.
- Access: Proper access must be afforded to maintenance crews to allow for upkeep of the facility. Typically, a backhoe can be expected to handle the excavation of accumulated sediment.
- Plantings: Plantings within the sediment forebay are welcomed. During maintenance events, the plantings can simply be scraped off the top of the sediment, placed to the side, and then replaced in the sediment forebay after excavation is completed.

5.4.2 Stormwater Best Management Practices

A water quality best management practices (BMP) locator assessment tool was used to identify optimal locations for BMPs within the City. The objective was to assess and classify the relative value of land for capturing, storing, and infiltrating stormwater runoff; and to identify vacant land that could be used to construct new water quality BMPs if desired to meet the City's stormwater management objectives.

5.5 Objective: Improve the Function of the Existing Basins

Improving the function of detention basins that will not be upgraded as part of this plan is also a goal of the City. A Detention Basin Management Plan has been developed that provides the guidelines for taking over operation and maintenance of these existing basins and is described below.

5.5.1 Detention Basin Management Program

The 248 detention basins in the City have a significant impact on stormwater management reducing peak flows and improving runoff water quality. However, many of these are not maintained properly and therefore do not reduce peak flows and improve water quality as designed and originally constructed. Therefore, the City is developing a plan to manage these basins so they function properly

and provide benefits to the community. A prioritized approach has been developed for the Detention Basin Management Program.

One of the most important considerations in taking over management of the basins is the annual costs the City will incur. General operations and maintenance (O&M) costs have been estimated from the Water Environment Research Foundation's "Performance and Whole-Life Costs of Best Management Practices (BMPs) and Sustainable Urban Drainage Systems (SUDS)" (WERF Report). The WERF Report examined BMP performance and costs primarily in the US and the UK and created a whole-life cost spreadsheet that can be used to estimate O&M costs. Many assumptions are made in the spreadsheet and the most significant is the level of maintenance provided with choices of low, medium, or high. For the purposes of this project, a medium level of maintenance was chosen. This choice then defines the frequency of the following:

- Inspection of facilities – once every three years
- vegetation management – once a year
- vector control – once every three years
- intermittent maintenance – once a year
- sediment removal – once every ten years

The Detention Basin Management Plan includes a prioritization of the basins for acquiring them and taking over responsibility for O&M. The highest priority basins are the 23 included in the Capital Improvements Program CIP. When they are upgraded as recommended in the CIP, the City will assume ownership and responsibility for their maintenance. The estimated annual O&M cost for these basins is approximately $49,000. These include five basins currently owned by the City of St. Peters.

One basin owned by the City is not included in the CIP and is also in the group of highest priority basins. This basin is DB-7171-01, located north of the water treatment plant. The estimated annual operations and maintenance cost for these basins is approximately $24,000.

The residential basins are the next priority. A list of these basins is provided in Table 5.

TABLE 5. RESIDENTIAL DETENTION BASINS, SPENCER CREEK WATERSHED

Detention Basin ID	Subdivision	Basin Type
DB-7169-01	CARRINGTON PLACE	DRY
DB-7268-04	COUNTRY CREEK	WET
DB-7268-06	ENWOOD	WET
DB-7268-07	HIDDEN LAKE ESTATES	WET
DB-7368-08	COUNTRY LAKE ESTATES	WET
DB-7368-09	LAUREL PARK	WET
DB-7369-06	HI-POINT ACRES	WET
DB-7468-06	LAUREL VILLAGE	WET

The remaining basins in the Spencer Creek watershed are in commercial or industrial areas. The maintenance of these should be provided by their owner. Therefore, it is recommended that the City not take over O&M of these basins and ensure their performance through inspection and enforcement of existing ordinances requiring maintenance by the owner.

5.5.2 Low-flow Flume Replacement

Many detention basins in the City include concrete flumes that convey low-flows from the discharge pipes to the basin outlet. These eliminate most wet areas and erosion in the bottom of grass-lined basins; however they convey the first flush of runoff through the basin with no storage time or exposure to the vegetation. This allows what is typically the most polluted runoff to move through the basin with no treatment or attenuation. The following recommendations are made to upgrade the flumes so they provide some water quality benefit while not impacting the detention basin's peak flow control performance significantly.

Intact Flumes

Flumes that are not in need of structural repair do not need to be replaced to provide some water quality benefit. A small berm made of selected rip-rap can be placed across the flume in the vicinity of the outlet structure. The berm will cause water to pond allowing it to spread out into the vegetated area of the basin. This will slow the water down allowing sediment to settle and for some of the water to be exposed to the vegetation allowing further removal of sediments and other water quality benefits. The berm should be permeable or have a low flow outlet to allow the ponded water to drain within 40 hours. Provisions should be made to allow sediment removal and the basins should be inspected once a year to identify maintenance needs and ensure that small semi-permanent pools are not being created.

The size of the rip-rap should be determined based on anticipated velocities in the flume. Also, the need for some type of stabilization in the vegetated area should be evaluated based on anticipated velocities and visual inspection.

A pilot program should be initiated to test the performance of the berm in trapping sediment and draining within 40 hours. A few basins should be retrofitted with the berms and inspected after storm events to monitor their performance and identify adjustments needed for satisfactory performance.

Flumes Needing Repair

For flumes needing concrete repair, it is recommended that the concrete sections be removed and replaced with rip-rap. The rip-rap should extend from the area needing repair to the low flow outlet. A berm should be placed near the outlet as described above. The rip-rap should be planted with appropriate plants as listed in Appendix F. The rip-rapped section will slow the water down allowing it to pond and trap sediment. Provisions should be made to allow sediment removal and the basins should be inspected once a year to identify maintenance needs and ensure that small semi-permanent pools are not being created.

The size of the rip-rap should be determined based on anticipated velocities in the flume. Also, the need for some type of stabilization in the vegetated area should be evaluated based on anticipated velocities and visual inspection.

A pilot program should be initiated to test the performance of the rip-rapped section and berm in trapping sediment and draining within 40 hours. A few basins should be retrofitted and inspected after storm events to monitor their performance and identify adjustments needed for satisfactory performance.

Flumes Needing Replacement

The concrete should be completely removed and replaced with a rip-rap channel. If possible, the channel should be designed with meanders to further slow the water down thereby trapping more sediment. The rip-rap should be planted with appropriate plants as listed in Appendix F. Provisions should be made to allow sediment removal and the basins should be inspected once a year to identify maintenance needs and ensure that small semi-permanent pools are not being created.

The size of the rip-rap should be determined based on anticipated velocities in the flume. Also, the need for some type of stabilization in the vegetated area should be evaluated based on anticipated velocities and visual inspection.

A pilot program should be initiated to test the performance of the rip-rapped channel in trapping sediment and draining within 40 hours. A few basins should be retrofitted and inspected after storm events to monitor their performance and identify adjustments needed for satisfactory performance.

5.5.3 Forebays

New detention basins should be designed with a forebay to capture sediment and trash from all inlets to the basin. The forebay should be sized to accumulate 5-10 years of sediment before requiring sediment removal. A maintenance ramp and access should be provided to allow the required equipment to be used for forebay maintenance (MARC Manual). Forebays should be inspected annually to ensure they drain properly and that small pools are not being created. Annual maintenance should include regrading required to ensure proper draining.

5.5.4 Basin Retrofits

A selection of the 29 detention basin retrofits in the CIP includes provisions for adding forebays. As the City acquires additional basins as part of the Detention Basin Management Program discussed below, the basins should be evaluated for the presence of a forebay or whether one can be added over time. The rip-rap dam recommended in the Flumes discussion above creates a sediment trap and in essence creates a forebay. This is a low-cost way to provide sediment removal and water quality benefit if the addition of a dedicated forebay is not feasible.

5.5.5 Detention Basin Location

Detention basins have been shown to be effective in providing water quality benefit and to reduce peak flows in the portion of the City south of I-70. Additionally, those basins located in areas protected by levees north of I-70 are effective at providing storage areas for subsequent pumping when the Mississippi River is in flood stage. For areas north of I-70 not protected by levees, the area within the City is flood prone from Mississippi River, Dardenne Creek and Spencer Creek flooding. Therefore, these areas are not going to benefit as much from local detention and can be excluded from the detention basin requirements.

6. Prioritization of Improvements and Actions

6.1 Project Locations and Conceptual Improvements

Field data and GIS analysis of existing conditions was used to establish project locations. The majority of flooding locations were selected as project locations. Stream reaches with scores greater than 13 were selected for stability improvements and then reaches were grouped with consideration to constructability. Special consideration was given to documentation of stream stability relative to infrastructure or buildings. Stream reaches with SAI scores of 1 and 2 were identified as preservation project areas. Detention basins that showed evidence of flooding or water quality issues such as excessive erosion or algae were selected as project locations. Project polygons were developed to encase project areas and are shown on Figure 22.

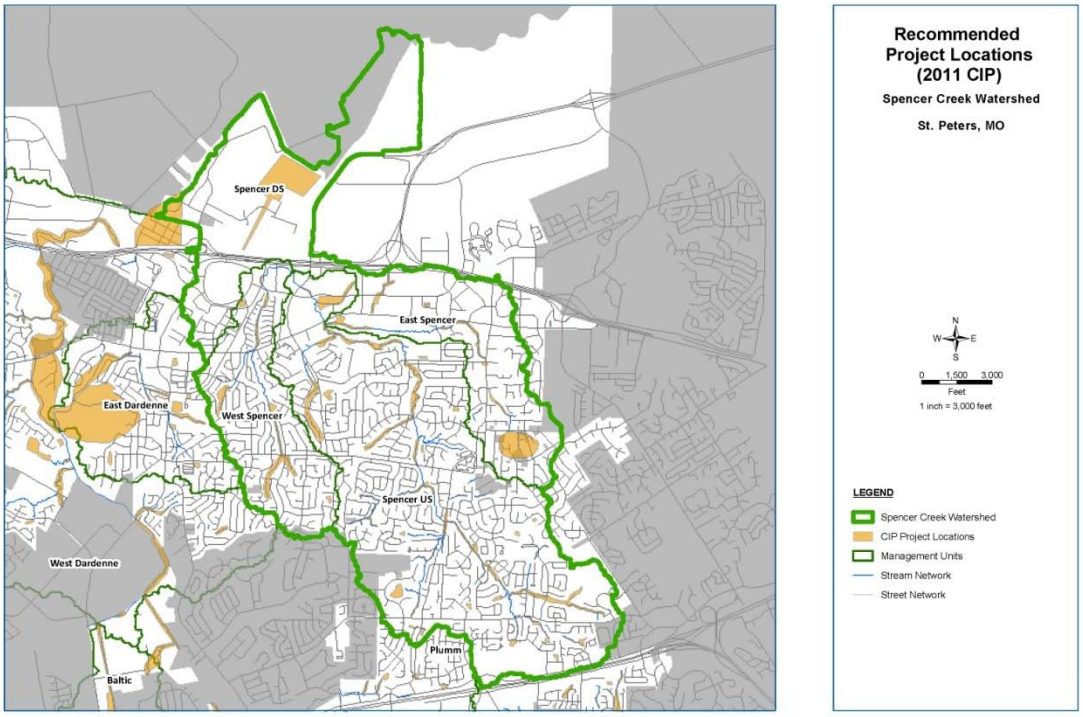

FIGURE 21. RECOMMENDED PROJECT LOCATIONS, SPENCER CREEK WATERSHED

The selected conceptual improvements are described in Section 5. Additional information related to plant palettes and plant species to be controlled is provided in Appendices F and G.

The integration of stormwater best management practices with management of the City's natural waterways may substantially benefit flooding, water quality, and habitat, and will provide opportunities for public education regarding water resource issues. A prioritization scheme was developed based on the conditions established during this study. To evaluate the priority of each CIP project, the following categories were evaluated: flooding, stream stability, and ecology. These categories were weighted and summed to develop a subtotal value.

TABLE 6. WEIGHTED CATEGORIES FOR PRIORITIZATION

Flooding	Stream Stability	Ecology
40%	35%	25%

FLOODING

Flooding locations were identified using hydrologic and hydraulic modeling results and anecdotal reports documented by the City and provided in a GIS database. The hydrologic model was used to determine when detention basin overtopping occurred during the 25-year event. The refined hydraulic model of the City waterways was used to generate a mapped area of inundation. This layer was

evaluated to determine flooding locations. At each flooded location, the number of impacted structures or the impacted roadway was documented. Each bridge crossing was also evaluated within the hydraulic model to determine overtopping of bridge or culvert crossings.

Stream Stability

Stream stability was prioritized using the Channel Condition Scoring Matrix (CCSM) and the assessment of a stream reach's impact on infrastructure or property. During the field evaluation, each stream reach was evaluated using the CCSM. A resulting score was documented for each reach. Project areas often overlapped multiple stream reaches and therefore, a weighted CCSM score was developed for each project reach. Each project was evaluated to determine if structures or property was negatively impacted by stream stability.

Ecology

The final category of prioritization relates to the ecology of the system. A water quality benefit was established for each detention basin retrofit. The categories were developed based on the potential increased removal of total suspended solid (TSS) provided by a retrofit option. This accounts for the contributing watershed characteristics and is influenced by the basin retrofit type. During the field evaluation, each stream reach was evaluated using the Stream Asset Inventory, as presented in Section 2.4.2. The resulting SAI score was used to establish a priority for restoring or protecting the stream reach within each project.

Once the scores for the flooding, stream stability, and ecology were tallied and multiplied as described in the form and paragraphs above, the result is a final prioritization score. This can be considered a measure of the project's benefit to the City stormwater system. This score is one important measure to be considered as the City allots capital funds to stormwater improvements over the coming years.

Another important measure to be considered is the cost benefit ratio that can be calculated for each project. This ratio is simply calculated by dividing the cost by the benefit score. For this study, the cost benefit scores were uniformly multiplied by 100 to avoid cumbersome decimal displays. Those projects with the smallest cost benefit ratios will provide the City with the most efficient use of improvement funds.

Appendix A includes descriptions of the recommended projects, approximate opinions of project costs, and priorities for the recommended improvements. The projects are listed in order for preservation projects and then the remaining projects.

6.2 Schedule

The schedule for improvements will be based upon the prioritization scheme presented above and the capital allotted to improvements in a given year. Some consideration of the prioritization scheme's inherent bias must occur when discussing the schedule of improvements.

For instance, if the City were to use the cost benefit ratio as the sole means to select projects, only a series of small projects would be completed. This is due to the fact that many of the projects with low cost benefit ratios are small projects that, while providing benefit to the watershed, have lower costs.

Alternatively, if the City were to use the benefit scores as the sole means to select projects, the City would likely only complete a very few, perhaps only a single, project(s) each year. This is due to the fact that many of the projects that provide a large benefit to the City's stormwater system are also large and expensive.

To avoid these scenarios, it is suggested that the City develop a hybrid selection and scheduling process. By this method, the City will develop a balanced schedule that will address multiple projects across the watersheds, but will also address important (high benefit) projects in as timely a manner as funding will permit.

7. Estimate of Required Financial and Technical Assistance

Once this planning process is complete, the citizens of St. Peters have authorized the City to spend up to $40 million over the next 20 years or more to implement the required projects. A revenue source to support this expenditure is needed and several state and Federal programs are available to help provide resources to implement this plan, listed in Table 7 Locally, potential revenue sources include implementation of a storm water user fee or utility, a sales tax, property tax, system development charges, and permitting fees.

Opinions of probable cost are provided in the Stormwater Master Plan for the recommended projects. Operations and maintenance costs are also provided for the City-owned and residential detention basins for which the City will assume responsibility. Many of the policy and other non-structural recommendations can be implemented by staff with some technical support. A preliminary estimate of the resources required to implement the non-structural recommendations are provided below.

BMPs.

- Require capture and treatment of the Water Quality Volume storm for new development and redevelopment when the volume of runoff from a site will includes by 15 percent or more.
- Focus on capturing and treating the runoff through extended dry or extended wet detention.
- Estimate of resources needed: $10,000 to $15,000 to develop the protocols for plan reviews and work with development community to understand and implement the new regulations. Several existing BMP manuals are available to consult and adopt as appropriate.

LID

- Require BMPs such as hydrodynamic separators or filters to treat runoff from "hot spots".
- Encourage LID and provide incentives for using LID in new development and redevelopment.
- Estimate of resources needed: $25,000 to develop standard and protocols for BMPs for hot spots. Several existing BMP manuals are available to consult and adopt as appropriate.

Stream Setbacks

- Prevent construction of habitable buildings in the 100-year floodplain.
- Keep the 25 foot setback preventing any development in this zone.

- Allow non-habitable structures outside of the 25 foot setback zone.
- Estimate of resources needed: $30,000 to $40,000 to develop and adopt an ordinance that codifies the modifications to the stream setback. Several existing stream setback model ordinances and from other communities are available to review and adopt as appropriate.

Street Sweeping

- Sweep streets near streams monthly beginning in early Spring.
- Estimate of resources needed: No additional funds needed to modify the street sweeping plan.

Sediment and Erosion Control

- Reduce the threshold for requiring sediment and erosion control to movement of 30 cubic yards of material or disturbing 2000 square feet.
- Adopt the new guideline published by MDNR: **Protecting Water Quality: A field guide to erosion, sediment, and storm water best management practices for development sites in Missouri and Kansas, January 2011.**
- Estimate of resources needed: $25,000 to $35,000 to modify the City's ordinances and involve the community and developers.

Homeowner Drainage Issues

- Develop a program to educate homeowners about alternative downspout and pool discharge practices.
- Estimate of resources needed: $5,000 to $10,000 to develop education program.

Education and Awareness

- Develop a comprehensive education program that targets homeowners, developers, staff and water quality related programming.
- Estimate of resources needed: $30,000 to $40,000 to create and implement the comprehensive program.

A number of state and federal programs are available to access resources for implementation of these recommendations. Availability of these Federal, State and local funding sources will vary from year to year based on budgetary limitations and competition(2). Table 7 provides a list of possible funding sources that can be explored.

TABLE 7. POTENTIAL FUNDING SOURCES

Funding Program	Overview
Nonpoint Source Implementation Grants (319 Program)	Continued participation in this program administered by MDNR to implement the recommendations of the plan
Native Plant Conservation Initiative	The National Fish and Wildlife Foundation's Native Plant Conservation Initiative supports on-the-ground conservation projects that protect, enhance, and/or restore native plant communities on public and private land.
Targeted Watershed Grants Program	EPA has asked the nation's Governors, Tribal Leaders, and leading watershed organizations to apply for the next round of funding to support collaborative partnerships to protect and restore the nation's water resources.
Water Quality Cooperative Agreements	EPA grants are provided to help states, Indian tribes, interstate agencies, and other public or nonprofit organizations develop, implement and demonstrate innovative approaches relating to the causes, effects, extent, prevention, and elimination of water pollution.
Private Donations	Public-private partnerships can leverage private donations – monetary, real property, or time to implement recommendations of this plan.

8. Monitoring Plan

The goal of the monitoring plan is to measure the water quality benefits of Best Management Practices to be implemented in the watershed. These BMPs are identified in this Stormwater Master Plan. The Stormwater Master Plan identifies and prioritizes BMPs throughout the City of St. Peters to improve stormwater management and water quality. BMPs should begin to be implemented in the late part of 2012. As part of this monitoring effort, the city would collect water quality and flow data from selected location(s) within Spencer Creek for 18-24 months prior to BMP implementation to establish a baseline of data. Monitoring will resume once BMPs are implemented and continue for at least 24 months afterwards to demonstrate improvement in water quality.

The data will be used for the following:

- To verify that hydrologic and water quality modeling conducted as part of the Stormwater Watershed plan is accurate;
- To demonstrate the effectiveness of BMPs implemented in the watershed at improving water quality;
- To help the City identify the most effective location for additional BMPs;
- To help make the case for more funding for water quality improvements by showing a link between BMPs, water quality and quality of life for citizens;

- To educate and encourage other communities and developers within the Dardenne Creek watershed to consider low impact development features in their projects.

The data that will be collected will include flow measurements and the following water quality data: temperature, pH, hardness, specific conductivity, dissolved oxygen, biochemical oxygen demand, total suspended solids, oil and grease, chlorides and sulfates, total phosphorus, total nitrogen, nitrate/nitrite, E. coli, turbidity and ammonia.

Very little data exists on the Lower Dardenne Creek or Spencer Creek for review. Flow monitors and water sampling equipment will be installed in two locations within the Spencer Creek watershed. City staff will be responsible for collecting samples and maintaining automatic data loggers. St. Peters will follow a written quality assurance plan for proper sampling, handling and analysis to ensure data quality.

The number and locations of monitoring stations was determined by the hydrologic and water quality modeling conducted under the watershed management plan as shown on Figure 23. The modeling determined the flow and pollutant characteristics of the water shed and where the critical problems exist (e.g. steep hydrographs, high pollutant runoff) Using the information, the monitoring stations will be located in those areas likely to yield data that is representative of Spencer Creek and will establish a baseline of data that will allow future sampling to capture the beneficial effects of BMPs that are implemented. As shown in Figure23, the city will establish five data collection points and will collect flow data and 10 to 12 composite samples during design flow per year, per station, for water quality evaluation.

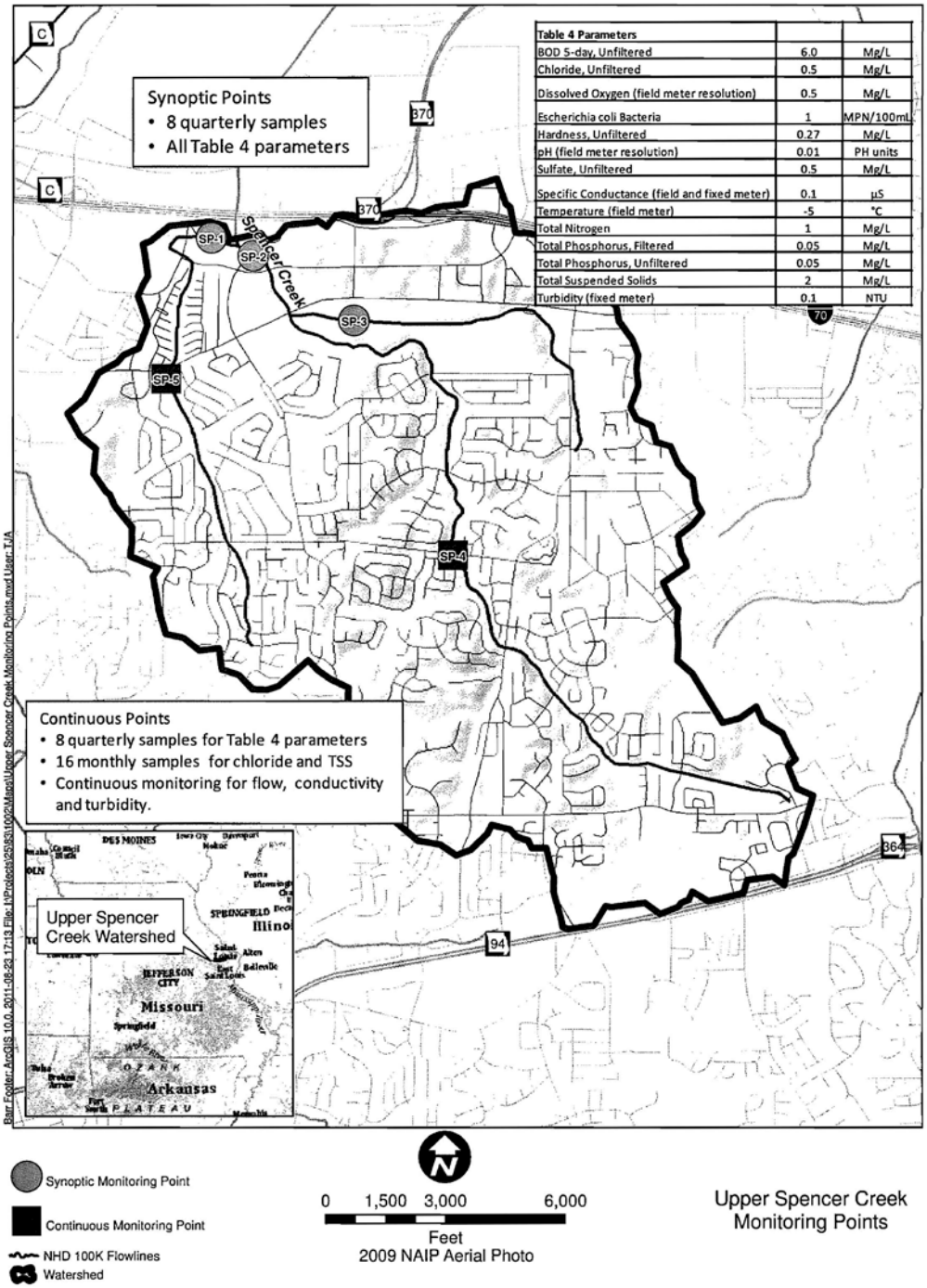

FIGURE 22. RECOMMENDED WATER QUALITY MONITORING LOCATIONS

By monitoring daily for flow and taking monthly composite samples for water quality and by establishing a baseline, the data collected should measure significant improvements in both hydrology and water

quality as a result of BMP implementation. As data are collected over time, St. Peters staff will correlate rainfall, flow and water quality data and look for relationships between flow and water quality during design rain event (e.g. 1" or less). This analysis will continue as BMPs are implemented and will be used to calibrate the water quality modeling and to determine whether the BMPs appear to be improving stream hydrography and quality under comparable rainfall conditions.

The data will be referenced to a baseline of 18-24 months prior to BMP installation and will measure improvements over time. The control measures will be stream hydrography and quality for the baseline period. Once BMPs begin to be installed, stream data should begin to show improvements in both hydrography and water quality. As data are collected over time, St. Peters staff will correlate rainfall, flow and water quality data and look for relationships between flow and water quality during design rain event (e.g. 1" or less). This analysis will continue as BMPs are implemented to determine whether the BMPs appear to be improving stream hydrography and quality under comparable rainfall conditions.

The City will install the field equipment and will collect samples and field data. St. Peters will contract with a qualified laboratory to run all sample analyses.

The project calls for two types of sampling equipment: portable equipment for grab samples and continuous monitoring equipment.

Portable, handheld monitoring instruments will be used to collect stream monitoring data. Portable instruments serve several purposes: they can be used to calibrate permanent monitoring equipment, correct continuous data for instrument drift, measure flow to develop stage-discharge relationships and to help identify possible problems in field methods or equipment.

The portable instruments used will be a handheld YSI 556 Multiparameter Probe, or equivalent.

Two stream monitoring stations will be designed to continuously measure stage, turbidity and conductivity. Flow data will be obtained using a stage-discharge relationship (rating curve) based on discharge measurements taken across the typical range of flows. Data for these parameters will be recorded at set intervals, typically from 5 to 30 seconds, on a datalogger and analyzed in 15 minute averages. Data will be periodically downloaded from the datalogger and checked for accuracy and completeness. All sensor readings will be periodically verified using handheld meters and recalibrated if drifting has occurred. All sensors will be periodically checked for bio-fouling or other interferences and cleaned if necessary. The equipment layout will be as follows:

- FTS DTS-12 Turbidity Sensor
- Hydrological Services HS30 Water Level Sensor (Bubbler) or
  Campbell Scientific CS475 Water Level Radar Sensor
- Campbell Scientific CS850 Datalogger
- Campbell Scientific Rechargeable Battery w/ AC Wall Mounted

Charger

- Campbell Scientific CS547A Conductivity/Temperature Sensor
- Campbell Scientific ENC12/14 Weather-Proof Enclosure
- Campbell Scientific Loggernet Software
- Metal Cabinet
- Hardware (i.e., conduit, fasteners, marine battery, etc.)
- Cell Phone Telemetry

In its first annual grant report, St. Peters will provide all chemistry data available to date; calibration records for flow metering; a summary of continuous data; electronic download of continuous data (if requested by DNR); and any preliminary data analysis including evaluations of rainfall/flow, conductivity/chlorides or turbidity/TSS.

In the second annual report, St. Peters will provide an update of all of the above and a final analysis of the data, including discussion of data anomalies and a discussion of the reasons for any factors that did not correlate as predicted.

The results of all data collected will be reported to DNR and be made available to citizens who are interested. This information will be used to inform other communities, developers and interested parties in St. Charles County and to stimulate water quality planning and promote similar practices throughout the Dardenne Creek Watershed.

Public Involvement

City staff plans to inform the community and other stakeholders of the findings and recommendations of this plan. It will also be used as a stepping stone work with a broader stakeholder group to develop a plan for the entire Dardenne Creek watershed.

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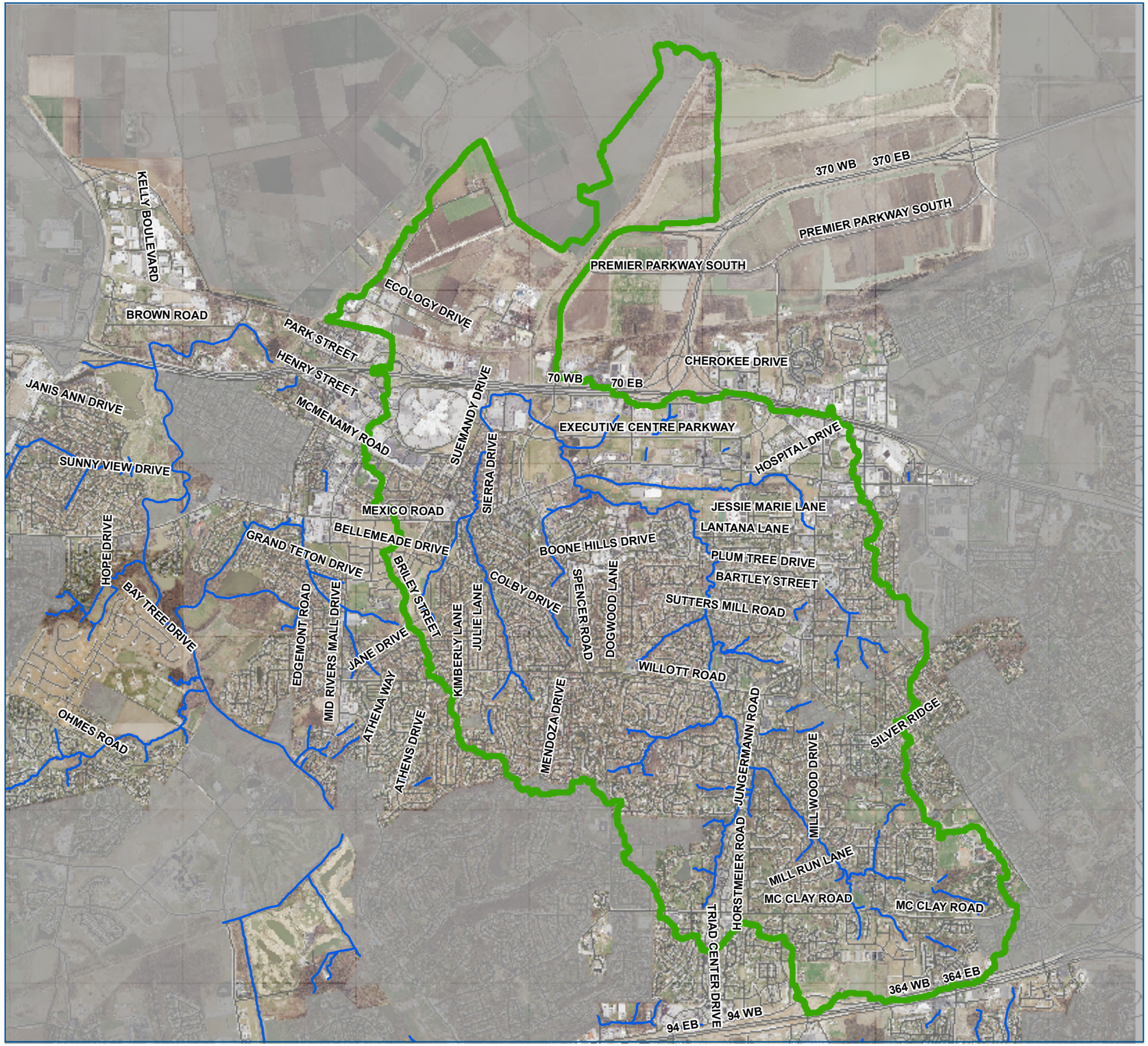
Appendix A. Maps



General Map with Aerial

Spencer Creek Watershed

St. Peters, MO

N
W E
S

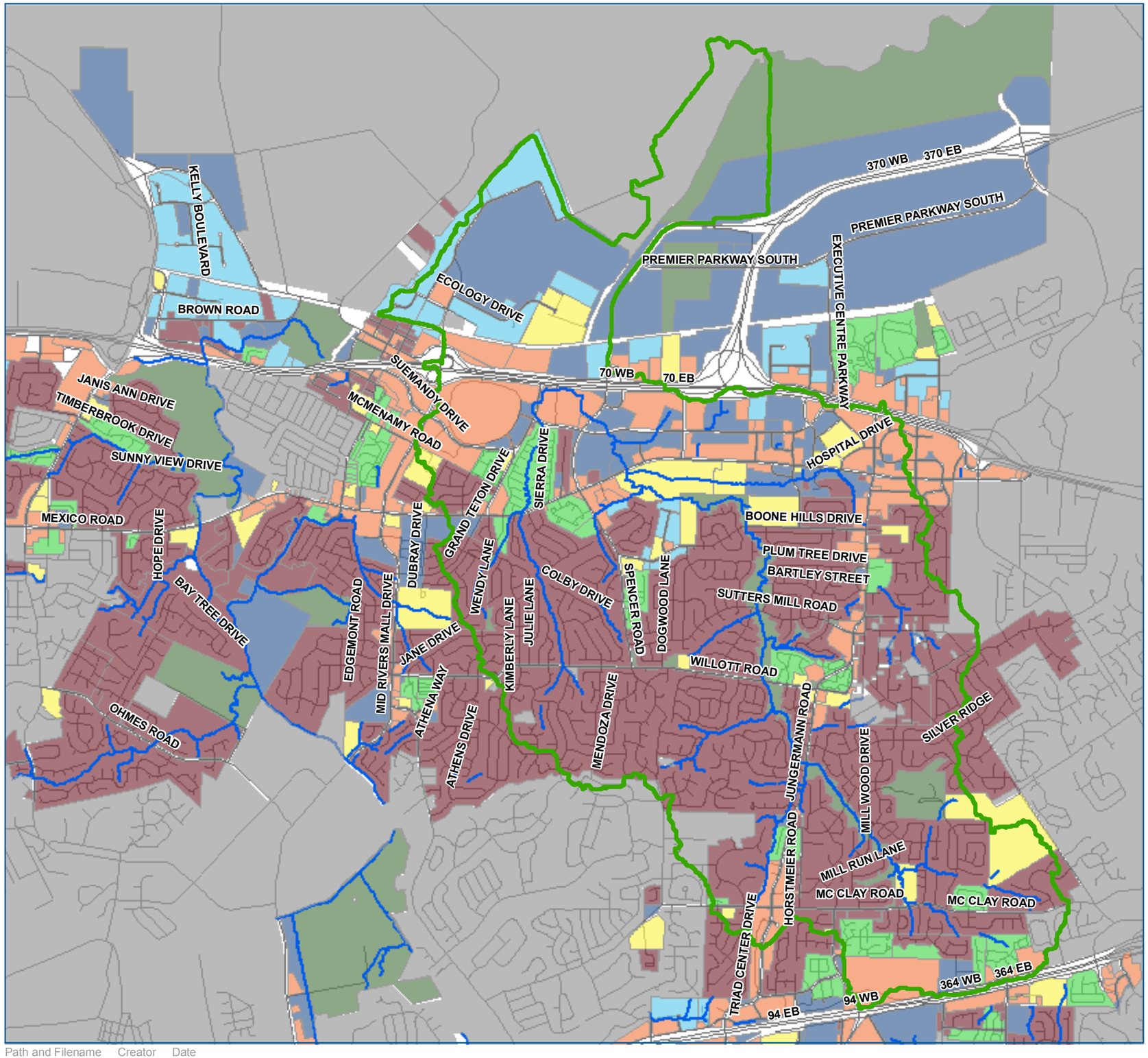
0 1,500 3,000
Feet

1 inch = 3,000 feet

LEGEND

- Stream Network
- Spencer Creek Watershed
- Street Network

Path and Filename Creator Date



Land Use
Spencer Creek Watershed

St. Peters, MO

N
W E
S

0 1,500 3,000
Feet

1 inch = 3,000 feet

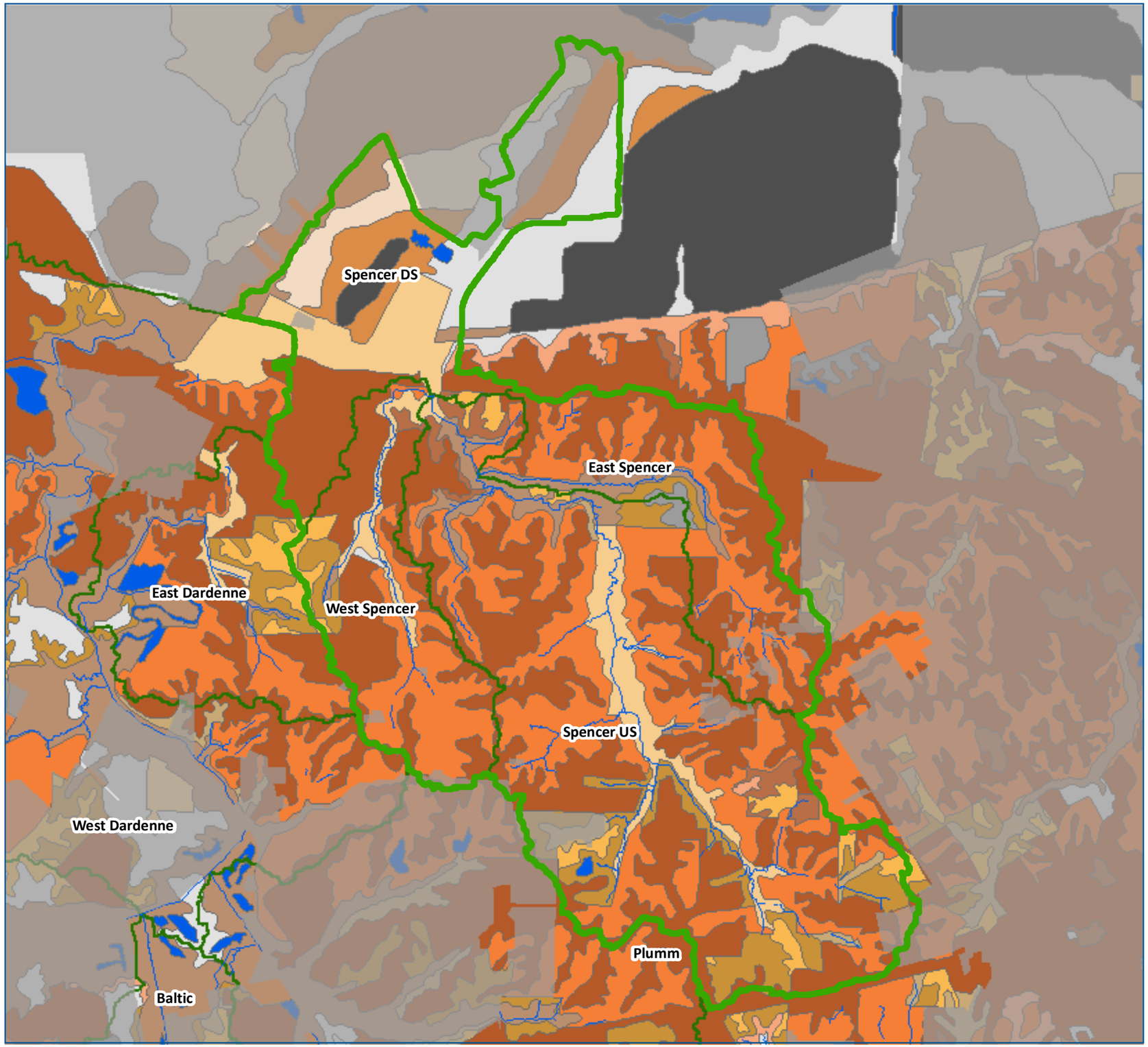
LEGEND

- Spencer Creek Watershed
- Stream Network

Current Land Use

- Single Family/ Multi-Family
- Commercial
- Industrial
- Public/ Semi-Public
- Park
- Single Family
- Vacant
- Street Network

Path and Filename Creator Date



Detailed Soils

Spencer Creek Watershed

St. Peters, MO

N
W E
S

0 1,500 3,000
Feet

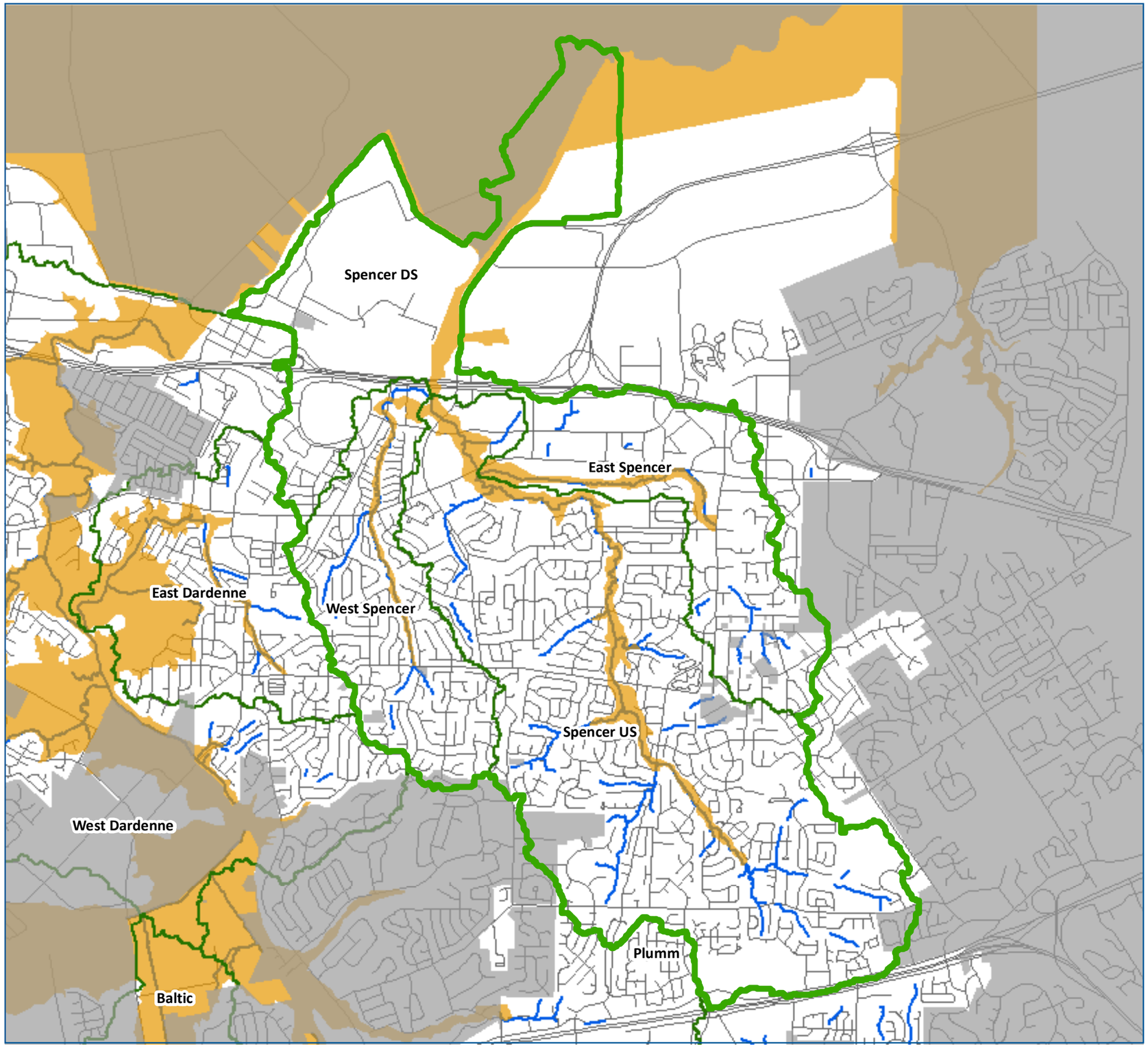
1 inch = 3,000 feet

LEGEND

- Spencer Creek Watershed
- Stream Network
- Management Units

NRCS SSURGO Soil Classification

- Other
- Carlow silty clay loam, 0 to 2 percent slopes, occasionally flooded
- Chequest silt loam, 0 to 2 percent slopes, occasionally flooded
- Dockery silt loam, 0 to 2 percent slopes, occasionally flooded
- Fishpot-Urban land complex, 0 to 5 percent slopes, rarely flooded
- Harvester-Urban land complex, 2 to 9 percent slopes
- Harvester-Urban land complex, 9 to 14 percent slopes
- Menfro silt loam, 20 to 35 percent slopes
- Menfro silt loam, 5 to 9 percent slopes
- Menfro silt loam, 9 to 14 percent slopes, eroded
- Menfro silt loam, karst, 5 to 20 percent slopes
- Portage clay, 0 to 2 percent slopes, occasionally flooded, frequently ponded
- Water
- Winfield silt loam, 9 to 14 percent slopes
- Winfield silty clay loam, 14 to 20 percent slopes, eroded
- Street Network



FEMA Floodplain Spencer Creek Watershed

St. Peters, MO

N
W E
S

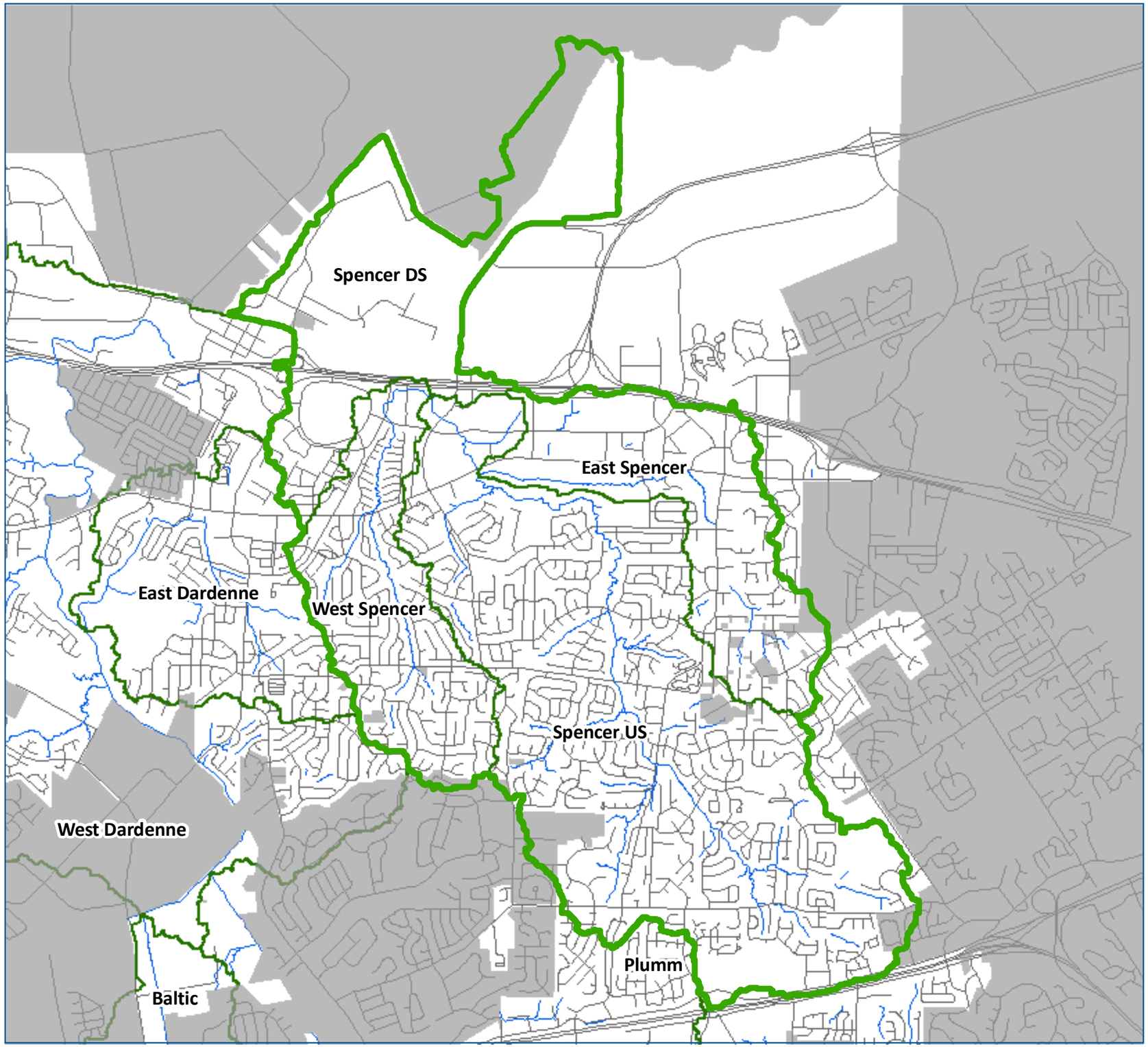
0 1,500 3,000
Feet

1 inch = 3,000 feet

LEGEND

- Spencer Creek Watershed
- Management Units
- FEMA Floodplain
- Stream Network
- Street Network

Path and Filename Creator Date



Management Units

Spencer Creek Watershed

St. Peters, MO

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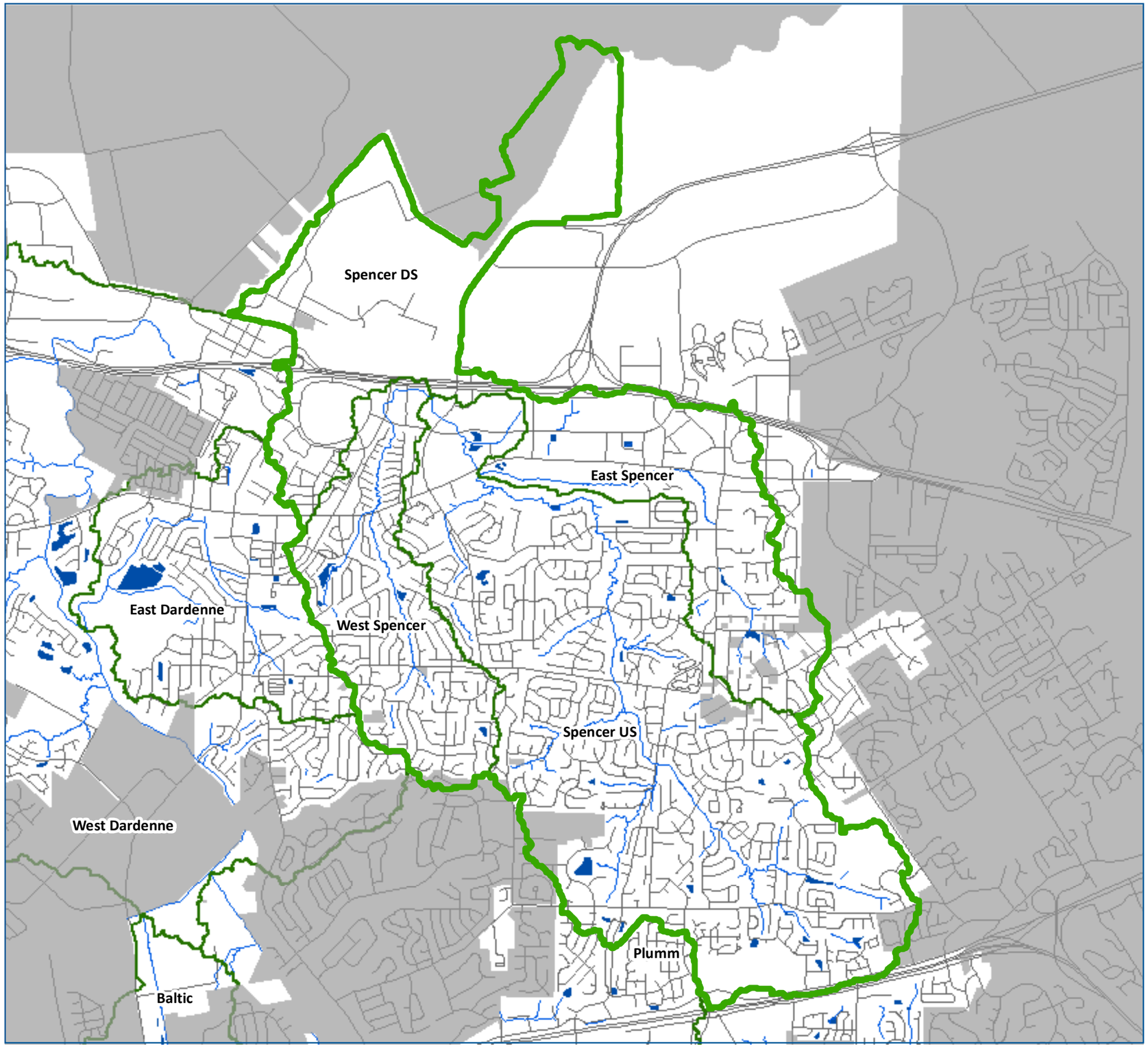
0 1,500 3,000
Feet

1 inch = 3,000 feet

LEGEND

- Spencer Creek Watershed
- Management Units
- Stream Network
- Street Network



Selected Detention Basins

Spencer Creek Watershed

St. Peters, MO

N
W E
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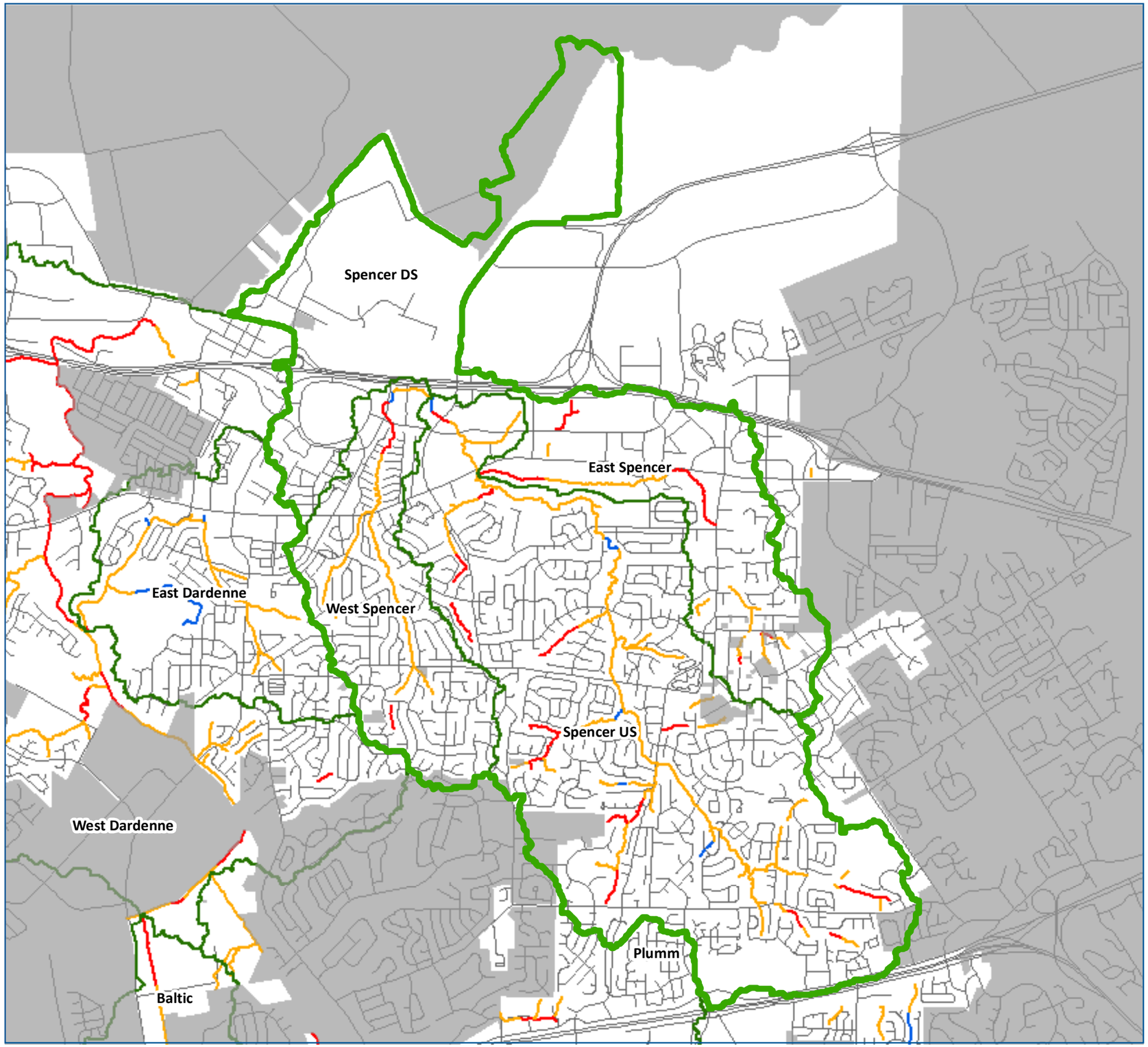
0 1,500 3,000
Feet

1 inch = 3,000 feet

LEGEND

- Spencer Creek Watershed
- Management Units
- Stream Network
- Street Network
- Selected Detention



Stream Stability (CCSM Scores)

Spencer Creek Watershed

St. Peters, MO

N
W E
S

0 1,500 3,000
Feet

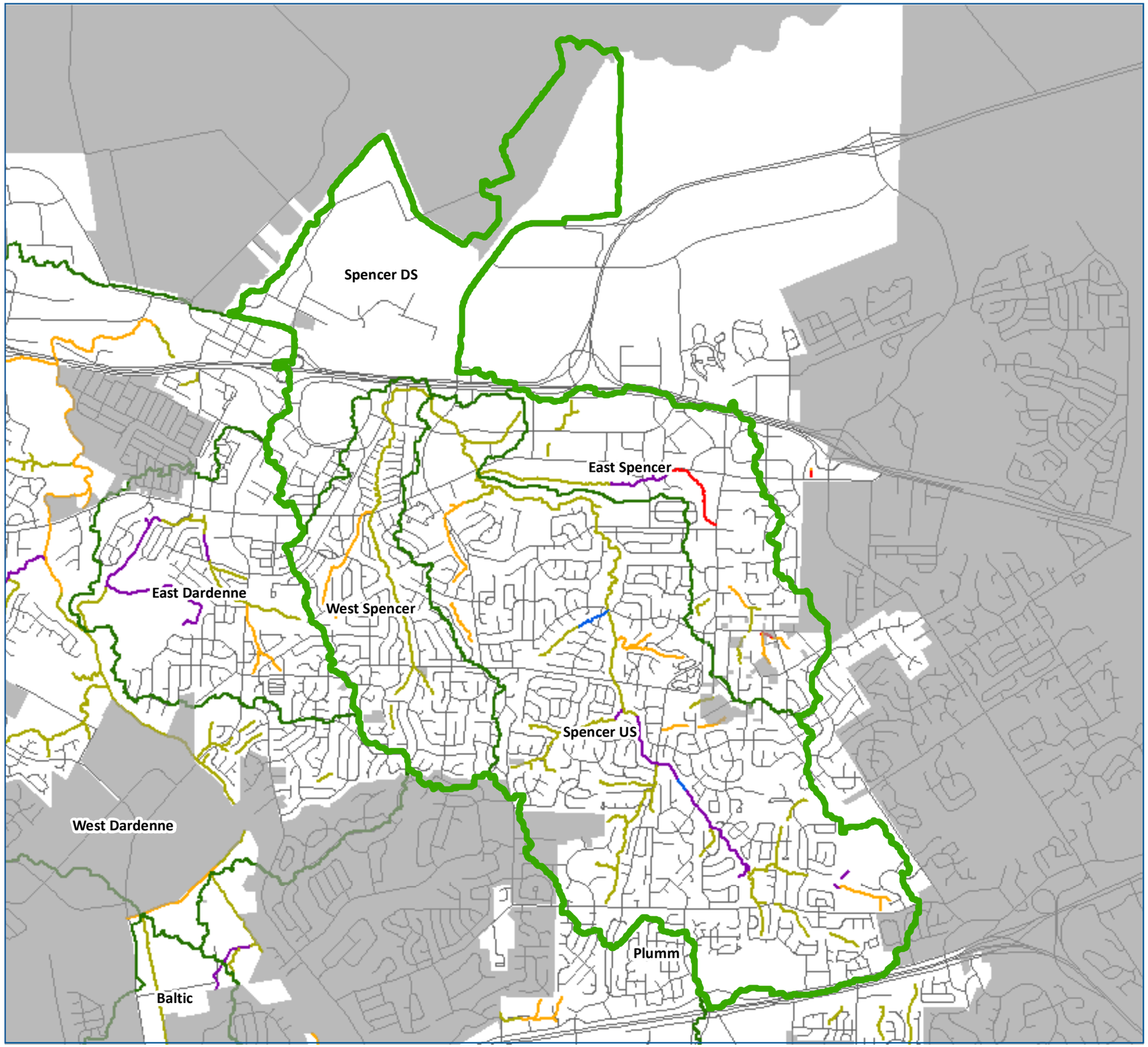
1 inch = 3,000 feet

LEGEND

- Spencer Creek Watershed
- Management Units

Stream Network

- 10-13, Stable
- 13-19, Stability Concerns
- 19-24, Significant Instability
- Street Network



Stream Assets (SAI Scores)

Spencer Creek Watershed

St. Peters, MO

N
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0 1,500 3,000
Feet

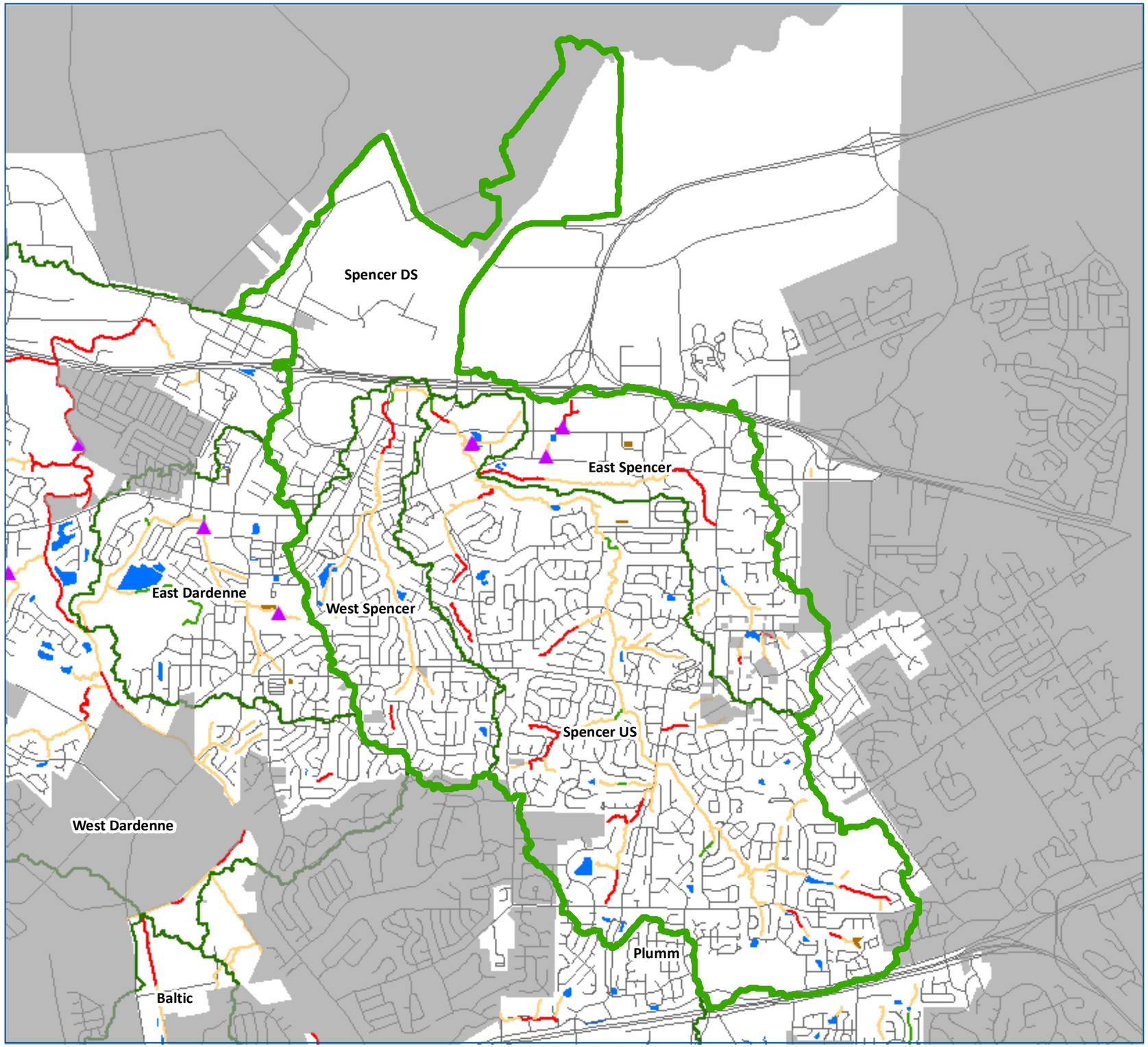
1 inch = 3,000 feet

LEGEND

- Spencer Creek Watershed
- Management Units

Stream Network

- 1
- 2
- 3
- 4
- 5
- Street Network



General Watershed Impairment Areas

Spencer Creek Watershed

St. Peters, MO

N
W E
S

0 1,500 3,000
Feet
1 inch = 3,000 feet

LEGEND

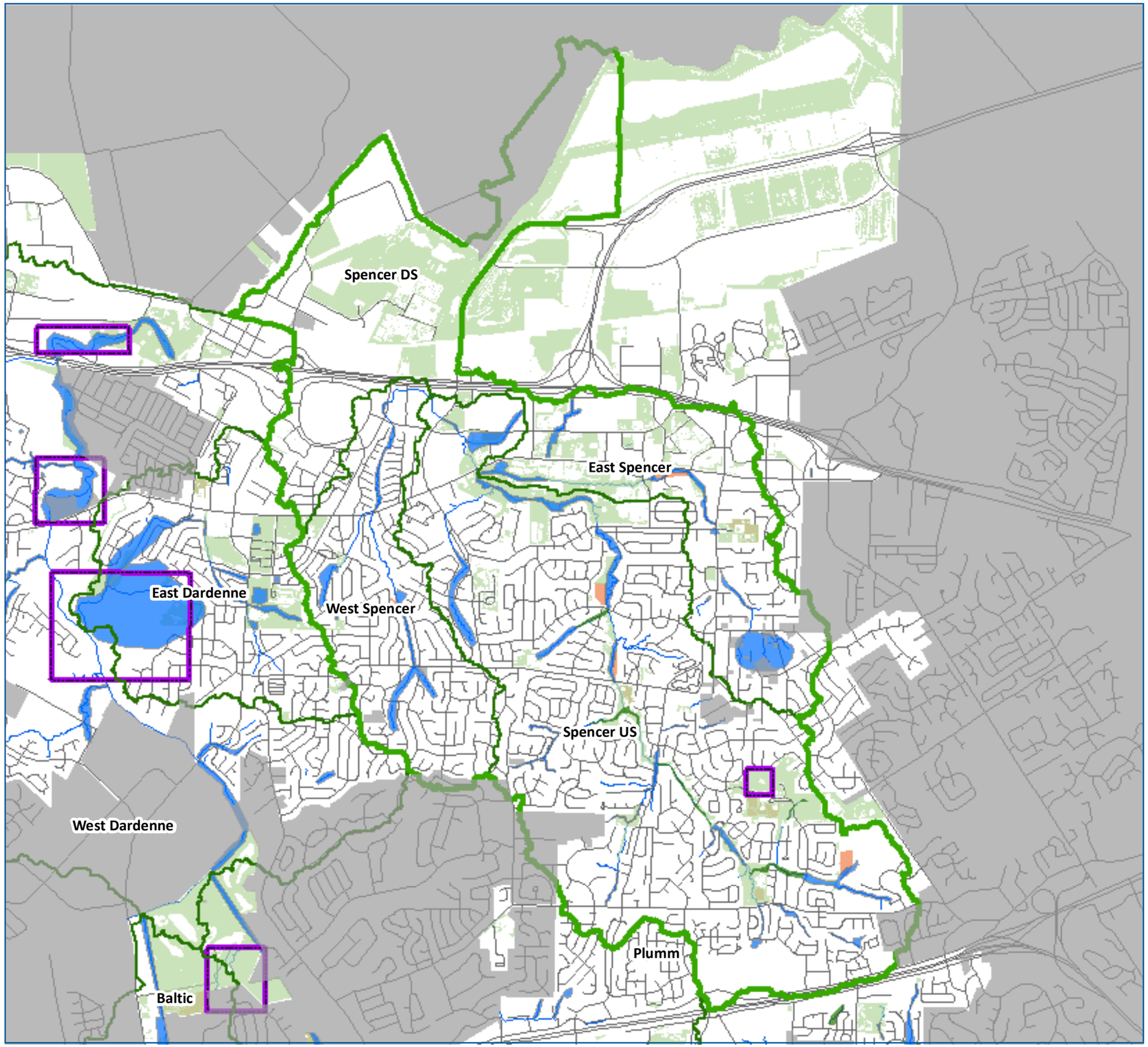
- Spencer Creek Watershed
- Management Units
- Water Quality Concern Points

Selected Detention

- Other Basins
- High TSS Discharge (>1000 lbs/yr)

Stream Network

- 10-13
- 13-19
- 19-24
- Stream Network
- Street Network



General Watershed Protection Areas

Spencer Creek Watershed

St. Peters, MO

N
W E
S

0 1,500 3,000
Feet

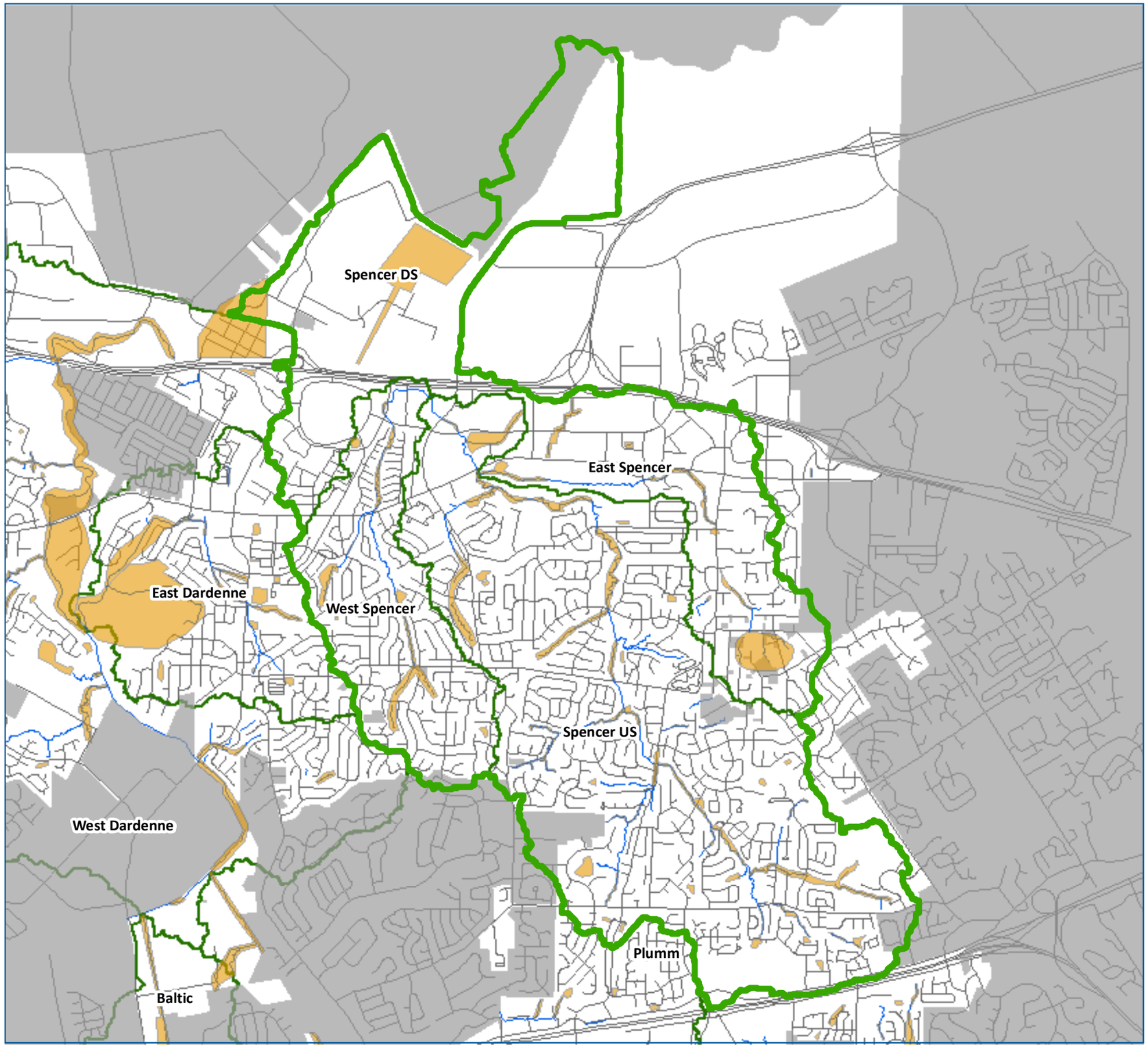
1 inch = 3,000 feet

LEGEND

- Spencer Creek Watershed
- Management Units
- Protection Zones

Projects

- Preservation
- Stream Stability
- Locations with BMP Suitability
- Regional Detention Opportunities
- Stream Network
- Street Network



Recommended Project Locations (2011 CIP)

Spencer Creek Watershed

St. Peters, MO

N
W E
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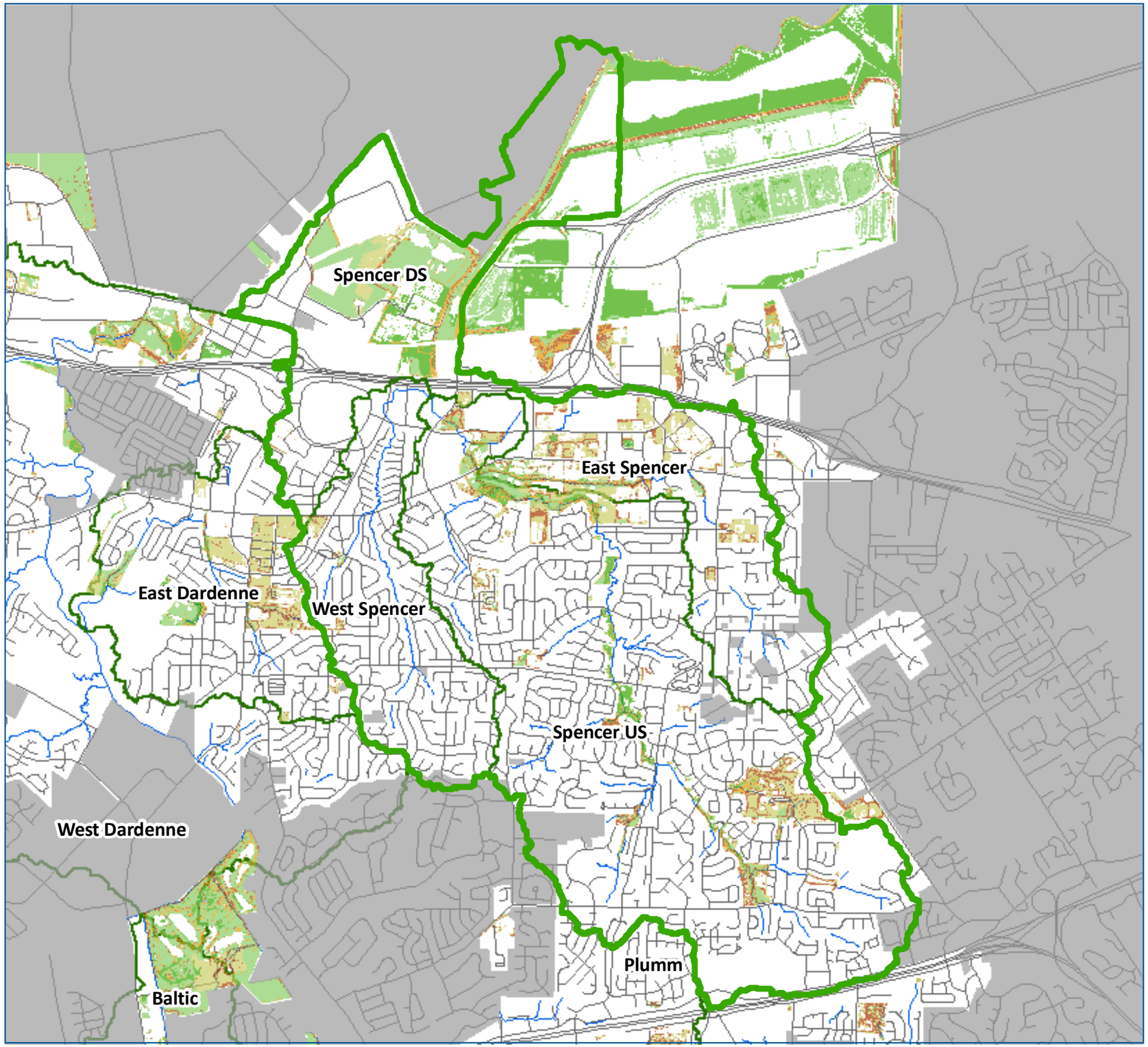
0 1,500 3,000
Feet

1 inch = 3,000 feet

LEGEND

- Spencer Creek Watershed
- CIP Project Locations
- Management Units
- Stream Network
- Street Network



Stormwater Best Managment Practice Locations

Spencer Creek Watershed

St. Peters, MO

N
W E
S

0 1,500 3,000
Feet

1 inch = 3,000 feet

LEGEND

- Spencer Creek Watershed

BMP Locater Results

- Low Suitability
- Moderately Low Suitability
- Moderate Suitability
- Moderately High Suitability
- High Suitability
- Management Units
- Stream Network
- Street Network

Appendix B. Stream Classification Summary

In April and May, Black & Veatch and PBA staff joined the City to evaluate stream stability and habitat within the City limits. As a team, Black & Veatch and PBA conducted a geomorphology and stream health field survey of the 47 miles of streams in the City of St. Peters. The team applied standards developed by the Kansas City Metropolitan Chapter of American Public Works Association and various state and federal natural resource agencies. This evaluation resulted in two scores: a channel condition score and a stream asset inventory (SAI) score. This appendix summarizes the significance of each score and provides a photograph of a representative reach.

Channel Condition Score

Black & Veatch applied a Channel Condition Scoring Matrix based on the matrix developed by the Kansas City chapter of American Public Works Association to determine the stability of stream reaches throughout the City. The matrix provides a comparative score of reaches throughout the City and will be used to identify areas of significant instability and to prioritize projects. The resulting score can be divided into three groups that range between 10 and 25.

Stable Streams

A rating between 10 and 13 indicates a stream of moderate stability and may require only standard levels of protection during construction in the contributing drainage area. Figure 1 presents a good example of a stable channel in St. Peters. This stream represents a restoration project; there is a diversity of vegetation, cobble bed, and very little bank erosion.

FIGURE 1. CRESCENT HILLS TRIBUTARY, SCORE: 10.2

Streams with Stability Concerns

A channel condition rating between 13 and 19 indicates that the reach may be experiencing instability and special measures may be needed to address specific issues that were rated poorly. Streams with scores in this range may have very different appearances because of the specific concern with each stream. In St. Peters, many of the channels show evidence of bank undercutting, excess sediment movement in the channel bed, debris jams, and undesirable vegetation. Figure 2 presents Spencer Creek north of Mexico Road. This reach is experiencing a transition to a wider stream after becoming incised (the channel bed material erodes and lowers the elevation). Bare soil on the banks is exposed to flow in the channel and the vegetation is mostly shrub honeysuckle, an invasive plant that out-competes native species.

FIGURE 2. SPENCER CREEK NORTH OF MEXICO, SCORE: 16

Another example of a reach with some instability is presented in Figure 3. This photograph was taken at a location along East Branch of Dardenne Creek where high banks showed evidence of active scouring. This stream channel is becoming more incised as the channel bed lowers. If not addressed, the channel will widen and many of the trees in the riparian corridor will fall into the stream.

FIGURE 3. EAST BRANCH DARDENNE CREEK, SCORE: 16

Significant Instability

A rating that is greater than 19 indicates that the stream may be experiencing significant system-wide instability. Figure 4 shows a reach of Dardenne Creek adjancent to a golf course and utility corridor. Streams in this category typically show significant erosion, active degradation, and threaten infrastructure. The vertical banks and lack of riparian corridor on this reach result in a very high score.

FIGURE 4. DARDENNE CREEK, SCORE: 22

Smaller reaches may also be scored poorly. Figure 5 was taken along a tributary to Dardenne Creek. This stream is very unstable and is actively eroding away soil on both banks.

FIGURE 5. EAST BRANCH DARDENNE CREEK, SCORE: 23

Stream Asset Inventory

PBA used the SAI procedure developed for assessing urban streams and watersheds in the Kansas City region, which incorporates the best elements of a number of accepted stream and habitat assessments. The SAI methodology provides rapid and scientifically defensible indicators of water quality, stream stability, in-stream and terrestrial habitat conditions. The assessment criteria are assigned individual weighted scores to create a composite score of stream quality at each sampled location and a relative ranking of stream quality throughout the entire watershed. Stream reaches were assigned a relative ranking from Type 1 (highest quality) through Type 5 (lowest quality) based on the relative condition of St. Peters' streams, as described and illustrated below.

Type 1 - Highest Quality

Generally described as the highest quality naturally occurring stream with little negative impact. Erosion and sedimentation is low, water quality indicators are positive and the surrounding riparian zone is healthy, mature, successional woodland or other high-quality environment.

FIGURE 6. SPENCER CREEK NEAR BIRCHWOOD DRIVE, TYPE 1

Type 2 - High Quality

This type of stream may have some down or side-cutting; however, bank and bed composition (bedrock) assist in keeping the impact low. Water quality is generally good and the riparian zone is largely intact, although vegetation may be negatively altered from that of a typical native plant association.

FIGURE 7. DARDENNE CREEK, NEAR FRONTIERS EDGE COURT, TYPE 2

Type 3 – Restorable

Deterioration of the channel and riparian corridor are more noticeable. While some remnant plant associations may be present, overall vegetative canopy cover is comprised of immature tree species. Water quality may be fair to marginal. The potential for restoration exists although erosion and sedimentation can be greater than desirable.

FIGURE 8. SPENCER CREEK, DOWNSTREAM OF MCCLAY ROAD, TYPE 3

Type 4 - Low Quality

Impacts are greater on this stream type with significant indicators of bank erosion and channel instability. The adjoining riparian corridor may be intact but vegetation is not representative of a native plant association. Water quality is typically poor.

FIGURE 9. EAST SPENCER, UPSTREAM OF OAKTREE RETIREMENT COMMUNITY, TYPE 4

Type 5 - Lowest Quality

The channel in this type is the most changed. The riparian corridor is impaired to the point of providing little protection or benefit, and erosion and sedimentation indicators are significantly high. Water quality is poor with degradation and absence of macroinvertebrates, fish, mollusks, and amphibians.

FIGURE 10. EAST SPENCER CREEK, DOWNSTREAM OF JUNGERMANN ROAD, TYPE 5

Appendix C. Detention Basin Water Quality Summary Tables

Detention Basin Summary Tables

Table 1. Stormwater Detention Basin Removal Efficiencies

This table summarizes the results from P8 modeling of TSS for each basin, given existing conditions. The area and general category (wet or dry) of the basin is also included.

Table 2. Stormwater Detention Basin Removal Efficiencies with Retrofits

This table summarizes the results from P8 modeling of TSS for each basin, given retrofit conditions. The area, general category (wet or dry), recommended retrofit, and flow input of the basin is also included.

Table 3. Detention Basin Characteristics

This table summarizes the detention basin and contributing watershed characteristics that were used for the P8 modeling of existing conditions.

Table 4. Detention Basin Characteristics with Retrofits

This table summarizes the detention basin and contributing watershed characteristics that were used for the P8 modeling of retrofit conditions.

Table 1. Stormwater Detention Basin Removal Efficiencies

Basin ID	Area	Wet/ Dry	TSS In	TSS Out	TSS Removal	TSS In	TSS Out
	ac	W or D	lb/yr	lb/yr	%	mg/L	mg/L
DB-6869-02	3.52	W	7,787	201	97.4	107	2.8
DB-6870-15	0.34	D	1,681	1,080	35.8	108	70.0
DB-6870-16	0.22	D	1,539	1,122	27.1	105	77.3
DB-6871-01	0.38	D	17,369	12,528	27.9	108	79.7
DB-6871-03	0.27	D	17,284	12,779	26.1	108	81.0
DB-6965-01	0.44	D	871	560	35.7	106	68.6
DB-6968-02	0.76	W	6,804	628	90.8	107	9.9
DB-6969-02	1.91	W	571	6	99.0	103	1.0
DB-6969-03	4.63	W	4,183	30	99.3	105	0.8
DB-6969-04	1.22	W	589	52	91.3	91	8.0
DB-6969-06	0.34	D	238	158	33.6	107	71.0
DB-6969-07	0.86	D	789	412	47.8	105	54.9
DB-6969-08	0.47	D	4,333	3,447	20.4	106	85.2
DB-6969-09	0.60	D	436	254	41.7	105	60.8
DB-6969-10	0.39	D	2,882	2,439	15.4	106	88.5
DB-6970-03	5.83	W	2,583	10	99.6	107	0.4
DB-6971-08	1.27	W	8,257	612	92.6	108	8.0
DB-7065-01	0.42	D	314	186	40.8	107	62.3
DB-7065-02	0.39	D	267	170	36.3	107	67.6
DB-7065-03	0.53	D	927	405	56.3	107	46.7

Basin ID	Area ac	Wet/ Dry W or D	TSS In lb/yr	TSS Out lb/yr	TSS Removal %	TSS In mg/L	TSS Out mg/L
DB-7065-04	0.21	D	22,034	11,671	47.0	106	57.5
DB-7065-05	2.89	W	2,915	37	98.7	106	1.4
DB-7067-01	3.31	W	17,131	886	94.8	121	6.3
DB-7067-02	0.53	D	419	269	35.8	76	48.5
DB-7069-06	15.56	W	8,593	33	99.6	104	0.4
DB-7069-07	1.40	W	3,548	81	97.7	107	81.4
DB-7069-08	0.88	W	2,494	77	96.9	107	3.3
DB-7069-10	1.54	W	7,289	290	96.0	107	4.2
DB-7069-12	0.14	D	112	67	40.4	103	60.8
DB-7069-13	0.63	D	2,143	1,529	28.7	106	76.1
DB-7070-03	0.19	D	19,124	15,815	17.3	108	89.4
DB-7070-10	0.85	D	111	52	53.1	91	42.7
DB-7071-04	1.40	W	23,630	2,625	88.9	108	12.0
DB-7169-01	0.43	D	692	483	30.2	107	73.0
DB-7169-02	0.16	D	17,617	12,465	29.2	108	78.4
DB-7169-04	0.27	D	17,041	12,621	25.9	107	81.1
DB-7169-08	0.55	W	401	11	97.2	104	3.0
DB-7169-09	0.20	D	1,026	684	33.3	107	71.9
DB-7169-10	1.20	D	370	162	56.2	100	43.6
DB-7169-11	0.14	D	478	334	30.1	104	72.8
DB-7267-04	0.37	D	8,939	6,031	32.5	93	25.8
DB-7267-14	0.44	D	23,090	18,710	19.0	108	88.8

Basin ID	Area ac	Wet/ Dry W or D	TSS In lb/yr	TSS Out lb/yr	TSS Removal %	TSS In mg/L	TSS Out mg/L
DB-7268-04	0.84	D	2,951	1,547	47.6	107	56.8
DB-7268-06	0.90	W	4,649	205	95.6	107	4.7
DB-7268-07	4.38	W	2,556	8	99.7	106	0.3
DB-7269-01	2.13	W	17,214	1,293	92.5	107	8.1
DB-7270-01	1.04	W	4,064	110	97.3	108	2.9
DB-7270-09	0.63	D	9,460	7,001	26.0	107	80.4
DB-7270-10	1.37	W	6,111	162	97.3	108	2.9
DB-7270-15	0.92	W	11,305	1,075	90.5	108	10.3
DB-7366-01	0.35	D	25,834	22,061	14.6	108	93.5
DB-7367-04	0.23	D	2,535	2,094	17.4	108	90.2
DB-7367-07	0.27	D	2,694	1,833	32.0	108	74.2
DB-7367-10	0.24	D	3,278	2,665	18.7	107	80.1
DB-7367-19	0.25	D	3,997	3,563	10.9	107	83.0
DB-7367-20	0.93	W	7,877	1,211	84.6	106	16.3
DB-7368-08	0.86	W	3,241	125	96.1	107	4.1
DB-7368-09	0.57	W	701	10	98.6	105	1.5
DB-7369-04	0.97	W	2,273	43	98.1	107	2.0
DB-7369-06	1.79	W	14,745	765	94.8	107	5.6
DB-7369-07	0.32	D	7,934	5,476	31.0	107	73.3
DB-7369-11	0.92	W	14,424	2,391	83.4	108	18.0
DB-7370-14	0.72	D	11,977	10,247	14.4	107	91.9
DB-7370-16	0.18	D	17,531	12,464	28.9	108	77.4

Basin ID	Area	Wet/ Dry	TSS In	TSS Out	TSS Removal	TSS In	TSS Out
	ac	W or D	lb/yr	lb/yr	%	mg/L	mg/L
DB-7467-04	0.15	D	15,689	12,406	20.9	108	86.0
DB-7467-06	0.24	D	5,816	3,927	32.5	107	66.5
DB-7467-07	0.40	D	9,236	8,047	12.9	108	94.6
DB-7467-12	0.11	D	9,086	8,076	11.1	108	95.2
DB-7467-13	0.44	D	3,290	224	93.2	108	7.3
DB-7467-14	0.11	D	274	201	26.6	101	74.0
DB-7467-15	0.26	D	683	579	15.2	101	84.6
DB-7467-16	0.38	D	5,849	4,471	23.6	107	82.5
DB-7468-01	0.37	W	631	12	98.1	106	2.0
DB-7468-06	2.21	W	33,318	3,504	89.5	107	11.3

Appendix C Table 2. Stormwater Detention Basin Removal Efficiencies with Retrofits

Basin ID	Area ac	Wet/Dry W or D	Retrofit	Flow Input ac-ft	TSS In lb/yr	TSS Out lb/yr	TSS Removal %	TSS In mg/L	TSS Out mg/L
DB-6869-02	3.52	W	WBR	267	7787	201	97.4	107	2.8
DB-6870-15	0.34	D	DWR	57.5	1681	163	90.3	108	10.4
DB-6870-16	0.22	D	DDR	53.9	1539	839	45.5	105	57.2
DB-6871-01	0.38	D	None	591	17369	12528	27.9	108	79.7
DB-6871-03	0.27	D	DDR	588	17284	11982	30.7	108	42.9
DB-6965-01	0.44	D	DDR	30.2	871	516	40.8	106	62.9
DB-6968-02	0.76	W	WBR	234	6804	628	90.8	107	9.9
DB-6969-02	0.86	W	None	20.5	571	5.8	99.0	103	1
DB-6969-03	4.63	W	None	146	4183	30.1	99.3	105	0.8
DB-6969-04	1.22	W	None	23.8	589	51.5	91.3	91	8
DB-6969-06	0.34	D	DWR	8.2	238	4.4	98.2	107	2
DB-6969-07	0.86	D	DWR	27.6	789	30.4	96.1	105	4.1
DB-6969-08	0.47	D	DWR	150	4333	411	90.5	106	10.1
DB-6969-09	0.60	D	DDR	15.3	436	252	42.2	107	60.4
DB-6969-10	0.39	D	DWR	100	2882	251	91.3	106	9.2
DB-6970-03	5.83	W	None	89.1	2583	10.4	99.6	107	0.4
DB-6971-08	1.27	W	WBR	282	8257	612	92.6	108	8
DB-7065-01	0.42	D	DDR	10.8	314	180	42.7	107	60
DB-7065-02	0.39	D	DDR	9.2	267	170	36.3	107	67.7
DB-7065-03	0.53	D	DDR	31.9	927	403	56.5	107	46.4
DB-7065-04	0.21	D	DDR	767	22034	9285	57.9	106	48.2
DB-7065-05	2.89	W	WBR	100.8	2915	37.4	98.7	106	1.4
DB-7067-01	3.31	W	WBR	519	17131	886	94.8	121	6.3
DB-7067-02	0.31	D	DDR	20.4	419	262	37.5	75.6	47.4
DB-7069-06	15.56	W	WBR	304	8593	33.2	99.6	104	0.4
DB-7069-07	1.40	W	WBR	212.7	3548	81.4	97.7	107	81.4

Basin ID	Area ac	Wet/Dry W or D	Retrofit	Flow Input ac-ft	TSS In lb/yr	TSS Out lb/yr	TSS Removal %	TSS In mg/L	TSS Out mg/L
DB-7069-08	0.88	W	None	85.6	2494	76.5	96.9	107	3.3
DB-7069-10	1.54	W	WBR	251	7289	290	96.0	107	4.2
DB-7069-12	0.14	D	DWR	4	112	5.2	95.4	103	4.8
DB-7069-13	0.63	D	DWR	74.3	2143	197	90.8	106	9.8
DB-7070-03	0.19	D	DDR	651	19124	15618	18.3	108	84.5
DB-7070-10	0.85	D	DWR	4.5	111	6.9	93.8	91	5.6
DB-7071-04	1.40	W	WBR	803.2	23630	2625.1	88.9	108	12
DB-7169-01	0.43	D	DDR	23.8	692	472	31.8	107	72.1
DB-7169-02	0.16	D	DWR	602	17617	4859	67.9	108	32.2
DB-7169-04	0.27	D	DWR	583	17041	5574	70.4	107	35.1
DB-7169-08	0.55	W	WBR	14.2	401	11.4	97.2	104	3
DB-7169-09	0.20	D	DWR	35.3	1026	96.1	90.6	107	10
DB-7169-10	1.20	D	DWR	13.6	370	13.7	96.3	100	3.7
DB-7169-11	0.14	D	DWR	16.9	478	32.4	93.2	104	7.1
DB-7267-04	0.37	D	DDR	306	8939	6019	32.7	107	71.5
DB-7267-14	0.44	D	DDR	789	23090	18069	21.7	108	85.3
DB-7268-04	0.84	W	WBR	101	2951	1547	47.6	107	56.8
DB-7268-06	0.90	W	WBR	159	4649	205	95.6	107	4.7
DB-7268-07	4.38	W	WBR	88.8	2556	8.3	99.7	106	0.3
DB-7269-01	2.13	W	WBR	590	17214	1293	92.5	107	8.1
DB-7270-01	1.04	W	WBR	139	4064	110	97.3	108	2.9
DB-7270-09	0.63	D	None	324	9460	7001	26.0	107	80.4
DB-7270-10	1.37	W	WBR	208	6111	162	97.3	108	2.9
DB-7270-15	0.92	W	WBR	386	11305	1075	90.5	108	10.3
DB-7366-01	0.35	D	DDR	882	25834	21562	16.5	108	91.3
DB-7367-04	0.23	D	DWR	86.5	2535	392	84.5	108	16.7
DB-7367-07	0.27	D	DWR	91.9	2694	380	85.9	108	14.7
DB-7367-10	0.24	D	DDR	112	3278	2663	18.8	107	15.2

Basin ID	Area ac	Wet/Dry W or D	Retrofit	Flow Input ac-ft	TSS In lb/yr	TSS Out lb/yr	TSS Removal %	TSS In mg/L	TSS Out mg/L
DB-7367-19	0.25	D	DDR	137	3997	3547	11.3	107	80.2
DB-7367-20	0.93	W	WBR	272	7877	1211	84.6	106	16.3
DB-7368-08	0.86	W	WBR	111	3241	125	96.1	107	4.1
DB-7368-09	0.57	W	WBR	24.5	701	9.8	98.6	105	1.5
DB-7369-04	0.97	W	WBR	78.3	2273	42.5	98.1	107	2
DB-7369-06	1.79	W	WBR	509	14745	765	94.8	107	5.6
DB-7369-07	0.32	D	DDR	272	7934	4810	39.4	107	65.8
DB-7369-11	0.92	W	WBR	493	14424	2391	83.4	108	18
DB-7370-14	0.72	D	None	411	11977	10247	14.4	107	91.9
DB-7370-16	0.18	D	DDR	597	17531	7656	56.3	108	47.2
DB-7467-04	0.15	D	DWR	536	15689	5323	66.1	108	36.5
DB-7467-06	0.24	D	None	199	5816	3927	32.5	107	66.5
DB-7467-07	0.40	D	None	315	9236	8047	12.9	108	94.6
DB-7467-12	0.11	D	DDR	310	9086	8055	11.3	108	96.1
DB-7467-13	0.44	D	None	112	3290	224	93.2	108	7.3
DB-7467-14	0.11	D	DDR	9.9	274	194	29.2	101	72.1
DB-7467-15	0.26	D	DDR	24.5	683	575	15.8	101	84.4
DB-7467-16	0.38	D	DDR	201	5849	4370	25.3	107	80.7
DB-7468-01	0.37	W	WBR	21.8	631	12	98.1	106	2
DB-7468-06	2.21	W	None	1145	33318	3504	89.5	107	11.3

WBR - Wet Basin Retrofit - No change in basin volume

DWR - Dry to Wet Basin Retrofit - Provide permanent pool volume

DDR - Dry Basin Retrofit - Increase in flood pool volume

Appendix C Table 3. Detention Basin Characteristics

	Detention Basin Characteristics						Watershed	
	Wet/Dry	Area	Perm Pool VOLUME	Flood Pool VOLUME	Weir Length	Orifice Equivalent Diameter	Area	Impervious
Basin ID	W or D	ac	ac-ft	ac-ft	ft	ft	ac	Fraction
DB-6869-02	W	3.52	10.19	14.13	20	-	30.6	0.26
DB-6870-15	D	0.34	0	1	-	0.92	5.1	0.34
DB-6870-16	D	0.22	0	0.88	-	0.92	16.6	0.09
DB-6871-01	D	0.38	0	1.3	-	1.49	27.8	0.65
DB-6871-03	D	0.27	0	1.76	-	0.86	27.3	0.66
DB-6965-01	D	0.44	0	1.82	-	0.83	6.7	0.13
DB-6968-02	W	0.76	2.1	6.65	12	-	32.9	0.21
DB-6969-02	W	1.91	3.6	4.61	15	-	10.4	0.05
DB-6969-03	W	4.63	44	0	10	-	40.9	0.10
DB-6969-04	W	1.22	1.8	3.68	5	-	35.0	0.01
DB-6969-06	D	0.34	0	2	-	0.98	1.1	0.21
DB-6969-07	D	0.86	0	2.04	-	1.03	8.5	0.09
DB-6969-08	D	0.47	0	2.8	-	1.69	33.1	0.13
DB-6969-09	D	0.60	0	1.8	-	1.13	5.2	0.08
DB-6969-10	D	0.39	0	2.3	-	2.26	22.0	0.13
DB-6970-03	W	5.83	32.6	0	10	-	15.3	0.17
DB-6971-08	W	1.27	3	14.1	20	-	24.3	0.35
DB-7065-01	D	0.42	0	1.82	-	2.39	1.5	0.22
DB-7065-02	D	0.39	0	1.9	-	0.83	1.6	0.17
DB-7065-03	D	0.53	0	2.1	-	0.33	4.7	0.20
DB-7065-04	D	0.21	0	1.4	-	0.33	197.1	0.11
DB-7065-05	W	2.89	6	3.5	10	-	19.5	0.15
DB-7067-01	W	3.31	15.8	15.1	35	-	43.5	0.54

	Detention Basin Characteristics						Watershed	
	Wet/Dry	Area	Perm Pool VOLUME	Flood Pool VOLUME	Weir Length	Orifice Equivalent Diameter	Area	Impervious
Basin ID	W or D	ac	ac-ft	ac-ft	ft	ft	ac	Fraction
DB-7067-02	D	0.42	0	3	-	0.65	56.5	0.00
DB-7069-06	W	0.39	114	22	3	-	116.4	0.07
DB-7069-07	W	0.53	6.6	0	3	-	15.1	0.24
DB-7069-08	W	0.21	2.9	0	35	-	10.6	0.24
DB-7069-10	W	1.54	8.5	0	10	-	43.2	0.17
DB-7069-12	D	0.14	0	0.42	-	0.46	2.0	0.05
DB-7069-13	D	0.63	0	4.5	-	1.13	16.4	0.13
DB-7070-03	D	0.19	0	1.17	-	4.00	38.1	0.52
DB-7070-10	D	0.85	0	3.3	-	0.83	6.6	0.01
DB-7071-04	W	1.40	4.2	2.9	3.5	-	31.6	0.78
DB-7169-01	D	0.43	0	2.4	-	2.50	3.2	0.22
DB-7169-02	D	0.16	0	0.89	-	0.63	49.1	0.37
DB-7169-04	D	0.27	0	1.3	-	1.00	58.3	0.30
DB-7169-08	W	0.55	0.4	1.32	10	-	5.4	0.07
DB-7169-09	D	0.20	0	0.53	-	0.80	5.0	0.21
DB-7169-10	D	1.20	0	2.1	-	1.13	10.3	0.03
DB-7169-11	D	0.14	0	0.58	-	0.56	6.5	0.07
DB-7267-04	D	0.37	0	0.75	-	2.75	31.6	0.29
DB-7267-14	D	0.44	0	4.1	-	1.50	67.9	0.36
DB-7268-04	D	0.84	0	1.2	-	1.38	12.5	0.24
DB-7268-06	W	0.90	4.3	3.2	20	-	16.4	0.29
DB-7268-07	W	4.38	29.2	4.5	1	-	21.1	0.12
DB-7269-01	W	2.13	7.6	0	2	-	65.2	0.27
DB-7270-01	W	1.04	3.4	1.9	1	-	12.0	0.35
DB-7270-09	D	0.63	0	2.5	-	2.36	37.2	0.26

	Detention Basin Characteristics						Watershed	
	Wet/Dry	**Area**	**Perm Pool VOLUME**	**Flood Pool VOLUME**	**Weir Length**	**Orifice Equivalent Diameter**	**Area**	**Impervious**
Basin ID	**W or D**	**ac**	**ac-ft**	**ac-ft**	**ft**	**ft**	**ac**	**Fraction**
DB-7270-10	W	1.37	14.3	0	100	-	12.2	0.52
DB-7270-15	W	0.92	4.1	0	4	-	27.2	0.43
DB-7366-01	D	0.35	0	3.8	-	2.00	72.0	0.37
DB-7367-04	D	0.23	0	1.94	-	1.00	6.4	0.41
DB-7367-07	D	0.27	0	1.07	-	0.84	6.6	0.42
DB-7367-10	D	0.24	0	1.08	-	2.76	12.9	0.26
DB-7367-19	D	0.25	0	2.03	-	4.00	18.5	0.22
DB-7367-20	W	0.93	0.45	5.09	10	-	60.2	0.13
DB-7368-08	W	0.86	3	0	8	-	13.2	0.25
DB-7368-09	W	0.57	2.2	1.9	1.3	-	6.9	0.10
DB-7369-04	W	0.97	6.4	0	10	-	12.8	0.18
DB-7369-06	W	1.79	11.4	4	4	-	92.5	0.16
DB-7369-07	D	0.32	0	0.9	-	1.38	29.0	0.28
DB-7369-11	W	0.92	0.44	1.8	4	-	40.2	0.37
DB-7370-14	D	0.72	0	5.5	-	3.17	50.9	0.24
DB-7370-16	D	0.18	0	0.5	-	1.92	29.4	0.62
DB-7467-04	D	0.15	0	0.69	-	2.00	46.2	0.35
DB-7467-06	D	0.24	0	0.48	-	3.50	21.3	0.28
DB-7467-07	D	0.40	0	3.44	-	2.59	19.2	0.50
DB-7467-12	D	0.11	0	1.3	-	1.66	26.7	0.35
DB-7467-13	D	0.44	0	2.05	-	0.53	6.7	0.51
DB-7467-14	D	0.11	0	0.44	-	0.73	6.0	0.04
DB-7467-15	D	0.26	0	3.125	-	1.61	15.1	0.04
DB-7467-16	D	0.38	0	1.73	-	1.76	23.0	0.26
DB-7468-01	W	0.37	1.2	0.8	2	-	4.2	0.15

	Detention Basin Characteristics						Watershed	
	Wet/Dry	**Area**	**Perm Pool VOLUME**	**Flood Pool VOLUME**	**Weir Length**	**Orifice Equivalent Diameter**	**Area**	**Impervious**
Basin ID	**W or D**	**ac**	**ac-ft**	**ac-ft**	**ft**	**ft**	**ac**	**Fraction**
DB-7468-06	W	2.21	9.16	8.01	10	-	161.1	0.21

Appendix C Table 4. Detention Basin Characteristics with Retrofits

		Basin									Watershed	
	Retrofit Recommendation	Area	Exist. Perm Pool VOLUME	Proposed Perm Pool AREA	Proposed Perm Pool VOLUME	Existing.Flood Pool VOLUME	Proposed Flood Pool AREA	Proposed Flood Pool VOLUME	Weir Length	Orifice Equivalent Diameter	Area	Impervious
Basin ID		**ac**	**ac-ft**	**ac**	**ac-ft**	**ac-ft**	**ac**	**ac-ft**	**ft**	**ft**	**ac**	**Fraction**
DB-6869-02	Wet Basin Retrofit	3.52	10.19			14.13			20	-	30.6	0.26
DB-6870-15	Dry to Wet Retrofit	0.34	0	0.34	0.23	1	0.34	1.00	-	0.92	5.1	0.34
DB-6870-16	Dry Detention Retrofit	0.22	0			0.88	1.14	4.57	-	0.92	16.6	0.09
DB-6871-01	None	0.38	0			1.3			-	1.49	27.8	0.65
DB-6871-03	Dry Detention Retrofit	0.27	0			1.76	0.41	2.70	-	0.86	27.3	0.66
DB-6965-01	Dry Detention Retrofit	0.44	0			1.819	0.68	2.85	-	0.83	6.7	0.13
DB-6968-02	Wet Basin Retrofit	0.76	2.1			6.636			12	-	32.9	0.21
DB-6969-02	None	0.86	3.6	0.86	0.27	4.61	2.00	4.61	15	-	10.4	0.05
DB-6969-03	None	4.63	44			0			10	-	40.9	0.10
DB-6969-04	None	1.22	1.8			3.68			5	-	35.0	0.01
DB-6969-06	Dry to Wet Retrofit	0.34	0	0.34	0.25	2	2.00	5.97	-	0.98	1.1	0.21
DB-6969-07	Dry to Wet Retrofit	0.86	0	0.86	0.27	2.044	0.86	2.04	-	1.03	8.5	0.09
DB-6969-08	Dry to Wet Retrofit	0.47	0	0.47	1.54	2.8	0.47	2.80	-	1.69	33.1	0.13
DB-6969-09	Dry Detention Retrofit	0.60	0			1.8	0.63	1.91	-	1.13	5.2	0.08
DB-6969-10	Dry to Wet Retrofit	0.39	0	0.39	1.07	2.3	0.39	2.30	-	2.26	22.0	0.13
DB-6970-03	None	5.83	32.6			0			10	-	15.3	0.17
DB-6971-08	Wet Basin Retrofit	1.27	3			14.1			20	-	24.3	0.35
DB-7065-01	Dry Detention Retrofit	0.42	0			1.82	0.45	1.95	-	2.39	1.5	0.22
DB-7065-02	Dry Detention Retrofit	0.39	0			1.9	0.39	1.92	-	0.83	1.6	0.17
DB-7065-03	Dry Detention Retrofit	0.53	0			2.1	0.54	2.13	-	0.33	4.7	0.20
DB-7065-04	Dry Detention Retrofit	0.21	0			1.4	0.42	2.78	-	0.33	197.1	0.11
DB-7065-05	Wet Basin Retrofit	2.89	6			3.5			10	-	19.5	0.15
DB-7067-01	Wet Basin Retrofit	3.31	15.8			15.1		21.10	35	-	43.5	0.54
DB-7067-02	Dry Detention Retrofit	0.42	0			3	0.36	3.45	-	0.65	56.5	0.00
DB-7069-06	Wet Basin Retrofit	0.39	114			22			3	-	116.4	0.07
DB-7069-07	Wet Basin Retrofit	0.53	6.6			0			3	-	15.1	0.24
DB-7069-08	None	0.21	2.9			0			35	-	10.6	0.24
DB-7069-10	Wet Basin Retrofit	1.54	8.5			0			10	-	43.2	0.17
DB-7069-12	Dry to Wet Retrofit	0.14	0	0.14	0.07	0.42	0.14	0.42	-	0.46	2.0	0.05
DB-7069-13	Dry to Wet Retrofit	0.63	0	0.63	0.13	4.5	0.63	4.50	-	1.13	16.4	0.13
DB-7070-03	Dry Detention Retrofit	0.19	0			1.171	0.64	3.95	-	4.00	38.1	0.52
DB-7070-10	Dry to Wet Retrofit	0.85	0	0.85	0.23	3.3	0.85	3.30	-	0.83	6.6	0.01
DB-7071-04	Wet Basin Retrofit	1.40	4.2			2.9			3.5	-	31.6	0.78

DB-7169-01	Dry Detention Retrofit	0.43	0			2.4	0.57	3.20	-	2.50	3.2	0.22
DB-7169-02	Dry to Wet Retrofit	0.16	0	0.16	0.60	0.89	0.89	5.63	-	0.63	49.1	0.37
DB-7169-04	Dry to Wet Retrofit	0.27	0	0.27	0.58	1.3	1.30	4.85	-	1.00	58.3	0.30
DB-7169-08	Wet Basin Retrofit	0.55	0.4			1.322			10	-	5.4	0.07
DB-7169-09	Dry to Wet Retrofit	0.20	0	0.20	0.19	0.53	0.20	0.53	-	0.80	5.0	0.21
DB-7169-10	Dry to Wet Retrofit	1.20	0	1.20	0.40	2.1	1.20	2.10	-	1.13	10.3	0.03
DB-7169-11	Dry to Wet Retrofit	0.14	0	0.14	0.25	0.58	0.14	0.58	-	0.56	6.5	0.07
DB-7267-04	Dry Detention Retrofit	0.37	0			0.75	0.45	0.92	-	2.75	31.6	0.29
DB-7267-14	Dry Detention Retrofit	0.44	0			4.1	0.66	6.13	-	1.50	67.9	0.36
DB-7268-04	Wet Basin Retrofit	0.84	0			1.2			-	1.38	12.5	0.24
DB-7268-06	Wet Basin Retrofit	0.90	4.3			3.2			20	-	16.4	0.29
DB-7268-07	Wet Basin Retrofit	4.38	29.2			4.5			1	-	21.1	0.12
DB-7269-01	Wet Basin Retrofit	2.13	7.6			0			2	-	65.2	0.27
DB-7270-01	Wet Basin Retrofit	1.04	3.4			1.9		3.76	1	-	12.0	0.35
DB-7270-09	None	0.63	0			2.5			100	-	37.2	0.26
DB-7270-10	Wet Basin Retrofit	1.37	14.3			0			4	-	12.2	0.52
DB-7270-15	Wet Basin Retrofit	0.92	4.1			0			-	2.00	27.2	0.43
DB-7366-01	Dry Detention Retrofit	0.35	0			3.8	0.58	6.30	-	1.00	72.0	0.37
DB-7367-04	Dry to Wet Retrofit	0.23	0	0.23	0.23	1.94	0.23	1.94	-	0.84	6.4	0.41
DB-7367-07	Dry to Wet Retrofit	0.27	0	0.27	0.26	1.07	0.27	1.07	-	2.76	6.6	0.42
DB-7367-10	Dry Detention Retrofit	0.24	0			1.08	0.28	1.26	-	4.00	12.9	0.26
DB-7367-19	Dry Detention Retrofit	0.25	0			2.033	0.30	2.40	10	-	18.5	0.22
DB-7367-20	Wet Basin Retrofit	0.93	0.4458			5.09			8	-	60.2	0.13
DB-7368-08	Wet Basin Retrofit	0.86	3			0			1.3	-	13.2	0.25
DB-7368-09	Wet Basin Retrofit	0.57	2.2			1.9			10	-	6.9	0.10
DB-7369-04	Wet Basin Retrofit	0.97	6.4			0		1.77	4	-	12.8	0.18
DB-7369-06	Wet Basin Retrofit	1.79	11.4			4			-	1.38	92.5	0.16
DB-7369-07	Dry Detention Retrofit	0.32	0			0.9	0.85	2.38	4	-	29.0	0.28
DB-7369-11	Wet Basin Retrofit	0.92	0.44			1.8			-	3.17	40.2	0.37
DB-7370-14	None	0.72	0			5.5			-	1.92	50.9	0.24
DB-7370-16	Dry Detention Retrofit	0.18	0	0.18	0.27	0.5	0.18	0.50	-	2.00	29.4	0.62
DB-7467-04	Dry to Wet Retrofit	0.15	0	0.15	1.18	0.69	0.15	0.69	-	3.50	46.2	0.35
DB-7467-06	None	0.24	0			0.48			-	2.59	21.3	0.28
DB-7467-07	None	0.40	0			3.44			-	1.66	19.2	0.50
DB-7467-12	Dry Detention Retrofit	0.11	0			1.3	0.19	2.38	-	0.53	26.7	0.35
DB-7467-13	None	0.44	0			2.05			-	0.73	6.7	0.51
DB-7467-14	Dry Detention Retrofit	0.11	0			0.44	0.15	0.62	-	1.61	6.0	0.04
DB-7467-15	Dry Detention Retrofit	0.26	0			3.125	0.29	3.53	-	1.76	15.1	0.04
DB-7467-16	Dry Detention Retrofit	0.38	0			1.73	0.48	2.17	2	-	23.0	0.26
DB-7468-01	Wet Basin Retrofit	0.37	1.2			0.8			10	-	4.2	0.15
DB-7468-06	None	2.21	9.16			8.01			10		161.1	0.21

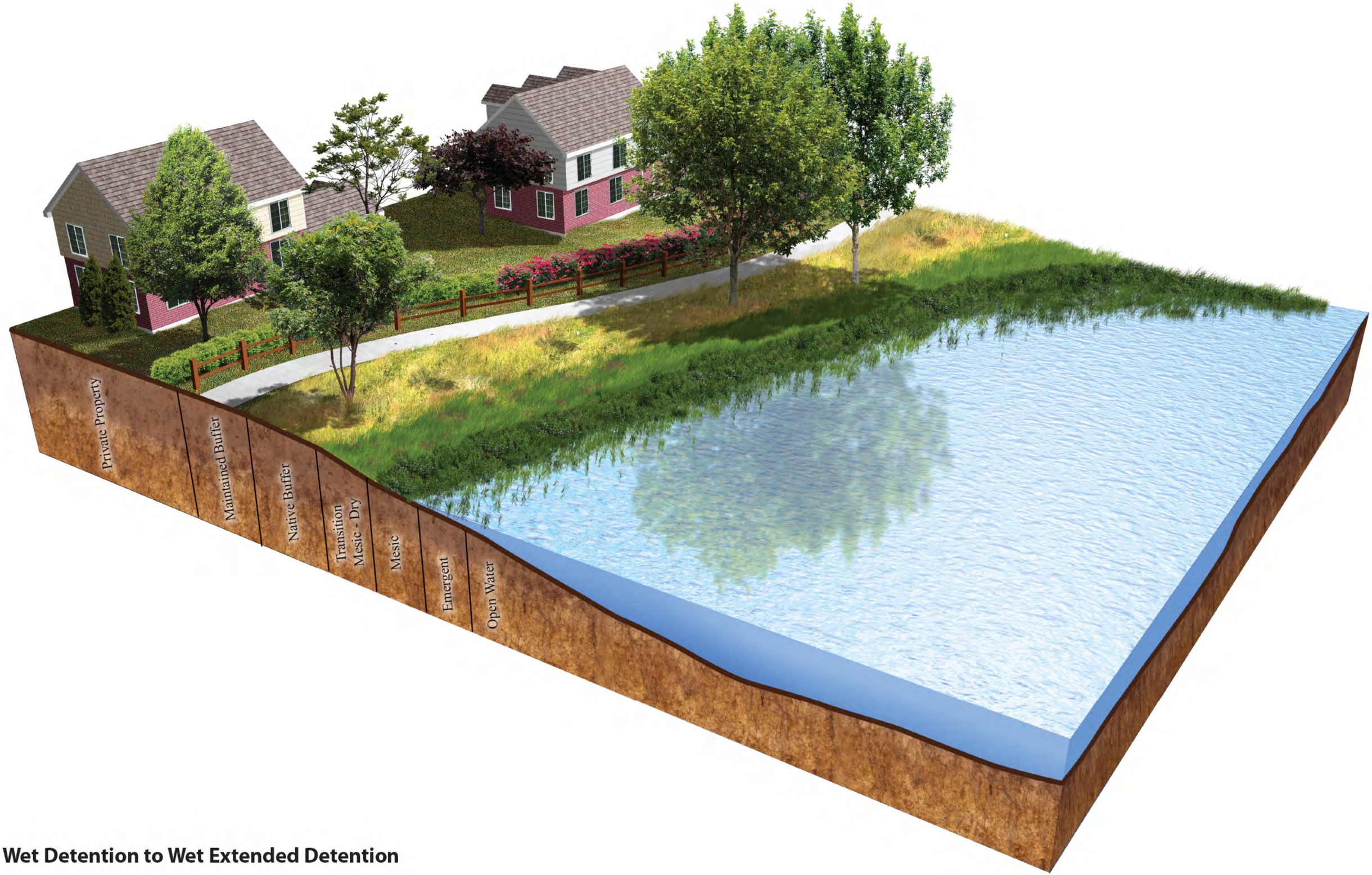
Appendix D. Detention Basin Retrofits and Stream Buffer Examples

Detention Basin Retrofit Examples

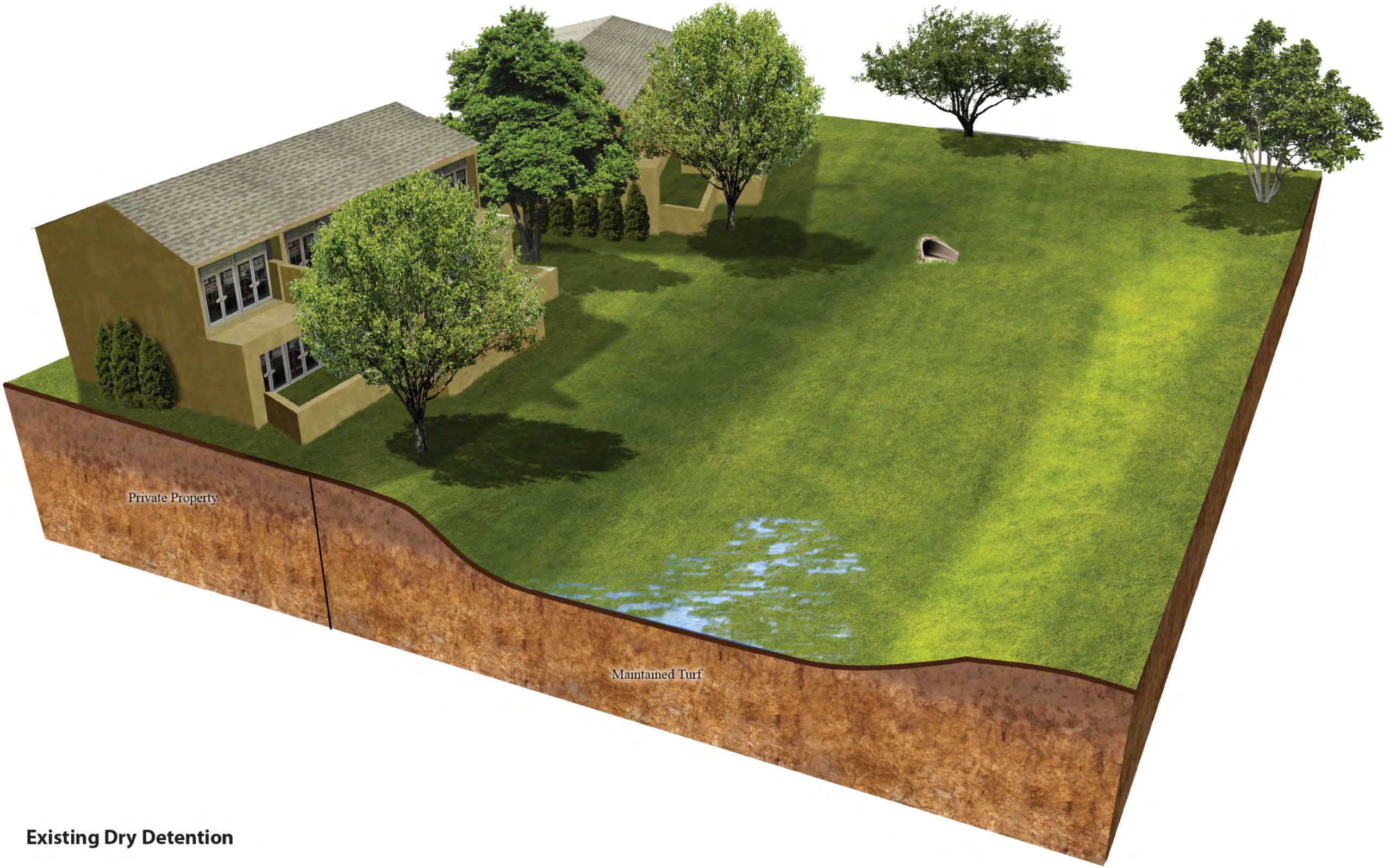
1. Wet Detention to Wet Extended Detention
2. Existing Dry Detention
3. Dry Detention to Dry Extended Detention
4. Dry Detention to Extended Wet Detention

Stream Buffer and Profile Examples

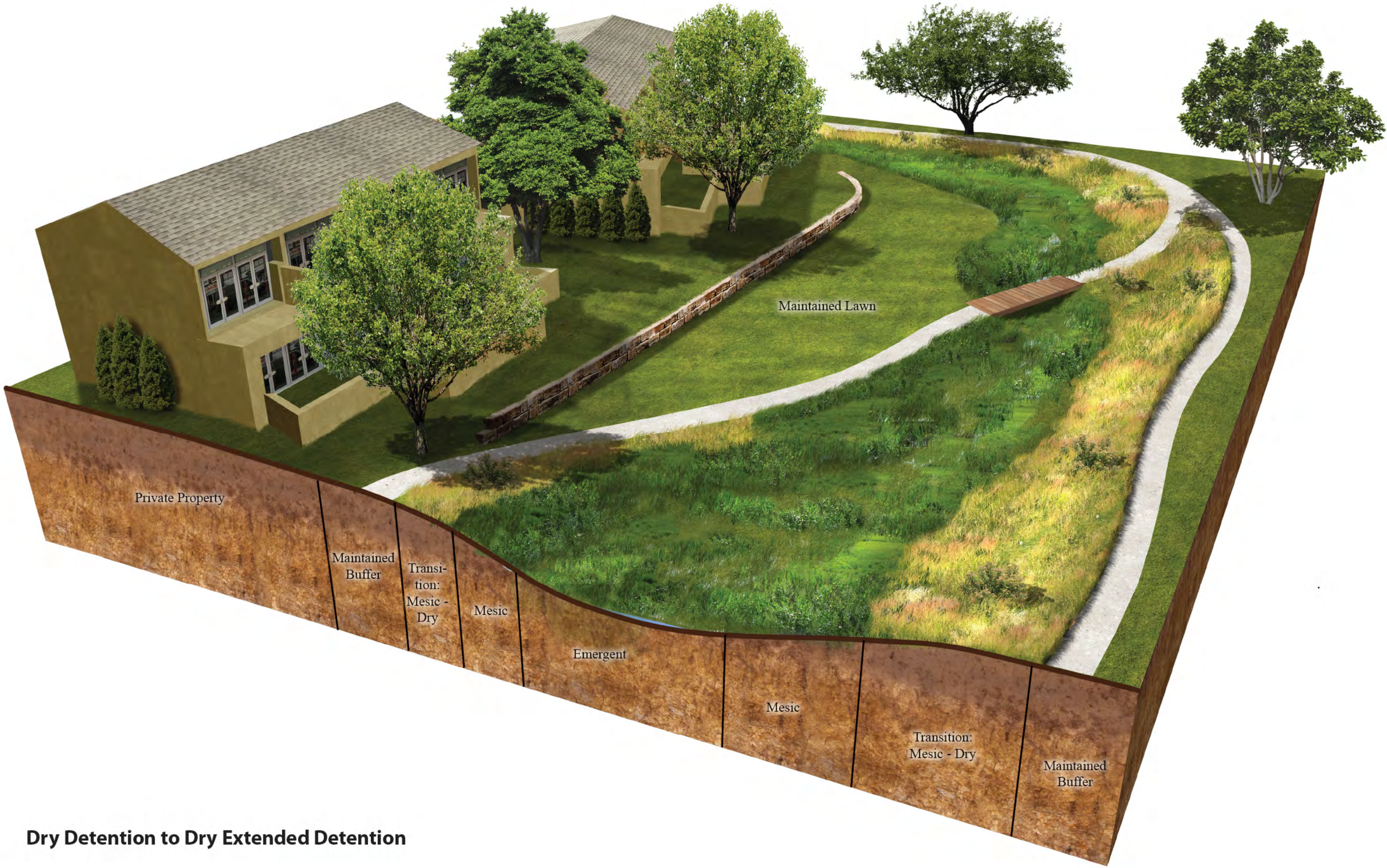
1. Stream Buffer with Recreational Trail
2. Stream Buffer with Encroaching Property Line
3. Stream Buffer with No Trail
4. Stream Profile Example for Step Pools with Grade Controls



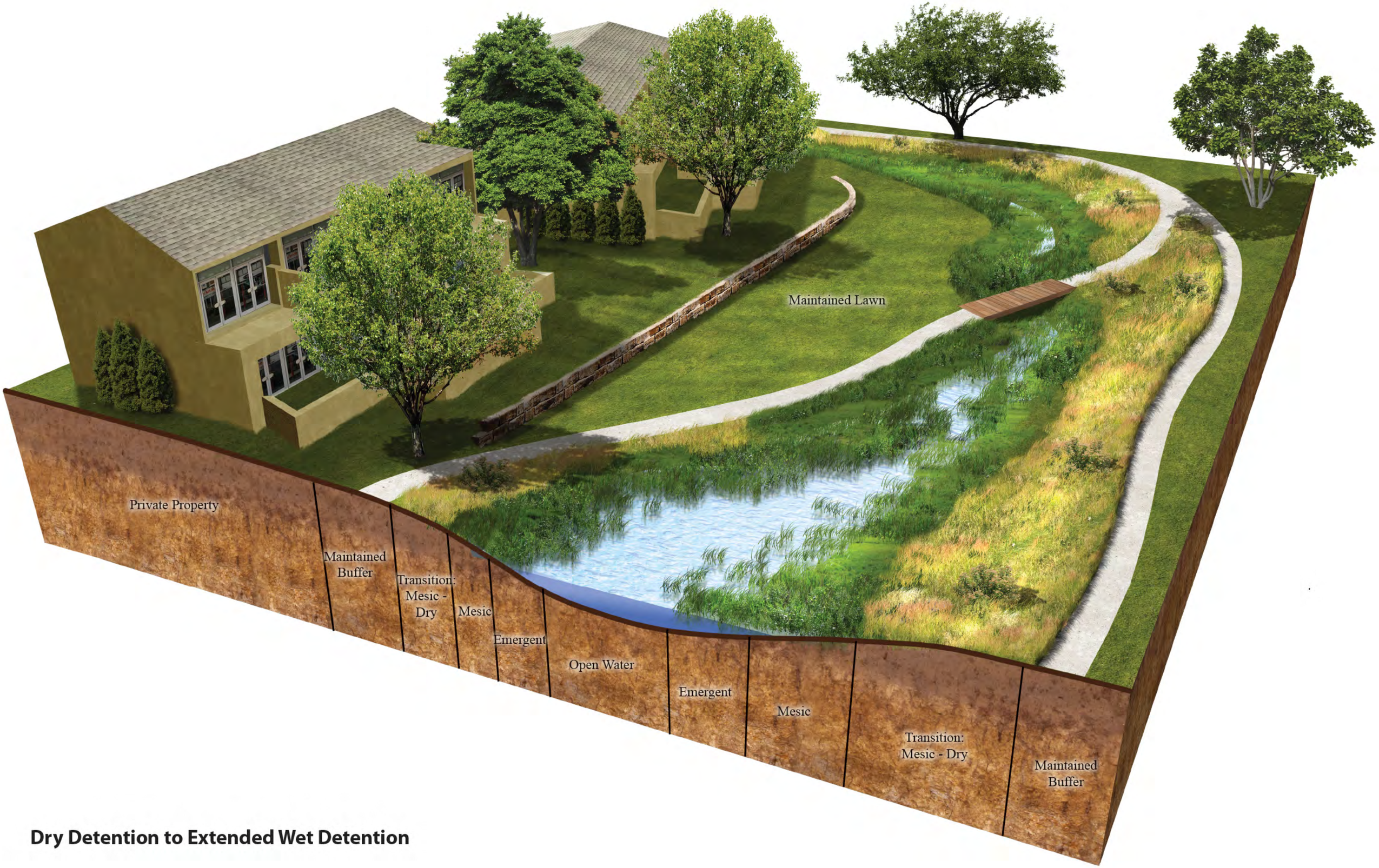
Wet Detention to Wet Extended Detention



Existing Dry Detention



Dry Detention to Dry Extended Detention

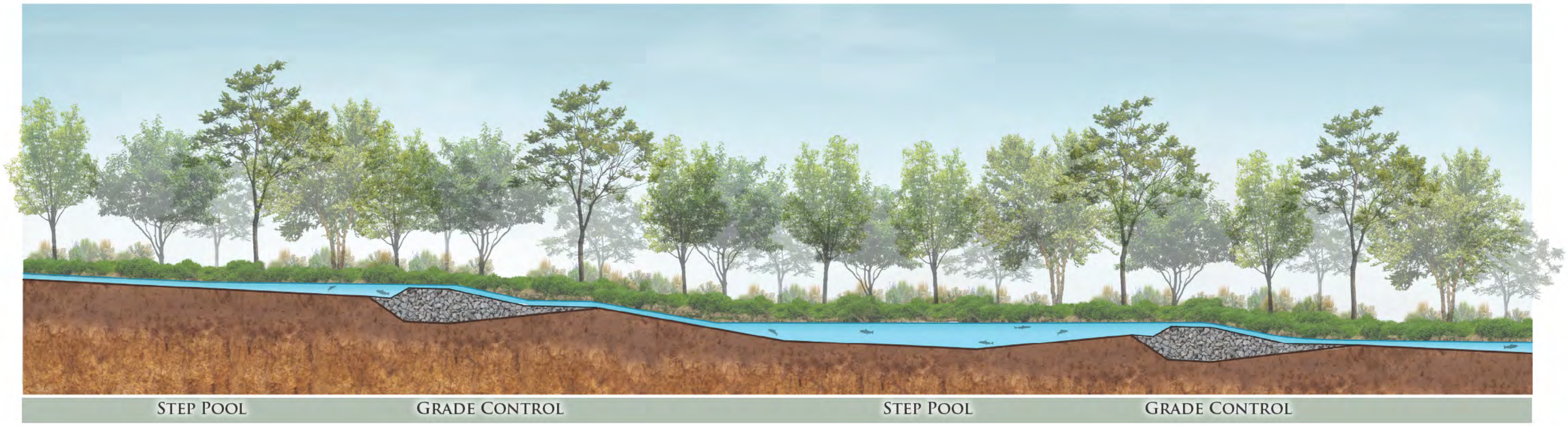


Dry Detention to Extended Wet Detention

Stream Buffer With Recreational Trail

Stream Buffer With Enchroaching Property Line

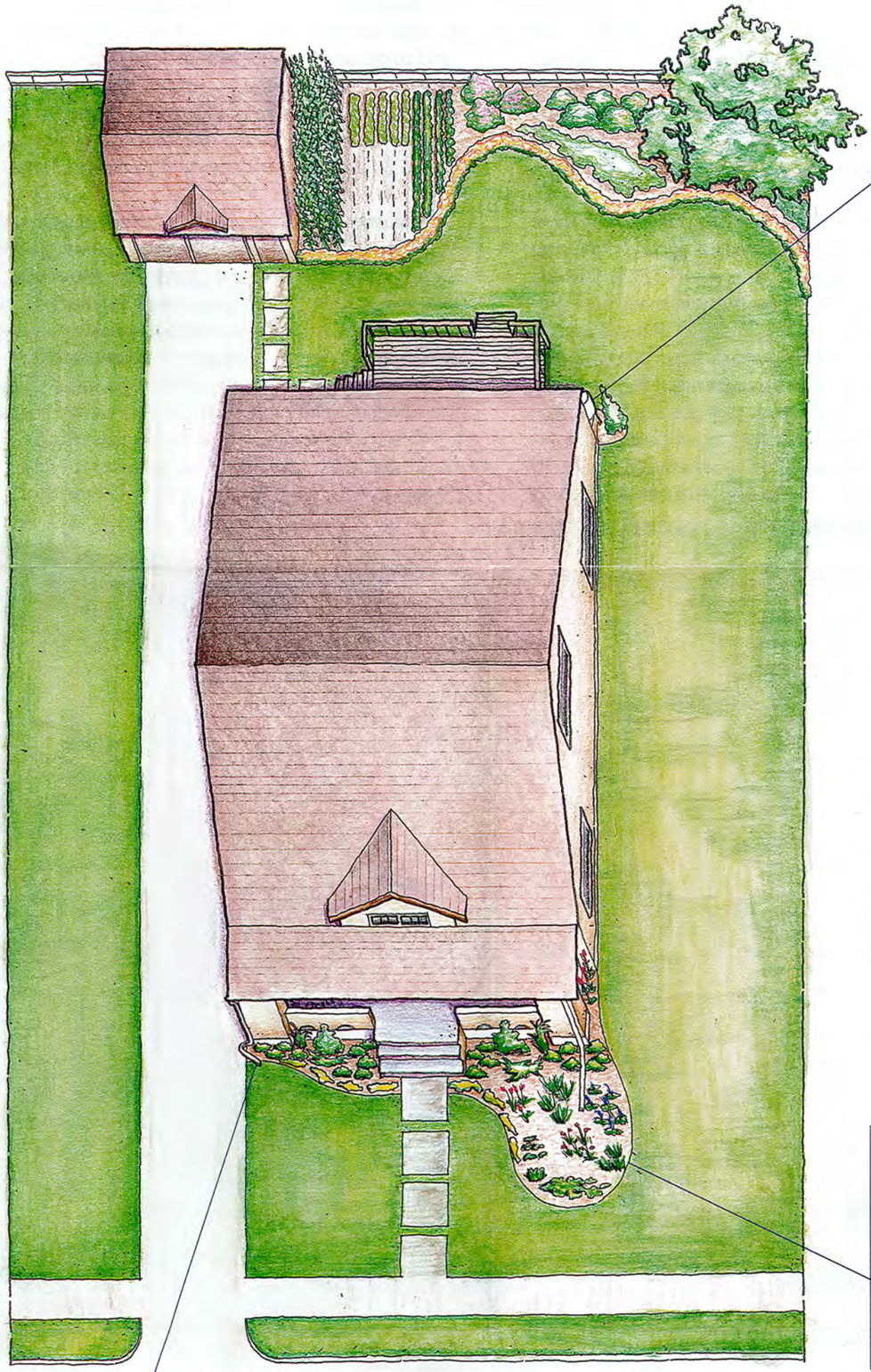
Stream Buffer With No Trail


STEP POOL
GRADE CONTROL
STEP POOL
GRADE CONTROL

Appendix E. Example Educational Materials

Get the most out of rain

Ideas for creating a rain-friendly yard



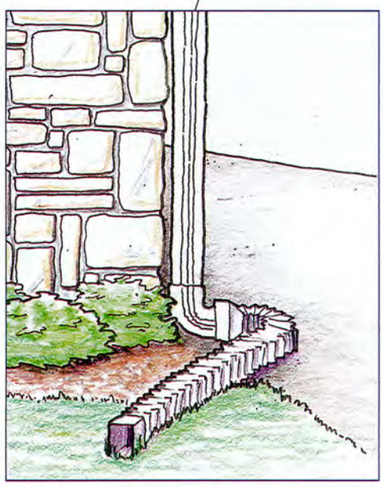
Save water with rain barrels

A rain barrel is a container that collects and stores rainwater from downspouts and rooftops for future use watering lawns and gardens. Generally a rain barrel is made using a 55-gallon drum, a vinyl garden hose, PVC couplings, a screen grate to remove debris and keep insects out, and other materials found at neighborhood hardware stores.

Rain barrels can be constructed in a number of ways, but they all serve the same purpose — to collect rainwater and decrease the amount of stormwater runoff that leaves your property.

During the summer months it is estimated that nearly 40 percent of household water is used for lawn and garden maintenance. A rain barrel collects water and stores it for those times that you need it most — during the dry summer months. Using rain barrels potentially helps homeowners lower water bills, while also improving the vitality of plants, flowers, trees, and lawns.

For more information about rain barrels, please visit **www.marc.org/rainbarrels.htm**



Redirect downspouts

Take full advantage of the rain that comes off your roof by making sure that your downspouts deposit rainwater where it can be put to good use. Redirect downspouts to gardens, grassy areas, rain barrels — places where water can infiltrate the ground and roots of plants, decreasing the amount of water that goes down storm drains.

Rain is naturally soft and devoid of minerals, chlorine, fluoride, and other harmful chemicals. The chemicals and hard water from many of our municipal water systems can add to chemical imbalances in soil and damage sensitive plants. Rainwater from the roofs of houses picks up very little contamination, and is very healthy for plants.

Use extension gutters or splash blocks to help direct the flow of water if your downspout isn't long enough. If directing stormwater to a yard, try to discharge the water at least five feet from foundations to prevent potenial leakage into the house.

Build a rain garden

A great way to complement your rain barrel and increase your property's ability to absorb runoff is through a rain garden. Rain gardens can be a fun and easy way to learn about beautiful native plants as well as help to improve water quality and reduce flooding.

Rain gardens typically absorb much more water than the same size area of lawn. They are drought resistant, winter hardy and less prone to destructive insects and diseases. Rain gardens create a preferred habitat for birds, butterflies and dragonflies. These specialty gardens are versatile; they can be any size or shape imaginable, but to maximize their benefit you should build them in an existing low spot or near the drainage area of your rain barrel or downspout.

For more information on rain gardens visit **www.marc.org/water/raingardens.pdf**

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For more information please visit www.marc.org/water, or call 816/474-4240.

Why disconnect your downspout?

Downspouts that connect directly to sewer pipes increase the risk of sewer overflow and flooding. Disconnecting your downspout from a sewer intake pipe (standpipe), then redirecting the flow of water to a grassy area or garden is a simple process that makes a big difference to the environment.

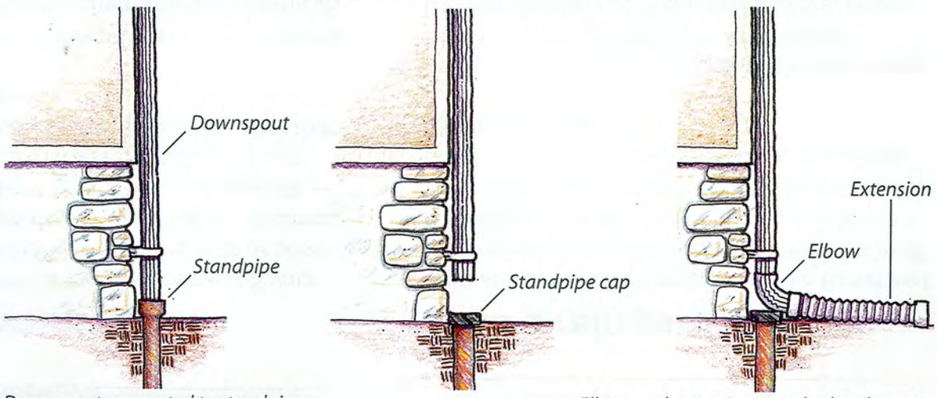
Supplies

- Hacksaw
- Cordless drill
- Tape measure
- Pliers
- Sheet metal screws
- Downspout elbow
- Downspout extension
- Standpipe cap

There are different types, lengths and sizes, of standpipe caps, so be sure to take measurements before shopping. Capping the standpipe prevents water from going in while keeping pests (such as rodents) from entering/exiting the pipe.

Instructions

1. Cut the existing downspout approximately 9 inches above the sewer standpipe with a hacksaw.
2. Cap the sewer standpipe.
3. Attach elbow by crimping the downspout with pliers to ensure a good fit. Connect elbow to downspout using sheet metal screws. It may be necessary to pre drill holes.
4. Attach the elbow INTO the extension and secure with sheet metal screws. Water should drain at least five feet away from the house, so direct the extension accordingly. A splash block may help direct water further away from the house.



Downspout connected to standpipe. *Elbow and extension attached to downspout.*

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Rain, roofs and runoff

Did you know that each downspout on a house can drain approximately 12 gallons of water per minute during a one-inch rainfall? If managed properly, the water that flows off rooftops can help keep lawns and gardens green while lowering utility bills during spring and summer months. However, most downspouts send rainwater down driveways, sidewalks, and underground pipes that lead to storm drains or sanitary sewer lines. This **"stormwater runoff"** picks up pollutants from motor oil, lawn chemicals, and pet waste along the way, before entering lakes and streams — **untreated.**

The large amount of untreated water entering the storm sewer system — and eventually our streams and lakes — has lasting health, safety, environmental and economic impacts on communities. Fortunately, there are many things that property owners can do to put rainwater to good use while reducing the amount of stormwater runoff that ends up in local waterways.

For more information, visit www.marc.org/water

The problem with pavement

During the construction of homes, roads and office buildings vegetation is often removed and replaced by large paved areas. These surfaces keep rain from infiltrating the soil and recharging groundwater supplies. The infiltration process helps clean water and feed the underground springs that supply drinking water. Paved surfaces also increase the speed and amount of water that rushes into streams, causing stream bank erosion and harming wildlife habitats. Direct the flow of water from downspouts away from paved surfaces whenever possible.

Combined sewer overflows

Combined sewers are older systems that carry both stormwater and wastewater to treatment plants. When rainstorms fill combined sewers beyond capacity, the result is a Combined Sewer Overflow — a discharge of untreated wastewater and stormwater into local waterways. Combined sewers are costly to replace and still used in older areas of the region. Residents are encouraged to disconnect downspouts from sewer pipes or redirect downspouts to grassy areas or gardens to reduce the rain that enters sewers.

Disconnect or Redirect Your Downspout

Did you know?

Plants act as filters to clean stormwater runoff before it enters the stream. Notice the native plants along the banks of the stream.

Can you see...

Cardinal Flowers

Tall Bellflowers

Green Bulrush

Mash Milkweed

Ohio Buckeyes

Sycamore Trees

A healthy stream, like a city, is a bustling place with plants, insects, fish and wildlife each doing their job to help the "city" grow. Trees, shrubs and groundcover on the banks of the stream stop erosion and provide important habitat, food and hiding places for insects and wildlife. Plants and animals use the nutrients in the water for food. Fish eat the plants and recycle the nutrients back into the system. Birds, mammals, amphibians and reptiles use the land surrounding the stream for nesting and breeding.

Notice this stream and many other natural streams in the area. They wind through the landscape. Deep pools form on the outside of bends and shallower, rockier sections called riffles form in between. Fish find shelter in the pools, where the water is deeper and moves slowly. Water moves through riffles more quickly, bubbling over the rocks, picking up oxygen, insects and other nutrients. This is an ideal environment for fish to feed and spawn.

The Shape of a Stream is Important Too

Stream Ecology

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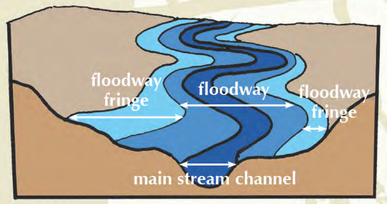
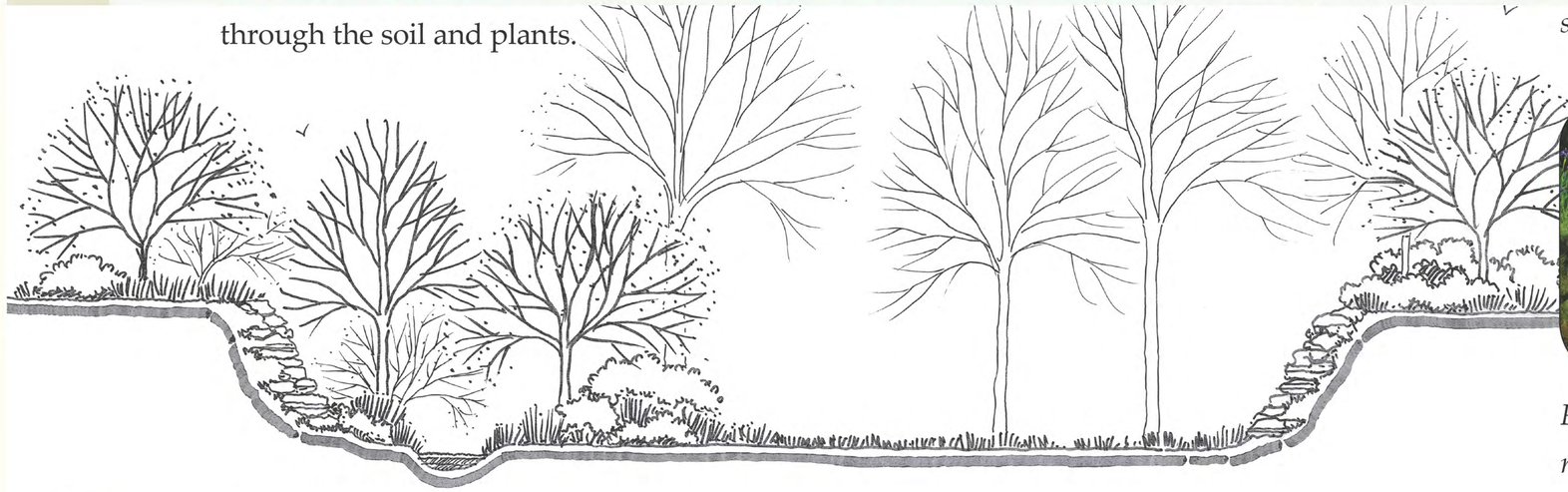
The Floodplain get connected



Part of the Rain to Recreation initiative is to **reconnect floodplains to their streams**. Streams connect communities while floodplains provide important wildlife travel corridors and are home to uniquely adapted trees and plants. The floodplain is the flat area of land adjacent to a river that can be covered with water when the river overflows its banks following a heavy rain. As a natural part of the landscape, the floodplain plays an important role in **maintaining the quality of our water and** the health of the **environment** by filtering pollutants through the soil and plants.

Floodplains provide important habitat and breeding sites for many species of birds and mammals.



Floodplains are suitable for recreational activities such as hiking, bird watching and fishing.

Safety tips

Flooding is the most common of all natural disasters and can happen in all parts of the United States.

Some floods happen slowly and with warning. Flash floods can happen very quickly, without warning and can be very dangerous.

During a flood, do not walk through moving water because you could fall and be quickly washed away.

Do not drive into flooded areas. A small car can float away in 7 inches of water over a roadway.

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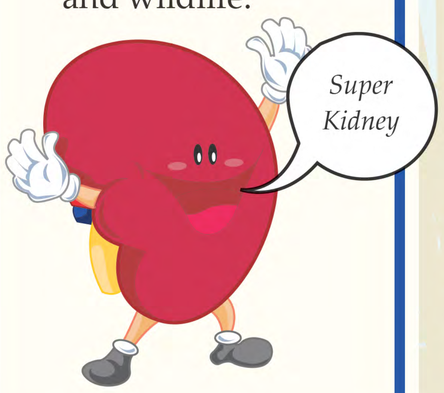
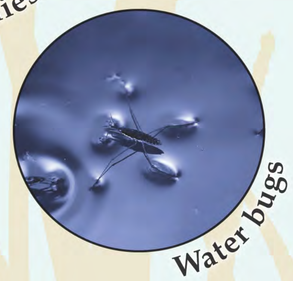
Why save the Wetlands?

Did you know?

Just like your kidneys filter toxins and waste from your body, wetlands filter waste from stormwater runoff, leaving clean healthy water for fish, birds, and wildlife.



Water lilies



Water bugs

Frogs

Fish

Snakes

Wetlands are one of the most important ecosystems in nature. They **store** and slowly release excess **stormwater** into the ecosystem, help to **stop** flooding and **erosion**, and filter out pollutants **and** sediments. They **are** also **home to** thousands of species of both **plants and animals**.

What do you see?

Mammals

Insects

Birds

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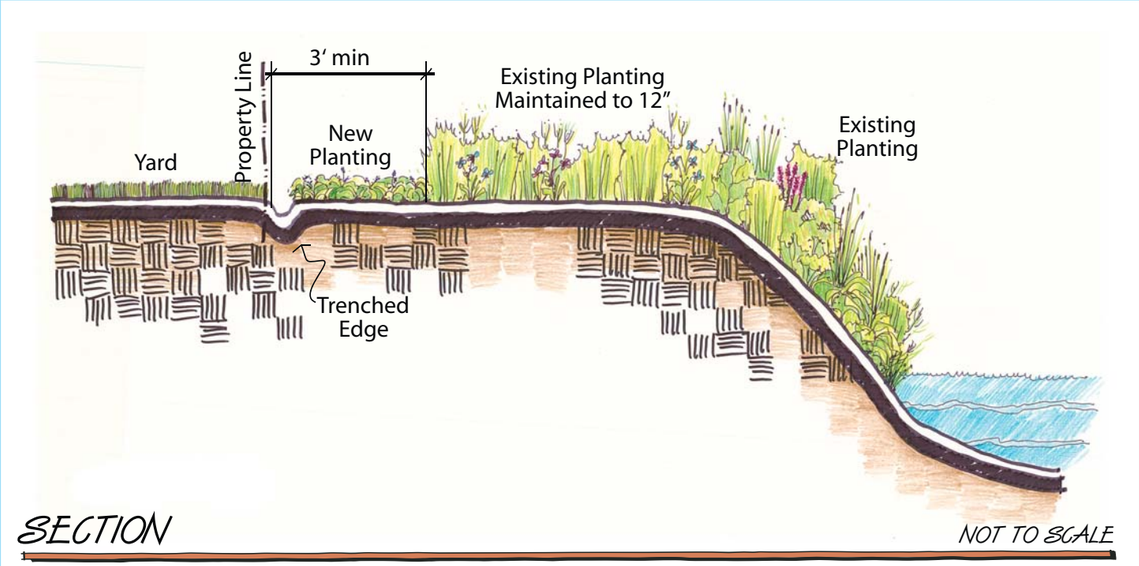
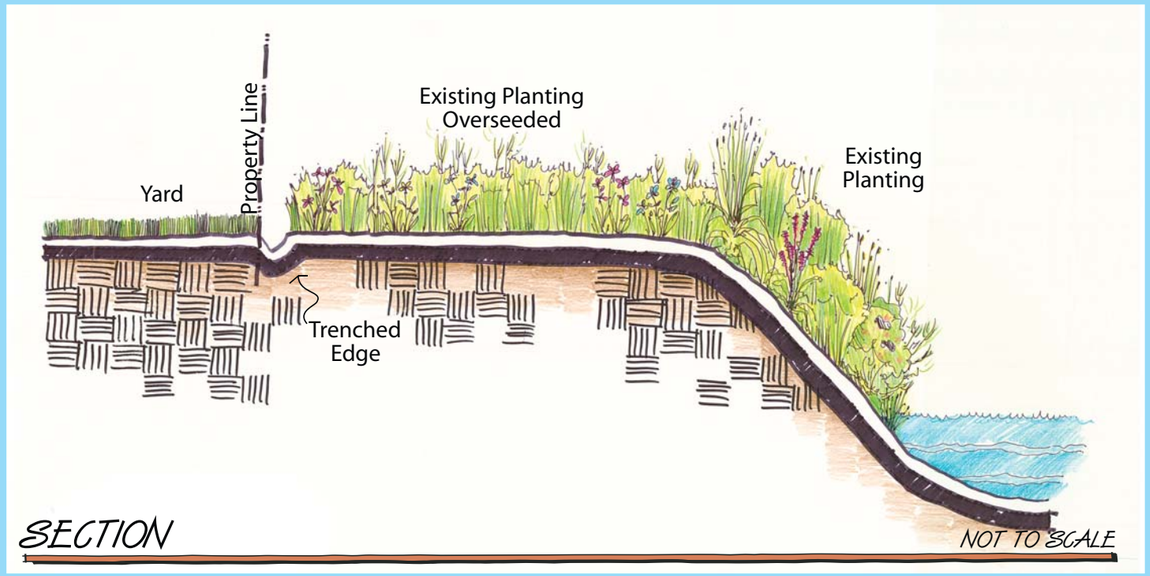
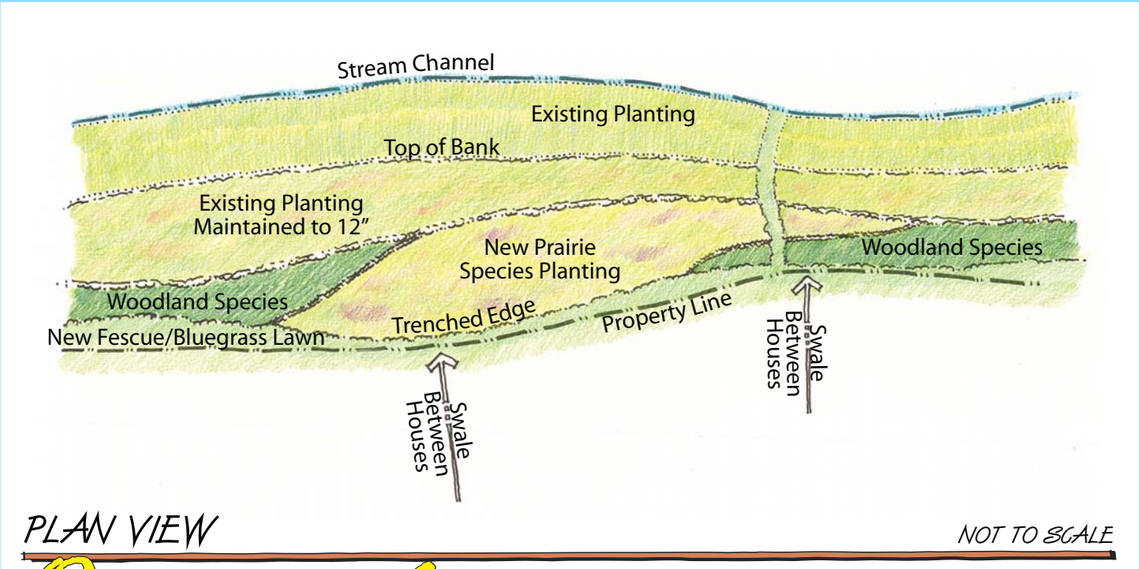
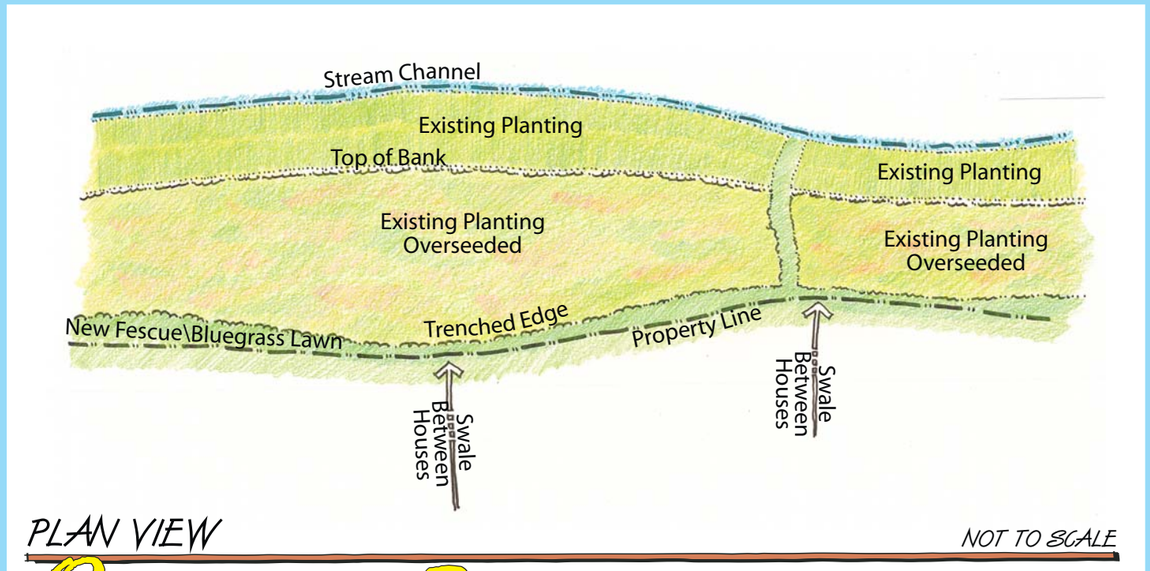
Funded in part by: U.S. EPA SECTION 319 GRANT & KANSAS WATER PLAN FUNDS Provided by KANSAS DEPT OF HEALTH AND ENVIRONMENT









Option 1

Option 2

83rd Terrace Stormwater

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Appendix F. Plant Palette Guidance

Plant Palette Recommendations

This appendix includes a list of plants recommended for projects, including grasses and forbs for wet detention basins and dominant tree species, understory trees and shrubs for stream corridors.

St. Louis MSD guidance and Missouri Botanical Garden resources should also be referenced.

Plant Palette Recommendation, Wet Detention Basin

botanical name	common name	height (ft)	spacing*	water	light	comments
Upper 5 Feet						
Asclepias incarnata	Marsh Milkweed	2 to 3	18" o.c.	moist soil	full sun	
Carex grayi	Gray's Sedge	2 to 3	18" o.c.	moist soil	full to medium sun	
Carex muskingumensis	Palm Sedge	2 to 3	18" o.c.	moist soil	full to medium sun	Plant in massings for best foliage effect
Middle 10 Feet						
Acorus calamus	Sweet Flag	2 to 4	18" o.c.	moist soil to shallow water	full sun	
Carex stricta	Tussock Sedge	1 to 3	18" o.c.	moist to wet soil	full to medium sun	
Iris fulva	Copper Iris	2 to 3	18" o.c.	moist to wet soil	full sun	Plant individuals with other plant massings
Iris virginica	Southern Blue Flag Iris	2 to 3	18" o.c.	moist to wet soil	full sun	Plant in massings for best flower effect
Saururus cernus	Lizard's Tail	2 to 4	18" o.c.	moist soil to shallow water	full to medium sun	
Lower 5 Feet						
Juncus effusus	Soft Rush	2 to 3	18" o.c.	moist soil to standing water (up to 4" deep)	full sun	Good for erosion control on moist banks
Pontederia cordata	Pickerel Weed	2 to 4	18"o .c.	standing water (3"-5" deep)	full sun	Plant in massings for best foliage/flower effect
Sagittaria latifolia	Arrowhead	1 to 4	18" o.c.	wet soil to shallow water	full sun	
Scirpus validus	Softstem Bulrush	1 to 6	24" o.c.	wet soil to shallow water	full sun	

Dominant Tree Species

Silver Maple	Acer saccharinum (not recommended for yards and landscapes)
Sugar Maple	Acer saccharum
Cottonwood	Populus deltoides
Green Ash	Fraxinus pennsylvanica
Sycamore	Platanus occidentalis
Box Elder	Acer negundo
American Elm	Ulmus americana
Slippery Elm	Ulmus rubra
Hackberry	Celtis occidentalis
Sugarberry	Celtis laevigata
Black Willow	Salix nigra
Bur Oak	Quercus macrocarpa
White Oak	Quercus alba
Swamp White Oak	Quercus bicolor
Black Walnut	Juglans nigra
Bitternut Hickory	Carya cordiformis
Shellbark Hickory	Carya laciniosa
River Birch	Betula nigra
Kentucky Coffeetree	Gymnocladus dioica
Bald Cypress	Taxodium distichum

Understory Trees and Shrubs

Sandbar Willow	Salix exigua
Gray Dogwood	Cornus foemina
Swamp Dogwood	Cornus amonum
Pawpaw	Asimina triloba
Ohio Buckeye	Aesculus glabra
Red Buckeye	Aesculus pavia
Horse Chestnut	Aesculus hippocastanuum
Eastern Witch Hazel	Hamamelis virginiana
Vernal Witch Hazel	Hamamelis vernalis
Buttonbush	Cephalanthus occidentalis
Spicebush	Lindera benzoin
Blackhaw Viburnum	Viburnum prunifolium
Shrubby St. John's Wort	Hypericum prolificum
Deciduous Holly	Ilex decidua
Ninebark	Physocarpus opulifolius

Appendix G. Plant Species to be Controlled

General Species to Control

Common Name	Scientific Name	Common Name	Scientific Name
velvetleaf	*Abutilon theophrasti*	quackgrass	*Elymus repens*
Russian knapweed	*Acroptilon repens*	euonymus	*Euonymus spp.*
redtop	*Agrostis gigantea*	leafy spurge	*Euphorbia esula*
wild garlic	*Allium vineale*	fescue	*Festuca spp.*
pigweed	*Amaranthus spp.*	fescue species	*Festuca spp.*
burr ragweed	*Ambrosia grayi*	English ivy	*Hedera helix*
ragweed	*Ambrosia spp.*	pignut (Indian rushpea)	*Hoffmannseggia glauca*
burrdock species	*Arctium spp.*	kochia	*Kochia scoparia*
shallards	*Brassicaceae* - Shallard Family	prickly lettuce	*Lactuca serriola*
California brome	*Bromus carinatus*	sericea lespedeza	*Lespedeza cuneata*
ripgut brome	*Bromus diandrus*	ryegrass species	*Lolium spp.*
soft brome	*Bromus hordeaceus*	honeysuckle	*Lonicera spp.*
Japanese brome	*Bromus japonicus*	birdsfoot trefoil	*lotus corniculatus*
mountain brome	*Bromus marginatus*	purple loosestrife	*Lythrum salicaria*
downy brome, cheat	*Bromus tectorum*	sweet clover	*Melilotus spp.*
marijuana	*Cannabis sativa*	Scotch cottonthistle	*Onopordum acanthium*
hoary cress	*Cardaria draba*	reed canarygrass*	*Phalaris arundinacea*
musk thistle	*Carduus nutans*	timothy	*Phleum pratense*
lamb's quarters	*Chenopodium album*	bluegrass species	*Poa spp.*
spotted water hemlock	*Cicuta maculata*	kudzu	*Pueraria spp.*

Common Name	Scientific Name	Common Name	Scientific Name
Canada thistle	*Cirsium arvense*	multiflora rose	*Rosa multiflora*
bull thistle	*Cirsium vulgare*	common sheep sorrel	*Rumex acetosella*
poison hemlock	*Conium maculatum*	pale dock	*Rumex altissimus*
field bindweed	*Convolvulus arvensis*	curly dock	*Rumex crispus*
Canadian horseweed	*Conyza canadensis*	bitter dock	*Rumex obtusifolius*
vetch species	*Coronilla spp.*	field sowthistle	*Sonchus arvensis*
orchardgrass	*Dactylis glomerata*	spiny sowthistle	*Sonchus asper*
jimsonweed	*Datura stramonium*	common sowthistle	*Sonchus oleraceus*
Queen Anne's lace	*Daucus carota*	Johnsongrass	*Sorghum halepense*
teasel	*Dipsacus fullonum*	clover species	*Trifolium spp.*
		cocklebur	*Xanthium strumarium*
*Removal of this species from project subject to approval of the Project Representative			

Control Recommendations: Shrub Honeysuckle

This guidance is sourced from the KC Wildlands.

Basic Procedure:

Wildlands uses volunteers for labor-intensive work to cut and stump-treat honeysuckle (using Tordon RTU). Volunteers work in teams of usually three, with two cutting the shrub (loppers or handsaws) and one applying Tordon RTU (using small, twist top plastic bottles so no one person has too much chemical - bottles are available through SKS Plastics). The attached diagram is used for training volunteers. All plants must be treated properly. They have experimented and found that they get a good kill rate on cut and treat ANY TIME of year (which is counterintuitive, considering sap flow). A follow up of Roundup (5%) should be applied to any resprouts the following late October or early November (for spring and summer treatments), or the following March (for fall and winter treatments). This application is done by staff.

Wildlands occasionally uses well qualified volunteers (restorationists, biologists, naturalists) to backpack spray Roundup on euonymus and shrub honeysuckle, but collateral damage can be high if spraying thick infestations of honeysuckle (and it can be expensive!). They think the best time for foliar treatment with Roundup is in late October when natives are dormant but shrub honeysuckle is still green; or in early spring when the honeysuckle plant starts to leaf. However, they don't do much foliar treatment of honeysuckle except on resprouts.

The last-ditch approach for really thick stands or areas that aren't conducive to volunteers is to hire a professional wild land restorationist to basal treat (chemically girdle). In that case they use Pathfinder II, applied in November or early December. Cost is about $280/acre per pass. Then follow up with Roundup of resprouts the following year, although though there shouldn't be many.

Note: Wildlands is restoring habitat remnants, so all decisions are based on doing the very least harm possible to the seed banks and plants that are still hanging on. In an area where there is NOTHING under the shrubs, a more aggressive strategy could be employed.

Also: if working by water, consider using Rodeo for foliar applications. It's like round-up, but is supposed to be safer for water.

Volunteers:

Wildlands lets volunteers use Tordon because they are dropping a few drips onto a stump rather than spraying leaves; this reduces liability. Also, a stump treatment minimizes pesticide use in the environment. On the toxicity side, Tordon is more detrimental than Roundup: it can travel through wet soil and harm other plants. However , the way the volunteers are trained to use it (as a stump treatment) is safer for the surrounding area, so long as they don't treat in the rain. Volunteers never have more than 3 oz of the Tordon.

Wildlands believes that the most worthwhile part of using volunteers is that you have an opportunity to educate folks about the big picture. They become stewards and advocates when they've invested their time on the land.

Finally, Wildlands notes that a good resource for volunteers and expertise may be Missouri Master Naturalists. There are a couple of chapters near St. Peters.